BURNSIDE

Hydrogeological Study, 211 Eliza Street Arthur

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1.0 Introduction

R.J. Burnside & Associates Limited (Burnside) was retained by Sarah Properties Limited to complete a hydrogeological assessment for approximately 18.46 ha of land located in Arthur, Ontario (Figure 1). The lands are slated for residential development and as part of the development process a hydrogeological study is required to characterize the local hydrogeological conditions. The proposed development will be on lands that are located at 211 Eliza Street and north of Wellington Road 109 in Arthur. The legal address of the lands is Part of Lot 1, Concession 1 in the geographic Township of West Luther, Township of Wellington North in Wellington County. The current land use includes cultivated areas with some open space. For the purposes of this study the lands are referred to as the subject lands and are shown in Figure 2.

1.1 Scope of Work

The scope of work completed for the hydrogeological study was developed based on Burnside's review of existing information and our experience in completing similar studies. In completing the current study, the scope of work included completion of the following tasks:

1. Drilling and installation of five monitoring wells (MW) including one monitoring well nest (one shallow and one deep well at same location) and one piezometer (PZ) to assess the shallow soil and groundwater conditions. The locations of the monitoring wells and piezometer are shown on Figure 2 and monitoring well construction details are provided on the borehole logs in Appendix A.

2. Compilation and review of available hydrogeological and geological data in the vicinity of the subject lands, including a review of the Ministry of the Environment, Conservation and Parks (MECP) online water well records. Borehole and well logs are provided in Appendix A. A list of the available MECP water well records for local wells is provided in Appendix B.

3. In situ well testing of three monitoring wells (MW1s, MW3 and MW4) to assess hydraulic conductivity of the soils encountered during drilling of monitor wells. The hydraulic conductivity field testing results are provided in Appendix C.

4. Infiltration testing using an infiltrometer was completed at three locations to assess the potential infiltration rates of the surficial soils. The infiltration test results are provided in Appendix C.

5. Groundwater level monitoring was completed in monitoring wells and the piezometer to identify groundwater conditions and track seasonal variations. Monitoring was completed monthly from January 2019 to June 2020 to record the groundwater

conditions and track the seasonal variations. Automatic water level recorders (data loggers) were installed in MW1s, MW3, MW4 and PZ1 to obtain a continuous record of groundwater fluctuations. The groundwater monitoring data and hydrographs are provided in Appendix D.

6. Collection of groundwater samples from two monitoring wells (MW1s and MW4) for laboratory testing to characterize the background water quality. The water quality results are provided in Appendix E.

7. Pre-development (based on existing land use conditions) and post-development (based on the proposed development concept) water balance calculations were completed to assess the potential impacts of land development on the local groundwater conditions. The local climate data and detailed water balance calculations are provided in Appendix F.

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

2.0 Physical Setting

2.1 Topography and Drainage

The subject lands are located in Arthur and are near the confluence of two rivers, the Conestogo River and Brandy Creek. The topography of the subject lands is hilly with a topographic high occurring in the center-west portion at an elevation of 467 metres above sea level (masl). The topography slopes to the west and south across most of the subject lands towards the Conestogo River valley where the topographic low at an elevation of 453 masl can be found. The topography along the eastern edge of the subject lands abuts the river channel and drops steeply into the valley (Figure 3).

The subject lands are located in the Grand River watershed within the jurisdiction of the Grand River Conservation Authority (GRCA). Conestogo River loops around the southern and eastern portions of the subject lands (Figure 3) and flows south and then west.

Brandy Creek, a tributary of Conestogo River joins the Conestogo River south of the subject lands and south of Wellington Road 109. There are no water courses on the subject lands (Figure 3). The site drains via overland drainage primarily to the southwest, while the eastern edge of the property drains east overland towards the Conestogo River.

2.2 Geology

The subject lands are located in the broad physiographic region known as the Stratford Till Plain which in the area of Arthur is characterized as by slightly rolling plain covered in by a ground moraine and interrupted by terminal moraines (Chapman and Putnam, 1984).

Surficial geology mapping published by the Ontario Geological Survey (2003) shows that the subject lands are underlain by stone poor, carbonate-derived silty to sandy till deposits (Figure 4). A glaciolacustrine-derived silty to clayey till is mapped south of the subject lands along the north river-banks which are bordered to the south by modern alluvial deposits associated with the Conestoga River and its tributary.

The bedrock underlying the subject lands consists of dolostone and shale of the Salina Formation (Figure 5). Water well records in the area indicate that limestone bedrock is found at approximately 395 masl.

2.3 Borehole Drilling and Monitoring Well Installation

In January 2019, five monitoring wells were installed using a conventional auger drilling rig at selected locations. One nest, consisting of one shallow and one deep well was installed at MW1 (MW1s, MW1d) to monitor vertical flow conditions. At each borehole, an observation well was installed using 51 mm diameter PVC riser pipe with a 1.5 m long 10-slot PVC screen. Sand was put in place around the screen and borehole and bentonite was used to seal the well to surface. Borehole logs outlining the construction details are included in Appendix A. Locations of monitoring wells are indicated in Figure 2.

A piezometer (PZ1) was installed on the subject lands near MW4 to assess the shallow groundwater elevations and vertical gradient at a low-lying area on the Subject Lands. The data would also be used in the estimation of recharge and discharge at the groundwater/ surface water interface. The piezometer, which consisted of 1.5 m of steel 3.0 m of steel pipe and a 0.31 m stainless steel drive point, was installed with a manual post pounder. The location of PZ1 is shown in Figure 2.

2.4 Site-Specific Geology

Five monitoring wells were installed on the site and the borehole logs are included in Appendix A. The logs indicate that the surficial soils generally consist of 0.25 to 2.5 m of topsoil and silty sand mixed with organics. At MW1s/d the mixed silty sand and organics was underlain by a 1.2 m deposit of organics to a depth of 3.7 m below ground. Below these layers a deposit of brown to grey silt (with trace to some clay, trace gravel) was encountered at MW1s/d, MW2 and MW3 to depths ranging from 4.6 to 7.6 m below ground (i.e., 461.0 to 451.4 masl). The silt was underlain by a deposit of silt and sand till (with some gravel, trace clay, occasional cobble) to the full depth of investigation.

Below the silty sand with organics at MW4, a deposit of compact brown sand and gravel was observed at MW4 to a depth of 1.5 m below ground. This deposit was underlain by a stiff brown silt to a depth of 2.3 m below ground. The silt was underlain by brown loose to compact gravelly sandy silt to a depth of 4.6 m below ground. The gravelly sandy silt was underlain by silt and sand till to the full depth of investigation (8.1 m below ground).

2.5 Stratigraphy

Two interpreted cross-sections through the subject lands have been prepared to illustrate the local stratigraphy of the subject lands. The cross-sections use site-specific geological information obtained from the geotechnical boreholes (logs provided in Appendix B) and MECP water well records (Appendix A).

The cross-section locations are shown on Figure 6 along with the borehole locations and MECP water well records that have been used to prepare the cross-sections. The interpreted cross-sections are provided as Figures 7 and 8. The cross-sections show the overburden of the subject lands consisting of a layer silt underlain by silty/sandy till. The top of the bedrock is located at elevations between 385 masl and 405 masl. 30 to 50 meters of till overburden overlies the bedrock.

2.6 Hydraulic Conductivity

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

2.6.1 Grainsize Analysis

During drilling representative soil samples of soil types encountered in the boreholes were collected and submitted for grain size analysis. A summary of the grainsize analyses is provided in Table 1 and data is provided in Appendix C-1.

Table 1: Summary of Grainsize Analyses

Sample ID	Depth of Sample (mbgs)	Soil Classification	% Fines	Estimated Hydraulic Conductivity (cm/sec)
MW1-SS7	6.1	Silt, some clay	99	N/A
MW2-SS3	1.5	Silt, some clay, some sand	90	N/A

Sample ID	Depth of Sample (mbgs)	Soil Classification	% Fines	Estimated Hydraulic Conductivity (cm/sec)
MW4-SS4	2.3	Gravelly sandy silt, trace clay	50	2.3×10^{-4}
MW4-SS6	4.6	Silt and Sand, trace clay, trace gravel	58	1.4×10^{-4}

Grainsize analyses results indicate that the sediments within the overburden include a fine-grained clayey silt and a courser grained silt and sand till. To estimate hydraulic conductivity based on grainsize analyses, an empirical method known as the Hazen estimation can be used. This method is an approximation of hydraulic conductivity based on grainsize curves for sandy soils. Where applicable, the approximated hydraulic conductivity for the samples are provided above in Table 1.

2.6.2 Single Well Response Tests

To assess the in situ hydraulic conductivity of the sediments, single well response tests (bail-down tests) were conducted at monitoring wells MW1s, MW3 and MW4. The results from the tests were plotted (Appendix C-2) and analyzed to calculate hydraulic conductivity of the sediments screened. A summary of 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)
MW1s	4.3 – 6.0	Silt	5.0×10^{-7}
MW3	4.8 – 6.7	Silt and Sand	9.5×10^{-6}
MW4	5.8 – 7.6	Silt and Sand	4.6×10^{-6}

*metres below ground surface

The single well response test analyses resulted in moderate to low hydraulic conductivities in the range of 10^{-5} to 10^{-7} cm/sec. MW1s was screened in the surficial silt layer with a low hydraulic conductivity. MW3 and MW4 screened in the silt and sand till had moderate hydraulic conductivity in the order of 10^{-5} and 10^{-6} cm/sec.

2.6.3 Infiltration Testing

Infiltration testing was completed in November 2019 at three locations across the subject lands. A Turf-Tec double ring infiltrometer was used to conduct the infiltration tests. The tests were completed by removing the topsoil in the test area and installing the infiltrometer into the underlying soil. Both rings of the infiltrometer were then filled with water and water level was recorded at regular intervals as it drained into the soil. The tests were continued until a consistent rate was obtained or the rate of infiltration was determined to be very low. The locations of the infiltration tests are shown on Figure 2 and are identified as IT-1, IT-2 and IT-3.

The use of the infiltrometer for measuring infiltration has advantages over lab methods as it is representative of all conditions at the site including compaction, soil texture and fractures within the soil. The results of the infiltration tests are provided in Appendix C-3. The infiltration rate was determined by plotting infiltration per hour versus elapsed time and then averaging the values where the curve begins to stabilize. At IT-2 multiple tests were completed to obtain a consistent rate. The infiltration rate is determined based on the curves where a stabilized rate has been obtained. A summary of the infiltration rates is provided in Table 3.

Table 3: Infiltration Testing Results

Location	Soil Type	Infiltration Rate (mm/hour)
IT-1	Silt and Clay, firm, trace sand, trace gravel, moist	1
IT-2	Silt and Sand, some clay, trace gravel, moist	175
IT-3	Silt and Clay, firm, trace sand, trace gravel, moist	2

The testing indicates that the soils on the subject lands generally range from 1 mm to 2 mm per hour. The infiltration rates may increase in areas with stones and fractures within the soil such as seen at IT-2, however in general the silt and clay soils have an average infiltration rate of 1.5 mm per hour.

3.0 Hydrogeology

It is interpreted that the overburden sediments form a shallow aquifer below the subject lands and that these sediments may interact with the local wetlands and water features within the low-lying areas of the subject lands. The shallow aquifer has a thickness that ranges from 5 m to 20 m. The bedrock forms a more regional aquifer that is the main source of water supply in the area.

3.1 Local Groundwater Use

The proposed development will be municipally serviced and there is no proposed groundwater use for the development. The Town of Arthur is serviced by three groundwater supply wells completed in the deep overburden aquifer at approximately 46 m below ground surface (LESPR, 2015). The subject lands are located within the WHPA-D (25-year time of travel zone) wellhead protection area for Arthur Well 7B located 2.3 km west of the subject lands (Figure 9). Arthur Wells 8A and 8B are located approximately 1.1 km south of the subject lands. There are no implications to the development with respect to the Clean Water Act.

Municipal servicing in Arthur is provided from Wells St (to the west) to Eliza Street, south to the river and north to the railroad (Figure 1). Areas outside of municipal servicing are assumed to have individual private water supply wells.

The Ministry of Environment, Conservation and Parks (MECP) maintains a database that provides geological records of water supply wells drilled in the province. A review of this database was completed and a table summarizing water well records within 500 m of the subject lands is provided in Appendix B. The MECP water well record database indicates that there are 70 water well records located within 500 m of the subject lands. The water well record details are 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.

Of the 79 identified water well records, 22 were private supply wells, 3 were municipal supply wells, 26 were monitoring wells and 19 were abandonment records. The 23 private water supply wells the wells ranged in depths from 24.4 m to 150.9 m. Eleven of the private water wells were completed in the bedrock and 12 were completed in the overburden. Three municipal water supply wells located in the vicinity of the subject lands ranged in depths from 46.6 m to 93 m. It is noted that there were abandonment records for three municipal wells within the MECP records reviewed.

3.2 Water Level Monitoring

Water levels in monitoring wells and piezometers were collected from January 2019 to June 2020 using a water level meter. Dataloggers (automatic water level recorders) were installed at MW1s, MW3, MW4 and PZ1 to provide continuous data (hourly readings) of water levels during the monitoring period. A barometric pressure logger was also installed to measure changes in barometric pressure. These data are used to correct the water level data by accounting for changes in atmospheric pressure.

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

- The groundwater elevations across the subject lands range between approximately 450.5 masl and 461.6 masl. The depths to water table ranged from 0.14 mbgs at MW4 to 5.5 mbgs at MW2.

- Seasonal variations observed in the water levels are typical for Southern Ontario with high groundwater levels in the spring months followed by a gradual decline over the summer months. Lowest levels were generally observed in late summer (September) and highest levels were observed in the spring (May-June). Seasonal variations in the wells ranged from 1.7 m (MW1s) to 2.5 m (MW2).

- Hourly automatic water level readings (datalogger readings) at monitoring wells show that the water table responds to individual precipitation events. During a large rain event at the end of October 2019, water levels at MW3 increased 1.98 m and 1.15 m at MW4 (Figures D-3 and D-4). Response to precipitation events is less at MW1s which is screened in the shallow silt aquitard (Figure D-1, Appendix D).

- At monitoring well MW4, water levels were close to surface from March to late May and November to March 2020 (Figure D-4). MW4 is located in the topographic low at the southwest corner of the site.

- At monitoring well nest MW1s/d water levels in the shallow well were consistently higher than levels in the deep well indicating a downward gradient (recharge conditions) (Figure D-1, Appendix D).

- PZ1 was installed about 10m south of MW4 in the topographic low at the southwest corner of the site. Water levels at PZ-1 show a seasonal trend with levels highest in the spring and lowest to dry in the summer, and close to grade from December 2019 to March 2020 (Figure D-5, Appendix D).

3.3 Recharge and Discharge Conditions

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

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.

At monitoring well nest MW1s/d, the shallow well is screened from 4.3 m to 6 m in silt and the deep well is screened from 8.8 m to 10.6 m in silt and sand. The water levels in the shallow well were consistently higher than levels in the deep well with an average downward gradient of 0.4 (Figure D-1, Appendix D). This suggests that recharge conditions are present at this location.

3.4 Groundwater Flow

Groundwater elevation data (March 2020) obtained from the monitoring wells and piezometers are shown on Figure 9, along with the interpreted groundwater elevation contours for the area. The groundwater is influenced by the surface topography with groundwater moving from topographic highs towards topographic lows. Arrows perpendicular to the groundwater contours are used to illustrate the groundwater flow directions. Groundwater on the eastern side of the subject lands flows east towards the creek located east of the site. On the western portion of the subject lands, groundwater flows west and southwest towards the Conestogo River.

4.0 Water Quality

To establish background water quality on the subject lands, groundwater samples were collected on November 28, 2019. Water samples were collected from two groundwater wells (MW1S and MW4). The samples were sent to AGAT Laboratories for analysis of general water quality indicator parameters and basic ions (e.g., pH, alkalinity, hardness, conductivity, chloride, nitrate, etc.) and selected metals. The analytical results from the laboratory are provided in Table E-1, Appendix E and are discussed below. The data reviewed showed the following:

- 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 155 mg/L (MW4) and 481 mg/L (MW1S). 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 13000 NTU (MW1S) and 52500 NTU (MW4). 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.

- There were no other exceedances of the ODWQS in the groundwater sample results.

- Nitrate in the groundwater ranged from <0.25 mg/L to 0.21 mg/L indicating that the groundwater has not been impacted by surrounding land use activities such as septic systems or agricultural activities.

5.0 Water Balance

In order to assess potential land development impacts on the local groundwater conditions, a detailed water balance analysis has been completed to determine the pre-development recharge volumes (based on existing land use conditions) and the post-development recharge volumes that would be expected based on the proposed land use plan. The detailed water balance calculations are provided in Appendix F.

5.1 Water Balance Components

A water balance is planning tool that incorporates 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. 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. 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. It is therefore important to note that the calculated water balance represents an approximation that is useful for planning purposes in order to understand the magnitude of impacts that are likely from a development.

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

Precipitation (P)

The long-term average annual precipitation for the subject lands is 945.7 mm based on data from the Environment Canada Fergus Shand Dam Climate Station (Station 6142400, 43°44'05.088" N, 80°19'49.098" W, elevation 417.6 masl) for the period between 1981 and 2010. The climate station is located 19 km southeast of the subject lands. Average monthly records of precipitation and temperature from this station have been used for the water balance calculations in this study (Appendix F).

Storage (S)

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

Evapotranspiration (ET)

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

Water Surplus (R + I)

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

5.2 Approach and Methodology

The analytical approach to calculate the water balance involves monthly soil-moisture balance calculations using a spreadsheet model 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).

For pre-development conditions a soil moisture storage capacity of 200 mm was used for the silt loam soils with predominantly short to moderate rooted vegetation used for agriculture (Table F-1, Appendix F) and a soil moisture storage capacity of 400 mm was used for the silt loam soils in the wooded areas (Table F-2, Appendix F). A soil moisture storage capacity of 125 mm was used for urban lawn cover under post-development conditions (Table F-3, Appendix F). Tables F-1 to F-3 in Appendix F detail the monthly potential evapotranspiration calculations accounting for latitude and climate, and then calculate the actual evapotranspiration and water surplus components of the water balance based on the monthly precipitation and soil moisture conditions.

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

5.3 Water Balance Component Values

The detailed monthly calculations of the water balance components are provided in Tables F-1 to F-3 in Appendix F. For these calculations, it has been assumed that silt loam soils are representative for the subject lands for estimating the soil infiltration factor. The calculations show that a water surplus is generally available from November to May (see Tables F-1 to F-3, Appendix F). 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 to F-3, Appendix F). A summary of these values is provided in Table 4.

Table 4: Water Balance Component Values

Water Balance Component	Agricultural Lands	Wooded Lands	Urban Lawn
Average Precipitation	946 mm/year	946 mm/year	946 mm/year
Actual Evapotranspiration	579 mm/year	579 mm/year	579 mm/year
Water Surplus	367 mm/year	367 mm/year	367 mm/year
Infiltration	147 mm/year	183 mm/year	165 mm/year
Runoff	220 mm/year	183 mm/year	202 mm/year

5.4 Pre-Development Water Balance (Existing Conditions)

The pre-development water balance calculations are presented in Table F-4 in Appendix F. As summarized on Table F-4, the total area of the subject lands is about 18.46 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 27,700 m^3/year (Table F-4, Appendix F).

5.5 Potential Urban Development Impacts to Water Balance

Development of an area affects the natural water balance. The most significant difference between pre- and post-development conditions is the addition of impervious surfaces as a type of surface cover (i.e., roads, parking lots, driveways, and rooftops). Impervious surfaces prevent infiltration of water into the soils and the removal of the vegetation removes the evapotranspiration component of the natural water balance resulting in evaporation as the only remaining loss mechanism (beside runoff). The evaporation component from impervious surfaces is relatively minor (estimated to be 10% to 20% of precipitation) compared to the evapotranspiration component that occurs with vegetation in this area (about 61% of precipitation in the subject lands). So, the net effect of the construction of impervious surfaces is that most of the precipitation that falls onto impervious surfaces becomes surplus water and direct runoff. The natural infiltration components (interflow and deep recharge) are reduced.

A water balance calculation of the potential water surplus for impervious areas is shown at the bottom of Table F-1 in Appendix F. The evaporation component for the impervious surfaces has been estimated at 15% of precipitation for the purposes of this study. The remaining 85% of the precipitation that falls on impervious surfaces is assumed to become runoff. Therefore, assuming an evaporation/loss from impervious surfaces of 15% of the precipitation, there is a potential water surplus from impervious areas of 804 mm/year.

It is noted that the proposed development will be serviced by municipal water supply and wastewater 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-4 in Appendix F. The land use areas and the associated percentage imperviousness were based on the current design layout provided by the design engineers.

The infiltration and runoff components for the post-development land uses have been calculated using the MECP SWM Planning and Design Manual (2003) methodology based on topography, soil type and land cover as shown on Table F-3 in Appendix F. In summary from these appendix tables, the average calculated post-development infiltration volume (without mitigation) is about 12,200 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 27,700 m^3/year to 12,200 m^3/year, i.e., a reduction of about 15,600 m^3/year or 56%.

These calculations assume no low impact development (LID) measures for stormwater management are in place.

