REPORT

Level 1 and Level 2 Water Report

Proposed Highland Line Pit, Township of Lanark Highlands, Ontario

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Executive Summary

Golder Associates Ltd. was retained by Thomas Cavanagh Construction Limited to conduct hydrogeological and hydrological studies at the proposed location of the Highland Line Pit located on Part Lot 15, Concession 10 in the Township of Lanark Highlands, Lanark County, Ontario. The purpose of these studies is to provide supporting documentation for a licence application for a Class ‘A’ licence for a Pit Below the Groundwater Table, under the Aggregate Resources Act and the Planning Act. The site is underlain by ice-contact stratified deposits and glaciolacustrine deposits of sand and gravel overlying Precambrian bedrock.

The study includes a hydrogeological and hydrological assessment to establish the groundwater conditions and water balance for the site. The results of the hydrogeological and hydrological investigation are used to assess the potential for adverse effects to groundwater users, surface water resources and natural environment features as a result of the proposed extraction below the groundwater table.

The assessment involved the following tasks:

- Review of available data/information and site visit;
- Ministry of the Environment, Conservation and Parks Water Well Inventory;
- Test pit investigation and monitoring well installation;
- Hydraulic conductivity testing program;
- Groundwater and surface water monitoring program;
- Development of a water balance for existing conditions, operational conditions and rehabilitation conditions for the study area; and,
- Assessment of potential impacts related to the development and rehabilitation of the proposed pit.

The extraction will include the removal of overburden materials to an approximate pit base elevation of 176 metres above seal level. Material extraction will not require dewatering. Given that the aggregate extraction below the groundwater table will occur without dewatering, there will be no significant lowering of the groundwater table in the overburden and underlying bedrock and thus no potential for proposed extraction activities to cause drawdown of the groundwater table such that it interferes with local water supply wells.

The water balance assessment suggests that overall, there is a decrease in water surplus for the site under operational conditions. Rehabilitated conditions are expected to have a similar decrease in surplus compared to existing conditions. Runoff volumes to Barbers Lake, Long Sault Creek, and the unnamed northern wetland are expected to decline, however baseflow to Barbers Lake and Long Sault Creek is expected to slightly increase as a result of the increase in infiltration at the pit. This change from site runoff to infiltration is expected to decrease peak flow contributed from the site and slightly increase a steadier base flow from the site.

Operation of the proposed pit area is not expected to contribute to flooding problems in the receiving drainage features, as there will be limited water discharge from the pit. The pit itself is expected to operate as a large infiltration basin with a surface outlet near Barbers Lake. The redirection of catchment areas from the north, from the east, and from the southeast to the pit area thus results in an overall reduction in peak surface flow rates in all directions.

Overall, the surface water impacts associated with the proposed pit are marginal. Changes in contributing catchment to the locations discussed are on the order of 2%, while infiltration is still estimated to report to two out of the three adjacent waterbodies as baseflow.

Based on the findings of this assessment, no adverse effects to groundwater and surface water resources and their uses are anticipated as a result of the proposed Highland Line Pit. A monitoring program has been proposed to measure and evaluate the actual effects on groundwater levels associated with long term pit operations, and to allow a comparison between the actual effects measured during the monitoring program with those predicted as part of this impact assessment.

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Thomas Cavanagh Construction Limited (Cavanagh) to conduct hydrogeological and hydrological studies at the proposed location of the Highland Line Pit located on Part Lot 15, Concession 10 in the Township of Lanark Highlands, Lanark County, Ontario (see Figure 1). The purpose of these studies is to provide supporting documentation for a licence application for a Class ‘A’ licence for a Pit Below the Groundwater Table, under the *Aggregate Resources Act* (ARA) and the *Planning Act*.

1.1 Site Description

The proposed pit is located on the south side of Highland Line, west of Leo Jay Lane in the Township of Lanark Highlands, Lanark County, Ontario (Figure 1). There are no buildings on the site. Surrounding land uses around the site include an existing sugarbush to the west, deciduous, mixed and coniferous forest and wetland to the south, east and north, interspersed with small patches of active shallow rooted agriculture. Immediately southeast of the site is Barbers Lake. A small sand extraction operation, owned by others, is located north of the site, on the north side of Highland Line. Beyond the site boundary, the nearest residences are located along Highland Line, Leo Jay Lane and Anderson Lane. The approximate locations of private water supply wells, with a UTM Reliability Code of 5 or less, within 500 metres of the proposed licensed extraction area (as provided in the Ministry of the Environment, Conservation and Parks Water Well Information System; MECP WWIS) are shown on Figure 2.

The ground surface elevation within the site area ranges from approximately 184 to 216 metres above sea level (asl) and is highest along a ridge running east-west in the southern portion of the site. (See Figure 1).

Surface water features within the proposed licensed area include a single small intermittent watercourse that flows to Barbers Lake and unevaluated wetlands. The watercourse originates from two seepage areas and is located outside of the proposed limit of extraction. There are low-moist areas throughout some of the forests on the site, including a small pond in the mixed forest, which are associated with the lowest topography. Barbers Lake is not within the proposed license area, but it is immediately adjacent to it.

1.2 Site Development

The site consists of a 50.6 hectare area proposed to be licensed under the ARA, of which the proposed extraction area occupies 35.1 hectares. In order to be conservative, the proposed extraction area in this report does not include the 1.3 hectare Natural Environment Exclusion Zone identified on the site plans. For the purposes of this report, the proposed extraction area is 36.3 hectares. The property is owned by the applicant (Cavanagh). Based on the nature of the subsurface materials, Cavanagh has advised that the approximate pit base elevation will be 176 metres asl. Only unconsolidated materials (sand, gravel, etc.) will be removed from the site. Any bedrock encountered on the site will remain in place.

It is understood from Cavanagh that extraction operations below the groundwater table will not involve dewatering of the excavation. The final rehabilitation plan includes a permanent pond located within the proposed limit of extraction area. Based on the groundwater level data collected at the site, the predicted elevation of the permanent pond will be approximately 186 metres asl based on the lowest elevation of the ground surface on the perimeter of the proposed extraction area (near Barbers Lake).

1.3 Study Objectives

The objective of this study was to fulfill the requirements of a Level 1and 2 Hydrogeological and Hydrological Assessment for the licensing of a Class ‘A’, Pit Below the Groundwater Table, under the ARA, and to support an application under the *Planning Act*. The study includes a hydrogeological and hydrological assessment to establish the groundwater conditions and water balance for the site. The results of the hydrogeological and hydrological investigation are used to assess the potential for adverse effects to groundwater users, surface water resources and natural environment features as a result of the proposed extraction below the groundwater table. The qualifications and experience of the report authors are presented in Appendix A.

2.0 SITE GEOLOGY AND HYDROGEOLOGY

2.1 Surficial Geology

The surficial geology in the vicinity of the site is shown on Figure 3. Published surficial geology mapping indicates the presence of ice contact stratified deposits (sand and gravel, minor silt, clay and glacial till) in the majority of the site and Precambrian bedrock-drift complex (thin layer of overburden over bedrock and bedrock outcrops) along the southern border (western half of the site) and in the northern corner and center of the eastern half of the site. There is also an area identified as a coarse-grained deposit (sand and gravel; Unit 9a on Figure 3) in the eastern half of the site. The Precambrian drift complex tends to coincide with the topographic high points on the site. The test pitting program completed at the site as part of the hydrogeology study confirmed the presence of overburden consisting of sand and gravel and fine to medium sand, as discussed further in Section 3.1.1.

Beyond the site, published surficial geology mapping indicates that there are some coarse-grained deposits (north), organic deposits and modern alluvial deposits (to the north) surrounding the site (see Figure 3).

2.2 Bedrock Geology

Published bedrock geology mapping indicates the upper bedrock unit in the vicinity of the site consists of Precambrian Bedrock consisting of Carbonate Metasedimentary Rocks (marble) in the northern portions of the site and Alkalic Plutonic Rocks (Syenite) in the south of the site (see Figure 4). Bedrock outcrops are visible within the proposed licensed extraction area in the topographically higher areas of the site.

A review of the MECP WWIS indicates that the bedrock surface ranges from 137 to 219 metres asl in vicinity of the site. The local depth to bedrock indicated in the WWIS well records varies from 17 to 23 metres below ground surface (bgs).

2.3 Hydrogeology

2.3.1 Overburden Aquifer

Deposits of coarse and permeable overburden capable of supplying sufficient quantities of groundwater may exist locally in the area around the site (see units 6, 9a and 19 on Figure 3). The majority of the area is mapped as Precambrian bedrock-drift where there is only a thin layer of overburden over bedrock. The thin overburden is unlikely to provide water of sufficient quantity for a water supply. Based on MECP WWIS data, the majority of water supply wells are completed in the Precambrian bedrock.

2.3.2 Bedrock Aquifer

The Precambrian bedrock is the main source of potable groundwater in the area of the proposed pit. Groundwater flow in the Precambrian bedrock is attributed to secondary porosity produced by fractures that have developed from tectonic processes (Golder, 2003). The density of fractures in the bedrock tends to decrease with depth (Golder, 2003). Estimates of hydraulic conductivity in fractured igneous and metamorphic rocks ranges from 10^{-8} to 10^{-4} metres per second (Freeze and Cherry, 1979). The actual value of hydraulic conductivity in the region are typically at the low end of the range (Golder, 2003). Generally, the fracture zones in the Precambrian bedrock yield marginal to adequate quantities of water for domestic use (Golder, 2003).

It estimated that approximately 8 private supply wells are located within 500 metres of the proposed boundary of the area to be licensed. The MECP WWIS identifies 2 private supply wells within 500 metres of the site boundary based on a UTM Reliability Code of 5 or less (within 300 metres). Based on an air photo review, an additional 6 supply wells may be located within 500 metres of the site boundary (refer to Figure 2). Local water supply wells for which information is provided in the MECP WWIS are exclusively completed in bedrock, at depths that generally range from 17 to 22 metres bgs and had static water levels generally ranging between 2 and 6 metres bgs at the time of drilling.

3.0 STUDY METHODS AND RESULTS

3.1 Hydrogeological Investigation

A hydrogeological assessment in support of the application was completed for the site. The hydrogeological assessment involved the following tasks:

- Review of available data/information and site visit;
- MECP Water Well Inventory (discussed in Section 2.0);
- Test pit investigation and monitoring well installation;
- Groundwater monitoring program; and,
- Assessment of potential impacts related to the development and rehabilitation of the proposed pit.

3.1.1 Test Pits and Monitoring Well Installation

An aggregate resource investigation was carried out on February 28, 2019 (TP1 to TP16) and on April 22, 2020 (TP17/MW20-1, TP18/MW20-2, TP19/MW20-3, TP20/MW20-4, TP21/MW20-5 and TP22/MW20-6) on the site. The objectives of the subsurface investigations were to determine the extent and nature of the aggregate resource in the area and install monitoring wells for the characterization of hydrogeological conditions at the site. The locations of the test pits and monitoring wells are shown on Figure 1.

Test pit excavation for the aggregate resource evaluations were carried out using an excavator supplied and operated by Cavanagh. The 2019 test pit investigation was completed by Cavanagh. The April 2020 field work was monitored by Golder field staff who located the test pits, observed the excavation operations, logged the test pits, and took custody of the soil samples retrieved. The collected soil samples were submitted to the Golder laboratory in Ottawa for gradation testing.

In each of the 2020 test pits, a monitoring well consisting of 5-cm diameter PVC screen and riser were installed in the sand overburden. The locations and geodetic ground surface elevations of the April 2020 test pits were surveyed by Cavanagh.

Borehole and test pit logs summarizing the subsurface conditions encountered in the test pits put down for the site investigations are included in Appendix B. The results of the gradation testing are included in Appendix C.

3.1.2 Site Stratigraphy

The test pitting program completed at the site as part of the hydrogeology study indicated that the overburden consists primarily of fine to coarse sand with gravel. In addition, three stratigraphic cross-sections are provided as Figure 5 (see Figure 1 for cross-section locations).

Cross-section A-A' (Figure 5) runs from southwest to northeast across the property. Along most of the section, there are between 2.6 and greater than 6 metres of sand and sand and gravel near ground surface. Coarse sand was encountered in the test pits on the northeastern end of the cross-section line. Fine and fine to medium sand was encountered in test pits in the middle of the cross-section line and coarse sand and gravel, sandy gravel and gravel with sand underlie the surface on the southwestern portion of the section line. Glacial till was encountered in test pit TP2 along the westernmost portion of the section line at 3 metres depth below ground surface.

Cross-section B-B' (Figure 5) runs from approximately north to south across the western portion of the site. Along the section, the overburden material consists of fine sand in the north, coarse sand and gravel and coarse to medium sand in the center and fine to medium sand in the south. The coarsest material in the western portion of the site is found in the open area in the centre of the property (i.e., west of the intersection of cross-sections A-A' and B-B'). Glacial till was encountered in test pit TP5 along the southernmost portion of the section line at 5 metres depth below ground surface.

Cross-section C-C' (Figure 5) runs from north to south across the eastern portion of the site. Along the section line, the overburden material consists of fine-to-medium sand in the north, becoming medium to coarse sand and coarse sand with gravel towards the south.

The cross-sections and test pit logs from across the property indicate that the coarsest materials on the property are primarily found in the open area in the centre of the western half of the property (i.e., west of the intersection of cross-sections A-A' and B-B') and along the edge of the forested area in the eastern area of the site (TP12, TP13, TP14, TP15 and TP16). Finer materials (i.e., fine sand) are found around the outside perimeter of the property. Glacial till was located on the westernmost edge of the property (TP1, TP2, TP3 and TP4) at surface or just below surface, and at TP5 approximately 5 metres below ground surface.

3.1.3 Hydraulic Conductivity Testing

A total of six well response tests were carried out in the monitoring wells installed in MW20-1, MW20-2, MW20-3, MW20-4, MW20-5 and MW20-6 using the rising/falling head method. The completed well response tests provide an estimate of the horizontal hydraulic conductivity of the overburden materials adjacent to the monitoring well interval. The response testing was performed by displacing water by inserting/removing a plastic slug and monitoring the recovery to the static water level by measuring the depth to the water using a water level tape and/or pressure transducer and datalogger at frequent intervals.

For analysis, the intervals for response testing were defined as the monitoring well screen. This definition of screen length was used to maintain the assumption for horizontal flow to the piezometer screen. The details regarding the locations of the test interval for each monitoring well are provided on the borehole logs in Appendix B. The well response test analyses are provided in Appendix D. The hydraulic conductivity value from each test was calculated using either the Hvorslev (1951) or the Bouwer and Rice (1976) method.

A summary of the well response testing results from on-site monitoring are provided in the following table:

Table 1: Hydraulic Conductivity Estimates from On-Site Hydraulic Testing

Monitoring Well	Estimated Hydraulic Conductivity (metres per second)
MW20-1	2×10^{-5}
MW20-2	7×10^{-5}
MW20-3	1×10^{-4}
MW20-4	1×10^{-5}
MW20-5	7×10^{-5}
MW20-6	3×10^{-6}

These estimates are relatively consistent with the range of hydraulic conductivity values reported for silty sand to gravel (Freeze and Cherry, 1979). The hydraulic conductivity values estimated from the well response testing ranges from 3×10^{-6} to 1×10^{-4} metres per second (m/s) with a geometric average of 3×10^{-5} m/s.

3.1.4 Groundwater Monitoring and Flow Direction

Groundwater monitoring sessions were undertaken between April 29, 2020, and June 16, 2021. During each groundwater monitoring event, the depth to the groundwater level below the top of the surveyed monitoring well casing was recorded in order to determine the groundwater level fluctuations in the area that occur within the overburden. The water level elevations are provided in the following table and plotted against time on Figure 6.

Table 2: Groundwater Elevations

Date	Groundwater Elevations (metres above sea level)					
	MW20-1	MW20-2	MW20-3	MW20-4	MW20-5	MW20-6
29-Apr-20	188.73	188.17	182.66	188.93	189.21	195.36
13-May-20	188.65	188.12	182.60	188.81	189.00	195.31
27-May-20	188.58	188.05	182.56	188.74	188.90	195.18
15-Jun-20	188.50	187.92	182.51	188.61	188.79	195.01
15-Jul-20	188.33	187.73	182.42	188.49	188.61	194.76
20-Aug-20	188.35	187.69	182.43	188.54	188.59	194.68
18-Sep-20	188.46	187.84	182.48	188.64	188.74	194.74
23-Oct-20	188.51	187.76	182.58	188.71	188.66	194.78
18-Nov-20	188.45	187.79	182.65	188.61	188.71	194.71
14-Dec-20	188.58	187.92	182.59	188.77	188.89	194.91
14-Jan-21	188.59	187.97	182.56	188.72	188.87	195.06
10-Feb-21	188.50	187.84	182.41	188.62	188.75	194.94
12-Mar-21	189.00	187.97	182.84	189.15	189.24	194.96
14-Apr-21	188.73	188.18	182.92	188.86	189.06	195.21
13-May-21	188.65	188.03	182.87	188.79	188.97	195.10
16-Jun-21	188.47	187.83	182.75	188.59	188.73	194.73

As shown on Figure 6, the pre-development groundwater elevations, which represent reference groundwater elevation conditions in the vicinity of the site, ranged from a low of 182.4 metres asl at MW20-3 in February 2021 to a high of 195.4 metres asl at MW20-6 in April 2020. Groundwater depths range from 1.5 (MW20-4) to 4.6 (MW20-2) metres bgs across the site. Groundwater elevations in all monitoring wells show seasonal variations, with the highest elevations observed in late spring/early summer, and the lowest generally observed during summer months (July and August).

Based on groundwater elevation data collected during the pre-development period, the general groundwater flow direction in the vicinity of the site is influenced by the topography of the site and seasonal water table fluctuations. Groundwater generally flows from southwest to east across the site, and toward the topographic low near Barbers Lake (where MW20-3 is located; see Figure 1).

3.1.5 Groundwater Drawdown

As discussed in Section 1.2, the proposed Highland Line Pit will not be dewatered during operations, but extraction will take place below the groundwater table. Based on the groundwater level data collected at the site, the predicted elevation of the pond during operations and after rehabilitation will be approximately 186 metres asl based on the lowest elevation of the ground surface on the perimeter of the proposed extraction area (near Barbers Lake).

Since the surface of the lake within the pit will be flat, there will be minor changes in the groundwater table in the area adjacent to the sides of the proposed pit. In areas where the existing groundwater table is above the estimated elevation of the lake, a drawdown will be observed during extraction operations whereas in areas where the existing groundwater table is below the estimated elevation of the lake, an increase in the groundwater table would be observed.

A radius of influence can be estimated based on the groundwater levels measured in the on-site monitoring wells (MW20-1 to MW20-5) and the hydraulic conductivity of the surficial sediments measured in the wells. The radius of influence can be estimated using the empirical formula developed by Marinelli and Niccoli (2000):

$$h = \sqrt{h_p^2 + \frac{W}{K_h}\left[r_0^2 ln\left(\frac{r}{r_p}\right) - \frac{\left(r^2 - r_p^2\right)}{2}\right]}$$

Where:

h = saturated thickness above the base of the aquifer at a given radius (m)

h_p = saturated thickness at the pit wall (m)

W = recharge flux (m/s)

K_h = horizontal hydraulic conductivity (m)

r_0 = radius of influence where drawdown is zero (m)

r = radius of influence (m)

r_p = effective pit radius (m)

Using a recharge flux of 200 millimetres per year and a geometric average of the estimates of hydraulic conductivity from the on-site monitoring wells (MW20-1 to MW20-5; 4x10^{-5} m/s) and the average of the drawdown at all of the on-site monitoring well locations (1.4 metres) due to the flattening of the water table in the area immediately surrounding the pit lake, the average radius of influence, based on one metre of water table change (increase or decrease) is estimated to be 50 metres (refer to Figure 2).

3.2 Hydrological Investigation and Water Balance Analysis

A water balance was completed for existing conditions, operational conditions and rehabilitation conditions for the study area. The study area includes the land within the property boundary of the proposed pit and contributing catchments. The total study area is approximately 157.2 ha. For detailed water balance tables refer to Appendix E.

3.2.1 Surface Water Monitoring

Staff gauges (SG) and a wellpoint (WP) were installed in the wetland along the northern site boundary, just south of the crossing of Highland Line Drive and Leo Jay Lane (SG2), and near the marshes along the eastern site boundary, adjacent to Barbers Lake (SG1, SG3 and WP1).

A list of the monitoring stations, their locations and their installation dates are provided in Table 3.

Table 3: Surface Water Monitoring Locations

Station Name	Zone	Easting	Northing	Installation Date	Measurements
SG1 (Edge of marshland, adjacent to Barbers Lake)	17	379649	4977248	October 16, 2020	Water Level
SG2 (Northern Wetland, south of Highland Line Drive and Leo Jay Lane)	17	379561	4977535	October 16, 2020	Water Level
SG3 (Edge of marshland, adjacent to Barbers Lake)	17	379684	4977184	October 16, 2020	Water Level
WP1 (Edge of marshland, adjacent to Barbers Lake)	17	379647	4977249	October 16, 2020	Water Level

The approximate locations of these monitoring stations are shown on Figure 1.

3.2.1.1 Surface Water Levels

Staff gauges were installed to assess the water level at the three locations. Data loggers were installed at each SG/WP and programmed to record water levels and at 15-minute intervals. In addition, water levels were manually recorded at the staff gauge locations during each site visit to verify continuous water level measurements recorded with the data logger. The monitoring stations at SG1, SG2, SG3 and WP1 were monitored four times since their installation. A hydrograph of the measured surface water levels for SG1, SG2, SG3 and WP1 are provided on Figure 7.

The daily average ranges in water levels at SG1, SG2, SG3 and WP1 are presented in Table 4 for the available period of record based on 15-minute interval minimum, maximum and averages.

Table 4: Summary of Continuous Water Levels at SG1, SG2, SG3 and WP1

Period of Record	SG1[1]			SG2[1]			SG3[1]			WP1[1]		
	Min. (masl)	Max. (masl)	Avg. (masl)	Min. (masl)	Max. (masl)	Avg. (masl)	Min. (masl)	Max. (masl)	Avg. (masl)	Min. (masl)	Max. (masl)	Avg. (masl)
2020	182.35	182.46	182.39	187.94	188.17	188.03	181.86	182.11	181.97	182.85	183.30	182.91
2021	182.23	182.36	182.32	187.67	188.26	188.03	182.08	182.21	182.17	182.81	183.07	182.93

Note: [1] Survey datum is based on Realtime Can-Net Network Observations (UTM Zone 18 CSRS 2010, Elevations are CGVD 1928, 1978 Adjustment).

Continuous water levels in the wetland at the north end of the property (SG2) fluctuated in response to precipitation and melt events with a total daily average fluctuation of approximately 0.59 m. However, the continuous water levels in the marshland adjacent to Barbers Lake (SG1 and WP1) showed a minimal response to precipitation and melt events with a daily average fluctuation ranging between 0.23 – 0.49 m through the monitoring period. Compared to the water levels seen at the edge of Barbers Lake (SG3), the water levels recorded at the other stations remain at a higher elevation.

The continuous water levels (instantaneous data) in the surface water stations in the northern wetland (SG2) and the marshland (SG1, SG3, and WP1) are shown on Figure 7. The continuous water level hydrographs show low water levels during the summer and early fall. Winter water levels generally remained low, marked with high water events likely caused by short melt events. Water levels through the spring were moderate to high following the freshet.

3.2.2 Water Balance Methodology

The water balance assessment relied on meteorological data obtained from Environment and Climate Change Canada (ECCC) for the Drummond Centre (ID 6102J13) Meteorological Station. Missing data in the data set were replaced by data collected at Carleton Place Meteorological Station (ID 6101250) from January 1984 to February 1999 and Appleton Meteorological Station (ID 6100285) from March 1999 to December 2019. The water balance was based on land use data and existing soil types as identified through the subsurface investigation activities at the site.

Land use at the site under current conditions was identified from previous ecological mapping studies conducted for the Natural Environment study for the site as seen in Appendix F. Land use under operational conditions was based on the ARA Site Plan. The proposed rehabilitation plan for the proposed pit will be flooded with the setback areas remaining vegetated. The land use data were compiled to estimate the total area of each land use within the site boundary. Meteorological data and information from this investigation were used with Table 3.1:

Hydrologic Cycle Component Values, from the Ministry of the Environment (MOE) *SWM Manual* (MOE 2003), to identify appropriate Water Holding Capacities (WHC) for each land use.

Water balance calculations are based on the following equation, which is described in more detail below:

$$P = S + ET + Surplus$$

Where: P = precipitation
S = change in soil water storage
ET = evapotranspiration
Surplus = Surplus water (available for runoff or infiltration)

Precipitation data obtained from ECCC for the Drummond Centre/Carleton Place/Appleton stations indicate a mean annual precipitation (P) of 925 mm/yr.

Short-term or seasonal changes in soil water storage (S) are anticipated to occur on an annual basis as demonstrated by the typically dry conditions in the summer months and the wet conditions in the winter and spring. Long-term changes (e.g., year to year) in soil water storage are considered negligible in this assessment.

Evapotranspiration (ET) refers to water lost to the atmosphere from vegetated surfaces. The term combines evaporation (i.e., water lost from soil or water surfaces) and transpiration (i.e., water lost from plants and trees). Potential ET refers to the loss of water from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of ET is typically less than the potential rate under dry conditions (e.g., during the summer months when there is a moisture deficit). The mean annual potential ET for the study area is approximately 613 mm/yr based on data provided by ECCC.

The mean annual water surplus (Surplus) is the difference between P and the actual ET. The water surplus represents the total amount of water available for either surface runoff (R) or groundwater infiltration (I) on an annual basis. On a monthly basis, surplus water remains after actual evapotranspiration has been removed from the sum of rainfall and snowmelt, and maximum soil or snowpack storage is exceeded. Maximum soil storage is quantified using a water holding capacity (WHC) specific to the soil type and land use. The WHC data obtained from ECCC for combined Drummond-Carleton Place-Appleton stations (IDs 6102J13, 6101250, 6100285) are shown in Table E-1, Appendix E.

Annual surplus values generated from the water balance method may be further divided into annual estimates of runoff and infiltration values. This is done by estimating an infiltration coefficient for each land use (including topography, soils and cover) based on literature values, then multiplying the infiltration coefficient by the surplus estimate to produce an approximate value for annual infiltration. The remaining surplus not accounted for in the infiltration is assumed to run off. For this analysis, the infiltration estimates from Table 3.1 of the MOE manual (MOE, 2003) were used to estimate an infiltration coefficient.

3.2.3 Catchment Delineation

The site is split into three catchments separated by a roadway (Anderson Lane) within the proposed Highland Line Pit property. The total site area is approximately 50.6 ha. Long Sault Creek is a tributary of Clyde River. Under pre-development conditions, approximately 46% of the site flows north to a ditch along Highland Line Road (23.1 ha) and approximately 30% of the site flows southeast into Barbers Lake (15.3 ha). A third, smaller portion comprising approximately 24% of the site (12.2 ha) flows southwest into the unevaluated wetland eventually discharging into Long Sault Creek.

The total drainage area associated with the proposed Highland Line Pit was delineated using the Ontario Flow Assessment Tool (OFAT). The drainage area, in which the study area is located, is approximately 8.5 km^2 (850 ha). The study area includes the land within the property boundary of the proposed licensed pit, Barbers Lake, and the wetland south of the site. The total study area is approximately 157.2 ha. For the purposes of the water balance, since the drainage area of each individual site catchment is small compared to the overall catchment the site is located in, the site will be analysed as a whole instead of individual catchments.

As a result of the proposed development, the pit footprint will have an approximate area of 36.3 ha which overlaps with all three pre-development drainage areas. The precipitation falling on the pit will be partially retained within the pond, ultimately infiltrating to recharge the groundwater, while the remaining is expected to drain to Barbers Lake, at an elevation of 186 metres asl. Ultimately, the precipitation falling within the site will continue to contribute to Long Sault Creek and the unnamed northern wetland.

Under rehabilitated conditions, the pit will remain flooded. The adjacent setback areas will be shrubs/natural growth.

3.2.4 Water Balance Scenarios

Under existing conditions, the site is separated into two sections by Anderson Lane. The northern section includes a section of mixed mineral shallow marsh along the north edge of the site and sections of white cedar organic coniferous swamp and cattail organic shallow marsh adjacent to Barbers Lake as well as a prickly ash deciduous thicket along the northeast site boundary. The southern section includes sections of coniferous forest and mixed meadow adjacent to the southeast site boundary. Both sections include sections of fallow agricultural land, open woodland, and logged/regenerating forests spread throughout the site. During the field investigation, several small areas of bedrock were also identified within the proposed licensed extraction area. These areas were found in notable high points within the site boundary.

Under operational conditions, the full area within the proposed licensed extraction area will be extracted with the exception of any bedrock areas that extend above the proposed base elevation of the pit. Bedrock encountered will not be blasted and removed. It is assumed that the proposed pit will be excavated directly to the edge of the bedrock areas. The below water extraction area will be a waterbody/pond with an outlet at an elevation of 186 metres asl near Barbers Lake along the northeast site boundary. The pond will go right up to the extraction area's edge based on a setback allowance of 30 metres from public roadways and sensitive wetland features (i.e., the mixed mineral shallow marsh [i.e., Zone 9] and white cedar organic coniferous swamp [i.e., Zone 12], see Appendix F) and a setback allowance of 15 metres from the proposed licensed boundary where it is adjacent to property not owned by Cavanagh and 0 metres where the adjacent property is owned by Cavanagh. The 30-metre setback allowance area from Highland Line is proposed to be modified for extraction of aggregate in the setback above the elevation of the existing roadway to match its grade. Barbers Lake is located approximately 100 metres from the edge of the proposed extraction area.

