WATER REPORT LEVEL 1 AND LEVEL 2

Hydrogeological and Hydrological Assessments in Support of an Aggregate Resources Act Application for the Proposed West Carleton Quarry Extension

City of Ottawa, Ontario

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Executive Summary

Thomas Cavanagh Construction Limited (Cavanagh) is applying for a Category 2, Class A license (Quarry Below Water) under the *Aggregate Resources Act* (ARA), as well as an Official Plan Amendment and Zoning By-law Amendment under the *Planning Act* to permit an extension to their existing West Carleton Quarry operation (referred to herein as the "Extension Lands"). The proposed Extension Lands are located directly adjacent to the northwestern portion of the existing West Carleton Quarry. The area proposed to be licensed under the *ARA* is 18.2 hectares (ha) and the proposed extraction area is 16.5 ha. The licensing of the Extension Lands would also include a setback reduction along the common boundaries with the existing licensed area.

The licensed area and extraction area under the current Ministry of Natural Resources and Forestry license for the West Carleton Quarry are 141.6 ha and 90.2 ha, respectively. The existing West Carleton Quarry and the Extension Lands are located in the City of Ottawa, Ontario. The existing West Carleton Quarry is currently licensed to be operated in a series of lifts with final approved floor elevations of 107 (metres above sea level) m ASL. The proposed final quarry floor base elevation for the Extension Lands is also 107 m ASL.

The work program associated with the preparation of this document included seven distinct tasks, as follows, data review and compilation; receptor identification; hydraulic conductivity testing program; groundwater level monitoring program; surface water assessment and water balance analysis; groundwater flow modelling and impact assessment.

Based on the results of this hydrogeological and hydrological investigation for the Extension Lands, the proposed additional quarry development will protect sensitive surface water and sensitive groundwater receptors during the operational period and under rehabilitated conditions. During the operational and rehabilitation periods, a multi-disciplinary monitoring program will be implemented for the purpose of verifying that the development of the proposed Extension Lands is not adversely impacting surface water or groundwater receptors (including private wells).

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1.0 INTRODUCTION

Thomas Cavanagh Construction Limited (Cavanagh) operates a number of pits and quarries in eastern Ontario. The materials extracted from these sites are used for local construction projects. Cavanagh operates the existing West Carleton Quarry in accordance with License No. 4085 issued by the Ministry of Natural Resources and Forestry (MNRF). The licensed area and extraction area under the current MNRF license for the West Carleton Quarry are 141.6 hectares (ha) and 90.2 ha, respectively. The general location of the existing West Carleton Quarry is shown on Figure 1.

Golder Associates Ltd. (Golder) was retained by Cavanagh to complete the necessary hydrogeological and hydrological assessments in support an application under the *Aggregate Resources Act* (ARA) and the Planning Act for the proposed extension of the West Carleton Quarry (referred to herein as the “Extension Lands” or “extension”), located on Part Lot 15, Concession 11, Former Geographic Township of Huntley, City of Ottawa, Ontario. The Extension Lands are located directly adjacent to the northwestern portion of the existing West Carleton Quarry. The proposed license boundary for the Extension Lands is shown on Figure 1. As shown on Figure 2, the existing West Carleton Quarry and Extension Lands are bounded to the northeast by Upper Dwyer Hill Road, to the northwest by March Road, to the south by a forested area and to the southeast by the Manion Corners Long Swamp Wetland Complex. The Burnt Lands Quarry owned and operated by others is located approximately 1.3 kilometres (km) west of the existing boundary of the Extension Lands. The licensed boundary for the Burnt Lands Quarry is shown on Figure 1.

The Extension Lands proposed to be licensed under the ARA is 18.2 ha and the proposed extraction area is 16.5 ha. The licensing of the Extension Lands would also include a setback reduction along the common boundaries with the existing licensed area. The extraction area within the Extension Lands will have a 30-metre (m) setback along March Road and a 15-m setback along the western boundary. The proposed final quarry floor base elevation for the Extension Lands is 107 metres above sea level (m ASL), which is equal to the approved floor elevation of the existing West Carleton Quarry. The boundaries of the licensed area and limit of extraction for the existing West Carleton Quarry and the proposed boundaries for the Extension Lands are shown on Figure 2.

The existing West Carleton Quarry permits below water extraction and is licensed to ship 2,000,000 tonnes per year; it has been in operation since the 1960’s. The existing primary entrance/exit is located in the northeastern portion of the West Carleton Quarry and connects to Upper Dwyer Hill Road. A secondary entrance/exit is located in the northcentral portion of the existing West Carleton Quarry and connects to March Road. The current operations on the existing West Carleton Quarry involve drilling, blasting, crushing, screening and trucking associated with the processing/production of aggregate. The proposed extension will have similar operations and utilize the existing entrances/exits and haul routes. The combined maximum amount that is proposed to be shipped from the existing West Carleton Quarry and the Extension Lands is 2,000,000 tonnes per year.

This report presents the results of the hydrogeological and hydrological studies completed in support of a site plan license application for a Category 2, Class “A” (Quarry Below Water) for the Extension Lands. These studies were conducted for the purpose of addressing the requirements for Aggregate Resources Ontario: Technical Reports and Information Standards dated August 2020.

The results of the ecological studies are presented in a separate Natural Environment Report (Golder, 2021).

1.1 Proposed Quarry Development and Rehabilitation

The development of the Extension Lands is anticipated to occur simultaneously with the operation of the existing West Carleton Quarry and will ultimately be operated as one combined extraction area. To remain consistent with the development plan for the existing West Carleton Quarry, the Extension Lands would be extracted in a series of five lifts to a final base elevation of 107 m ASL. The various lifts may be operated simultaneously depending on rock quality and market demand. It is anticipated that any water collecting within the excavation on the Extension Lands will flow by gravity into the existing West Carleton Quarry. The existing West Carleton Quarry has a Permit to Take Water (PTTW) Number 4175-AB4RS4 that authorizes dewatering of the extraction area and an Environmental Compliance Approval (ECA) Number 5863-6TSPZ3 that authorizes discharge of water off-site.

Following the completion of site operations, the proposed rehabilitation of the Extension Lands involves backfilling to existing ground surface. As per the ARA site plans, the existing West Carleton Quarry to the east and south of the Extension Lands will be rehabilitated as a lake. Along these boundaries, 2:1 (horizontal:vertical) slopes down to the lake will be constructed and some shallow littoral zones will be created along the lake edge.

In the impact assessment presented in this report, as a conservative measure and to demonstrate that backfilling to original ground surface for the Extension Lands is more preferable than rehabilitation as a lake from both a water balance and residual groundwater level drawdown perspective, the impacts were assessed for both backfilling of the Extension Lands and rehabilitation of the Extension Lands as a lake.

If Cavanagh is successful in obtaining a license under the ARA from the MNRF for the proposed Extension Lands, this technical document would be used as supporting documentation to apply to the Ministry of the Environment, Conservation and Parks (MECP) for an amendment to the PTTW for the existing West Carleton Quarry. It is envisaged that the management of water collecting within the confines of the Extension Lands excavation could be accommodated within the conditions of approval imposed by the existing ECA without requiring a technical amendment to the ECA during the initial years of extraction.

1.2 Scope of Hydrogeological and Hydrological Study

The main objectives of the hydrogeological and hydrological studies were to:

- Characterize the existing hydrogeological and hydrological conditions in the vicinity of the existing West Carleton Quarry and Extension Lands.
- Assess potential impacts on groundwater and surface water associated with operation and rehabilitation of the Extension Lands.

The work program consisted of the following:

- Data review and compilation
- Receptor identification
- Hydraulic conductivity testing program
- Groundwater level monitoring program
- Desktop Surface water assessment and water balance analysis
- Groundwater flow modelling and impact assessment

1.3 Document Structure

This report is organized into a main text and supporting tables, figures and appendices. The text provides a discussion of the following:

- Regional setting (Section 2.0)
- Summary of previous investigations (Section 3.0)
- Site-specific conditions based on a summary of the completed work program, as well as data gathered as part of previous investigations (Section 4.0)
- Receptor identification (Section 5.0)
- Groundwater flow modelling (Section 6.0)
- Desktop surface water assessment and water balance analysis (Section 7.0)
- An impact assessment focused on assessing the potential impacts associated with the development of the Extension Lands (Section 8.0)
- Complaints response program (Section 9.0)
- Proposed water monitoring programs (Section 10.0)
- Summary and conclusions (Section 11.0).

The qualifications and experience of the report authors are presented in Appendix H.

2.0 REGIONAL SETTING

2.1 Physiography/Topography

Chapman and Putnam (1984) indicate that the study area is located within the Smiths Falls Limestone Plains physiographic region. This physiographic region is characterized by shallow soils overlying relatively flat-lying limestone or dolostone bedrock. The area is generally flat with a slight dip to the northeast. Many parts of the area are poorly drained as evident by the occurrence of many bogs and wetlands throughout the region.

The local topography in the vicinity of the existing West Carleton Quarry and the Extension Lands is shown on Figure 3. Within the active extraction area at the existing West Carleton Quarry, the ground surface elevations range between 126 metres above sea level (m ASL) in the northeast portion and 138 m ASL in the southwestern portion, with some localized higher elevations shown on the quarry floor associated with aggregate stockpiles. The western and southwestern most portions of the existing West Carleton Quarry are unextracted and the ground surface ranges between 148 m ASL and 152 m ASL. Within the Extension Lands, the ground surface is consistently approximately 152 m ASL to 153 m ASL.

A local topographic high of approximately 165 m ASL is located approximately 600 m west of the site and the ground surface slopes down towards the east/northeast to an elevation of approximately 124 m ASL to 126 m ASL in the vicinity of the Manion Corners Long Swamp Wetland Complex located to the east of the site.

2.1.1 Hydrological Setting

The existing West Carleton Quarry and proposed Extension Lands drain east to the Manion Corners Long Swamp Wetland Complex, which forms part of the Cody Creek Watershed. Cody Creek has a watershed area of approximately 104 square kilometres (km^2) with primary land uses including agriculture, coniferous forest and wetland. Cody Creek flows northwards to its confluence with the Mississippi River near Pakenham. The Mississippi River has a watershed area of approximately 3,734 km^2 and contributes to the Ottawa River near Arnprior, Ontario.

2.2 Geology and Hydrogeology

The following sections provide general information from published sources on the local geology and hydrogeology in the vicinity of the existing West Carleton Quarry and Extension Lands.

2.2.1 Surficial Geology

Figure 4 show the surficial geology in the vicinity of the existing West Carleton Quarry and Extension Lands. In the Extension Lands and the majority of the extraction area for the existing West Carleton Quarry, bedrock is exposed at surface or overlain by a thin, laterally discontinuous, cover of overburden (Map Unit 3). Along the eastern edge of the existing West Carleton Quarry and further to the east/southeast there is an extensive area of organic deposits associated with the Manion Corners Long Swamp Wetland Complex (Map Unit 20). Additional organic deposits associated with low-lying and/or poorly drained areas are found to the west and south of the site. As shown on Figure 4, deposits of sand and gravel (Map Units 11b and 11c), till (Map Unit 5b) and silt/clay (Map Unit 10) are found in the vicinity of the site, with the largest deposits of these materials located to the northeast.

2.2.2 Bedrock Geology

Figure 5 shows the upper bedrock units identified in the vicinity of the existing West Carleton Quarry and the Extension Lands. The upper bedrock unit beneath the Extension Lands and the majority of the extraction area for the existing quarry is mapped as the Bobcaygeon Formation (Map Unit 9). In the southwestern most portion of the extraction area for the existing quarry, the upper bedrock unit is mapped as the Gull River Formation (Map Unit 8).

A fault zone referred to as the Pakenham Fault is located to the north of the site and runs along the east side of the existing West Carleton Quarry (Williams, et. al. 1984). The Pakenham Fault is mapped along the sharp decline in topography to the north of the site, and results in an area of the much older Nepean Formation (Map Unit 3) being mapped as the upper bedrock unit in a small area to the north and east of the site. A minor fault associated with this fault zone is interpreted to be located along the edge of the boundary between the Extension Lands and the existing West Carleton Quarry; however, based on geophysical logging of the bedrock formations on-site and to the west of the site it is unlikely that this fault exists, or if present there is no significant offset associated with it.

Within the fault zone to the north of the site, there are areas where the March Formation (Map Unit 4), Oxford Formation (Map Unit 5) and the Rockcliffe Formation (Map Unit 6) are mapped as the upper bedrock unit. Further to the east of the fault zone, the upper bedrock units return to the Bobcaygeon and Gull River Formations observed on the west side of the fault zone.

For the bedrock formations east and west of the fault zone, the Gull River Formation consists of interbedded limestone and silty dolostone, fine grained calcareous quartz sandstone and finely crystalline limestone, all with shaley partings (Williams 1991). The Bobcaygeon Formation consists of interbedded fine and coarsely crystalline limestone with shaley partings (Williams 1991). Each formation contains interbeds similar in composition to the adjacent formation. The crystalline limestone layers are often massive and yield little water (GSC 2006).

For the bedrock formations located within the fault zone and at depth outside the fault zone, the Nepean Formation sandstone overlies the unevenly eroded Precambrian granitic basement within the study area. Williams (1991) describes the Nepean Formation sandstone as white to cream coloured, weathering to grey. It is generally thick-bedded; however, portions are thinly bedded and water-bearing. The March Formation is characterized by interbedded quartz sandstone and dolostone. The lithology of the quartz sandstone beds of the March Formation are similar to those of the underlying Nepean Formation, while the lithology of the dolostone beds are similar to those of the overlying Oxford Formation (Williams 1991). The Oxford Formation consists mainly of thin to thickly bedded dolostone. Shaly interbeds up to 30 centimetres in thickness occur within the Oxford Formation (Williams 1991). The Rockcliffe Formation contains a sequence of limestone, sandstone, and shale. The lower portion of the sequence contains interbedded shale and sandstone, while the upper portion contains additional interbeds of limestone. Within the Rockcliffe Formation, the sandstones are light grey to green grey, and are generally fine grained (Williams 1991).

2.2.3 Hydrogeology

2.2.3.1 Overburden Aquifers

Extensive deposits of coarse and permeable overburden, capable of supplying sufficient quantities of groundwater for domestic use, are not prevalent in the vicinity of the existing West Carleton Quarry and the Extension Lands. For this reason, the bedrock is considered the principal aquifer for water supply.

2.2.3.2 Bedrock Aquifers

There are two distinct hydrogeological areas in the vicinity of the site. To the east and west of the Pakenham Fault Zone, the Gull River and Bobcaygeon Formations are near surface and are considered to be marginal aquifers. Within the area east and west of the fault zone, the Rockcliffe Formation provides an aquifer that is generally accessible (i.e., around 50 m below ground surface) and provides acceptable water quantity for domestic use; however, the quality may be marginal. Within the fault zone, the better aquifers of the Oxford, March and Nepean Formations are closer to surface and easily provide water of adequate quality and quantity for domestic use.

2.2.3.3 Local Supply Wells

Information provided in the MECP Water Well Information System (WWIS) indicates that the private wells in the area are primarily completed in grey limestone or white sandstone. On the west side of the Pakenham Fault Zone near the site (i.e., along March Road and along Burnt Lands Road) the wells are completed in grey limestone and most wells are 50 m deep or greater. These wells are interpreted to be drilled through the overlying Bobcaygeon and Gull River Formations and completed in the underlying Rockcilffe Formation. Within the fault zone and to the east of the fault zones the wells are typically shallower (i.e., less than 40 m deep). Within the centre of the fault zone several wells are completed in white sandstone of the Nepean Formation. Along the eastern portion of the fault zone, wells completed in grey limestone are interpreted to be completed in the Oxford Formation. Further to the east, the upper bedrock formations are the Bobcaygeon and Gull River Formations, and the primary water supply aquifer in this area is again the underlying Rockcliffe Formation.

Overall, the geology described on the water well records is consistent with the published bedrock mapping. The wells completed in sandstone are found within the central portion of the Pakenham Fault Zone and the geology for wells to the east and west of the central fault zone is typically describe as grey limestone. For private wells within 750 m of the site, the well yields vary between 13 Litres per minute (L/min) and 136 L/min, with the average being 45 L/min. Based on the available data, it appears that the local aquifers are typically capable of suppling enough water for domestic use, although drilling through the overlying Bobcaygeon and Gull River Formations (where present) is often required.

2.2.3.4 Village of Almonte Water Supply

The Village of Almonte is located approximately 4 km southwest of the site. Almonte obtains water from five drilled well completed in the Oxford, March and Nepean Formations. Groundwater studies show that the upper bedrock and overburden units do not contribute a significant amount of water to the Almonte wells and that the underlying Nepean Formation is the primary supply aquifer for the wells (Mississippi-Rideau Source Protection Region, 2011). As such, the Wellhead Protection Areas (WHPAs) delineated for the Almonte wells are mapped within the Nepean Formation. WHPA-D for the Almonte wells (i.e., the area where groundwater may reach the supply wells within 5 to 25 years) extends to the lands immediately west of the Extension Lands and onto the southwestern most corner of the Extension Lands. Potential impacts to the WHPA for the Almonte wells are discussed in Section 8.1.1.3.

3.0 PREVIOUS HYDROGEOLOGICAL INVESTIGATIONS

Several hydrogeological investigations have previously been completed in the vicinity of the existing West Carleton Quarry. Hydrogeological data collected as part of these previous investigations and the ongoing monitoring programs have been utilized, where appropriate, during the preparation of this report. A summary of the previous investigations is provided below.

3.1 Stanton Drilling Ltd. (2001)

Stanton Drilling Ltd. (Stanton) was retained by Cavanagh to conduct a hydrogeological evaluation in support of the proposed deepening of the existing West Carleton Quarry. As part of a 2001 investigation, three water wells were drilled at the site on May 1 and 2, 2001, to depths of approximately 76 metres below ground surface (mbgs). The three wells were identified as TW-1, TW-2 and TW-3 and the approximate locations of the wells are shown on Figure 2. Water well records for TW-1, TW-2 and TW-3 are provided in Appendix A. Following drilling, the well locations were surveyed by Cavanagh. Stanton identified two additional wells that had been drilled at the property prior to the 2001 investigation and identified them as TW-4 and TW-5. Water well records for TW-4 and TW-5 are not available. For reference, the locations of TW-4 and TW-5 are shown on Figure 2.

The water found within TW-1, TW-2 and TW-3 was at depth (i.e., greater than 60 mbgs) and these well are interpreted to obtain water from the Rockcliffe Formation.

Pumping tests were attempted on TW-1, TW-2 and TW-3. TW-1 and TW-2 were each pumped for 2 hours at a rate of 55 L/min. Some recovery data was collected following the pumping tests at TW-1 and TW-2. The maximum drawdown observed at TW-1 and TW-2 during the pumping tests were 1.54 m and 0.13 m, respectively. The drawdown at TW-1 and TW-2 had mostly stabilized by the end of the two hours of pumping indicating both well are capable of supplying at least 55 L/min. The transmissivity values estimated using the drawdown and recovery data measured during the pumping tests at TW-1 and TW-2 ranged between 121 square metres per day (m^2/day) and 361 m^2/day, with an average of 248 m^2/day.

TW-3 was pumped at a rate of 23 L/min for one hour. After the first hour of pumping at TW-3, drawdown exceeded the depth of the pump setting and testing was abandoned. The maximum drawdown observed at TW-3 following one hour of pumping was 29.46 m. The results of the pumping test at TW-3 demonstrate that TW-3 is not capable of suppling 23 L/min. Stanton estimated a transmissivity value of 0.28 m^2/day for TW-3.

Groundwater analytical chemistry data from TW-1, TW-2 and TW-3 indicated differing water quality at TW-3 compared to TW-1 and TW-2, indicating the TW-3 is not within the same flow regime as TW-1 and TW-2.

The Stanton report recommended a final floor elevation for the proposed deepening of 107 m ASL. No assessment of the potential impacts to existing groundwater users or surface water features was completed as part of the Stanton report.

3.2 Golder Associates Ltd. (2004)

Golder was retained by Cavanagh to undertake a borehole drilling and geophysical logging program to better understand the geology at the existing West Carleton Quarry. In November 2003, a bedrock drilling program consisting of two holes (DDH03-1 and DDH03-2) was completed by Marathon Drilling using diamond drill techniques. DDH03-1 and DDH03-2 were drilled to depths of 45.7 mbgs and 47.5 mbgs, respectively. The bottom elevations of boreholes were at or slightly below the final licensed base elevation of the existing West Carleton Quarry. The borehole locations are shown on Figure 2. HQ-sized rock core was recovered to allow for the logging of the rock core and the definition of the bedrock geological formations beneath the site. The core was logged in detail on a bed-by-bed basis and stratigraphically interpreted based on Golder's work in the local area. The detailed core logs for DDH03-1 and DDH03-2 are provided in Appendix B.

Following core logging, DDH03-1 and DDH03-2 as well as TW-1, TW-2 and TW-3 (installed during the Stanton 2001 investigation) were geophysically logged using natural gamma and apparent conductivity logging tools. The results of the geophysical logging, combined with the detailed core logging at DDH03-1 and DDH03-2, provides a comprehensive three-dimensional (3-D) understanding of the geological conditions beneath the existing West Carleton Quarry. The results of the geophysical logging are presented on the logs provided in Appendix B. The detailed geology at the diamond drill hole and test well locations is summarized in Table 1 below.

Table 1: Geological Summary (DDH03-1, DDH03-2, TW-1, TW-2 and TW-3)

Location	Ground Surface (m ASL)	Top of Rock (m ASL)	Top of Bobcaygeon Formation (m ASL)	Top of Gull River Formation (m ASL)	Top of Rockcliffe Formation (m ASL)	Top of Oxford Formation (m ASL)
DDH03-1	149.99	149.99	149.99	119.03	NA	NA
DDH03-2	148.30	148.30	148.30	127.42	NA	NA
TW-1	145.95	145.95	145.95	127.35	90.55	NA
TW-2	148.33	147.33	147.33	124.13	88.23	NA
TW-3 (within quarry)	126.295	excavated	excavated	115.90	79.00	54.80

Notes: NA – not available

Based on the results of the detailed core logging and geophysical logging, the upper bedrock formation at the existing West Carleton Quarry is the Bobcaygeon Formation. The thickness of the Bobcaygeon Formation varies between 18.6 m (TW-1) and 31 m (DDH03-1). Beneath the Bobcaygeon Formation is the Gull River Formation which varies in thickness between 35.9 m (TW-1) and 36.9 m (TW-3). Beneath the Gull River Formation is the Rockcliffe Formation. The full thickness of the Rockcliffe Formation was drilled through at TW-3. At this location, the thickness of the Rockcliffe Formation was 24.2 m. Beneath the Rockcliffe Formation is the Oxford Formation. The full thickness of the Oxford Formation was not drilled through at the site.

3.3 Golder Associates Ltd. (March 2006)

Golder was retained by Cavanagh to prepare a PTTW application and supporting technical report for the existing West Carleton Quarry (Golder 2006a). The scope of work for the supporting technical report included groundwater level monitoring, hydraulic conductivity testing, review of surface water drainage, groundwater flow modelling and an impact assessment for identified receptors.

3.3.1 Groundwater Level Monitoring

Groundwater levels were measured at TW-1 through TW-5, DDH03-1 and DDH03-2 four times between May 2004 and December 2005. The groundwater elevations in the shallower boreholes (DDH03-1 and DDH03-2) ranged between 140.8 m ASL and 151.5 m ASL. The groundwater elevations in the deeper test wells drilled through the Bobcaygeon and Gull River Formations into the underlying Rockcliffe Formation (and Oxford Formation at TW-3) ranged between 125.3 m ASL and 136.5. Based on the measured groundwater elevations, a downward vertical gradient of approximately 0.6 m/m was interpreted, consistent with recharging conditions. Based on the measured groundwater elevations, the horizontal hydraulic gradient in the Rockcliffe Formation was estimated to be 0.004 to the north/northeast.

3.3.2 Hydraulic Conductivity Testing

The in-situ horizontal hydraulic conductivity of the bedrock within the existing licensed extraction area was assessed through rising-head tests carried out in boreholes DDH03-1 and DDH03-2. The open-hole test intervals at DDH03-1 and DDH03-2 spanned the Bobcaygeon and Gull River Formations, and the hydraulic conductivity estimates for the bedrock were calculated using the Hvorslev method (Hvorslev 1951). The open-hole hydraulic conductivity results for DDH03-1 and DDH03-2 are summarized in Table 2 below.

Table 2: Open-Hole Hydraulic Conductivity Results (DDH03-1 and DDH03-2)

Location	Bedrock Geological Units Tested	Hydraulic Conductivity (m/s)
DDH03-1	Bobcaygeon and Gull River Formations	6×10^{-8}
DDH03-2	Bobcaygeon and Gull River Formations	2×10^{-7}
	Geometric Mean	1×10^{-7}

Notes: m/s – metres per second

As part of the 2006 investigation, Golder re-interpreted the short-term pumping tests completed by Stanton at TW-1, TW-2 and TW-3 (Stanton 2001) and converted the estimated transmissivity values to hydraulic conductivity values using an aquifer thickness 24 m. Based on the depths where water was found in TW-1, TW-2 and TW-3, the wells obtain their water from the Rockcliffe Formation. As discussed in Section 3.2, the thickness of the Rockcliffe Formation was estimated to be approximately 24 metres at the existing West Carleton Quarry. The re-interpreted pumping test results are summarized in Table 3 below.

Table 3: Hydraulic Conductivity Results (TW-1, TW-2 and TW-3)

Location	Bedrock Geological Unit Tested	Transmissivity (m2/s)	Estimated Hydraulic Conductivity (m/s)*
TW-1	Rockcliffe Formation	1×10^{-3}	6×10^{-5}
TW-2	Rockcliffe Formation	4×10^{-3}	2×10^{-4}
TW-3	Rockcliffe Formation	4×10^{-6}	2×10^{-7}

Notes: *assumed aquifer thickness of 24 m

Based on the results of the pumping tests completed by Stanton (2001), hydraulic conductivity of the Rockcliffe Formation varies between 2×10^{-7} m/s and 2×10^{-4} m/s, and the geometric mean is 1×10^{-5} m/s.

3.3.3 Groundwater Modelling

A 3-D numerical groundwater flow model was developed for the existing West Carleton Quarry and surrounding area using MODFLOW. The model domain covered an area of approximately 12 km by 9 km centred on the existing West Carleton Quarry. The available geological and hydrogeological information was incorporated into the development of the model layers and assigned hydraulic conductivities. The effects of streams and creeks in the model area were simulated with drain boundaries. A constant head boundary was used to simulate the Mississippi River. Development of the existing West Carleton Quarry was simulated using drains within the quarry footprint.

3.3.4 Impact Assessment

An impact assessment was completed for water wells located within 500 m of the site as well as the Manion Corners Long Swamp Wetland Complex located to the east of the site and the Burnt Lands Alvar located west and northwest of the site. Overall, it was concluded that quarry dewatering was not predicted to cause significant impacts to the identified potential surface water and terrestrial receptors, and water well interference was not anticipated.

3.4 Golder Associates Ltd. (September 2006)

Following submission of the March 2006 PTTW application package for the existing West Carleton Quarry, the MECP issued a technical memorandum providing comments. A work program including a private well survey for residences within 500 m of the existing quarry, review of available water quality data, installation of monitoring wells in existing on-site boreholes, installing a new monitoring well and surface water staff gauge near the Upper Dwyer Hill site entrance and additional hydraulic conductivity testing was developed to address the MECP comments. The results of the work program were presented in an addendum report date September 2006 (Golder 2006b) and are summarized below.

3.4.1 Private Well Survey

The objective of the private well survey was to obtain information regarding private water well construction and general information about the owners' experiences regarding water well quantity and quality. In August 2006, nine homes were visited within 500 m of the existing West Carleton Quarry and a water well survey was provided to the homeowners. Homeowners at 1331 Upper Dwyer Hill Road and 1616 Burnt Lands Road elected not to participate in the survey. The data gathered as part of the private well survey and a review of the available water well records is summarized in Table 4.

Table 4: Summary of Private Well Survey

Location	Well Depth	WWR Number	Static Water Level from WWR	Recommended Pumping Rate from WWR	Reported Water Quantity from Survey	Reported Water Quality from Survey
1661 Upper Dwyer Hill Road	26.82 m (WWR)	1535044	2.30 m	54.6 L/min	Good	Poor (sulphur and iron)
4061 March Road	44.2 m (WWR)	1513680	12.19 m	113.56 L/min	Good	Good
1616 Burnt Lands Road	49.7 m (WWR)	1525284	6.10 m	34.07 L/min	NA	NA
1644 Burnt Lands Road	60.4 m (WWR)	1513826	13.72 m	18.93 L/min (tested at 37.85 L/min)	Good	NA
1654 Burnt Lands Road	53.3 m (WWR)	1514195	17.07 m	11.36 L/min (tested at 18.93 L/min)	Good	Excellent (sulphur)
1674 Burnt Lands Road	24.4 m (WWR)	1513825	1.83 m	18.93 L/min	Good	Good
1550 Upper Dwyer Hill	22.9 m (WWR)	1532850	1.83 m	18.93 L/min	Good	Good
3950 March Road	18.3 m (WWR)	1533879	2.44 m	56.78 L/min	Good	Good
1331 Upper Dwyer Hill Road	NA	NA	NA	NA	NA	NA

Notes: WWR – water well record; NA – not available

3.4.2 Water Quality Data Review

The Stanton 2001 report presented analytical results of water samples taken from TW-1, TW-2 and TW-3. The water quality results indicate that there were no exceedances of health-related Ontario Drinking Water Quality Standards (ODWQS). Hardness exceeded the applicable aesthetic objective in all samples (typical for limestone aquifers) and iron and manganese exceeded the applicable aesthetic objectives at TW-2 and TW-3. The concentrations of iron and manganese at TW-2 and TW-3 were below the maximum concentrations considered treatable as per Table 3 of MECP Procedure D-5-5, Technical Guideline for *Private Wells: Water Supply Assessment*.