A summary of the infiltration deficit by land use type, which can be used as an infiltration target for LID measures, is provided in Table F-5, Appendix F.

5.7 Mitigation Strategies for Infiltration

The use of Low Impact Development (LID) measures for stormwater management can be used to mitigate the potential impacts of development on the water balance.

The basic premise for low impact development is to try to manage stormwater to minimize the runoff of rainfall and increase the potential for infiltration. As outlined in the MECP SWMP Design Manual (2003) and Low Impact Development Stormwater Management Planning and Design Guide published by the CVC and TRCA (2010), there are a wide variety of mitigation techniques that can be used to try to reduce the increases in direct runoff that occur with land development and increase the potential for post-development infiltration.

Techniques to maximize the water availability in pervious areas such as designing grades to direct roof runoff towards lawns, side and rear yard swales, and other pervious areas throughout the development where possible can considerably increase the volume of infiltration in developed areas. These types of surface LID techniques promote natural infiltration simply by providing additional water volumes in the pervious areas (i.e., these areas would receive precipitation as well as extra water from roof runoff). 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 mitigation techniques that can be considered to mitigate increases in runoff and reductions in infiltration include such measures as: permeable pavements, rain gardens, bioswales, subsurface infiltration trenches, galleries and pervious pipe systems. Subsurface methods should only be considered in areas where there is sufficient depth to water table to accommodate the systems within the unsaturated zone and sufficient soil hydraulic conductivity to function effectively. The MECP manual recommends that subsurface galleries or trenches should be about 1 m above the high-water table.

Further discussion of potential LID options for the subject lands is provided in the Stormwater Management Report prepared by Burnside under separate cover.

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 range from 0.1 m to 5.5 m below ground surface. Installation of buried services at depths within this range may encounter groundwater if the construction is below the water table. 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 PTTW process applies. An evaluation of the requirements for construction dewatering should be confirmed by the geotechnical investigations completed in support of detailed design.

It is recommended that based on the design of services, that an assessment of the dewatering requirements and method of permitting be undertaken.

Basements will need to be constructed at depths that allow for sufficient separation from the groundwater table in order to ensure that basement sump pumps do not run continuously. As part of detailed design, it is recommended that an evaluation of basement elevations versus groundwater table depths be undertaken. This assessment will inform which areas of the development are of concern for potential interactions between basements and groundwater table. Where this is a potential concern it is recommended that the use of foundation drain collectors (FDC) be evaluated. FDCs have been used in numerous locations in Ontario to serve to reduce groundwater table elevation and provide suitable separation between the water table and basements. FDCs are a passive groundwater control mechanism and do not require maintenance or operation of sump pumps to control groundwater.

6.2 Private Water Wells

Most of the area surrounding the subject lands are municipally serviced however it is likely that there are some properties that still rely on private wells as a water supply. It is recommended that a water well survey be conducted prior to construction to determine if any private water supply wells are still in use within approximately 500 m of the subject lands and that a monitoring and mitigation strategy be established to ensure that private water wells are not impacted during construction.

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 to the groundwater observation wells installed for this study unless they are maintained throughout the construction for monitoring purposes.

7.0 References

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

LERSPC, 2019. Grand River Source Protection Area Approved Assessment Report – Lake Erie Region Source Protection Committee, March 11, 2019.

Ontario Ministry of the Environment, Storm Water Management Planning and Design Manual, March 2003.

Ontario Ministry of the Environment, Conservation and Parks, Water Well Records.

OGS, 2003. Surficial Geology of Southern Ontario, Ontario Geological Survey, Miscellaneous Release – Data 128. Scale 1:50,000.

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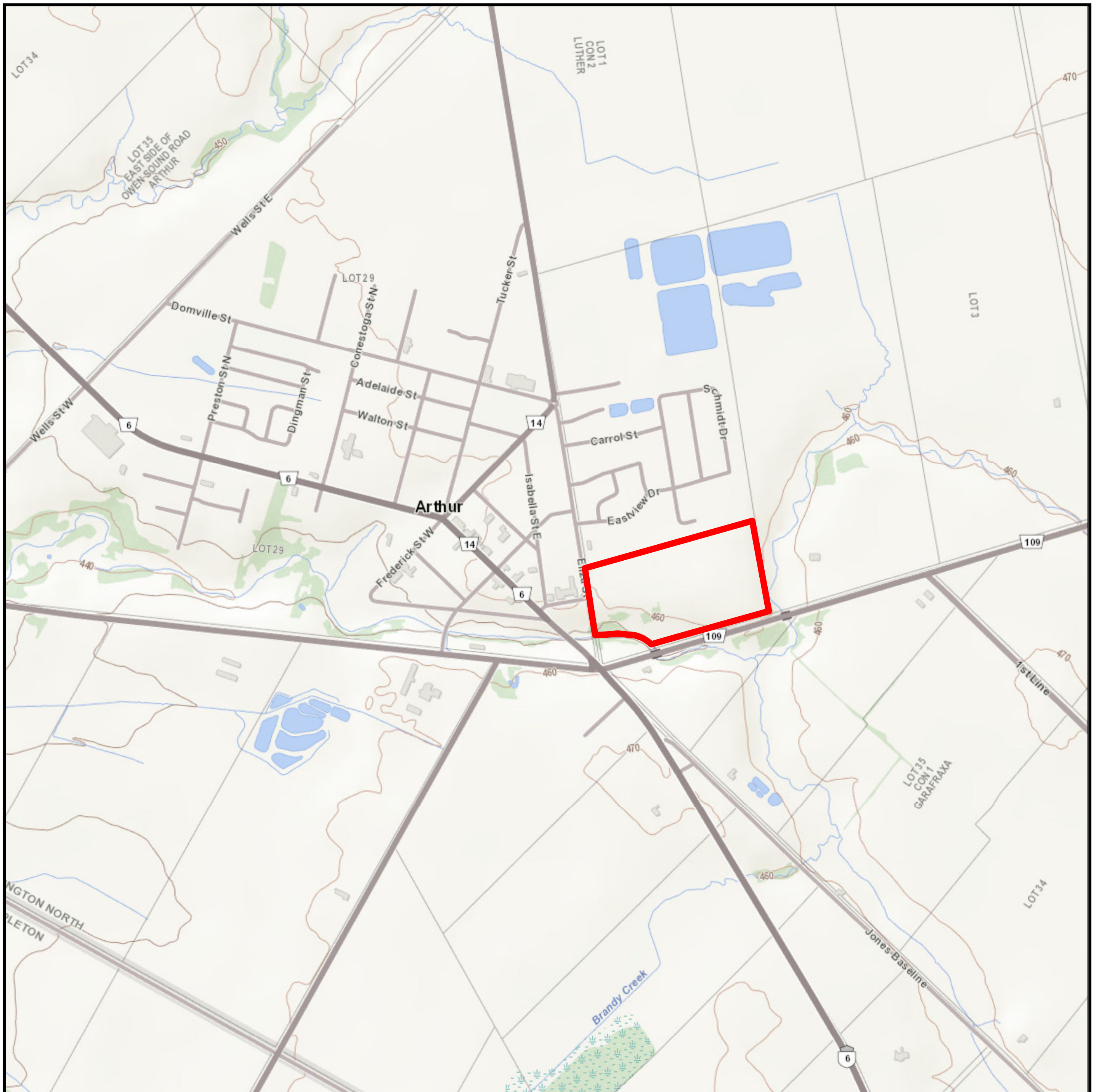
Figures



LEGEND

SUBJECT LANDS

province_extent

0 250 500 1,000 1,500

Meters

N

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Client / Report

SARAH PROPERTIES LIMITED
ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title:

SITE LOCATION

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	1
Scale		Project No.	
1:20,000		300042585.1000	

File Path: Nigel/Shared Work Areas/042585 Eliza Street/042585 Site Location.mxd

LEGEND

SUBJECT LANDS

WATERCOURSE

MONITORING WELL (RJB, 2019)

DRIVE POINT PIEZOMETER

INFILTRATION TEST LOCATION

0 50 100 200 300

Meters

N

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ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title:

SITE PLAN

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	2
Scale		Project No.	
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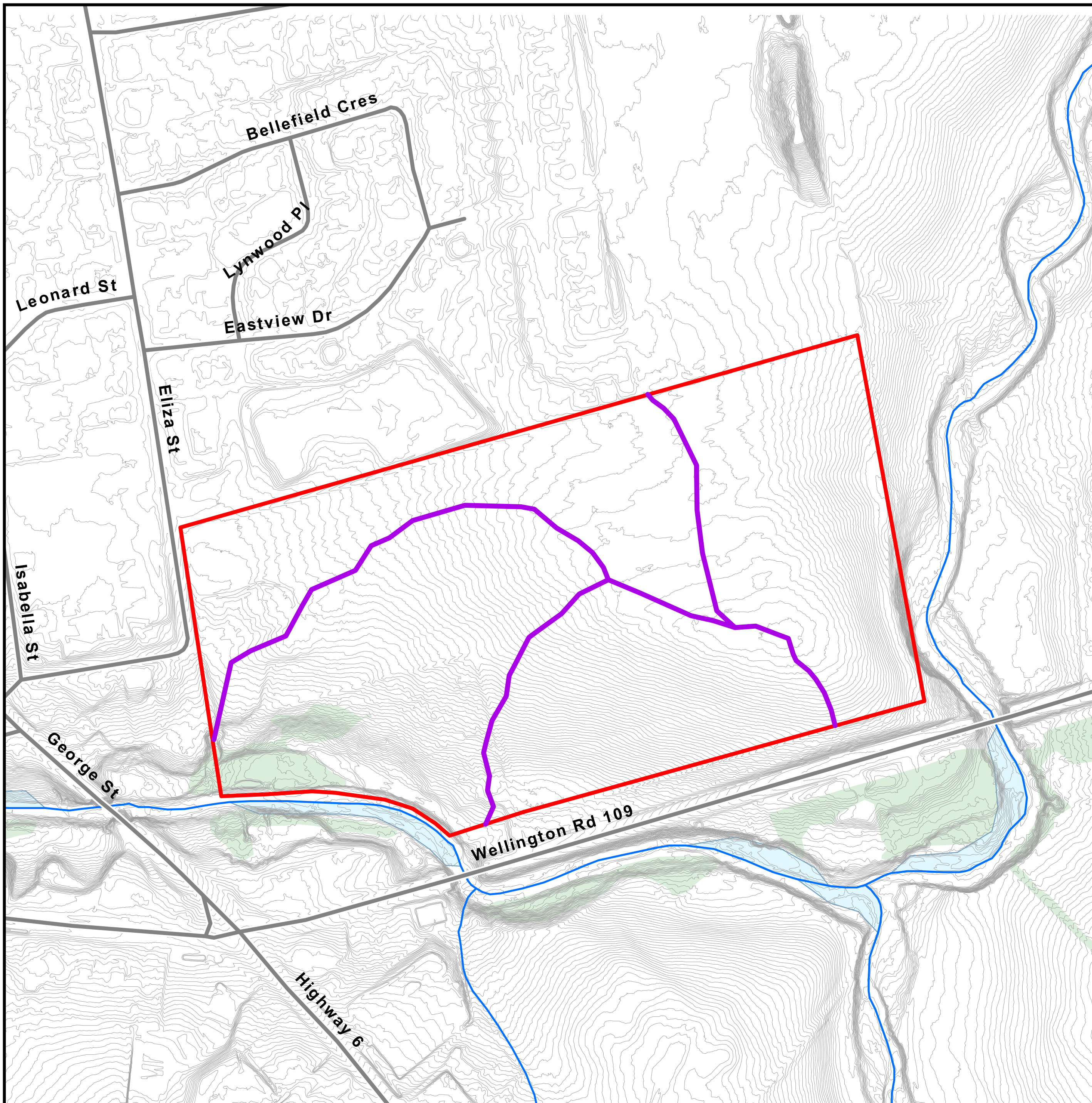

LEGEND

- SUBJECT LANDS
- ROADWAY
- WATERCOURSE
- DRAINAGE BOUNDARY
- CONTOUR (0.25m intervals - masl)
- OPEN WATER
- WOODED AREA

0 50 100 200 300 400
Meters

N

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ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title:

TOPOGRAPHY AND DRAINAGE

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	3
Scale		Project No.	
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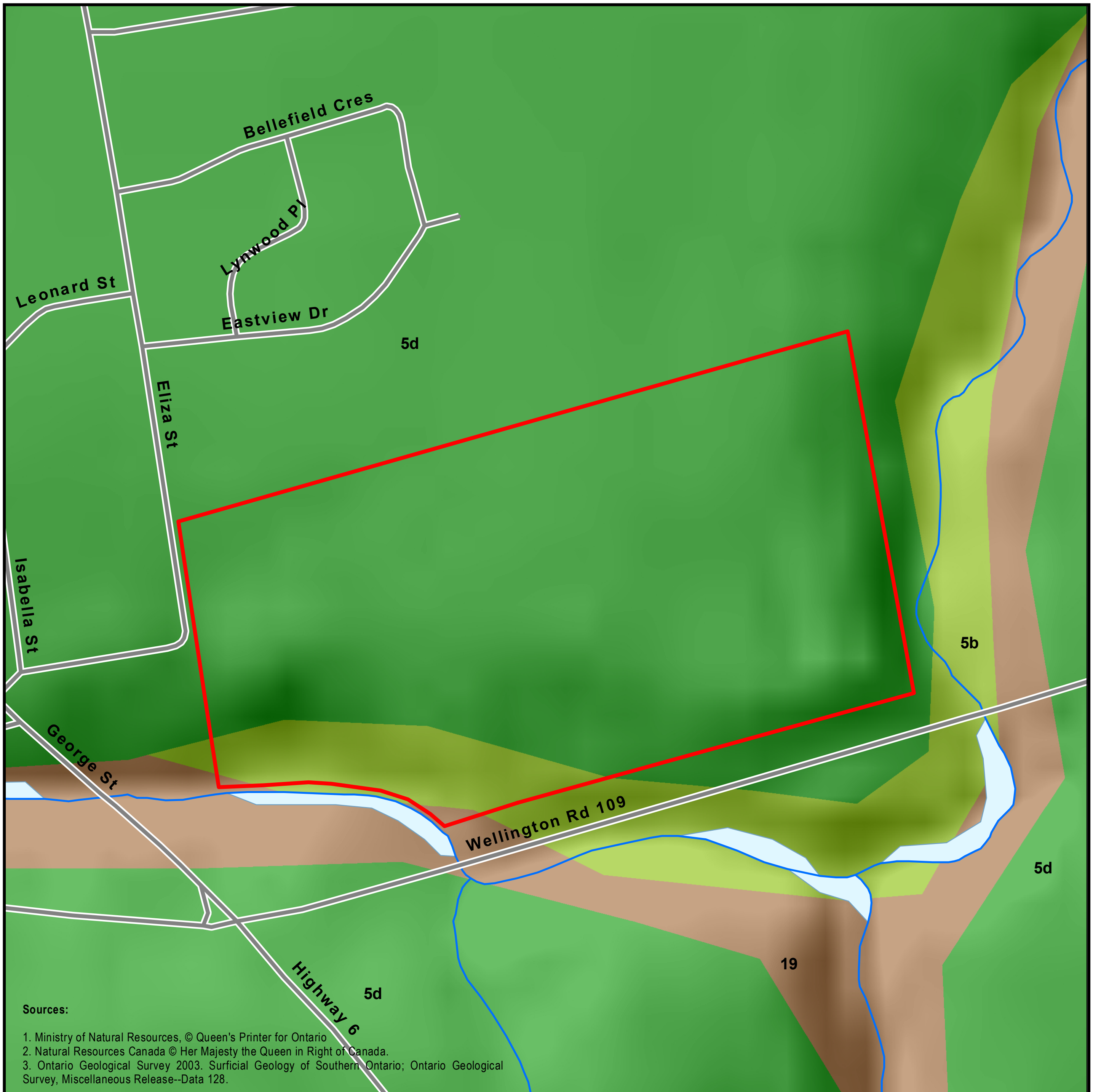
File Path: Nigel/Shared Work Areas/042585 Eliza Street/042585 Topography & Drainage.mxd



Sources:

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

LEGEND

SUBJECT LANDS

ROADWAY

WATERCOURSE

OPEN WATER

5b: Stone-poor, carbonate-derived silty to sandy till

5d: Glaciolacustrine-derived silty to clayey till

19: Modern alluvial deposits

0 50 100 200 300 400

Meters

N

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HYDROGEOLOGICAL STUDY

Figure Title:

SURFICIAL GEOLOGY

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	4
Scale		Project No.	
1:5,000		300042585.1000	

File Path: Nigel/Shared Work Areas/042585 Eliza Street/042585 Site Location.mxd

LEGEND

SUBJECT LANDS

ROADWAY

WATERCOURSE

OPEN WATER

UPPER SILURIAN - 57 Limestone, dolostone, shale, sandstone, gypsum, salt

57c Salina Fm.

0 50 100 200 300 400

Meters

N

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ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title:

BEDROCK GEOLOGY

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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File Path: Nigel/Shared Work Areas/A:\042585 Eliza Street\042585 Bedrock Geology.mxd Print Date: 2024/11/15 Time: 03:12 PM

LEGEND

- SUBJECT LANDS
- 500m BUFFER
- WATERCOURSE
- MONITORING WELL (RJB, 2019)
- MECP WELL RECORD LOCATION
- CROSS-SECTION LOCATION KEY

0 50 100 200 300 400 500 600 700 800
Meters

N

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SARAH PROPERTIES LIMITED
ARTHUR, ONTARIO
HYDROGEOLOGICAL STUDY

Figure Title:

WELL AND CROSS-SECTION LOCATION PLAN

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	6
Scale		Project No.	
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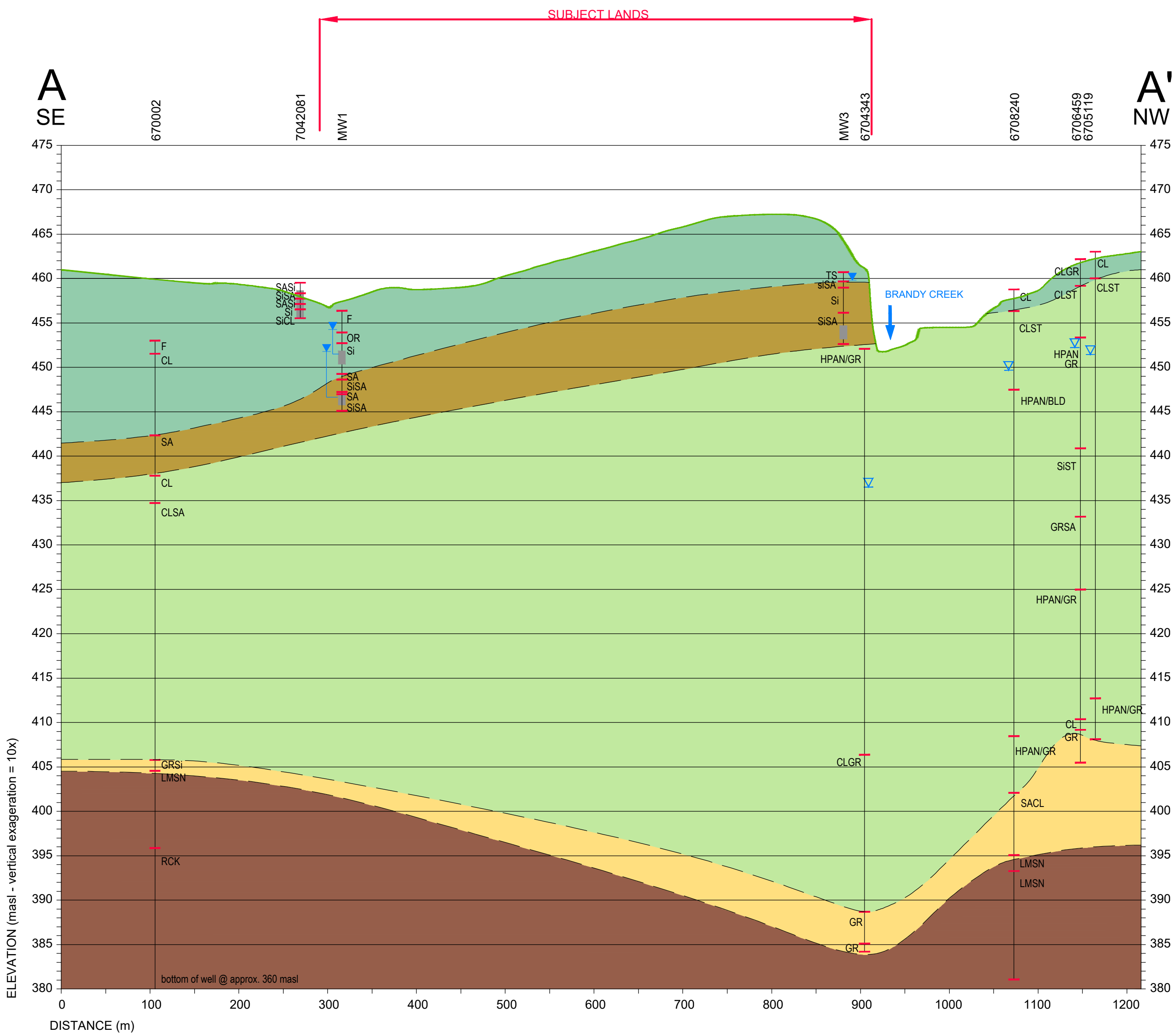