For the purposes of this assessment, it is assumed that the setback allowance area will remain untouched compared to existing conditions with the exception of the setback area adjacent to Highland Line, which will be considered bare during operational conditions. It is also assumed that the water within the pond will not drain to Barbers Lake and will remain as a closed depression.

Rehabilitated conditions were also considered in this study to determine the water surplus after excavation operations have ceased and the pit is decommissioned. Similarly, the rehabilitated condition will go right up to the boundary's edge and the pit pond will remain a closed depression. The setback allowance from Highland Line will also be revegetated at this time.

3.2.5 Water Balance Parameters

Land use information was derived from previous ecological mapping studies conducted during the Natural Environment studies for the site (refer to Appendix F). As seen on Figure 3, the site is primarily composed of bedrock exposed at surface or overlain by a laterally discontinuous cover of overburden primarily comprised of sand and gravel. Fine sandy loam was used as the soil type for the proposed pit under operational conditions based on existing borehole results as discussed in Section 3.1.2

The maximum soil storage is quantified using a Water Holding Capacity (WHC) that is based on guidelines provided in Table 3.1 of the MOE *Stormwater Management Planning and Design Manual* (MOE 2003). The WHC represents the practical maximum amount of water that can be stored in the soil void space and is defined as the difference between the water content at the field capacity and wilting point (the practical maximum and minimum soil water content), respectively.

WHCs are specific to the soil type and land use, whereby values typically range from approximately 10 mm for bedrock to 400 mm for mature forest over silt loam. For temperate region watersheds, soil storage is typically relatively stable year-round, remaining at or near field capacity except for the typical mid- to late-summer dry period. As such, the change in soil storage is a minor component in the water budget, particularly at an annual scale. Surplus water is caused after actual ET has been removed (ET demand is met) and the maximum WHC is exceeded (soil-water storage demand is met).

For the open water areas (flooded pit and cattail organic shallow marsh), it was assumed surplus equals the difference of the precipitation and lake evaporation, which was estimated using the NOAA-GLERL Great Lakes Evaporation Model by the National Oceanic and Atmospheric Administration (NOAA) for Lake Ontario (656 mm) over the same period as the water budget (1985 – 2019). With the unavailability of recent pan evaporation data from local meteorological stations, lake evaporation estimates from Lake Ontario were deemed to be representative of evaporation conditions within the region. For the purposes of this assessment, a null (i.e., 0%) infiltration factor was adopted for the cattail organic shallow marsh area as the continuous water level data exhibited an upward gradient during the majority of the year while the proposed pit will remain a closed depression and fully infiltrate for this assessment.

Water holding capacities at the site were estimated using the values in Table 3.1 of the MOE manual (MOE, 2003). Existing, Operational and Rehabilitated catchment areas are summarized by land use, WHC, soil type and infiltration coefficient are listed below in Tables 5, 6, and 7 for existing conditions, operational conditions and rehabilitated conditions, respectively.

Table 5: Summary of Catchment Areas, WHCs, Soil Types, and Infiltration Factors – Existing Conditions

Existing Conditions					
Type	**WHC**	**Type of Land Use**	**Soil Type**	**Infiltration Factor**	**Catchment Areas**
					(m^2)
Fallow Agricultural Field / Mixed Meadow	150 mm	Pasture & Shrubs / Tilled	Fine Sandy Loam	0.60	183,947
Open Woodland / Coniferous Forest / Logged/Regenerating Poplar-Conifer-Mixed Forest	300 mm	Mature Forest	Fine Sandy Loam	0.70	199,968
Prickly Ash Deciduous Thicket	250 mm	Pasture & Shrubs	Silt Loam	0.50	7,345
Logged/Regenerating Deciduous Forest	400 mm	Mature Forest	Silt Loam	0.60	22,681
Mixed Mineral Shallow Marsh	250 mm	Wetland	Organics	0.30	3,623
White Cedar Organic Coniferous Swamp	300 mm	Treed Wetland	Organics	0.40	22,117
Cattail Organic Shallow Marsh	Precip. - Lake Evap.	Wetland	Organics	0.00	9,739
Fallow Agricultural Field	100 mm	Pasture / Tilled	Bedrock	0.20	1,940
Open Woodland / Coniferous Forest / Logged/Regenerating Deciduous-Poplar-Conifer-Mixed Forest	100 mm	Mature Forest	Bedrock	0.30	54,825
Total					**506,186**

Notes:

1) The mixed mineral shallow marsh was modeled with a WHC of 250 mm due to the presence of organic detritus and observed channels of water during spring and dry channels by late summer.

2) The white cedar organic coniferous swamp was modeled with a WHC of 300 mm due to the presence of organic detritus and several observed seepage areas, where pooling of water occurs, at the time of field inspection.

Table 6: Summary of Catchment Areas, WHCs, Soil Types, and Infiltration Factors – Operational Conditions

Operational Conditions (Proposed Excavation Pit)					
Type	**WHC**	**Type of Land Use**	**Soil Type**	**Infiltration Factor**	**Catchment Areas (m^2)**
Fallow Agricultural Field	150 mm	Pasture & Shrubs / Tilled	Fine Sandy Loam	0.60	11,865
Open Woodland / Coniferous Forest / Logged/Regenerating Poplar-Conifer-Mixed Forest	300 mm	Mature Forest	Fine Sandy Loam	0.70	48,917
Prickly Ash Deciduous Thicket	250	Pasture & Shrubs	Silt Loam	0.50	3,682
Logged/Regenerating Deciduous Forest	400	Mature Forest	Silt Loam	0.60	5,091
Mixed Mineral Shallow Marsh	250 mm	Wetland	Organics	0.30	3,623
White Cedar Organic Coniferous Swamp	300 mm	Treed Wetland	Organics	0.40	22,117
Cattail Organic Shallow Marsh	Precip. - Lake Evap.	Wetland	Organics	0.00	9,739
Fallow Agricultural Field	100 mm	Pasture / Tilled	Bedrock	0.20	1,940
Open Woodland / Coniferous Forest / Logged/Regenerating Deciduous-Poplar-Conifer-Mixed Forest	100 mm	Mature Forest	Bedrock	0.30	51,254
Highland Line Road Allowance Setback (Potential Material Extraction)	75 mm	Potential Extraction Area (Bare)	Fine Sandy Loam	0.50	40,976
Below Water Extraction Area	Precip. - Lake Evap.	Pond	Fine Sand (Saturated)	1.00	306,981
Total					**506,186**

Notes:
1) The infiltration factor for the proposed extraction area is 1.0 (i.e., 100% infiltration) as the pit was assumed to be a closed depression with no surface outlet for the purpose of the water balance assessment. Therefore, all available surplus is expected to infiltrate.

2) The mixed mineral shallow marsh was modeled with a WHC of 250 mm due to the presence of organic detritus and observed channels of water during spring and dry channels by late summer.

3) The white cedar organic coniferous swamp was modeled with a WHC of 300 mm due to the presence of organic detritus and several observed seepage areas, where pooling of water occurs, at the time of field inspection.

Table 7: Summary of Catchment Areas, WHCs, Soil Types, and Infiltration Factors – Rehabilitated Conditions

Rehabilitated Conditions					
Type	**WHC**	**Type of Land Use**	**Soil Type**	**Infiltration Factor**	**Catchment Areas (m^2)**
Fallow Agricultural Field	150 mm	Pasture & Shrubs / Tilled	Fine Sandy Loam	0.00	11,865
Open Woodland / Coniferous Forest / Logged/Regenerating Poplar-Conifer-Mixed Forest	300 mm	Mature Forest	Fine Sandy Loam	0.00	48,917
Prickly Ash Deciduous Thicket	250 mm	Pasture & Shrubs	Silt Loam	0.00	3,682
Logged/Regenerating Deciduous Forest	400 mm	Mature Forest	Silt Loam	0.60	5,091
Mixed Mineral Shallow Marsh	250 mm	Wetland	Organics	0.30	3,623
White Cedar Organic Coniferous Swamp	300 mm	Treed Wetland	Organics	0.40	22,117
Cattail Organic Shallow Marsh	Precip. - Lake Evap.	Wetland	Organics	0.00	9,739
Fallow Agricultural Field	100 mm	Pasture / Tilled	Bedrock	0.20	1,940
Open Woodland / Coniferous Forest / Logged/Regenerating Deciduous-Poplar-Conifer-Mixed Forest	100 mm	Mature Forest	Bedrock	0.30	51,254
Highland Line Road Allowance Setback (Re-Vegetated)	150 mm	Pasture & Shrubs	Fine Sandy Loam	0.60	40,976
Below Water Extraction Area	Precip. - Lake Evap.	Pond	Fine Sand (Saturated)	1.00	306,981
Total					**506,186**

Notes:

1) The infiltration factor for the proposed extraction area is 1.0 (i.e., 100% infiltration) as the pit was assumed to be a closed depression with no surface outlet for the purpose of the water balance assessment. Therefore, all available surplus is expected to infiltrate.

2) The mixed mineral shallow marsh was modeled with a WHC of 250 mm due to the presence of organic detritus and observed channels of water during spring and dry channels by late summer.

3) The white cedar organic coniferous swamp was modeled with a WHC of 300 mm due to the presence of organic detritus and several observed seepage areas, where pooling of water occurs, at the time of field inspection.

For the pit area in the proposed operational and rehabilitated conditions, the active area was assumed as open water with the surplus assumed as the difference between the sum of the inputs (rain and melt) minus the Lake Ontario evaporation estimates from NOAA. This method does not account for any groundwater flow through the pit; actual groundwater inflows will be additive to the precipitation surplus predicted by this method.

An infiltration coefficient of 1.0 (indicating 100% infiltration with no runoff) was applied to the proposed extraction area in the operational and rehabilitated conditions. This infiltration coefficient was used to acknowledge that with no dewatering or surface water outflow (for water balance assessment purposes only), and assuming the amount of water in the pit does not change on an annual basis, the total annual surplus from the pit area must leave the pit through infiltration.

3.2.6 Water Balance Results

The following sections present the water balance analysis under existing, operational and rehabilitation conditions. A discussion of the potential impacts to surface water features as a result of changes to the water balance during pit development is presented in Section 5.3.

3.2.6.1 Existing Conditions

The results from the existing conditions water balance are shown in Table 8.

Table 8: Existing Conditions Water Balance Results

Component	Average Annual Volume - Site Wide	
	mm/yr	m^3/yr
Precipitation (P)	925	468,225
Evapotranspiration (ET)	474	240,120
Surplus (S)	333	168,755
Infiltration (I)	192	97,315
Runoff (R)	141	71,440

The total average annual surplus for the site area under existing conditions was estimated to be approximately 333 mm or 168,755 m^3 per year and the estimated infiltration is approximately 192 mm or 97,315 m^3 per year. Runoff was calculated as the difference between surplus and infiltration and was estimated to be approximately 141 mm or 71,440 m^3 per year.

3.2.6.2 Operational Conditions

The results from the operational conditions water balance are shown in Table 9.

Table 9: Operational Conditions Water Balance Results

Component	Average Annual Volume – Site Wide	
	mm/yr	m^3/yr
Precipitation (P)	925	468,225
Evapotranspiration (ET)	598	302,640
Surplus (S)	299	151,180
Infiltration (I)	226	114,365
Runoff (R)	73	36,815

The total average annual surplus for the proposed extraction area under operational conditions was estimated to be approximately 299 mm or 151,180 m^3/year and the estimated infiltration is approximately 226 mm or 114,365 m^3/year. Runoff was calculated as the difference between surplus and infiltration and was estimated to be approximately 73 mm or 36,815 m^3/year.

3.2.6.3 Rehabilitated Conditions

The results from the rehabilitated conditions water balance are shown below in Table 10.

Table 10: Rehabilitated Conditions Water Balance Results

Component	Average Annual Volume – Site Wide	
	mm/yr	m^3/yr
Precipitation (P)	925	468,225
Evapotranspiration (ET)	601	304,280
Surplus (S)	295	149,340
Infiltration (I)	200	101,000
Runoff (R)	95	48,340

The total average annual surplus for the proposed extraction area under rehabilitation conditions was estimated to be approximately 295 mm or 149,340 m^3/year and the estimated infiltration is approximately 200 mm or 101,000 m^3/year. Runoff was calculated as the difference between surplus and infiltration and was estimated to be approximately 95 mm or 48,340 m^3/year.

3.2.7 Hydrological Summary

A summary of the annual water balance considering surplus, infiltration, and runoff for the pre-development, operational, and rehabilitated conditions is provided in Table E-2 in Appendix E.

Under operational conditions, surplus is anticipated to decrease by approximately 10% from 168,755 to 151,180 m^3 per year. Based on the site layout approximately 36,815 m^3/year of runoff will be produced from the site, which is a decrease of approximately 34,625 m^3/year (approximately 48%) from the existing conditions. Runoff will likely flow away from the pit towards Long Sault Creek, Barbers Lake, and the unevaluated Northern Wetland as the areas surrounding the proposed pit naturally flow in those directions.

Under rehabilitated conditions, it is assumed the pit will remain flooded. The plantings on-site will consist of shrubs/natural growth in the setback area (characterized within the MOE SWM Manual as Pasture and Shrubs), however, for the purpose of this analysis the land uses within the setback allowance area will remain the same as in existing conditions with the exception of the stripped area between Highland Line and the proposed pit. Therefore, total surplus is anticipated to decrease by approximately 19,415 m^3/year (12%) to 149,340 m^3/year and runoff is estimated to decrease by approximately 23,100 m^3/year (32%) compared to existing conditions.

Overall, during the operational and rehabilitated conditions, an increase in evaporative losses is expected to decrease the total annual surplus from the site. The operational and rehabilitated conditions will also result in a decrease in total runoff and an increase in total infiltration. Due to the direction of groundwater flow (primarily from the southwest to the east), it is assumed that infiltration in the pit area will report as baseflow toward the Barbers Lake, thereby increasing the surplus discharged toward Barbers Lake and decreasing the surplus toward the unnamed northern wetland and Long Sault Creek, which also discharges to Barber's Lake.

4.0 RECEPTOR IDENTIFICATION

4.1 Water Supply Wells

The MECP WWIS includes records for approximately 2 private water supply wells located within 500 metres of the site based on a UTM Reliability Code of 5 (i.e., 300 metres or less). The approximate locations of these wells are shown on Figure 2. In addition, a review of a recent aerial photograph indicates that approximately 6 additional wells could be located within 500 metres of the site but are not listed in the MECP WWIS. The highest concentration of water wells is to the east of the site, particularly along Leo Jay Lane.

4.2 Surface Water Features

There is one single small intermittent watercourse that flows to Barbers Lake that is located within the proposed licensed area. Municipal drains are also located north and west of the site, while a wetland complex is located within approximately 60 metres of the eastern site boundary and 200 metres of the northern site boundary.

5.0 ASSESSMENT OF POTENTIAL IMPACTS OF PROPOSED PIT

Based on the nature of the subsurface materials, Cavanagh has advised that the approximate pit base elevation will be 176 metres asl. The proposed pit base elevation is between 6.4 metres below the measured seasonal low and 19.4 metres below the historic seasonal high groundwater table. Based on the controlling elevation (lowest point on the edge of the proposed extraction area), it is predicted that the surface water level in the pit under full operational and rehabilitated conditions will be approximately 186 metres asl.

5.1 Potential Impact to Groundwater Users

Approximately 8 private well users have been identified within the 500 metres of the proposed boundary area to be licensed, of which 2 are listed in the MECP WWIS (with a UTM Reliability Code of 5 or less). A review of the completion details available for the 2 water supply wells listed in the MECP WWIS provided the following information:

Table 11: Summary of MECP WWIS wells

Parameter	Range in Values in MECP WWIS Wells
Number of Wells Completed in Bedrock	2*
Number of Wells Completed in Overburden	0
Bottom of Well (Depth)	16.8 to 21.9 metres
Bottom of Well (Elevation)	170.3 to 195.6 metres asl
Uppermost Water-Bearing Zone (Depth)	16 to 18.3 metres asl
Uppermost Water-Bearing Zone (Elevation)	173.9 to 196.4 metres asl

Notes: *The well record for well 7106890 indicates gravel under 4.8 metres of granite. For this analysis, the well was interpreted to be a bedrock well completed in fractured bedrock.

Overburden wells, including dug or drilled wells, may be present in the vicinity of the site, but it is anticipated that most of the water supply wells not listed in the MECP WWIS are east of the site where the shallow overburden consists of thin drift over Precambrian bedrock, and therefore would be bedrock wells.

Given that the aggregate extraction below the groundwater table will occur without dewatering, there will be no significant lowering of the groundwater table in the overburden and underlying bedrock and thus no potential for proposed extraction activities to cause drawdown of the groundwater table such that it interferes with local water supply wells. As the material is extracted from below the groundwater table, there would be a localized and temporary depression of the groundwater level as the aggregate material is extracted but this would rapidly recover given the permeable nature of the subsurface materials.

A monitoring program has been proposed to measure and evaluate the actual effects on groundwater levels associated with long term pit operations, and to allow a comparison between the actual effects measured during the monitoring program with those predicted as part of this impact assessment

Impacts to existing groundwater users associated with the proposed Highland Line Pit are not anticipated.

5.2 Potential Impacts to Groundwater Flow Directions

Generally speaking, extraction of aggregate material from below the established water table has the potential for interference with groundwater flow directions in the area of a site. However, given that no dewatering is proposed during the extraction below the water table, it is considered that the proposed pit will not significantly impact groundwater flow directions in the vicinity of the site.

5.3 Potential Impact to Existing Surface Water Features

As discussed above, Barbers Lake, Long Sault Creek, and the unnamed northern wetland lie outside of the site boundaries and receive drainage from the site. The total catchment areas near the confluence of the two named waterbodies (i.e., Barbers Lake and Long Sault Creek) and at the downstream end of the wetland (before draining under Highland Line Road east of the Site) are 8.5 km^2 and 9.6 km^2, respectively (estimated using the Ontario Flow Assessment Tool, OFAT). The pit excavation will convert approximately 0.20 km^2 and 0.16 km^2 of the surface water catchments for the two named waterbodies and the unnamed northern wetland, respectively (approximately 2.4% and 1.7%, respectively) to a depression with a surface outlet to Barbers Lake at 186 metres asl, along the east part of the site, that will both internally drain to shallow groundwater and outflow as surface runoff during different seasons. Although direct runoff from the pit area to either of the named water features will be reduced, the water surplus collecting in the pit will also infiltrate and continue downgradient to Barber's Lake and Long Sault Creek as shallow groundwater flow.

The water balance assessment in Section 3.0 suggests that overall, there is a decrease in water surplus of 10% from 168,755 to 151,180 m^3 per year for the site under operational conditions. Rehabilitated conditions are expected to have a similar decrease in surplus compared to existing conditions. Runoff volumes to Barbers Lake, Long Sault Creek, and the unnamed northern wetland are expected to decline, however baseflow to Barbers Lake and Long Sault Creek is expected to slightly increase as a result of the increase in infiltration at the pit. This change from site runoff to infiltration is expected to decrease peak flow contributed from the site and slightly increase a steadier base flow from the site.

Operation of the proposed pit is also not expected to contribute to flooding problems in the receiving drainage features, as there will be limited water discharge from the pit. The pit itself is expected to operate as a large infiltration basin with a surface outlet at Barbers Lake at 186 metres asl. The redirection of catchment areas from the north (unnamed northern wetland), from the east (Barbers Lake), and from the southeast (Long Sault Creek) to the pit area thus results in an overall reduction in peak surface flow rates in all directions.

Overall, the surface water impacts, associated with the proposed pit, that are discussed in this report are marginal. Changes in contributing catchment to the locations discussed are on the order of 2%, while infiltration is still estimated to report to two of the three adjacent waterbodies as baseflow.

5.4 Natural Heritage Features

As presented in the Natural Environment Report (Golder, 2022), the significant features and functions on the site will be avoided through implementation of setbacks from the extraction area and protection of the Natural Environment Exclusion Area, and indirect impacts relating to surface water and groundwater are unlikely to be significant. Measures to be employed to mitigate other potential impacts to the natural environment are discussed below.

To avoid direct or indirect impacts to wildlife, no clearing of vegetation should take place within the core breeding bird season (April 1 – August 31) to avoid contravention of the *Migratory Birds Convention Act* (Canada, 1994) unless a nesting survey has been completed by a qualified biologist within 24 hours of the clearing, and no active nests were observed. If an active nest is observed, the area must be buffered and vegetation clearing at that location postponed until the nest is no longer active.

Fence and protect the area identified as maternity roost habitat for tri-coloured bat (Natural Environment Exclusion Area) to prevent intrusion into this area and avoid placing lighting in the vicinity of this area.

To mitigate the potential for turtles, especially Blanding's turtle, to be harmed on the site during extraction, Golder recommends the following mitigation be undertaken:

- Install permanent fencing around the site to prevent turtles from entering; to be removed post-extraction.
- Encounter Protocol: The protocol will include information on how to identify Blanding's turtle, how to protect a nest, how to report sightings to the Ministry of Natural Resources and Forestry (MNRF) Natural Heritage Information Center (NHIC), and instructions on what to do in the event that a turtle or nest is found on-Site.

- All on-site staff are to be familiar with and trained on the components of the Encounter Protocol described above.
- If Blanding's turtle is identified on the site, all work shall stop and the species shall be protected from harm. Ministry of Environment, Conservation and Parks (MECP) shall be notified immediately to seek guidance on ways to avoid impacts under the provincial *Endangered Species Act* (ESA; Ontario 2007) (e.g., mitigation, conditional exemption) prior to resuming work.

An Awareness Package, Species at Risk (SAR) Encounter Protocol and SAR Training Program is to be prepared that lists the SAR that may be present on the site or in the local landscape, and identifies what to do if one is observed on the Site. The Awareness Package will include:

- Information / training on identifying SAR;
- What to do if a SAR is observed (moving, injured, dead or nesting);
- How to protect a turtle or bird nest;
- Information on how to report a SAR sighting to the NHIC; and,
- Instructions that if a SAR is found on the Site, all work must stop and the species shall be protected from harm. MECP shall be notified immediately to seek guidance on ways to avoid impacts under the ESA (e.g., mitigation, conditional exemption) prior to resuming work.

Standard best management practices for noise and dust mitigation at pit operations will be employed to reduce impacts on adjacent lands, and the habitats they provide.

5.5 Source Water Protection

The proposed Highland Line Pit falls outside of the mapped Wellhead Protection Areas (A through D) within the Mississippi-Rideau Source Protection Region protection plans. Impacts to groundwater quality or quantity at the water supply wells, where Wellhead Protection Areas have been established, as a result of the proposed development of the Highland Line Pit are not predicted.

The site lies outside of the identified Intake Protection Zones 1 and 2 within the Mississippi-Rideau Source Protection Region protection plans however parts of the site lie within an Intake Protection Zone 3. The proposed site is located greater than 35 kilometres (in a straight line) from the closest downstream water supply (Carleton Place). As such, impacts to the water quality or quantity at the Carleton Place surface water supply, and those further downstream, as a result of the proposed development of the Highland Line Pit are not predicted.

Portions of the site have been identified as Significant Groundwater Recharge Areas by MECP (refer to Figure 1). The Significant Groundwater Recharge Areas lie both within the proposed extraction area as well as the setbacks within the licensed area. Areas within the setbacks will not be altered, with the exception of areas along Highland Line where the extraction of aggregate in the setback above the elevation of the existing roadway to match its grade is proposed.

Both within the setback area and the extraction area, groundwater recharge will still occur as the proposed pit will not be dewatered. Infiltration will take place through the overburden (in the case of the area within the setbacks) or through the bottom and sides of the pit lake.

6.0 MONITORING PROGRAM

During pit operations, as the pit deepens below water, the water level in the pit lake will flatten out (as compared to existing conditions) thus creating areas of groundwater drawdown or areas of groundwater level increases adjacent to the pit. Given that there will not be any active dewatering of the pit and the predicted changes to groundwater levels due to pit operations are localized, no impacts to surface water features and groundwater resources are anticipated.

A monitoring program has been proposed to measure and evaluate the actual effects on water resources associated with long term pit development, and to allow a comparison between the actual effects measured during the monitoring program with those predicted as part of the impact assessment. It is proposed that the groundwater monitoring program consist of the following:

- Quarterly groundwater level monitoring during pit operations, in monitoring wells MW20-1, MW20-2, MW20-3, MW20-4, MW20-5 and MW20-6 once the pit is operating below the water table.
- Quarterly surface water level monitoring during pit operations, at surface water station SG-1 once the pit is operating below the water table.

7.0 SUMMARY AND CONCLUSIONS

The Level 1 and 2 Water Report was completed for the proposed Cavanagh Highland Line Pit located in the Township of Lanark Highlands, Lanark County, Ontario. Based on the results of the investigation, the following summary and conclusions are presented:

- The local overburden deposits on the property consist primarily of sand and gravel and fine to coarse sand. Glacial till was generally encountered on the westernmost edge of the property at surface;
- The upper bedrock unit is Precambrian Bedrock consisting of Carbonate Metasedimentary Rocks (marble) in the northern portions of the site and Alkalic Plutonic Rocks (Syenite) in the south of the site. The local depth to bedrock indicated in the WWIS well records varies from 17 to 23 metres bgs;
- Two field investigations were carried out at the site in 2019 and 2020 and included the excavation of 22 test pits and the installation of six monitoring wells (MW20-1 to MW20-6). Water levels were measured monthly from April 2020 to June 2021;
- Staff gauges were installed to assess the water level at three surface water locations in the wetland along the northern site boundary, just south of the crossing of Highland Line Drive and Leo Jay Lane, and near the marshes along the eastern site boundary, adjacent to Barbers Lake. A wellpoint was also installed adjacent to Barbers Lake. Data loggers were installed at each location and programmed to record water levels at 15-minute intervals;
- Groundwater depths range from 1.5 to 4.6 metres bgs across the site. Based on groundwater elevation data collected during the pre-development period, the general groundwater flow direction in the vicinity of the site is influenced by the topography of the site and seasonal water table fluctuations. Groundwater generally flows from southwest to east across the site, and toward the topographic low near Barbers Lake;
- The extraction will include the removal of overburden materials to an approximate pit base elevation of 176 metres asl. Material extraction will not require dewatering. Given that the aggregate extraction below the groundwater table will occur without dewatering, there will be no significant lowering of the groundwater table

in the overburden and underlying bedrock and thus no potential for proposed extraction activities to cause drawdown of the groundwater table such that it interferes with local water supply wells;

- The predominant water supply for the area is derived from the bedrock, which further reduces the potential for impacts to local groundwater users as a result of extraction of the overlying aggregate material;
- Barbers Lake, Long Sault Creek, and the unnamed northern wetland lie outside of the site boundaries and receive drainage from the site. The total catchment areas near the confluence of the two known waterbodies (i.e., Barbers Lake and Long Sault Creek) and at the downstream end of the wetland (before draining under Highland Line Road east of the Site) are 8.5 km^2 and 9.6 km^2, respectively. The pit excavation will convert approximately 0.20 km^2 and 0.16 km^2 of the surface water catchments for the two known waterbodies and the unnamed northern wetland, respectively (approximately 2.4% and 1.7%, respectively) to a depression with a surface outlet to Barbers Lake at 186 metres asl along the east part of the site that will both internally drain to shallow groundwater and outflow runoff. Although the pit area will no longer be directing a substantial amount of runoff to either of the detailed water features, the water surplus collecting in the pit will also infiltrate and continue downgradient to Barber's Lake and Long Sault Creek as shallow groundwater flow. Changes in runoff to the unnamed northern wetland will not be mitigated from shallow groundwater flow due southwest to the east groundwater flow direction;
- The water balance assessment suggests that overall, there is a decrease in water surplus of 10% for the site under operational conditions. Rehabilitated conditions are expected to have a similar decrease in surplus compared to existing conditions. Runoff volumes to Barbers Lake, Long Sault Creek, and the unnamed northern wetland are expected to decline, however baseflow to Barbers Lake and Long Sault Creek is expected to slightly increase as a result of the increase in infiltration at the pit. This change from site runoff to infiltration is expected to decrease peak flow contributed from the site and slightly increase a steadier base flow from the site;
- Operation of the proposed pit area is not expected to contribute to flooding problems in the receiving drainage features, as there will be limited water discharge from the pit. The pit itself is expected to operate as a large infiltration basin with a surface outlet near Barbers Lake at 186 metres asl. The redirection of catchment areas from the north, from the east, and from the southeast to the pit area thus results in an overall reduction in peak surface flow rates in all directions;
- Overall, the surface water impacts associated with the proposed pit are marginal. Changes in contributing catchment to the locations discussed are on the order of 2%, while infiltration is still estimated to report to two out of the three adjacent waterbodies as baseflow;
- Based on the findings of this assessment, no adverse effects to groundwater and surface water resources and their uses are anticipated as a result of the proposed Highland Line Pit.

The impact assessment present in this report addresses the specific policies identified within the Provincial Policy Statement (PPS) as summarized in the table below.