The data from the on-site test wells indicate that the groundwater quality in the local deeper bedrock formations is acceptable (i.e., below the proposed extraction depth of the quarry). As such, deepening of local private water supply wells (i.e., into the Rockcliffe Formation) is considered to be a feasible contingency.

3.4.3 Monitoring Well Installations

Groundwater monitors were installed in DDH03-1, DDH03-2, TW-2 and TW-3 in July 2006. Monitoring well TW-1 was found to be blocked at a depth of 24 mbgs and no monitors were installed. A new borehole TW-6 was drilled in July 2006 on the southern edge of the parking lot located at the intersection of Upper Dwyer Hill Road and March Road (see location on Figure 2). Due to the significant thickness of overburden encountered at TW-6, only one monitoring well was installed in the bedrock at this location.

For locations having multiple monitoring wells, the deepest monitoring well installation at the drilling location is designated as monitoring well "A", with each successively shallower monitoring well at each borehole designated as "B" and "C", where appropriate. The monitoring wells were developed following their installation prior to undertaking hydraulic conductivity testing and groundwater level measurements. The construction details and surveyed elevations for the monitoring intervals are presented on the borehole logs in Appendix B, and a summary of the well completion details is provided in Table 5 below.

Table 5: Summary of Monitoring Well Completion Details (DDH03-1, DDH03-2, TW-2, TW-3 and TW-6)

Location	Ground Surface Elevation (m ASL)	TOP Elevation (m ASL)	Elevation of Screened Interval (m ASL)
DDH03-1A	149.99	150.60	107.0 – 113.1
DDH03-1B	149.99	150.65	132.1 – 138.2
DDH03-2A	148.30	149.21	107.2 – 113.4
DDH03-2B	148.30	149.21	132.2 – 138.2
TW-2A	148.33	148.86	75.4 – 81.6
TW-2B	148.33	148.86	105.8 – 112.0
TW-2C	148.33	148.86	131.6 – 137.6
TW-3A	126.30	126.67	61.4 – 67.6
TW-3B	126.30	126.69	105.6 – 111.8
TW-6	124.50	125.60	105.1 – 111.5

Notes: TOP – top of monitoring well pipe (i.e., measuring point for groundwater levels)

The initial round of groundwater levels collected in the newly installed monitoring wells indicate downward hydraulic gradients, which is similar to what was previously interpreted based on the water levels in the open holes at the site (Golder 2006a).

3.4.4 Hydraulic Conductivity Testing

Following installation of the monitoring wells and well development, in-situ hydraulic conductivity tests were conducted in each monitor. Table 6 below summarizes the results of the hydraulic conductivity testing.

Table 6: Hydraulic Conductivity Testing Results (DDH03-1, DDH03-2, TW-2, TW-3 and TW-6)

Location	Elevation of Screened Interval (m ASL)	Formation Tested	Calculated Hydraulic Conductivity (m/s)
DDH03-1A	107.0 – 113.1	Upper Gull River	5×10^{-8}
DDH03-1B	132.1 – 138.2	Lower Bobcaygeon	3×10^{-10}
DDH03-2A	107.2 – 113.4	Lower Gull River	2×10^{-6}
DDH03-2B	132.2 – 138.2	Lower Bobcaygeon	4×10^{-8}
TW-2A	75.4 – 81.6	Rockcliffe	3×10^{-6}
TW-2B	105.8 – 112.0	Lower Gull River	2×10^{-7}
TW-2C	131.6 – 137.6	Lower Bobcaygeon	8×10^{-8}
TW-3A	61.4 – 67.6	Rockcliffe	6×10^{-7}
TW-3B	105.6 – 111.8	Upper Gull River	3×10^{-7}
TW-6	105.1 – 111.5	Nepean	8×10^{-5}*

Notes: * assumed value for hydraulic conductivity – recovery in the well was too fast to measure during the well response test at TW-6.

3.4.5 Staff Gauge Installation

In July 2006, Golder installed a staff gauge in the low-lying wet area south of the Upper Dwyer Hill Road entrance to the existing West Carleton Quarry approximately 250 m east of the eastern limit of the extraction area (see location of SG-1 on Figure 2). The top of the staff gauge was surveyed following installation.

3.4.6 Impact Assessment

Based on the results of the numerical modelling results presented in the Golder March 2006 report and the results of the additional field work, significant impacts to identified potential receptors due to the operation of the West Carleton Quarry were not predicted.

3.5 Golder Associates Ltd. (December 2015)

During the April 24, 2015, groundwater monitoring session at the existing West Carleton Quarry, it was noted that TW-2 had been removed by progressive quarry development. In December 2015, a replacement monitoring well MW15-1 was installed along the western boundary of the Extension Lands (see location on Figure 2). Location MW15-1 was instrumented with three monitoring well installations at specific depth intervals. All three monitoring intervals were installed within one 0.15-metre diameter air percussion borehole. The three monitoring wells installed at MW15-1 were constructed of 0.032-m diameter, threaded, PVC slot #10 screen and solid risers. Silica sand was placed in the boreholes around the screened portions of the monitors and bentonite was used to provide seals above the screened intervals. A near surface bentonite seal was installed within the borehole. The borehole locations and elevations (ground surface and top of monitoring well pipes) were surveyed by Cavanagh. For reference, a copy of the borehole log for MW15-1 is provided in Appendix B and the well completion details are summarized in Table 7 below.

Table 7: Summary of Monitoring Well Completion Details (MW15-1)

Location	Ground Surface Elevation (m ASL)	TOP Elevation (m ASL)	Elevation of Screened Interval (m ASL)
MW15-1A	152.08	153.64	109.33 – 118.53
MW15-1B	152.08	153.66	124.58 – 132.28
MW15-1C	152.08	153.64	137.53 – 145.95

Starting in 2016, the monitoring intervals in MW15-1 were added to the ongoing PTTW groundwater level monitoring program for the existing West Carleton Quarry.

3.6 Golder Associates Ltd. (2006 - 2020)

The existing West Carleton Quarry has a PTTW (No. 4175-AB4RS4) issued by the MECP on July 18, 2016 (replaced the previous PTTW No. 4865-7HUKDS). This PTTW authorizes water takings for quarry dewatering, aggregate washing and dust suppression/construction purposes. The PTTW requires monitoring of water levels in on-site wells DDH03-1A, DDH03-1B, TW-1, TW-2A, TW-2B, TW-2C, TW-3A, TW-3B and TW-6 and staff gauge SG-1 once during April or May, once during June or July, once during August or September and once during October or November each year. When TW-2A, TW-2B and TW-2C were removed by progressive quarry development, the monitoring locations were replaced by MW15-1A, MW15-1B and MW15-1C.

The groundwater level data collected between 2006 and 2020 has demonstrated that the impacts associated with dewatering of the existing West Carleton Quarry are not greater than those predicted by the modelling completed in support of the original PTTW application (Golder 2006a). As such, interference with off-site water supply wells is not anticipated. To date, there have been no well interference complaints from surrounding groundwater users that could be attributed to the ongoing operation of the existing West Carleton Quarry. The water level trends measured in the on-site monitoring wells and at SG-1 as part of the ongoing PTTW monitoring program are discussed further in Section 4.3.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The current assessment does not include the collection of field data except for the completion of additional well response tests. Available data collected as part of previous investigations completed at the existing West Carleton Quarry, as well as data collected as part of the ongoing monitoring program and the additional well response tests have been compiled and reviewed. These data included previous borehole drilling, groundwater level monitoring, hydraulic conductivity testing and groundwater modelling. This section compiles the relevant data from the previous investigations and ongoing groundwater monitoring program and uses these data to development an updated hydrogeological conceptual model for the site.

4.1 Geology

4.1.1 Surficial Geology

There was no overburden present at drilling locations DDH03-1, DDH03-2, TW-1, TW-3 and MW15-1. The thickness of overburden at TW-2 and TW-6 was 1.0 m and 9.75 m, respectively (see borehole logs provided in Appendix B). This is consistent with the published mapping (see Figure 4), which shows the majority of the extraction area for the existing West Carleton Quarry and the proposed Extension Lands as Paleozoic bedrock at surface. TW-6 is located east of the extraction area for the existing West Carleton Quarry (see location on Figure 4). During drilling at TW-6, 1.21 m of topsoil was encountered followed by 1.53 m of sand and 7.01 m of clay. The sand unit encountered at TW-6 is interpreted to be Map Unit 11c, which is interpreted to be underlain by Map Unit 10a.

4.1.2 Bedrock Geology

Prior to 2003, detailed logging of bedrock core from the existing West Carleton Quarry had not been completed, and the description of the bedrock on the previous borehole logs simply identified limestone bedrock. In 2003, boreholes DDH03-1 and DDH03-2 were drilled at the existing West Carleton Quarry (see locations on Figure 2). To develop a 3-D understanding of the geological conditions beneath the existing West Carleton Quarry, detailed logging of the core from DDH03-1 and DDH03-2 was completed, and locations DDH03-1 and DDH03-2, as well as TW-1, TW-2 and TW-3 were geophysically logged using natural gamma and apparent conductivity logging tools. The results of the core logging and geophysical logging were previously discussed in Section 3.2.

The upper bedrock formation at the existing West Carleton Quarry is the Bobcaygeon Formation. This is consistent with the published mapping shown on Figure 5. The thickness of the Bobcaygeon Formation varies between 18.6 m (TW-1) and 31 m (DDH03-1) at the site. Beneath the Bobcaygeon Formation is the Gull River Formation which varies in thickness between 35.9 m (TW-1) and 36.9 m (TW-3) at the site. Beneath the Gull River Formation is the Rockcliffe Formation. The full thickness of the Rockcliffe Formation was drilled through at TW-3. At this location, the thickness of the Rockcliffe Formation was 24.2 m. Beneath the Rockcliffe Formation is the Oxford Formation. The full thickness of the Oxford Formation was not drilled through at the site.

Based on contouring of the contact between the Bobcaygeon Formation and the Gull River Formation, the dip of the bedrock at the existing West Carleton Quarry is towards the north. Based on the elevations of the formational contacts, the existing West Carleton Quarry (licensed to a base elevation of 107 m ASL) will extract material from the Bobcaygeon Formation and Gull River Formation and will leave a minimum of 16.5 m of Gull River Formation above the top of the Rockcliffe Formation.

At test well TW-6 located to the east of the extraction area for the existing West Carleton Quarry (see location on Figure 5), the upper bedrock unit is white sandstone (found at a depth of 9.75 mbgs). TW-6 is located within the Pakenham Fault Zone, and the presence of sandstone (Nepean Formation) as the upper bedrock unit is consistent with the published mapping.

4.2 Bedrock Hydraulic Conductivity

As part of the previous investigations completed at the existing West Carleton Quarry, well response tests were completed in available on-site monitoring wells. The current investigation included completing well response tests at MW15-1, which had not previously been performed, as well as retesting the remaining available monitoring wells (DDH03-1A, DDH03-1B, TW-3A, TW-3B and TW-6) to confirm previous well response test results. For all monitoring intervals except for TW-6, the hydraulic testing data was analyzed using the Hvorslev method (1951). The rapid recovery measured at TW-6 (oscillating water levels) were analyzed using the Butler method (1998). The Butler method accounts for oscillatory slug test responses in high-hydraulic conductivity aquifers like the Nepean Formation. The results of the hydraulic conductivity analyses completed as part of the current study are provided in Appendix C.

The on-site monitoring wells are completed in limestone of the Bobcaygeon and Gull River Formations, sandstone/shale of the Rockcliffe Formation, and sandstone of the Nepean Formation (within the Pakenham Fault Zone). Table 8 includes a summary of the hydraulic conductivity results for the West Carleton Quarry, the approximate screened interval elevation and the bedrock formation tested. For the locations that were re-tested, notes are provided if the retesting results differed from the original results.

Table 8: Hydraulic Conductivity Testing Results Summary (all locations)

Location	Elevation of Screened Interval (m ASL)	Formation Tested	Calculated Hydraulic Conductivity (m/s)	Comments
DDH03-1A	107.0 – 113.1	Upper Gull River	2 x 10^{-6}	The well response test was redone at this location as part of the current investigation. The original test from 2006 analysed the late-time data resulting in a hydraulic conductivity estimate of 5 x 10^{-8} m/s. The water levels measured during the retest were similar to the original 2006 data; however, based on the available data, the early-time data should have been used to estimate the hydraulic conductivity. This results in a more representative hydraulic conductivity estimate of 2 x10^{-6} m/s for this location.
DDH03-1B	132.1 – 138.2	Lower Bobcaygeon	6 x 10^{-10}	The retest of this location resulted in a similar hydraulic conductivity estimate (original estimate was 3 x 10^{-10} m/s).
DDH03-2A	107.2 – 113.4	Lower Gull River	2 x 10^{-6}	This well no longer exists so no retest could be completed.
DDH03-2B	132.2 – 138.2	Lower Bobcaygeon	4 x 10^{-8}	This well no longer exists so no retest could be completed.
TW-2A	75.4 – 81.6	Rockcliffe	3 x 10^{-6}	This well no longer exists so no retest could be completed.
TW-2B	105.8 – 112.0	Lower Gull River	2 x 10^{-7}	This well no longer exists so no retest could be completed.
TW-2C	131.6 – 137.6	Lower Bobcaygeon	8 x 10^{-8}	This well no longer exists so no retest could be completed.
TW-3A	61.4 – 67.6	Rockcliffe	3 x 10^{-6}	The original hydraulic conductivity result was 6 x 10^{-7} m/s. The retest result was slightly higher.
TW-3B	105.6 – 111.8	Upper Gull River	1 x 10^{-6}	The original hydraulic conductivity result was 3 x 10^{-7} m/s. The retest result was slightly higher.
TW-6	105.1 – 111.5	Nepean	3 x 10^{-4}	Recovery during the well response test completed in 2006 was too fast to measure. During the retest in 2019, a data logger was used to measure water levels every second, which allowed for an accurate estimate of the hydraulic conductivity at TW-6.
MW15-1A	109.33 – 118.53	Upper Gull River	6 x 10^{-6}	Not previously tested.
MW15-1B	124.58 – 132.28	Bobcaygeon	5 x 10^{-8}	Not previously tested.
MW15-1C	137.53 – 145.95	Bobcaygeon	2 x 10^{-8}	Not previously tested.
TW-1	Open Hole	Rockcliffe Formation (based on water found depths)	6 x 10^{-5}	Based on groundwater level measurements during a pumping test (Stanton 2001) and an assumed aquifer thickness of 24 metres (thickness of Rockcliffe Formation at the site).

Based on the available hydraulic conductivity results, Table 9 below summarizes the range in hydraulic conductivity values and the geometric mean for the formations present at the site.

Table 9: Summary of Hydraulic Conductivity Results by Formation

Formation	Range in Hydraulic Conductivity (m/s)	Geometric Mean of Hydraulic Conductivity (m/s)
Bobcaygeon	6 x 10-^{10} to 8 x 10^{-8}	2 x 10^{-8}
Upper Gull River	1 x 10^{-6} to 6 x 10^{-6}	2 x 10^{-6}
Lower Gull River	2 x 10^{-7} to 2 x 10^{-6}	6 x 10^{-7}
Rockcliffe	3 x 10^{-6} to 6 x 10^{-5}	8 x 10^{-6}
Nepean	3 x 10^{-4}	3 x 10^{-4}

4.3 Groundwater Elevations and Flow Directions

Under Condition 4.2 of PTTW No. 4175-AB4RS4 (dated July 18, 2016), the ongoing groundwater monitoring program at the site consists of groundwater level measurements at the following on-site monitoring wells:

- DDH03-1A, DDH03-1B, TW-1, TW-2A, TW-2B, TW-2C, TW-3A, TW-3B and TW-6 once during April or May, once during June or July, once during August or September and once during October or November each year.

To gather additional data in support of the ongoing licensing project for the Extension Lands, the frequency of groundwater level measurements at the on-site wells included in the PTTW monitoring program was increased to monthly starting in June 2019. The available borehole logs providing the well completion details for the monitoring wells included in the current monitoring program are provided in Appendix B.

Monitoring well TW-2 was located within the licensed extraction area of the existing West Carleton Quarry. When TW-2A, TW-2B and TW-2C were removed by progressive quarry development in 2015, the monitoring locations were replaced by MW15-1A, MW15-1B and MW15-1C.

4.3.1 Groundwater Elevation Data

This section presents the available groundwater elevation data measured as part of the ongoing groundwater level monitoring program for the existing West Carleton Quarry. Figures D1 through D8 in Appendix D show the groundwater elevations plotted versus time at DDH03-1A, DDH03-1B, DDH03-2A, DDH03-2B, TW-1, TW-2A, TW-2B, TW-2C, TW-3A, TW-3B, TW-6, MW15-1A, MW15-1B and MW15-1C. The groundwater elevation data used to generate Figures D1 through D8 is provided in Table D1 in Appendix D. The groundwater elevation trends for the monitoring wells are discussed below.

4.3.1.1 DDH03-1

Figure D1 presents groundwater elevation data measured at DDH03-1A and DDH03-1B between August 11, 2006, and December 9, 2020. As shown on Figure D1, the groundwater elevations at DDH03-1A and DDH03-1B are generally stable and typically vary annually by less than four metres at both monitoring intervals. The groundwater elevation at DDH03-1A has historically varied between 135.06 m ASL and 140.31 m ASL and the groundwater elevation at DDH03-1B has historically varied between 138.55 m ASL and 145.24 m ASL.

The changes in groundwater elevations at DDH03-1A are considered to represent seasonal variations. There is no significant ongoing decline in the groundwater elevations at DDH03-1A, and the groundwater elevations at this location are not interpreted to be influence by the development of the existing West Carleton Quarry. The changes in groundwater elevation at DDH03-1B shown on Figure D1 typically show changes associated with seasonal variation. During the second half of 2020, a gradual decline in groundwater elevation is observed at DDH03-1B. This decline in groundwater elevation at DDH03-1B below the typical range observed at this location may represent the first influence of quarry development on the groundwater elevation. At the closest point, the edge of the extracted area for the existing West Carleton Quarry is approximately 80 m from DDH03-1. The quarry floor elevation is the area closest to DDH03-1 is at approximately 133 m ASL. During all monitoring sessions, the vertical gradient at DDH03-1 is downward.

4.3.1.2 DDH03-2

Figure D2 presents groundwater elevation data measured at DDH03-2A and DDH03-2B between August 11, 2006, and March 15, 2007. DDH03-2 was removed as a result of progressive quarry development following the March 15, 2007, monitoring session. The limited available groundwater elevation data available for DDH03-2A and DDH03-2B indicate both monitoring intervals were generally stable, and the groundwater elevation varied by less than 3 metres at both monitoring intervals. The available groundwater elevation data also indicates that the vertical gradient at DDH03-2 was consistently downward.

4.3.1.3 TW-1

Figure D3 presents groundwater elevation data measured at TW-1 between July 9, 2008, and December 9, 2020. TW-1 is a 0.15-m diameter open hole monitoring well. As shown on Figure D3, the groundwater elevations at TW-1 are initially stable around 135 m ASL and steadily decline between June 2009 and July 2010 to an elevation around 127 m ASL. The groundwater elevation returns to around 135 m ASL in April 2012 and remains relatively stable (i.e., varies by less than 3 metres) until October 2016. Between April 2017 and October 2018, the groundwater elevation at TW-1 is consistently above 142 m ASL, followed by a significant decline between October 2018 and June 2019. Between July 2019 and June 2020, the groundwater elevation at TW-1 remains stable at around 137 m ASL.

The groundwater elevation at TW-1 is typically between 135 and 137.5 m ASL with the exception of one extended period of lower than typical groundwater elevations (September 2009 to November 2011) and one extended period of higher than typical groundwater elevations (April 2017 to October 2018). The cause(s) of the periods of higher and lower groundwater elevations are not known. Overall, there is no significant ongoing decline in the groundwater elevations at TW-1, and the groundwater elevations at this location are not interpreted to be influence by the development of the existing West Carleton Quarry.

4.3.1.4 TW-2

Figure D4 presents groundwater elevation data measured at TW-2A, TW-2B and TW-2C between August 11, 2006, and October 6, 2014. TW-2 was removed early in 2015 by progressive quarry development. As shown on Figure D4, the groundwater elevations at TW-2A, TW-2B and TW-2C are generally stable and typically vary annually by less than two metres, although slightly larger variation in groundwater levels were observed during the first 1.5 years of groundwater level monitoring. The groundwater elevation at TW-2A has historically varied between 121.78 m ASL and 126.25 m ASL. The groundwater elevation at TW-2B has historically varied between 133.73 m ASL and 137.72 m ASL and the groundwater elevation at TW-2C has historically varied between 140.91 m ASL and 147.07 m ASL. Although the groundwater elevations at TW-2A and

TW-2B display a gradual decline during the period of monitoring, no significant decline in groundwater elevations was observed as the quarry development approached TW-2. During all monitoring sessions, the vertical gradient at TW-2 was downward.

4.3.1.5 TW-3

Figure D5 presents groundwater elevation data measured at TW-3A and TW-3B between August 11, 2006, and December 9, 2020. As shown on Figure D5, the groundwater elevations at TW-3A and TW-3B are generally stable and typically vary annually by less than three metres at both monitoring intervals. The groundwater elevation at TW-3A has historically varied between 122.41 m ASL and 126.27 m ASL and the groundwater elevation at TW-3B has historically varied between 123.62 m ASL and 126.69 m ASL. The changes in groundwater elevations at TW-3 are considered to represent seasonal variations.

The existing West Carleton Quarry is located on a topographic rise that slopes down towards the east (see topography on Figure 3). TW-3 is located on the east side of the extraction area for the existing West Carleton Quarry where the ground surface is around 126.3 m ASL. The excavation at the site to date has primarily been west of this location removing rock that is topographically higher than the ground surface at TW-3. As such, changes in groundwater elevations at TW-3 associated with the development of the existing West Carleton Quarry to date would not be expected at this time. During most monitoring sessions, the vertical gradient at TW-3 is slightly downward.

4.3.1.6 TW-6

Figure D6 presents groundwater elevation data measured at TW-6 between August 11, 2006, and December 9, 2020. As shown on Figure D6, the groundwater elevations at TW-6 are generally stable and typically vary annually by less than two metres. The groundwater elevation at TW-6 has historically varied between 122.25 m ASL and 125.57 m ASL. The changes in groundwater elevations at TW-6 are considered to represent seasonal variations. TW-6 is located at the eastern extent of the licensed boundary for the existing West Carleton Quarry where the ground surface is around 124.5 m ASL. The excavation at the site to date has been west of this location removing rock that is topographically higher than the ground surface at TW-6. As such, changes in groundwater elevations at TW-6 associated with the development of the existing West Carleton Quarry to date would not be expected at this time.

4.3.1.7 MW15-1

Figure D7 presents groundwater elevation data measured at MW15-1A, MW15-1B and MW15-1C between April 6, 2016, and December 9, 2020. As shown on Figure D7, the groundwater elevations at MW15-1B and MW15-1C are stable and typically vary by less than one metres. Monitoring intervals MW15-1B and MW15-1C are not interpreted to be influence by the development of the existing West Carleton Quarry.

The groundwater elevations at MW15-1A display greater variability than is observed at MW15-1B and MW15-1C. Initially at MW15-1A there is a decline in the groundwater elevation between April 2016 and August 2016. In April 2017, the groundwater elevation returns to the higher level observed in April 2016. This decline in groundwater elevation is considered to represent seasonal variations during a dry summer in 2016. Between April 2017 and June 2019, the groundwater elevation at MW15-1A gradually declines by approximately 3 m. The groundwater elevation at MW15-1A declines more rapidly between June 2019 and October 2019 followed by a rise in groundwater elevations between October 2019 and January 2020. Between June 2020 and December 2020, the groundwater elevation generally increased at MW15-1A. Monitoring interval MW15-A is not interpreted to be influence by the development of the existing West Carleton Quarry.

4.3.2 Groundwater Flow Directions

4.3.2.1 Horizontal Groundwater Flow

In the vicinity of the existing West Carleton Quarry, groundwater flow generally follows topography and flows from west to east. Figure D8 in Appendix D provides the available groundwater elevations for all monitoring wells. The highest groundwater elevations are found in monitoring wells installed on the topographically higher west/northwest sides of the site (i.e., MW15-1 and DDH03-1) and the lower groundwater elevations are found in the monitoring wells installed along the eastern edge of the extraction area (TW-3) and further east of the extraction area (TW-6).

Figure 6 shows the contoured groundwater elevations within the model domain for the groundwater flow model. The groundwater elevation data used to generate Figure 6 include elevations from on-site monitoring wells and static water levels in private wells included in the MECP WWIS. A local topographic high is located west of the existing West Carleton Quarry. Based on available data, the groundwater elevation in the vicinity of the topographic high is approximately 150 m ASL. Groundwater flow appears to generally follow topography and flows radially away from the topographic high.

4.3.2.2 Vertical Groundwater Flow

The groundwater elevation data from the multilevel monitoring wells currently (DDH03-1, TW-3 and MW15-1) and historically (DDH03-2 and TW-2) installed at the site show the vertical gradients in the bedrock are typically downward indicating recharging conditions (see Figures D1, D2, D4, D5 and D7 in Appendix D).

4.3.2.3 Maximum Predicted Water Table

Based on the available groundwater elevation data, the maximum predicted water table within the Extension Land is 151.8 m ASL on the west side (as measured at MW15-1C). Based on the groundwater elevation data measured at DD03-01B located just east of the Extension Land, the water table slopes down moving from west to east, and the maximum predicted water table on the east side of the Extension Lands is approximately 143 m ASL. Because the horizontal groundwater flow direction is from west to east across the Extension Lands, the groundwater elevations are generally consistent moving in the north-south direction through the Extension Lands.

4.4 Surface Water Elevation Data

Condition 4.2 of PTTW No. 4175-AB4RS4 requires the water level be measured at SG-1 once during April or May, once during June or July, once during August or September and once during October or November each year. Monitoring location of SG-1 is located within the site boundary in the Manion Corners Long Swamp Wetland Complex as shown on Figure 2. As with the frequency of groundwater level measurements, the frequency of water levels measurements at SG-1 was increased to monthly starting in June 2019.

Figure D9, in Appendix D, presents water elevation data measured at SG-1 between July 9, 2008, and June 23, 2020. As shown on Figure D9, the water elevations at SG-1 are generally stable and have historically varied by approximately 0.7 m (i.e., between 123.68 m ASL and 124.39 m ASL). Based on available data, SG-1 typically goes dry during the summer. The changes in water elevations at SG-1 are considered to represent seasonal variations.

4.5 Geological and Hydrogeological Conceptual Model

Data from a variety of sources were considered during the development of the conceptual model for the site including:

- Mapping data from the Natural Resources Values Information System, maps from the MNRF, and published geological mapping.
- Subsurface information was obtained from on-site drilling programs and from the MECP WWIS.
- At the local scale, references included various previous investigation completed for the existing West Carleton Quarry (see Section 3.0).

As described below, the data presented in the previous sections formed the basis for the development of the site conceptual model.

The western portion of the existing quarry and the Extension Lands are located on a local topographic high. The ground surface on the west side of the site is approximately 152 m ASL and slopes down to approximately 124 m ASL on the east side of the existing West Carleton Quarry. The thickness of overburden material in the boreholes completed at the site ranged from 0 m to 9.75 m. The majority of the extraction area for the existing West Carleton Quarry and the proposed Extension Lands has bedrock at or near surface. The overburden thickens to the east of the existing West Carleton Quarry extraction area. Along the eastern edge of the existing West Carleton Quarry and further to the east/southeast there is an extensive area of organic deposits associated with the Manion Corners Long Swamp Wetland Complex. Smaller areas of organic deposits associated with low-lying and/or poorly drained areas to the west and south of the site.

The upper bedrock formation at the existing West Carleton Quarry and the Extension Lands is the Bobcaygeon Formation. This is consistent with the published bedrock geology mapping. The thickness of the Bobcaygeon Formation varies between 18.6 m (TW-1) and 31 m (DDH03-1) at the site. Beneath the Bobcaygeon Formation is the Gull River Formation which varies in thickness between 35.9 m (TW-1) and 36.9 m (TW-3) at the site. Beneath the Gull River Formation is the Rockcliffe Formation. The full thickness of the Rockcliffe Formation was drilled through at TW-3. At this location, the thickness of the Rockcliffe Formation was 24.2 m. Beneath the Rockcliffe Formation is the Oxford Formation. The full thickness of the Oxford Formation was not drilled through at the site.

Based on contouring of the contact between the Bobcaygeon Formation and the Gull River Formation, the dip of the bedrock at the existing West Carleton Quarry and the Extension Lands is towards the north. Based on the elevations of the formational contacts, the existing West Carleton Quarry (licensed to a base elevation of 107 m ASL) will extract material from the Bobcaygeon Formation and Gull River Formation and will leave a minimum of 16.5 m of Gull River Formation above the top of the Rockcliffe Formation.

A fault zone referred to as the Pakenham Fault is located to the north of the site and runs along the east side of the existing West Carleton Quarry. The Pakenham Fault is mapped along the sharp decline in topography to the north of the site, and results in an area of the much older Nepean Formation being mapped as the upper bedrock unit in a small area to the north and east of the site. The Pakenham Fault has been included in the conceptual model for the site.