LEGEND

BH1	WELL NUMBER / ID
	EXISTING GROUND PROFILE
	GEOLOGICAL CONTACT
	MEASURED WATER LEVEL (MARCH 2020)
	WELL SCREEN
	INTERPRETED STRATIGRAPHY

si	SILTY
sa	SANDY
cl	CLAYEY
F	FILL
TS	TOPSOIL
O	ORGANICS
BLD	BOULDER
GR	GRAVEL
SA	SAND
Si	SILT
CL	CLAY
ST	STONES
LSMN	LIMESTONE
RCK	ROCK

SILT TILL
SILTY SAND TILL
SAND / GRAVEL
TILL OVERBURDEN
BEDROCK

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ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION A-A'

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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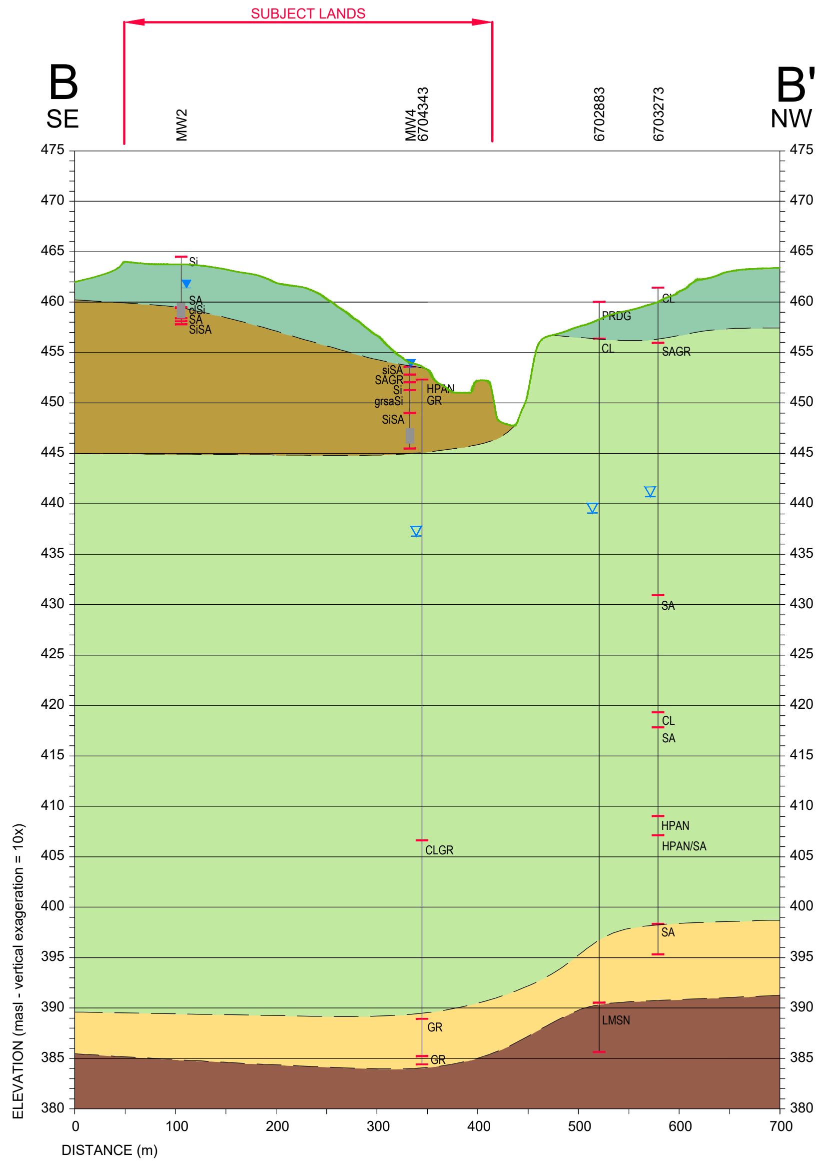

LEGEND

BH1	WELL NUMBER / ID
	EXISTING GROUND PROFILE
	GEOLOGICAL CONTACT
	MEASURED WATER LEVEL (MARCH 2020)
	WELL SCREEN
— — —	INTERPRETED STRATIGRAPHY

si	SILTY
sa	SANDY
cl	CLAYEY
F	FILL
TS	TOPSOIL
O	ORGANICS
BLD	BOULDER
GR	GRAVEL
SA	SAND
Si	SILT
CL	CLAY
ST	STONES
LSMN	LIMESTONE
RCK	ROCK

- SILT TILL
- SILTY SAND TILL
- SAND / GRAVEL
- TILL OVERBURDEN
- BEDROCK

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ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION B-B'

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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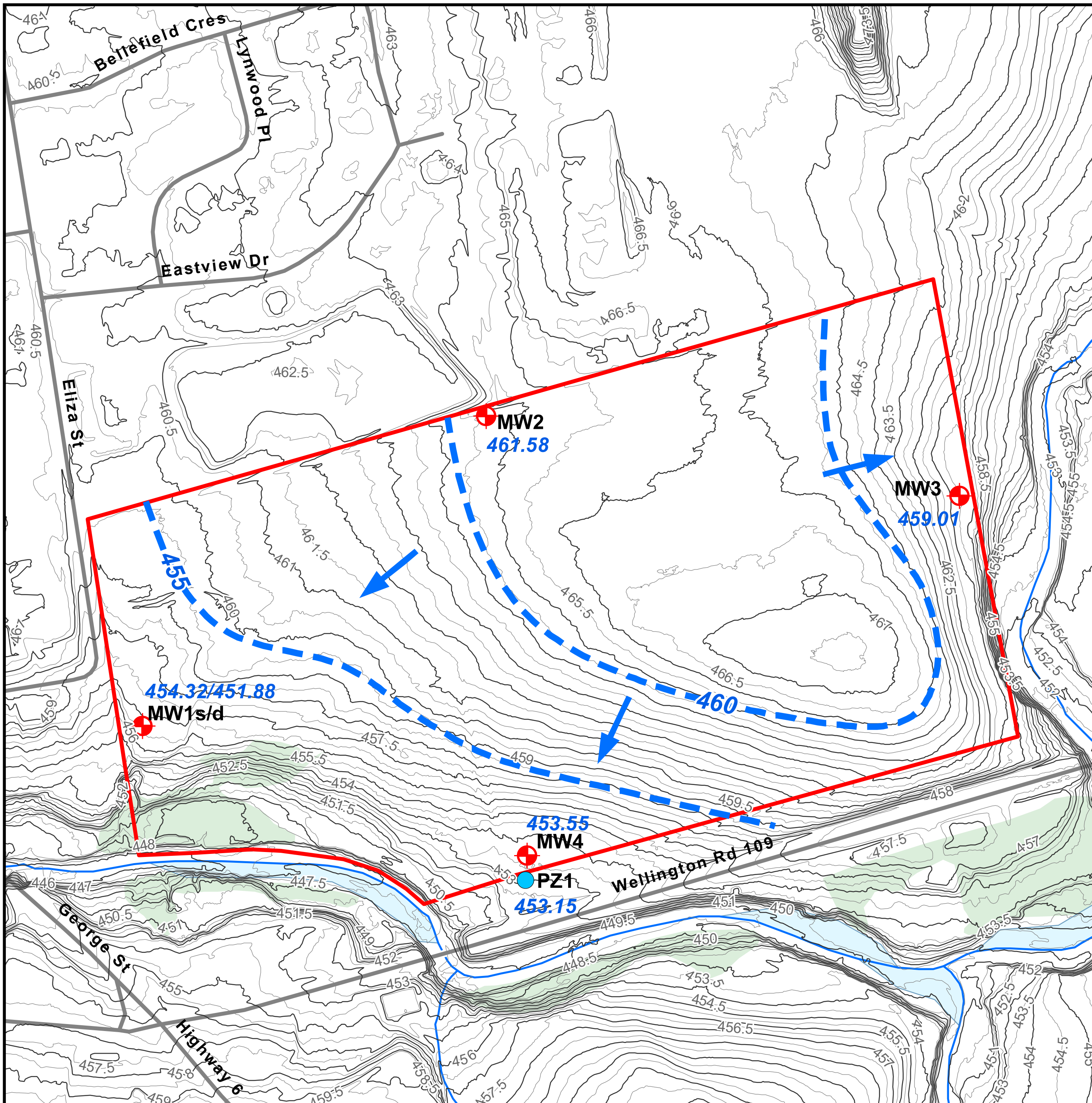

LEGEND

- SUBJECT LANDS
- ROADWAY
- WATERCOURSE
- OPEN WATER
- WOODED AREA
- MONITORING WELL (RJB, 2019)
- DRIVE POINT PIEZOMETER
- CONTOUR (1m intervals - masl)
- CONTOUR (0.5m intervals - masl)
- INTERPRETED GROUNDWATER CONTOUR (masl)
- INTERPRETED GROUNDWATER FLOW DIRECTION
- 177.95 MEASURED WATER LEVEL (NOVEMBER 7, 2018)

0 50 100 200 300
Meters

N

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ARTHUR, ONTARIO

HYDROGEOLOGICAL STUDY

Figure Title:

INTERPRETED GROUNDWATER FLOW

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	9
Scale		Project No.	
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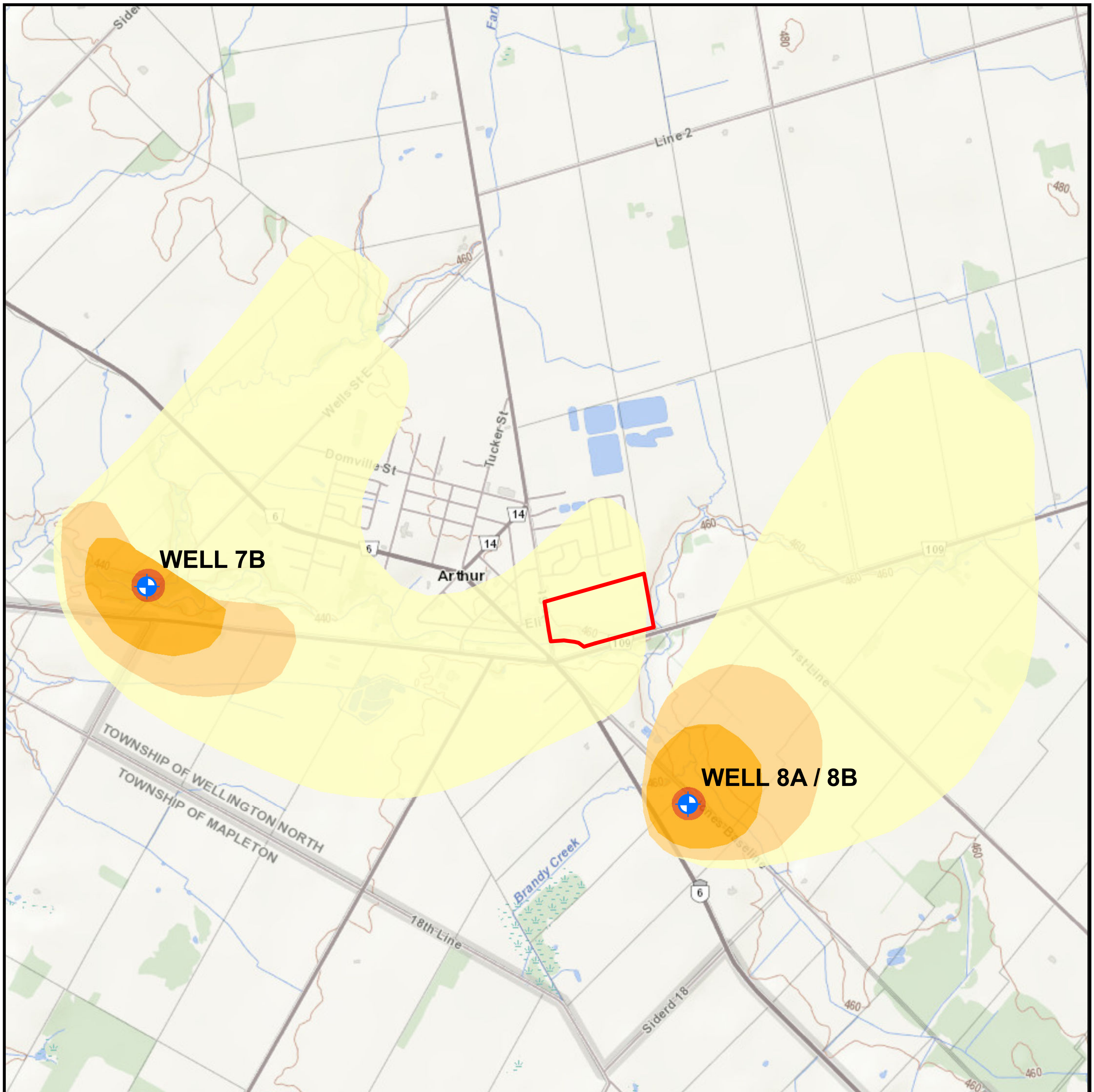

LEGEND

- province_extent
- SUBJECT LANDS
- MUNICIPAL SUPPLY WELL
- WHPA-A
- WHPA-B
- WHPA-C
- WHPA-D

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

N

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SARAH PROPERTIES LIMITED
ARTHUR, ONTARIO
HYDROGEOLOGICAL STUDY

Figure Title:
WELLHEAD PROTECTION AREAS

Drawn	Checked	Date	Figure No.
SK	SC	November 2024	10
Scale		Project No.	
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File Path: Nigel/Shared Work Areas/042585 Eliza Street/042585 WHPA.mxd

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Appendix A

Monitoring Well Logs

LOG OF DRILLING OPERATIONS

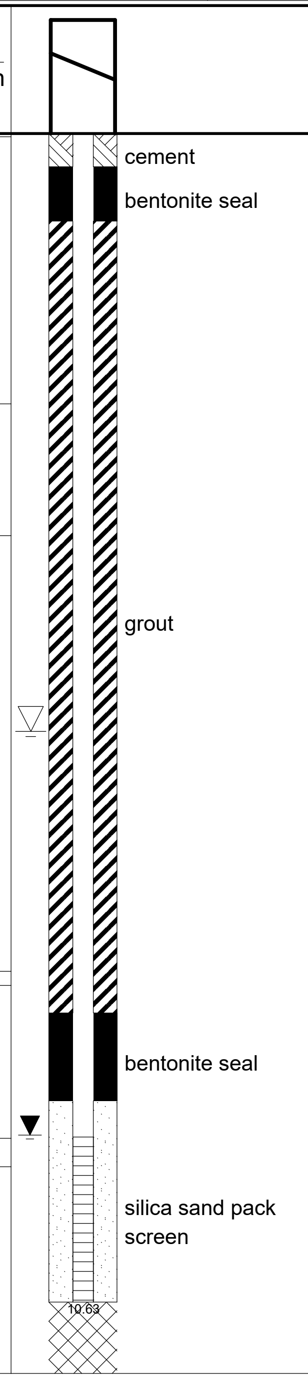
MW1d

BURNSIDE
R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Unit 20, Guelph, Ontario, N1H 1C4
telephone (519) 823-4995 fax (519) 836-5447

Client: **Jane, Lambert Altena**	Project Name: **211 Eliza Street Subdivision**	Logged by: **J. Donkersgoed**
Project No.: **300042585**	Location: **Arthur, ON**	Ground (m amsl): **459.00**
Drilling Co.: **Geo-Environmental Drilling Inc.**	Date Started: **1/10/2019**	Static Water Level Depth (m): **5.44**
Drilling Method: **Hollow Stem Auger**	Date Completed: **1/10/2019**	Sand Pack Depth (m) : **8.8 - 10.6**

Surface Elevation (m): **459.00**

Stratigraphic Description	Elev. / Depth (m)
TOPSOIL, 25mm	458.97 / 0.03
FILL silty sand, trace gravel, trace clay, trace organics, brown to dark brown, loose to compact. moist to wet grey with organic pockets @ 1.9m	456.54 / 2.46
ORGANICS including wood, peat, trace gravel, black, loose, moist	455.34 / 3.66
SILT some clay, some sand, trace gravel (angular), grey, medium to stiff, moist, cohesive, massive damp, no gravel, clay layers @ 6.0m	451.38 / 7.62
SAND trace silt, grey, dense, wet	451.25 / 7.75
SILT AND SAND some gravel, trace clay, grey, very dense, moist	449.86 / 9.14
SAND trace gravel, grey, dense, moist	449.60 / 9.40
SILT AND SAND some gravel, trace clay, grey, very dense, moist	447.72 / 11.28
End of Borehole	



Sample Num.	Type	Int.	
1	SS		8
2	SS		13
3	SS		8
4	SS		3
5	SS		10
6	SS		21
7	SS		31
8	SS		62
9	SS		59
10	SS		86

Prepared By: **J. Donkersgoed** Checked By: **S. Charity** Date Prepared: **1/11/2019**

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	MONITORING WELL DATA	SAMPLE TYPE
▼ Water found @ time of drilling	Pipe: **51 mm dia. PVC**	AC Auger Cutting; CS Continuous; RC Rock Core
▽ Static Water Level - 2/22/2019	Screen: **51 mm dia. PVC #10 slot**	SS Split Spoon; AR Air Rotary; WC Wash Cuttings

LOG OF DRILLING OPERATIONS

MW1s

R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Unit 20, Guelph, Ontario, N1H 1C4
telephone (519) 823-4995 fax (519) 836-5447

Client: **Jane, Lambert Altena**	Project Name: **211 Eliza Street Subdivision**	Logged by: **J. Donkersgoed**
Project No.: **300042585**	Location: **Arthur, ON**	Ground (m amsl): **459.00**
Drilling Co.: **Geo-Environmental Drilling Inc.**	Date Started: **1/9/2019**	Static Water Level Depth (m): **3.74**
Drilling Method: **Hollow Stem Auger**	Date Completed: **1/9/2019**	Sand Pack Depth (m) : **4.3 - 6.0**

Surface Elevation (m): **459.00**

Stratigraphic Description	Elev. / Depth (m)
TOPSOIL, 25mm	458.97 / 0.03
FILL silty sand, trace gravel, trace clay, trace organics, brown to dark brown, loose to compact. moist to wet grey with organic pockets @ 1.9m	
ORGANICS including wood, peat, trace gravel, black, loose, moist	456.54 / 2.46
SILT some clay, some sand, trace gravel (angular), grey, medium to stiff, moist, cohesive, massive damp, no gravel, clay layers @ 6.0m	455.34 / 3.66
End of Borehole	452.29 / 6.71

Well construction: cement; bentonite seal; silica sand pack; screen (bottom 6.04 m)

SAMPLE

Num.	Type	Int.	
1	SS		8
2	SS		13
3	SS		8
4	SS		3
5	SS		10
6	SS		21
7	SS		31

Prepared By: **J. Donkersgoed** Checked By: **S. Charity** Date Prepared: **1/11/2019**

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	MONITORING WELL DATA	SAMPLE TYPE	
▼ Water found @ time of drilling	Pipe: **51 mm dia. PVC**	AC Auger Cutting	SS Split Spoon
▽ Static Water Level - 2/22/2019	Screen: **51 mm dia. PVC #10 slot**	CS Continuous	AR Air Rotary
		RC Rock Core	WC Wash Cuttings

2019_BHLOG_COLOUR P:\GINTPROJECTS\300 JOBS\300042585 211 ELIZA ST ARTHUR.GPJ 2019_1.GDT 4/29/20

BURNSIDE
R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Unit 20, Guelph, Ontario, N1H 1C4
telephone (519) 823-4995 fax (519) 836-5447

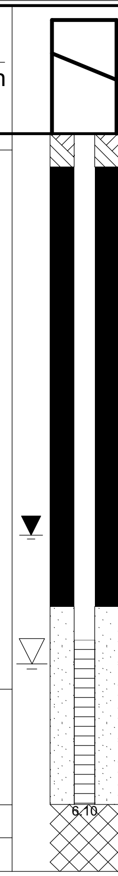
LOG OF DRILLING OPERATIONS

MW2

Client: **Jane, Lambert Altena**	Project Name: **211 Eliza Street Subdivision**	Logged by: **J. Donkersgoed**
Project No.: **300042585**	Location: **Arthur, ON**	Ground (m amsl): **466.00**
Drilling Co.: **Geo-Environmental Drilling Inc.**	Date Started: **1/9/2019**	Static Water Level Depth (m): **4.82**
Drilling Method: **Hollow Stem Auger**	Date Completed: **1/9/2019**	Sand Pack Depth (m) : **4.3 - 6.1**

Surface Elevation (m): **466.00**

Stratigraphic Description	Elev. (m)	Depth (m)
TOPSOIL, 150 mm	465.85	0.15
SILT some clay, trace gravel, brown, medium to hard, moist, cohesive, some oxidization sand inclusion @ 2.4m grading coarser, some sand @ 3.0m grey, increasing clay, occasional clay layer @ 4.6m 50 mm medium sand @ 5.0m	460.95	5.05
CLAYEY SILT grey, very stiff, moist, layered	459.90	6.10
SAND grey, compact, saturated	459.60	6.40
SILT AND SAND some gravel, trace clay, grey, dense, moist	459.29	6.71
End of Borehole		