Table 12: Summary of Policies Considered during Assessment

Policy Considered	How the Policy was Addressed
PPS 2.1.2 recognizing linkages between and among natural heritage features and groundwater features.	Groundwater features, surface water and natural heritage features within the vicinity of the site were identified. These features and the potential linkages between these features were evaluated as part of the completed impact assessment from a groundwater, surface water and natural environment perspective.
PPS 2.2.1 b) minimizing potential negative impacts, including cross-jurisdictional and cross-watershed impacts.	The potential impacts to groundwater and surface water features associated with the proposed operations at the Highland Line Pit were assessed and no cross-jurisdictional or cross-watershed impacts were identified.
PPS 2.2.1 d) identifying water resource systems consisting of groundwater features, hydrologic functions, natural heritage features and areas.	The groundwater, surface water and natural heritage features were identified in the vicinity of the proposed Highland Line Pit.
PPS 2.2.1 e) maintaining linkages and related functions among groundwater features, hydrologic functions, natural heritage features and areas.	The impact assessment completed for the proposed Highland Line Pit concluded that the linkages between identified groundwater, surface water and natural heritage features will not be impacted.
PPS 2.2.1 f) implementing necessary restrictions on development and site alteration.	Recommendations related to restrictions on site development (i.e., required setback from wetland/marsh) were identified as part of the natural environment assessment for the Highland Line Pit ARA application (Golder 2022) and were carried forward into this document and onto the Highland Line Pit site plan. No additional restrictions were identified as part of the impact assessment completed within this document.
PPS 2.2.2 development and site alteration shall be restricted in or near sensitive surface water features and sensitive groundwater features such that these features and their related hydrologic functions will be protected, improved or restored. Mitigative measures and/or alternative development approaches may be required.	There are no sensitive surface water or groundwater features on the site. There are appropriate setbacks between the Highland Line Pit and the off-site wetlands and surface water bodies. The impact assessment completed within this document concluded there will be no negative impacts to groundwater and surface water features and their related hydrologic functions. Mitigative measures identified in the natural environment report (Golder 2022) have been carried forward in this document and on the site plans for the Highland Line Pit.
PPS 2.5.2.2 extraction shall be undertaken in a manner which minimizes social, economic and environmental impacts.	The proposed Highland Line Pit operation involves extraction of the available aggregate resource without the requirement for dewatering and minimizes the potential impacts to surrounding groundwater, surface water and natural heritage features.

8.0 LIMITATIONS AND USE OF REPORT

This report was prepared for the exclusive use of Thomas Cavanagh Construction Limited. The report, which specifically includes all tables, figures and appendices, is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this report. Each of these reports must be read and understood collectively and can only be relied upon in their totality.

Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore authenticity of any electronic media versions of Golder's report should be verified.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The assessment of environmental conditions and possible hazards at this site has been made using the results of physical measurements and chemical analyses of liquids from a limited number of locations. The site conditions between monitoring locations have been inferred based on conditions observed at monitoring locations. Conditions may vary from these sampled locations.

The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

9.0 CLOSURE

We trust this report meets your current needs. If you have any questions regarding this report, please contact the undersigned.

Golder Associates Ltd.

LICENSED PROFESSIONAL ENGINEER
B. J. HENDERSON
100110984
2022-12-12
PROVINCE OF ONTARIO

B. Henderson, M.A.Sc., P.Eng.
Environmental Engineer

K.A. Marentette, M.Sc., P.Geo.
Senior Hydrogeologist/Principal

LICENSED PROFESSIONAL ENGINEER
K. M. MacKENZIE
12/12/2022
PROVINCE OF ONTARIO

Kevin MacKenzie, M.Sc., P.Eng. (ON, NS) Senior Principal / Water Resources

BH/MR/KMM/KAM/rk

https://golderassociates.sharepoint.com/sites/112126/project files/6 deliverables/water report/final/19126620-r-rev0-highland line water report_12dec2022.docx

REFERENCES

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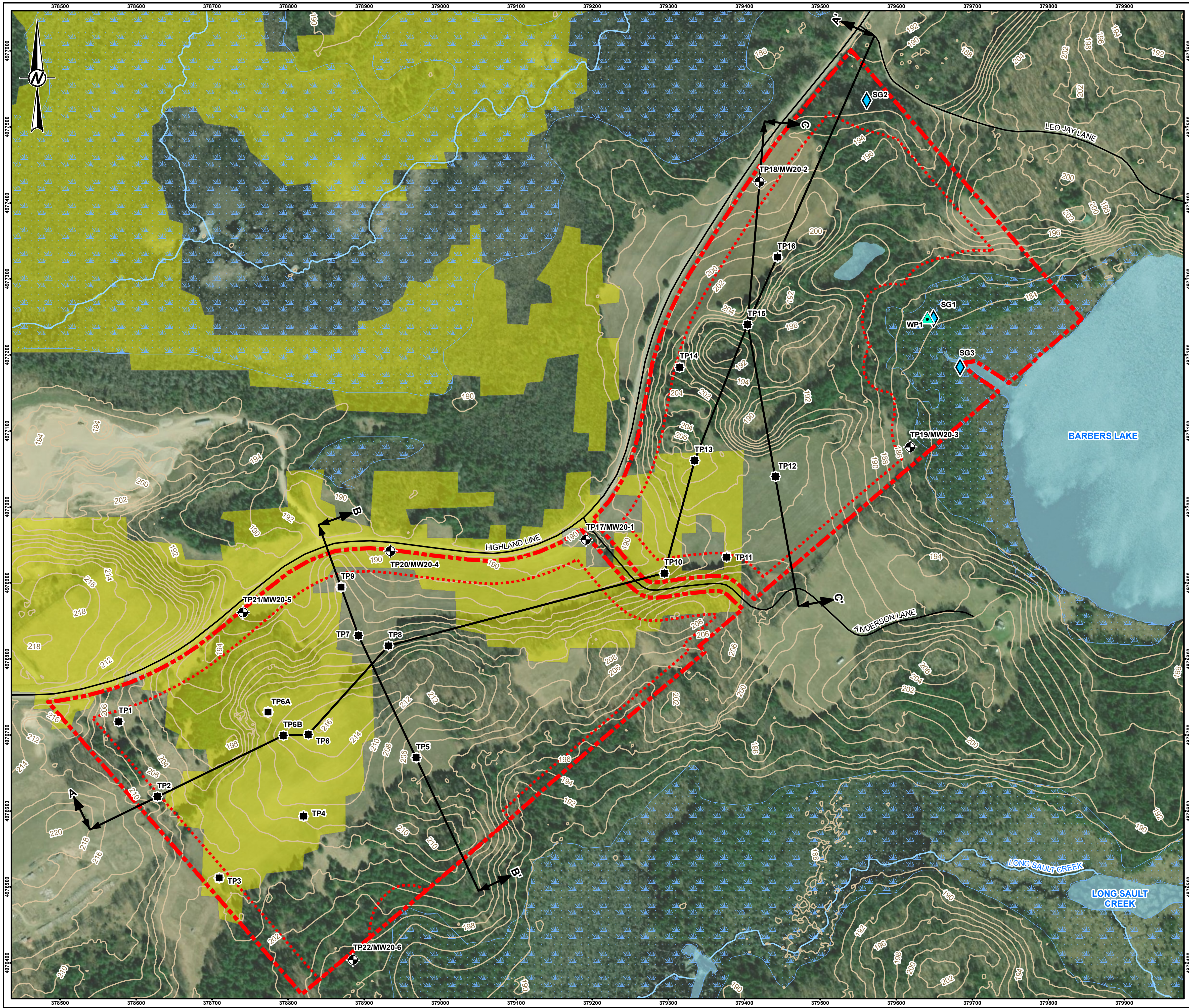

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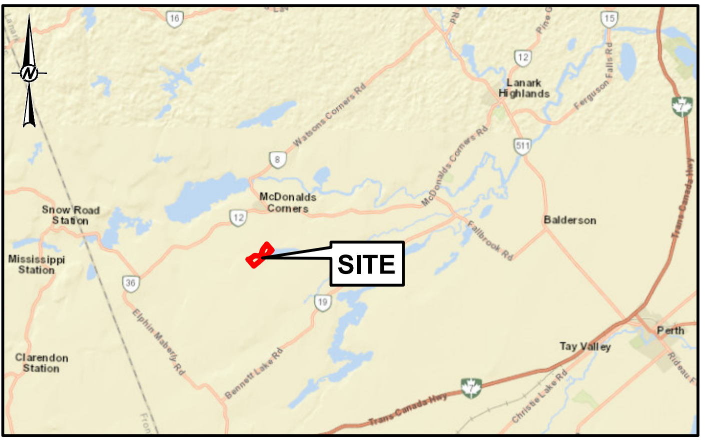


SCALE 1:425,000

LEGEND

⊕	TEST PIT/MONITORING WELL
■	TEST PIT LOCATION
◆	STAFF GAUGE LOCATION
▲	WETLAND PIEZOMETER LOCATION
←	CROSS-SECTION LOCATION
▭	LICENSED BOUNDARY
▭	LIMIT OF EXTRACTION
—	ROADWAY
—	TOPOGRAPHIC CONTOUR, METRES
—	WATERCOURSE
▭	WATERBODY

WETLAND SIGNIFICANCE

▨	UNEVALUATED PROVINCIAL WETLAND
🟨	SIGNIFICANT GROUNDWATER RECHARGE AREA

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
2. SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, USGS, INTERMAP, INCREMENT P, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI KOREA, ESRI (THAILAND), NGCC, (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

0 50 100 200
1:5,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HIGHLAND LINE PIT PROPERTY, PART OF LOTS 4 & 5,
CONCESSION 10, DALHOUSIE TOWNSHIP, LANARK COUNTY,
ONTARIO

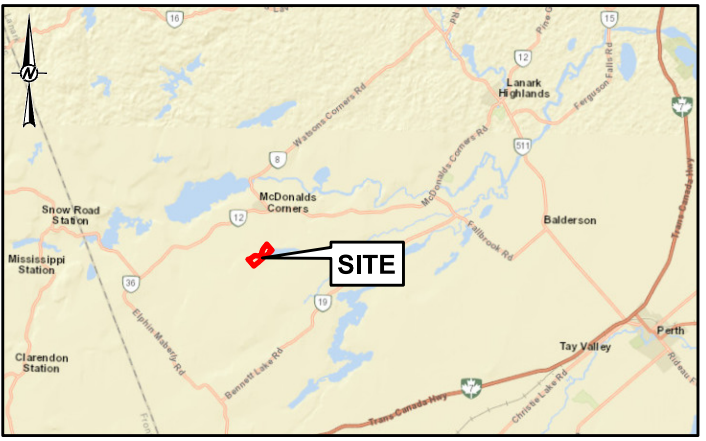
TITLE
SITE PLAN

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-12-06
DESIGNED	BH
PREPARED	BR/MG
REVIEWED	BH
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
19126620	0018	0	1

KEY MAP



SCALE 1:425,000

LEGEND

⊕	TEST PIT/MONITORING WELL
■	TEST PIT LOCATION
⊕	MECP WWIS WATER WELL LOCATION
⊕	ASSUMED WATER WELL
▭	LICENSED BOUNDARY
▭	LIMIT OF EXTRACTION
▭	500 METRE BUFFER
▭	ESTIMATED AVERAGE RADIUS OF INFLUENCE BASED ON ONE METRE OF WATER LEVEL CHANGE (INCREASE OR DECREASE) RELATED TO PIT DEVELOPMENT
—	ROADWAY
—	WATERCOURSE
▨	WATERBODY

WETLAND SIGNIFICANCE

▨	UNEVALUATED PROVINCIAL WETLAND

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
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SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83,
COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

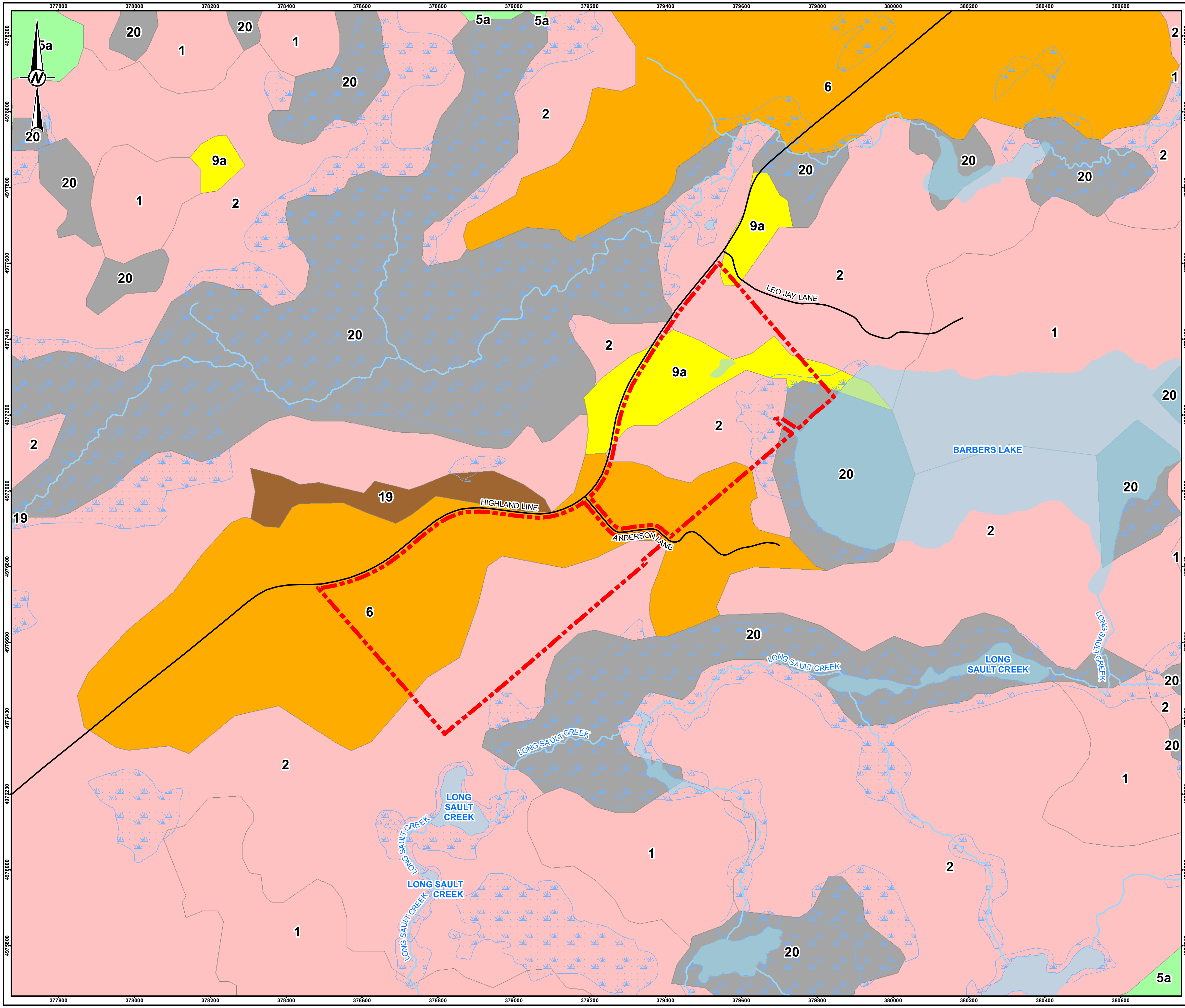
PROJECT
HIGHLAND LINE PIT PROPERTY, PART OF LOTS 4 & 5, CONCESSION 10, DALHOUSIE TOWNSHIP, LANARK COUNTY, ONTARIO

TITLE
WATER SUPPLY WELLS

CONSULTANT
wsp GOLDER

YYYY-MM-DD	2022-12-06
DESIGNED	BH
PREPARED	BR/MG
REVIEWED	BH
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
19126620	0018	0	2



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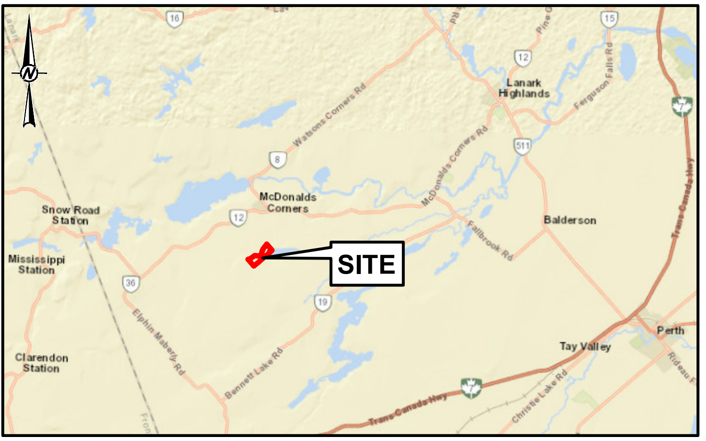

SCALE 1:425,000

LEGEND

🟥 LICENSED BOUNDARY

— ROADWAY

— WATERCOURSE

🟦 WATERBODY

WETLAND SIGNIFICANCE

▨ UNEVALUATED PROVINCIAL WETLAND

OGS SURFICIAL GEOLOGY

- 1. **PRECAMBRIAN BEDROCK**
- 2. **BEDROCK-DRIFT COMPLEX IN PRECAMBRIAN TERRAIN:**
- 5a. **TILL:** SILTY SAND TO SAND-TEXTURED TILL ON PRECAMBRIAN TERRAIN
- 6. **ICE-CONTACT STRATIFIED DEPOSITS:** SAND AND GRAVEL MINOR, SILT, CLAY AND TILL
- 9a. **COARSE-TEXTURED GLACIOLACUSTRINE DEPOSITS:** SAND, GRAVEL, MINOR SILT AND CLAY; DELTAIC DEPOSITS
- 19. **MODERN ALLUVIAL DEPOSITS:** DAY, SILT, SAND, GRAVEL, MAY CONTAIN ORGANIC REMAINS
- 20. **ORGANIC DEPOSITS:** PEAT, MUCK, MARL

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. ONTARIO GEOLOGICAL SURVEY 2010. SURFICIAL GEOLOGY OF SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE--DATA 128-REV
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
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4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

0 100 200 400

1:10,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HIGHLAND LINE PIT PROPERTY, PART OF LOTS 4 & 5, CONCESSION 10, DALHOUSIE TOWNSHIP, LANARK COUNTY, ONTARIO

TITLE
SURFICIAL GEOLOGY MAP

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2022-12-06
DESIGNED	BH
PREPARED	BR/MG
REVIEWED	BH
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
19126620	0018	0	3

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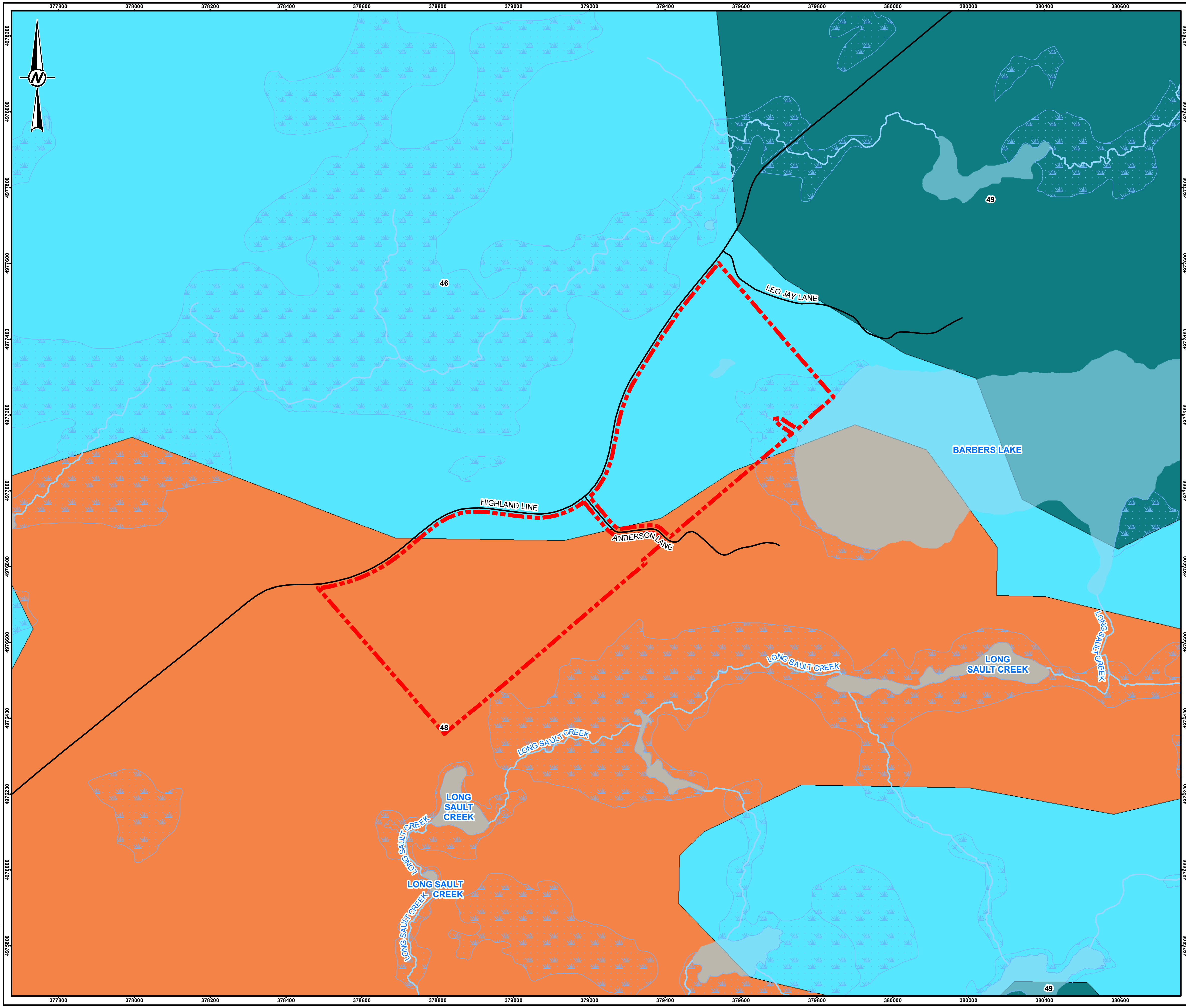
25mm



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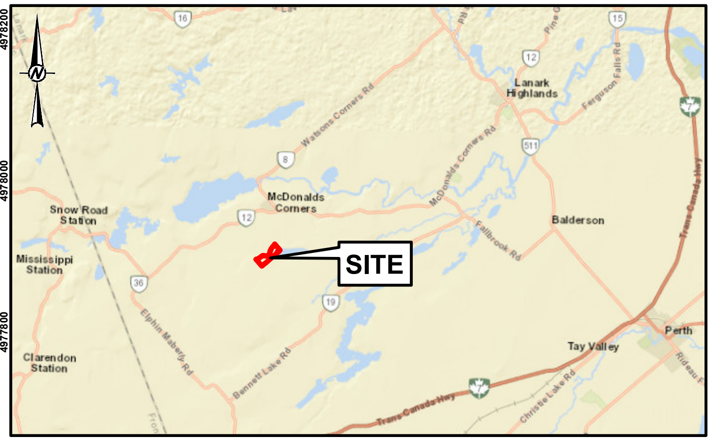

SCALE 1:425,000

LEGEND

🟥	LICENSED BOUNDARY
—	ROADWAY
—	WATERCOURSE
▨	WATERBODY

WETLAND SIGNIFICANCE

▨	UNEVALUATED PROVINCIAL WETLAND
🟦	49 Mafic to ultramafic plutonic rocks
🟧	48 Alkalic plutonic rocks
🟦	46 Carbonate metasedimentary rocks

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. ONTARIO GEOLOGICAL SURVEY 2011. 1:250 000 SCALE BEDROCK GEOLOGY OF ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE–DATA 126 - REVISION 1
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
3. SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, USGS, INTERMAP, INCREMENT P, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI KOREA, ESRI (THAILAND), NGCC, (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83,
COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

0 100 200 400

1:10,000 METRES

CLIENT

THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT

HIGHLAND LINE PIT PROPERTY, PART OF LOTS 4 & 5, CONCESSION 10, DALHOUSIE TOWNSHIP, LANARK COUNTY, ONTARIO

TITLE

BEDROCK GEOLOGY MAP

CONSULTANT

wsp GOLDER

YYYY-MM-DD	2022-12-06
DESIGNED	BH
PREPARED	BR/MG
REVIEWED	BH
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
19126620	0018	0	**4**

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25mm

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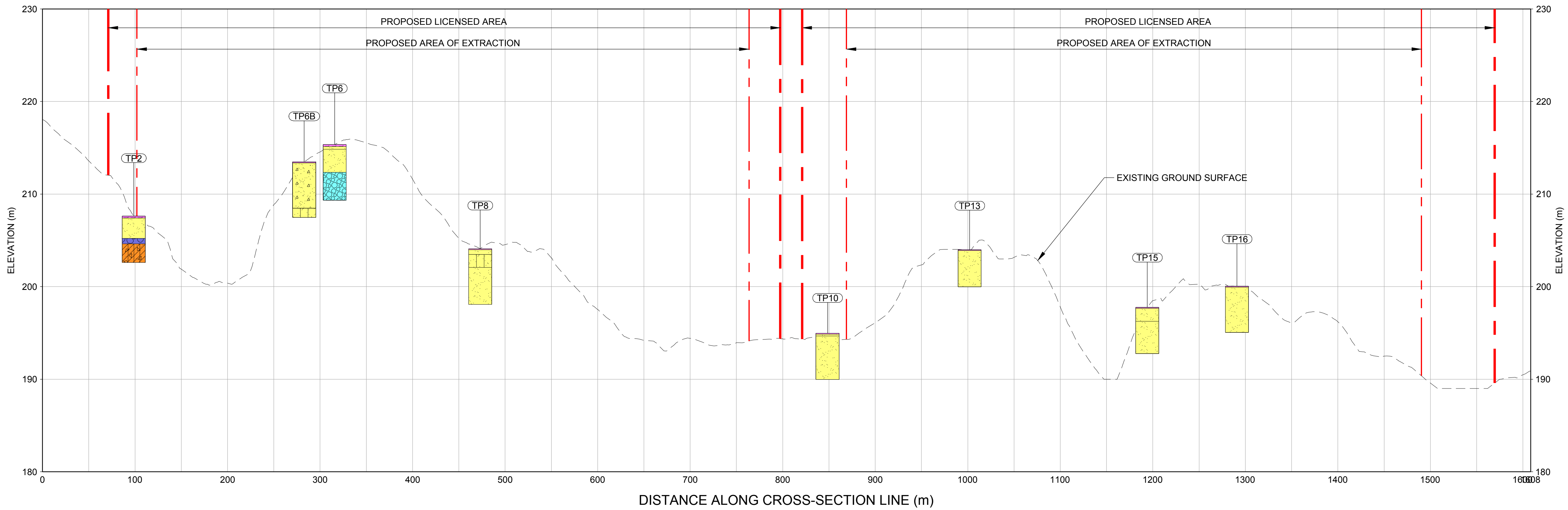
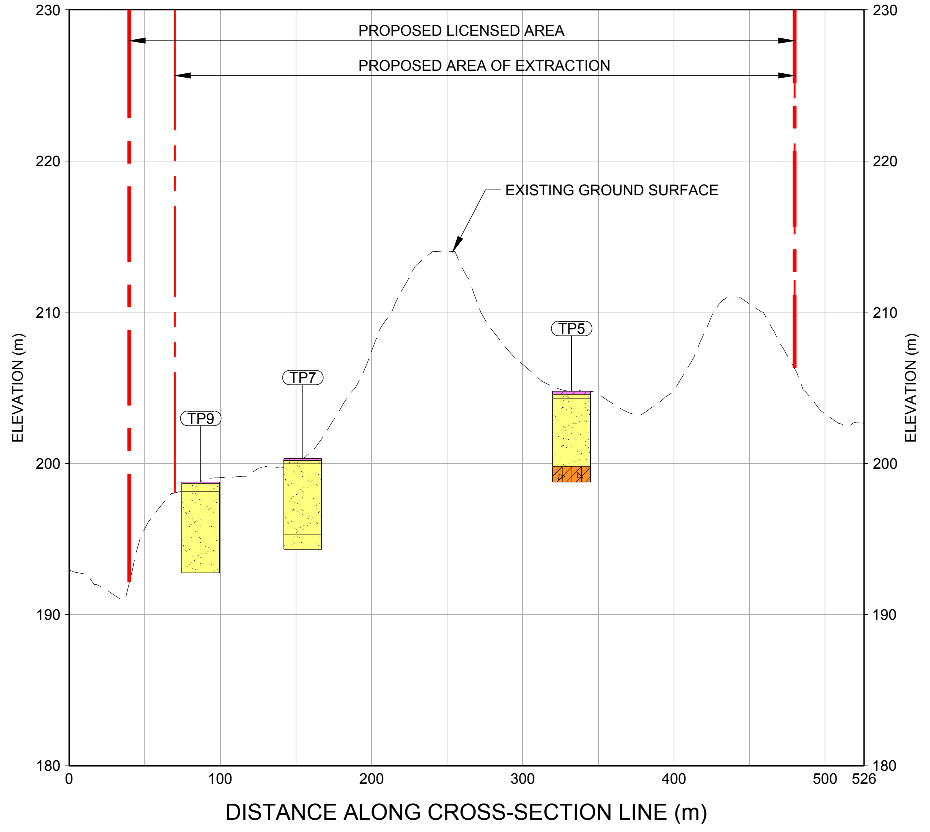