In areas where the Bobcaygeon and Gull River Formations are at surface, water supply is typically obtained from the underlying Rockcliffe Formation. Within the Pakenham Fault Zone and immediately east of the fault zone, the Nepean Formation and Oxford Formations, which provide better quality and quantity of groundwater, are utilized for water supply. The information on local water supply aquifers has been incorporated into the site conceptual model.

Based on the interpretation of well response tests completed at the site, the geometric mean of the hydraulic conductivity for the Bobcaygeon Formation was 2 x 10^{-8} m/s. The Gull River Formation was divided into the upper Gull River and lower Gull River. The geometric means of the hydraulic conductivity results for the upper Gull River and lower Gull River are 2 x 10^{-6} m/s and 6 x 10^{-7} m/s, respectively. The geometric means of the hydraulic conductivity data for the Rockcliffe Formation and the Nepean Formation are 8 x 10^{-6} m/s and 3 x10^{-4} m/s, respectively. The geometric means of the hydraulic conductivity results for the various formations were used as a starting point during the construction and calibration of the numerical model.

Surface water features on the Site are limited to ditches along access roads, flooding in disturbed areas, and unevaluated wetlands. Water pools and/or flows through these features during freshet, but based on observations during the 2018 field surveys, they were almost dried up with no flow by the end of April. The nearest surface water receptor is the Manion Corners Long Swamp Wetland Complex located east and southeast of the existing West Carleton Quarry.

Based on available groundwater level data from monitoring wells and water supply wells, the water table in the vicinity of the Extension Lands is interpreted to be within the bedrock between 0.5 m to 4 m below the bedrock surface. At most locations, the water table is at least 2 m below ground surface. During wet periods of the year, it is expected that water would be found at the overburden/bedrock interface (i.e., perched on top of the lower hydraulic conductivity bedrock). In the vicinity of the existing West Carleton Quarry, groundwater flow generally follows topography and flows from west to east. The groundwater elevation data from the multilevel monitoring wells installed at the site show the vertical gradients in the bedrock are typically downward indicating recharging conditions. Local surface water features and seasonally wet areas in the vicinity of the site are not interpreted to be supported by significant groundwater discharge. For the site conceptual model, the local water features are interpreted to be primarily surface water fed with limited groundwater input.

The approved base elevation of the extraction area within the existing West Carleton Quarry is 107 m ASL. The proposed Extension Lands would have the same base elevation. As such, the development plan included in the conceptual model for the site sets the proposed final base of the existing extraction area and proposed extension area at 107 m ASL. The Burnt Lands Quarry located approximately 1.6 km west of the existing West Carleton Quarry has an approved base elevation of 122 m ASL. The presence of the approved Burnt Lands Quarry to the west of the site was incorporated into the conceptual model.

The above information was used to create the numerical model as described in Section 6.0.

5.0 RECEPTOR IDENTIFICATION

As part of the current investigation, potential receptors in the vicinity of the existing West Carleton Quarry and Extension Lands that could be affected by the progressive quarry development are identified and discussed in the following subsections.

5.1 Groundwater Receptors

The MECP water well records within the WWIS with a UTM Reliability Code of 300 m or less (i.e., the well is expected to be within 300 metres of the actual location) were plotted on a map centred on the existing quarry and the Extension Lands to aid in the assessment of groundwater use within the area. The water well records were examined to determine the general yield and depth of identified private supply wells. There are no municipal services in the vicinity of the site, and water supply is obtained exclusively from private water supply wells. Extensive deposits of coarse and permeable overburden, capable of supplying sufficient quantities of groundwater for domestic use, are not prevalent in the vicinity of the existing West Carleton Quarry and the Extension Lands. For this reason, the bedrock is considered the principal aquifer for water supply.

Based on a review of the MECP WWIS, there are approximately 22 water supply wells within 750 metres of the site with a UTM Reliability Code of 300 m or less. Wells having a location accuracy code of greater than 300 metres were screened out because of the uncertainty associated with the well location. The wells in the vicinity of the site primarily service the residences along March Road, Burnt Lands Road and Upper Dwyer Hill Road. A summary of the depth to bedrock, well depths, static water levels, theoretical available drawdown and recommended pumping rate for the 22 wells is provided in Table 10.

Table 10: Summary of Private Well Completion Details

Parameter	Minimum	Maximum	Average
Depth to Bedrock (m)	0 (bedrock at surface)	12.2	2.0
Well Depth (m)	18.0	90.2	42.8
Static Water Level (m)	0.61	17.1	6.6
Theoretical Available Drawdown* (m)	15.8	77.5	36.2
Recommended Pumping Rate (L/min)	13	136	45

Notes: * calculated using the static water level measured at the time of drilling and the well depth

The primary hydrogeological consideration with respect to nearest water supply wells is the development of the groundwater drawdown cone that is associated with quarry dewatering, and the potential for drawdown (depressurization) to cause an interruption of the water supply because of the lowering of water levels in the water supply wells. The potential for impacts to existing groundwater users is assessed as part of the impact assessment presented in Section 8.0.

5.2 Surface Water Receptors

MNRF provincial mapping was reviewed for local and regional drainage features. Based on the mapping review, subsequent air photo review and a site reconnaissance, there are existing wetlands mapped on the site and in the surrounding areas. The most prominent surface water feature in the vicinity of the existing West Carleton Quarry and the Extension Land is the Manion Corners Long Swamp Wetland Complex located to the east/southeast. Golder’s certified OWES evaluators completed an investigation of the on-site wetlands and concluded that the on-site wetlands should not be complexed with the Manion Corners Long Swamp Provincially Significant Wetland (PSW) (Golder 2021). The only functional contribution identified between the on-site wetlands and the PSW was the movement of surface water in the early spring, from the site to the PSW. They further concluded that the proposed extraction will not result in any encroachment into a PSW, and it will not negatively impact the Manion Corners Long Swamp PSW. The functional contribution of water that moves across the site, through the existing quarry into the PSW, will be maintained through surface water management as required by the site ECA. For further discussion of the PSW and on-site wetlands, please refer to the accompanying Natural Environment Report (Golder 2021). There are no other significant surface water features located within the proposed Extension Lands. The potential for impacts to downstream surface water features is assessed in the impact assessment presented in Section 8.0.

6.0 GROUNDWATER FLOW MODELLING

6.1 Background

In March 2006, Golder prepared hydrogeological documentation in support of the PTTW application for the existing West Carleton Quarry (Golder 2006a). Part of this work involved development of a groundwater flow model, which was used to evaluate potential changes to the groundwater flow system associated with the development of the quarry. The groundwater flow model developed in 2006 was used as a starting point for the current work and updated to reflect the current understanding of hydrogeological conditions at the site.

6.2 Methodology

6.2.1 Model Approach

As part of the current study, groundwater flow simulations were completed using MODFLOW-NWT (Newton-Raphson formulation) to estimate the potential drawdown associated with the proposed Extension Lands (details on MODFLOW-NWT can be found in Niswonger et al 2011). The groundwater flow system in the study area was represented as an "equivalent porous media" (EPM) at the scale of the extent of the simulated drawdown under consideration. Under this assumption, the rate of groundwater flow towards the quarry occurs as a function of the hydraulic gradient, the hydraulic conductivity, and the porosity of the aquifer. While groundwater flow in bedrock aquifers is controlled primarily by fractures, an EPM approach is commonly used to represent groundwater flow. This approach is considered reasonable provided the scale of the observation (i.e., in this case the dewatering of the existing quarry and proposed extension) is greater than the scale of the individual fractures.

It should be recognized that the steady-state model does not account for seasonal variation in the overall water budget, but rather assumes that recharge rates and groundwater seepage rates are representative of long-term annual average conditions. The steady-state model also represents the maximum extent of groundwater impacts from quarry dewatering. Given that the expected duration of operations for the project is on the order of several decades, the time to reach this maximum extent will be dependent on the rate of development of the existing West Carleton Quarry and Extension Lands. As such, the steady-state approach to calculating drawdown is considered reasonable.

The general assumptions and limitations of the groundwater flow model are summarized below.

Numerical Model (MODFLOW)

- Flow is laminar and steady and is governed by Darcy's Law.
- Groundwater flow is represented by an EPM.
- Hydraulic heads are vertically averaged within a given model layer.

Conceptual Model

- There is no vertical differentiation of the overburden deposits (i.e., the overburden units are modelled vertically as a single hydrostratigraphic unit).
- Anisotropy of the hydrostratigraphic units was applied in the model as determined based on the results of the model calibration. Anisotropy ranged from horizontal to vertical ratios of 1:1 to 100:1.
- The conceptual model was based upon geologic and water level data compiled up to June 2020, including boreholes completed in the bedrock and overburden local to the site.

Calibration

- Groundwater elevations from November 2019 for each of the on-site wells were used in the calibration process. These are assumed to be representative of current conditions. Groundwater elevation data from the MECP WWIS database were also considered as calibration targets. Under both predevelopment and current conditions, calibration was evaluated using steady-state model results.
- Recharge estimates reflect deeper recharge and discharge characteristics of the groundwater flow system, and do not account for shallow infiltration and discharge to intermittent streams (i.e., interflow).
- A "regionalized" approach to model calibration was employed, such that parameter values were established for the hydrostratigraphic units on a regional scale.

6.2.2 Model Extents and Layering

The model grid and layering are illustrated on Figure 7. The model domain covers an area of approximately 14 km (in the east-west direction) by 12 km (in the north-south direction). Model grid cell spacing was specified as 100 m on the model periphery and transitioned to 10 m in the vicinity of the existing West Carleton Quarry and Extension Lands.

A total of 12 numerical model layers were specified to represent the overburden and bedrock within the model domain. Model layer thicknesses were selected so that the bedrock unit contacts were concurrently represented on the northeast and southwest sides of the Pakenham Fault. Additional detail on the model layering is provided below.

Model layer 1 represents the full thickness of the overburden within the model domain. Where overburden is absent, this layer represents a 1-m thick weathered bedrock unit. The upper surface of layer 1 was defined by topography (as illustrated on Figure 8). The bottom surface of model layer 1 was defined as the contact between overburden and bedrock (as illustrated in the bedrock topography map on Figure 9), which was delineated using “top of bedrock” data points from the available data. These data included on-site borehole records and lithological descriptions from the MECP WWIS. As shown in the overburden isopach map on Figure 9, the overburden is generally thickest at the southern, western, and northern periphery of the model, with minimal thickness (<5 m) throughout the central portion of the model, including the area in the vicinity of the existing West Carleton Quarry and Extension Lands. The bedrock elevation is highest to the west of the Extension Lands (in the vicinity of the Burnt Lands Quarry, reaching a maximum elevation of approximately 165 m ASL) and decreasing to approximately 75 m ASL in the westernmost portion of the model domain and 115 m ASL in the northeastern portion of the model domain.

In areas to the west of the Pakenham Fault Zone the following approach was adopted for defining the bedrock layers:

- Model layer 2 represents the Bobcaygeon Formation (where present). The contact of the bottom of the Bobcaygeon Formation and upper Gull River Formation was defined based on interpretation of borehole geophysical survey data (see section 4.1.2).
- Model layers 3 through 6 represent the Gull River Formation. The bottom of model layer 6 was selected based on data interpretation of borehole geophysical survey data. The borehole geophysical survey data were also used to define the upper and lower sub-units of the Gull River Formation (approximately 1/3 and 2/3 of the total unit thickness, respectively).

- Model layers 7 and 8 represent the Rockcliffe Formation, which was specified with an overall total thickness of 25 m.
- Model layers 9 and 10 represent the Oxford Formation, which was specified with an overall total thickness of 40 m.
- Model layers 11 and 12 represent the combined March and Nepean Formations, which were assigned a total thickness of 40 m. The resulting contact elevation between the Oxford and March Formations (i.e., top of layer 11) was confirmed in the vicinity of the West Carleton groundwater supply wells based on information contained in source water protection documentation (MRSPR 2011).

In areas to the east of the Pakenham Fault Zone the following approach was adopted to represent the bedrock layers:

- Model layers 2 and 3 represent a 5 m thick portion of the Rockcliffe Formation. The upper surface of model layer 2 is defined as the base of the 1-m thick weathered rock unit (where present).
- Model layers 4 through 7 represent the Oxford Formation. Consistent with the bedrock layering to the west of the fault this unit was specified with a total thickness of 40 m.
- Model layers 8 and 9 represent the combined March/Nepean Formations. Consistent with the bedrock layering to the west of the fault this unit was specified with a total thickness of 40 m.
- Model layers 10 through 12 represent the Precambrian bedrock unit.
- Within the Pakenham Fault Zone, the following approach was adopted to represent the bedrock layers: Model layers 2 through 5 represent the Nepean Formation, which was specified a thickness of 20 m within this zone.
- Model layers 6 through 12 represent the Precambrian bedrock unit and end to the bottom of the model.

For each of the bedrock layers defined above, where the overlying formation is interpreted to be absent the thickness of the layer was reduced to a minimum value (1 m) and the underlying hydrostratigraphic unit was specified.

6.2.3 Model Boundaries

The flow boundaries specified in the model are illustrated in Figure 10. Constant head boundaries were assigned along the Mississippi River at variable elevations in model layer 1, based on the digital elevation model (DEM). Minor streams and creeks were represented in the model using drain boundaries specified at variable elevations based on the DEM. The eastern edge of the model domain follows a stream, which was represented as a drain boundary at variable elevations in model layer 1. This type of boundary is only capable of removing water from the groundwater model. This approach is considered conservative with respect to calculation of drawdown in the vicinity of these features. The northwestern and southeastern edges of the model domain were assigned as no flow boundaries.

The existing West Carleton Quarry and Burnt Lands Quarry were represented in the model using drain boundaries specified at the current sump and quarry floor elevations. The quarry walls were also specified as drain boundaries, which permits the free drainage of groundwater from the excavation faces. Details on existing West Carleton Quarry and Burnt Lands Quarry drain boundary configuration are provided on Figure 10.

The Almonte municipal supply wells (3, 7, and 8) were included in the model simulation as pumping well nodes. Pumping rates for each of these wells were assigned based on an average of the pumping rates reported in the Mississippi Mills (Almonte) Drinking Water System summary reports from 2013- 2018. The locations of these wells are shown on Figure 10.

6.2.4 Model Parameterization

The hydraulic conductivity and recharge values applied in the model were originally based on the available measured data (i.e., interpretation of hydraulic response testing data), and subsequently adjusted through the model calibration process (as detailed in the following section). The resulting hydraulic conductivity distribution applied in the model is provided on Figure 11.

The hydraulic conductivity values assigned to the overburden and bedrock units are summarized in Table 11 below. In areas where a model layer reaches a minimum thickness of one metre (i.e., where the geological unit is not present), the hydraulic conductivity value is assigned based on the underlying geologic unit (shown in Figure 11). This occurs on the western side of the model domain, where the Bobcaygeon, Gull River, Rockcliffe and Oxford Formations pinch out.

All geologic units were assigned the same hydraulic conductivity value on both the east and west side of the Pakenham Fault. As indicated on Figure 11, anisotropy ranges from horizontal to vertical ratios of 1:1 to 100:1.

The Bobcaygeon, Gull River and Rockcliffe Formations were assigned lower hydraulic conductivity values than the March/Nepean Formations. The Gull River Formation was divided into upper and lower hydrostratigraphic units, which is consistent with the results of hydraulic testing onsite. The hydraulic conductivity of the upper Gull River Formation was assigned a hydraulic conductivity 8x higher than the lower Gull River Formation. Based on calibration, the assigned hydraulic conductivity values for the Rockcliffe and March/ Nepean Formations were approximately one order of magnitude lower than the results of hydraulic testing on site. The Oxford Formation was assigned a hydraulic conductivity of 1 x 10^{-7} m/s, which is consistent with previous groundwater modelling completed at other quarries in the Ottawa area.

Table 11: Model Hydraulic Conductivity Values

Unit	Hydraulic Conductivity (m/s)	
	Horizontal	Vertical
Overburden (Clay)	$1x10^{-7}$	$1x10^{-8}$
Weathered Bedrock	$1x10^{-4}$	$1x10^{-4}$
Bobcaygeon Formation	$2x10^{-8}$	$2x10^{-9}$
Upper Gull River Formation	$8x10^{-7}$	$8x10^{-9}$
Lower Gull River Formation	$1x10^{-7}$	$1x10^{-9}$
Rockcliffe Formation	$5x10^{-7}$	$5x10^{-9}$
Oxford Formation	$1x10^{-7}$	$1x10^{-9}$
March/ Nepean Formations	$3x10^{-5}$	$3x10^{-7}$
Precambrian Bedrock	$1x10^{-8}$	$1x10^{-8}$

The model recharge distribution is illustrated on Figure 12. Recharge values applied in the model were originally defined based on surficial geology, and subsequently refined through the model calibration process (described below). The resulting model recharge in the areas with overburden clay deposits at surface is 1 millimetre per year (mm/yr). Where no overburden is present the recharge applied to weathered bedrock is divided into two zones, where 30 mm/yr is applied to the topographic high area (elevation >155 m ASL) and 17mm/yr is applied to the remaining weathered bedrock area.

6.2.5 Model Calibration

Calibration of the groundwater flow model involved refinement of the material properties of the main hydrostratigraphic units until the simulated hydraulic head distribution compared reasonably well with measured conditions. The primary calibration targets were comprised of a set of 11 measured groundwater elevations at on-site monitoring points and 321 static groundwater elevations from the MECP WWIS database. Monitoring locations DD03-2A/B and TW-2A/B/C were excluded from the target dataset as they were last monitored in 2007 and 2014, respectively, and have since been removed. These measurements are not considered representative of the conditions considered in the groundwater model due to changes in the quarry configuration since the last groundwater levels were measured at these locations. Similarly, spurious MECP WWIS data were not included in the calibration dataset. The data within the MECP WWIS spans the period from 1953 to 2017. Due to the varying frequency of groundwater level measurement collection between monitoring locations these data represent time-averaged conditions and are not representative of a single “snapshot”.

Results of the model calibration are shown on Figure 13, and summarized as follows:

- The overall calibrated model achieved a normalized root mean squared (nRMS) error of 9.96%, with an absolute mean difference of 4.46 m and a residual mean error of -2.22 m. For the 11 on-site monitoring points the calibrated model achieved a nRMS error of 7.62%, with an absolute mean difference of 1.90 m and a residual mean error of 0.23 m.
- The simulated head was generally within 5 m of the measured value (this was true for over half of the data points). A review of the spatial distribution of residual error does not show any significant spatial bias.
- A visual comparison of the simulated (Figure 13) and measured (Figure 6) groundwater head distribution and groundwater flow paths show that the simulated groundwater flow patterns are reasonable. Groundwater flow is generally simulated to follow the central surface divide (i.e., follows topography) in the model domain.

Based on the calibration statistics in combination with the general patterns of groundwater flow and overall water balance, the model is considered to provide a reasonable match to observed conditions at the site. The calibrated groundwater model, as described above, is subsequently used as the basis for construction of the forecast groundwater model.

6.3 Forecast Simulations

The groundwater flow model was configured through adjustments to the quarry drain boundaries to represent six scenarios, defined as follows:

- **Scenario 1** – full development of the existing West Carleton Quarry (i.e., final floor elevation 107 m ASL) and the Burnt Lands Quarry at current conditions. Current conditions for the Burnt Lands Quarry were estimated using topography from the Ontario Ministry of Natural Resources Digital Raster Acquisition Project Eastern Ontario (DRAPE) 2014 Digital Terrain Model (DTM) and Orthoimagery. This condition represents the current partial development of Burnt Lands Quarry.
- **Scenario 2** – full development of the existing West Carleton Quarry and Extension Lands (i.e., final floor elevation 107 m ASL) with the Burnt Lands Quarry at current conditions.
- **Scenario 3** – full development of the existing West Carleton Quarry and Extension Lands (i.e., final floor elevation of 107 m ASL) with the Burnt Lands Quarry at predevelopment conditions.
- **Scenario 4** – full development of the Burnt Lands Quarry (i.e., final floor elevation of 122 m ASL) with the existing West Carleton Quarry and Extension Lands at predevelopment conditions.
- **Scenario 5** – full development of the existing West Carleton Quarry and Extension Lands to 107 m ASL and full development of the Burnt Lands Quarry to 122 m ASL.
- **Scenario 6** – existing West Carleton Quarry and Extension Lands at rehabilitation conditions (lake level at 124 m ASL) and Burnt Lands Quarry at rehabilitation conditions (lake level at 150 m ASL).

The rehabilitation plan for the Extension Lands involves backfilling to original ground surface, which would result in a water table that is above the lake level (124 m ASL) in the backfilled areas. However, we have assumed for modelling purposes (i.e., Scenario 6) that the Extension Lands have been rehabilitated as a lake at the same level as the existing West Carleton Quarry (124 m ASL). This is considered to be a conservative assumption and would result in the maximum potential residual drawdown following rehabilitation. When the Extension Lands are backfilled as proposed, the residual drawdown following rehabilitation would be less than presented in the results for Scenario 6 provided below.

Results of the forecast scenario simulations 1, 2, 3, 4 and 6 are presented on Figure 14 through 18 in terms of the simulated drawdown in the Rockcliffe Formation relative to predevelopment conditions. Based on the modelling results, the greatest drawdown under the modelling scenarios was observed in the Rockcliffe Formation. Scenarios 3 and 4 were completed to identifying the area between the quarries where cumulative drawdown occurs and to assist with estimating the proportion of cumulative drawdown (as calculated in Scenario 5) attributable to the development of the existing West Carleton Quarry plus the Extension Lands versus the development of the Burnt Lands Quarry for each well within the model domain. Scenario 5 was completed to estimate the cumulative drawdown for the wells within the model domain associated with the full development of the existing West Carleton Quarry plus Extension Lands, and the full development of the Burnt Lands Quarry. A separate figure illustrating the drawdown contours for Scenario 5 is not presented.

A review of the figures allows the following observations:

- As shown on Figure 14, simulated drawdown resulting from the full development of the existing West Carleton Quarry with the Burnt Lands Quarry at current conditions (Scenario 1) extends approximately 3 km to the northwest, and 2 km to the northeast, southeast and southwest (as measured from the existing West Carleton Quarry property boundary to the 1-m drawdown contour). As noted previously, this includes drawdown resulting from the Burnt Lands Quarry under current conditions. It is recognized that the drawdown reaches the northeast model boundary. This is considered conservative with respect to the estimation of the overall extents of drawdown as there is a no-flow boundary in the lower portion of the model at this location.
- As shown on Figure 15, the addition of the proposed Extension Lands (Scenario 2) results in the 1-m drawdown contour extending an additional 100 m to 200 m to the northeast and southwest, and 50 m to 400 m to the southeast, compared to Scenario 1. Figure 16 provides the simulated incremental drawdown resulting from the development of the proposed Extension Lands. The incremental drawdown is calculated by subtracting the predicted Scenario 1 drawdown from the predicted Scenario 2 drawdown and contouring the remaining drawdown). As shown on Figure 16, the incremental change in drawdown resulting from adding the Extension Lands was estimated to extend approximately 700 m in all directions from the northwest corner of the Extension Lands (based on the 1-m drawdown contour).
- Figure 17 shows the simulated drawdown resulting from the full development of the existing West Carleton Quarry plus the Extension Lands with the Burnt Lands Quarry at predevelopment conditions (Scenario 3 – blue contours on Figure 17) and the simulated drawdown resulting from the full development of the Burnt Lands Quarry with the existing West Carleton Quarry plus the Extension Lands at predevelopment conditions (Scenario 4 – green contours on Figure 17). The area where the 1-m drawdown contours for Scenario 3 and Scenario 4 overlap is referred to as the ‘Zone of Cumulative Impact’ as identified on Figure 17.
- Figure 18 shows the simulated residual drawdown following the rehabilitation of the existing West Carleton Quarry, the Extension Lands and the Burnt Lands Quarry (Scenario 6). The residual drawdown extends approximately 3 km to the west/northwest, and 1.5 km to the southeast and southwest (based on the 1-m drawdown contour). On the east/northeast side of the existing West Carleton Quarry, the residual drawdown is minimal due to the decline in topography in this direction. This represents a condition where the existing West Carleton Quarry and Extension Lands are flooded to an elevation of 124 m ASL and the Burnt Lands Quarry is flooded to and elevation of 150 m ASL.

6.4 Sensitivity Simulations

Additional simulations were completed in order to examine the sensitivity of model results to some of the key controlling parameters of the hydrogeological system and assumptions made in the development of the conceptual model. The focus of these simulations was on the hydraulic conductivity of the Rockcliffe Formation and the surficial recharge applied to the top surface of the model. In selecting these scenarios, an effort was made to maximize the deviation from the base case parameter value while maintaining an acceptable model calibration. A total of four additional simulations were completed with model Scenario 1 (full development of the West Carleton Quarry under the existing license with the Burnt Lands Quarry at current conditions) and Scenario 2 (full development of the existing West Carleton Quarry and Extension Lands with the Burnt Lands Quarry at current conditions) described as follows:

- **Sensitivity Run 1 (SR1)** – For this simulation, the hydraulic conductivity of the Rockcliffe Formation was increased by a factor of 2 (i.e., from 5 x 10^{-7} m/s to 1 x 10^{-6} m/s)
- **Sensitivity Run 2 (SR2)** – For this simulation, the hydraulic conductivity of the Rockcliffe Formation was decreased by a factor of 2 (i.e., from 5 x 10^{-7} m/s to 1 x 10^{-6} m/s)
- **Sensitivity Run 3 (SR3)** – For this simulation, a 10% global increase in surficial recharge was applied.
- **Sensitivity Run 4 (SR4)** – For this simulation, a 10% global decrease in surficial recharge was applied.

The results of the sensitivity simulations using forecast Scenarios 1 and 2 were used to calculate the change in the incremental drawdown associated with changes to the hydraulic conductivity of the Rockcliffe Formation and surface recharge resulting from developing the proposed Extension Lands. The results are presented on Figure 19 as an illustration of the combined range in spatial extent of the 1-m incremental drawdown contour resulting from all four sensitivity simulations. In general, the sensitivity simulation results showed minimal change in the extent of incremental drawdown, indicating that the base case simulation is a reasonable estimate with respect to the calculated drawdown. For SR2 (hydraulic conductivity of the Rockcliffe Formation decreased by a factor of 2), the extent of incremental drawdown was reduced by a maximum of approximately 150 m towards the northeast of the proposed Extension Lands. SR4 (10% global decrease in surficial recharge) showed a similar result to SR2, with a reduction of the extent of incremental drawdown by up to 100 m in the northeast and northwest of the proposed Extension Lands. For SR1 (hydraulic conductivity of the Rockcliffe Formation increased by a factor of 2), the extent of incremental drawdown was increased by a maximum of approximately 100 m in the area to the northwest of the proposed quarry extension, though was typically within 50 m of the base case. For SR3 (10% global decrease in surficial recharge), the incremental drawdown was within 50 m of the base case.

7.0 DESKTOP SURFACE WATER ASSESSMENT AND WATER BALANCE ANALYSIS

A water balance was completed for baseline conditions (full extraction of the existing quarry - Scenario 1), operational conditions (full extraction of both the existing quarry and extension lands - Scenario 2) and rehabilitation conditions (Scenario 6) for the study area. The study area includes the land within the property boundary of the existing licensed quarry and the proposed Extension Lands. The total study area is approximately 157.2 ha. For detailed water balance tables and figures refer to Appendix G.

7.1 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 baseline conditions was identified from satellite imagery. Land use under operational conditions was based on the ARA Site Plan. Although the proposed rehabilitation plan for the Extension Lands involves backfilling of the site to original ground surface, the land use during rehabilitation conditions conservatively assumes the Extension Lands and the existing West Carleton Quarry excavations are flooded with the setback areas remaining vegetated (discussed further in Section 7.5.3). The land use data was 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:

$$P = S + ET + \text{Surplus}$$

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 station 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 G1, Appendix G. For wetland and open water, the evaporation is calculated as precipitation minus potential evapotranspiration. This assumption is generally supported by comparing available lake evaporation from Environment Canada.

7.2 Catchment Delineation

The drainage area associated with the existing West Carleton Quarry and the proposed Extension Lands was delineated using the Ontario Flow Assessment Tool (OFAT) and ground-truthed in the field (refer to Figure 2). The drainage area in which the study area is located is approximately 6.8 km^2 (681 ha). Surface drainage is generally to the east, following topography, under Scenario 1 conditions. The study area includes the land within the property boundary of the existing licensed quarry and the proposed Extension Lands. The total study area is approximately 157.2 ha. The proposed extension is within the same catchment as the existing quarry area. Therefore, the catchment area and drainage direction will be preserved with the extraction of the proposed Extension Lands. The Extension Lands boundary is approximately 18.2 ha with 16.5 ha being proposed for extraction. Runoff from a small area west of the proposed extension will be within the setback and will primarily flow into the excavation with some areas being diverted around the excavation using perimeter berms. As mentioned previously, the entire site is within the baseline drainage area.

The existing West Carleton Quarry property boundary is approximately 141.6 ha based on the MNRF site plan. The approved extraction area within the existing property boundary is approximately 90.2 ha. It has been assumed for Scenario 2 (full extraction of the West Carleton Quarry and the Extension Lands) that any precipitation inputs to the proposed excavation will be drained east on the quarry floor and contribute to the existing quarry sump along with groundwater seepage. Water collected in the quarry sump will be detained long enough to settle suspended solids, then discharge to the east and north to the Manion Corners Long Swamp, similar to existing conditions and in compliance with MECP permits and approvals for the site. Under existing conditions, water discharges by gravity from the quarry sump, while pumping will be required in the future when extraction in the existing extraction area proceeds below the surrounding grade along the east side of the quarry.