SAMPLE

Num.	Type	Int.	
1	SS		4
2	SS		6
3	SS		19
4	SS		21
5	SS		33
6	SS		18
7	SS		42

Prepared By: **J. Donkersgoed** Checked By: **S. Charity** Date Prepared: **1/11/2019**

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	MONITORING WELL DATA	SAMPLE TYPE
▼ Water found @ time of drilling	Pipe: **51 mm dia. PVC**	AC Auger Cutting; SS Split Spoon
▽ Static Water Level - 2/22/2019	Screen: **51 mm dia. PVC #10 slot**	CS Continuous; AR Air Rotary
		RC Rock Core; WC Wash Cuttings

LOG OF DRILLING OPERATIONS

MW3

R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Unit 20, Guelph, Ontario, N1H 1C4
telephone (519) 823-4995 fax (519) 836-5447

Client: **Jane, Lambert Altena**	Project Name: **211 Eliza Street Subdivision**	Logged by: **J. Donkersgoed**
Project No.: **300042585**	Location: **Arthur, ON**	Ground (m amsl): **461.00**
Drilling Co.: **Geo-Environmental Drilling Inc.**	Date Started: **1/10/2019**	Static Water Level Depth (m): **2.97**
Drilling Method: **Hollow Stem Auger**	Date Completed: **1/10/2019**	Sand Pack Depth (m) : **4.8 - 6.7**

Surface Elevation (m): **461.00**

Stratigraphic Description	Elev. (m) / Depth (m)	Well	Sample Num.	Type	Int.	Blows
TOPSOIL silty sand, dark brown, loose, moist	459.96 / 1.04	cement	1	SS		8
			2	SS		7
SILTY SAND with organics, some clay, trace gravel, brown, loose, moist to wet	459.27 / 1.73		3	SS		5
SILT some clay, trace gravel, brown, medium to hard, moist	456.43 / 4.57	bentonite seal	4	SS		30
			5	SS		40
SILT AND SAND some gravel, trace clay, brown, very dense, moist, cohesive grey, no cohesion @ 6.0m	454.27 / 6.73	silica sand pack screen	6	SS		>100
		6.73	7	SS		>100

End of Borehole

Depth Scale: (ft) 5.0, 10.0, 15.0, 20.0; (m) 1.0, 2.0, 3.0, 4.0, 5.0, 6.0

Prepared By: **J. Donkersgoed** Checked By: **S. Charity** Date Prepared: **1/11/2019**

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	MONITORING WELL DATA	SAMPLE TYPE
▼ Water found @ time of drilling	Pipe: **51 mm dia. PVC**	AC Auger Cutting; SS Split Spoon
▽ Static Water Level - 2/22/2019	Screen: **51 mm dia. PVC #10 slot**	CS Continuous; AR Air Rotary
		RC Rock Core; WC Wash Cuttings

LOG OF DRILLING OPERATIONS

MW4

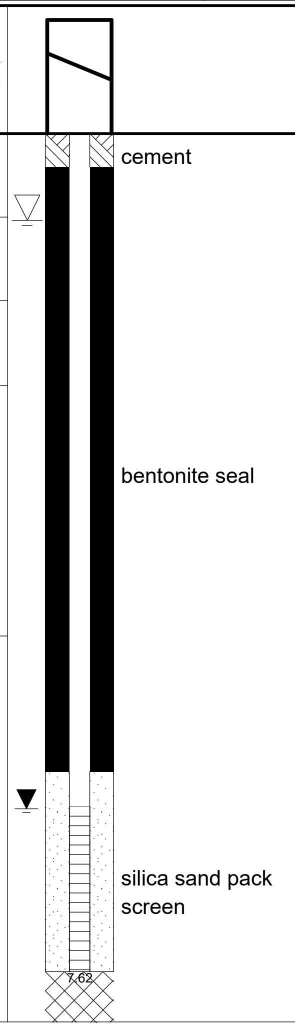
R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Unit 20, Guelph, Ontario, N1H 1C4
telephone (519) 823-4995 fax (519) 836-5447

Client: **Jane, Lambert Altena**	Project Name: **211 Eliza Street Subdivision**	Logged by: **J. Donkersgoed**
Project No.: **300042585**	Location: **Arthur, ON**	Ground (m amsl): **456.75**
Drilling Co.: **Geo-Environmental Drilling Inc.**	Date Started: **1/9/2019**	Static Water Level Depth (m): **0.79**
Drilling Method: **Hollow Stem Auger**	Date Completed: **1/9/2019**	Sand Pack Depth (m) : **5.8 - 7.6**

Surface Elevation (m): **456.75**

Stratigraphic Description	Elev. (m)	Depth (m)
SILTY SAND with organics, dark brown, very loose, moist.	455.99	0.76
SAND AND GRAVEL some silt, brown, compact, saturated	455.23	1.52
SILT some sand, some clay, brown, stiff, moist, mottled, cohesive	454.46	2.29
GRAVELLY SANDY SILT trace clay, brown, lightly mottled, medium to very stiff, wet	452.18	4.57
SILT AND SAND some gravel, occasional cobble, trace clay, brown to grey, very dense, moist	448.67	8.08

End of Borehole



SAMPLE

Num.	Type	Int.	
1	SS		2
2	SS		19
3	SS		11
4	SS		5
5	SS		17
6	SS		64
7	SS		63
8	SS		90

Prepared By: **J. Donkersgoed** Checked By: **S. Charity** Date Prepared: **1/11/2019**

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 - 2/22/2019

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

2019_BHLOG_COLOUR P:\GINTPROJECTS\300 JOBS\300042585 211 ELIZA ST ARTHUR.GPJ 2019_1.GDT 4/29/20

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix B

MECP Well Logs

Appendix B

Table B-1 - Summary of MECP Well Records

MECP Well #	Well Use	Well Status	Borehole Depth (m)	Aquifer	Date Drilled	Location Detail
6700002	Well: Supply - Municipal		93.00	Bedrock	6/28/1950	
6700003	Well: Supply		54.60	Bedrock	9/23/1963	
6701957	Well: Supply		150.90	Bedrock	8/13/1952	
6701958	Well: Supply		30.80	Overburden	8/17/1950	
6701959	Well: Supply		86.30	Bedrock	4/21/1956	
6702882	Well: Supply		65.80	Bedrock	10/15/1952	
6702883	Well: Supply		74.40	Bedrock	10/24/1956	
6703273	Well: Supply - Domestic		66.10	Overburden	7/9/1968	
6703367	Well: Supply - Industrial		78.30	Bedrock	6/2/1969	
6703483	Well: Supply		65.50	Bedrock	12/1/1969	
6704343	Well: Supply		68.00	Overburden	9/7/1972	
6705119	Well: Supply		54.90	Overburden	6/17/1974	
6706459	Well: Supply		56.70	Overburden	7/6/1977	
6706605	Well: Supply		63.40	Overburden	12/3/1977	
6706945	Well: Supply		109.70	Bedrock	8/23/1978	
6708240	Well: Supply		77.70	Bedrock	5/30/1985	
6708594	Well: Supply		66.40	Overburden	11/28/1986	
6708870	Well: Supply		64.00	Bedrock	7/8/1987	
6709740	Well: Supply		65.80	Overburden	5/4/1989	
6710893	Well: Supply		62.80	Overburden	2/21/1991	
6712213	Well: Supply		67.10	Bedrock	4/9/1997	
6712214	Well: Abandoned	Abandoned	34.10	N/A	4/10/1997	
6712301	Well: Supply - Municipal		52.70	Overburden	7/28/1997	
6712367	Well: Supply		59.70	Overburden	10/2/1997	
6712922	Well: Supply - Municipal	Abandoned	46.60	Overburden	12/11/1998	Near Gas Station
6715545	Well: Abandoned	Abandoned	182.90	N/A	10/18/2005	
6715601	Well: Abandoned	Abandoned	68.00	N/A	12/15/2005	
6715657	Well: Municipal Abandoned	Abandoned	0.00	N/A	1/30/2006	6712922 - Abandoned
6715886	Well: Abandoned	Abandoned	0.00	N/A	8/30/2006	
7040778	Well: Observation/Monitoring		7.60	Overburden	12/20/2006	
7042081	Well: Observation/Monitoring		4.00	Overburden	3/30/2006	
7044990	Well: Supply - Domestic		24.40	Overburden	2/7/2007	Jones Baseline
7105361	Well: Observation/Monitoring		4.60	Overburden	3/11/2008	110 Charles
7105361	Well: Observation/Monitoring		4.60	Overburden	3/11/2008	110 Charles
7105361	Well: Observation/Monitoring		4.60	Overburden	3/11/2008	110 Charles

Table B-1 - Summary of MECP Well Records

MECP Well #	Well Use	Well Status	Borehole Depth (m)	Aquifer	Date Drilled	Location Detail
7105361	Well: Observation/Monitoring		4.60	Overburden	3/14/2008	110 Charles
7105361	Well: Observation/Monitoring		4.60	Overburden	4/9/2008	110 Charles
7109131	Well: Abandoned	Abandoned	0.00	N/A	7/30/2008	110 Charles East
7123321	Well: Observation/Monitoring		5.40	Overburden	5/4/2009	
7123322	Well: Observation/Monitoring		4.80	Overburden	5/4/2009	
7123323	Well: Observation/Monitoring		3.60	Overburden	5/4/2009	
7123324	Well: Observation/Monitoring		4.20	Overburden	5/4/2009	
7145549	Well: Observation/Monitoring		20.00	Overburden	5/18/2010	7994 Wellingon Road
7145549	Well: Observation/Monitoring		20.00	Overburden	5/19/2010	7994 Wellingon Road
7145549	Well: Observation/Monitoring		20.00	Overburden	5/19/2010	7994 Wellingon Road
7145549	Well: Observation/Monitoring		20.00	Overburden	5/19/2010	7994 Wellingon Road
7145549	Well: Observation/Monitoring		20.00	Overburden	5/19/2010	7994 Wellingon Road
7149904	Well: Abandoned	Abandoned	0.00	N/A	5/20/2010	
7149905	Well: Abandoned	Abandoned	0.00	N/A	5/20/2010	
7158779	Well: Abandoned	Abandoned	0.00	N/A	5/3/2010	
7161021	Well: Observation/Monitoring		4.80	Overburden	3/9/2011	7643 Highway 6
7161022	Well: Observation/Monitoring		5.10	Overburden	3/9/2011	7643 Highway 6
7161023	Well: Observation/Monitoring		6.00	Overburden	3/9/2011	7643 Highway 6
7163571	Well: Abandoned Monitoring Well	Abandoned	0.00	N/A	5/17/2011	7994 Wellingon Road
7163864	Well: Observation/Monitoring		4.60	Overburden	5/11/2011	
7171480	Well: Observation/Monitoring		7.00	Overburden	10/20/2011	8021 Wellington Road 109
7183961	Well: Abandoned Municipal Water Supply	Abandoned	60.30	N/A	6/21/2012	7641 Highway 6
7185004	Well: Observation/Monitoring		4.50	Overburden	7/4/2012	7643 Highway 6
7185005	Well: Observation/Monitoring		4.80	Overburden	7/4/2012	7643 Highway 6
7185006	Well: Observation/Monitoring		4.50	Overburden	7/4/2012	7643 Highway 6
7185007	Well: Observation/Monitoring		4.50	Overburden	7/4/2012	7643 Highway 6
7187196	Well: Abandoned	Abandoned	15.54	N/A	8/22/2012	7995 Wellington Road 109
7210891	Well: Abandoned Monitoring Well	Abandoned	4.60	N/A	10/9/2013	7643 Highway 6
7210892	Well: Abandoned Monitoring Well	Abandoned	4.60	N/A	10/9/2013	7643 Highway 6
7210893	Well: Abandoned Monitoring Well	Abandoned	4.60	N/A	10/9/2013	7643 Highway 6
7210895	Well: Abandoned Monitoring Well	Abandoned	4.60	N/A	10/9/2013	7643 Highway 6
7210896	Well: Abandoned Monitoring Well	Abandoned	4.60	N/A	10/9/2013	7643 Highway 6
7220861	Well: Observation/Monitoring		6.10	Overburden	5/13/2014	
7223173	Well: Municipal Abadoned	Abandoned	0.00	N/A	6/13/2014	
7228721	Well: Abandoned	Abandoned	0.00	N/A	6/17/2014	

Water Well Records

Wednesday, December 18, 2019

12:03:23 PM

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
ARTHUR TOWNSHIP	17 537639 4853114 W	2006/03 6988	2.00				0003 10	7042081 (Z41261) A037358	BRWN SAND SILT LOAM 0004 BRWN SILT SAND CLAY 0006 BRWN SAND SILT 0008 BRWN SILT 0010 GREY SILT CLAY SAND 0013 GREY CLAY 0013
ARTHUR TOWNSHIP	17 537183 4853019 W	2006/12 6607	0.75	0016			0017 8	7040778 (Z59650) A051099	BRWN SILT LOAM FILL 0015 BLCK PEAT 0017 BRWN SAND GRVL 0019 GREY SILT SAND CLAY 0025
ARTHUR TOWNSHIP	17 537631 4852888 W	2010/05 7383	0.79 0.79			MO		7145549 (M06954) A069003	BLCK 0007 BRWN SAND GRVL FILL 0016 BRWN SILT CLAY SOFT 0041 BRWN SAND SILT LOOS 0066
ARTHUR TOWNSHIP	17 537254 4853279 W	2012/07 7241	1.58			MT	0005 10	7185004 (Z151068) A109742	BLCK ---- SOFT 0000 BRWN SAND GRVL SOFT 0005 BRWN SILT SAND SOFT 0015
ARTHUR TOWNSHIP	17 537254 4853279 W	2012/07 7241	1.58			MT	0006 10	7185005 (Z151070) A109744	BLCK ---- SOFT 0000 BRWN SAND GRVL LOOS 0007 BRWN SILT SAND SOFT 0016
ARTHUR TOWNSHIP	17 537254 4853279 W	2012/07 7241	1.58			MT	0005 10	7185006 (Z151072) A109745	BLCK ---- SOFT 0000 BRWN SAND GRVL SOFT 0007 BRWN SILT SAND SOFT 0015
ARTHUR TOWNSHIP	17 537254 4853279 W	2012/07 7241	1.58			MT	0005 10	7185007 (Z151069) A109743	BLCK ---- SOFT 0000 BRWN SAND GRVL SOFT 0007 BRWN SILT SAND SOFT 0015
ARTHUR TOWNSHIP	17 537307 4853285 W	2014/06 7221				MN NU		7223173 (Z188882) A	
ARTHUR TOWNSHIP	17 537641 4852940 W	2014/05 7190	2			MO	0010 10	7220861 (Z180443) A146221	BRWN SILT SAND SOFT 0015 GREY SILT SAND SOFT 0020
ARTHUR VILLAGE	17 537693 4853116 W	2006/08 6634						6715886 (Z71053) A043259 A	
ARTHUR VILLAGE	17 537394 4853463 W	1963/09 1804	4 4	FR 0162	60/75/18/10:0	DO		6700003 ()	LOAM 0004 GRVL BLDR 0020 GREY CLAY 0040 GREY CLAY STNS 0100 GREY CLAY MSND 0115 GREY QSND 0150 YLLW MSND 0161 BRWN ROCK 0179
ARTHUR VILLAGE	17 537302 4853291 W	1997/07 3428	6		65/148/60/23:0	MN		6712301 (093334)	PRDR 0173
ARTHUR VILLAGE	17 537731 4852904 W	1998/12 3406	6	UK 0056 UK 0143	27/43/20/24:0	CO		6712922 (201732)	BRWN FILL 0011 BRWN CLAY STNS TILL 0056 BRWN SAND CLAY SILT 0061 BRWN CLAY STNS 0121 BRWN CLAY STNS 0143 BRWN GRVL SAND 0153
ARTHUR VILLAGE	17 537490 4853366 W	2005/10 7221	7.86		67///:			6715545 (Z26595) A	

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
ARTHUR VILLAGE	17 537716 4852903 W	2006/01 6061						6715657 (Z39480) A	
ARTHUR VILLAGE	17 537484 4853003 W	1950/06 2414	10 10	FR 0285	30/130/70/8:0	MN		6700002 ()	FILL 0005 BRWN CLAY 0035 BRWN FSND 0050 BLUE CLAY 0060 BLUE CLAY MSND 0155 GRVL SILT 0159 BRWN LMSN 0183 WHIT LMSN 0187 BLUE ROCK 0194 GREY ROCK 0203 BRWN ROCK 0240 BLUE ROCK 0259 WHIT ROCK 0267 BLUE ROCK 0269 GREY ROCK 0273 BRWN ROCK 0288 BLUE ROCK 0305
ARTHUR VILLAGE	17 537394 4853217 W	2008/04 7366	1.5			MO		7105361 (M01110) A058441	BRWN LOAM LOOS 0002 BRWN SAND SILT LOOS 0008 BRWN CLAY SILT DNSE 0015
ARTHUR VILLAGE	17 537394 4853217 W	2008/07 7366	3.79			OT	0010 5	7109131 (Z82317) A058441 A	
ARTHUR VILLAGE	17 537769 4852678 W	2009/05 7238	1.97			MO	0008 10	7123321 (Z098684) A083323	BRWN CLAY SILT 0018
ARTHUR VILLAGE	17 537754 4852658 W	2009/05 7238	1.97			MO	0011 5	7123322 (Z098685) A083342	BRWN CLAY SILT 0016
ARTHUR VILLAGE	17 537767 4852649 W	2009/05 7238	1.97			MO	0007 5	7123323 (Z098686) A083354	BRWN CLAY SILT 0012
ARTHUR VILLAGE	17 537783 4852629 W	2009/05 7238	1.97			MO	0009 5	7123324 (Z098687) A083355	BRWN CLAY SILT 0014
ARTHUR VILLAGE	17 537663 4852858 W	2011/05 7190	2 2	UT 0015		MT	0005 10	7163864 (Z120266) A105833	BRWN LOAM LOOS 0001 BRWN SAND GRVL LOOS 0003 BRWN SILT GRVL 0010 GREY SAND GRVL DNSE 0015
ARTHUR VILLAGE	17 537670 4853074 W	2010/05 7221				MO		7149905 (Z104704) A	
ARTHUR VILLAGE	17 537985 4852936 W	2010/05 7221						7158779 (Z125322) A	
ARTHUR VILLAGE	17 537210 4853276 W	2010/05 7221	1.25 0.98 1.25			MO		7149904 (Z104703) A	
ARTHUR VILLAGE	17 537597 4852908 W	2011/05 7383						7163571 (M07840) A099198 P	
ARTHUR VILLAGE	17 537785 4852864 W	2013/10 7241	1.5			MT	0005 10	7210892 (Z179159) A152547	BRWN FILL LOOS 0002 BRWN SAND SILT LOOS 0013 BRWN SAND SILT HARD 0015
ARTHUR VILLAGE con 01 029	17 537307 4853285 W	2005/12 7221	5.90					6715601 (Z42941) A	

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
PEEL TOWNSHIP	17 537334 4852835 W	2013/10 7241	1.5			MT	0005 10	7210896 (Z179157) A152549	BRWN FILL LOOS 0002 BRWN SILT SAND LOOS 0013 BRWN TILL DNSE 0015
PEEL TOWNSHIP CON 19 009	17 537265 4852774 W	1991/02 3406	6	UK 0091 UK 0182 UK 0206	38/90/10/72:0	DO		6710893 (61709)	BRWN GRVL CLAY SAND 0060 GREY GRVL CLAY BLDR 0095 GREY CLAY GRVL SAND 0182 GRVL SAND CGRD 0206
PEEL TOWNSHIP CON A 023	17 537734 4852623 W	1969/06 1804	4	FR 0248	48/55/15/3:0			6703367 ()	LOAM 0003 YLLW CLAY MSND 0050 HPAN BLDR 0085 CLAY MSND 0160 CLAY STNS 0210 BLDR 0215 GREY MSND 0225 BRWN LMSN 0240 ROCK 0257
PEEL TOWNSHIP CON B 022	17 537920 4852514 W	1952/08 1723	4 4	FR 0491	78/200/5/:	ST DO		6701957 ()	CLAY 0030 GRVL 0090 LOAM MSND STNS 0269 GREY LMSN 0333 WHIT LMSN 0495
PEEL TOWNSHIP CON B 023	17 537814 4852673 W	1978/08 2332	4 4	FR 0320	59/60/6/4:0	DO		6706945 ()	BRWN OBDN SAND STNS 0018 GREY CLAY 0105 GREY CLAY STNS GRVL 0150 GREY CLAY STNS 0225 BLUE UNKN 0231 HPAN 0249 WHIT STNS LYRD 0315 GREY STNS LMSN 0360
PEEL TOWNSHIP CON B 023	17 537463 4852816 W	1950/08 4314	4	FR 0101	34/55/6/5:0	DO		6701958 ()	CLAY STNS 0014 MSND 0020 CLAY HPAN STNS 0050 MSND CLAY HPAN 0090 STNS 0094 HPAN 0098 GRVL 0101
PEEL TOWNSHIP CON B 023	17 537824 4852647 W	1989/05 1804	5	FR 0206	52/102/16/2:10	DO		6709740 (14070)	BLCK LOAM 0002 BRWN SAND CLAY 0205 BRWN SAND 0216
PEEL TOWNSHIP CON B 023	17 537647 4852806 W	2012/08 7221				DO		7187196 (Z143759) A	
PEEL TOWNSHIP CON B 023	17 537704 4852817 W	1956/04 1723	4 4	FR 0200 FR 0274	28/80/2/:	DO		6701959 ()	CLAY STNS 0220 SHLE 0225 GREY LMSN 0283
PEEL TOWNSHIP CON B 023	17 537693 4852774 W	1997/10 2576	6	FR 0190	45//30/1:30	DO	0192 4	6712367 (177667)	LOAM 0001 BRWN CLAY 0008 BRWN SILT GRVL 0141 BRWN CLAY GRVL 0176 BRWN SAND GRVL CGRD 0196
WEST GARAFRAXA TOWNS	17 537744 4852832 W	2013/10 7241	1.5			MT	0005 10	7210893 (Z179155) A152550	BRWN FILL LOOS 0003 BRWN SAND SILT LOOS 0012 BRWN TILL DNSE 0015
WEST GARAFRAXA TOWNS	17 537758 4852832 W	2011/03 7241	1.58			MT	0006 10	7161021 (Z124017) A096345	BLCK SOFT 0000 BRWN SAND SOFT 0013 BRWN FSND SOFT 0016
WEST GARAFRAXA TOWNS	17 537749 4852823 W	2013/10 7241	1.5			MT	0005 10	7210895 (Z179158) A150688	BRWN FILL LOOS 0002 BRWN SAND SILT DNSE 0009 BRWN TILL DNSE 0015
WEST GARAFRAXA TOWNS	17 537760 4852854 W	2013/10 7241	1.5			MT	0005 10	7210891 (Z179156) A152548	BRWN FILL LOOS 0004 GREY SAND SILT GRVL 0012 GREY SAND GRVL SILT 0015
WEST GARAFRAXA TOWNS	17 537767 4852842 W	2011/03 7241	1.58			MT	0007 10	7161022 (Z124018) A096285	BLCK SOFT 0000 BRWN SAND SOFT 0013 BRWN SILT FSND SOFT 0017
WEST GARAFRAXA TOWNS	17 537769 4852841 W	2011/03 7241	1.58			MT	0010 10	7161023 (Z124019) A096284	BLCK SOFT 0000 BRWN SAND SOFT 0016 BRWN SILT FSND SOFT 0020