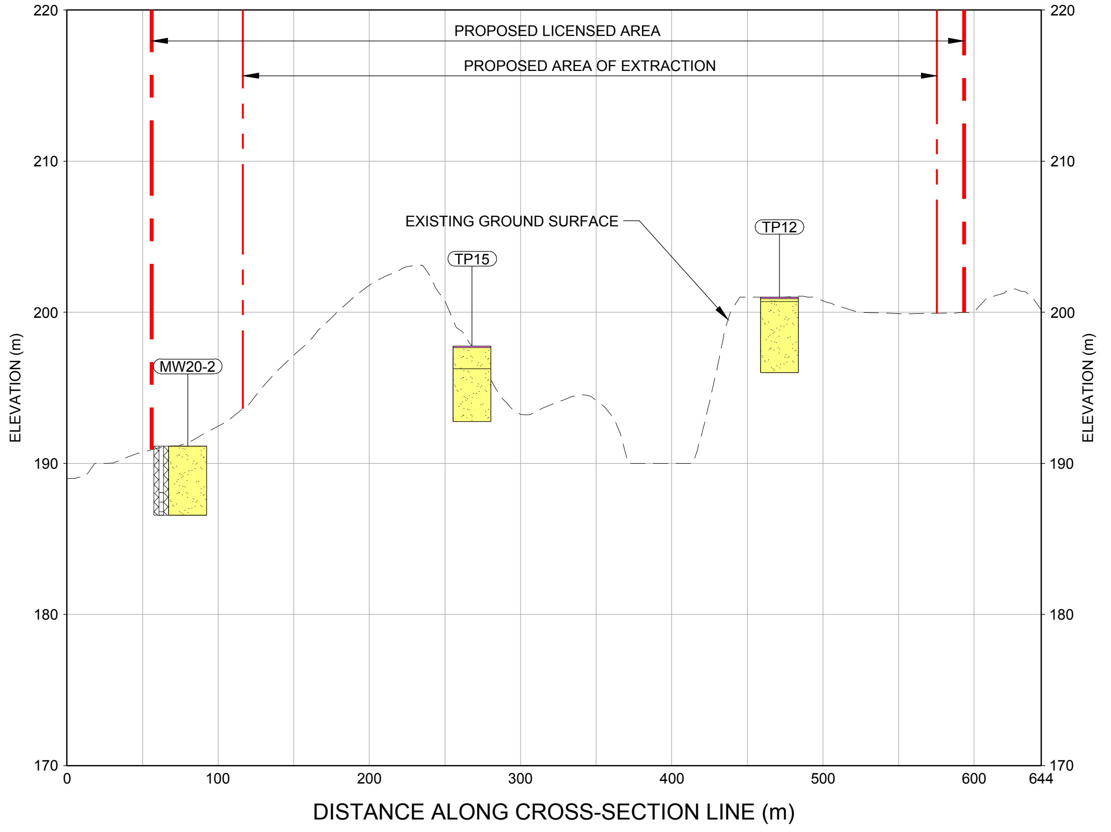
CROSS-SECTION A-A'

HORIZ. SCALE 1:5,000
VERT. SCALE 1:500



CROSS-SECTION B-B'

HORIZ. SCALE 1:5,000
VERT. SCALE 1:500



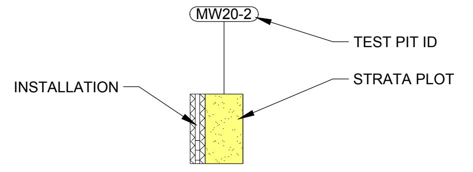
CROSS-SECTION C-C'

HORIZ. SCALE 1:5,000
VERT. SCALE 1:500

SUBSURFACE STRATIGRAPHY

▨	TOPSOIL	▨	GRAVEL
▨	SAND	▨	COBBLES AND BOULDERS
▨	SANDY GRAVEL	▨	GLACIAL TILL
▨	SILTY SAND		

TEST PIT LEGEND



REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2016
2. FOR CROSS-SECTION LOCATIONS REFER TO FIGURE 1

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HIGHLAND LINE PIT PROPERTY, PART OF LOTS 4 & 5,
CONCESSION 10, DALHOUSIE TOWNSHIP,
LANARK COUNTY, ONTARIO

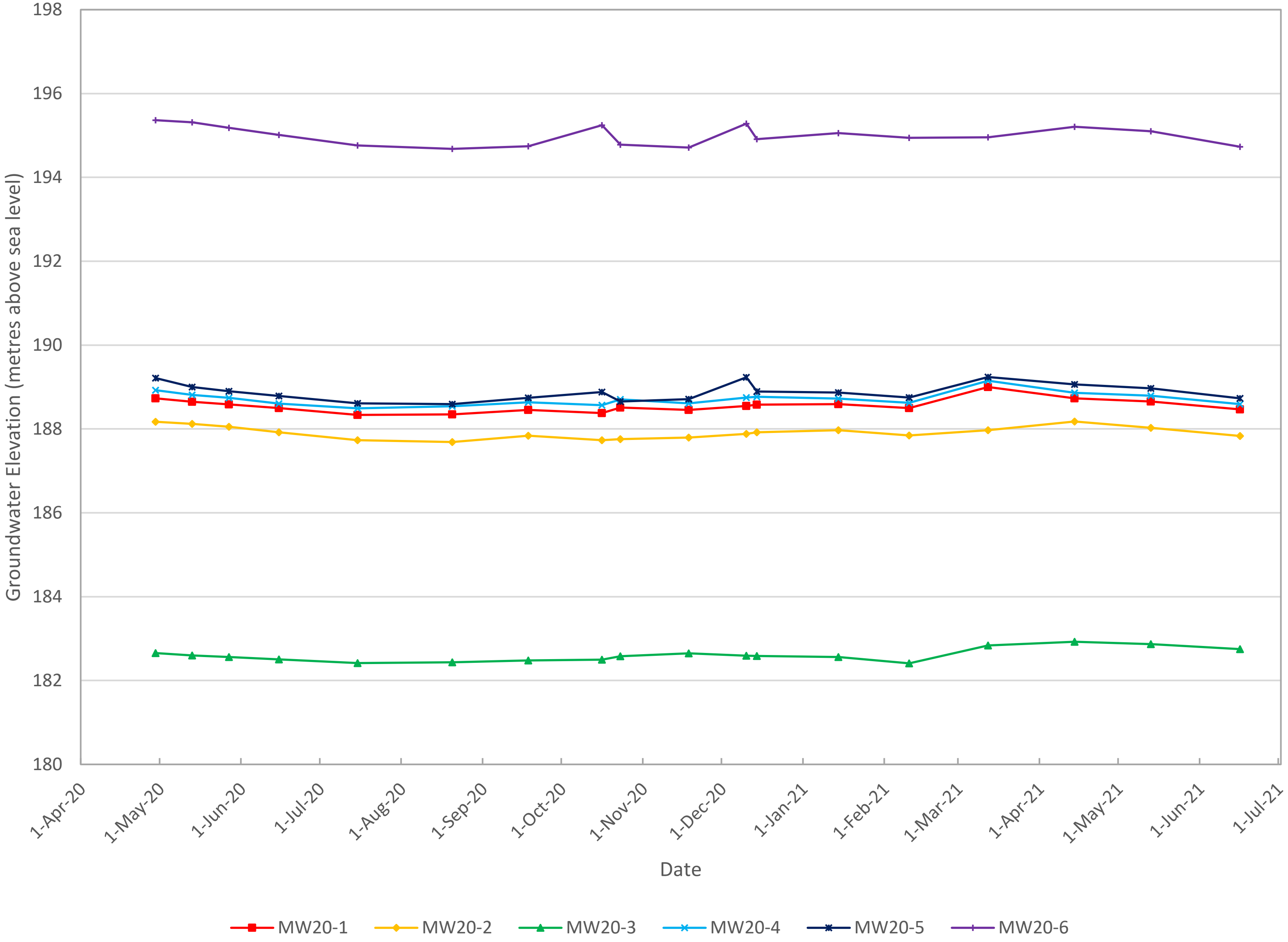
TITLE
CROSS-SECTIONS

CONSULTANT

WSP GOLDER

YYYY-MM-DD	2022-12-06
DESIGNED	----
PREPARED	JM
REVIEWED	BH
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
19126620	0018	0	5



CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

CONSULTANT
wsp GOLDER

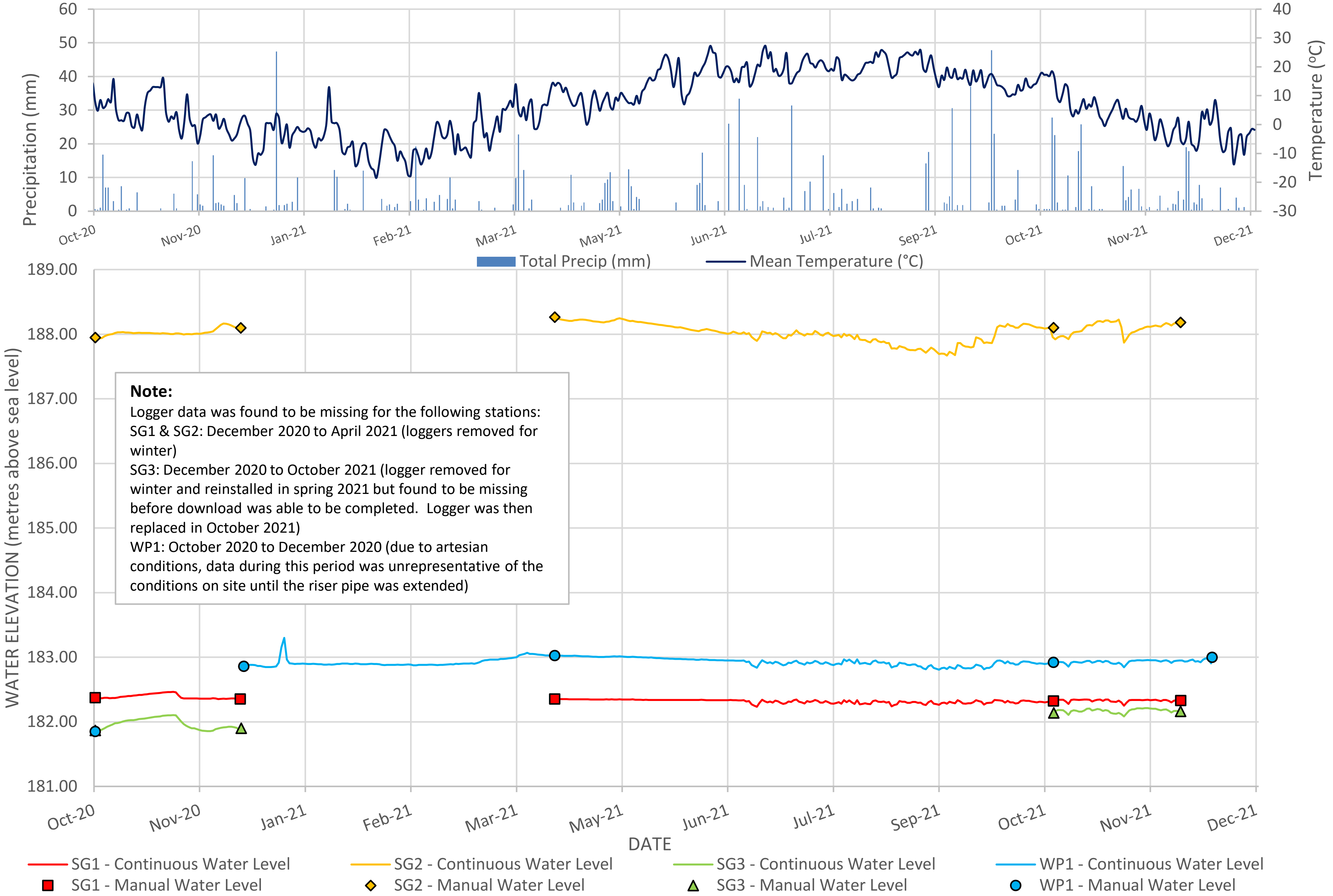
YYYY-MM-DD 2022-02-24
PREPARED BH
DESIGN BH
REVIEW KAM
APPROVED KAM

PROJECT
HIGHLAND LINE PIT

TITLE
GROUNDWATER ELEVATIONS AT MONITORING WELLS MW20-1, MW20-2, MW20-3, MW20-4, MW20-5 AND MW20-6

PROJECT No. 19126620
Rev.

FIGURE 6



Note:
Logger data was found to be missing for the following stations:
SG1 & SG2: December 2020 to April 2021 (loggers removed for winter)
SG3: December 2020 to October 2021 (logger removed for winter and reinstalled in spring 2021 but found to be missing before download was able to be completed. Logger was then replaced in October 2021)
WP1: October 2020 to December 2020 (due to artesian conditions, data during this period was unrepresentative of the conditions on site until the riser pipe was extended)

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HIGHLAND LINE PIT

CONSULTANT

YYYY-MM-DD	2022-04-13
PREPARED	MR
DESIGN	BH
REVIEW	KMM
APPROVED	KAM

TITLE
WATER LEVELS AT HIGHLAND LINE PIT (SG1-SG3 & WP1) ADJACENT TO BARBERS LAKE (2020-2021)

PROJECT No.
19126620

Rev.

FIGURE 7

APPENDIX A

Qualifications and Experience of the Authors

Education

Master's of Applied Science Environmental Engineering, Carleton University, Ottawa, Ontario, 2006

Bachelor Environmental Engineering, Carleton University, Ottawa, Ontario, 2003

Bachelor of Arts Psychology, University of Guelph, Guelph, Ontario, 1996

Certifications

Registered Professional Engineer, Professional Engineers of Ontario, March 2009

Golder Associates Ltd. – Ottawa

Career Summary

Brian Henderson, P.Eng., is an Environmental Engineer with Golder Associates in Ottawa. He holds B.Eng. and M.A.Sc. degrees, both from the department of Civil and Environmental Engineering at Carleton University. He manages a wide variety of hydrogeological and environmental projects including borehole drilling, groundwater and surface water analysis and groundwater monitoring well installation. He has experience with the construction of numerical groundwater flow models used to assess the potential hydrogeological impacts of quarry and construction de-watering and larger scale models for regional studies.

Employment History

Golder Associates Ltd. – Ottawa, Ontario

Environmental Engineer (2006 to Present)

Brian is responsible for project management, technical analysis, data management and reporting for a variety of hydrogeological and environmental projects. In this role he leads the planning, management and execution of permitting applications, groundwater resource protection studies and other environmental/hydrogeological projects. Brian carries out groundwater sampling, field investigations (including soil and groundwater investigations and monitoring); residential groundwater sampling; data management, analysis and interpretation. In addition, he monitors and reports on the compliance of quarry sites and landfills in accordance with their Certificates of Approval and Permits to Take Water. Brian performs groundwater modelling for wellhead protection studies, construction-related groundwater control and quarry hydrogeological studies.

Carleton University – Ottawa, Ontario

Teaching Assistant (2003 to 2005)

Conducted problem analysis sessions for several environmental engineering courses; prepared and coordinated seminars; and helped students one on one. Courses included third year contaminant transport, third year water resources engineering and a fourth year risk assessment course.

City of Ottawa – Ottawa, Ontario

Engineering Assistant (2003)

Working under supervision of City of Ottawa standards engineer, helped to write the City of Ottawa's Sewer Use Guidelines, attended meetings from other departments about the guidelines, researched current acceptable products to determine if they would meet future standards and reviewed new products to establish if they meet with the City's standards.

Carleton University – Ottawa, Ontario

Research Assistant – NSERC Undergraduate Research Award (2002)

Conducted research on the separation of cellulose from sugarcane bagasse plant residue; applied laboratory procedures and analytical techniques to investigate the effectiveness of the separation for a series of individual experimental trials; and designed a bench-scale model for the continuous separation of cellulose based on the experimental trials.

City of Ottawa – Ottawa, Ontario

Laboratory Assistant (2001 to 2002)

Laboratory tested asphalt, aggregates and concrete used in road construction. Laboratory tests included particle size distribution and proctor values for aggregates, the compressive strength of concrete, and particle distribution, volume of voids, percent asphalt cement, and marshal properties for asphalt. In the field, core samples were taken and densities of asphalt were measured using a nuclear density gauge.

PROJECT EXPERIENCE – HYDROGEOLOGY

Rehabilitation of the West Block Ottawa, Ontario	Undertook the hydrogeological components associated with the rehabilitation of the West Block prior to occupation by the House of Commons. Brian prepared a Category 3 Permit to Take Water (PTTW) application and supporting documentation for water taking for construction dewatering from the proposed excavations inside and outside of the building.
Retrofit, Historical Restoration and Seismic Upgrade of the Wellington Building Ottawa, Ontario	Undertook the hydrogeological components associated with the assessment, and development of a treatment system for contaminated groundwater which was encountered under the floor slab. Brian undertook the modelling required to estimate potential groundwater inflow to the treatment system.
Major Rehabilitation of the Government Conference Centre Ottawa, Ontario	Undertook the hydrogeological components associated with the rehabilitation of the Government Conference Center prior to occupation by the Senate of Canada. Brian designed the field testing components of the hydrogeological program and prepared a Category 3 Permit to Take Water (PTTW) application and supporting documentation for water taking for construction dewatering from the proposed excavations inside and outside of the building.
Integrated Road, Sewer and Watermain Replacement/ Rehabilitation Ontario	Conducted background review, technical hydrogeological analysis and reporting related to infrastructure installation/replacement throughout the City of Ottawa. Analysis included predictions of the rate of groundwater inflow, water quality testing and the identification of hydrogeological risks.
Permit to Take Water Applications/ Environmental Activity and Sector Registry Documentation Ontario	Conducted background review, technical hydrogeological analysis and reporting related to Category 1, 2 and 3 Permit to Take Water (PTTW) applications as well as dewatering and discharge plans to support Environmental Activity and Sector Registry (EASR) registrations for construction dewatering projects, quarry dewatering and pumping tests.
Groundwater Numerical Modelling Ontario	Conducted hydrogeological investigations for proposed and existing quarry sites and construction dewatering projects. Developed detailed conceptual and numerical models for groundwater flow, and demonstrated impacts to local environment.
Groundwater and Surface Water Monitoring Programs Ontario	Managed groundwater and surface water monitoring programs; conducted data checks, technical review and analysis; and, prepared a comprehensive annual report for various landfill and quarry sites.

Potable Water and Wastewater Expansion
Village of Limoges, Ontario

In response to a hydraulic review of the potable water and wastewater systems for the Village of Limoges, Golder completed the necessary studies to inform a Master Plan for the two systems in accordance with the requirements of a Municipal Class Environmental Assessment. The Master Plan addressed the growth potential and the capacity constraints to develop a long-term outlook for the community. Brian served as Project Manager and Hydrogeologist for this project. As Project Manager he was responsible for budget/schedule maintenance and control, QA/QC of deliverables, development of a health & safety plan, communication with client and stakeholders, contractor guidance and supervision as well as team organization and communication. Brian also carried out data analysis, report preparation, field program design and water level/sample collection to complete a hydrogeological study to evaluate possible well locations.

Hydrogeological and Hydrological Assessments for Quarry Licensing
Ottawa (Goulbourn Twp.), Ontario

Golder carried out the necessary hydrogeological, hydrological and ecological studies to support applications under the Aggregate Resource Act and the Planning Act for a site plan license for a new quarry. Brian developed detailed conceptual and numerical models of groundwater flow, demonstrated potential impacts to local environment and proposed mitigative measures.

Hydrogeological Assessment for Quarry Licensing
Ottawa (Gloucester Twp.), Ontario

Golder carried out a hydrogeological studies to support an application under the Aggregate Resource Act and the Planning Act for a site plan license for a new quarry. Brian developed detailed conceptual and numerical models of groundwater flow, demonstrated potential impacts to local environment and proposed mitigative measures. He carried out on-site hydraulic conductivity testing and groundwater/surface water interaction studies. He was responsible for designing the field program and health & safety plan and preparing the report.

Hydrogeological Assessment for Quarry Licensing
Canaan Quarry Expansion, Ottawa, Ontario

Golder carried out a hydrogeological study to support an application under the Aggregate Resource Act and the Planning Act for a site plan license for a quarry expansion. Brian developed detailed conceptual and numerical models of groundwater flow, demonstrated potential impacts to local environment and proposed mitigative measures. He carried analysis of on-site hydraulic conductivity testing data. He was responsible for designing the field program and health & safety plan and preparing the report.

Conceptual Design for the Remediation of a Closed Landfill
County of Northumberland, Ontario

Golder presented a number of remediation alternatives to the County to address surface water compliance issues arising from leachate derived impacts identified in a nearby creek caused by a closed landfill. After a review and analysis of existing data, Brian developed the conceptual groundwater flow model, carried out numerical modelling of the remediation options, and prepared reports.

Options Evaluation and Preliminary Design for Tailings Management Option
Nunavut

Golder completed a tailings and waste rock management options evaluation and preliminary design of selected tailings management options at a mine site in Nunavut. Brian completed monitoring well development and sampling for groundwater quality of a deep monitoring well below permafrost using the WestbayTM monitoring well system.

Groundwater Vulnerability Study Kingston, Ontario	Golder completed a Groundwater Vulnerability Study for the municipal water supply well servicing a subdivision in the northeast part of Kingston, Ontario. The groundwater vulnerability study included the delineation of the wellhead protection area (WHPA) around the well and the determination of vulnerability scores for the different zones within the WHPA. Brian was responsible for field program design, compilation, interpretation and analysis of data and report preparation. He also carried out the QA/QC of deliverables, conceptual model development and numerical modelling.
Phase III ESA at the Ottawa International Airport Ottawa, Ontario	Golder completed a Phase III Environmental Site Assessment at the MacDonald-Cartier Ottawa International Airport which attempted to define the extent of groundwater and soil impacts based on the data gap analysis and the water quality results from the available monitoring wells installed during previous investigations. Brian was responsible for the collection of soil and groundwater samples, field program development, data analysis and report preparation. He also carried out compilation and interpretation of data, conceptual model development and contractor guidance and supervision.
Wellhead Protection Study Deloro, Ontario	Golder carried out a Wellhead Protection Study for the Village of Deloro municipal well. The study included a groundwater vulnerability analysis, a threats inventory and a water quality risk assessment. Brian carried out groundwater flow modelling for the delineation of wellhead protection areas for the municipal well in Deloro. He conducted groundwater vulnerability mapping using ISI methods within the delineated areas.

PROJECT EXPERIENCE – HYDROGEOLOGY - INFRASTRUCTURE

Combined Sewage Storage Tunnel Ottawa, Ontario	Golder carried out geotechnical and hydrogeological investigations for a new 6 km combined sewer storage tunnel system in Ottawa. A field investigation and reporting program was completed through the downtown core to support the preliminary and detail design team. Brian assisted with the design and implementation of the hydrogeological field program, carried out the packer test data analysis, compiled and interpreted data and completed pumping tests which were challenging due to the location on the streets of downtown Ottawa. Results of the hydrogeological assessment were included in a report used as a supporting document for a Permit to Take Water application for construction dewatering for the project. Brian also provided technical review and guidance to the team and the guidance and supervision of contractors.
South Nepean Collector Sewer Phase Two Ottawa, Ontario	Undertook hydrogeological investigation for 2.5 kilometers of new deep trunk sewer in Barrhaven just north of the Jock River through sensitive clays, bouldery glacial till with permeable sand seams, and limestone bedrock. Providing hydrogeological input to design, tender documents and construction, including a PTTW application with supporting documentation. Key issues included assessment of the potential for basal heave, basal instability and general excavation conditions for the 6 to 10 metre deep excavations.

Ottawa Light Rail Transit Preliminary Design Ottawa, Ontario	From 2010 to 2012, Golder carried out geotechnical, environmental and hydrogeological investigations for a new 12.5 km light rail transit system in Ottawa. A field investigation and reporting program was completed through the downtown core to support the preliminary design team. Brian assisted with the design and implementation of the hydrogeological field program, carried out the packer test data analysis, compiled and interpreted data and completed pumping tests which were challenging due to the location on the streets of downtown Ottawa. Brian also provided technical review and guidance to the team and the guidance and supervision of contractors.
West Transitway Extension (Bayshore Station to Moodie Drive) Ottawa, Ontario	Undertook the hydrogeological components of the functional and detailed design for the West Transitway extension from Bayshore Station to Moodie drive. Subsurface conditions were determined using pre-existing information and a limited number of new test pits and boreholes/monitoring wells. A pumping test was carried out in the vicinity of Moodie Drive, due to the high hydraulic conductivity of the shallow bedrock, and numerical modelling analyses were undertaken to evaluate the issues related to construction dewatering. Golder obtained draft PTTW's for construction dewatering associated with construction of Phases 1 and 2.
Manotick Watermain Link Ottawa, Ontario	Undertook hydrogeological investigations for detailed design of a watermain through the Village of Manotick, including two crossings under the Rideau River. Completed a Permit to Take Water application with supporting documentation.
Spencer Avenue Integrated Road, Sewer and Watermain Construction Ottawa, Ontario	Undertook the, hydrogeological investigation for the integrated replacement of the roadway, watermain and sewer along Spencer Avenue from Western Avenue to Holland Avenue. Providing hydrogeological input to design and construction, and a Permit to Take Water application with supporting documentation.
Gilmour Trunk Sewer Reconstruction Ottawa, Ontario	Undertook the hydrogeological investigation for the integrated replacement of the roadway, watermain and a deep trunk sewer along Gilmour Street, Waverley Street, Cartier Street and Elgin Street, with deep shaft connection to the Rideau Canal Interceptor trunk sewer. Providing hydrogeological input to design, tender documents and construction, including a Permit to Take Water application with supporting documentation.
Lavergne Street Integrated Road Sewer and Watermain Reconstruction Ottawa, Ontario	undertook the hydrogeological component of the design and construction for the integrated replacement of the roadway, watermain and sewer along Lavergne Street, Jolliet Avenue, Ste Monique Street, et al. in Vanier. Project included deep excavations in peats, highly permeability sands below the water table, and shallow shale bedrock. Non-standard construction measures were considered and assessed as a means of limiting the potential for impacts to adjacent structures resulting from compression of the underlying peat soils due to groundwater level lowering. A Permit to Take Water application with supporting documentation was prepared.
Holland Avenue Watermain Replacement Ottawa, Ontario	Geotechnical, hydrogeological and environmental subsurface investigations in support of design and tender of watermain replacement. Mr. Henderson undertook the hydrogeological components of the project, completed a Permit to Take Water application for the City of Ottawa, and assisted in developing construction specifications for soil and groundwater management.

Jockvale Road Jock River Bridge Replacement
Ottawa, Ontario

Undertook the hydrogeological components associated with the detailed design of the Jock River bridge replacement and the widening and reconstruction of Jockvale Road and associated subsurface utilities in Barrhaven. Golder obtained a Category 3 Permit to Take Water (PTTW) for water taking from the excavation for the Jockvale roadway/sewer service trenches, the bridge caissons and the North and South shafts for the construction of the horizontal utility bore below the Jock River. Analytical and numerical modelling was carried out to evaluate rates of water taking and impacts to the sensitive clay deposit and two dozen private water supply wells located within 500 metres of the site. Golder developed a monitoring program to support the water taking activities.

Education

M.Sc. Geology, University of Windsor, Windsor, Ontario, 1988

B.Sc. Geology, Honours, University of Windsor, Windsor, Ontario, 1986

Certifications

Registered Professional Geoscientist,
2002

Languages

English – Fluent

Golder Associates Ltd. – Ottawa

Employment History

Golder Associates Ltd. – Ottawa, Ontario
Principal/Senior Hydrogeologist (1997 to Present)

Mr. Kris A. Marentette, M.Sc., P.Geo., is a Principal and Senior Hydrogeologist in the Ottawa office of Golder Associates and has 20 years of broad experience in the fields of water supply development, physical hydrogeological characterization studies, regional scale groundwater studies, waste management, contaminated sites assessment /remediation, aggregate resource evaluations and the licensing and permitting of quarry development and expansion projects. Kris is responsible for business development, project management, and senior technical review of hydrogeology, quarry and sand and gravel pit development and expansion, golf course irrigation, site assessment and remediation projects, and waste facility siting, design, operation and environmental compliance monitoring assignments from the Ottawa office.

From 1997 to 2001, Mr. Marentette was Project Manager for Golder Associates' component of one of the largest Environmental Site Assessment (ESA) contracts in Canada which involved the assessment of over 780 sites which were being transferred from Transport Canada to NAV CANADA. Golder Associates completed Phase I ESA of approximately 400 sites of which about 130 sites required Phase II ESA activities. The sites ranged from small antennas towers to large, complex international airports. Project involved considerable logistic planning to mobilize personnel across the country, familiarity with federal and provincial soil and groundwater remediation criteria, development of site-specific remediation options (including permafrost sites), and ongoing interaction with consultant team and Transport Canada/NAV CANADA.