Under rehabilitated conditions (Scenario 6), the Extension Lands quarry area was assumed to be flooded along with the existing quarry area as this scenario represents a conservative bounding case for rehabilitated conditions. For comparison purposes, Golder also assessed a second rehabilitation scenario assuming that the extension lands are backfilled, and the existing quarry area is flooded as described in Section 1.1.

7.3 Water Balance Scenarios

Under baseline conditions (Scenario 1 as described in Section 6.3), the Extension Lands are primarily composed of shallow bedrock / stripped land and wooded areas as shown on Figure G1 (i.e., Scenario 1a). A second baseline condition (Scenario 1b) was completed for comparison purposes, assuming rehabilitation of the existing licensed quarry (i.e., flooded) and the Extension Lands as current conditions. Scenario 1b is shown on Figure G2.

Under operational conditions (Scenario 2 as described in Section 6.3), most of the site will be extracted within the existing West Carleton Quarry and Extension Lands. A narrow border of shrubs/natural growth areas (setback boundary), lawn/grass (berm) and gravel/paved (entrance) will be left along the north and west borders of the Extension Lands, as shown on Figure G3. The Manion Corners Long Swamp Wetland Complex will remain adjacent to the east side of the West Carleton Quarry. During operation, runoff will flow from the proposed Extension Lands extraction area to the existing quarry sump as described in Section 7.2.

Rehabilitated conditions (Scenario 6 as described in Section 6.3) were also considered in this study to estimate the water surplus after extraction has ceased within the Extension Lands. The rehabilitation plan for the Extension Lands includes backfilling to original ground surface. To remain conservative, potential changes to the water balance under rehabilitated conditions were assessed for both backfilling of the Extension Lands and rehabilitation of the Extension Lands as a lake. The intension was to identify which of the rehabilitation options resulted in the worst-case changes to the water balance and the results of the worst-case option would be carried forward for use in the impact assessment (see Section 8.2.2). The flooded conditions scenario is conservative (worst-case) due to increased evaporation resulting in less available surplus. As such, the flooded conditions scenario is carried forward in the assessment presented below. The flooded conditions rehabilitation scenario is shown on Figure G4.

7.4 Water Balance Parameters

Soil information was taken from SOLRIS 3.0, Ontario Ministry of Natural Resources and Forestry (May 2019). Soils at the site are primarily composed of bedrock exposed at surface or overlain by a thin, laterally discontinuous, cover of overburden. Further to the east/southeast there is an extensive area of organic deposits associated with the Manion Corners Long Swamp Wetland Complex. Bedrock was used as the soil type for the proposed quarry under operational conditions based on existing borehole results as discussed in Section 4.1.

The maximum soil storage is quantified using a 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 open water, the average annual surplus is assumed as the average annual precipitation minus the average potential evapotranspiration (reflecting the significant depth of water from which evapotranspiration can be drawn). For surface water areas (including wetlands, treed swamp and marsh), the actual evaporation losses are assumed to equal the potential evaporation losses. While lake evaporation may differ from Potential Evapotranspiration (PET) based on surface areas, orientation, aspect ratio, fetch and wind shelter, review of available pan evaporation data in Southern and Eastern Ontario suggests that Lake Evaporation is typically similar to PET.

Scenario 1 (Baseline), Scenario 2 (Operational) and Scenario 6 (Rehabilitated) catchment areas are summarized by land use, WHC and soil type are listed below and can be found in Table G2 in Appendix G.

- For quarry extraction areas, a WHC of 10 mm was used, representing the impermeable quarry floor.
- For forested areas over bedrock, a WHC of 150 mm was used, representing rolling woodlands over impervious soil.
- For forested areas over organic deposits, a WHC of 400 mm was used, representing rolling woodlands over combinations of clay and loam.
- For swampland and open water, the WHC is calculated as precipitation minus potential evapotranspiration. This assumption is generally supported by comparing available lake evaporation from Environment Canada.
- For transportation (i.e., quarry entrance and haul roads) a WHC of 3 mm was used to reflect average depression storage.

7.5 Water Balance Results

Surplus values were calculated as the annual precipitation minus annual actual evapotranspiration. The results of the full assessment can be found in Appendix G. The water balance results for the baseline, operational and rehabilitated conditions are provided in Table G3 in Appendix G.

7.5.1 Scenario 1 Baseline Conditions

Two baseline scenarios were completed for comparison purposes. The first baseline scenario (Scenario 1a) assumes that the existing West Carleton Quarry is fully extracted, and the Extension Lands are represented as current conditions. The second baseline scenario (Scenario 1b) assumes that the existing quarry is rehabilitated (i.e., flooded) based on the approved license, and the Extension Lands are represented as current conditions.

The total average annual surplus for the site area under baseline conditions Scenario 1a (i.e., the existing West Carleton Quarry is fully extracted and Extension Lands as current conditions) was estimated to be approximately 403 mm or 633,600 m^3 per year.

The total average annual surplus for the site area under baseline conditions Scenario 1b (i.e., the existing West Carleton Quarry is flooded and Extension Lands as current conditions) was estimated to be approximately 327 mm or 514,500 m^3 per year.

7.5.2 Scenario 2 Operational Conditions (Full Extraction)

The total average annual surplus under operational conditions (i.e., full extraction of the existing West Carleton Quarry and the Extension Lands) was estimated to be approximately 410 mm or 644,700 m^3/year.

7.5.3 Scenario 6 Rehabilitation Conditions

The rehabilitation plan for the Extension Lands involves backfilling to original ground surface. To remain conservative, potential changes to the water balance were assessed for both backfilling of the Extension Lands and rehabilitation of the Extension Lands as a lake. As discussed in Section 7.3, based on the water balance assessment, the flooded quarry scenario is more conservative (i.e., worst-case), allowing additional lake evaporation to occur compared to vegetated land. Although the flooded lake scenario is slightly more conservative, both rehabilitation scenarios result in similar surplus values, therefore either scenario will result in a similar minor change to the water balance.

The total average annual surplus for the site under the worst-case rehabilitated conditions scenario (i.e., both the existing West Carleton Quarry and the Extension Lands are flooded) was estimated to be approximately 321 mm or 503,800 m^3 per year.

7.6 Water Balance Summary

A summary of the of the annual water balance for the baseline, operational, and rehabilitated conditions is provided in Table 12 below. A detailed summary of the water balances is provided in Table G3 in Appendix G.

Table 12: Water Balance Summary

Scenario	Annual Surplus (m3/yr)	Percent Change
Scenario 1a	633,600	-
Scenario 1b	514,500	-
Scenario 2	644,700	+1.8% (comparison between 1a and 2)
Scenario 6	503,800	-2.1% (comparison between 1b and 6)

Under operational conditions, surplus is anticipated to increase by approximately 1.8% from 633,600 m^3 (Scenario 1a) to 644,700 m^3 (Scenario 2) per year due to the extraction of the extension lands. Under rehabilitated conditions, it is assumed that the Extension Lands and the existing quarry will be flooded. The total surplus is anticipated to decrease by approximately 10,700 m^3/year (2.1%) from 514,500 (Scenario 1b) to 503,800 m^3 (Scenario 6) per year.

8.0 IMPACT ASSESSMENT

The following section provides an assessment of the potential impacts on surrounding receptors associated with the development and rehabilitation of the proposed Extension Lands, as well as an assessment of the potential cumulative impacts associated with the development of the existing West Carleton Quarry plus the Extension Lands, and the existing Burnt Lands Quarry located to the west (see location on Figure 1).

The primary groundwater receptors in the vicinity of the site are the private wells located within the predicted zone of groundwater drawdown. Potential impacts to the existing WHPA-D for the Village of Almonte water supply wells located west of the site is also discussed. The main surface water receptors in the vicinity of the site are the Manion Corners Long Swamp Wetland Complex located to the east/southeast and Cody Creek.

8.1 Existing Groundwater Users

8.1.1 Operations

During operations, dewatering of the existing West Carleton Quarry and Extension Lands, and the existing Burnt Lands Quarry below the groundwater table has the potential to cause a decline in groundwater levels/piezometric levels in adjacent areas. These drawdown/depressurization effects have the potential to lower the groundwater levels in nearby water supply wells. The wells in the vicinity of the site primarily service the residences along March Road, Burnt Lands Road and Upper Dwyer Hill.

8.1.1.1 Development of Extension Lands – Incremental Drawdown Assessment

Figure 14 presents the drawdown associated with the development of the existing West Carleton Quarry to an approved base elevation of 107 m ASL and the Burnt Lands Quarry at current conditions (Scenario 1). Figure 15 presents the drawdown associated with the development of the existing West Carleton Quarry plus the Extension

Lands to a base elevation of 107 m ASL and the Burnt Lands Quarry at current conditions (Scenario 2). Figure 16 displays the incremental drawdown associated with the development of the Extension Lands. Incremental drawdown refers to the additional drawdown resulting from the development of the proposed Extension Lands (i.e., above and beyond the drawdown associated with dewatering the fully extracted existing West Carleton Quarry and current extraction conditions at the existing Burnt Lands Quarry). The incremental drawdown was calculated by contouring the remaining drawdown after subtracting the Scenario 1 drawdown (Figure 14) from the Scenario 2 drawdown (Figure 15). The 'Zone of Incremental Drawdown' is defined as the area within the 1-m incremental drawdown contour as shown on Figure 16 and Figure 20. The locations of the water supply wells within the Zone of Incremental Drawdown as provided by the MECP WWIS (filtered for locations having an accuracy code within 300 of the correct location) are shown on Figure 20. A total of 7 water supply wells are identified within the Zone of Incremental Drawdown (identified as 1525284, 1514922, 1513826, 1514195, 1513825, 1513680 and 1514257).

Table 13 below summarizes the predicted drawdown for each well within the Zone of Incremental Drawdown under Scenario 1 and Scenario 2, and presents the total predicted additional drawdown associated with the development of the Extension Lands.

Table 13: Predicted Incremental Drawdown Associated with the Development of the Extension Lands

Location	Scenario 1 – Drawdown Associated with Full Development of the Existing West Carleton Quarry (m)	Scenario 2 – Drawdown Associated with Full Development of the Existing West Carleton Quarry Plus Extension Lands (m)	Incremental Additional Drawdown Associated with the Development of the Extension Lands (m)
1525284	7.04	10.09	3.05
1514922	6.88	9.91	3.04
1513826	5.99	8.10	2.11
1514195	5.14	6.64	1.50
1513825	4.91	6.27	1.36
1513680	9.02	10.24	1.22
1514257	4.47	5.61	1.14

As shown in Table 13, the maximum additional drawdown predicted at a nearby water supply well as a result of the development of the Extension Lands is approximately 3 m.

8.1.1.2 Cumulative Drawdown Assessment – Full Development of the Existing West Carleton Quarry Plus Extension Lands, and Full Development of the Burnt Lands Quarry

The predicted drawdown under the following operational scenarios was used to assess the cumulative drawdown associated with the full development of the existing West Carleton Quarry plus Extension Lands, and full development of the Burnt Lands Quarry.

- Scenario 3 – Full development of the existing West Carleton Quarry and Extension Lands (i.e., final floor elevation of 107 m ASL) with the Burnt Lands Quarry at predevelopment conditions. Scenario 3 was completed to define the drawdown contours associated with the full development of the existing West Carleton Quarry and Extension Lands in the absence of any development at the Burnt Lands Quarry, and to assist with estimating the proportion of cumulative drawdown attributable to the development of the existing West Carleton Quarry and Extension Lands.

- Scenario 4 – Full development of the Burnt Lands Quarry (i.e., final floor elevation of 122 m ASL) with the existing West Carleton Quarry and Extension Lands at predevelopment conditions. Scenario 4 was completed to define the drawdown contours associated with the full development of the Burnt Lands Quarry in the absence of any development at the existing West Carleton Quarry and Extension lands, and to assist with estimating the proportion of cumulative drawdown attributable to the development of the Burnt Lands Quarry.
- Scenario 5 – Full development of the existing West Carleton Quarry and Extension Lands to 107 m ASL and full development of the Burnt Lands Quarry to 122 m ASL.

Figure 20 displays the overlapping area between the 1-m drawdown contour associated with the full development of the existing West Carleton Quarry and the Extension Land (Scenario 3) and the 1-m drawdown contour associated with the full development of the Burnt Lands Quarry (Scenario 4). The area where the 1-m drawdown contours for Scenario 3 and Scenario 4 overlap is referred to as the 'Zone of Cumulative Impact' (see identified area on Figure 20). Using the drawdown results from Scenario 3 and Scenario 5, the percentage of cumulative drawdown attributable to the development of the existing West Carleton Quarry plus the Extension Lands was calculated at each water supply well within the identified Zone of Cumulative Impact. The impact assessment presented below focuses on all water supply wells within the Zone of Cumulative Impact where 50 percent or more of the predicted cumulative drawdown results from the development of the existing West Carleton Quarry plus Extension Lands. In addition, well location 1513680, which is located within the identified Zone of Incremental Drawdown (see location on Figure 20) but is outside the Zone of Cumulative Impact, is included in the impact assessment present below.

The predicted drawdown as a result of quarry operations for development Scenarios 1 through Scenario 5 for each water supply well within the Zone of Cumulative Impact having 50 percent or greater of the predicted cumulative drawdown attributed to the development of the existing West Carleton Quarry and the Extension Lands, plus well location 1513680, is provided in Table E1 in Appendix E. Table E1 also provides well completion details for the water supply wells, as well as the static water level measured at the time of drilling (as per the water well record). In Table E1, the static water elevation (Column 7) and the well bottom elevation (Column 6) were used to estimate the available drawdown (Column 8) for each water supply well. The percentage of cumulative drawdown attributed to the development of the existing West Carleton Quarry plus the Extension Lands is provided in Column 15 of Table E1.

The wells originally identified within the Zone of Incremental Drawdown (see Section 7.1.1.1) are included within the Zone of Cumulative Impact except for location 1513680. These wells are presented in the first seven rows of Table E1. As shown in Table E1, the drawdown predicted at these wells is greater under Scenario 5 (Column 14) than Scenario 2 (Column 10). As such, to remain conservative, for the impact assessment present below the potential impacts for <u>all</u> well locations in Table E1 are assessed based on the predicted drawdown associated with Scenario 5 (i.e., full development of the existing West Carleton Quarry plus the Extension Lands and full development of the Burnt Lands Quarry).

Column 16 in Table E1 presents the predicted remaining available drawdown for each well location following the full development of the existing West Carleton Quarry and the Extension Lands with full development of the Burnt Lands Quarry and was calculated by subtracting the predicted drawdown under Scenario 5 (Column 14) from the available drawdown (Column 8).

Table 14 below summarizes the predicted available drawdown at the private well locations following full development (Scenario 5).

Table 14: Predicted Available Drawdown Following Full Development of Existing West Carleton Quarry plus Extension Lands and Full Development of Burnt Lands Quarry (Scenario 5)

Location	Predicted Available Drawdown Following Full Development (Scenario 5)
1525284	32.1
1514922	58.2
1513826	37.0
1514195	27.9
1513825	14.6
1513680	21.2
1514257	52.9
1514679	57.3
7160750	17.7
7113238	47.2
7047643	36.2
3514716	67.0
1510248	25.8
1526758	22.6
3508784	23.6
3503840	13.6
1529986	20.5
3502291	16.4
3506819	18.14
3502143	10.87

As shown in Table 14, the predicted available drawdown following full development of the existing West Carleton Quarry plus the Extension Lands and the full development of the Burnt Lands Quarry (Scenario 5) is greater than 15 m for all locations except 1513825, 3503840 and 3502143. Well interference at water supply wells having greater than 15 m of available drawdown remaining is not anticipated. The potential for impacts at water supply wells 1513825, 3503840 and 3502143 are discussed below. For reference, water well records for 1513825, 3503840 and 3502143 are provided in Appendix F.

8.1.1.2.1 Private Well 1513825

Based on the groundwater modelling results, the predicted remaining available drawdown for private well 1513825 is 14.6 m following full development of the existing West Carleton Quarry plus the Extension Land and full development of the Burnt Lands Quarry. At the time of drilling, supply well 1513825 was pumped at a rate of approximately 23 L/min for one hour. Based on the water level data recorded during the pumping test, drawdown occurred for the first 30 minutes of pumping and was then stable for the remainder of the test. Supply well 1513825 appears to be capable of supplying at least 23 L/min and is not considered to be a low yield well. As such, the remaining 14.6 m of available drawdown is considered sufficient and well interference is not predicted at 1513825.

8.1.1.2.2 Private Well 3503840

Based on the groundwater modelling results, the predicted remaining available drawdown for private well 3503840 is 13.6 m following full development of the existing West Carleton Quarry plus the Extension Lands and full development of the Burnt Lands Quarry. At the time of drilling, supply well 3503840 was pumped at a rate of approximately 38 L/min for one hour. Based on the water level data recorded during the pumping test and the recommended pumping rate on the water well record, supply well 3503840 appears to be capable of supplying 38 L/min and is not considered to be a low yield well. As such, the remaining 13.6 m of available drawdown is considered sufficient and well interference is not predicted at 3503840.

8.1.1.2.3 Private Well 3502143

Based on the groundwater modelling results, the predicted remaining available drawdown for private well 3502143 is 10.9 m following full development of the existing West Carleton Quarry plus the Extension Lands and full development of the Burnt Lands Quarry. At the time of drilling, supply well 3502143 was pumped at a rate of approximately 38 L/min for one hour. Based on the water level data recorded during the pumping test, there was minimal drawdown (i.e., less than 2 m). Supply well 3502143 appears to be capable of supplying at least 38 L/min and is not considered to be a low yield well. As such, the remaining 10.9 m of available drawdown is considered sufficient and well interference is not predicted at 3502143.

8.1.1.3 Village of Almonte Wellhead Protection Area

Based on groundwater modelling completed for the Mississippi Valley Source Protection Area Assessment Report (2011), WHPA-D (5- to 25-year time of travel) for the Village of Almonte supply wells was mapped on the lands immediately to the west of the Extension Lands and on the southwestern most corner of the Extension Lands. Because the Nepean Formation is the primary source of water for the Almonte wells, the WHPAs for the Almonte wells are mapped within the Nepean Formation. The proposed extraction within the Extension Lands will occur within the Bobcaygeon and Gull River Formations. Beneath, and immediately to the west of the Extension Lands there is a significant separation between the Bobcaygeon and Gull River Formations and the deeper Nepean Formation (i.e., the Nepean Formation is at a depth of greater than 80 metres beneath the base of the proposed quarry within the Extension Lands). In addition, there will be no fuel storage within the Extension Lands. As such, impacts to the groundwater quality or quantity at the Village of Almonte supply wells as a result of the proposed development of the Extension Lands is not predicted.

8.1.1.4 Operations Impact Assessment Summary

Based on the above impact assessment (including an assessment of cumulative impacts associated with development of the Burnt Lands Quarry), interference with private water supply wells and the Village of Almonte supply wells as a result of the full development of the existing West Carleton Quarry and the Extension Lands is not predicted. As discussed in Section 10, the proposed groundwater level monitoring program will permit the collection of long-term groundwater level data as the existing West Carleton Quarry and Extension Lands develop. These data will show the actual changes in groundwater levels within the monitoring wells completed around the extraction areas as the quarry expands laterally and vertically and can be used to further assess the propagation of the drawdown cone. In the unlikely event that complaints are received regarding interference to water wells in the vicinity of the site, the complaints response plan discussed in Section 9 would be implemented.

8.1.1.5 Rehabilitation

Following the completion of site operations, the proposed rehabilitation of the Extension Lands involves backfilling to existing ground surface. To the east and south of the Extension Lands, the existing West Carleton Quarry will be rehabilitated as a lake. Along these boundaries, 2:1 (horizontal:vertical) slopes down to the lake will be constructed and some shallow littoral zones will be created along the lake edge. The elevation of the water level within the flooded Existing West Carleton Quarry will be controlled by the low point around the perimeter of the extraction area. Based on a review of the available elevation data, flood back will result in the creation of a lake with a surface elevation of approximately 124 m ASL.

As discussed in Section 6.3, to remain conservative, we have assumed for modelling and impact assessment purposes that the Extension Lands have been rehabilitated as a lake at the same level as the existing West Carleton Quarry (124 m ASL). This results in the maximum potential residual drawdown following rehabilitation. When the Extension Lands are backfilled as proposed, the residual drawdown, and the associated potential impacts to surrounding receptors, following rehabilitation would be less than discussed in the impact assessment below.

The predicted residual drawdown following quarry operations (i.e., when the existing West Carleton Quarry and Extension Lands have flooded back to 124 m ASL) for the water supply wells included in Table E1 is presented in Column 17 (Scenario 6) and is presented on Figure 18. Scenario 6 also assumes that the Burnt Lands Quarry is rehabilitated and has a lake level of 150 m ASL. As shown in Table E1, the predicted drawdown following rehabilitation (Column 17) is significantly less than the predicted drawdown during the full development of the existing West Carleton Quarry plus the Extension Lands, and the full development of the Burnt Lands Quarry (Column 14) for all well locations. As such, because well interference is not predicted under the full development scenario (Scenario 5; Column 14 in Table E1), interference with water supply wells following rehabilitation is also not predicted.

8.2 Surface Water Features

8.2.1 Surface Water Receptors

The surface water receptor for both the existing West Carleton Quarry and the proposed Extension Lands is the Manion Corners Long Swamp wetland located east of the site. The proposed extension is within the catchment of the wetland and does not change the drainage area contributing to it. The nearby Burnt Lands Quarry is located in an adjacent subcatchment of Cody Creek and drainage from it does not interact with drainage from the West Carleton Quarry until it reaches the main channel of Cody Creek north of the site. On site wetlands were investigated by Golder's certified OWES evaluators, who concluded that the on-Site wetlands should not be complexed with the Manion Corners Long Swamp PSW and that they provide limited and seasonal hydrological function (Golder 2021).

8.2.2 Surface Water Effects Assessment

Under operational conditions (Scenario 2), surplus is anticipated to increase by approximately 1.8% or 11,100 m^3/year compared to the baseline condition (Scenario 1a) due to land use change to impervious extracted land type with a smaller WHC and larger annual surplus rate.

Under rehabilitated conditions (Scenario 6), it is assumed that the Extension Lands and the existing quarry will be flooded. The total surplus, compared to baseline Scenario 1b, is anticipated to decrease by approximately 2.1% or 10,700 m^3/year. This change is a result of the land use change from forest on bedrock to a flooded lake resulting in additional evaporation. Table 15 below summarizes the expected change in surplus under operational conditions (Scenario 2) and rehabilitated conditions (Scenario 6), compared to the baseline conditions (Scenario 1a and 1b).

Table 15: Summary of changes. Scenario 2 and 6 compared to Scenario 1

Scenarios	Surplus Change compared to Scenarios 1a and 1b	
	m3/year	%
Scenario 2	+11,100	+1.8
Scenario 6	-10,700	-2.1

Precipitation falling within the Extension Lands will flow overland to the existing quarry sump and discharge will be managed through the existing permits and infrastructure on that site.

Ultimately, there will be no change in catchment area contributing to the Manion Corners Long Swamp or Cody Creek since all site runoff from baseline, operational, and rehabilitated conditions will continue to flow east via the existing West Carleton Quarry water management infrastructure. Quarry discharge rates are specified by the existing ECA for the site. Any future changes to the discharge rate, required to accommodate the Extension Lands, will require MECP review and approval as part of an ECA amendment application.

9.0 COMPLAINTS RESPONSE PROGRAM

Based on the results of the groundwater modelling and the review of local water supply wells, it is concluded that water well interference complaints attributable to the development of the existing West Carleton Quarry and the Extension Lands are unlikely. Water well interference complaints will be responded to in light of the collected monitoring data and under the *Complaints Response Program* described below.

A comprehensive complaints response program has been developed for the purpose of responding to well interference complaints from local water supply well users. Each complaint will be dealt with on a case-by-case basis. When a complaint is received by Cavanagh, a representative of Cavanagh and/or their agent will visit the site to make an initial assessment within three days of receiving the complaint. This will include a well/system inspection (where accessible) by a licensed pump maintenance contractor to determine the groundwater level, pump depth setting and condition of the well system. The available groundwater level data from the existing on-site monitoring well network will be reviewed by a licensed professional hydrogeologist/engineer to develop an estimate of the potential groundwater level drawdown at the potentially affected well that is the subject of the complaint response. The information obtained by the contractor from the well/well system inspection and the review of the available groundwater level data will be used by the professional hydrogeologist/engineer to prepare an opinion on the likelihood that the well interference complaint is attributable to quarry dewatering.

If it is concluded that the well interference complaint is most likely attributable to quarry dewatering activities at the site and the water supply is at risk, then a temporary supply will immediately be arranged, and a water supply restoration program will be implemented. The decision as to whether to proceed with the water supply restoration program will be based on a review of groundwater level information by the professional hydrogeologist/engineer and well construction and performance information from the licensed pump maintenance contractor as noted above.

The water supply restoration program consists of the following measures which are applicable for local water supply wells where the operation of the water supply wells may have been compromised by quarry excavation or based on the analysis of all monitoring data, are assessed to likely be compromised in the near future:

- Well System Rehabilitation – The well system could be rehabilitated by replacement or lowering of pumps, pump lines flushing, well deepening, etc. to improve performance. Where water is unavailable in the shallow bedrock and a well in deeper bedrock is being considered, a water sample(s) would be taken from the existing well for chemical, physical and bacteriological analyses prior to deepening the well to provide a basis of comparison. If the groundwater in the deeper bedrock is found to be of acceptable quality by the homeowner, either directly from the well or with treatment, it will be developed as the domestic supply. Any modifications to a well would be conducted in accordance with *Ontario Regulation 903*.
- Well Replacement or Additional Well(s) – The well could be replaced or augmented with a new well(s) that could be located further from the quarry excavation. The feasibility of well replacement would be based on a test drilling program that could include more than one test well. Where water is unavailable in the shallow bedrock and a well in deeper bedrock (compared to the original water supply well) is being considered, a water sample(s) would be taken from the existing well for chemical, physical and bacteriological analyses to provide a basis of comparison. If the groundwater in the deeper bedrock is found to be of acceptable quality by the homeowner, either directly from the well or with treatment, it will be developed as the domestic supply. Construction of a new well(s) would be conducted in accordance with *Ontario Regulation 903*.
- Trickle Wells and Storage – Where feasible, the existing well(s) could be converted to a low yield pumping system, or installation of an additional well(s), along with non-pressurized water storage to augment water supplies, if required.
- Water Treatment Considerations – Appropriate water treatment will be incorporated into any restored water supply as discussed above.

The data from the on-site test wells collected during pumping tests (Stanton 2001) indicate that the groundwater quality and quantity in the local deeper bedrock formations is acceptable (i.e., below the proposed extraction depth of the quarry). As such, deepening of local private water supply wells (i.e., into the Rockcliffe Formation) is considered to be a feasible contingency.

Cavanagh would be responsible for all costs associated with the water supply restoration program. It is important to note that water supply restoration activities undertaken to address an adverse effect would be done so in consultation with the affected property owner in order to ensure a mutually agreeable solution is implemented.

10.0 MONITORING PROGRAMS

Site-specific groundwater and surface water monitoring programs have been developed to measure and evaluate the actual effects on potential receptors associated with long-term development of the existing West Carleton Quarry and/or the Extension Lands, and to allow for a comparison of the actual effects measured during the monitoring program and those predicted as part of the impact assessment provided Section 8.0. The groundwater and surface water monitoring programs are discussed in the following sections.

If the results of the monitoring program indicate the potential for adverse impact to groundwater users or surface water features, then appropriate enhanced monitoring and/or mitigative actions would be developed.

10.1 Proposed Groundwater Level Monitoring Program

Recommendations for the site plan associated with the proposed monitoring program described below are provided in Section 12.0. The proposed groundwater level monitoring program would include the existing on-site monitoring wells listed below:

- DDH03-1A, DDH03-1B, TW-1, TW-3A, TW-3B, TW-6, MW15-1A, MW15-1B and MW15-1C

Under Condition 4.2 of PTTW No. 4175-AB4RS4 (dated July 18, 2016), the ongoing groundwater monitoring program at the site consists of groundwater level measurements in the existing on-site wells once during April or May, once during June or July, once during August or September and once during October or November each year.

The locations of the above existing monitoring wells included in the monitoring program are shown on Figure 2. Based on the locations of DDH03-1 and TW-3, these wells will be removed as part of quarry operations. These monitoring locations would not be replaced. Monitoring location MW15-1 is close to the edge of the extraction area and will likely need to be removed when progressive quarry development reaches this area. When MW15-1 is removed, it would be replaced with a similarly constructed monitoring well placed within the setback in the northwest corner of the site (i.e., across from Burnt Lands Road). The remaining existing monitoring well locations (TW-1 and TW-6) are not within the proposed extraction areas at the site. These wells would be replaced if damaged during site development.

10.1.1.1 Monitoring Frequency and Data Review

The existing PTTW requires groundwater levels be measured in on-site wells once during April or May, once during June or July, once during August or September and once during October or November each year. The proposed monitoring program for the combined West Carleton Quarry and Extension Lands would increase the frequency of groundwater level measurements to monthly. The groundwater level monitoring data would be used to assess groundwater level drawdown in bedrock in response to progressive quarry development and would be compared to the drawdown predicted by the groundwater flow model. The groundwater level monitoring program would be reassessed on an on-going basis to determine if changes to the monitoring program should be considered.