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
WEST GARAFRAXA TOWNS	17 537950 4852863 W	2011/10 7366						7171480 (M10955) A121250 P	
WEST GARAFRAXA TOWNS CON 01 033	17 538120 4852497 W	2007/02 2644	6.25	FR 0074	45/60/4/2:0	DO		7044990 (Z41979) A037667	BRWN SAND CLAY 0036 BRWN SAND GRVL 0054 BRWN GRVL SLTY 0078 GREY GRVL SAND CLAY 0080
WEST GARAFRAXA TOWNS CON 01 036	17 538014 4852623 W	1977/12 1804	5	FR 0090	58/105/15/3:30	DO		6706605 ()	BRWN FILL 0008 BRWN CLAY 0090 BRWN SAND HPAN STNS 0160 BRWN SAND 0195 BRWN GRVL 0208
WEST GARAFRAXA TOWNS CON 01 037	17 537845 4852850 W	1952/10 2411	4 4	FR 0216	40/44/10/5:0	CO		6702882 ()	CLAY BLDR 0060 CLAY 0115 GRVL 0200 LMSN 0216
WEST GARAFRAXA TOWNS CON 01 037	17 537873 4852775 W	1956/10 1723	4 4	FR 0244	70/75/15/:	DO		6702883 ()	PRDG 0012 CLAY 0228 LMSN 0244
WEST GARAFRAXA TOWNS CON 01 037	17 537934 4852723 W	1968/07 1705	4	FR 0217	68/79/7/5:0	DO		6703273 ()	CLAY 0018 MSND GRVL CLAY 0100 MSND 0138 CLAY 0143 MSND HPAN 0172 HPAN 0178 HPAN MSND GRVL 0207 CSND 0217
WEST GARAFRAXA TOWNS CON 01 037	17 538164 4852953 W	1969/12 2406	6	FR 0210	22/28/10/3:0	DO		6703483 ()	BRWN CLAY BLDR 0035 BRWN CLAY STNS 0070 BRWN CLAY GRVL 0120 BRWN MSND SILT CLAY 0186 YLLW CLAY 0196 LMSN MSND 0215
WEST GARAFRAXA TOWNS CON 01 037	17 537849 4852855 W	1997/04 2576	6 6	FR 0156 FR 0198 FR 0217	23//150/2:0	DO		6712213 (177322)	FILL 0002 GREY CLAY STKY 0010 GREY CLAY SLTY GRVL 0049 BRWN GRVL SILT 0094 BRWN SAND GRVL WBRG 0103 GREY CLAY GRVL 0120 BRWN CLAY STNS WBRG 0156 BRWN SAND GRVL WBRG 0175 YLLW SHLE LMSN FCRD 0220
WEST GARAFRAXA TOWNS CON 01 037	17 538514 4853073 W	1977/07 4856	4 4	FR 0186	33/80/12/1:30	DO		6706459 ()	BLCK LOAM 0001 BRWN CLAY GRVL 0010 GREY CLAY STNS 0029 BRWN HPAN GRVL 0070 GREY SILT STNS 0095 WHIT GRVL SAND 0122 BRWN HPAN GRVL 0170 RED CLAY 0174 BRWN GRVL 0186
WEST GARAFRAXA TOWNS CON 01 037	17 537770 4852812 W	2012/06 7466						7183961 (Z119352) A	
WEST GARAFRAXA TOWNS CON 01 037	17 537977 4852612 W	1986/11 1804	5	FR 0208	58/80/18/2:20	DO		6708594 (05999)	BRWN FILL 0005 GREY CLAY 0066 BRWN HPAN STNS 0202 BRWN GRVL SAND 0218
WEST GARAFRAXA TOWNS CON 01 037	17 538211 4852929 W	1987/07 3740	5 5	FR 0210	15/20/30/1:	DO		6708870 (06077)	BRWN CLAY 0040 GREY HPAN BLDR 0188 BRWN SHLE SOFT 0198 GREY LMSN 0210
WEST GARAFRAXA TOWNS CON 01 037	17 537849 4852855 W	1997/04 2576	5			NU		6712214 (177323) A	PRDG 0112
WEST LUTHER TOWNSHIP	17 537748 4852912 W	2014/06 7383						7228721 (C18533) A151231 P	
WEST LUTHER TOWNSHIP CON 01 002	17 538443 4853154 W	1985/05 3740	5	FR 0245 FR 0255	30/90/6/1:45	DO ST		6708240 ()	BLCK LOAM 0001 BRWN CLAY 0008 GREY CLAY STNS 0037 GREY HPAN BLDR 0165 GREY HPAN GRVL 0186 BRWN SAND CLAY 0209 BRWN LMSN 0215 GREY LMSN 0255

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
WEST LUTHER TOWNSHIP CON 01 002	17 538863 4853233 W	1988/10 4854	30	UK 0017		DO		6709487 (39106)	BRWN CLAY 0008 BRWN SAND CLAY SNDY 0010 BRWN CLAY 0017 BRWN SAND CLAY SNDY 0020 BLUE CLAY 0033 GREY CLAY BLDR 0044
WEST LUTHER TOWNSHIP CON 01 002	17 538514 4853173 W	1974/06 2519	5	FR 0180	38/60/10/2:0	DO		6705119 ()	BRWN CLAY 0010 GREY CLAY STNS 0165 GREY HPAN 0180 GRVL 0180

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

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Appendix C

Hydraulic Conductivity

Appendix C

BURNSIDE

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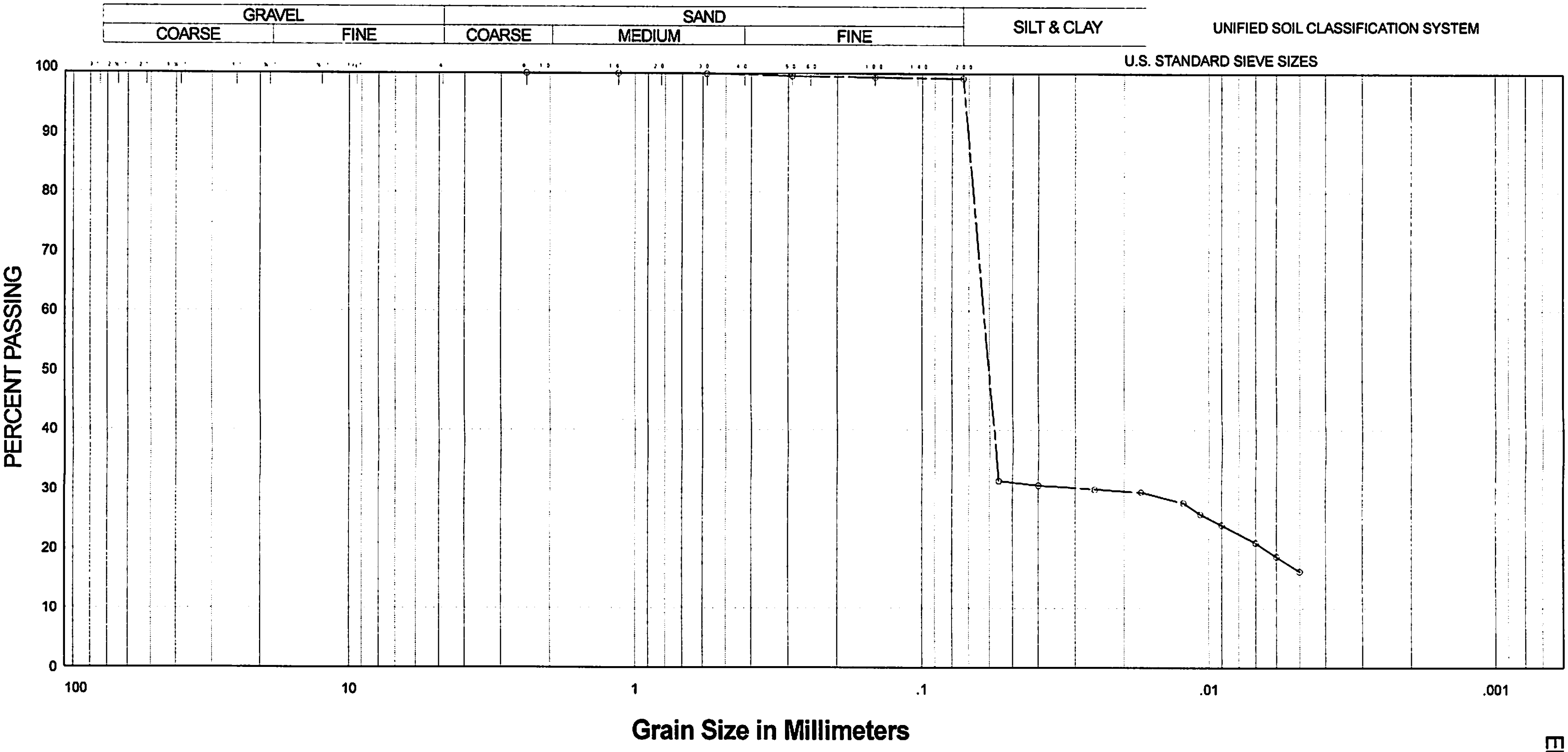
Appendix C-1

Grainsize Analysis

GRAIN SIZE DISTRIBUTION

OUR REFERENCE N° G4090-19-2



PROJECT N°: 300042585
LOCATION: 211 Eliza Street Subdivision, Arthur, ON
MONITORING WELL N°: 1
SAMPLE N°: 7
DEPTH: 6.1 - 6.4m
ELEVATION:

COEFFICIENT OF UNIFORMITY:
COEFFICIENT OF CURVATURE:

Classification of Sample and Group Symbol:

SILT, some clay

PLASTIC PROPERTIES

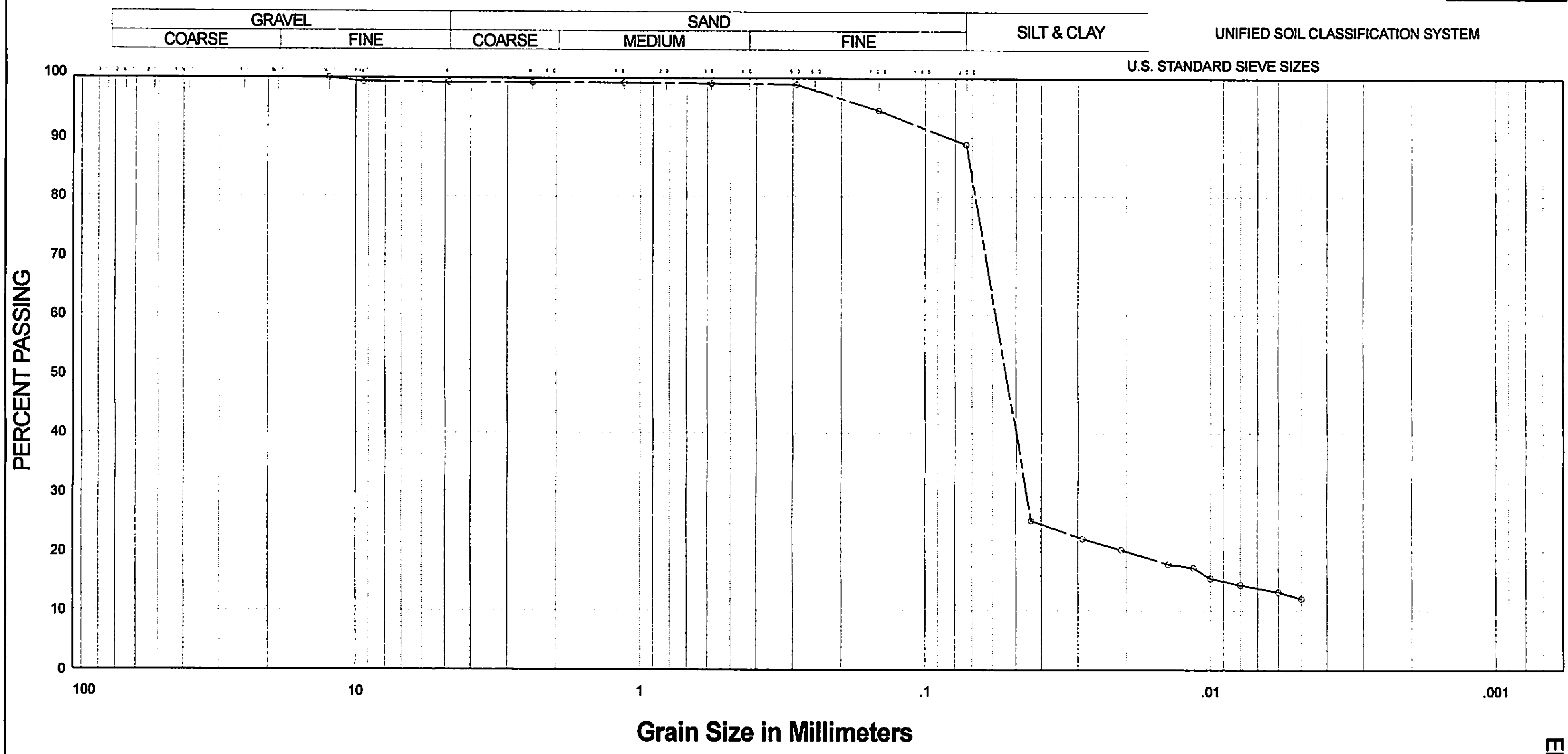
LIQUID LIMIT	% = 25.5
PLASTIC LIMIT	% = 17.8
PLASTICITY INDEX	% = 7.7
MOISTURE CONTENT	% = 17.6

ENCLOSURE N° 1

V. A. WOOD (GUELPH) INCORPORATED

GRAIN SIZE DISTRIBUTION

OUR REFERENCE N° G4090-19-2



PROJECT N°: 300042585
LOCATION: 211 Eliza Street Subdivison, Arthur, ON
MONITORING WELL N°: 2
SAMPLE N°: 3
DEPTH: 1.5-1.8m
ELEVATION:

COEFFICIENT OF UNIFORMITY:
COEFFICIENT OF CURVATURE:

Classification of Sample and Group Symbol:

SILT, some clay, some sand

PLASTIC PROPERTIES

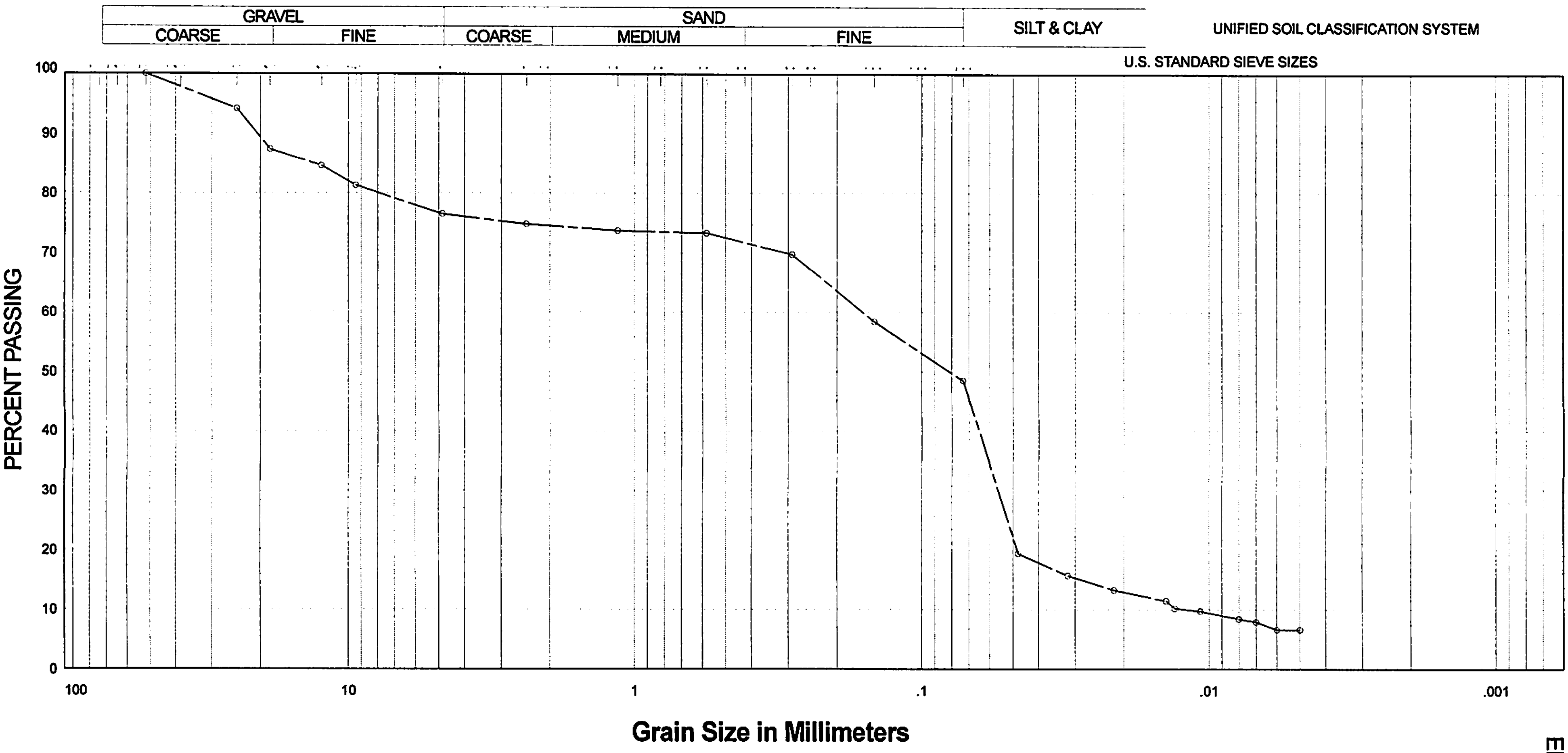
LIQUID LIMIT	% = 30.0
PLASTIC LIMIT	% = 20.9
PLASTICITY INDEX	% = 9.1
MOISTURE CONTENT	% = 17.6

ENCLOSURE N° 2

V. A. WOOD (GUELPH) INCORPORATED

GRAIN SIZE DISTRIBUTION

OUR REFERENCE N° G4090-19-2



PROJECT N°: 300042585
LOCATION: 211 Eliza Street Subdivision, Arthur, ON
MONITORING WELL N°: 4
SAMPLE N°: 4
DEPTH: 2.3 - 2.6m
ELEVATION:

COEFFICIENT OF UNIFORMITY:
COEFFICIENT OF CURVATURE:

Classification of Sample and Group Symbol:

GRAVELLY SANDY SILT, trace clay

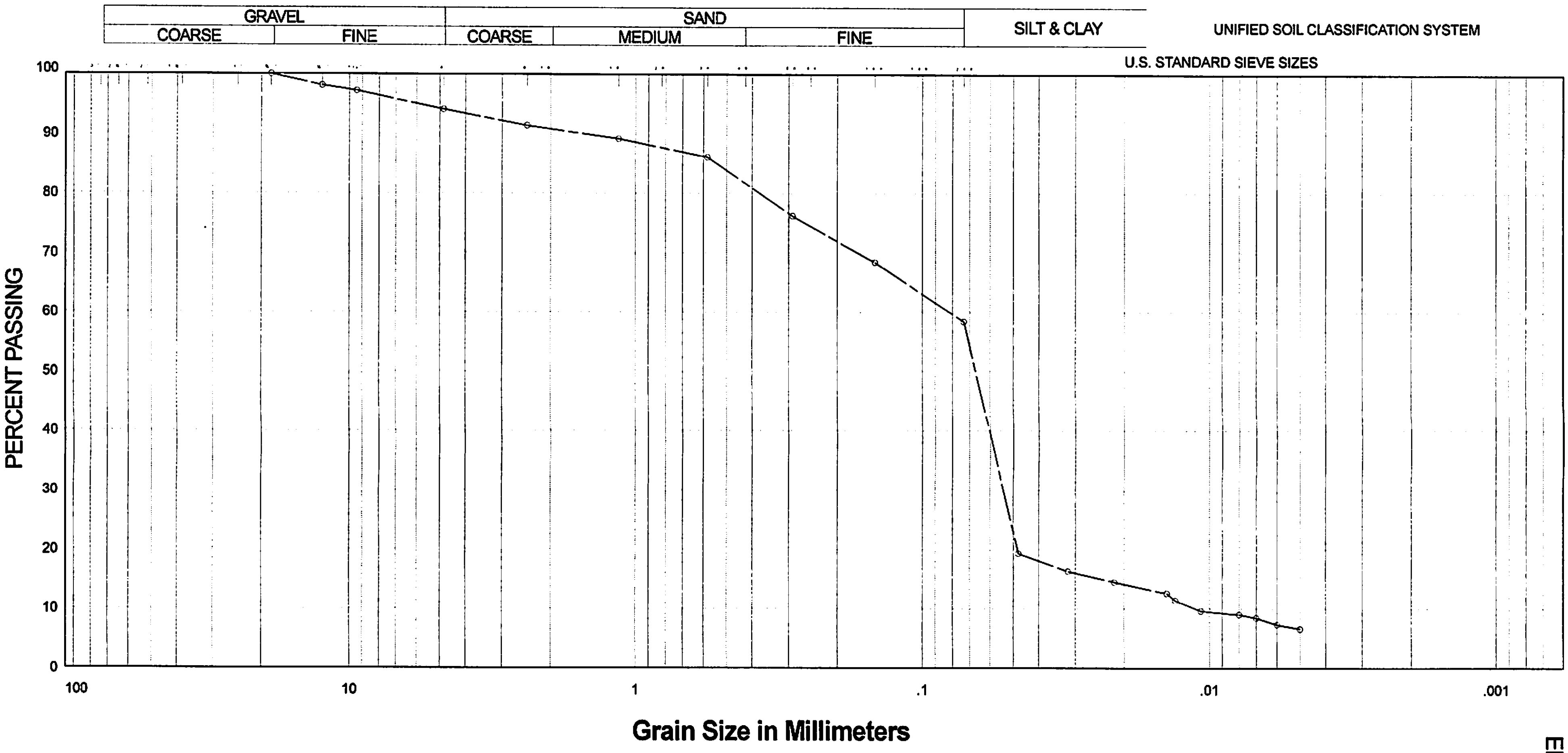
PLASTIC PROPERTIES
LIQUID LIMIT % =
PLASTIC LIMIT % =
PLASTICITY INDEX % =
MOISTURE CONTENT % = 8.8

ENCLOSURE N° 3

V. A. WOOD (GUELPH) INCORPORATED

GRAIN SIZE DISTRIBUTION

OUR REFERENCE N° G4090-19-2



PROJECT N°: 300042585
LOCATION: 211 Eliza Street Subdivision, Arthur, ON
MONITORING WELL N°: 4
SAMPLE N°: 6
DEPTH: 4.6 - 4.9m
ELEVATION:

COEFFICIENT OF UNIFORMITY:
COEFFICIENT OF CURVATURE:

Classification of Sample and Group Symbol:

SILT AND SAND, trace clay, trace gravel

PLASTIC PROPERTIES

LIQUID LIMIT	% =
PLASTIC LIMIT	% =
PLASTICITY INDEX	% =
MOISTURE CONTENT	% = 15.5

ENCLOSURE N° 4

V. A. WOOD (GUELPH) INCORPORATED

Appendix C-2

BURNSIDE

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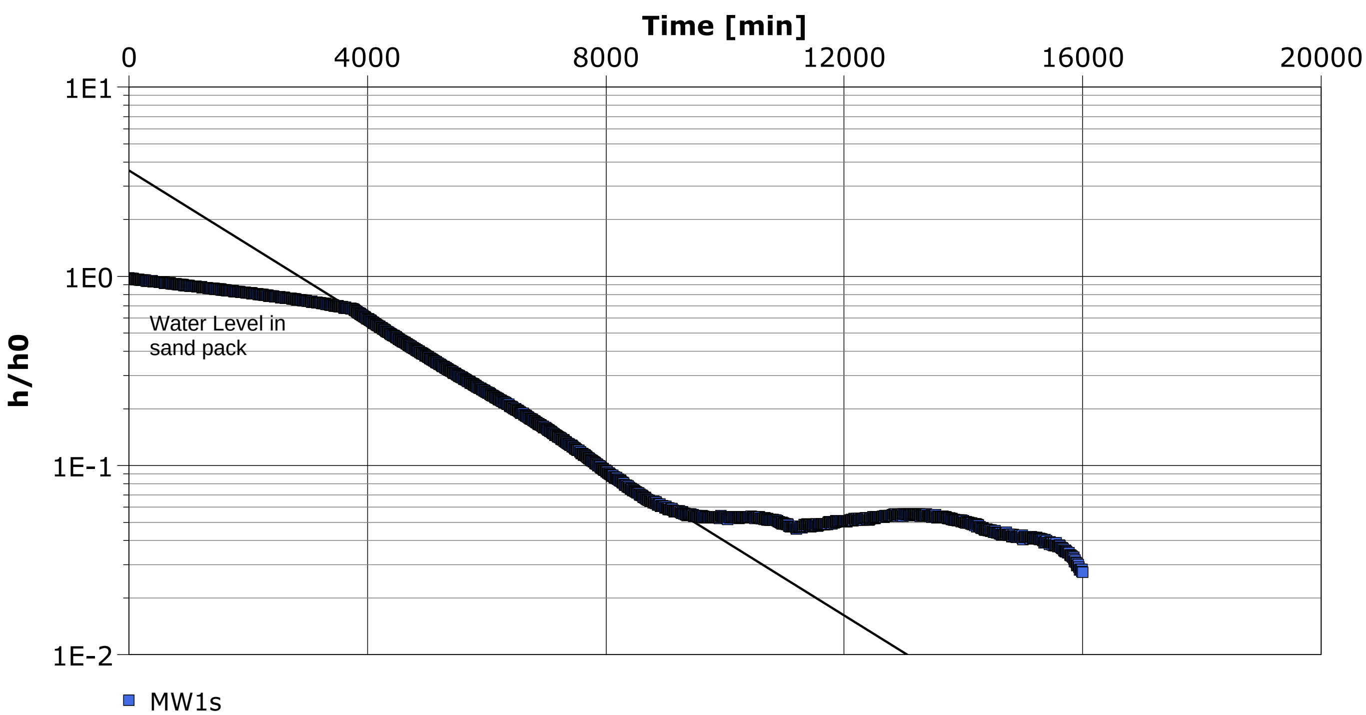
Appendix C-2

Single Well Response Testing

	Slug Test Analysis Report	Appendix C-2
BURNSIDE	Project: 211 Eliza Street	
	Number: 300042585	
	Client: Lambert and Janna Altena	

Location: Arthur, ON	Slug Test: MW1s Bail Down Test	Test Well: MW1s
Test Conducted by: MM		Test Date: 11/28/2019
Analysis Performed by: JD	MW1s	Analysis Date: 4/13/2020
Aquifer Thickness: 1.52 m		

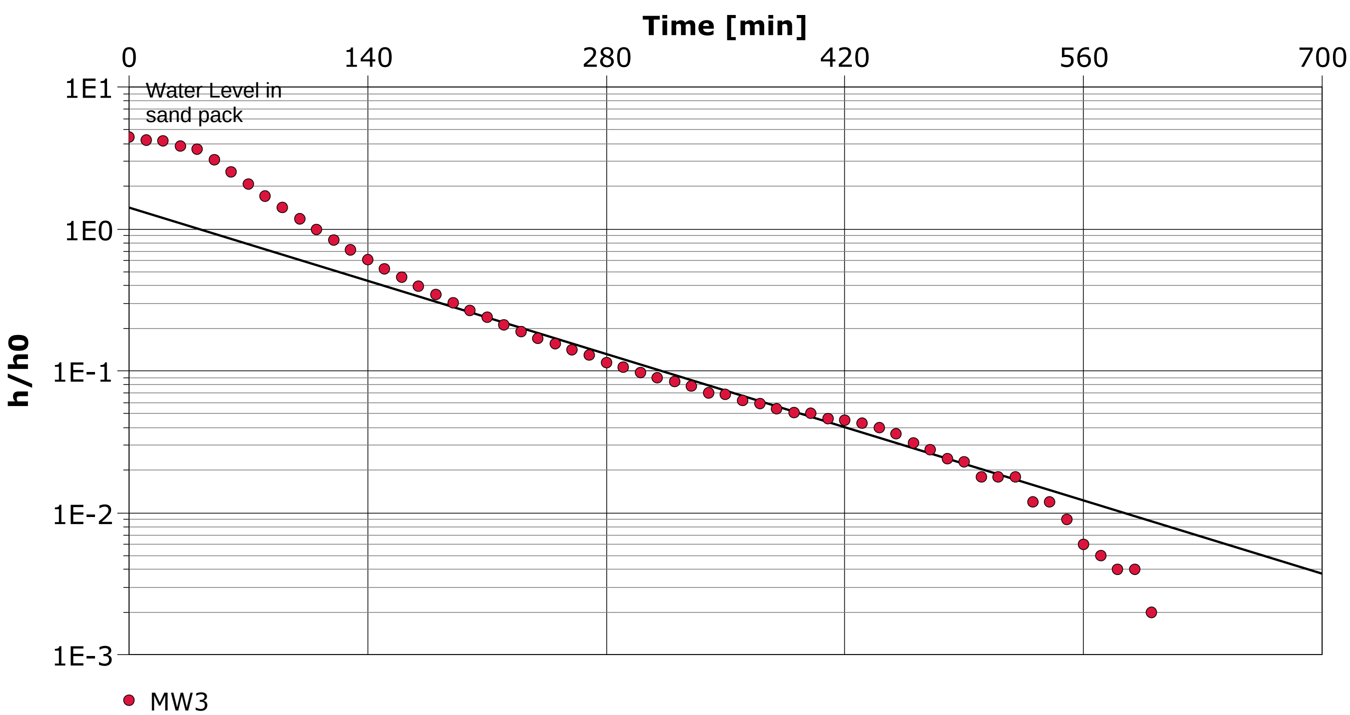


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [cm/s]	
MW1s	5.03×10^{-7}	

BURNSIDE	**Slug Test Analysis Report**	Appendix C-2
	Project: 211 Eliza Street	
	Number: 300042585	
	Client: Lambert and Janna Altena	

Location: Arthur, ON	Slug Test: MW3 Bail Down Test	Test Well: MW3
Test Conducted by: MM		Test Date: 11/28/2019
Analysis Performed by: JD	MW3	Analysis Date: 4/13/2020
Aquifer Thickness: 1.52 m		

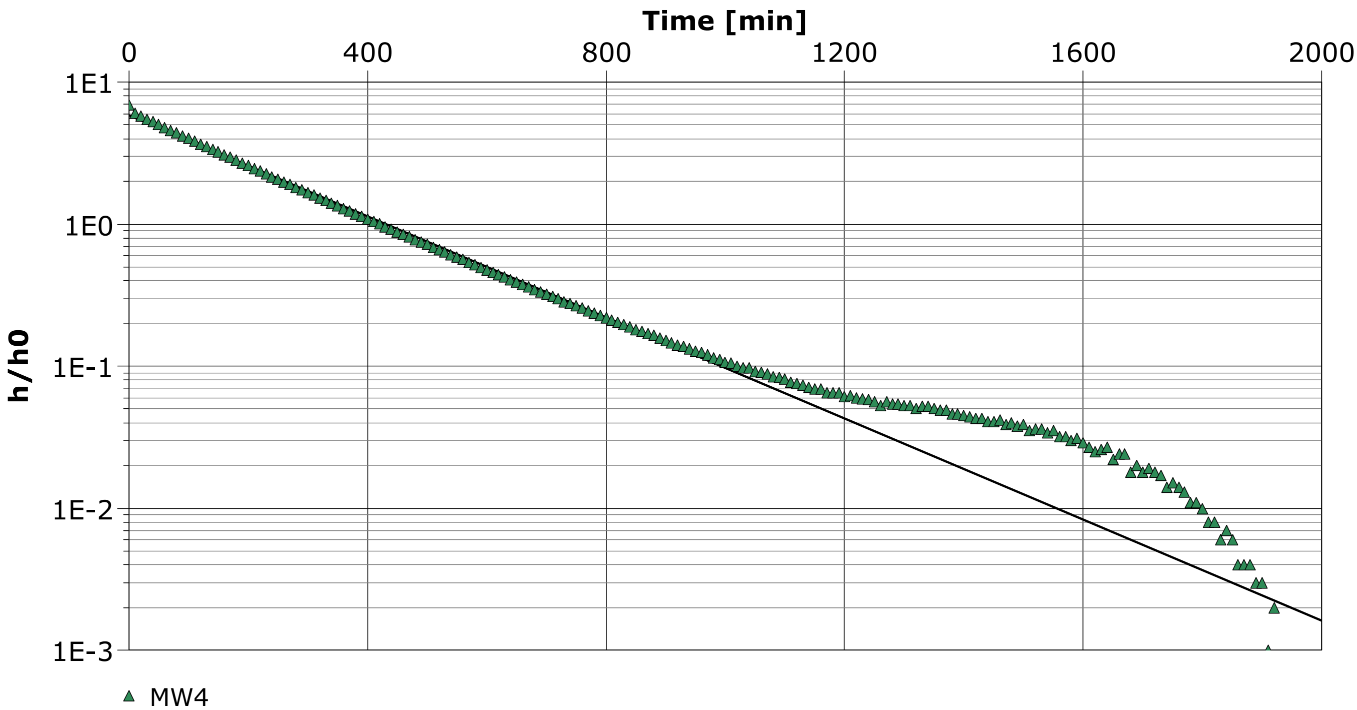


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [cm/s]	
MW3	9.48×10^{-6}	

	Slug Test Analysis Report Appendix C-2
	Project: 211 Eliza Street
	Number: 300042585
	Client: Lambert and Janna Altena

Location: Arthur, ON	Slug Test: MW4 Bail Down Test	Test Well: MW4
Test Conducted by: MM		Test Date: 11/28/2019
Analysis Performed by: JD	MW4	Analysis Date: 4/13/2020
Aquifer Thickness: 1.52 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [cm/s]
MW4	4.57×10^{-6}

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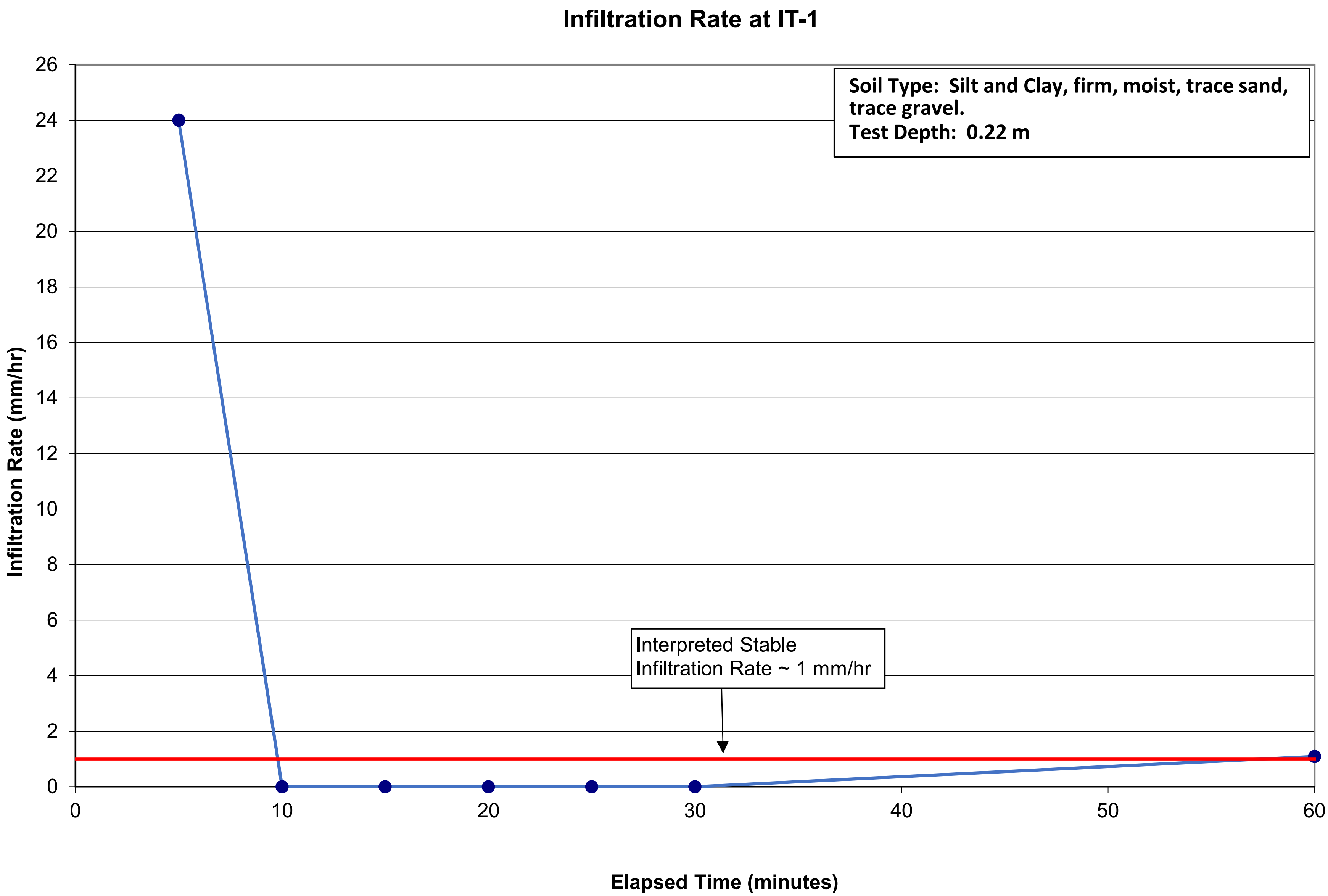
Appendix C-3