Kris has also been involved as principal consultant or senior reviewer for over 100 Phase I ESAs and over 50 Phase II ESAs completed by the Ottawa office. These projects included industrial, commercial, and residential properties ranging from former coal gasification plants to microcircuit manufacturers. Projects have included an evaluation of permitting requirements related to waste water discharges and air emissions as well as designated substances surveys. Kris has also conducted subsurface investigations at numerous bulk storage, fuel dispensing and pipeline sites; development of groundwater and soil vapour monitoring programs; design and permitting of remedial measures including product recovery and excavation of contaminated soil; supervision and verification of site remediation.

Kris has provided environmental consultation services to many wood product manufacturers in Renfrew County and Lanark County in the context of assessing environmental impacts of wood waste storage and lumber yard and sawmill operations on the natural environment. While working for the wood product manufacturers, Kris established a consistent approach to site investigations and set a focused list of leachate indicator parameters for groundwater and surface water assessments which has met with Ontario Ministry of Environment (MOE) approval.

Kris has been the Golder Associates Project Manager on a number of Ministry of Natural Resources quarry and pit licensing projects for both new operations and expansions to existing operations and has extensive experience in managing these complex, multi-disciplinary projects. Participated in comprehensive aggregate resource evaluations of Paleozoic sedimentary sequences (limestone) and Precambrian marble deposits at quarries in eastern Ottawa for the purpose of developing preferred site development plans to maximize the production of high quality aggregate products. The aggregate resource evaluations have typically included borehole coring, geological core logging, geophysical evaluations and comprehensive laboratory testing programs. Participated in other quarry-related projects associated with the Ministry of Environment Permit to Take Water Program and the issuance of Certificates of Approval (Industrial Sewage Works) under Section 53 of the Ontario Water Resources Act as well as studies undertaken for the purpose of complying with requirements under the Aggregate Resources Act. In the case of the Permit to Take Water approvals and industrial sewage works applications under Sections 34 and 53 of the Ontario Water Resources Act, Kris has consulted with, and interacted extensively, with MOE personnel in both the local District and Regional offices and with key personnel within the Environmental Assessment and Approvals Branch of the MOE in Toronto. Kris was the Project Manager assigned to assist the City of Ottawa in a comprehensive project focused on assisting City staff in understanding the intricate details of the MOE's Permit to Take Water Program. Kris is also well known to the local conservation authorities (Rideau Valley Conservation Authority, Mississippi Valley Conservation Authority and South Nation Conservation) as a result of involvement in water supply and quarry-related projects in the Ottawa area and has interacted with the Ontario Stone, Sand & Gravel Association on various issues related to the aggregate industry (e.g., addressing the MOE concern associated with the potential presence of dinitrotoluene in quarry discharge water, source water protection, etc.). Kris has appeared as an expert witness before the Ontario Municipal Board on quarry-related applications.

Golder Associates Ltd. – Ottawa, Ontario

Hydrogeologist/Senior Hydrogeologist (1988 to 1997)

Responsible for business development and the initiation, implementation and direction of hydrogeological investigations from the Ottawa office. Projects have included test well drilling programs for private services developments; subsurface investigations as related to the installation of subsurface sewage disposal systems; communal water supply investigations; and, regional hydrogeological studies to assist in establishing planning policies for future private services developments and to develop standards for water well construction.

Project manager for numerous hydrogeological studies of existing/proposed landfill sites including the assessment of impacts on water resources and developing and implementing monitoring programs and contingency and remedial action plans. Participated in hydrogeological aspects of waste management studies, preparation and submission of documentation to obtain Emergency Certificates of Approval and Site Interim Expansions of landfill sites under both the Environmental Assessment Act and Environmental Protection Act. Projects have included preparation of landfill site development and operations plans including evaluations of landfill final cover design options. Expert testimony at hearings before the Environmental Assessment Board.

Also responsible for investigation, design and implementation of soil and groundwater remediation programs at hydrocarbons, metals, solvents, and PAH contaminated sites including the risk assessment approach to site management. Projects have included third party peer review of site remediation programs.

Conducted hydrogeological assessments of quarry developments/expansions and pre-acquisition environmental site audits.

PROJECT EXPERIENCE – WATER RESOURCES MANAGEMENT

Village of Winchester Water Supply Project Ontario, Canada	Project Hydrogeologist for the Village of Winchester Water Supply Expansion Project. This project included the preliminary evaluation of potential target aquifers followed by a comprehensive test well investigation and aquifer characterization program. Participated in the development of a comprehensive Water Resources Protection Strategy.
Rural Subdivision Development Ontario, Canada	Supervised test well drilling programs for numerous residential, industrial and commercial private services subdivision developments including evaluation and selection of target aquifers, development of site specific well construction requirements, analysis and interpretation of physical hydrogeological data and groundwater chemical data and preparation and submission of detailed hydrogeological reports. Responsible for conducting many subsurface investigations as related to the installation of small and large subsurface septic sewage disposal systems for private services developments including projects subject to the Ontario Ministry of the Environment Reasonable Use Guideline B-7.
Communal / Commercial Water Supply Evaluation Ontario, Canada	Project Manager for communal water supply investigations for non-profit housing developments in Elgin and Clayton, Ontario and time share condominium development in Cobden, Ontario; responsible for groundwater resource evaluation with respect to project specific water supply requirements. Conducted hydrogeological assessment of the Evergreen Spring Water Site in the Township of Sebastopol, Ontario for Cott Beverages Ltd.; assessment included characterization of geological setting, quantity, quality and age of spring water and evaluation of potential sources of contamination in the vicinity of the spring.
Township of Kingston Planning Study Ontario	Conducted hydrogeological study and general terrain analysis of rural Kingston Township to characterize the present status of the Township's groundwater resources to assist in establishing planning policies for locating new developments on private services and to provide standards for water well construction within the Municipality.
Land Development Evaluation Ontario	Conducted a preliminary hydrogeological and terrain evaluation of a 400 acre parcel of land south of the Ottawa International Airport with respect to the feasibility of developing the site as a rural residential subdivision on private services.

PROJECT EXPERIENCE – WASTE MANAGEMENT

Township of Clarence Landfill Buchanan Landfill Bourget, Ontario/Chalk River, Ontario, Canada	Preparation and submission of documentation to the Ontario Ministry of the Environment to obtain an exemption from the Environmental Assessment Act and approval under the Environmental Protection Act for interim expansions of the Township of Clarence Landfill and Buchanan Landfill. Project involved detailed hydrogeological and geophysical site characterization studies, development of mitigation measures to address existing off-site impacts on groundwater and surface water resources and participation in the preparation of the site development and operations reports, trigger mechanisms, and contingency measures, site closure plans, public participation/presentations, document preparation and representation to regulatory agencies. Expert testimony at the Environmental Assessment Board hearings resulting in successful applications.
Dodge Landfill Espanola, Ontario, Canada	Project Hydrogeologist responsible for hydrogeological studies of existing landfill in support of an application to the Ontario Ministry of Environment for a long-term site expansion.
Lanark County Waste Management Master Plan City/Township of Kingston Waste Management Master Plan Ontario, Canada	Hydrogeological consultant on the master plan study teams involving technical aspects and document preparation, Environmental Assessment process, EA level field investigations and evaluation of site-specific engineered containment system requirements at the preferred sites and presentations to the steering committees and the public.
Armbro Mine Landfill Development Marmora, Ontario, Canada	Project Hydrogeologist as part of the Metro Toronto area landfill site search, for hydrogeological assessment, conceptual design and technical feasibility evaluation of constructing a municipal landfill in the 250 metre deep former open pit iron ore mine.
Township of Clarence Waste Management Planning Study Ontario, Canada	As part of a multi-disciplinary team, responsible for the hydrogeological aspects of a long term waste management planning study under the Environmental Assessment Act and Environmental Protection Act, including development and evaluation of alternative waste management components and systems, a systematic landfill site selection process and interaction with the Public Liaison Committee, municipal council and the public.
Municipal Waste Management Planning Studies Ontario, Canada	Participated in hydrogeological aspects of waste management planning studies to identify potentially suitable areas for landfill development to satisfy the long term waste disposal requirements for the Township of Grattan, Township of Pittsburgh and the Townships of Palmerston, North and South Canonto.

Various Landfill Sites
Eastern and Northern Ontario, Canada

Responsible for undertaking and/or managing hydrogeological and waste management studies at in excess of 50 municipal landfill sites. The typical objectives of these studies have been to define the physical and contaminant hydrogeology including use of geophysical methods; undertake site-specific impact assessments on groundwater and surface water resources and gas migration; complete site performance evaluations in terms of current regulatory requirements; develop site-specific remedial action plans; design and implement annual hydrogeological monitoring programs; assist in the preparation of site development, operations and contingency and remedial action plans; and, to assemble the necessary documentation required to apply to the Ontario Ministry of Environment for Certificate of Approval revisions to permit continued disposal. Conducted evaluations of final cover design options using the Hydrologic Evaluation of Landfill Performance (HELP) computer model for the purpose of selecting the most appropriate final cover design for numerous landfills based on hydrogeological considerations, economics and availability of construction materials in the vicinity of the sites.

PROJECT EXPERIENCE – CONTAMINATED SITES INVESTIGATION AND REMEDIATION

Nation-Wide Environmental Site Assessments
Canada

Project Manager for Golder Associates' component of one of the largest environmental site assessment contracts in Canada which involved the assessment of over 780 sites which were being transferred from Transport Canada to NAV CANADA. Golder Associates completed Phase I ESAs of approximately 400 sites of which about 130 sites required Phase II ESA activities. The sites ranged from small antenna towers to large, complex international airports. Project involved considerable logistic planning to mobilize personnel across the country, familiarity with federal and provincial soil and groundwater remediation criteria, development of site-specific remediation options (including permafrost sites), and ongoing interaction with consultant team and Transport Canada/NAV CANADA.

Assessment of Rockcliffe Airbase Lands
Ottawa, Ontario, Canada

Project Manager to participate as part of a multi-disciplinary team assembled to conduct an existing conditions assessment related to potential redevelopment of the Rockcliffe site for residential land use. Completed a review of subsurface environmental investigation reports in terms of identifying potential development constraints associated with soil and groundwater conditions at the site. Presented recommended actions for evaluating issues of potential environmental concern including development of cost estimates to address these concerns.

Environmental Site Assessments
Eastern Ontario, Canada

Senior Reviewer for over 100 Phase I ESAs and over 50 Phase II ESAs completed by the Ottawa office. These projects included industrial, commercial and residential properties ranging from former coal gasification plants to microcircuit manufacturers. Projects have included an evaluation of permitting requirements related to waste-water discharges and air emissions as well as designated substances surveys.

Assessment of Diesel Fuel Release
Smiths Falls, Ontario, Canada

Project Manager for an environmental impact study which focused on a diesel fuel leak at a large industrial site and included the delineation of the areal extent of contamination, assessment with respect to current soil and groundwater remediation criteria and participation in the development and implementation of a site specific monitoring program and evaluation of remedial options.

Petroleum Hydrocarbon Releases
Eastern Ontario, Canada

Conducted subsurface investigations at numerous bulk storage, fuel dispensing and pipeline sites; development of groundwater and soil vapour monitoring programs; design and permitting of remedial measures including product recovery and excavation of contaminated soil; supervision and verification of site remediation.

Investigation of Salt Storage Facilities
Eastern Ontario, Canada

Project Manager for hydrogeological investigation relating to an assessment of poor groundwater quality adjacent to a salt dome near Almonte, Ontario. Project involved an evaluation of existing water quality data, development and implementation of a replacement well drilling program and long term groundwater quality monitoring program; project involved extensive consultation with municipal officials, affected homeowners and representatives from the Ontario Ministry of the Environment. Responsible for hydrogeological impact assessments relating to salt storage facilities near Eganville and Deep River, Ontario. Investigations included reconnaissance level geophysical surveys to characterize general dimension of the contaminant plumes followed by confirmation drilling, monitoring well installation and groundwater sampling programs to delineate the nature and extent of the contaminant plumes originating from the salt storage facilities and to differentiate between groundwater impacts from the salt storage facilities and that from nearby landfill sites.

PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Stittsville Quarry
Township of Goulbourn (Ottawa), Ontario, Canada

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class “A” license for a 44 million tonne quarry which intends to extract limestone from below the established groundwater table. Assignment also included preparation and submission of applications to the Ontario Ministry of Environment for approval under Section 34 (Permit to Take Water) and Section 53 (Industrial Sewage Works) of the Ontario Water Resources Act. All required approvals were obtained and the quarry became operational in September 2002. Kris continues to be involved as Project Director on all environmental compliance monitoring requirements associated with the Ministry of Natural Resources aggregate license and the Ministry of Environment approvals under Section 34 and 53 on the Ontario Water Resources Act.

Rideau Road Quarries
City of Gloucester (Ottawa), Ontario, Canada

In 2003, Golder Associates was retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class “A” license for a 40 hectare parcel of land adjacent to Tomlinson’s existing quarry operations. The quarry was designed to extract limestone from below the established groundwater table for the production of high quality aggregate suitable for all types of asphalt pavements. Kris was Project Director and Project Hydrogeologist for this assignment and Golder Associates’ primary responsibilities included preparation of Level 1 and Level 2 Hydrogeological studies and Natural Environment evaluations of the property. Of particular significant for this project was the innovative approach develop by Golder Associates (in consultation with the Ministry of Natural Resources) for the purpose of addressing the presence of the American ginseng plant species and butternut trees on the property. The aggregate license was issued by the Ministry of Natural Resources in 2006.

Tatlock Quarry
Township of Lanark Highlands, Ontario, Canada

Project Director and Project Hydrogeologist retained in 2002 by Omya Canada Inc. to conduct Level 1 and Level 2 hydrogeological studies in support of an application to the Ministry of Natural Resources for a Category 2, Class “A” license for the extraction of calcitic marble (crystalline limestone) at the Omya Tatlock Quarry located northwest of Perth, Ontario. Golder Associates was also responsible for the preparation of an application for an industrial sewage works approval under Section 53 of the Ontario Water Resources Act. The quarry license application was issued by the Ministry of Natural Resources in April 2006 and the industrial sewage works approval was issued by the Ministry of Environment in March 2006. Kris continues to advise Omya Canada Inc. on matters related to environmental compliance monitoring and other issues pertaining to Ministry of Natural Resources aggregate license and the Ministry of Environment approvals under Section 34 and 53 on the Ontario Water Resources Act.

Dunvegan Quarry
Township of North Glengarry, Ontario, Canada

Project Hydrogeologist retained by the Township of North Glengarry to conducted a peer review of the hydrogeological aspects of the Cornwall Gravel Company Ltd. Dunvegan Quarry license application. The peer review focused on developing an opinion as to whether the Hydrogeological Assessment Report addressed the various components specified as part of a Hydrogeological Level 1 study and Hydrogeological Level 2 study in the context of a Category 2, Class “A” Quarry Below Water.

Klock Quarry
Aylmer, Quebec, Canada

Golder Associates was retained by Lafarge Canada Inc. to conduct the hydrogeological and natural environment assessments associated with obtaining approval for the extraction of limestone from a property situated adjacent to the existing Klock Quarry. Kris is responsible for overall project co-ordination and direction of a multi-disciplinary team.

Brechin Quarry
City of Kawartha Lakes,
Ontario, Canada

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to complete the necessary hydrogeological, hydrological and ecological studies to support an application under the Aggregate Resources Act. The proposed Brechin Quarry is located in the former Township of Carden within the City of Kawartha Lakes, Ontario. The property covers an area of approximately 206 hectares and involves an aggregate resource of 70 million tonnes with an expected operational timeframe of over 70 years. The assignment involves a comprehensive assessment of the potential effects of quarry development on private water supply wells and an adjacent Provincially Significant Wetland and other natural environment (biological) features as well as consideration of the potential cumulative impacts associated with multiple quarry developments in the area of the proposed Tomlinson Brechin Quarry. This project involves extensive municipal and public consultation as well as interaction with representatives of the Ontario Ministry of Natural Resources and Ontario Ministry of Environment. The aggregate license was issued by the Ministry of Natural Resources in 2009.

TRAINING

Ministry of Environment Approvals Reform and Air Emission Summary and Dispersion Modelling Report Workshop
Ministry of the Environment, 1998

Site Specific Risk Assessment Seminar
Ottawa, 1998

Contaminated and Hazardous Waste Site Management
1997

Occupational Health and Safety Course
1989, 1995

Groundwater Protection in Ontario Conference
Toronto, 1991

Short Course in Dense, Immiscible Phase Liquid Contaminants (DNAPLs) in Porous and Fractured Media
Waterloo Centre for Groundwater Research, 1990

PROFESSIONAL AFFILIATIONS

Associate Member, Ontario Stone Sand and Gravel Association (OSSGA)

Member, Association of Groundwater Scientists and Engineers (N.G.W.A.)

Member, International Association of Hydrogeologists

Member, Ottawa Geotechnical Group, The Canadian Geotechnical Society

Member, Ontario Water Well Association

PROJECT EXPERIENCE – HYDROLOGY/HYDRAULICS

Moira River Flood Mitigation Alternatives Assessment
Foxboro, Ontario

Reviewed and updated floodplain mapping for the Foxboro area, identified several alternative flood mitigation alternatives ranging from floodways and hydraulic controls to lot level flood proofing. Alternatives were assessed and compared based on triple bottom line scores. Triple bottom line analysis considered detailed economic analysis using regions specific flood damage curves developed by Golder's project partner.

Atlantic Gold Hydraulic and Geomorphic Channel Assessments
Central Nova Scotia

Senior reviewer and technical advisor for hydraulic and fluvial geomorphic characterization and baseline studies for a mine development northeast of Halifax, Nova Scotia. Tributaries of 15 Mile Stream were inventoried and used as analogues to design channel diversions around proposed open pit mine excavations.

Low Impact Development Treatment Train Tool (LID-TTT)
GTA, Ontario

Team lead and hydrology advisor for development of a software tool for modelling and evaluating water balance and nutrient budgets for development sites. Worked with three large conservation authorities in the GTA, through several phases implementation of the LID-TTT, to progressively add model capability for assessing the benefits of various LIDs to support planning and early stage engineering of urban development sites.

Garson Mine Water Management and Inundation Study
Sudbury, Ontario

Senior review and technical advice for flood inundation study downstream of the Vale Garson Mine near Sudbury Ontario. The study included an options assessment, development of improved water management operating practices and conceptual design of reservoir retrofits.

International Falls Dam Rule Curve Cultural Study
Rainy River, Ontario

The effects of a recently updated operating rule curve at the International Falls Dam on water levels in Rainy River and the potential for changed water levels to affect locations of cultural significance are being investigated on behalf of the International Joint Commission on the Great Lakes.

Credit River Floodline Mapping
Mississauga, Ontario

Golder completed the most recent comprehensive update of the flood risk investigation and floodline mapping for the Credit River between Old Derry Road and Lake Ontario. This reach alternately flows through an entrenched bedrock valley and remnant beach plains adjacent to Lake Ontario in the most urbanised part of Mississauga. Mr. MacKenzie served as project staff on this project.

Water Quality Forecasting and Infrastructure Annapolis Basin, Nova Scotia	Golder was part of a project team working with the Atlantic Innovation Fund / Applied Geomatics Research Group to develop a complex water quality forecasting tool for use by the shell fishing industry in the Digby Gut area. Real time weather forecasts were used to drive real time hydrology and database scenario models of runoff, water quality (bacteriological) and Bay of Fundy tidal fluctuations and their effects on contaminant movement in the Digby Gut. Hydrodynamic modelling was used to estimate contaminant movement and exposure of shell fishing areas to contamination. This information was packaged for use by shell fishers in order to minimize harvests of contaminated shellfish, thereby protecting the resource and minimizing post-harvest dupurification costs. Mr. MacKenzie was the hydrology and hydrometry technical lead for Golder on this project.
Brookfield Homes – Channel Rehabilitation Brantford, Ontario	Assisted a channel rehabilitation/stabilization assessment and associated ‘field fit’ design for Brookfield at a tributary of Fairchild Creek to address debris removal and channel instability - responsible for field investigations and construction supervision/inspections.
River Diversion Design Northern Ontario	Technical advisor for baseline channel hydraulics and fluvial geomorphic studies in support of a major mine development project in Northern Ontario to characterize baseline conditions at several stream channels, as well as to advance a conceptual design for a proposed diversion channel.
Borer’s Creek Modelling and Restoration Design Dundas, Ontario	HEC-RAS modelling and assessment of a failing reach of Borer’s Creek that threatened to expose a high-pressure natural gas pipeline. Design of remedial measures for failing banks and restoration of the affected reach. Coordinated regulatory approvals. The project was successfully implemented before the spring freshet and significantly reduced the risk of damage to the pipeline.
Voisey’s Bay Nickel Mine Voisey’s Bay, Labrador	A theoretical tailings dam breach was investigated using DAMBREAK to quantify potential impacts on an environmentally sensitive creek. Flood passage downstream of the breach was complicated by several small ponds and alternating sub and supercritical river reaches. Proposed mining operations at the Voisey’s Bay nickel deposit require extensive management of surface waters. Five small dams were considered to safely convey clean water around the proposed tailings facility and to contain and treat tailings water. Modelling and design of the reservoirs and outflow structures was completed using GAWSER.
Plains Midstream – Dechlorination and Approval Sarnia, Ontario	Technical advisor for the design and permitting of a dechlorination system for the Plains Midstream fractionation plant in Sarnia, Ontario. The system is being designed to reduce the free chlorine concentration in the wastewater discharge. Golder is also preparing the ECA (Industrial Sewage Works) amendment package for the facility, to include additional Limited Operational Flexibility (LOF) for the facility for the additional of the dechlorination system, and future sewage work modifications. LOF for the facility will grant future modifications to the works through the appropriate MOE reporting progress, if a professional engineer can demonstrate the modifications will not alter the process discharge quantity and quality limits established for the facility.

Channel Restoration Design
Algonquin Park, Ontario

Technical advisor for the hydraulic design of a stream re-alignment with associated grade controls at an historic train derailment site. Contaminated materials will be removed from the stream bed and banks and adjacent railway embankment. Removal of the contaminated materials will result in a net loss of stream substrate and a change to the fluvial geomorphology of the reach. Grade and stream bank controls were designed to minimize the risks of mobilizing residual contaminants and of significant channel migration.

Omya – Stormwater Management Design and Approvals
Perth, Ontario

A review of existing stormwater management infrastructure was completed for an industrial mineral processing site near Perth Ontario. As a result of incremental development of the site, parts of the stormwater management infrastructure were found to be inadequate. Additional stormwater management works were conceptualized and submitted to MOE for approval. Following approval, Golder provided liaison with the local Conservation Authority, completed basic design drawings suitable for design-build and applied for permitting under the Conservation Authorities Act.

OSSGA Carden Plain Cumulative Impact Assessment
Carden, Ontario

Due to the increased level of aggregate extraction activity in the Carden Plain area, the Ontario Ministry of the Environment (MOE) requested a multidisciplinary study and impact assessment to evaluate the potential cumulative impacts of quarry dewatering at multiple sites on groundwater, surface water and ecological receptors. Golder was retained by the Ontario Stone, Sand & Gravel Association to complete the required study. The project included extensive interaction with the MOE and the Ministry of Natural Resources (MNR). The objectives of the study were to screen out areas where cumulative impacts are unlikely, identify areas where cumulative impacts are likely, and to provide a preliminary assessment of the potential magnitude of predicted cumulative impacts. For the purpose of this study, a cumulative impact was defined as the additive effect of multiple quarry dewatering operations on groundwater, surface water and/or natural environment features. Golder was responsible for all aspects of this project including the development of the final field programs in consultation with personnel from the MOE. Mr. MacKenzie was the surface water lead for the project and participated in the public consultation aspects of the project.

Technical Reviewer Contaminated Site Channel Design
Mississauga, Ontario

Golder was retained to review an options analysis and remedial channel design for a PCB contaminated channel in Mississauga. The remedial design included removal of the most contaminated material and design of a hardened channel lining to secure residual contaminants in-situ. Mr. MacKenzie reviewed the hydraulic channel analysis and design and provided a technical review report for consideration by the municipality and the channel designer.

Contaminated Site Channel Stability Analysis Welland, Ontario	Golder recently completed Phase IV of an assessment of 12 sites in the Niagara River Area of Concern that were identified in the RAP Stage 1 Update as requiring further assessment. The Phase IV study is a detailed assessment of remedial alternatives for the site including passive and intervention options. In support of the passive treatment options, Golder completed a detailed investigation of the complicated stream and wetland hydraulics of one of the sites on Lyon's Creek. In the intervening years since the historic contamination, the site had developed into a wetland, which provided habitat for threatened plant and animal species. The hydraulic conditions were evaluated using one- and two-dimensional hydraulic models (HEC-RAS and RIVER-2D) to identify areas that are at risk for re-suspension of contaminated sediments and areas that are likely to accumulate new un-contaminated sediment with time. The results supported the passive treatment alternative. Mr. MacKenzie led the hydraulic investigation component of the Lyon's Creek study.
Confidential Mine Site Closure Eastern Ontario	Technical advisor for comprehensive surface water investigations in support of a risk assessment at two former uranium mines near Bancroft, Ontario. The studies included meteorology and flow monitoring, water column profiling with a particular focus on lake stratification and turnover, and water quality sampling.
Confidential Mine Site Closure Northern Ontario	Technical advisor for surface water investigations, including streamflow studies, lake column profiling and water quality sampling, at a former nickel mine near Kenora, Ontario.
OPG Atikokan – Environmental Compliance Approval Northern Ontario	Technical advisor for the Environmental Compliance Approval ('ECA') Sewage (including Stormwater) amendment application for the Atikokan GS Biomass Conversion project. The study included a review of existing sewage works and associated ECA and MISA conditions. Implications from the proposed site changes to the sewage works, consisting of process streams (Furnace Ash Treatment Plant, Condenser Cooling Water), sanitary sewage system/lagoons and the coal pile runoff pond, along with their associated ECA conditions.
Confidential Manufacturing Client Norval, Ontario	Baseline characterisation and impact assessment modelling of a proposed shale quarry in order to quantify and where necessary mitigate potential flow, water quality and thermal effects of the quarry on nearby watercourse and wetlands. Included conceptual design of mitigation measures and preparation of application materials for re-zoning and license under the Ontario Aggregate Resources Act.
Big Bay Point Water Balance Barrie, Ontario	Monthly and annual water budgets were prepared using the Thornthwaite Water Budget method. This water budget assessment was performed to determine the rate of marina water pumping required from the proposed development area at Big Bay Point, to the golf course and Environmental Protection Area in support of detailed design of stormwater management facilities to meet post-development peak flow targets. Mr. MacKenzie provided technical advice and senior review for this project.
Baseline Hydrology Study for Proposed Mine Ring of Fire, Northern Ontario	Technical advisor for baseline hydrology studies and effects evaluations in support of a major mine development project in Northern Ontario. Assessments were prepared as part of a multi-disciplinary Environmental Impact Statement (EIS) and Environmental Assessment (EA) under the Canadian Environmental Assessment Act (CEAA).

Quarry License Expansion Flamborough, Ontario	A level II hydrogeology study was completed in support of a rock quarry license expansion application. The surface water component of the study included establishment of eight continuous stream flow gauges and associated baseflow separation analysis. The baseflow separations were used to estimate mean annual recharge to groundwater. This information was provided to Golder hydrogeologists for use in estimating boundary conditions for the FEFLOW groundwater model. In addition, monthly and annual surface water balances were modelled using the Thornthwaite Water Budget method coupled to a GIS procedure. The fraction of surplus water that infiltrates was estimated using GIS and the method outlined in MOE 2003. The infiltration estimates were initially assumed to equal recharge. The resulting modelled groundwater levels were reviewed to identify areas of upward gradient or minimal downward gradient. This information was used in subsequent iterations to adjust the recharge estimates.
Quarry License Expansion Northern Ontario	A level II hydrogeology study is underway in support of a rock quarry license expansion application. Surface water features in the area are characterized by shallow intermittent streams flowing on top of bedrock above a small escarpment running through the site. Below the escarpment, there is a line of small watercourses connecting a series of small lakes. The surface water study includes monitoring of several of the small intermittent watercourses and the outlet of two of the small lakes. Surface hydrological. The results of this analysis will form input to the groundwater modelling discipline. Recharge will initially be assumed to equal infiltration in the groundwater model; however, we expect this will cause mounding in parts of the model. Further iterations will be used to calibrate the recharge estimates subject to a mass balance at the surface.
Aggregate Site Water Use Study Southern Ontario	Participated in a “typical water use” study for the aggregate industry. The study was initiated by the Aggregate Producers Association of Ontario (now the Ontario Stone Sand and Gravel Association) in preparation for planned changes, by the MOE, to the Permit to Take Water application process. Changes to the process were anticipated to include charges for water taking or use. The MOE was simultaneously working on new Source Water Protection legislation. As a result, the APAO felt it would be prudent to quantify actual water use versus maximum permitted water taking rate and to illustrate typical water use at aggregate sites.
Aggregate Site Permitting and Approvals Southern Ontario	Application packages including MNRF and MECP applications and supporting studies and reports have been prepared for numerous aggregate sites across Southern Ontario. Applications have been completed for aggregate pit and quarry licenses under the Aggregate Resources Act, Permits to Take Water (PTTW) to allow quarry dewatering and for Environmental Compliance Approvals (ECA) under Section 53 of the Ontario Water Resources Act to allow offsite discharge of quarry and storm water.
Simcoe County Groundwater Studies Simcoe County, Ontario	A base flow survey was conducted to quantify groundwater discharge in a series of watershed in Simcoe County. The project was conducted in two phases, one for North Simcoe and one for South Simcoe. Water budget and average annual infiltration calculations were completed in support of groundwater modelling. Surface-groundwater interactions were estimated throughout the region to provide a water balance.