10.2 Proposed Surface Water Monitoring Program

The proposed surface water level monitoring program would include the existing on-site staff gauge SG-1. Under Condition 4.2 of PTTW No. 4175-AB4RS4 (dated July 18, 2016), water levels are to be measured at SG-1 once during April or May, once during June or July, once during August or September and once during October or November each year. The proposed monitoring program for the combined West Carleton Quarry and Extension Lands would increase the frequency of surface water level measurements at SG-1 to monthly.

Additional monitoring or restrictions on discharge rate, retention time and water quality will be regulated by the site ECA and PTTW, if required.

10.3 Instruments Prescribing Monitoring Program

The monitoring program for the existing West Carleton Quarry is undertaken to satisfy conditions included on the existing PTTW No. 4175-AB4RS4. Prior to the start of quarrying operations associated within the proposed Extension Lands, the PTTW for the site would be amended to increase the monitoring frequency for groundwater levels and surface water levels to monthly for the location identified in Condition 4.2. In addition, water management on site and discharge from the site are approved under the existing Environmental Compliance

Approval (ECA) No. 5863-6TSPZ3. During the initial phases of the proposed extension, the existing water management system is expected to have sufficient capacity to handle the gradually increasing surplus from the extension. If/when required to manage increased capacity or water quality, the site industrial sewage works capacity will be redesigned and Cavanagh will apply for an amendment to the ECA.

11.0 SUMMARY AND CONCLUSIONS

Cavanagh is applying for a Category 2, Class A license (Quarry Below Water) under the ARA, and a City of Ottawa Zoning By-law Amendment under the *Planning Act* to permit an extension to their existing West Carleton Quarry operation. The proposed Extension Lands are located directly adjacent to the northwestern portion of the existing West Carleton Quarry. The area proposed to be licensed under the *ARA* is 18.2 ha and the proposed extraction area is 16.5 ha. The licensing of the Extension Lands would also include a setback reduction along the common boundaries with the existing licensed area. The proposed extension of the West Carleton Quarry is located on Part Lot 15, Concession 11, Former Geographic Township of Huntley, City of Ottawa, Ontario.

The licensed area and extraction area under the current MNRF license for the existing West Carleton Quarry are 141.6 ha and 90.2 ha, respectively. The existing West Carleton Quarry is currently licensed to be operated in a series of lifts with final approved floor elevations of 107 m ASL. The proposed final quarry floor base elevation for the Extension Lands is also 107 m ASL.

The western portion of the existing quarry and the Extension Lands are located on a local topographic high. The ground surface on the west side of the site is approximately 152 m ASL and slopes down to approximately 124 m ASL on the east side of the existing West Carleton Quarry. The thickness of overburden material in the boreholes completed at the site ranged from 0 m to 9.75 m. The majority of the extraction area for the existing West Carleton Quarry and the proposed Extension Lands has bedrock at or near surface. The overburden thickens to the east of the existing West Carleton Quarry extraction area. Along the eastern edge of the existing West Carleton Quarry and further to the east/southeast there is an extensive area of organic deposits associated with the Manion Corners Long Swamp Wetland Complex. Smaller areas of organic deposits associated with low-lying and/or poorly drained areas to the west and south of the site.

The upper bedrock formation at the existing West Carleton Quarry and the Extension Lands is the Bobcaygeon Formation. This is consistent with the published bedrock geology mapping. The thickness of the Bobcaygeon Formation varies between 18.6 m and 31 m at the site. Beneath the Bobcaygeon Formation is the Gull River Formation which varies in thickness between 35.9 m and 36.9 m at the site. Beneath the Gull River Formation is the Rockcliffe Formation. The full thickness of the Rockcliffe Formation was drilled through at the site and was approximately 24 m thick. Beneath the Rockcliffe Formation is the Oxford Formation.

Based on contouring of the contact between the Bobcaygeon Formation and the Gull River Formation, the dip of the bedrock at the existing West Carleton Quarry and the Extension Lands is towards the north. Based on the elevations of the formational contacts, the existing West Carleton Quarry (licensed to a base elevation of 107 m ASL) will extract material from the Bobcaygeon Formation and Gull River Formation and will leave a minimum of 16.5 m of Gull River Formation above the top of the Rockcliffe Formation.

A fault zone referred to as the Pakenham Fault is located to the north of the site and runs along the east side of the existing West Carleton Quarry. The Pakenham Fault is mapped along the sharp decline in topography to the north of the site, and results in an area of the much older Nepean Formation being mapped as the upper bedrock unit in a small area to the north and east of the site.

Based on the interpretation of well response tests completed at the site, the geometric mean of the hydraulic conductivity for the Bobcaygeon was 2 x 10^{-8} m/s. The Gull River Formation was divided into the upper Gull River and lower Gull River. The geometric means of the hydraulic conductivity results for the upper Gull River and lower Gull River are 2 x 10^{-6} m/s and 6 x 10^{-7} m/s, respectively. The geometric means of the hydraulic conductivity data for the Rockcliffe Formation and the Nepean Formation are 8 x 10^{-6} m/s and 3 x10^{-4} m/s, respectively.

No significant surface water features are identified on the existing West Carleton Quarry or the Extension Lands. The nearest surface water receptor is the Manion Corners Long Swamp Wetland Complex located east and southeast of the existing West Carleton Quarry. The existing West Carleton Quarry and the proposed extension are both located within the existing Manion Corners Long Swamp wetland's catchment area, which is part of the Cody Creek watershed. No drainage diversions between catchments are required and, as such, the water balance of Manion Corners Long Swamp and Cody Creek are not expected to be measurably affected.

In the vicinity of the existing West Carleton Quarry, groundwater flow generally follows topography and flows from west to east. The groundwater elevation data from the multilevel monitoring wells installed at the site show the vertical gradients in the bedrock are typically downward indicating recharging conditions.

The wells in the vicinity of the site primarily service the residential development along March Road, Burnt Lands Road and Upper Dwyer Hill Road. Information provided in the MECP WWIS indicates that the private wells in the area are primarily completed in grey limestone or white sandstone. On the west side of the Pakenham Fault Zone near the site (i.e., along March Road and along Burnt Lands Road) the wells are completed in grey limestone and most wells are 50 m deep or greater. These wells are interpreted to be drilled through the overlying Bobcaygeon and Gull River Formations and completed in the underlying Rockcilffe Formation. Within the fault zone and to the east of the fault zones, the wells are typically shallower (i.e., less than 40 m deep). Within the centre of the fault zone several wells are completed in white sandstone of the Nepean Formation. Along the eastern portion of the fault zone, wells completed in grey limestone are interpreted to be completed in the Oxford Formation. Further to the east, the upper bedrock formations are the Bobcaygeon and Gull River Formations, and the primary water supply aquifer in this area is again the underlying Rockcliffe Formation.

Based on the results of the groundwater modelling and the review of local water supply wells, it is concluded that interference with water supply wells as a result of the proposed full development of the existing West Carleton Quarry and the Extension Lands is not predicted. Well interference as a result of cumulative drawdown associated with the development of the existing West Carleton Quarry plus the Extension Lands, and the Burnt Lands Quarry is not predicted. In addition, impacts to the groundwater quality or quantity at the Village of Almonte supply wells as a result of the proposed development of the Extension Lands is not predicted.

The proposed groundwater level monitoring program will permit the collection of long-term groundwater level data as the existing West Carleton Quarry and Extension Lands develop. These data will show the actual changes in groundwater levels within the monitoring wells completed around the extraction areas as the quarry expands laterally and vertically and can be used to further assess the propagation of the drawdown cone. In the unlikely event that complaints are received regarding interference to water wells in the vicinity of the site, the complaints response plan would be implemented.

Overall, based on the results of this hydrogeological and hydrological investigation for the Extension Lands, the proposed additional quarry development will protect sensitive surface water and sensitive groundwater receptors during the operational period and under rehabilitated conditions.

12.0 RECOMMENDATIONS

Based on the results of the hydrogeological and hydrological assessments for the Extension Lands, the following recommendations are provided for inclusion on the site plans:

a) Prior to the start of water taking for the Extension Lands, the Permit to Take Water for the existing West Carleton Quarry shall be amended to include the water taking assocated with proposed quarry extension and to increase the frequency of the groundwater and surface water level measurements for locations included in the monitoring program to monthly.

b) The monitoring program for the site shall be completed in accordance with the Permit to Take Water and Environmental Compliance Approval.

c) In the event of a well interference complaint, the Licensee shall implement the Complaints Response Program outlined in the hydrogeological and hydrological assessment report.

13.0 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 property at the time of the work. Any use which a third party makes of this report, or any reliance on, or decisions to be made based of 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 taken based on this report.

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 from a number of locations. The site conditions between testing locations have been inferred based on conditions observed at the testing locations. Actual conditions may deviate from the inferred values.

The groundwater level lowering, and groundwater inflow/seepage estimates developed from the groundwater model described in this report are considered to represent reasonable "theoretical" estimates based on the available data. There is uncertainty inherently associated with the (subsequent) forecasts by the groundwater model, stemming from limitations in the available subsurface information and can be related to variability in the bedrock properties (e.g., hydraulic conductivity, porosity, etc.) or uncertainties with the conceptual model (e.g., groundwater-surface water interactions, location of flow boundaries, recharge rates, continuity in aquitards, direction of regional groundwater flow, etc.). It is the intention of Golder Associates Ltd. that the model results be used as a screening tool to predict groundwater inflow/seepage rates and groundwater level lowering for the purposes of this license application process, and not for any other purposes.

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.

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.

14.0 CLOSURE

We trust the information presented in this report meets your requirements. Should you have any questions or concerns, please contact the undersigned.

Golder Associates Ltd.

PROFESSIONAL GEOSCIENTIST
JAIME P. A. OXTOBEE
PRACTISING MEMBER
1095
7/7/2021
ONTARIO

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JPAO/MK/KMM/KAM/sg

https://golderassociates.sharepoint.com/sites/25725g/deliverables/hydrogeology/final water report/1899975-r-rev 1-hydrogeology and hydrology assessments west carleton quarry extension_july_2021.docx

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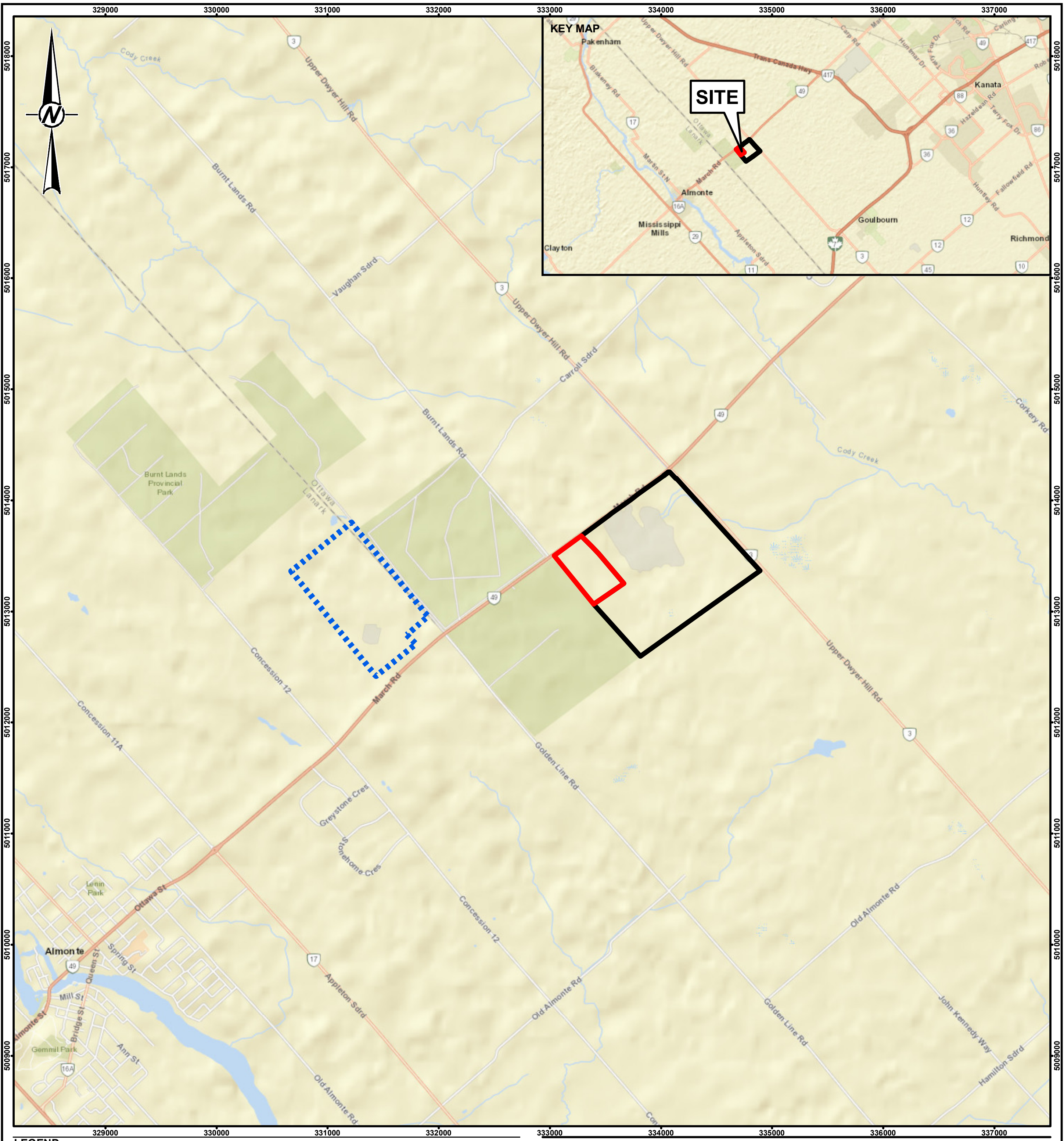

LEGEND

🟥	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
⬛	EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
⬚	BURNT LANDS QUARRY LICENSE BOUNDARY

0 500 1,000 2,000

1:50,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. 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
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
KEY PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	MAP
1899975	0007	0	1

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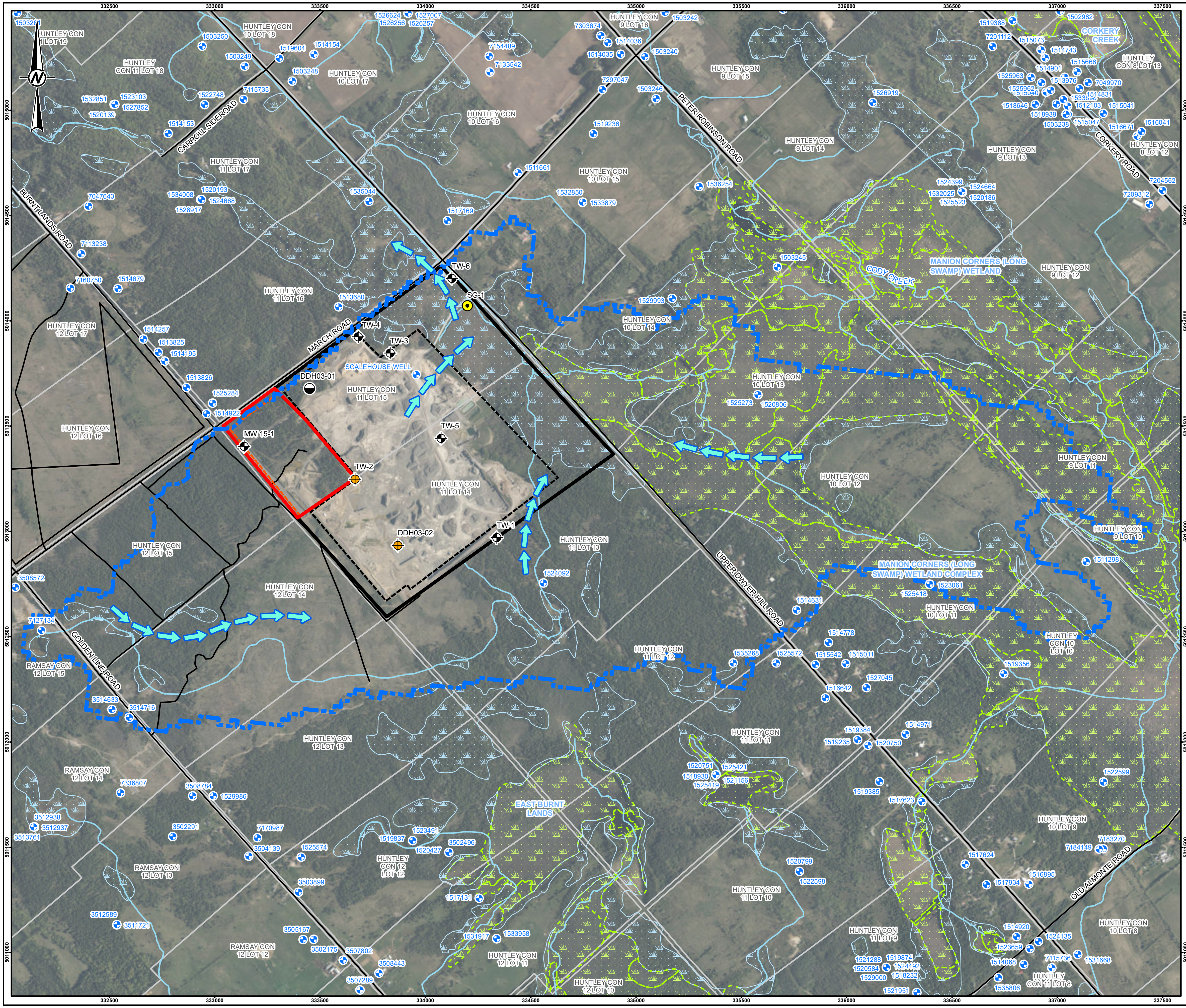

LEGEND

- ● WATER WELL LOCATION (AS PER MECP WWIS)
- ⊙ STAFF GAUGE LOCATION
- ⊕ TEST WELL
- ◒ DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)
- ⊕ TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT
- 🟥 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- ⬚ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
- ⬛ EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- ⬚ EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION
- ⇨ FLOW DIRECTION
- ⬚ LOCAL CATCHMENT BOUNDARY
- — ROADWAY
- — WATERCOURSE
- ▨ WETLAND
- ▨ SIGNIFICANT WETLAND
- ☐ LOT FABRIC

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 2014
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

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CLIENT

THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT

HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE

SITE PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0007	0	2

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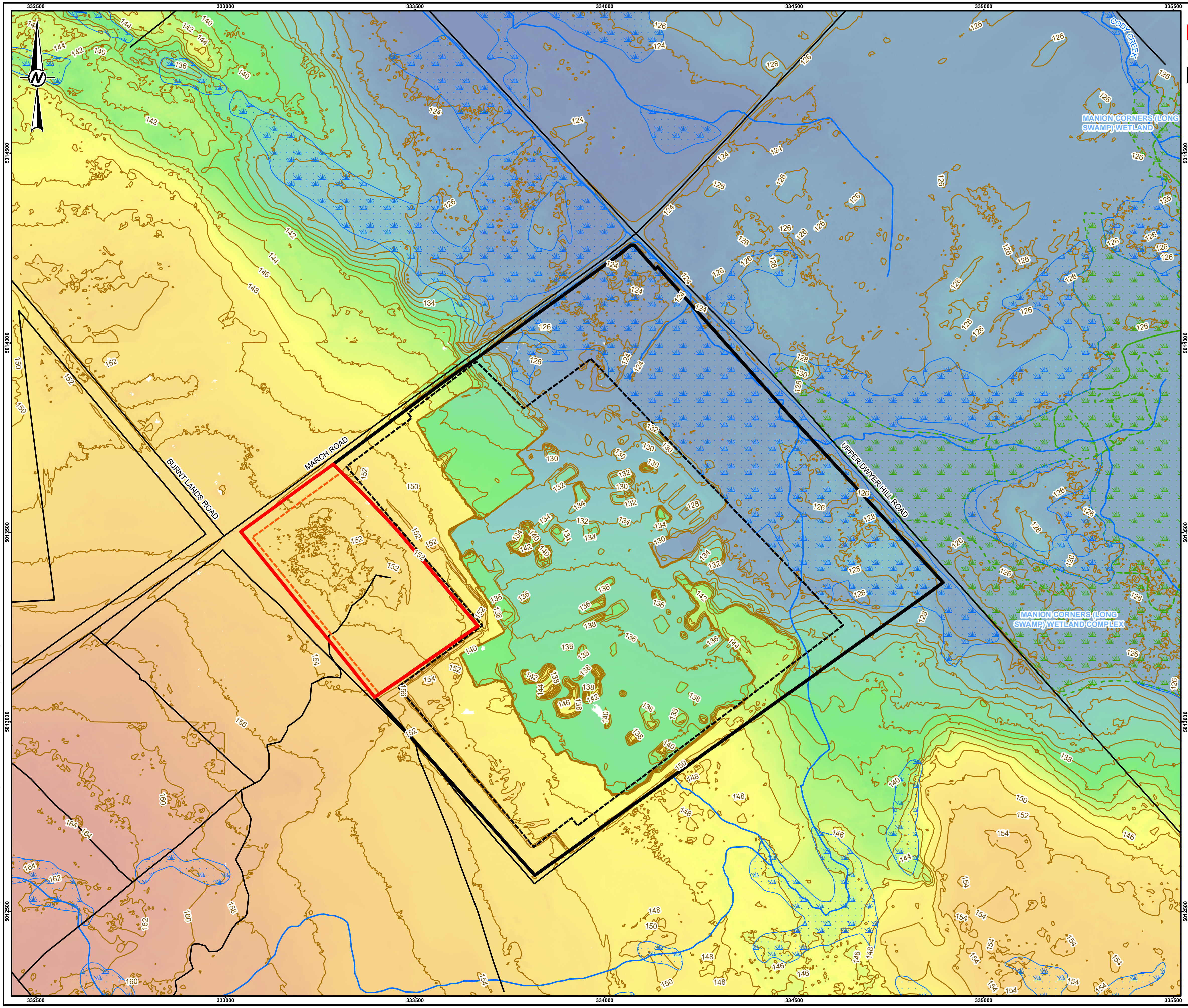

LEGEND

🟥	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
⬚	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
⬛	EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
⬚	EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION
—	ROADWAY
—	WATERCOURSE
▨	WETLAND
▨	SIGNIFICANT WETLAND

ELEVATION (m)

High : 165 m

Low : 120 m

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 2014
2. CITY OF OTTAWA 2012 TOPO LIDAR TILES
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

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1:10,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
LOCAL TOPOGRAPHY

CONSULTANT

GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
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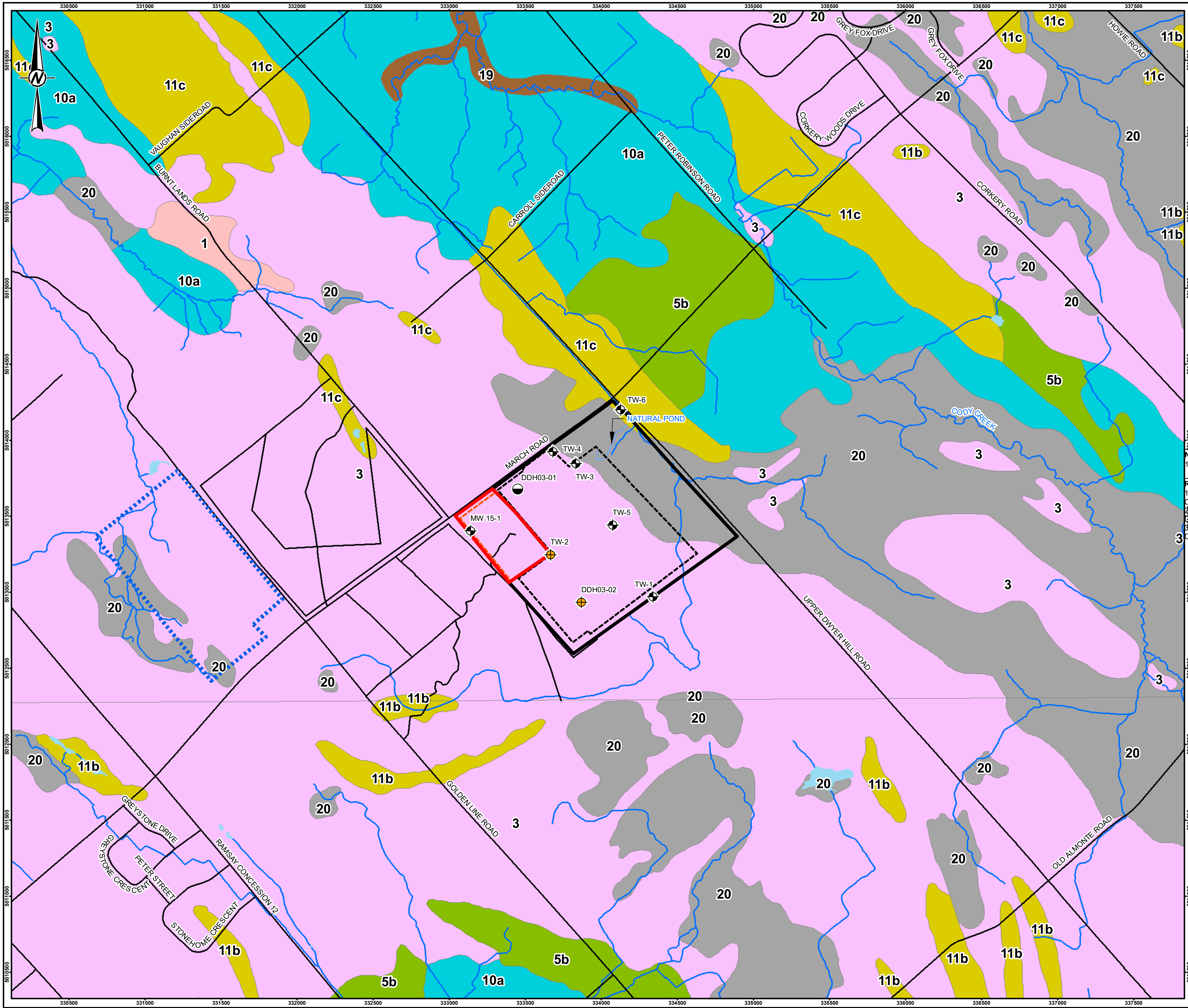

LEGEND

⊕ TEST WELL

◒ DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)

⊕ TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT

🟥 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY

⬚ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION

⬛ EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY

⬚ EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION

⬚ BURNT LANDS QUARRY LICENSE BOUNDARY

— ROADWAY

— WATERCOURSE

🟦 WATERBODY

🟥 1. **PRECAMBRIAN BEDROCK**

🟪 3. **PALEOZOIC BEDROCK**

🟩 5b. **TILL:** STONE-POOR, SANDY SILT TO SILTY SAND-TEXTURED TILL ON PALEOZOIC TERRAIN

🟦 10a. **FINE-TEXTURED GLACIOMARINE DEPOSITS:** SILT AND CLAY, MINOR SAND AND GRAVEL; MASSIVE TO WELL LAMINATED

🟨 11b. **COARSE-TEXTURED GLACIOMARINE DEPOSITS:** SAND, GRAVEL, MINOR SILT AND CLAY; LITTORAL DEPOSITS

🟨 11c. **COARSE-TEXTURED GLACIOMARINE DEPOSITS:** SAND, GRAVEL, MINOR SILT AND CLAY; FORESHORE AND BASINAL 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 2014
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 250 500 1,000
1:25,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
SURFICIAL GEOLOGY

CONSULTANT
GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
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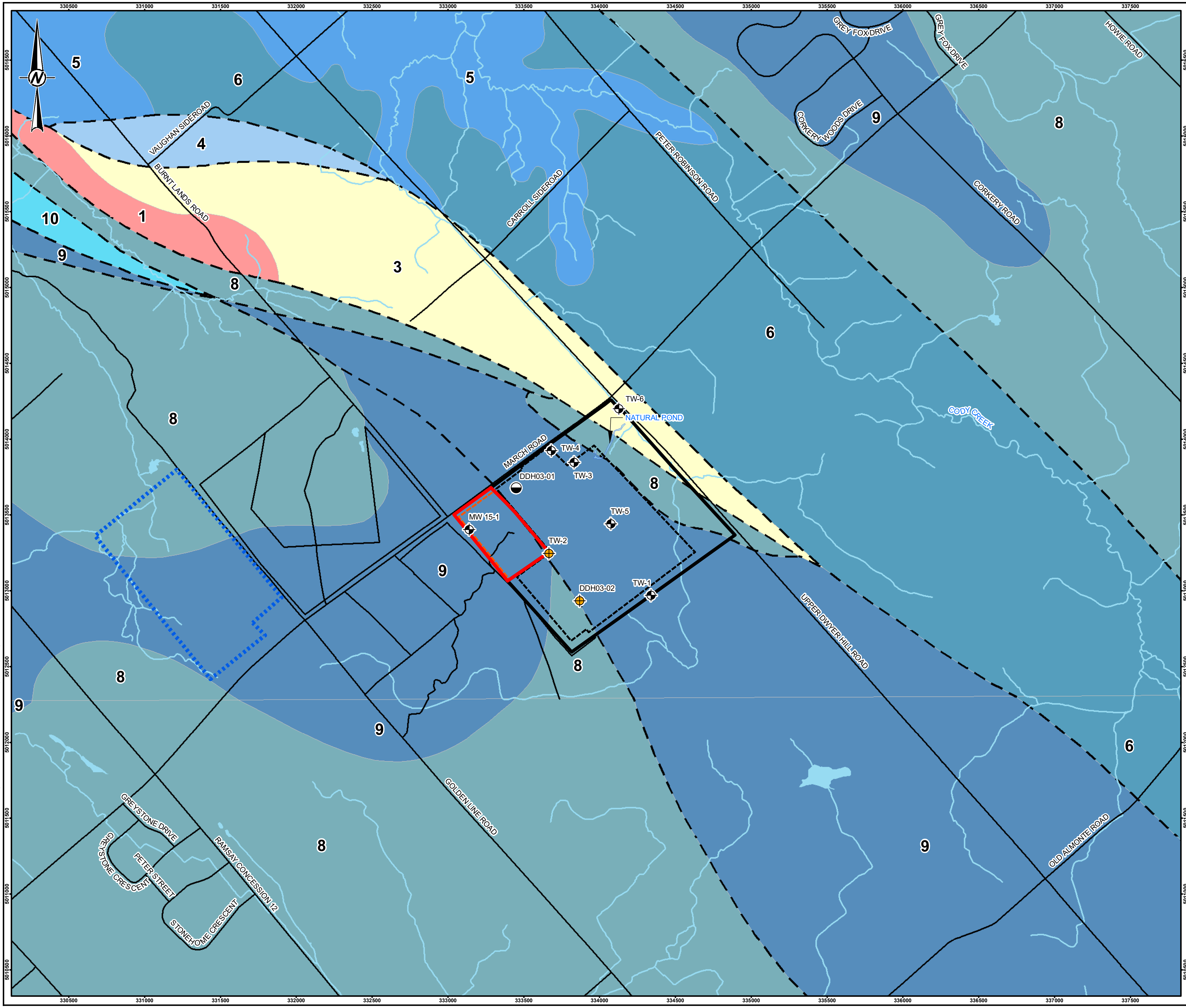