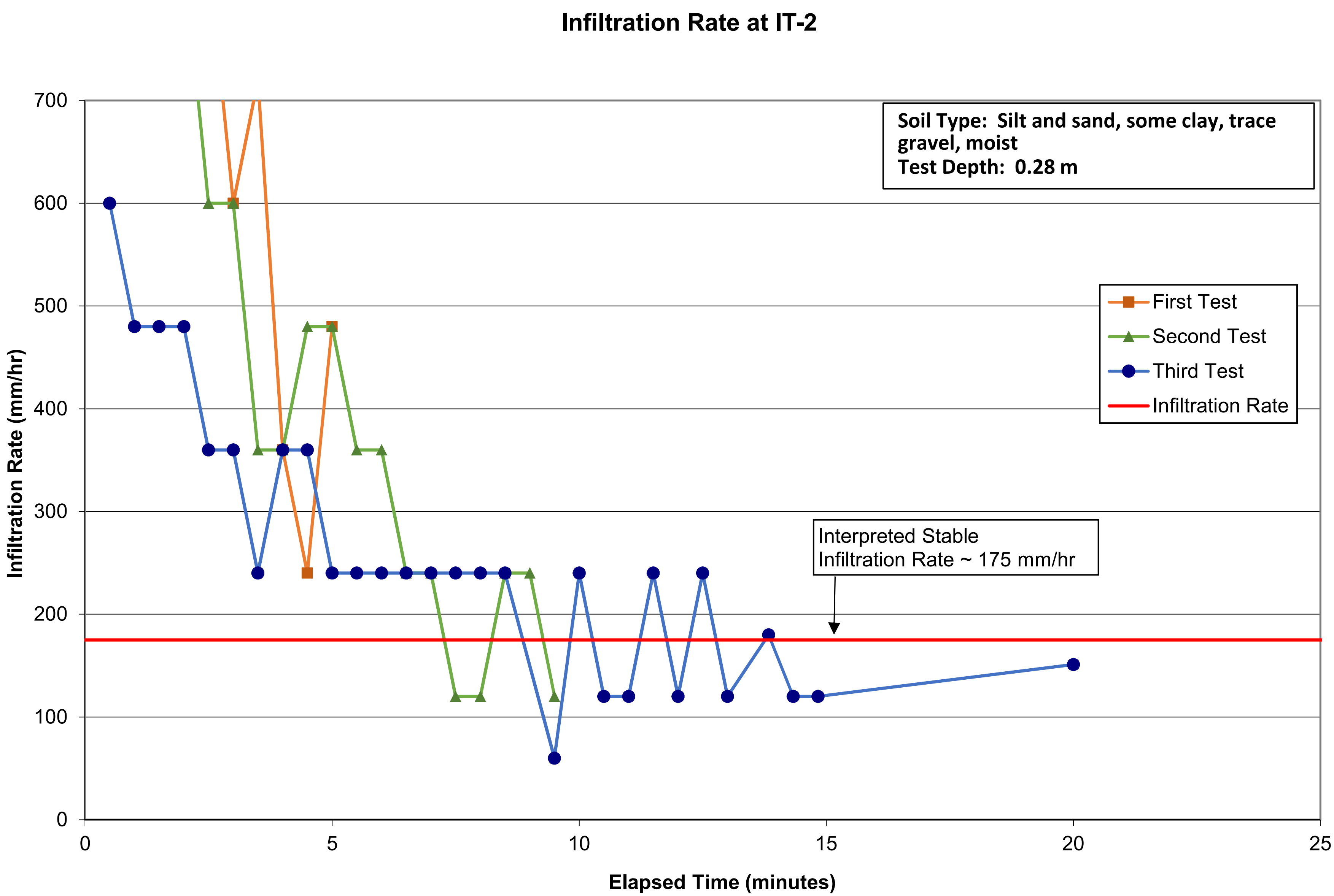
Infiltration Testing

Appendix C-3



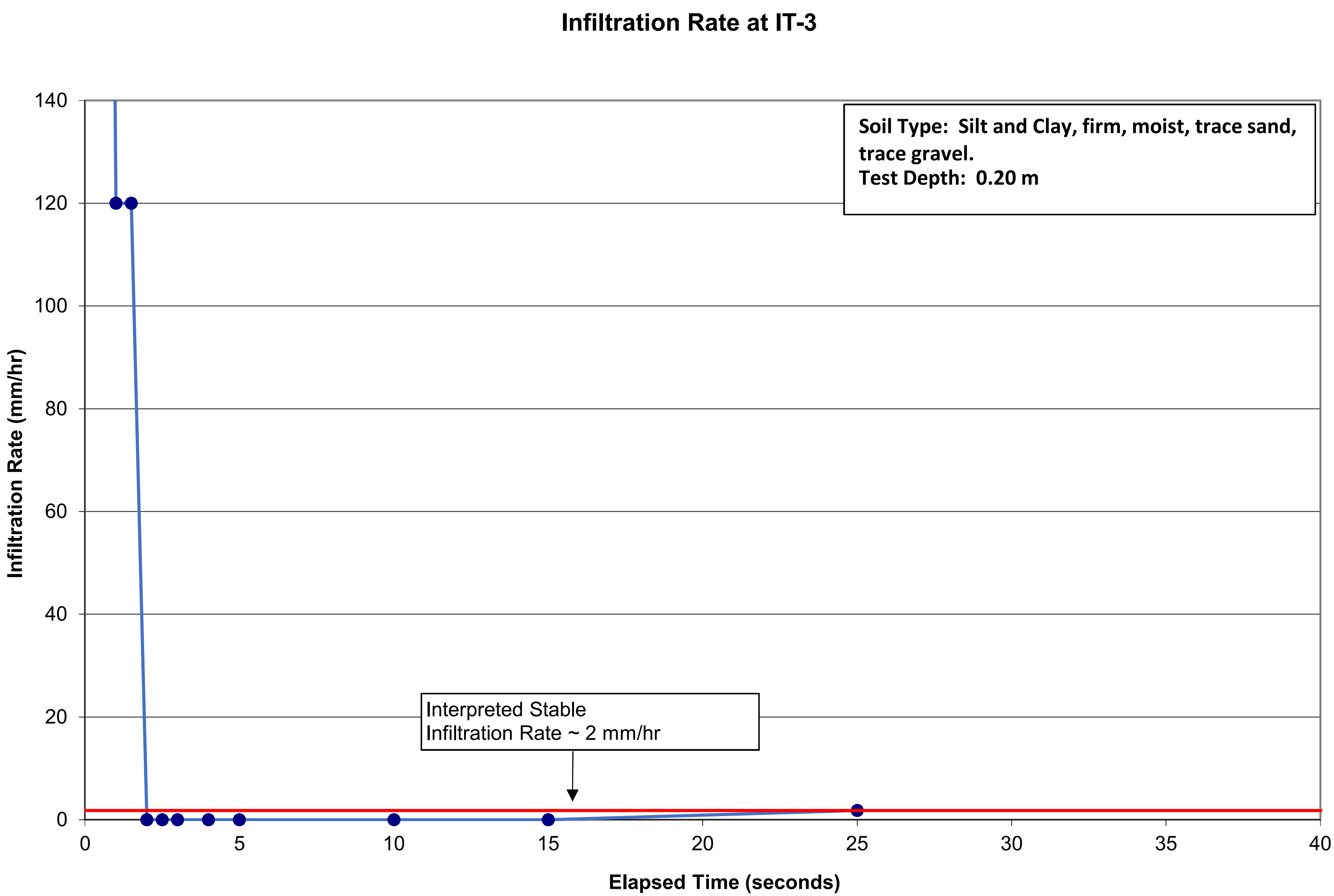
Appendix C-3
211 Eliza Street
300042585

R.J. Burnside & Associated Limited



Appendix C-3
211 Eliza Street
300042585

R.J. Burnside & Associated Limited



Appendix C-3
211 Eliza Street
300042585

R.J. Burnside & Associated Limited

BURNSIDE

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Appendix D

Groundwater Level Monitoring

Table D-1
Groundwater Elevations

	Well Depth (mbgs)	Ground Surface Elevation (masl)	11-Jan-19		25-Jan-19		22-Feb-19		26-Mar-19		2-May-19	
			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)
MW1s	6.04	456.70	5.70	451.00	3.83	452.87	3.74	452.96	3.28	453.42	2.79	453.91
MW1d	10.63	456.70	9.11	447.59	5.20	451.50	5.44	451.26	4.85	451.85	4.78	451.92
MW2	5.79	464.60	3.71	460.89	4.30	460.30	4.82	459.78	4.28	460.32	3.04	461.56
MW3	6.73	460.50	6.53	453.97	2.00	458.50	2.97	457.53	2.00	458.50	1.49	459.01
MW4	7.55	453.70	0.51	453.19	0.29	453.41	0.79	452.91	Frozen	Frozen	0.14	453.56
PZ1	1.77	453.25	1.77	451.48	0.82	452.43	0.62	452.63	0.30	452.95	0.10	453.15

Notes

mbtop - meters below top of pipe

masl - metres above sea level

Table D-1
Groundwater Elevations

	Well Depth (mbgs)	Ground Surface Elevation (masl)	29-May-19		27-Jun-19		7-Aug-19		28-Aug-19		25-Sep-19	
			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)
MW1s	6.04	456.70	3.04	453.66	3.74	452.96	3.98	452.73	4.01	452.69	4.06	452.64
MW1d	10.63	456.70	4.89	451.81	5.50	451.21	5.91	450.79	6.00	450.70	6.07	450.63
MW2	5.79	464.60	3.32	461.28	4.58	460.02	5.23	459.37	5.39	459.21	5.54	459.07
MW3	6.73	460.50	1.93	458.57	2.85	457.65	3.34	457.16	3.56	456.94	3.91	456.59
MW4	7.55	453.70	0.18	453.52	0.94	452.77	1.58	452.12	1.80	451.90	1.99	451.71
PZ1	1.77	453.25	0.20	453.05	0.85	452.40	1.63	451.62	Dry	Dry	Dry	Dry

Notes

mbtop - meters below top of pipe

masl - metres above sea level

Table D-1
Groundwater Elevations

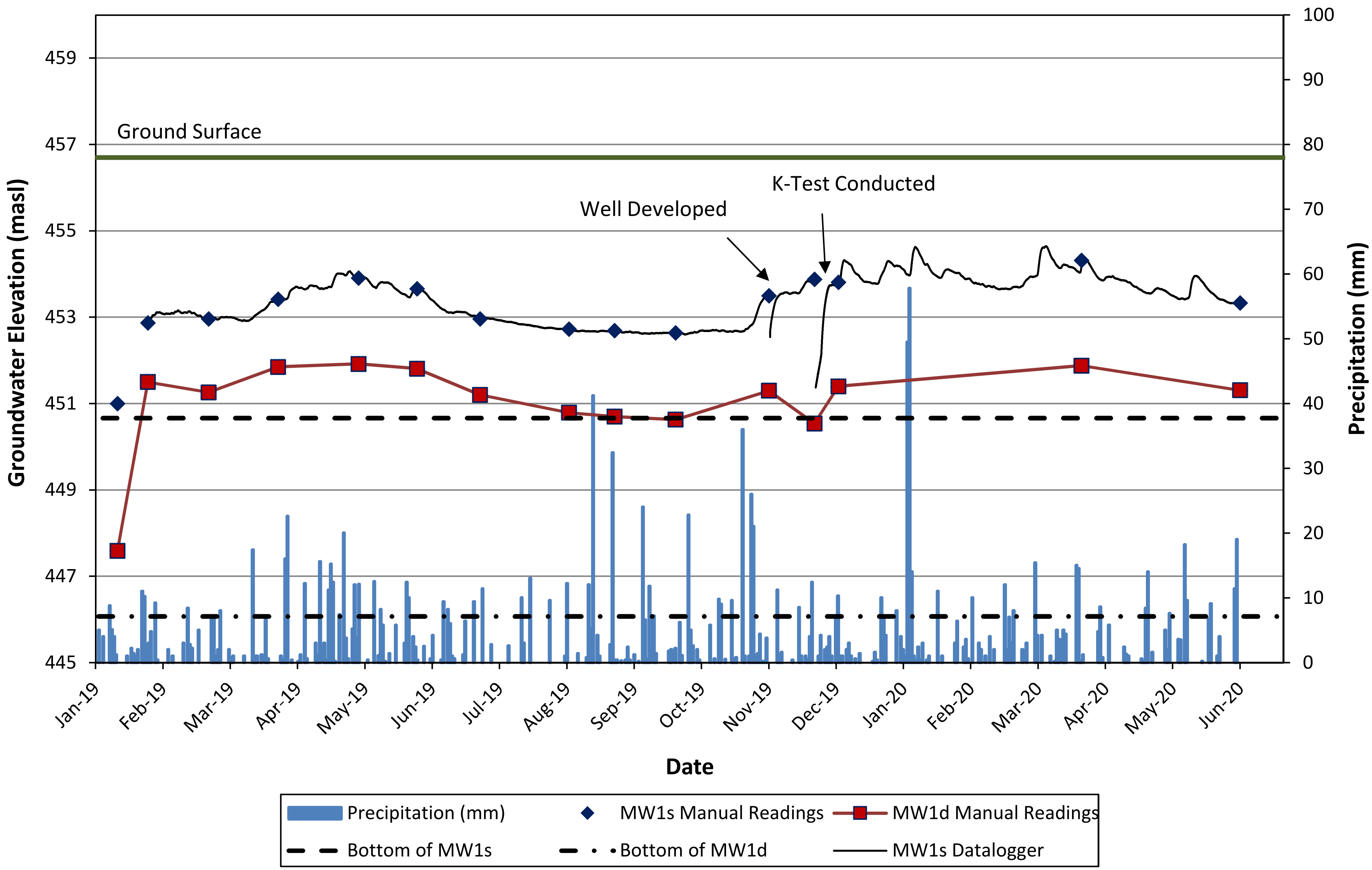
	Well Depth (mbgs)	Ground Surface Elevation (masl)	7-Nov-19		28-Nov-19		9-Dec-19		30-Mar-20		11-Jun-20	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
MW1s	6.04	456.70	3.20	453.50	2.82	453.88	2.89	453.81	2.39	454.32	3.37	453.33
MW1d	10.63	456.70	5.40	451.30	6.16	450.54	5.30	451.40	4.82	451.88	5.39	451.31
MW2	5.79	464.60	4.82	459.78	4.04	460.56	4.71	459.89	3.02	461.58	4.57	460.03
MW3	6.73	460.50	2.17	458.33	1.66	458.84	2.23	458.27	1.50	459.01	3.01	457.49
MW4	7.55	453.70	0.43	453.27	0.20	453.50	0.19	453.51	0.15	453.55	0.80	452.90
PZ1	1.77	453.25	0.79	452.46	0.21	453.04	0.20	453.05	0.10	453.15	0.87	452.38

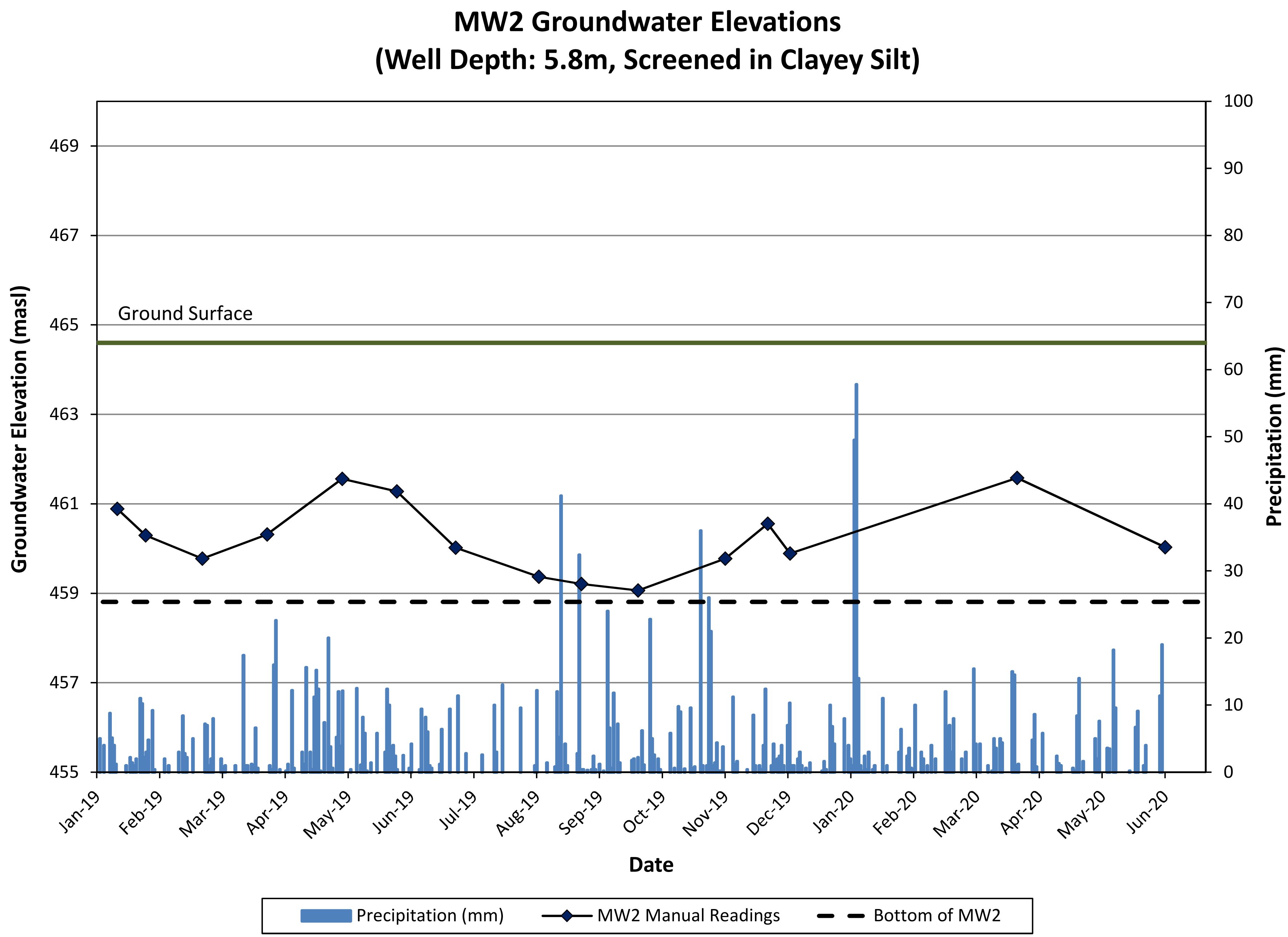
Notes

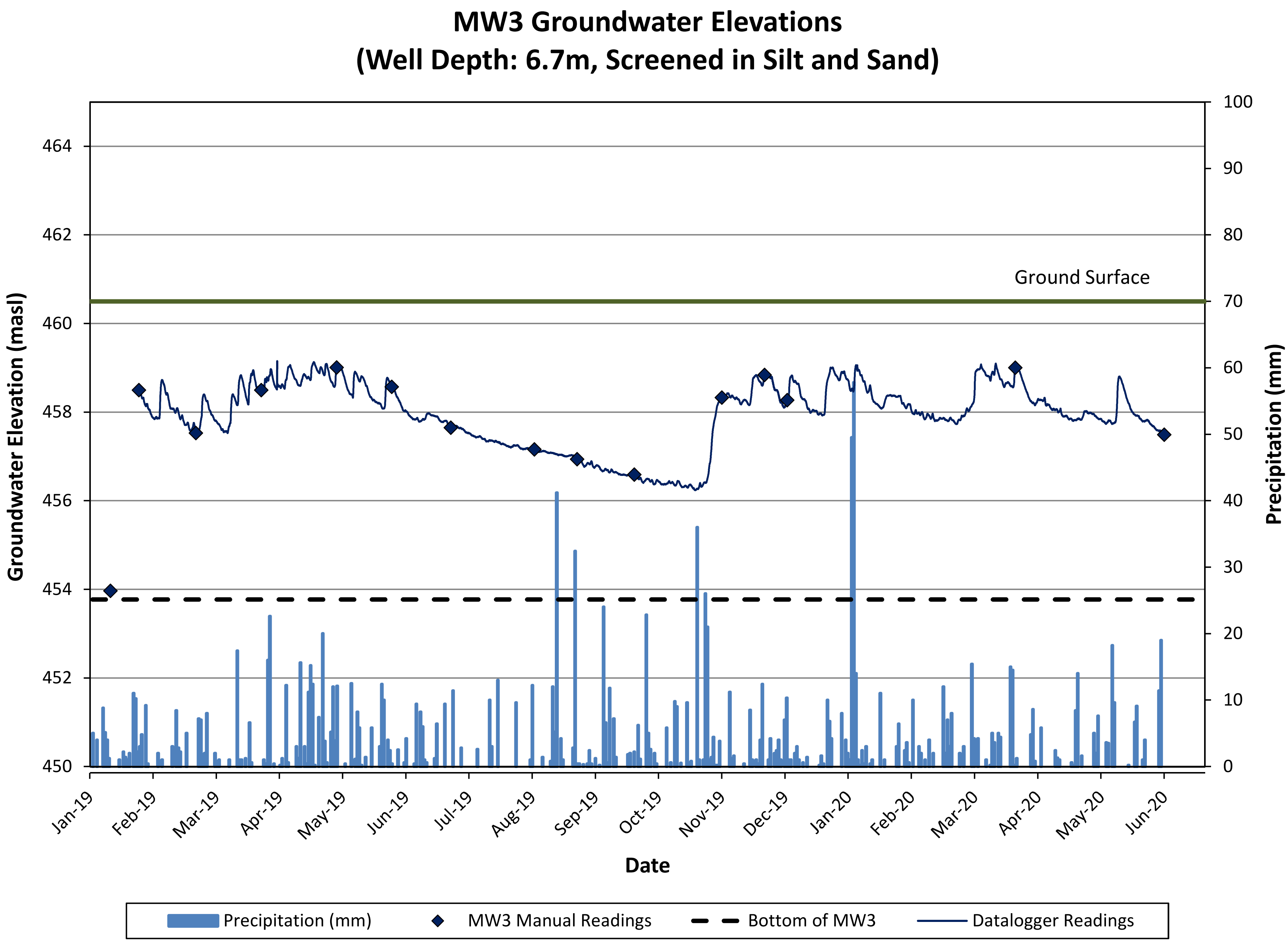
mbtop - meters below top of pipe

masl - metres above sea level

MW1s/d Groundwater Elevations
(MW1s Depth: 6.0m, Screened in Silt)
(MW1d Depth: 10.6m, Screened in Silt and Sand)