Hydrology Studies for Quarry Developments Ottawa Region, Ontario	A series of water resources investigations were completed for aggregate producing clients in the Ottawa area. The studies were completed in support of Certificate of Approval applications made under Section 53 of the Water Resources Act. Each study included a water balance analysis for the quarry and an estimate of future quarry discharge rates. These data were used to estimate the effects of quarry development on downstream water resources.
Water Supply Studies Sudbury, Ontario	Two municipal water supplies were investigated as Groundwater Under Direct Influence of surface water (GUDI). Surficial water resources were investigated, and a water balance was prepared in support of groundwater modelling studies.
Hydrological Effects Assessment Hagersville, Ontario	A long-term field monitoring programme was designed and implemented to track changes in flow regime resulting from closure of an underground Gypsum mine. Part of the mine was closed and allowed to flood. Three flow monitoring stations were established in Boston Creek, which flows over the mine. The stations were selected to represent background conditions upstream of the mines influence, conditions above the mine and downstream of the mine influence. Data loggers and transducers were installed to continuously (hourly) record water levels and flows in the creek.
GORO Nickel Mine New Caledonia	The GORO Nickel mine is located in an area of extreme precipitation. Hydrological and preliminary erosion assessments were completed in support of mine development planning and design. These data were used, by the multi-disciplinary project team, to design tailing basin capacities, diversion ditches and dams.
Round Lake Water Level Control Study Engelhart, Ontario	Flow exiting Round Lake flows down several kilometres of a very mild sloped reach of the Blanche River before cascading down a set of rapids at a rock outcrop. The rock outcrop was historically blasted to facilitate log driving practices. This modification has caused large fluctuations in water levels in Round Lake and the Blanche River. A hydrological and hydraulic study of the river and lake were completed and a fish-friendly rock-fill weir was designed to stabilise water levels.
Bruce Nuclear Generating Station Bruce County, Ontario	Participated in background water quality assessments in the surrounding environment. This work included water quality sampling in Baie du D'Or and Lake Huron. The data were used to assess potential effects of the generating station on the quality of surrounding water resources.
Pickering-A Nuclear Generating Station Pickering, Ontario	A multi-disciplinary environmental assessment was completed for the re-start of four CANDU reactors at the Pickering A generating station. A comprehensive review of existing water quantity and quality data was completed. Potential effects, of operating the station, on surrounding water resources were identified and evaluated.
Falconbridge Smelter Area Closure Falconbridge, Ontario	Performing a detailed analysis of water quantity and quality to address potential long-term impacts of the closure on the watersheds of Coniston and Emery Creeks. A daily water budget and reservoir routing model was implemented on a spreadsheet to investigate the efficiency of a variety of different closure scenarios. Also involved in hydrometry, automated water level monitoring, water quality sampling, hydrologic modelling.

Fire Water Intake Blind River, Ontario	Alternative designs for a fire water intake structure modification were assessed to minimise maintenance and sediment deposition and increase safety. Two-dimensional finite element flow modelling of the intake environment and one dimensional, coupled, unsteady, sediment and hydraulic modelling of the river reach was completed. Modelling results indicated that relocating the intake structure would reduce the risk of failure resulting from sediment accumulation.
Asacha Gold Mine Russia	The Asacha gold mine lies close to the divide between a pristine watershed and a partially developed watershed. Hydrologically modelled areas potentially affected by mining operations to aid in developing a safe and detailed water management plan.

PROJECT EXPERIENCE – LINEAR INFRASTRUCTURE

Trans Canada Pipelines Vaughan Mainline Expansion Vaughan, Ontario	Senior technical advisor for baseline hydrology studies, effects assessments and permitting, in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing process and construction planning and design for a ~12 km pipeline expansion in the Greater Toronto Area.
Trans Canada Pipelines Eastern Mainline Expansion Vaughan, Ontario	Senior technical advisor for baseline hydrology studies, effects assessments and permitting in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing for the Eastern Mainline Expansion in Ontario (~260 km long gas pipeline through central and eastern Ontario).
Trans Canada Pipelines Parkway West Connection Vaughan, Ontario	Senior technical advisor for baseline hydrology studies, effects assessments and permitting, in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing process for a local service connection in the Greater Toronto Area.
Trans Canada Pipelines Kings North Connection Ontario	Surface water discipline lead for the Kings North Connection Project, including baseline hydrology studies and effects assessments in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) process. Scour assessments, sag-bend setback recommendations and permitting were also completed to support construction activities.
Pipeline Corridor Investigations Timmins, Ontario	A pipeline was proposed to slurry tailing from the Kidd Metallurgical Site to the Kidd Mine, approximately 35 km away. The tailings are to be used for paste back-filling of depleted areas of the underground mine. An environmental review of water resources along the proposed pipeline corridor was completed. Larger watercourse crossings were mapped, and directional drilling was proposed to mitigate environmental effects.
Trans Canada Pipelines Borer's Creek Modelling and Restoration Design Dundas, Ontario	HEC-RAS modelling and assessment of a failing reach of Borer's Creek that threatened to expose a high pressure natural gas pipeline. Design of remedial measures for failing banks and restoration of the affected reach. Coordinated regulatory approvals. The project was successfully implemented before the spring freshet and significantly reduced the risk of damage to the pipeline.

PROJECT EXPERIENCE – CLIMATE CHANGE

Goldcorp Sudbury Integrated Nickel Operations – East End Water Management
Sudbury, Ontario

Senior review and technical advisor for an assessment of potential climate change effects and vulnerabilities on a multi-site water management system including eight reservoirs, flooded underground mine works, an active smelter complex, a water treatment plant and associated dams and infrastructure. A Goldsim model of the water management system was constructed and validated. Ensemble Global Circulation Model (GCM) results, from approximately ninety model runs, were obtained for the 2050 horizon. Monte Carlo simulations were used to simulate daily weather patterns constrained by the GCM results and the same daily weather patterns were used to model a potential future range of water management scenarios using the Goldsim water management model.

Goldcorp Sudbury Integrated Nickel Operations – East End Infrastructure Assessment
Sudbury, Ontario

Evaluated climate change risks to several small flow conveyance structures including culverts, pipes and flow measurement structures. Peak flows from small sub-catchments are typically sensitive to short duration intense precipitation events. A trend analysis and curve fitting exercise was completed on observed maximum annual events, over recent site history, for a range of event durations ranging up to 24 hours. The trend analysis was used to estimate potential changes to Intensity-Duration-Frequency statistics at the 2050 horizon. This information was used to assess the capacity of existing flow conveyance infrastructure in small sub-catchments.

Meteorological Service of Canada – Environment Canada
Ottawa and across Canada

Participated on a national research team studying the effects of climate change on hydrological variables. Contribution to the study was to complete a regionalization study based on measured hydrologic variables from the Reference Hydrometric Basin Network (RHBN) including mean annual flow, lowest annual daily flow and peak annual daily flow. The data series were grouped according to their similarity using a cluster analysis routine. The homogeneous hydrologic regions identified by this method were compared to hydrologic regions identified in previous studies using meteorological and physiographic variables. Cluster analysis results consistently identified three homogeneous regions in the British Columbia mountains as well as several regions in Ontario, the Maritimes and along the St. Lawrence. The study demonstrated a significant lack of RHBN coverage in the northern part of the Prairie Provinces and the North West Territories, such that homogenous regions, if they exist in these areas, could not be identified by cluster analysis.

Infrastructure Ontario (Ontario Realty Corp.) – Infrastructure Climate Risk Assessment
Ontario

Completed the water resources and drainage components of a climate risk assessment on three typical buildings owned by Infrastructure Ontario. Risk was assessed using guidance provided in Engineers Canada's PIEVC protocol. Co-led focus group workshops with building operators and subject matter experts to assess potential future risk.

Iqaluit Water Supply
Nunavut

Senior technical reviewer for a climate risk investigation of the Town of Iqaluit's water supply. A Goldsim model was developed for the lake-based water supply. Various scenarios were investigated to assess the vulnerability of the supply to climate change.

BHP Billiton
Elliot Lake, Ontario

Technical advisor for applying climate change projections to extreme precipitation events used to assess potential climate change implications for tailings storage facilities and water management ponds. This work was completed as a part of the Dam Safety Surveillance and Management program at BHP Billiton's closed Canadian and U.S. sites.

PROJECT EXPERIENCE – SOURCE WATER PROTECTION

Ontario Clean Water Agency
Lake Ontario, Canada

Hydrology and river boundary conditions lead for the Ontario Clean Water Agency (OCWA) Lake Ontario Decision Support System (DSS). OCWA, in partnership with GTA municipalities, is developing a DSS for managing Lake Ontario based drinking water intakes. Golder teamed with DHI to develop a hydrodynamic, thermodynamic and water quality model to integrate into a web-based forecasting platform for Lake Ontario. The system is expected to go live in 2021 to provide municipalities with the advance information to anticipate and mitigate the effects of accidental spills on water supply infrastructure.

Source Water Protection: Midland and Penetanguishene Tier 3
Midland, Ontario

Surface water lead for the Midland and Penetanguishene Tier 3 water budget and water quantity risk level assessment. This study involved implementation of a combined surface and groundwater model using MIKE-SHE. The modelled recharge distribution was applied to a groundwater model developed by Golder using FEFLOW in order to further refine drawdown effects in close proximity to wells and surface water features. The study area included the whole of the Midland Peninsula and areas of provincially significant wetlands in close proximity to municipal wells with GUDI designation. Groundwater and surface water interactions, both recharge and discharge areas were significant in spatial scale and an important part of this project.

Source Water Protection: Peer Reviewer York Region Tier 3
York Region, Ontario

Peer reviewer for the surface water components of the ongoing York Region Tier 3 water budget and water quantity risk level assessment for the area between and surrounding Aurora and Stouffville. The project team is proposing to use GSFLOW to model both the surface and groundwater systems. GSFLOW is an integrated surface and groundwater hydrology model developed by the US Geological Survey, based on MODFLOW and PRMS components. The study area is complex as it includes the southern flank of the Oak Ridges Moraine and straddles the divide between Lake Ontario and Lake Simcoe. Stouffville is in the headwaters of the Rouge River watershed.

Source Water Protection: Peer Reviewer Halton Hills Tier 3
Halton, Ontario

Peer reviewer for the surface water components of the ongoing Halton Region Tier 3 water budget and water quantity risk level assessment for the Georgetown and Acton areas. The project team used MIKE-SHE to model surface and groundwater hydrology and applied the modelled recharge distribution to FEFLOW to provide further discretization around key areas of interest including wells and surface water features. The study area is complex as it includes the Niagara Escarpment, the Acton re-entrant valley and several buried bedrock valleys which are believed to play and important role in delivering groundwater to the area. The study area also straddles the divide between the Grand River and Credit River watersheds.

Source Water Protection: Peer Reviewer Orangeville Tier 3
Orangeville, Ontario

Peer reviewer for the surface water components of the ongoing Orangeville, Mono and Amaranth Pilot Tier 3 water budget and water quantity risk level assessment. The project team is using HSPF and MODFLOW to model surface and groundwater hydrology respectively. The study area is complex as it includes the Niagara Escarpment and the Oak Ridges Moraine. The study area also straddles the divides between the Grand River, Credit River and Nottawasaga River watersheds.

Source Water Protection: Peer Reviewer CTC Tier 1 and Tier 2
Southern Ontario

Peer reviewer for the surface water components of the Tier 1 and Tier 2 water quantity stress assessments for the CTC Source Protection Region, which includes the Credit River (CVC), Toronto Region (TRCA) and Central Lake Ontario (CLOCA) watersheds. Data availability and modelling approaches used by the different conservation authorities and their consultants varied across the CTC region.

Source Water Protection: Lower Speed River (Guelph) Tier 3
Guelph, Ontario

Golder Associates teamed with AquaResource to complete a Tier 3 water budget and water quantity risk level assessment for the Lower Speed River watershed. The study area includes the City of Guelph, part of Cambridge and contributing drainage and recharge areas located north and east of Guelph. An extensive baseflow survey was conducted across the study. Baseflow was measured at thirty-two locations during the spring, summer and autumn of 2008. This information was used to estimate varying groundwater discharge and recharge rates to support definition of boundary conditions for the groundwater model.

Source Water Protection: Nickel District CA Valley East Tier 3
Sudbury, Ontario

Senior technical advisor for the Valley East Tier 2 and Tier 3 water quantity stress assessment. The City of Sudbury draws drinking water from several wells located in the Valley East area. Worked with project team to identify a modelling approach that would make the best use of, sometimes limited, existing data. The Tier 2 results led to the initiation of the Tier 3 Local Area Water Budget for the groundwater supply in Valley East.

Source Water Protection: Ramsay Lake Tier 1 and Tier 2
Sudbury, Ontario

Senior technical advisor for the Ramsay Lake Tier 3 water budget and water quantity risk level assessment. The City of Sudbury draws water directly from Ramsay Lake for part of its drinking water supply. Ramsay Lake and its contributing drainage areas are being modelled using HEC-HMS (Hydraulic Engineering Corps - Hydrological Modelling System). Based on existing information, it appears that the hydrology of Ramsay Lake is dominated by surface water inputs and as such, there is no plan to include groundwater modelling at this time. HEC-HMS will be used to complete the risk level assessments. Additional field data collection has been initiated to fill existing data gaps regarding key inflows to the lake and the outflow adjacent to Science North.

Source Water Protection: Bronte Creek
Halton, Ontario

Golder Associates were commissioned to undertake a Threats Assessment of a potential intake at Bronte Creek. Mr. MacKenzie directed the project for Golder. The intake, intended to deliver surface water to a small water treatment plant, was identified as one potential alternative for providing a drinking water supply to nearby residential properties possibly affected through the construction of an adjacent quarry. The Threats Assessment identified eleven water quality issues at the potential intake location, attributing causes to a number of likely contaminant sources throughout the watershed. In accordance with MOE Draft Guidance Modules, the work undertaken as part of this assessment included stakeholder liaison, hydraulic modelling, IPZ delineation, vulnerability analysis, the compilation of issues and threats inventories and a description of data knowledge gaps. Should surface water abstraction from Bronte Creek be identified as the preferred alternative for providing long-term drinking water supply, this Threats Assessment report will provide the basis for the Tier 2 assessment.

Source Water Protection: Timmins IPZ Study
Timmins, Ontario

An Intake Protection Zone (IPZ) and the vulnerability scores for the City of Timmins drinking water treatment plant on the Mattagami River were assessed. The delineation of the IPZ included the consideration of river flow conditions, influences of dam operation, location of significant potential upstream sources of contamination, local transportation routes, storm sewer drainage patterns and the behaviour of spills in the river. The project also included the collection of site-specific data through a field program. The field program used non-conventional methods to measure travel time due to restrictions on the use of dye tracers in the river because of the presence of private drinking water intakes. The field program collected detailed velocity data that was used to estimate dispersion and to calibrate a HEC-RAS model that was used to predict the travel time under various flow conditions.

PROJECT EXPERIENCE – WASTE MANAGEMENT

Barrie Landfill Reclamation
Barrie, Ontario

Technical advisor for stormwater management modelling and conceptual stormwater infrastructure design. The project included a significant removal and replacement of historic municipal waste. Daily and permanent cover design required new stormwater management strategies and facility design. Interacted with groundwater modellers to develop representative and conservative boundary conditions for modelling.

Nexcycle
Southern Ontario

Technical advisor in support of the ECA (Sewage) application package for a glass recycling facility. The project included conceptual design of Best Management Practices and source controls to improve stormwater quality.

Eagleson Landfill Brookside Creek Channel Design
Northumberland, Ontario

Ongoing support regarding a channel remediation design/assessment for the County of Northumberland on a reach of Brookside Creek located downstream of the closed Eagleson Landfill to reroute unaffected surface water flows away from a zone of leachate influenced groundwater.

Edgewood Landfill Monitoring Flamborough, Ontario	Designed and implemented a flow and water quality monitoring programme to assess potential historic effects of watercourses surrounding the closed Edgewood Landfill site in Flamborough Ontario. This work was completed as part of an inventory and assessment of historic landfill operations in the City of Hamilton.
Bath CKD Landfill Design and Monitoring Kingston, Ontario	Monitored existing water quality and flows associated with an existing Cement Kiln Dust landfill. Designed stormwater control measures for design of a new landfill cover for the existing landfill as well as four new cells to increase the capacity of the landfill.
Brow Landfill Storm-water Management Plan Flamborough, Ontario	Developed a storm-water management plan to address drainage requirements for the site and mitigation measures required to control potential impacts as part of the closure process. Designed drainage channels, a stormwater management pond, hydraulic flow control structures and a drop structure to safely convey stormwater over the edge of the Niagara Escarpment into a purpose designed plunge pool.
Adams Mine Landfill Kirkland Lake, Ontario	Completed a baseline hydrology assessment including flow and water quality monitoring as part of an investigation into the feasibility of a proposed land-filling operation at Adams Mine. Monitoring included flow measurements from boats in medium to large rivers.

SUPPLEMENTAL SKILLS

Soil Erosion

Upland inter-rill soil erosion by rainfall impact; Upland soil erosion by concentrated flow in rills and gullies; In stream, bed and bank erosion and transport.

Hydrology

Stream-flow monitoring and hydrometry; Hydrologic modelling and calibration for event and continuous simulations; Potential and actual evapo-transpiration estimates; Single station frequency analysis; and Water balance calculations.

Hydraulics

Sediment transport hydraulics; Velocity profiling; Flood-wave routing in complex channels; Channel erosion potential analysis, including tractive force indices; and Hydraulic design of water management structures.

Fluvial Geomorphology

Initiation of sediment movement; Constructed bed-form frequency and channel stability issues; Channel plan-form and section morphology; Impacts of sediment transport on channel morphology and Stream form classification using the Rosgen Classification Scheme.

PROFESSIONAL AFFILIATIONS

Professional Engineers Ontario

Engineers Nova Scotia

PUBLICATIONS

Other

MacKenzie, K.M., Singh, K., Binns, A.D., Whiteley, H.R. and Gharabaghi, B., 2022. Effects of urbanization on stream flow, sediment, and phosphorous regime. *Journal of Hydrology*, *612*, p.128283.

MacKenzie, K.M., Gharabaghi, B., Binns, A.D. and Whiteley, H.R., 2022. Early detection model for the urban stream syndrome using specific stream power and regime theory. *Journal of Hydrology*, *604*, p.127167.

Rose, G. T and MacKenzie, K. M. (2013). Water Quality Forecasting and Infrastructure Optimization System. Meeting #68 of the Atlantic Coastal Zone Information Steering Committee (ACZISC). Bedford Institute of Oceanography, Halifax, Nova Scotia, January 16-17, 2013.

S. I. Ahmed, K. MacKenzie, B. Gharabaghi, R.P. Rudra, W.T. Dickinson. (2011). Within-storm rainfall distribution effect on soil erosion rate. ISELE Paper Number 11000. International Symposium on Erosion and Landscape Evolution. Anchorage, Alaska September 18-21, 2011.

Bell, J., K. MacKenzie and J. Southwood. (2011). Down Under Up North - Could an Australian water- sensitive urban design project work in the Canadian context? Water Canada July/August 2011.

DeVito, C. and MacKenzie K. (2011). Critical Shear Velocity Estimates Improved with In-Situ Flume. 20th Canadian Hydrotechnical Conference, Ottawa Ontario June 14th to 17th 2011.

Davidson C. and MacKenzie K. (2011). Golder Daily Climate Record Generator. 20th Canadian Hydrotechnical Conference, Ottawa Ontario June 14th to 17th 2011.

MacKenzie, Kevin. (2009). Industrial Wastewater Approvals. Canadian Environmental Compliance Conference and Trade Show (CANECT). Metro Toronto Convention Centre, April 2009.

MacKenzie, Kevin. (2007). Industrial Wastewater Approvals. Canadian Environmental Compliance Conference and Trade Show (CANECT). Metro Toronto Convention Centre, April 2007.

Mackenzie, K.M., R.P. Rudra and W.T. Dickinson. (1996). Modelling the inter-rill detachment process: Some considerations for improving model results. ASAE Paper No. NABEC96-94, Amer. Soc. Agr. Engr., St. Joseph, MI.

MacKenzie, K.M., R.P. Rudra and W.T. Dickinson. (1995). The effect of temporal distribution of rainfall on inter-rill detachment. ASAE Paper No. 95-2378, Amer Soc. Agr. Engr., St. Joseph, MI.

APPENDIX B

Record of Test Pits and Monitoring Well Logs

PROJECT: 19126620

RECORD OF TEST PIT: TP17/MW20-1

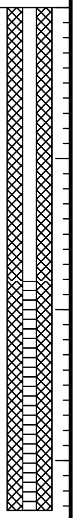
SHEET 1 OF 1

LOCATION: N 4976956.9 ;E 379191.9

BORING DATE: April 22, 2020

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; WATER CONTENT PERCENT Wp ⊢ W ○ ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		189.60							
0	Excavator Open Hole	SILTY SAND, fine; brown		0.00							Cuttings 50 mm Diam. PVC #10 Slot Screen
		End of Test Pit		186.20 3.40							



DEPTH SCALE

1 : 50

WSP GOLDER

LOGGED: CJA

CHECKED: BH

PROJECT: 19126620

RECORD OF TEST PIT: TP18/MW20-2

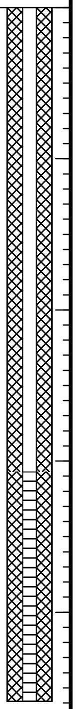
SHEET 1 OF 1

LOCATION: N 4977427.7 ;E 379420.2

BORING DATE: April 22, 2020

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		191.15							
0	Excavator Open Hole	SAND, fine to medium, some silt; brown		0.00							Cuttings
3		Not Sampled		188.00 3.15							50 mm Diam. PVC #10 Slot Screen
		End of Test Pit		186.56 4.59							



DEPTH SCALE

1 : 50

LOGGED: CJA

CHECKED: BH

PROJECT: 19126620

RECORD OF TEST PIT: TP19/MW20-3

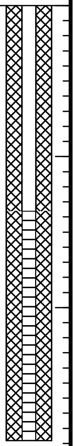
SHEET 1 OF 1

LOCATION: N 4977078.7 ;E 379618.5

BORING DATE: April 22, 2020

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		184.45							
0	Excavator Open Hole	SAND, fine to medium, some gravel and cobbles; brown		0.00							Cuttings 50 mm Diam. PVC #10 Slot Screen
3		End of Test Pit		181.45 3.00							



DEPTH SCALE

1 : 50

LOGGED: CJA

CHECKED: BH

PROJECT: 19126620

RECORD OF TEST PIT: TP20/MW20-4

SHEET 1 OF 1

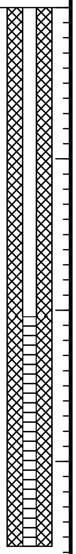
LOCATION: N 4976941.8 ;E 378934.4

BORING DATE: April 22, 2020

DATUM: Geodetic

DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80) | SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80) | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}) | WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20, 40, 60, 80) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		189.50				
0	Excavator Open Hole	SAND and GRAVEL, trace cobbles; brown		0.00				
1		SAND, fine, some silt, trace cobbles; brown		188.50 1.00				Cuttings
3								50 mm Diam. PVC #10 Slot Screen
		End of Test Pit		186.00 3.50				



Depth scale marks: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DEPTH SCALE

1 : 50

WSP GOLDER

LOGGED: CJA

CHECKED: BH

PROJECT: 19126620

RECORD OF TEST PIT: TP21/MW20-5

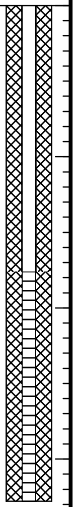
SHEET 1 OF 1

LOCATION: N 4976861.3 ;E 378740.8

BORING DATE: April 22, 2020

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20, 40, 60, 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20, 40, 60, 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		191.59							
0	Excavator Open Hole	SAND, fine to coarse with gravel, some cobble layers; brown		0.00							Cuttings 50 mm Diam. PVC #10 Slot Screen
3.40		End of Test Pit		188.19 3.40							



DEPTH SCALE

1 : 50

WSP GOLDER

LOGGED: CJA

CHECKED: BH

PROJECT: 19126620

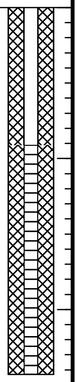
RECORD OF TEST PIT: TP22/MW20-6

SHEET 1 OF 1

LOCATION: N 4976404.1 ;E 378885.5

BORING DATE: April 22, 2020

DATUM: Geodetic

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		196.52							
0	Excavator Open Hole	SAND, fine to medium with gravel, cobbles and boulders; brown		0.00							Cuttings 50 mm Diam. PVC #10 Slot Screen 
		End of Test Pit		194.02 2.50							

DEPTH SCALE

1 : 50

LOGGED: CJA

CHECKED: BH

MIS-BHS 001 19126620.GPJ GAL-MIS.GDT 6/6/22 ZS

RECORD OF TEST PITS – April 22, 2020

Test Pit Number (Elevation)	Depth (metres)	Description
TP17/ MW20-1 (189.60)	0.00 – 3.40	Brown silty fine SAND Note: Water seepage at 2.2 metres depth. Monitoring Well MW20-1 installed within test pit
TP18/ MW20-2 (191.15)	0.00 – 3.15 3.15 – 4.59	Brown fine to medium SAND with some silt Not sampled Note: Water seepage at 2.6 metres depth. Monitoring Well MW20-2 installed within test pit
TP19/ MW20-3 (184.45)	0.00 – 3.00	Brown fine to medium SAND with some gravel and cobbles Note: Water seepage at 1.8 metres depth. Monitoring Well MW20-3 installed within test pit
TP20/ MW20-4 (189.50)	0.00 – 1.00 1.00 – 3.50	Brown SAND AND GRAVEL with trace cobbles Brown fine SAND with some silt and trace cobbles Note: Water seepage at 2.0 metres depth. Monitoring Well MW20-4 installed within test pit
TP21/ MW20-5 (191.59)	0.00 – 3.40	Brown fine to coarse SAND with gravel with some cobble layers Note: Water seepage at 2.1 metres depth. Monitoring Well MW20-5 installed within test pit
TP22/ MW20-6 (196.52)	0.00 – 2.50	Brown fine to medium SAND with gravel cobbles and boulders Note: Water seepage at 1.5 metres depth. Monitoring Well MW20-6 installed within test pit
Note: All elevations are referenced to Geodetic.		

Test pits MW20-1 to MW20-6 were dug on April 22, 2020 by Thomas Cavanagh Construction Limited and logged by Golder Associates Ltd.