LEGEND

TEST WELL

DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)

TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT

PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY

PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION

EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY

EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION

BURNT LANDS QUARRY LICENSE BOUNDARY

ROADWAY

WATERCOURSE

WATERBODY

FAULT

10: VERULAM FORMATION - LIMESTONE AND SHALE

9: BOBCAYGEON FORMATION - LIMESTONE, WITH MINOR SHALES IN UPPER PART

8: GULL RIVER FORMATION - LIMESTONE, WITH DOLOSTONE BEDS TOWARDS BASE

6: ROCKCLIFFE FORMATION - SANDSTONE, SHALE, LIMESTONE, DOLOSTONE

5: OXFORD FORMATION - DOLOSTONE, MINOR SHALE AND SANDSTONE

4: MARCH FORMATION - SANDSTONE, DOLOMITIC SANDSTONE, DOLOSTONE

3: NEPEAN FORMATION - SANDSTONE, MINOR CONGLOMERATE

1: PRECAMBRIAN

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. ARMSTRONG, D.K. AND DODGE, J.E.P. 2007. PALEOZOIC GEOLOGY OF SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE--DATA 219
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2014
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 250 500 1,000
1:25,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
BEDROCK GEOLOGY

CONSULTANT

GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0007	0	5

Path: N:\Active\Spatial_IM\ThomasCavanagh\Almonte\99_PROJ\1899975_ThomasCavanagh_ARA_Application\40_PROD\0007_CH_HydroG_Hydrological_Assessments\1899975-0007-CH-0005.mxd

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

25mm
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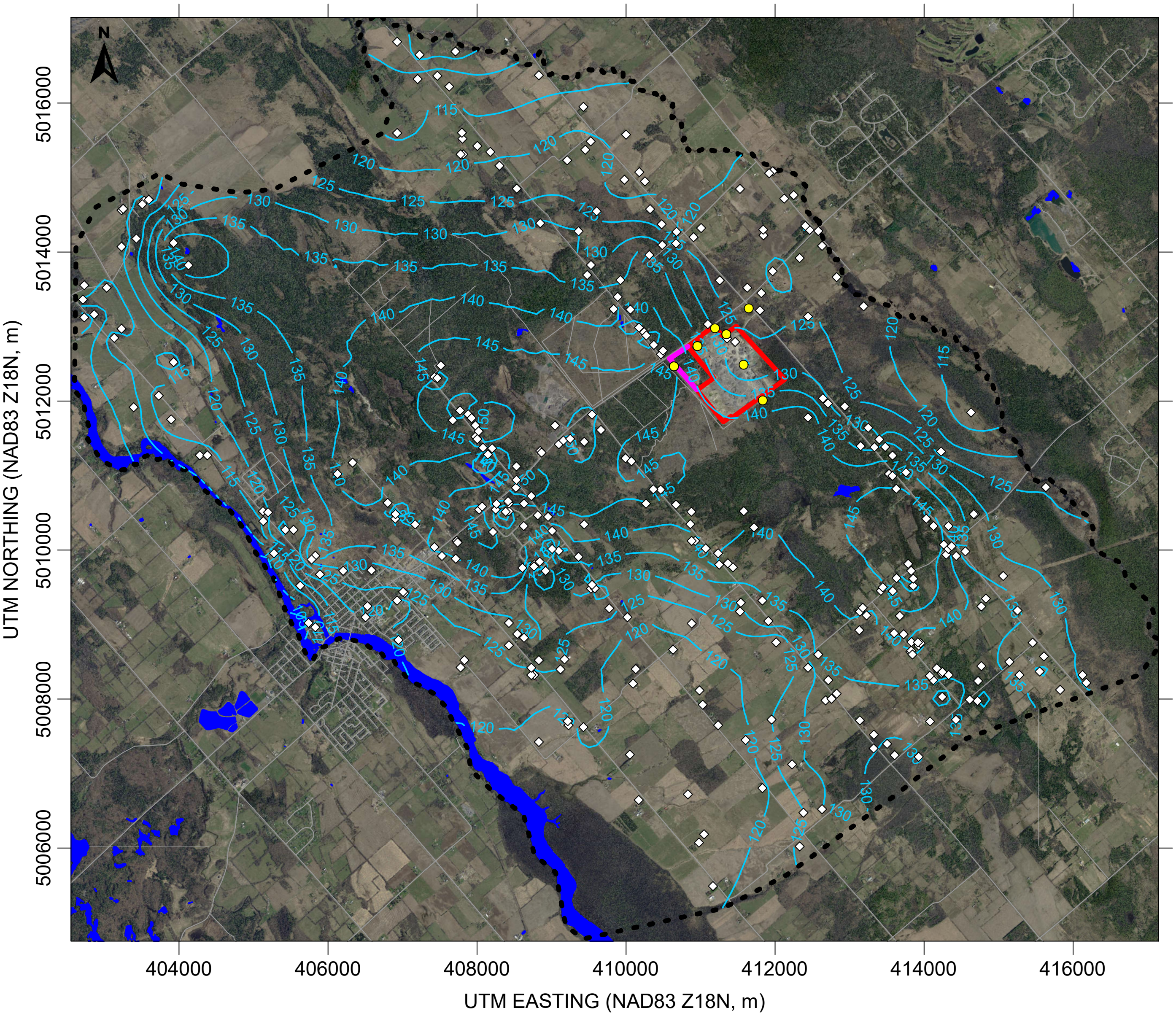


LEGEND

— EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY

— PROPOSED WEST CARLETON QUARRY EXTENSION LICENSE BOUNDARY

— WATERBODY

— ROAD

•••• MODEL BOUNDARY

◆ MECP WWIS GROUNDWATER ELEVATION DATA POINT

● WEST CARLETON QUARRY MONITORING WELL GROUNDWATER ELEVATION DATA POINT

NOTES:

1. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENSE- ONTARIO.
2. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

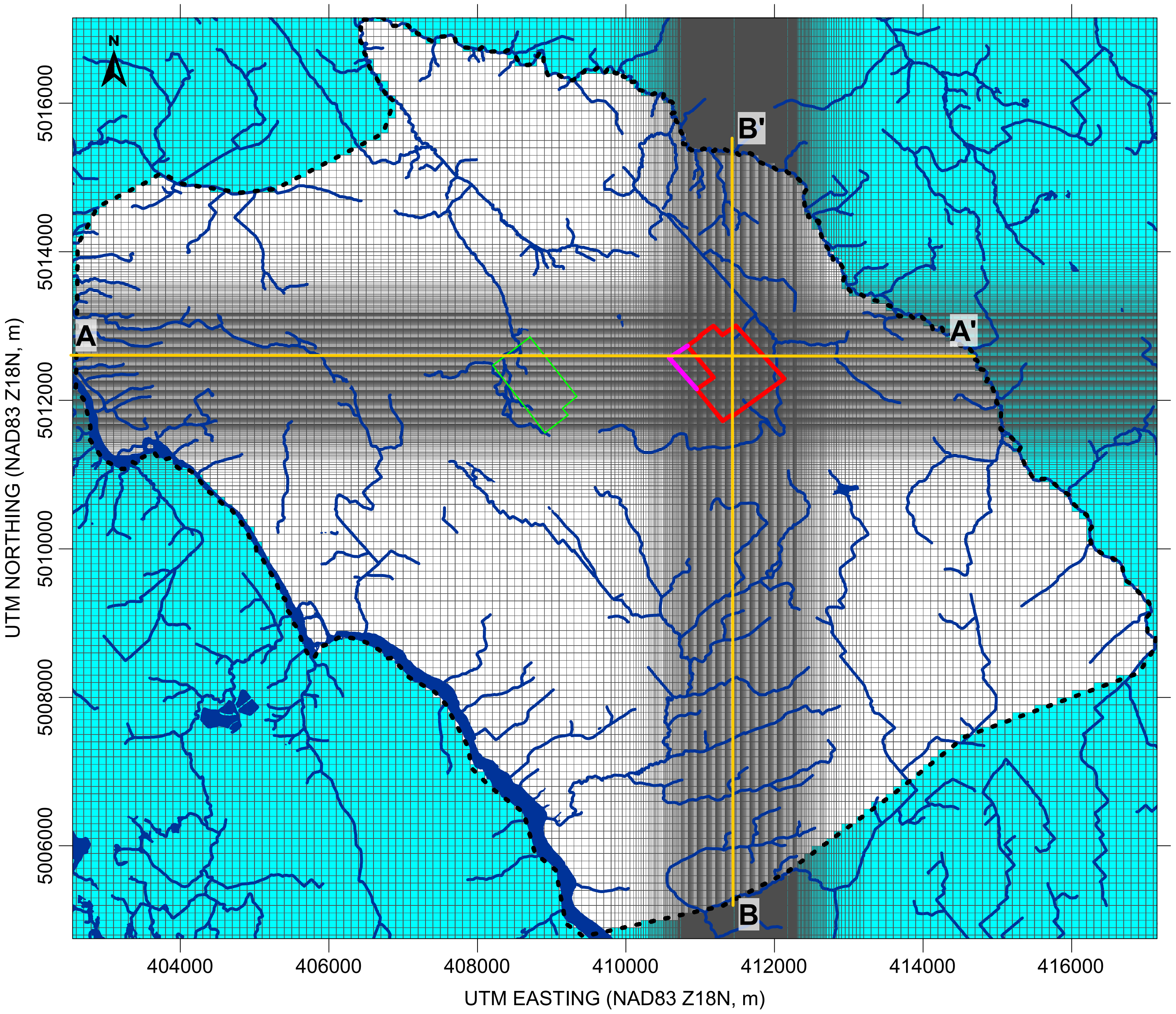
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS- PROPOSED WEST CARLETON QUARRY EXTENSION

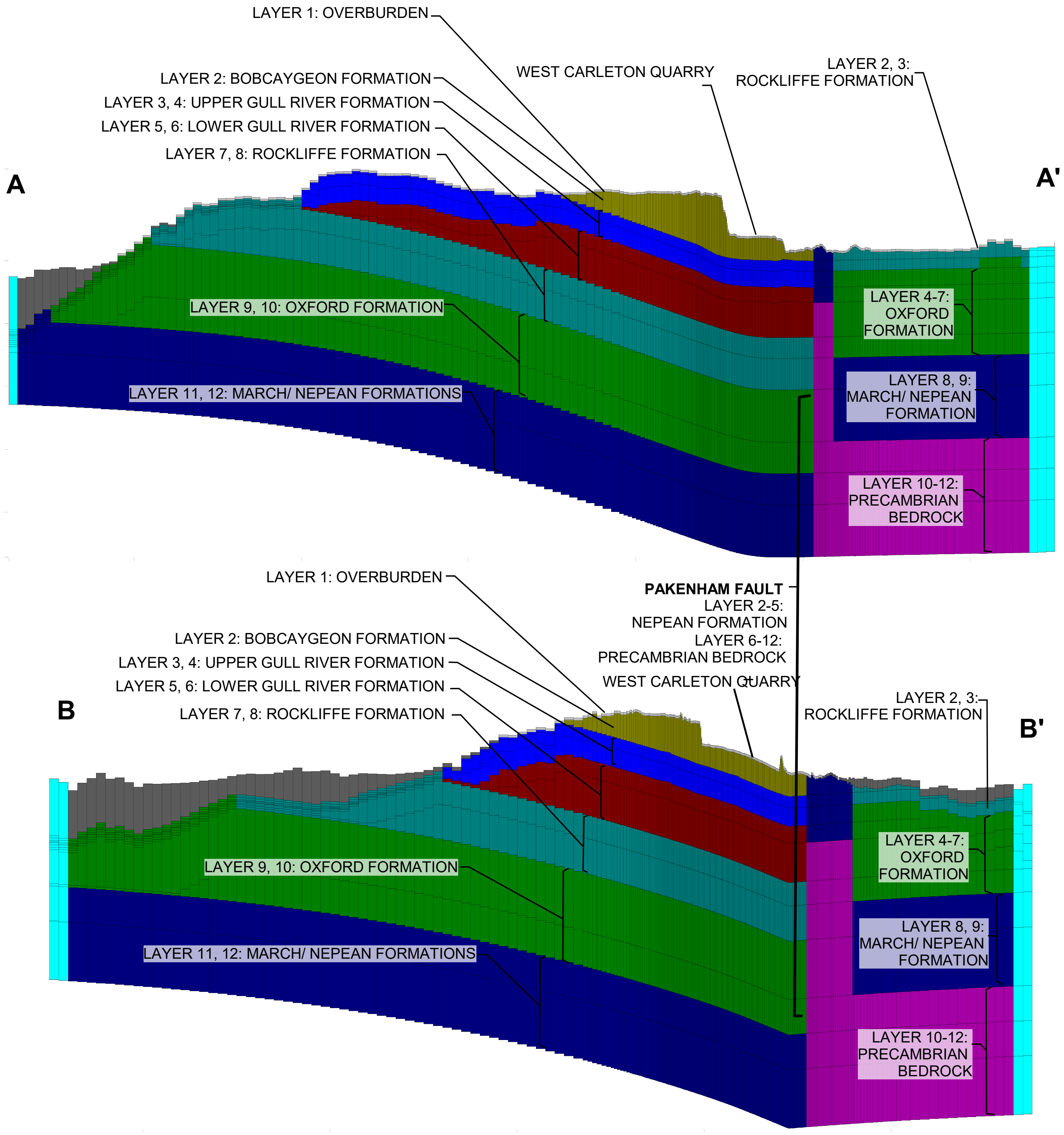
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
INTERPRETED GROUNDWATER ELEVATION CONTOURS

PROJECT No.	Rev.	FIGURE
1899975	0	6





VERTICAL EXAGGERATION 25X

LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- 🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERCOURSE/ WATERBODY
- •••• MODEL BOUNDARY
- 🟦 INACTIVE FLOW BOUNDARY

NOTES:

1. SOURCE FOR TOPOGRAPHY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014 DIGITAL TERRAIN MODEL (DTM). CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENSE- ONTARIO.
2. SOURCE FOR ROAD AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

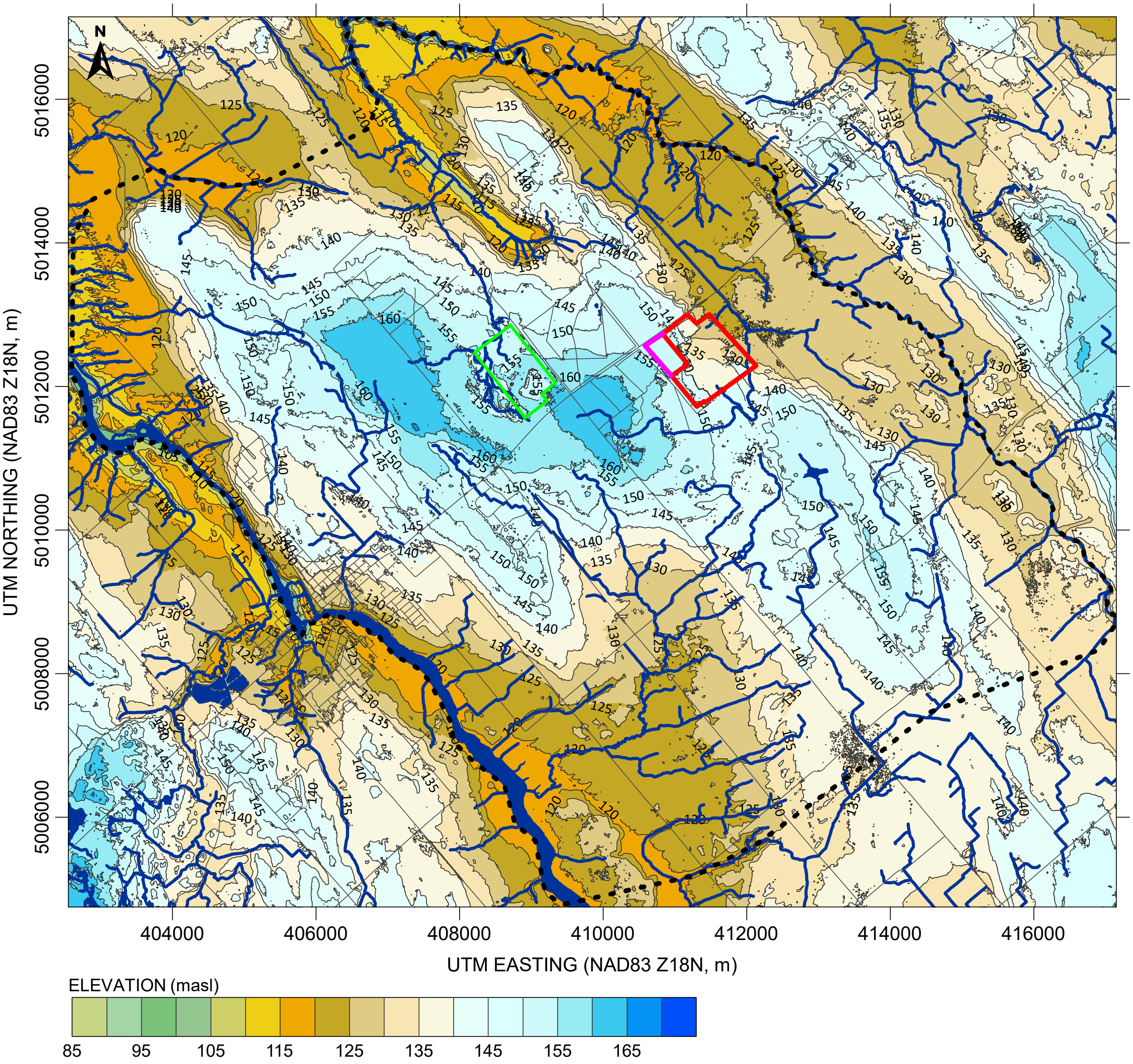
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
MODEL GRID AND LAYERING

PROJECT No.	Rev.	FIGURE
1899975	0	7



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- 🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERCOURSE/ WATERBODY
- — ROAD
- •••• MODEL BOUNDARY

NOTES:

1. SOURCE FOR TOPOGRPAHY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014 DIGITAL TERRAIN MODEL (DTM). CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENSE- ONTARIO.
2. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

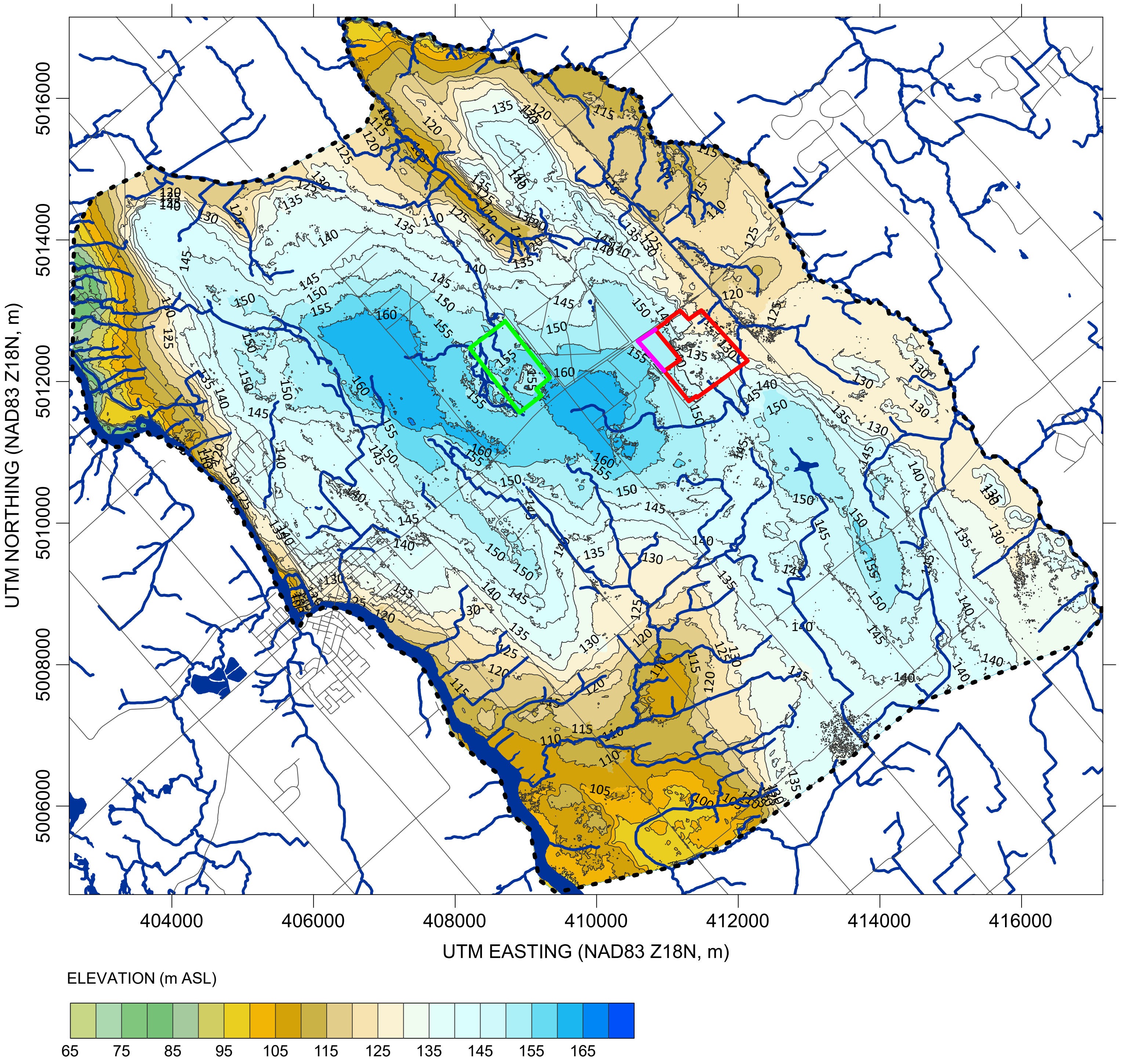
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

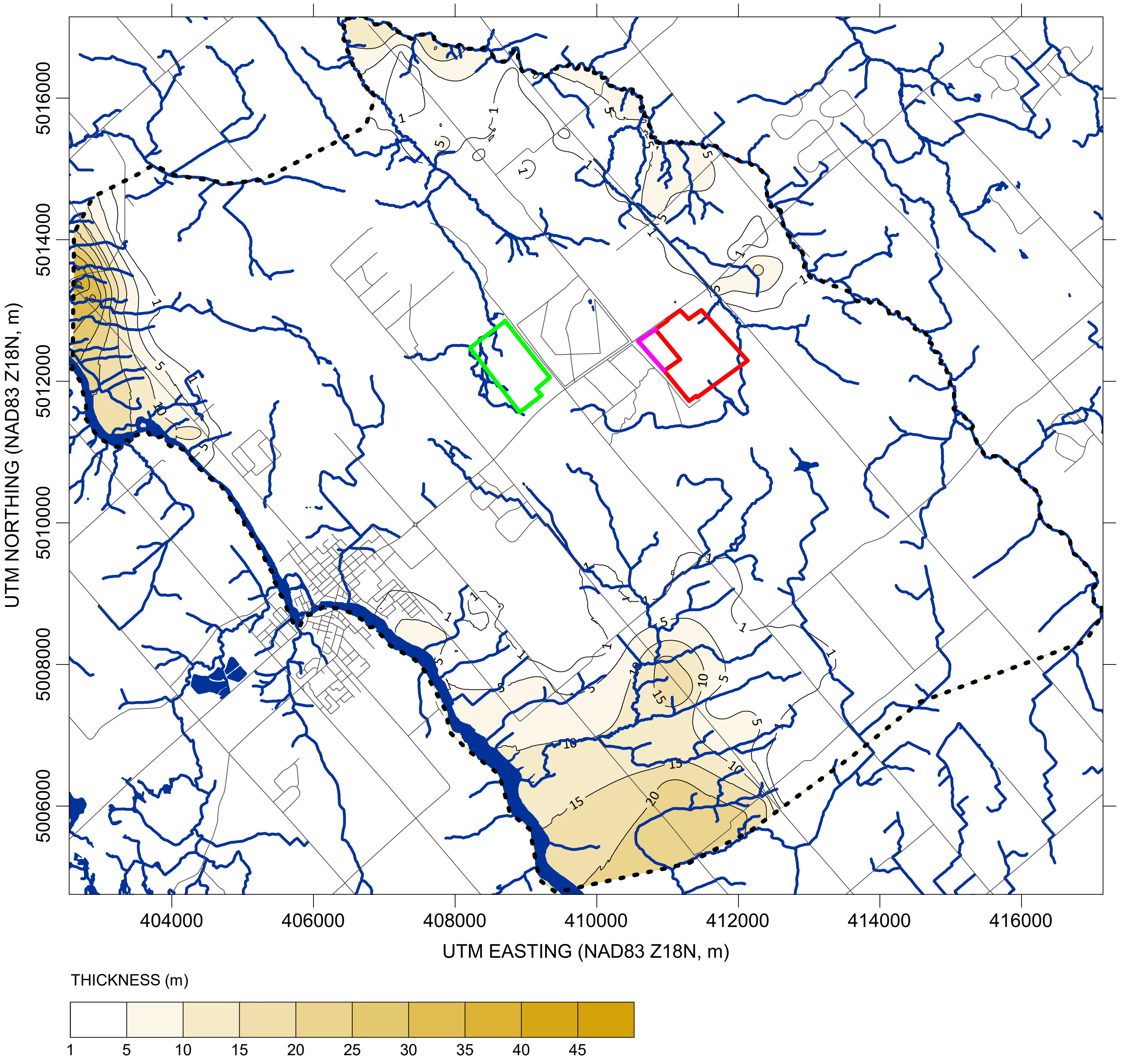
TITLE
TOPOGRAPHY AND DRAINAGE

PROJECT No.	Rev.	FIGURE
1899975	0	8

BEDROCK TOPOGRAPHY (masl)



OVERBURDEN ISOPACH (m)



LEGEND

- EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- BURNT LANDS QUARRY LICENSE BOUNDARY
- WATERCOURSE/ WATERBODY
- ROAD
- MODEL BOUNDARY

NOTES:

1. SOURCE FOR ROAD AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

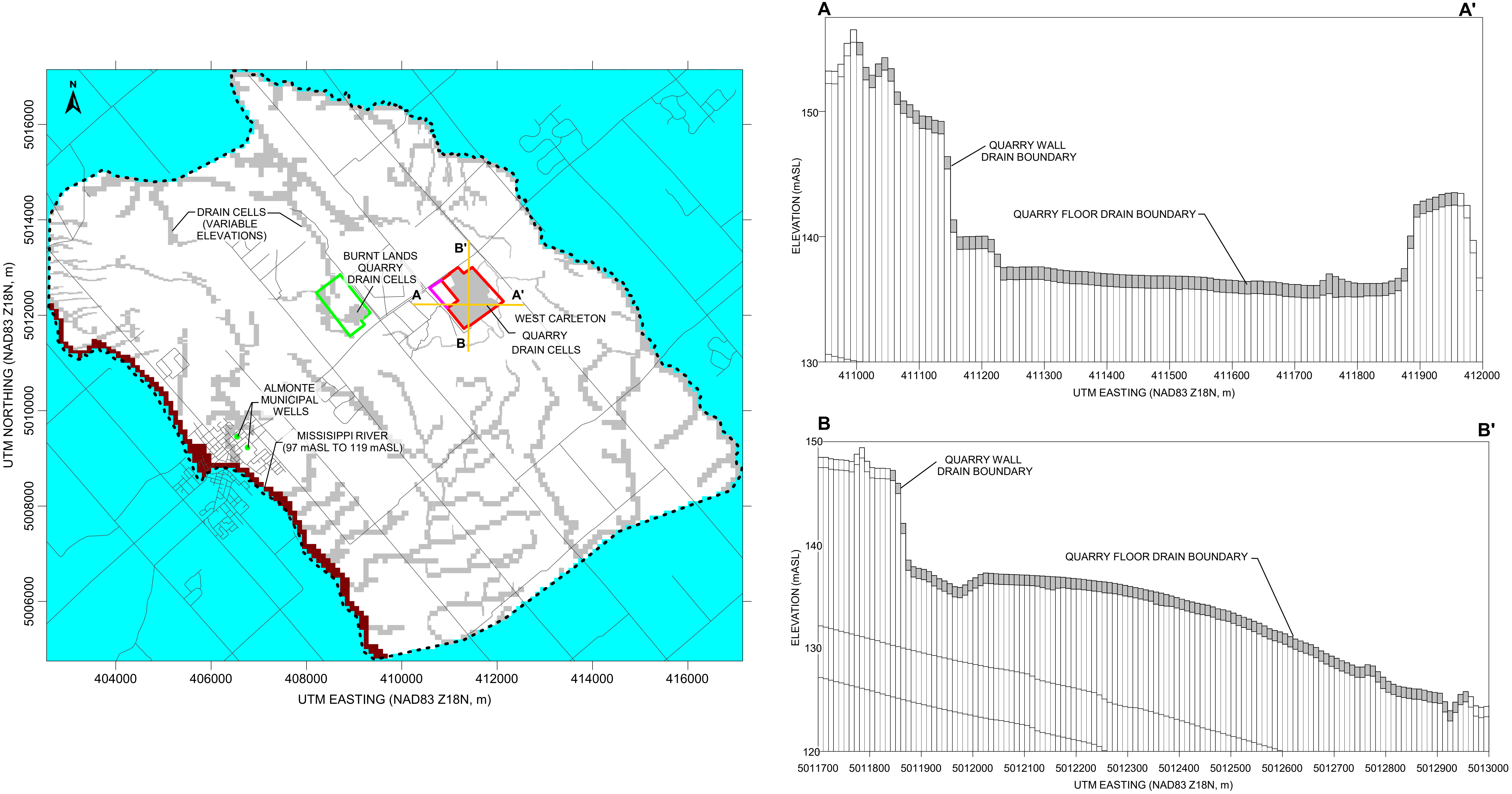
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-15
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
BEDROCK SURFACE TOPOGRAPHY AND OVERBURDEN ISOPACH

PROJECT No.	Rev.	FIGURE
1899975	0	9



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- — PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- — WATERCOURSE/ WATERBODY
- — ROAD
- •••• MODEL BOUNDARY
- ■ CONSTANT HEAD BOUNDARY
- ■ DRAIN BOUNDARY
- ■ INACTIVE FLOW BOUNDARY
- ● PUMPING WELL

NOTES:

1. SOURCE FOR TOPOGRAPHY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014 DIGITAL TERRAIN MODEL (DTM). CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENSE- ONTARIO.
2. SOURCE FOR ROAD AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020
3. DRAIN ELEVATIONS ASSIGNED BASED ON TOPOGRAPHIC ELEVATION

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

CONSULTANT
GOLDER

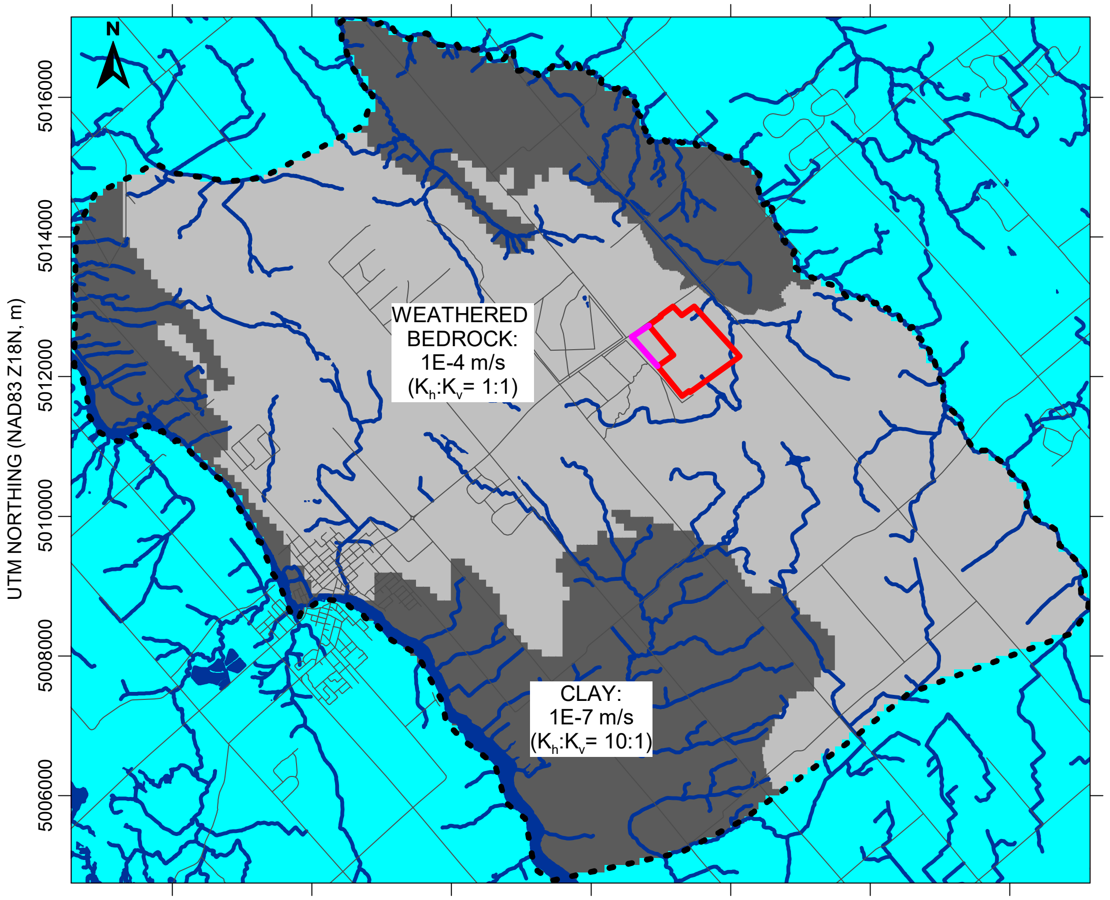
YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

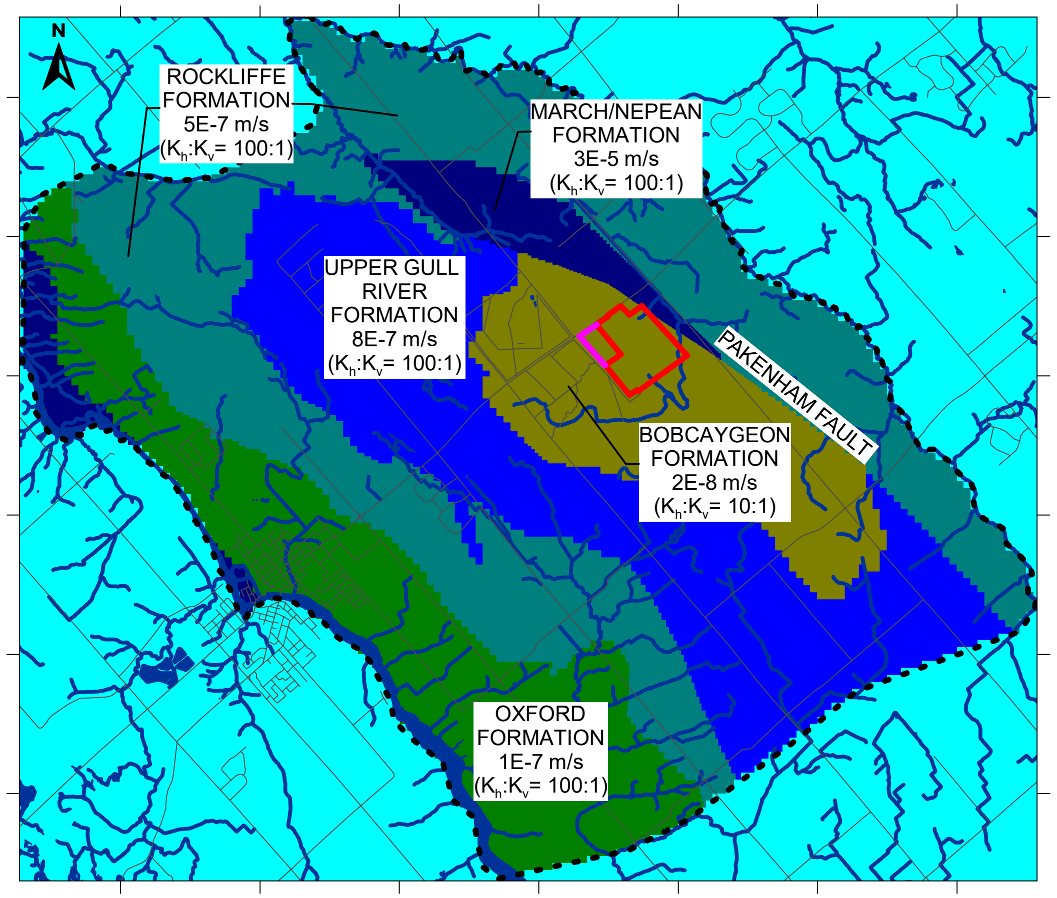
TITLE
MODEL BOUNDARIES

PROJECT No.	Rev.	FIGURE
1899975	0	10

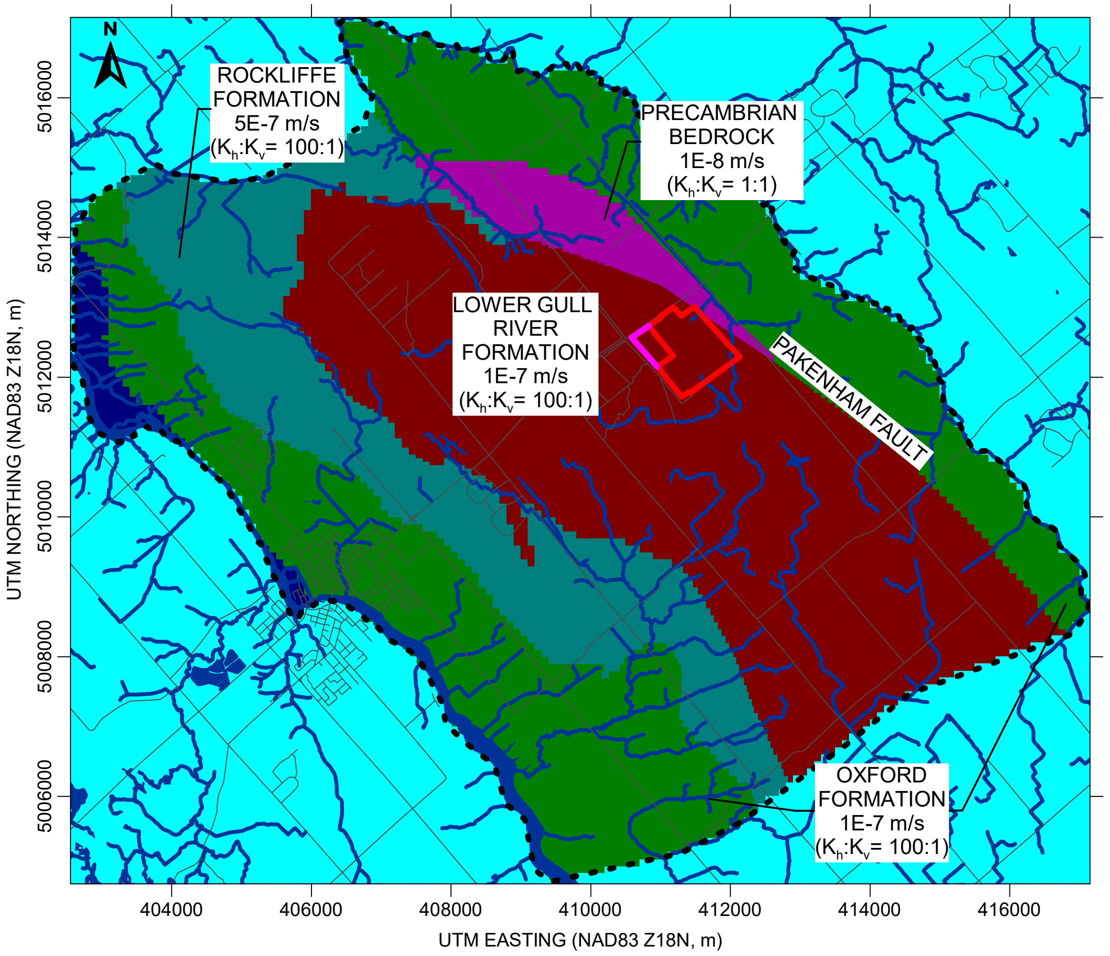
MODEL LAYER 1



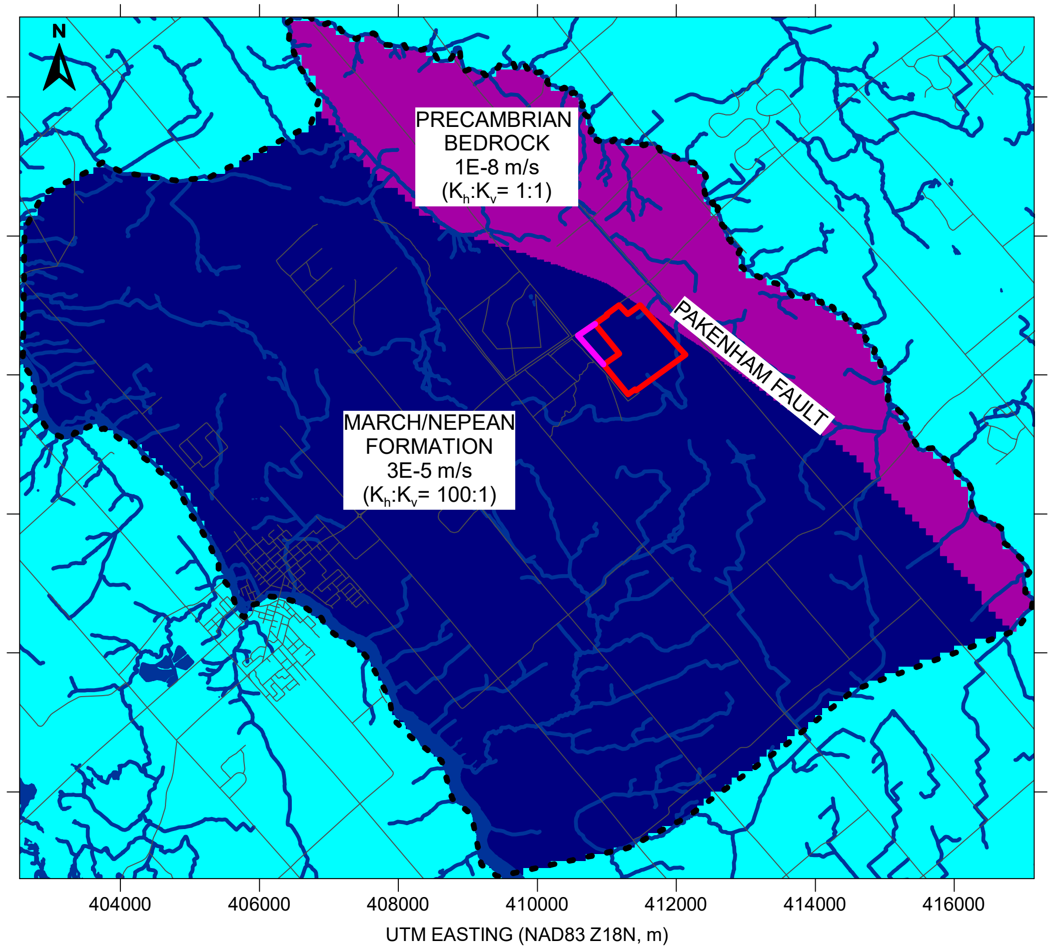
MODEL LAYER 2



MODEL LAYER 6 & 7



MODEL LAYER 11 & 12



LEGEND

- EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- WATERCOURSE/ WATERBODY
- ROAD
- MODEL BOUNDARY
- 🟦 INACTIVE FLOW BOUNDARY
- ⬜ WEATHERED BEDROCK
- ⬛ CLAY
- 🟫 BOBCAYGEON FORMATION
- 🟦 UPPER GULL RIVER FORMATION
- 🟥 LOWER GULL RIVER FORMATION
- 🟩 ROCKLIFFE FORMATION
- 🟩 OXFORD FORMATION
- 🟦 MARCH/NEPEAN FORMATION
- 🟪 PRECAMBRIAN BEDROCK

NOTES:

1. GEOGLOGIC UNIT THICKNESS' OF 0m WERE SIMULATED IN THE MODEL USING HYDRAULIC CONDUCTIVITY TRANSITION ZONES. WHEN THE MODEL LAYER REACHES A MINIMUM THICKNESS OF 1m THE HYDRAULIC CONDUCTIVITY VALUE IS ASSIGNED BASED ON THE GEOLOGIC UNIT BELOW.
2. SOURCE FOR ROAD AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

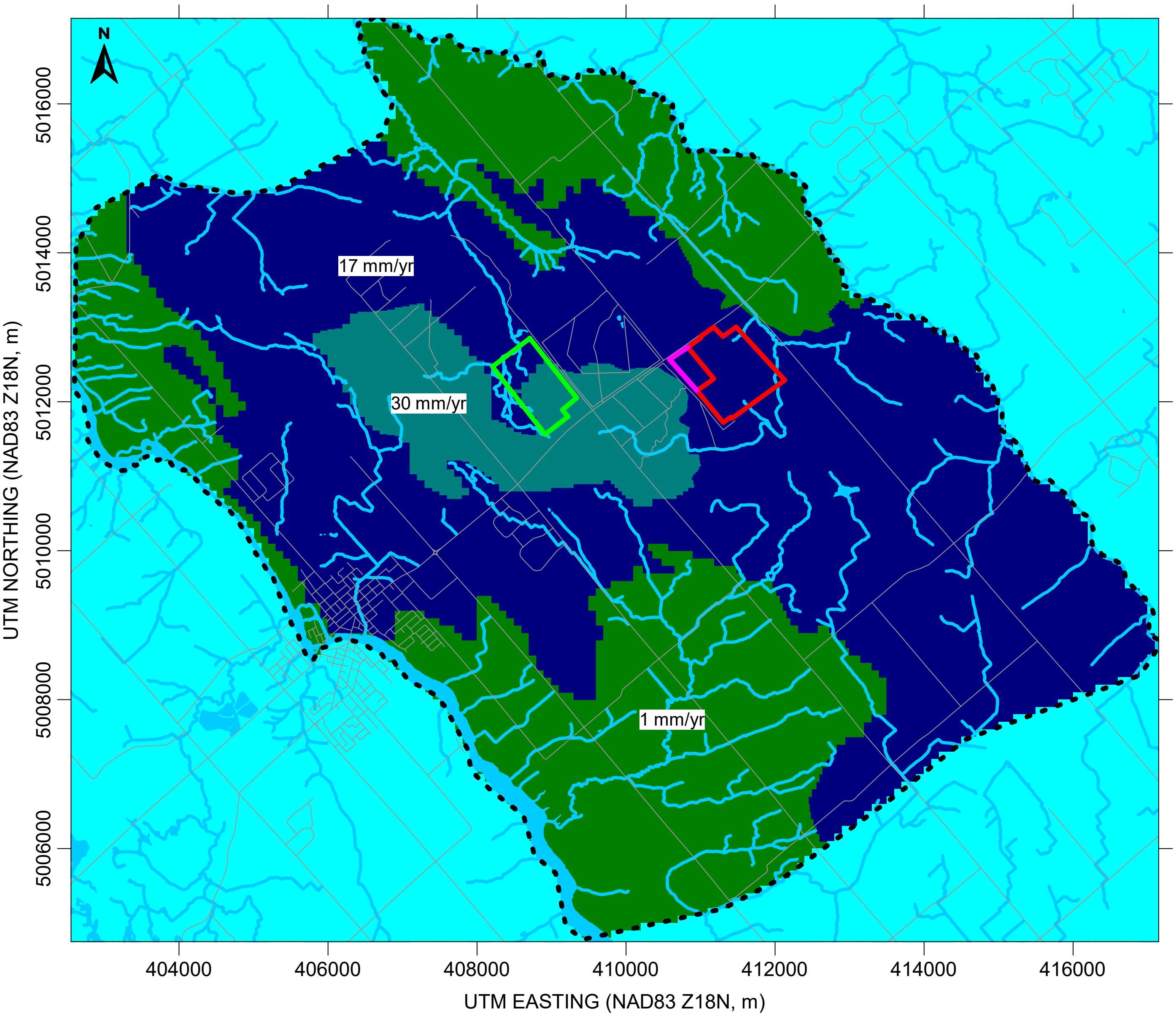
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
MODEL HYDRAULIC CONDUCTIVITY VALUES

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-15
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

PROJECT No. 1899975
Rev. 0
FIGURE 11



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- 🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERCOURSE/ WATERBODY
- ▬ ROAD
- •••• MODEL BOUNDARY
- 🟦 INACTIVE FLOW BOUNDARY

NOTES:

1. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

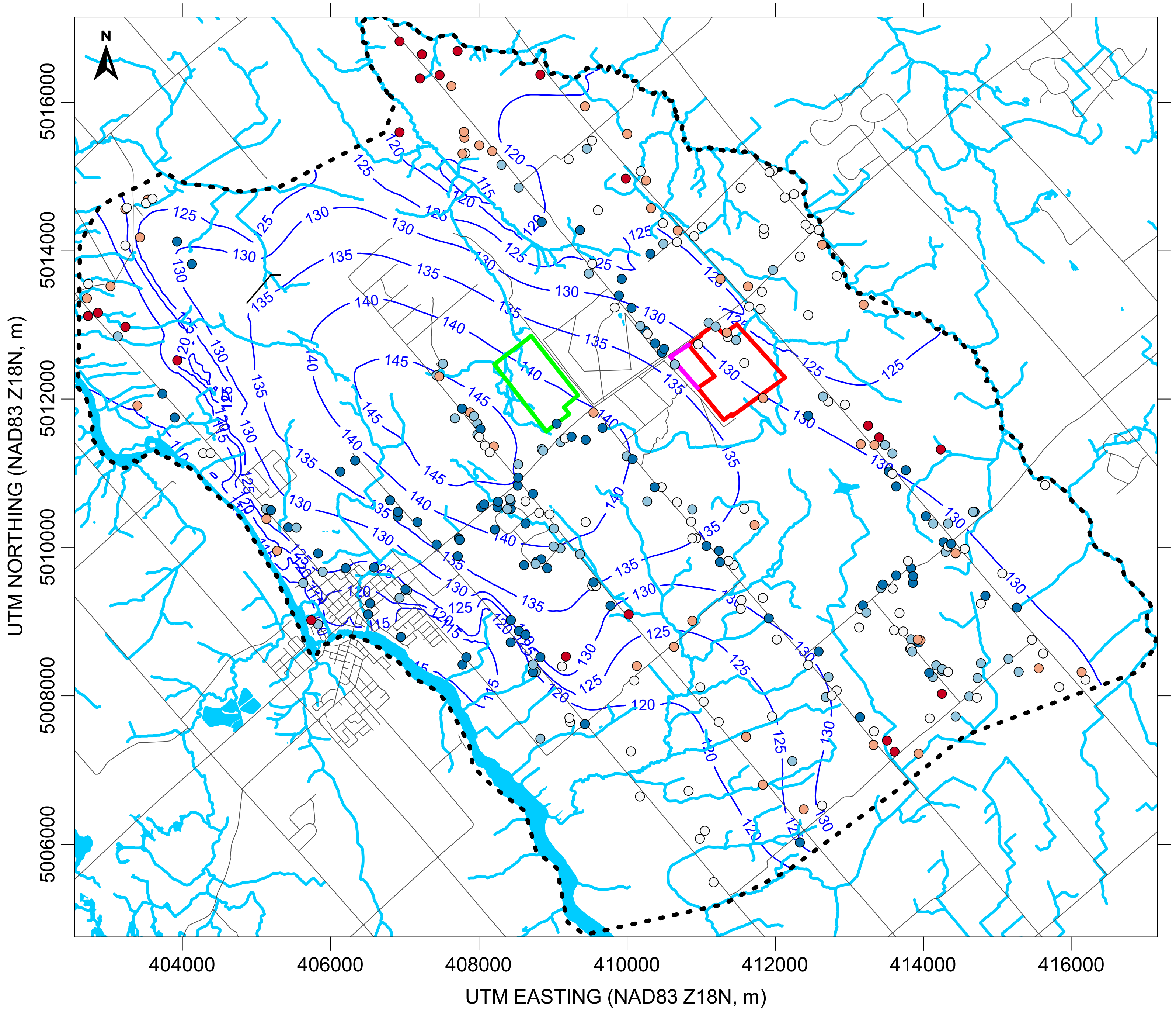
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

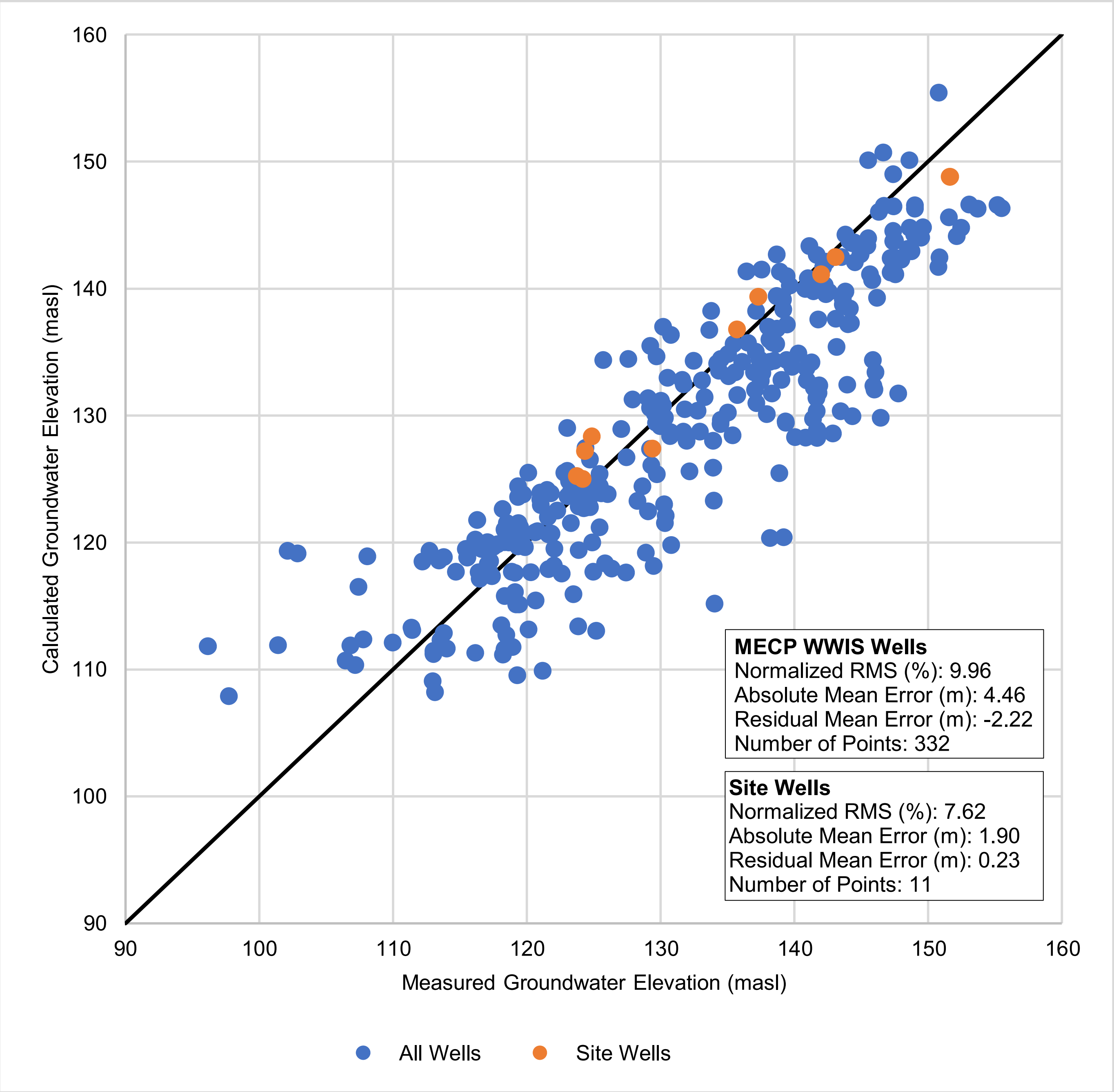
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-15
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
MODEL RECHARGE DISTRIBUTION

PROJECT No.	Rev.	FIGURE
1899975	0	12





MECP WWIS Wells
Normalized RMS (%): 9.96
Absolute Mean Error (m): 4.46
Residual Mean Error (m): -2.22
Number of Points: 332

Site Wells
Normalized RMS (%): 7.62
Absolute Mean Error (m): 1.90
Residual Mean Error (m): 0.23
Number of Points: 11

LEGEND

🟥	EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
🟪	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
🟩	BURNT LANDS QUARRY LICENSE BOUNDARY
🟦	WATERCOURSE/ WATERBODY
—	ROAD
••••	MODEL BOUNDARY

RESIDUAL ERROR (m)

●	< -5
●	-5 to -2
○	-2 to 2
●	2 to 5
●	> 5

NOTES:

1. RESIDUAL ERROR= SIMULATED GROUNDWATER ELEVATION- OBSERVED GROUNDWATER ELEVATION
2. GROUNDWATER CONTOURS ARE SHOWN FOR THE ROCKCLIFFE FORMATION (MODEL LAYER 7)
3. SOURCE FOR ROAD AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. 2020