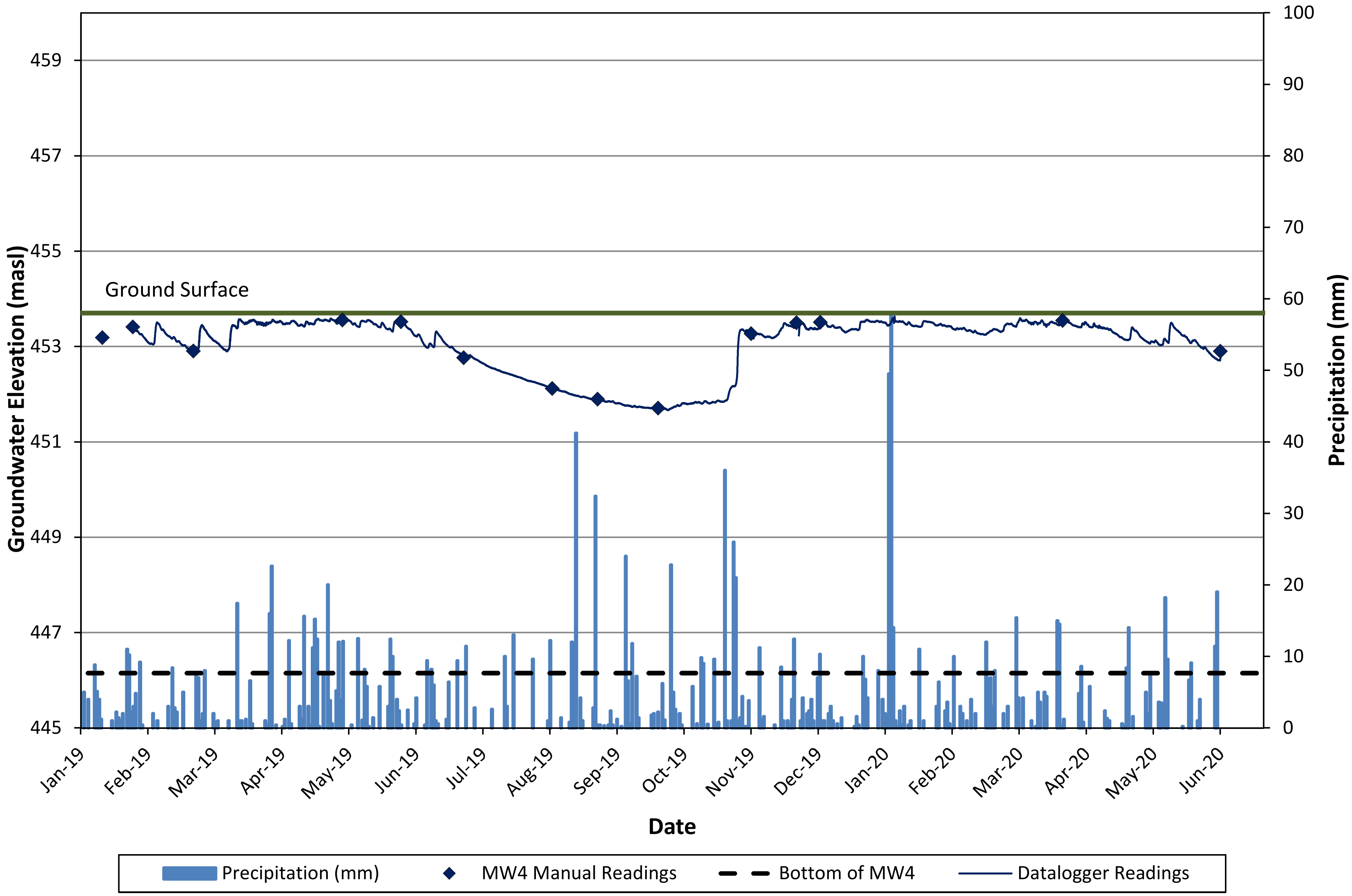



MW2 Groundwater Elevations
(Well Depth: 5.8m, Screened in Clayey Silt)
Groundwater Elevation (masl)
Precipitation (mm)
Ground Surface
469
467
465
463
461
459
457
455
100
90
80
70
60
50
40
30
20
10
0
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Date
Precipitation (mm)
MW2 Manual Readings
Bottom of MW2



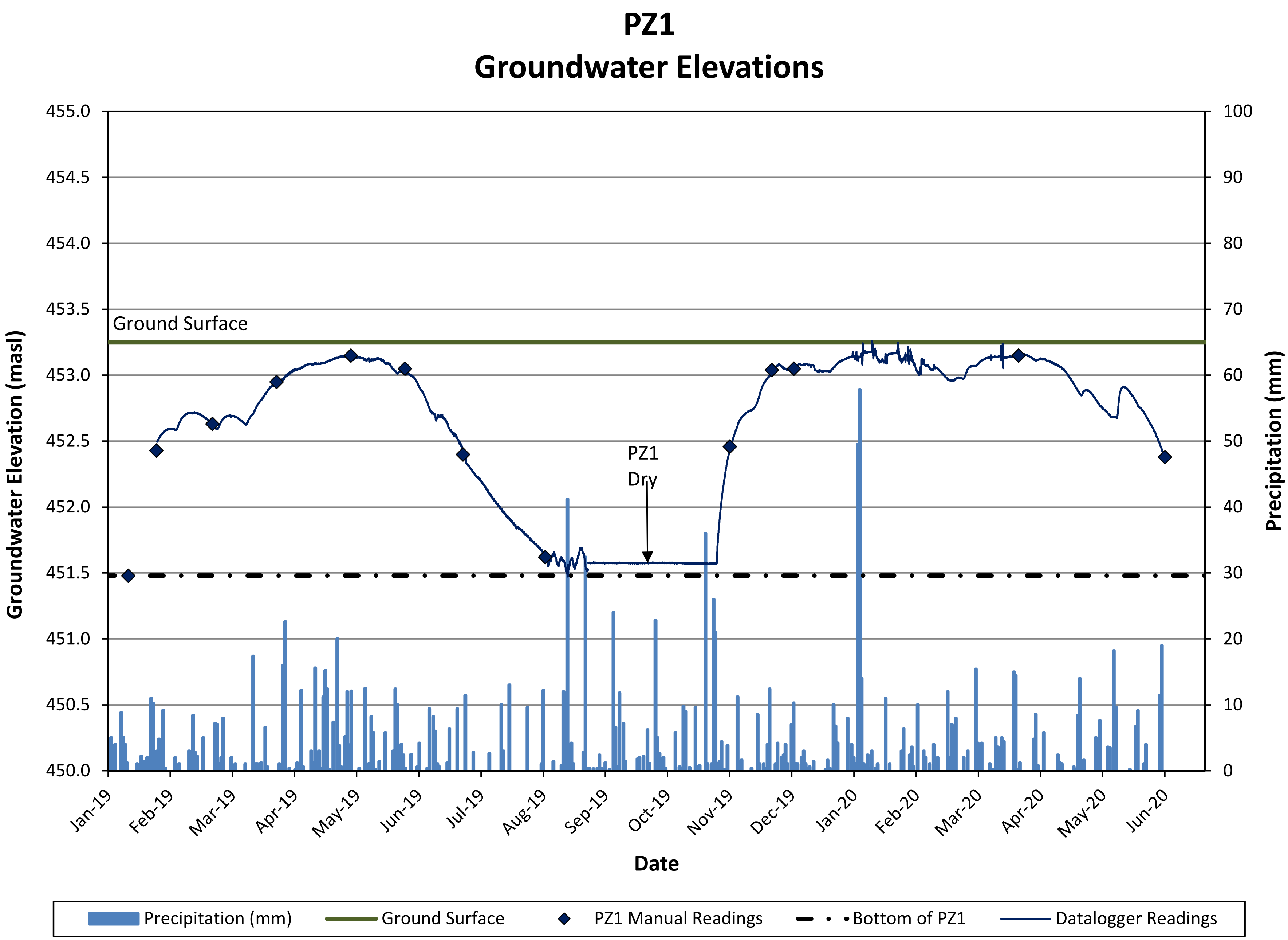
MW3 Groundwater Elevations
(Well Depth: 6.7m, Screened in Silt and Sand)
Ground Surface
Groundwater Elevation (masl)
Precipitation (mm)
464
462
460
458
456
454
452
450
100
90
80
70
60
50
40
30
20
10
0
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Date
Precipitation (mm)
MW3 Manual Readings
Bottom of MW3
Datalogger Readings

MW4 Groundwater Elevations
(Well Depth: 7.6m, Screened in Silt and Sand)



R.J. Burnside & Associates Limited

Figure D-4


PZ1
Groundwater Elevations
Groundwater Elevation (masl)
Precipitation (mm)
455.0
454.5
454.0
453.5
453.0
452.5
452.0
451.5
451.0
450.5
450.0
100
90
80
70
60
50
40
30
20
10
0
Ground Surface
PZ1
Dry
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Date
Precipitation (mm)
Ground Surface
PZ1 Manual Readings
Bottom of PZ1
Datalogger Readings

Appendix E

Water Quality

Appendix E

Table E-1
Groundwater Quality

Monitoring Well			MW1S		MW4	
Date Sampled			**28-Nov-19**		**28-Nov-19**	
Parameter	**Unit**	**ODWQS**	**RDL**	**Results**	**RDL**	**Results**
Electrical Conductivity	µS/cm		2	868	2	437
pH	pH Units	(6.5-8.5)	NA	7.85	NA	7.63
Saturation pH				6.49		7.29
Langelier Index				1.36		0.34
Total Hardness (as CaCO3)	mg/L	(80-100)	0.5	**481**	0.5	**155**
Total Dissolved Solids	mg/L	500	20	540	20	250
Alkalinity (as CaCO3)	mg/L	(30-500)	5	527	5	222
Bicarbonate (as CaCO3)	mg/L		5	527	5	222
Carbonate (as CaCO3)	mg/L		5	<5	5	<5
Hydroxide (as CaCO3)	mg/L		5	<5	5	<5
Fluoride	mg/L	1.5	0.25	<0.25	0.05	0.33
Chloride	mg/L	250	0.50	11.6	0.10	12.9
Nitrate as N	mg/L	10.0	0.25	<0.25	0.05	0.21
Nitrite as N	mg/L	1.0	0.25	<0.25	0.05	<0.05
Bromide	mg/L		0.25	<0.25	0.05	<0.05
Sulphate	mg/L	500	0.50	38.6	0.10	42.9
Ortho Phosphate as P	mg/L		0.50	<0.50	0.10	<0.10
Reactive Silica	mg/L		0.05	17.7	0.05	10.8
Ammonia as N	mg/L		0.02	<0.02	0.02	<0.02
Total Phosphorus	mg/L		0.02	3.51	0.02	0.02
Total Organic Carbon	mg/L		1.0	10.6	1.0	7.8
Colour	TCU	5	5	7	5	7
Turbidity	NTU	5	3.0	**13000**	6	**52500**
Calcium	mg/L		0.10	123	0.05	23
Magnesium	mg/L		0.10	42.3	0.05	23.7
Sodium	mg/L	20 (200)	0.10	27.8	0.05	42.2
Potassium	mg/L		0.10	2.49	0.05	4.31
Aluminum (Dissolved)	mg/L	0.1	0.004	0.013	0.004	0.031
Antimony	mg/L	0.006	0.003	<0.003	0.003	<0.003
Arsenic	mg/L	0.025	0.003	0.004	0.003	<0.003
Barium	mg/L	1	0.002	0.146	0.002	0.022
Beryllium	mg/L		0.001	<0.001	0.001	<0.001
Boron	mg/L	5	0.010	0.023	0.010	0.088
Cadmium	mg/L	0.005	0.001	<0.001	0.001	<0.001
Chromium	mg/L	0.05	0.003	<0.003	0.003	<0.003
Cobalt	mg/L		0.001	<0.001	0.001	<0.001
Copper	mg/L	1	0.003	<0.003	0.003	<0.003
Iron	mg/L	0.3	0.010	0.205	0.010	<0.010
Lead	mg/L	0.01	0.001	<0.001	0.001	<0.001
Manganese	mg/L	0.05	0.002	0.118	0.002	0.011
Mercury (Dissolved)	mg/L	0.001	0.0001	<0.0001	0.0001	<0.0001
Molybdenum	mg/L		0.002	<0.002	0.002	0.02
Nickel	mg/L		0.003	<0.003	0.003	<0.003
Selenium	mg/L	0.01	0.004	<0.004	0.004	<0.004
Silver	mg/L		0.002	<0.002	0.002	<0.002
Strontium	mg/L		0.005	0.311	0.005	0.207
Thallium	mg/L		0.006	<0.006	0.006	<0.006
Tin	mg/L		0.002	<0.002	0.002	<0.002
Titanium	mg/L		0.002	0.003	0.002	<0.002
Tungsten	mg/L		0.010	<0.010	0.010	<0.010
Uranium	mg/L	0.02	0.002	<0.002	0.002	<0.002
Vanadium	mg/L	3	0.002	<0.002	0.002	<0.002
Zinc	mg/L	5	0.005	<0.005	0.005	<0.005
Zirconium	mg/L		0.004	<0.004	0.004	<0.004
% Difference/ Ion Balance	%		NA	3.46	NA	6.42

ODWQS - Ontario Drinking Water Quality Standards
RDL - Reported Detection Limit
Bold indicates an exceedence of the ODWQS

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Appendix F

Water Balance Calculations

WATER BALANCE CALCULATIONS
211 Eliza Street, Arthur Ontario
Sarah Properties Limited

PROJECT No. 300042585.1000

TABLE F-1

Pre- and Post-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 200 mm (moderately rooted vegetation in silt soils)

Climate data from Fergus Shand Dam Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.40	-6.30	-1.90	5.70	12.20	17.50	20.00	19.00	14.90	8.30	2.10	-3.90	**6.7**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.00	1.22	3.86	6.66	8.16	7.55	5.22	2.15	0.27	0.00	**35.1**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	26.65	59.36	86.76	99.85	94.61	73.26	39.58	9.32	0.00	**489**
Adjusting Factor for U (Latitude 43° 44' N)	0.81	0.82	1.02	1.12	1.26	1.28	1.29	1.2	1.04	0.95	0.81	0.77	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	68	56	60	74	87	84	89	97	93	77	93	69	**946**
Potential Evapotranspiration (PET)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
P - PET	68	56	60	44	12	-27	-40	-17	17	40	85	69	**367**
Change in Soil Moisture Storage	0	0	0	0	0	-27	-40	-17	17	40	27	0	**0**
Soil Moisture Storage max 200 mm	200	200	200	200	200	173	133	116	133	173	200	200	
Actual Evapotranspiration (AET)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
Soil Moisture Deficit max 200 mm	0	0	0	0	0	27	67	84	67	27	0	0	
Water Surplus - available for infiltration or runoff	68	56	60	44	12	0	0	0	0	0	58	69	**367**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	27	22	24	18	5	0	0	0	0	0	23	27	**147**
Potential Direct Surface Water Runoff (independent of temperature)	41	34	36	27	7	0	0	0	0	0	35	41	**220**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	946	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	142	mm/year											
P-PE (surplus available for runoff from impervious areas)	804	mm/year											

Assume January storage is 100% of Soil Moisture Storage
Soil Moisture Storage 200 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - hilly land	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silt soils	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - agricultural lands	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.4**	

Latitude of site (or climate station) 43 °N.

WATER BALANCE CALCULATIONS
211 Eliza Street, Arthur Ontario
Sarah Properties Limited

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TABLE F-2

Pre-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 400 mm (wooded areas in silt soils)

Climate data from Fergus Shand Dam Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.40	-6.30	-1.90	5.70	12.20	17.50	20.00	19.00	14.90	8.30	2.10	-3.90	**6.7**
Heat index: i = $(t/5)^{1.514}$	0.00	0.00	0.00	1.22	3.86	6.66	8.16	7.55	5.22	2.15	0.27	0.00	**35.1**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	26.65	59.36	86.76	99.85	94.61	73.26	39.58	9.32	0.00	**489**
Adjusting Factor for U (Latitude 43° 44' N)	0.81	0.82	1.02	1.12	1.26	1.28	1.29	1.2	1.04	0.95	0.81	0.77	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	68	56	60	74	87	84	89	97	93	77	93	69	**946**
Potential Evapotranspiration (PET)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
P - PET	68	56	60	44	12	-27	-40	-17	17	40	85	69	**367**
Change in Soil Moisture Storage	0	0	0	0	0	-27	-40	-17	17	40	27	0	**0**
Soil Moisture Storage max 400 mm	400	400	400	400	400	373	333	316	333	373	400	400	
Actual Evapotranspiration (AET)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
Soil Moisture Deficit max 400 mm	0	0	0	0	0	27	67	84	67	27	0	0	
Water Surplus - available for infiltration or runoff	68	56	60	44	12	0	0	0	0	0	58	69	**367**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	34	28	30	22	6	0	0	0	0	0	29	34	**183**
Potential Direct Surface Water Runoff (independent of temperature)	34	28	30	22	6	0	0	0	0	0	29	34	**183**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	946	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	142	mm/year											
P-PE (surplus available for runoff from impervious areas)	804	mm/year											

Assume January storage is 100% of Soil Moisture Storage
Soil Moisture Storage 400 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - hilly land	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silt soils	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - wooded areas	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.5**	

Latitude of site (or climate station) 43 ° N.

WATER BALANCE CALCULATIONS
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TABLE F-3

Post-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 125 mm (urban lawn in silt soils)

Climate data from Fergus Shand Dam Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.40	-6.30	-1.90	5.70	12.20	17.50	20.00	19.00	14.90	8.30	2.10	-3.90	**6.7**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.00	1.22	3.86	6.66	8.16	7.55	5.22	2.15	0.27	0.00	**35.1**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	26.65	59.36	86.76	99.85	94.61	73.26	39.58	9.32	0.00	**489**
Adjusting Factor for U (Latitude 43° 44' N)	0.81	0.82	1.02	1.12	1.26	1.28	1.29	1.2	1.04	0.95	0.81	0.77	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	68	56	60	74	87	84	89	97	93	77	93	69	**946**
Potential Evapotranspiration (PET)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
P - PET	68	56	60	44	12	-27	-40	-17	17	40	85	69	**367**
Change in Soil Moisture Storage	0	0	0	0	0	-27	-40	-17	17	40	27	0	**0**
Soil Moisture Storage max 125 mm	125	125	125	125	125	98	58	41	58	98	125	125	
Actual Evapotranspiration (AET)	0	0	0	30	75	111	129	114	76	38	8	0	**579**
Soil Moisture Deficit max 125 mm	0	0	0	0	0	27	67	84	67	27	0	0	
Water Surplus - available for infiltration or runoff	68	56	60	44	12	0	0	0	0	0	58	69	**367**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	31	25	27	20	5	0	0	0	0	0	26	31	**165**
Potential Direct Surface Water Runoff (independent of temperature)	37	31	33	24	7	0	0	0	0	0	32	38	**202**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	946	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	142	mm/year											
P-PE (surplus available for runoff from impervious areas)	804	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage	125	mm	<-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003
*MOE SWM infiltration calculations			
topography - hilly land	0.1		<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silt soils	0.2		<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - urban lawn	0.15		<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.45**		
Latitude of site (or climate station)	43	°N.	

WATER BALANCE CALCULATIONS
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TABLE F-4

Water Balance - Existing Conditions and Post-Development

Catchment Area	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 to Feature (m^3/a)	Total Infiltration Volume (m^3/a)
Exising Land Use												
Agricultural Lands/Open Space	166,500	0.00	0	0.804	0	166,500	0.220	36,615	0.147	24,410	36,615	24,410
Wooded Lands	18,100	0.00	0	0.804	0	18,100	0.183	3,317	0.183	3,317	3,317	3,317
TOTAL PRE-DEVELOPMENT	**184,600**		**0**		**0**	**184,600**		**39,932**		**27,727**	**39,932**	**27,727**
Post-Development Land Use												
Residential - Single-Detached	62,800	0.55	34,540	0.804	27,771	28,260	0.202	5,697	0.165	4,661	33,467	4,661
Residential - Medium Density	15,400	0.80	12,320	0.804	9,905	3,080	0.202	621	0.165	508	10,526	508
Townhouse Residential	7,200	0.65	4,680	0.804	3,763	2,520	0.202	508	0.165	416	4,271	416
Bungalow Townhomes	13,200	0.65	8,580	0.804	6,898	4,620	0.202	931	0.165	762	7,830	762
Commercial	22,300	0.95	21,185	0.804	17,033	1,115	0.202	225	0.165	184	17,258	184
Roads and Right of Ways	37,300	0.80	29,840	0.804	23,992	7,460	0.202	1,504	0.165	1,230	25,496	1,230
Natural Heritage Area/Park - open space	8,300	0.10	830	0.804	667	7,470	0.220	1,643	0.147	1,095	2,310	1,095
Natural Heritage Area - wooded	18,100	0.00	0	0.804	0	18,100	0.183	3,317	0.183	3,317	3,317	3,317
TOTAL POST-DEVELOPMENT	**184,600**		**111,975**		**90,030**	**72,625**		**14,445**		**12,173**	**104,475**	**12,173**
% Change from Pre to Post											262	56
Effect of development (with no mitigation)											2.6 times increase in runoff	56% reduction in infiltration

*figures from Tables F-1 to F-3

To balance pre- to post-,
the infiltration target (m^3/a)= **15,554** **m^3/a**

WATER BALANCE CALCULATIONS
211 Eliza Street, Arthur Ontario
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TABLE F-5

Infiltration Deficit by Post-Development Land Use Type				
	Approx. Land Area (m^2)	**Pre-Development Infiltration Volume (m^3/a)**	**Post-Development Infiltration Volume (m^3/a)**	**Infiltration Deficit (m^3/a)**
Residential - Single-Detached	62,800	9,207	4,661	4,546
Residential - Medium Density	15,400	2,258	508	1,750
Townhouse Residential	7,200	1,056	416	640
Bungalow Townhomes	13,200	1,935	762	1,173
Commercial	22,300	3,269	184	3,085
Roads and Right of Ways	37,300	5,468	1,230	4,238
Natural Heritage Area/Park	26,400	4,534	4,412	122
TOTAL	**184,600**	**27,727**	**12,173**	**15,554**

R.J. Burnside & Associates Limited