RECORD OF TEST PITS – February 28, 2019

Test Pit Number (Elevation)	Depth (metres)	Description
TP1	0.0 – 0.2 0.2 – 3.0	Topsoil Clay glacial till with boulders
TP2	0.0 – 0.2 0.2 – 2.4 2.4 – 3.0 3.0 – 5.0	Topsoil Fine gray sand with silt Cobbles and boulders Clay glacial till with boulders
TP3	0.0 – 0.2 0.2 – 0.6 0.6 – 3.0 3.0 – 6.0	Topsoil Red sand Sandy glacial till fill Brown silty sand with trace gravel *Water noted at 6.0 metres
TP4	0.0 – 0.2 0.2 – 2.4 2.4 – 5.0	Topsoil Fine sand Sandy glacial till
TP5	0.0 – 0.2 0.2 – 0.5 0.5 – 5.0 5.0 – 6.0	Topsoil Red sand Fine to medium brown sand Sandy glacial till
TP6	0.0 – 0.2 0.2 – 0.5 0.5 – 3.0 3.0 – 6.0	Topsoil Red sand Fine to medium grey sand Brown gravel with coarse sand
TP6A	0.0 – 0.1 0.1 – 0.2 0.2 – 2.1 2.1 – 3.0 3.0 – 5.5	Topsoil Sand with gravel Brown coarse sand with gravel Gray sandy silt Gray fine sand with silt and trace boulders
TP6B	0.0 – 0.1 0.1 – 5.0 5.0 – 6.0	Topsoil Sandy gravel Fine sandy silt/silty sand
TP7	0.0 – 0.1 0.1 – 0.3 0.3 – 5.0 5.0 – 6.0	Topsoil Brown gravely coarse sand Brown coarse sand with some gravel Brown medium to coarse sand
TP8	0.0 – 0.1 0.1 – 0.6 0.6 – 2.0 2.0 – 6.0	Topsoil Red sand Gray fine silty sand Gray fine sand
TP9	0.0 – 0.1 0.1 – 0.6 0.6 – 6.0	Topsoil Red sand Gray fine sand
TP10	0.0 – 0.1 0.1 – 0.3 0.3 – 5.0	Topsoil Red sand Fine sand

RECORD OF TEST PITS – February 28, 2019

Test Pit Number (Elevation)	Depth (metres)	Description
TP11	0.0 – 0.1 0.1 – 0.3 0.3 – 5.0	Topsoil Red sand Fine sand
TP12	0.0 – 0.1 0.1 – 0.3 0.3 – 5.0	Topsoil Red sand Coarse sand with gravel
TP13	0.0 – 0.1 0.1 – 4.0	Topsoil Coarse sand
TP14	0.0 – 0.1 0.1 – 2.5 2.5 – 5.0	Topsoil Coarse sand Medium to coarse sand
TP15	0.0 – 0.1 0.1 – 1.5 1.5 – 5.0	Topsoil Coarse sand Medium to coarse sand
TP16	0.0 – 0.1 0.1 – 5.0	Topsoil Coarse sand

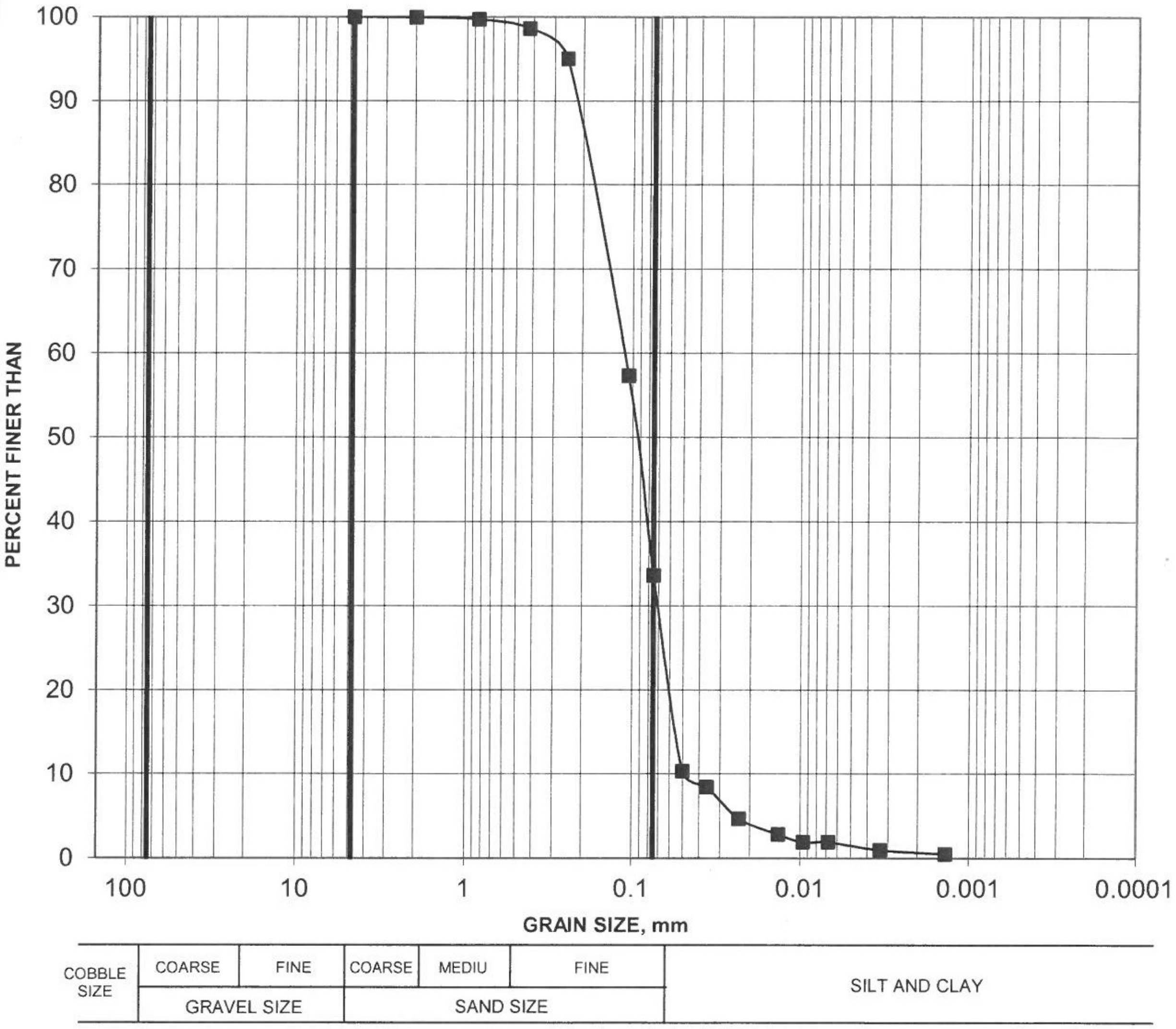
Test pits TP1 through TP16 were dug and logged on February 28, 2019 by Thomas Cavanagh Construction Limited.

APPENDIX C

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

FIGURE C-1



			Constituents (%)			
Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
■ TP17		0.00-3.40	0	66	33	1

GOLDER

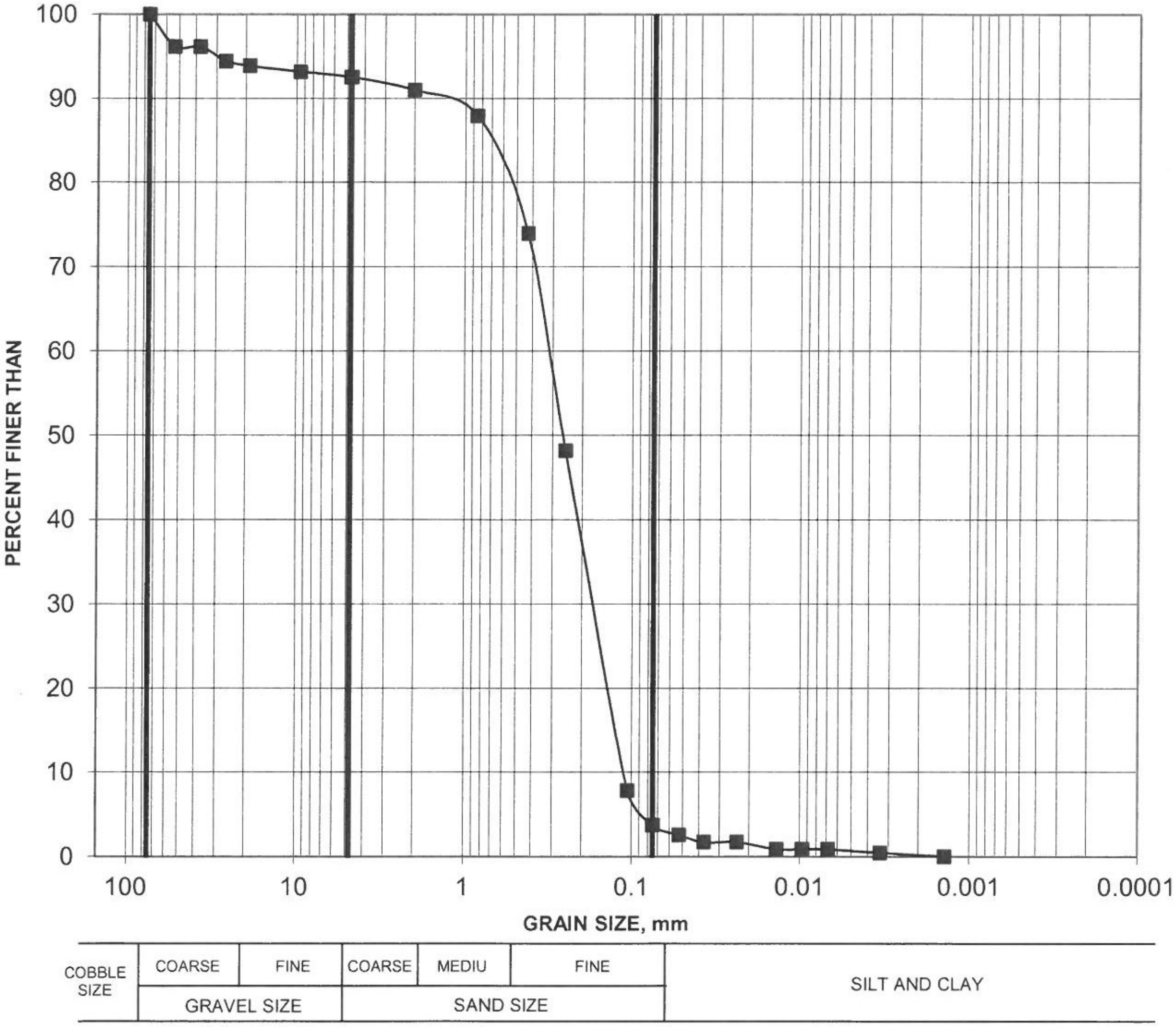
Project: 19126620

Created by:

Checked by:

GRAIN SIZE DISTRIBUTION

FIGURE C-2



			Constituents (%)			
Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
—■— TP18		2.00-3.15	7	89	4	0

Project: 19126620

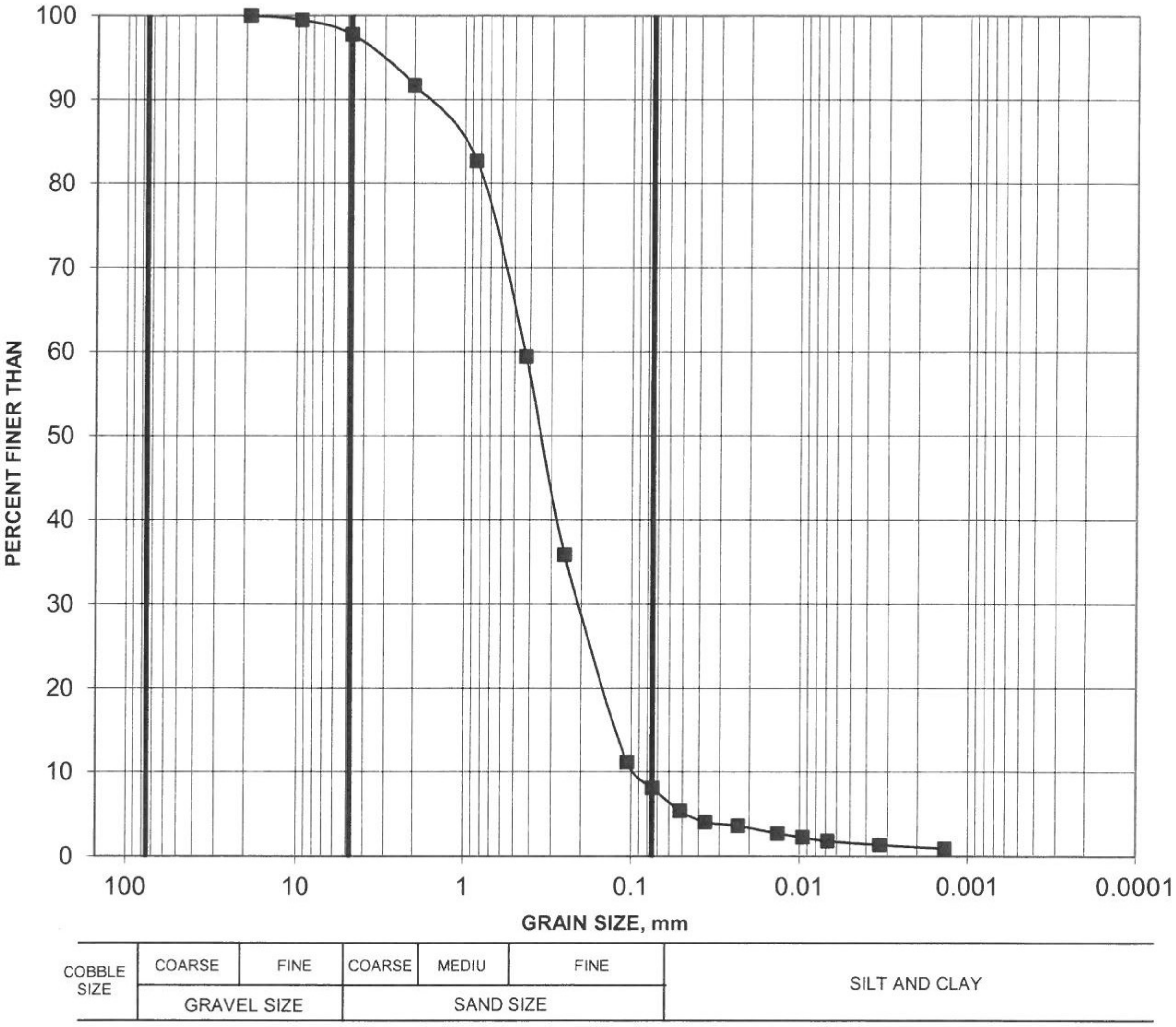
GOLDER

Created by:

Checked by:

GRAIN SIZE DISTRIBUTION

FIGURE C-3



			Constituents (%)			
Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
—■— TP19		0.00-3.00	2	90	7	1

GOLDER

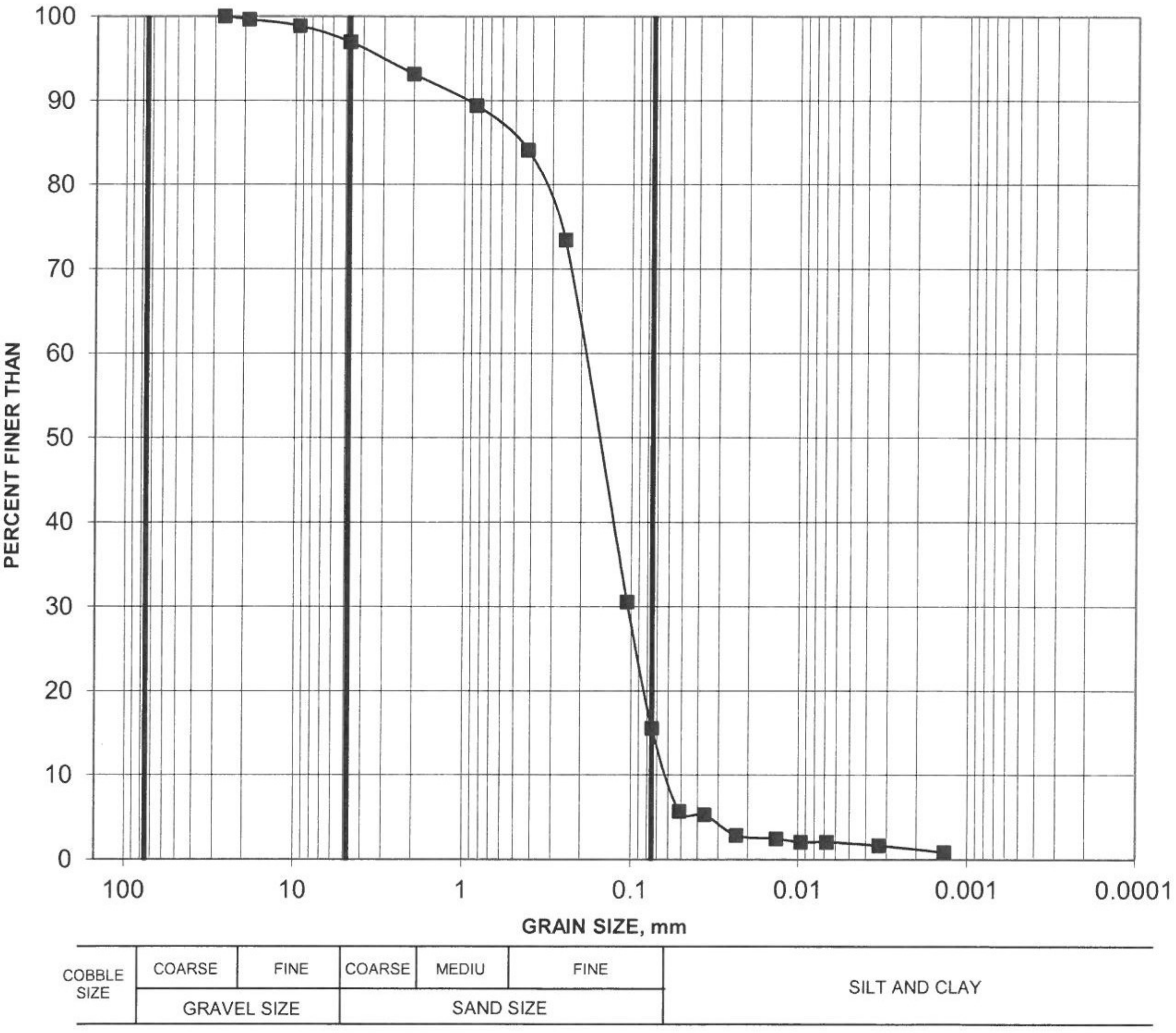
Project: 19126620

Created by:

Checked by:

GRAIN SIZE DISTRIBUTION

FIGURE C-4



				Constituents (%)			
	Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
—■—	TP20		0.00-3.50	3	81	15	1

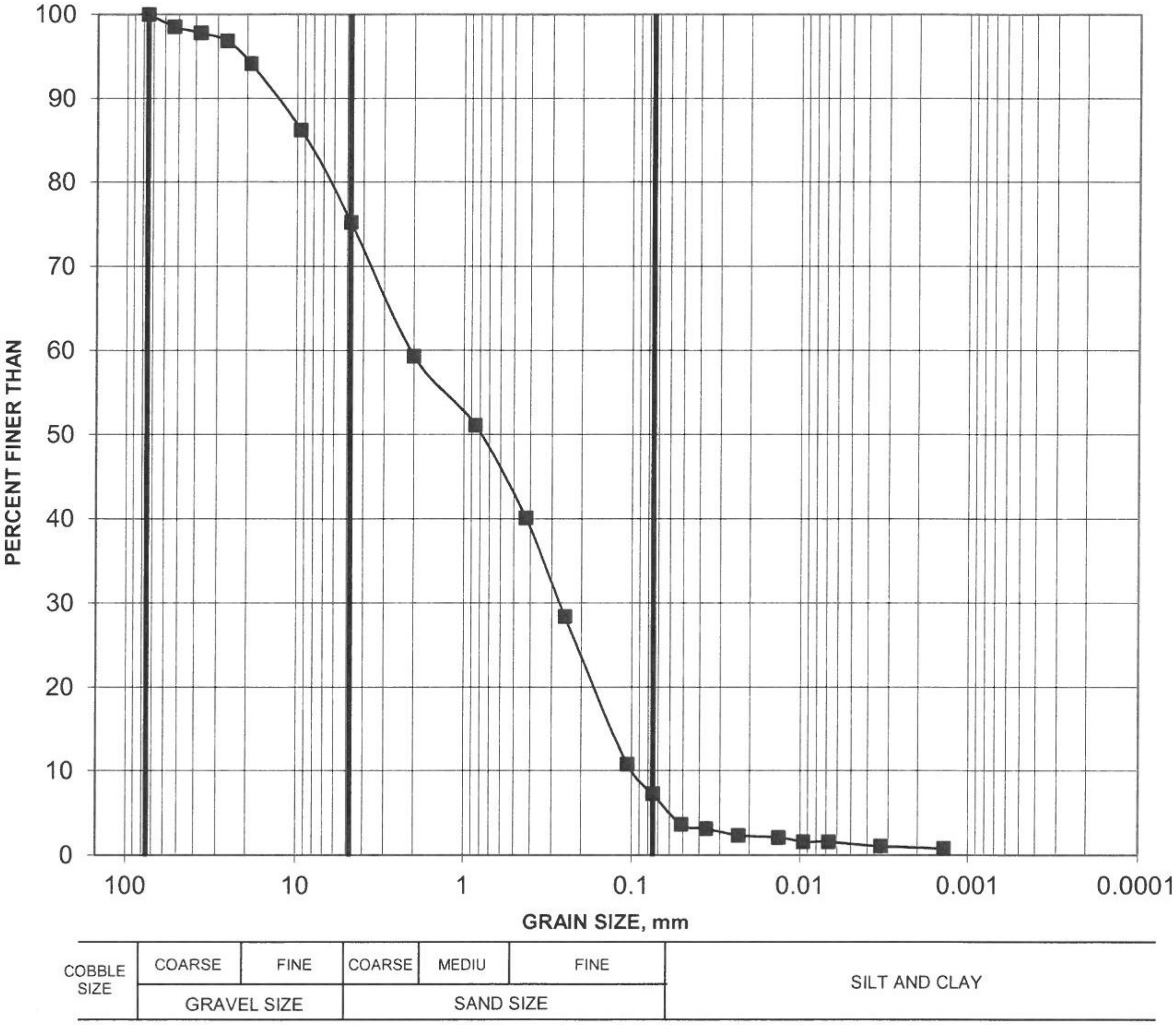
GOLDER

Project: 19126620

Created by:

Checked by:

GRAIN SIZE DISTRIBUTION	FIGURE C-5



				Constituents (%)			
	Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
─■─	TP21		0.00-3.40	25	68	6	1

GOLDER

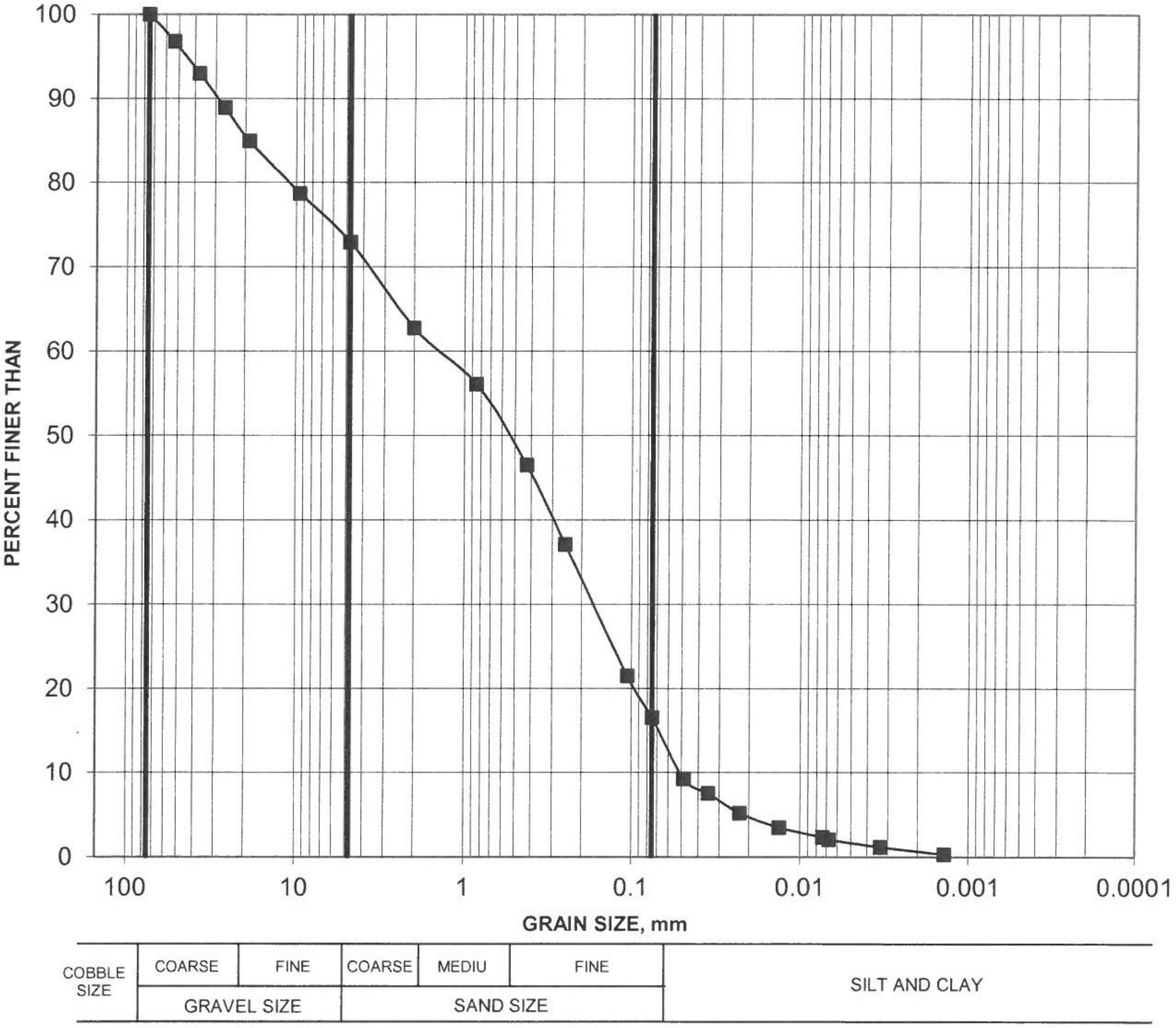
Project: 19126620

Created by:

Checked by:

GRAIN SIZE DISTRIBUTION

FIGURE C-6



			Constituents (%)			
Borehole	Sample	Depth (m)	Gravel	Sand	Silt	Clay
—■— TP22		0.00-2.50	27	56	16	1

GOLDER

Project: 19126620

Created by:

Checked by:

APPENDIX D

Well Response Test Analyses

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST MW20-1

INTERVAL (metres below ground surface)

Top of Interval = 1.81
Bottom of Interval = 3.33

$$K = \frac{r_c^2}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$

where K = (m/sec)

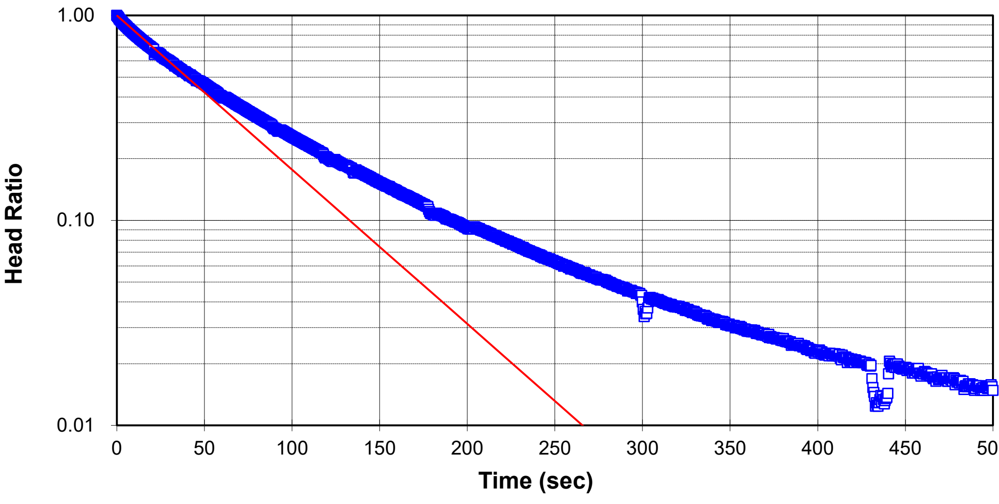
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	2.5E-02
R_e =	2.5E-02
L_e =	1.5
t_1 =	0
t_2 =	40
h_1/h_0 =	1.00
h_2/h_0 =	0.50

RESULTS

K=	2E-05	m/sec
K=	2E-03	cm/sec



Project Name: Cavanagh/Highland Line Pit/Ottawa
Project No.: 19126620
Test Date: 28-May-20

Analysis By: SPS
Checked By: BH
Analysis Date: 29-May-20

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST MW20-2

INTERVAL (metres below ground surface)

Top of Interval = 3.07
Bottom of Interval = 4.59

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e}\frac{1}{t}\ln\frac{y_0}{y_t}$$ where K=m/sec

where:

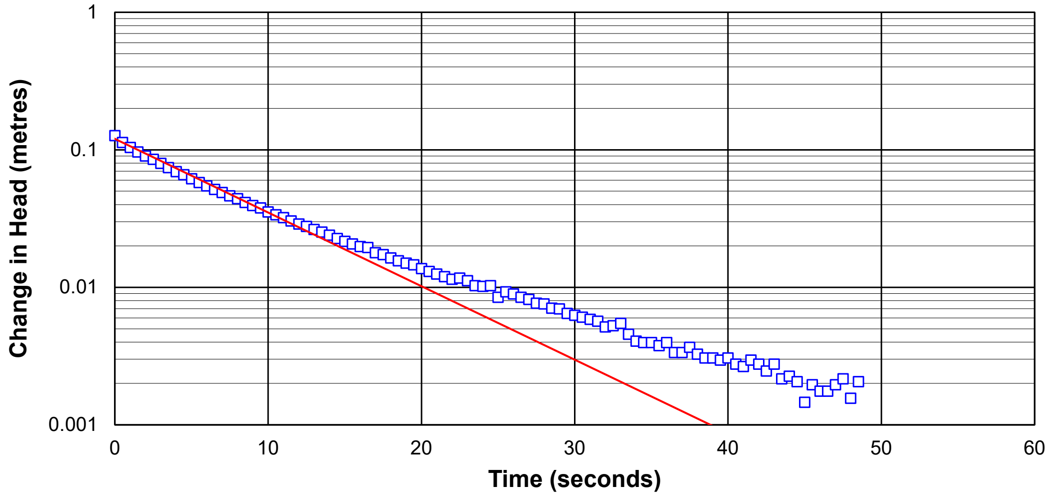
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.03
L_e =	1.44
$ln(R_e/r_w)$	2.69
y_0 =	0.12
y_t =	0.04
t =	10

RESULTS

K=	7E-05	m/sec
K=	7E-03	cm/sec



Project Name: Cavanagh/Highland Line Pit/Ottawa
Project No.: 19126620
Test Date: 28-May-20

Analysis By: SPS
Checked By: BH
Analysis Date: 29-May-20

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST MW20-3

INTERVAL (metres below ground surface)

Top of Interval = 1.36
Bottom of Interval = 2.88

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e}\frac{1}{t}\ln\frac{y_0}{y_t}$$ where K=m/sec

where:

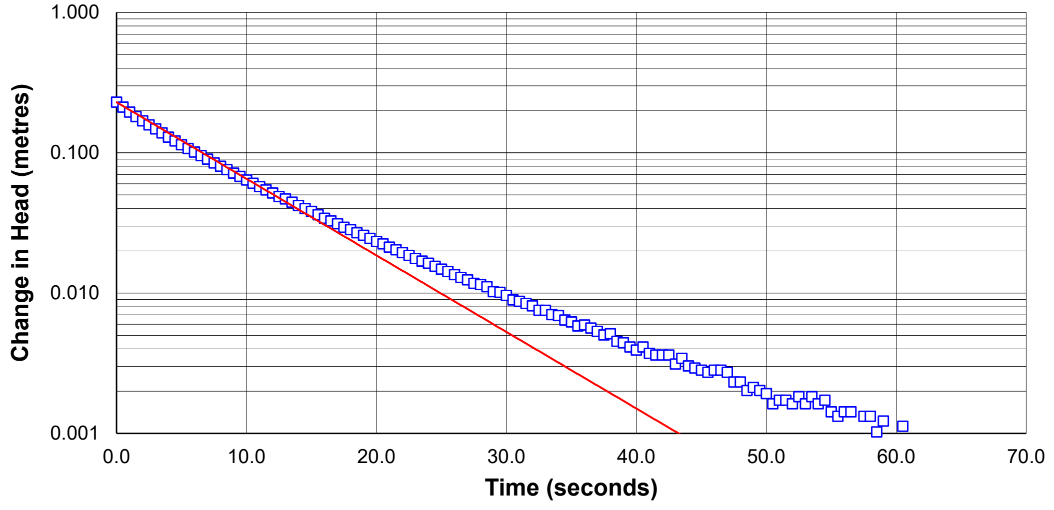
r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.03
L_e =	1.01
$ln(R_e/r_w)$	2.39
y_0 =	0.23
y_t =	0.05
t =	12

RESULTS

K=	1E-04	m/sec
K=	1E-02	cm/sec



Project Name: Cavanagh/Highland Line Pit/Ottawa
Project No.: 19126620
Test Date: 28-May-20

Analysis By: SPS
Checked By: BH
Analysis Date: 29-May-20

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST MW20-4

INTERVAL (metres below ground surface)

Top of Interval =	**2.04**
Bottom of Interval =	**3.56**

$$K = \frac{r_c^2}{2L_e} ln\left[\frac{L_e}{2R_e} + \sqrt{1 + \left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$

where K = (m/sec)

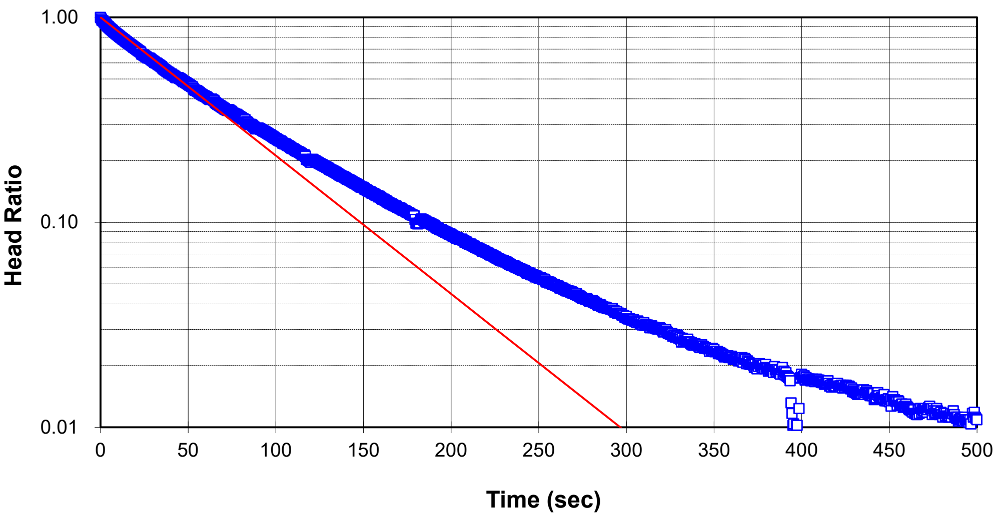
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	2.5E-02
R_e =	2.5E-02
L_e =	1.5
t_1 =	0
t_2 =	50
h_1/h_0 =	1.00
h_2/h_0 =	0.46

RESULTS

K=	1E-05	m/sec
K=	1E-03	cm/sec



Project Name: Cavanagh/Highland Line Pit/Ottawa
Project No.: 19126620
Test Date: 28-May-20

Analysis By: SPS
Checked By: BH
Analysis Date: 29-May-20

Golder Associates Ltd.

BOUWER AND RICE SLUG TEST ANALYSIS
RISING HEAD TEST MW20-5

INTERVAL (metres below ground surface)

Top of Interval = 1.76
Bottom of Interval = 3.28

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{r_w}\right)}{2L_e}\frac{1}{t}\ln\frac{y_0}{y_t}$$ where K=m/sec

where:

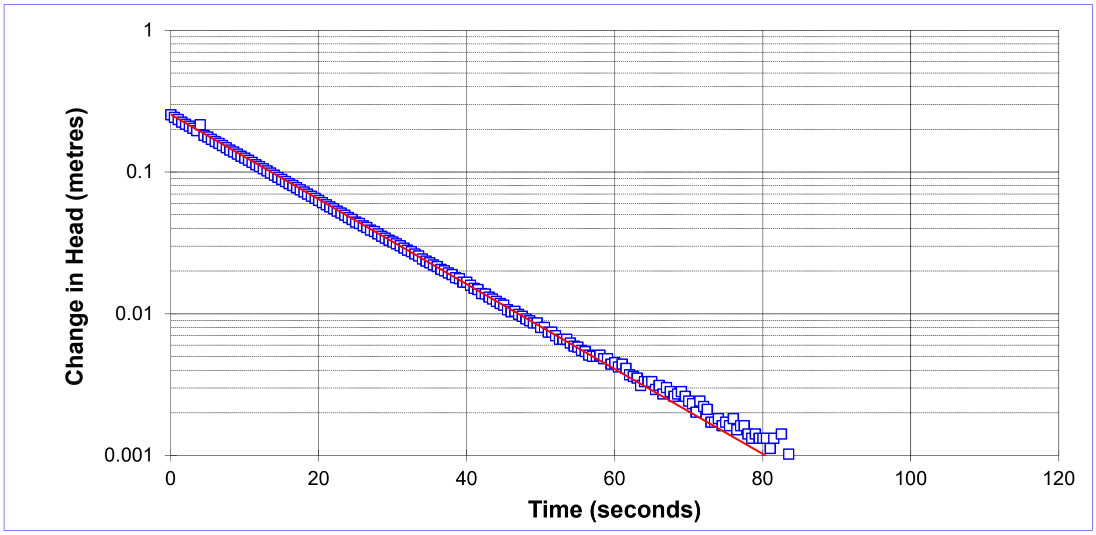
r_c = casing radius (metres);	r_w = radial distance to undisturbed aquifer (metres)
R_e = effective radius (metres);	y_0 = initial drawdown (metres)
L_e = length of screened interval (metres);	y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS

r_c =	0.03
r_w =	0.03
L_e =	0.68
$ln(R_e/r_w)$	2.07
y_0 =	0.25
y_t =	0.01
t =	57

RESULTS

K=	7E-05	m/sec
K=	7E-03	cm/sec



Project Name: Cavanagh/Highland Line Pit/Ottawa
Project No.: 19126620
Test Date: 28-May-20

Analysis By: SPS
Checked By: BH
Analysis Date: 29-May-20

BOUWER AND RICE SLUG TEST ANALYSIS
FALLING HEAD TEST MW20-6

INTERVAL (metres below ground surface)

Top of Interval = 0.91
Bottom of Interval = 2.43

$$K = \frac{r_c^2 ln\left(\frac{R_e}{r_w}\right)}{2L_e}\frac{1}{t}ln\frac{y_0}{y_t}$$ where K=m/sec

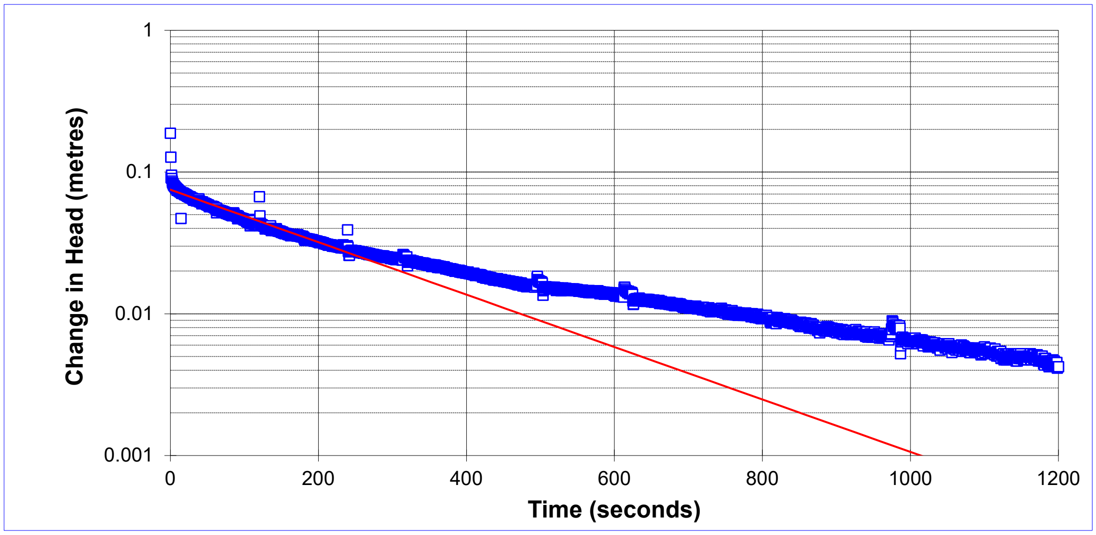
where:

r_c = casing radius (metres);
R_e = effective radius (metres);
L_e = length of screened interval (metres);
r_w = radial distance to undisturbed aquifer (metres)
y_0 = initial drawdown (metres)
y_t = drawdown (metres) at time t (seconds)

INPUT PARAMETERS	
r_c =	0.03
r_w =	0.03
L_e =	1.12
$ln(R_e/r_w)$	2.48
y_0 =	0.08
y_t =	0.03
t =	200

RESULTS

K=	3E-06	m/sec
K=	3E-04	cm/sec



Project Name: Cavanagh/Highland Line Pit/Ottawa
Project No.: 19126620
Test Date: 28-May-20

Analysis By: SPS
Checked By: BH
Analysis Date: 29-May-20

APPENDIX E

Water Balance

Table E-1
Meteorological Data

Drummond Centre WATER BUDGET MEANS FOR THE PERIOD 1985-2019 DC20492

75 mm

LAT.... 45.03 WATER HOLDING CAPACITY... 75 MM HEAT INDEX... 36.33
LONG... 76.25 LOWER ZONE.............. 45 MM A........... 1.074

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31-Jan	-9.4	68	17	25	1	1	0	41	60	74	301
28-Feb	-8.1	56	16	30	1	1	0	44	70	75	356
31-Mar	-2.1	61	31	77	8	8	0	101	22	75	416
30-Apr	6	76	71	27	33	33	0	66	0	74	494
31-May	13.3	77	77	0	82	82	0	10	0	59	571
30-Jun	17.9	95	95	0	114	105	-9	11	0	38	667
31-Jul	20.5	89	89	0	133	108	-25	2	0	17	757
31-Aug	19.3	79	79	0	116	82	-34	1	0	14	837
30-Sep	15	91	91	0	76	71	-6	5	0	29	928
31-Oct	8.2	86	86	1	37	37	0	16	0	63	87
30-Nov	1.5	76	60	11	10	10	0	50	5	74	163
31-Dec	-5.6	71	26	17	2	2	0	40	33	75	235
AVE	6.3	925	738	188	613	540	-74	387			

100 mm

LAT.... 45.03 WATER HOLDING CAPACITY... 100 MM HEAT INDEX... 36.33
LONG... 76.25 LOWER ZONE.............. 60 MM A........... 1.074

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31-Jan	-9.4	68	17	25	1	1	0	41	60	99	301
28-Feb	-8.1	56	16	30	1	1	0	43	70	100	356
31-Mar	-2.1	61	31	77	8	8	0	101	22	100	416
30-Apr	6	76	71	27	33	33	0	66	0	99	494
31-May	13.3	77	77	0	82	82	0	10	0	84	571
30-Jun	17.9	95	95	0	114	109	-4	11	0	58	667
31-Jul	20.5	89	89	0	133	115	-18	2	0	31	757
31-Aug	19.3	79	79	0	116	87	-29	1	0	22	837
30-Sep	15	91	91	0	76	71	-5	3	0	38	928
31-Oct	8.2	86	86	1	37	37	0	11	0	77	87
30-Nov	1.5	76	60	11	10	10	0	41	5	97	163
31-Dec	-5.6	71	26	17	2	2	0	38	33	100	235
AVE	6.3	925	738	188	613	556	-56	368			

Table E-1
Meteorological Data

150 mm

LAT.... 45.03 WATER HOLDING CAPACITY... 150 MM HEAT INDEX... 36.33
LONG... 76.25 LOWER ZONE.............. 90 MM A........... 1.074

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31-Jan	-9.4	68	17	25	1	1	0	39	60	147	301
28-Feb	-8.1	56	16	30	1	1	0	42	70	149	356
31-Mar	-2.1	61	31	77	8	8	0	100	22	150	416
30-Apr	6	76	71	27	33	33	0	66	0	149	494
31-May	13.3	77	77	0	82	82	0	10	0	134	571
30-Jun	17.9	95	95	0	114	113	0	11	0	104	667
31-Jul	20.5	89	89	0	133	123	-9	2	0	68	757
31-Aug	19.3	79	79	0	116	98	-18	1	0	48	837
30-Sep	15	91	91	0	76	72	-4	3	0	63	928
31-Oct	8.2	86	86	1	37	37	0	7	0	106	87
30-Nov	1.5	76	60	11	10	10	0	30	5	137	163
31-Dec	-5.6	71	26	17	2	2	0	31	33	147	235
AVE	6.3	925	738	188	613	580	-31	342			

250 mm

LAT.... 45.03 WATER HOLDING CAPACITY... 250 MM HEAT INDEX... 36.33
LONG... 76.25 LOWER ZONE.............. 150 MM A........... 1.074

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31-Jan	-9.4	68	17	25	1	1	0	32	60	242	301
28-Feb	-8.1	56	16	30	1	1	0	40	70	246	356
31-Mar	-2.1	61	31	77	8	8	0	97	22	250	416
30-Apr	6	76	71	27	33	33	0	66	0	249	494
31-May	13.3	77	77	0	82	82	0	10	0	234	571
30-Jun	17.9	95	95	0	114	114	0	11	0	204	667
31-Jul	20.5	89	89	0	133	131	-1	2	0	159	757
31-Aug	19.3	79	79	0	116	109	-7	1	0	129	837
30-Sep	15	91	91	0	76	74	-2	3	0	142	928
31-Oct	8.2	86	86	1	37	37	0	6	0	186	87
30-Nov	1.5	76	60	11	10	10	0	26	5	221	163
31-Dec	-5.6	71	26	17	2	2	0	26	33	236	235
AVE	6.3	925	738	188	613	602	-10	320			

300 mm

LAT.... 45.03 WATER HOLDING CAPACITY... 300 MM HEAT INDEX... 36.33
LONG... 76.25 LOWER ZONE.............. 80 MM A........... 1.074

DATE	TEMP (C)	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31-Jan	-9.4	68	17	25	1	1	0	31	60	289	301
28-Feb	-8.1	56	16	30	1	1	0	38	70	295	356
31-Mar	-2.1	61	31	77	8	8	0	96	22	300	416
30-Apr	6	76	71	27	33	33	0	66	0	299	494
31-May	13.3	77	77	0	82	82	0	10	0	284	571
30-Jun	17.9	95	95	0	114	114	0	11	0	254	667
31-Jul	20.5	89	89	0	133	132	0	2	0	208	757
31-Aug	19.3	79	79	0	116	112	-4	1	0	175	837
30-Sep	15	91	91	0	76	75	-1	3	0	188	928
31-Oct	8.2	86	86	1	37	37	0	6	0	232	87
30-Nov	1.5	76	60	11	10	10	0	26	5	267	163
31-Dec	-5.6	71	26	17	2	2	0	26	33	282	235
AVE	6.3	925	738	188	613	607	-5	316			

400 mm

LAT.... 45.03 WATER HOLDING CAPACITY... 400 MM HEAT INDEX... 36.33
LONG... 76.25 LOWER ZONE.............. 240 MM A........... 1.074

DATE	TEMP	PCPN	RAIN	MELT	PE	AE	DEF	SURP	SNOW	SOIL	ACC P
31-Jan	-9.4	68	17	25	1	1	0	30	60	385	301
28-Feb	-8.1	56	16	30	1	1	0	36	70	393	356
31-Mar	-2.1	61	31	77	8	8	0	94	22	400	416
30-Apr	6	76	71	27	33	33	0	66	0	399	494
31-May	13.3	77	77	0	82	82	0	10	0	384	571
30-Jun	17.9	95	95	0	114	114	0	11	0	354	667
31-Jul	20.5	89	89	0	133	133	0	2	0	308	757
31-Aug	19.3	79	79	0	116	114	-1	1	0	272	837
30-Sep	15	91	91	0	76	76	-1	3	0	284	928
31-Oct	8.2	86	86	1	37	37	0	6	0	328	87
30-Nov	1.5	76	60	11	10	10	0	25	5	363	163
31-Dec	-5.6	71	26	17	2	2	0	25	33	379	235
AVE	6.3	925	738	188	613	611	-2	309			

Table E-2
Water Balance Summary

Existing Conditions - Estimated Annual Average Water Balance

Land Use	Area	Precipitation		ET		Surplus		Infiltration		Runoff	
	(m^2)	(mm/a)	Volume (m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Fallow Agricultural Field / Mixed Meadow	183,947	925	170150	580	106690	342	62910	205	37750	136.8	25160
Open Woodland / Coniferious Forest / Logged/Regenerating Poplar-Conifer-Mixed Forest	199,968	925	184970	316	63190	316	63190	221	44235	95	18960
Prickly Ash Deciduous Thicket	7,345	925	6795	602	4420	320	2350	160	1180	160	1180
Logged/Regenerating Deciduous Forest	22,681	925	20,980	611	13,860	309	7,010	185	4,205	124	2,800
Mixed Mineral Shallow Marsh	3,623	925	3350	472	1710	453	1640	136	490	317.1	1150
White Cedar Organic Coniferous Swamp	22,117	925	20460	556	12300	368	8140	147	3255	221	4880
Cattail Organic Shallow Marsh	9,739	925	9010	656	6390	269	2625	0	0	269	2620
Fallow Agricultural Field	1,940	925	1795	556	1080	368	715	74	145	294	570
Open Woodland / Coniferous Forest / Logged/Regenerating Decidious-Poplar-Conifer-Mixed Forest	54,825	925	50715	556	30480	368	20175	110	6055	258	14120
TOTAL	**506,186**	**925**	**468,225**	**474**	**240,120**	**333**	**168,755**	**192**	**97,315**	**141**	**71,440**

Operational Conditions - Estimated Average Annual Water Balance

Land use	Area	Precipitation		Evapotranspiration		Surplus		Infiltration		Runoff	
	(m^2)	(mm/a)	Volume (m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Fallow Agricultural Field	11,865	925	10,975	580	6,880	342	4,060	205	2,430	137	1,625
Open Woodland / Coniferious Forest / Logged/Regenerating Poplar-Conifer-Mixed Forest	48,917	925	45,250	316	15,460	316	15,460	221	10,820	95	4,635
Prickly Ash Deciduous Thicket	3,682	925	3,405	602	2,220	320	1,180	160	590	160	590
Logged/Regenerating Deciduous Forest	5,091	925	4,710	611	3,110	309	1,575	185	945	124	630
Mixed Mineral Shallow Marsh	3,623	925	3,350	602	2,180	320	1,160	96	350	224	810
White Cedar Organic Coniferous Swamp	22,117	925	20,460	607	13,430	316	6,990	126	2,795	190	4,195
Cattail Organic Shallow Marsh	9,739	925	9,010	656	6,390	269	2,620	0	0	269	2,625
Fallow Agricultural Field	1,940	925	1,790	556	1,080	368	715	74	145	294	570
Open Woodland / Coniferous Forest / Logged/Regenerating Decidious-Poplar-Conifer-Mixed Forest	51,254	925	47,410	556	28,500	368	18,860	110	5,660	258	13,205
Highland Line Road Allowance Setback	40,976	925	37,905	540	22,130	387	15,860	194	7,930	194	7,930
Below Water Extraction Area	306,981	925	283,960	656	201,260	269	82,700	269	82,700	0	0
TOTAL	**506,186**	**925**	**468,225**	**598**	**302,640**	**299**	**151,180**	**226**	**114,365**	**73**	**36,815**

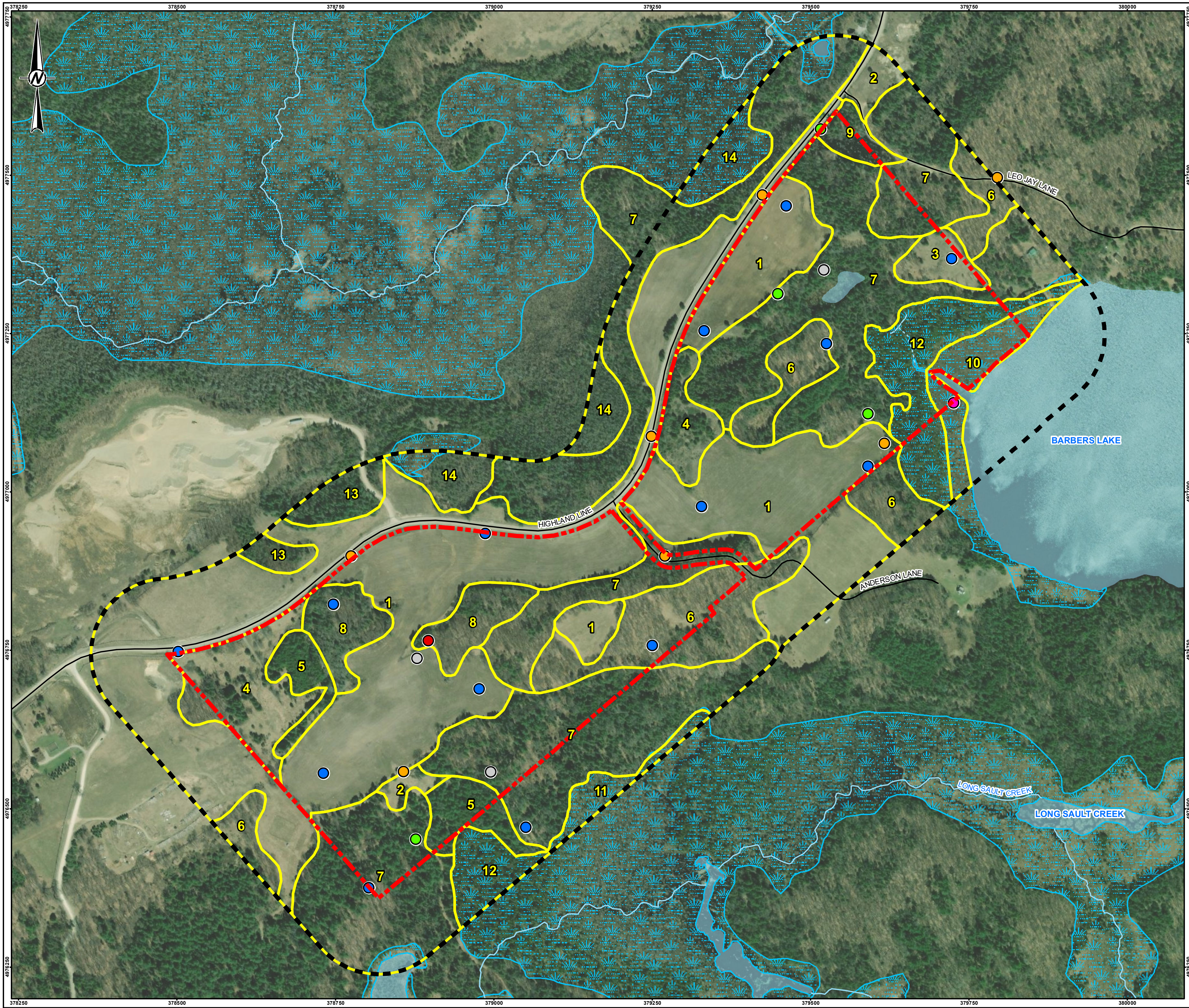
Rehabilated Conditions - Estimated Average Annual Water Balance

Land use	Area	Precipitation		Evapotranspiration		Surplus		Infiltration		Runoff	
	(m^2)	(mm/a)	Volume (m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Fallow Agricultural Field	11,865	925	10,975	580	6,880	342	4,060	0	0	342	4,060
Open Woodland / Coniferious Forest / Logged/Regenerating Poplar-Conifer-Mixed Forest	48,917	925	45,250	316	15,460	316	15,460	0	0	316	15,460
Prickly Ash Deciduous Thicket	3,682	925	3,410	602	2,220	320	1,180	0	0	320	1,180
Logged/Regenerating Deciduous Forest	5,091	925	4,710	611	3,110	309	1,575	185	940	124	630
Mixed Mineral Shallow Marsh	3,623	925	3,350	602	2,180	320	1,160	96	350	224	810
White Cedar Organic Coniferous Swamp	22,117	925	20,460	607	13,430	316	6,990	126	2,795	190	4,195
Cattail Organic Shallow Marsh	9,739	925	9,010	656	6,390	269	2,625	0	0	269	2,625
Fallow Agricultural Field	1,940	925	1,790	556	1,080	368	715	74	145	294	570
Open Woodland / Coniferous Forest / Logged/Regenerating Decidious-Poplar-Conifer-Mixed Forest	51,254	925	47,410	556	28,500	368	18,860	110	5,660	258	13,205
Highland Line Road Allowance Setback	40,976	925	37,900	580	23,770	342	14,015	205	8,410	137	5,605
Below Water Extraction Area	306,981	925	283,960	656	201,260	269	82,700	269	82,700	0	0
TOTAL	**506,186**	**925**	**468,225**	**601**	**304,280**	**295**	**149,340**	**200**	**101,000**	**95**	**48,340**

Entered by: MR
Checked by: KMM

APPENDIX F

Ecological Land Classification Figure



KEY MAP

SCALE 1:100,000

LEGEND

- 🔴 POTENTIAL TRI-COLOURED BAT MATERNITY ROOST
- 🔵 BREEDING BIRD SURVEY STATION
- 🟣 MARSH MONITORING STATION
- ⚪ BAT DETECTOR LOCATION
- 🟠 EASTERN WHIP-POOR-WILL STATION
- 🟢 NOCTURNAL AMPHIBIAN STATION
- — ROADWAY
- ┄ INTERMITTENT STREAM
- — PERMANENT WATERCOURSE
- ▨ WETLAND (UNEVALUATED)
- ▭ WATERBODY
- ⬚ SITE
- ⬚ STUDY AREA
- ▭ ECOLOGICAL LAND CLASSIFICATION

1. CUM1A: FALLOW AGRICULTURAL FIELD
2. CUM1B: MIXED MEADOW
3. CUT1: PRICKLY ASH DECIDUOUS THICKET
4. CUW1: OPEN WOODLAND
5. FOC4-1: FRESH TO MOIST WHITE CEDAR CONIFEROUS FOREST
6. FOD5-4: LOGGED/REGENERATING SUGAR MAPLE – IRONWOOD – MIXED HARDWOOD – DECIDUOUS FOREST
7. FOM2-2: LOGGED/REGENERATING DRY TO FRESH WHITE PINE – SUGAR MAPLE MIXED FOREST
8. FOM5: LOGGED/REGENERATING DRY TO FRESH WHITE BIRCH – POPLAR – CONIFER - MIXED FOREST
9. MAS1: MIXED MINERAL SHALLOW MARSH
10. MAS3-1: CATTAIL ORGANIC SHALLOW MARSH
11. MAS3-10: FORB ORGANIC SHALLOW MARSH
12. SWC3-1: WHITE CEDAR ORGANIC CONIFEROUS SWAMP
13. FOC: CONIFEROUS FOREST
14. FOC/SWC CONIFEROUS FOREST/SWAMP

REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2014
2. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83, COORDINATE SYSTEM: UTM ZONE 18, VERTICAL DATUM: CGVD28

0 60 120 240

1:6,000 METRES

CLIENT

THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT

NATURAL ENVIRONMENT LEVEL 1/2 ASSESSMENT
HIGHLAND LINE PIT, LANARK, ONTARIO

TITLE

ECOLOGICAL LAND CLASSIFICATION AND SURVEY STATIONS

CONSULTANT

wsp GOLDER

YYYY-MM-DD	2019-09-18
DESIGNED	----
PREPARED	JEM
REVIEWED	GW
APPROVED	HM

PROJECT NO.	CONTROL	REV.	FIGURE
19126620	0001	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

0

Path: S:\Clients\Thomas_Cavanagh_Construction\Duncan_Pit\99_PROJ\19126620_Cavanagh_ARA\0011_Natural_Environment_Level_I-II\19126620-0011-HN-0001.mxd

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