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

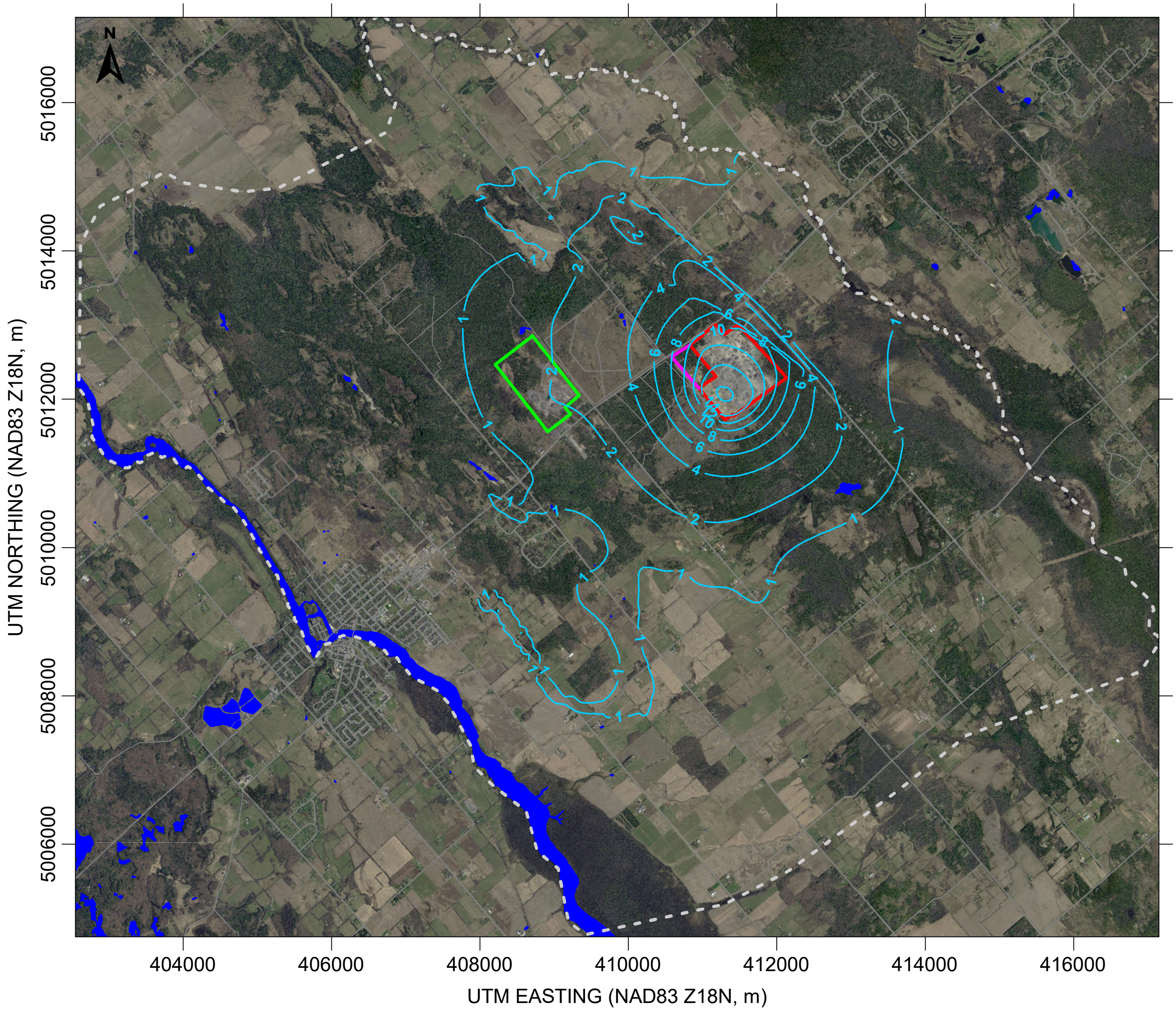
CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-15
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
SIMULATED GROUNDWATER ELEVATIONS AND MODEL CALIBRATION

PROJECT No.	Rev.	FIGURE
1899975	0	13



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- 🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERBODY
- — ROAD
- •••• MODEL BOUNDARY
- — SIMULATED GROUNDWATER DRAWDOWN (m)

NOTES:

1. EXISTING WEST CARLETON QUARRY IS REPRESENTED IN THE MODEL AT FULL DEVELOPMENT (FINAL FLOOR ELEVATION OF 107 m ASL)
2. BURNT LANDS QUARRY IS REPRESENTED IN THE MODEL AT CURRENT CONDITIONS
3. DRAWDOWN IS CALCULATED RELATIVE TO PRE-DEVELOPMENT CONDITIONS IN THE ROCKLIFFE FORMATION (MODEL LAYER 7)
4. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014.
5. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

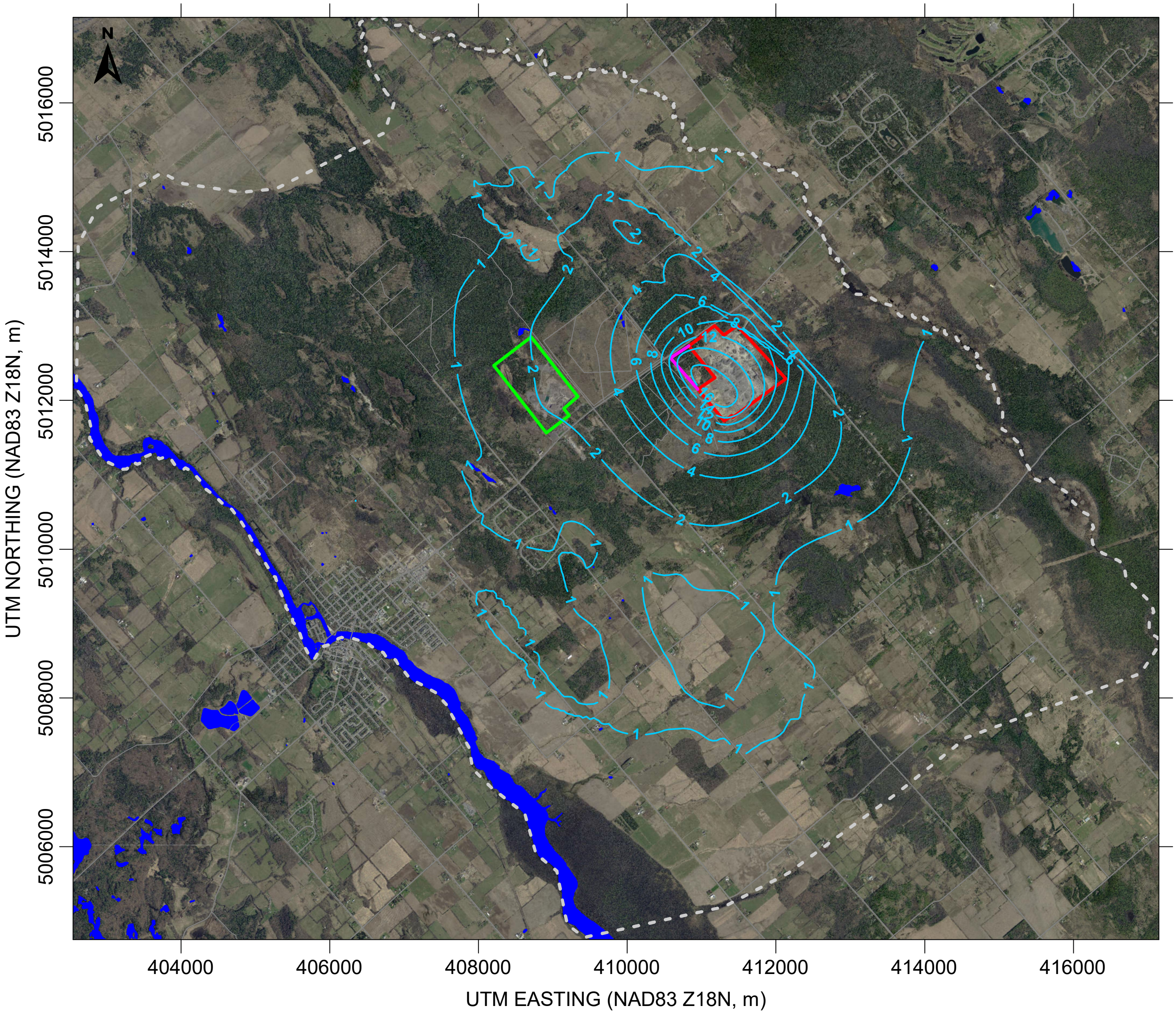
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
SCENARIO 1: FULL DEVELOPMENT OF EXISTING WEST CARLETON QUARRY AND BURNT LANDS QUARRY AT CURRENT CONDITIONS

PROJECT No.	Rev.	FIGURE
1899975	0	14



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- 🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE
- 🟩 BOUNDARY BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERBODY
- ▬ ROAD
- •••• MODEL BOUNDARY
- ▬ SIMULATED GROUNDWATER DRAWDOWN (m)

NOTES:

1. EXISTING WEST CARLETON QUARRY AND EXTENSION LANDS ARE REPRESENTED IN THE MODEL AT FULL DEVELOPMENT (FINAL FLOOR ELEVATION OF 107 m ASL)
2. BURNT LANDS QUARRY IS REPRESENTED IN THE MODEL AT CURRENT CONDITIONS
3. DRAWDOWN IS CALCULATED RELATIVE TO PRE-DEVELOPMENT CONDITIONS IN THE ROCKLIFFE FORMATION (MODEL LAYER 7)
4. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014.
5. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

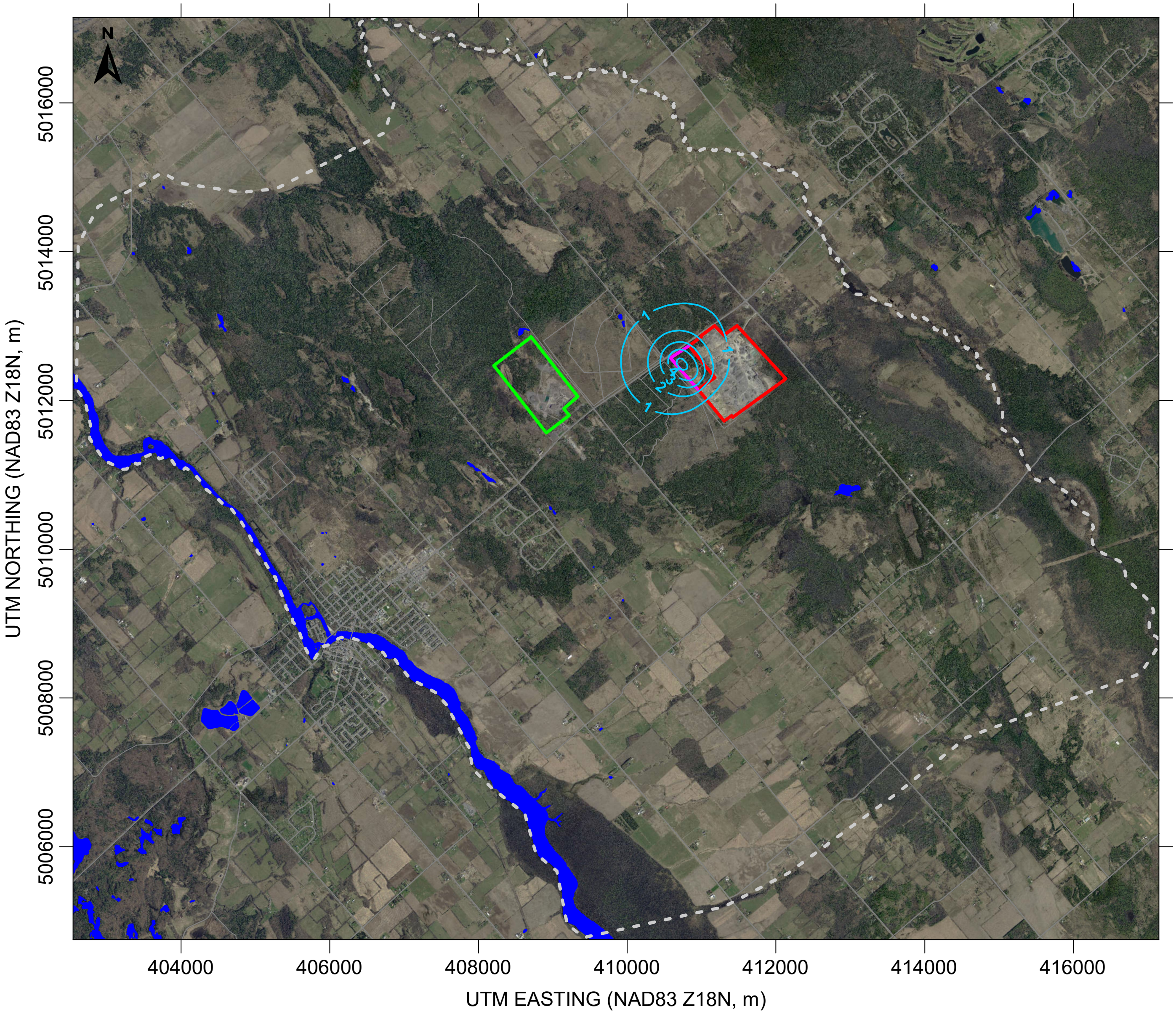
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
SCENARIO 2: FULL DEVELOPMENT OF EXISTING WEST CARLETON QUARRY PLUS EXTENSION LANDS AND BURNT LANDS QUARRY AT CURRENT CONDITIONS

PROJECT No.	Rev.	FIGURE
1899975	0	15



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERBODY
- ROAD
- ●●●● MODEL BOUNDARY
- SIMULATED GROUNDWATER DRAWDOWN (m)

NOTES:

1. BURNT LANDS QUARRY IS REPRESENTED IN THE MODEL AT CURRENT CONDITIONS
2. INCREMENTAL DRAWDOWN IS CALCULATED AS THE SIMULATED DRAWDOWN FOR SCENARIO 2 MINUS THE SIMULATED DRAWDOWN FOR SCENARIO 1 IN THE ROCKLIFFE FORMATION (MODEL LAYER 7)
4. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014.
5. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

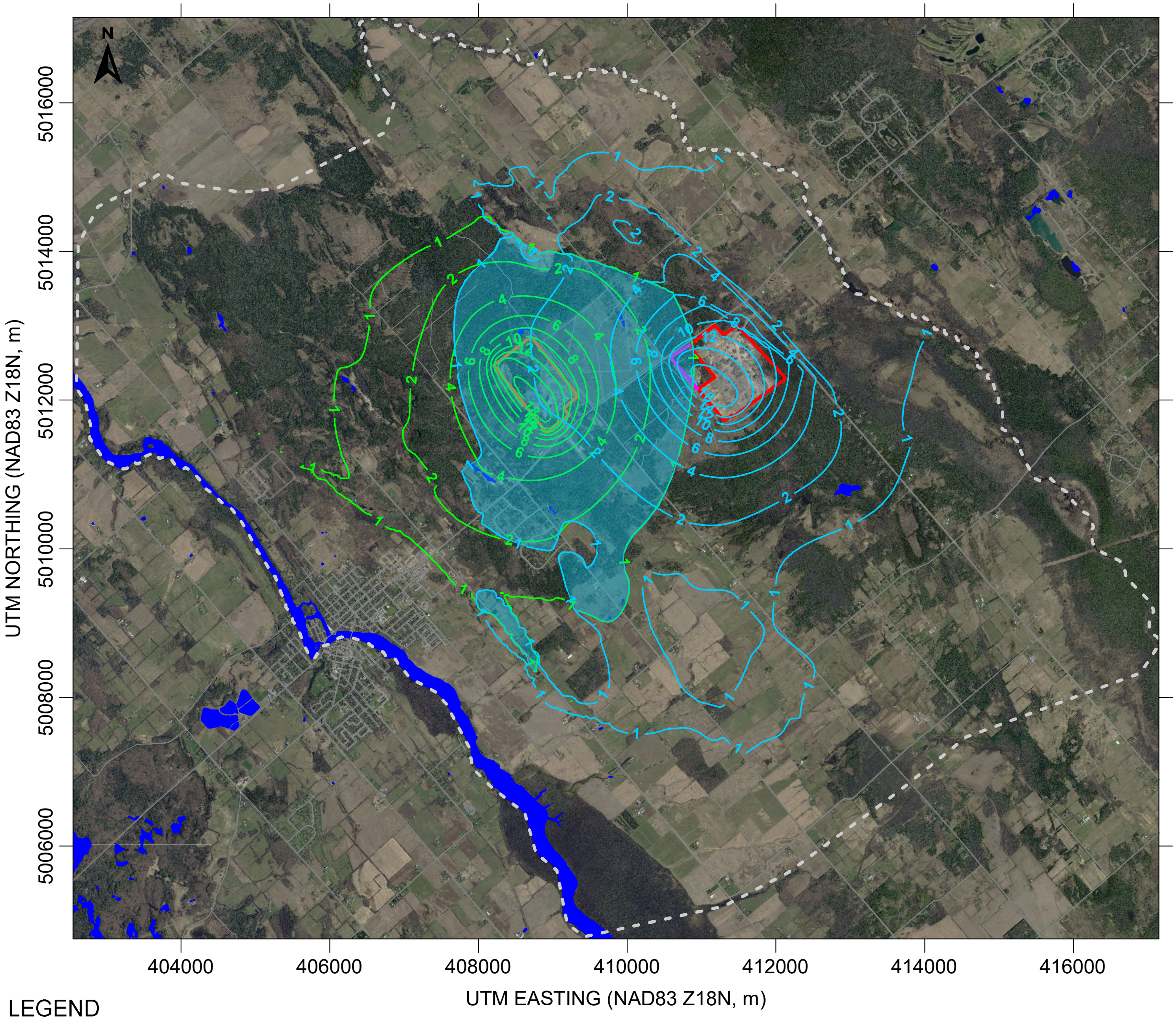
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
SIMULATED INCREMENTAL DRAWDOWN ASSOCIATED WITH DEVELOPMENT OF EXTENSION LANDS

PROJECT No.	Rev.	FIGURE
1899975	0	16



LEGEND

🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY

🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY

🟩 BURNT LANDS QUARRY LICENSE BOUNDARY

🟦 WATERBODY

— ROAD

•••• MODEL BOUNDARY

— SIMULATED GROUNDWATER DRAWDOWN (m)

▨ ZONE OF CUMULATIVE IMPACT

NOTES:

1. FOR SCENARIO 3 THE EXISTING WEST CARLETON QUARRY AND EXTENSION LANDS ARE REPRESENTED IN THE MODEL AT FULL DEVELOPMENT (FINAL FLOOR ELEVATION OF 107 m ASL) AND THE BURNT LANDS QUARRY IS REPRESNTED AT PREDEVELOPMENT CONDITIONS
2. FOR SCENARIO 4 THE BURNT LANDS QUARRY IS REPRESENTED IN THE MODEL AT FULL DEVELOPMENT (FINAL FLOOR ELEVATION OF 122 m ASL) AND THE EXISTING WEST CARLETON QUARRY AND EXTENSION LANDS ARE REPRESENTED AT PREDEVELOPMENT CONDITIONS
3. DRAWDOWN IS CALCULATED RELATIVE TO PRE-DEVELOPMENT CONDITIONS IN THE ROCKLIFFE FORMATION (MODEL LAYER 7)
4. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014.
5. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

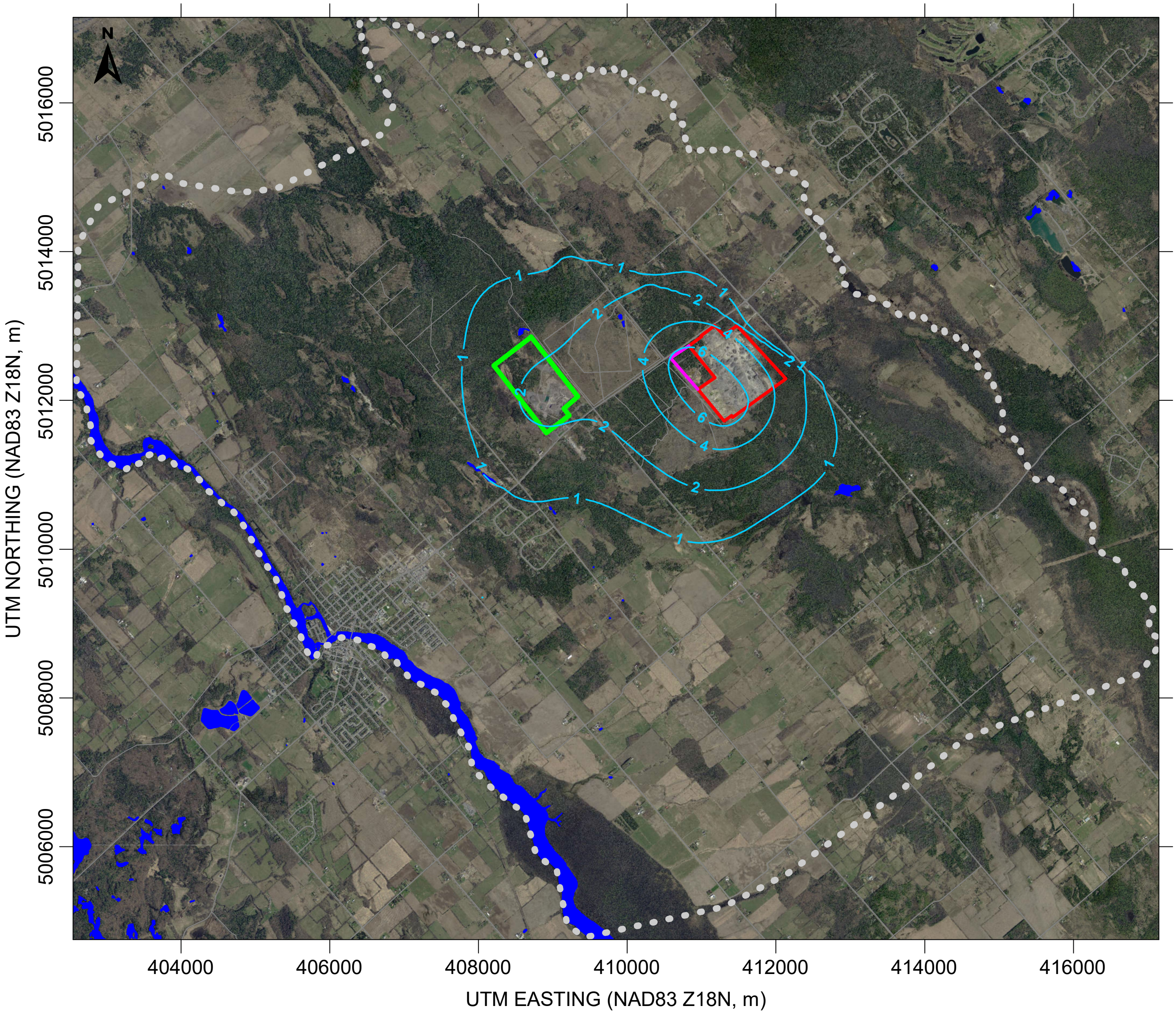
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-xx
PREPARED	HW
DESIGN	HW
REVIEW	NB
APPROVED	xxx

TITLE
SCENARIO 3 AND SCENARIO 4: SIMULATED DRAWDOWN AND ZONE OF CUMULATIVE IMPACT

PROJECT No.	Rev.	FIGURE
1899975	0	17



LEGEND

🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY

🟪 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY

🟩 BURNT LANDS QUARRY LICENSE BOUNDARY

🟦 WATERBODY

— ROAD

●●●● MODEL BOUNDARY

— SIMULATED GROUNDWATER DRAWDOWN (m)

NOTES:

1. EXISTING WEST CARLETON QUARRY AND EXTENSION LANDS ARE REPRESENTED IN THE MODEL AT REHABILITATION CONDITIONS (FLOODED LAKE ELEVATION OF 124 m ASL)
2. BURNT LANDS QUARRY IS REPRESENTED IN THE MODEL AT REHABILITATION CONDITIONS (FLOODED LAKE ELEVATION OF 150 m ASL)
3. DRAWDOWN IS CALCULATED RELATIVE TO PREDEVELOPMENT CONDITIONS IN THE ROCKLIFFE FORMATION (MODEL LAYER 7)
4. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014.
5. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

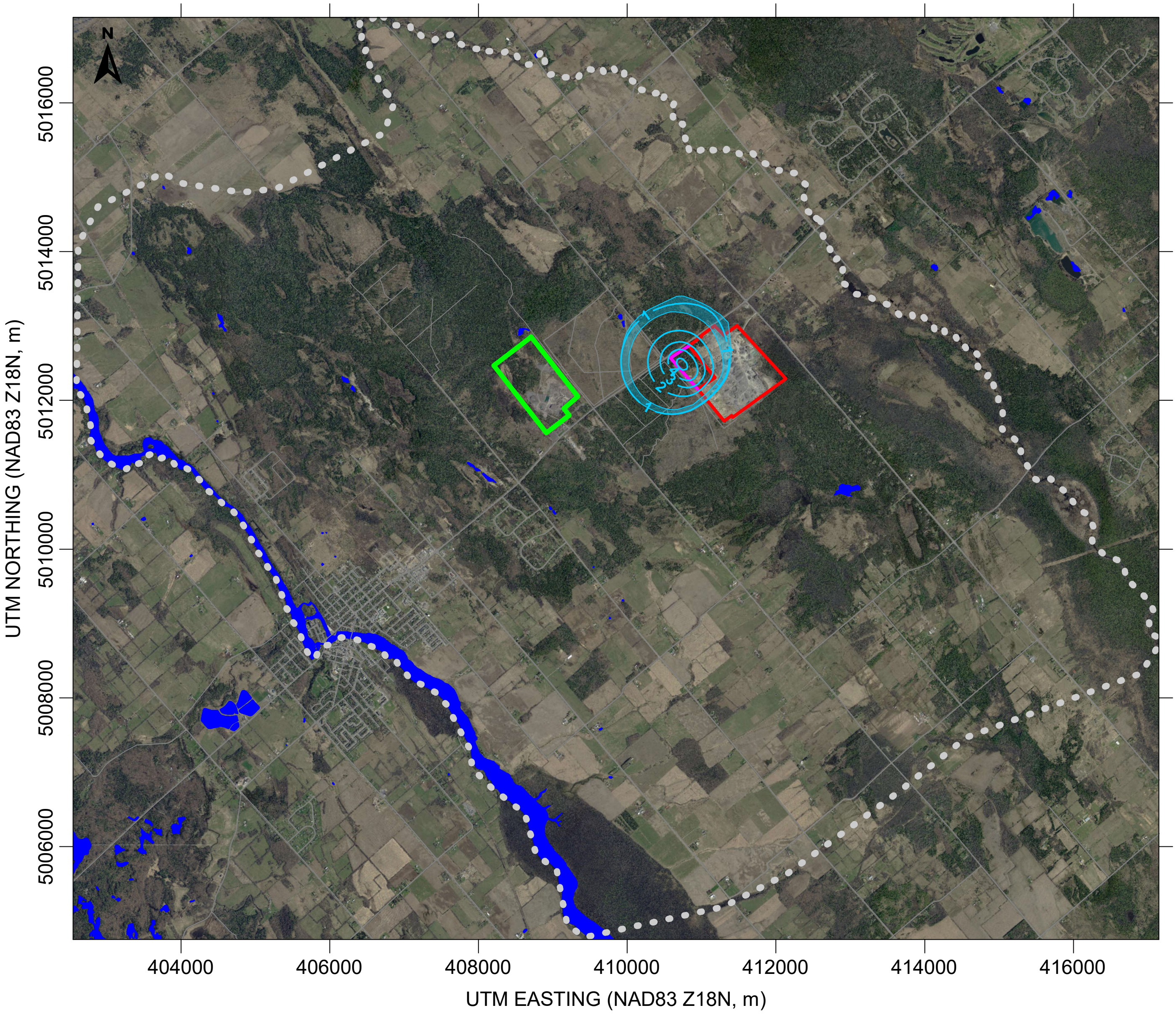
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	NB/JO
APPROVED	JO

TITLE
SCENARIO 6: EXISTING WEST CARLETON QUARRY, EXTENSION LANDS AND BURNT LANDS QUARRY AT REHABILITATION CONDITIONS

PROJECT No.	Rev.	FIGURE
1899975	0	18



LEGEND

- 🟥 EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- ━ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- 🟩 BURNT LANDS QUARRY LICENSE BOUNDARY
- 🟦 WATERBODY
- ━ ROAD
- ●●●● MODEL BOUNDARY
- ━ SIMULATED GROUNDWATER DRAWDOWN (m)
- ▨ SIMULATED 1m DRAWDOWN CONTOUR ENVELOPE

NOTES:

1. BURNT LANDS QUARRY IS REPRESENTED IN THE MODEL AT CURRENT CONDITIONS
2. INCREMENTAL DRAWDOWN IS CALCULATED AS THE SIMULATED DRAWDOWN FOR SCENARIO 2 MINUS THE SIMULATED DRAWDOWN FOR SCENARIO 1 IN THE ROCKLIFFE FORMATION (MODEL LAYER 7)
4. SOURCE FOR AERIAL IMAGERY: ONTARIO MINISTRY OF NATURAL RESOURCES, DIGITAL RASTER ACQUISITION PROJECT EASTERN ONTARIO (DRAPE) 2014.
5. SOURCE FOR ROADS AND WATERBODIES: MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAND INFORMATION ONTARIO (LIO) DATA

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

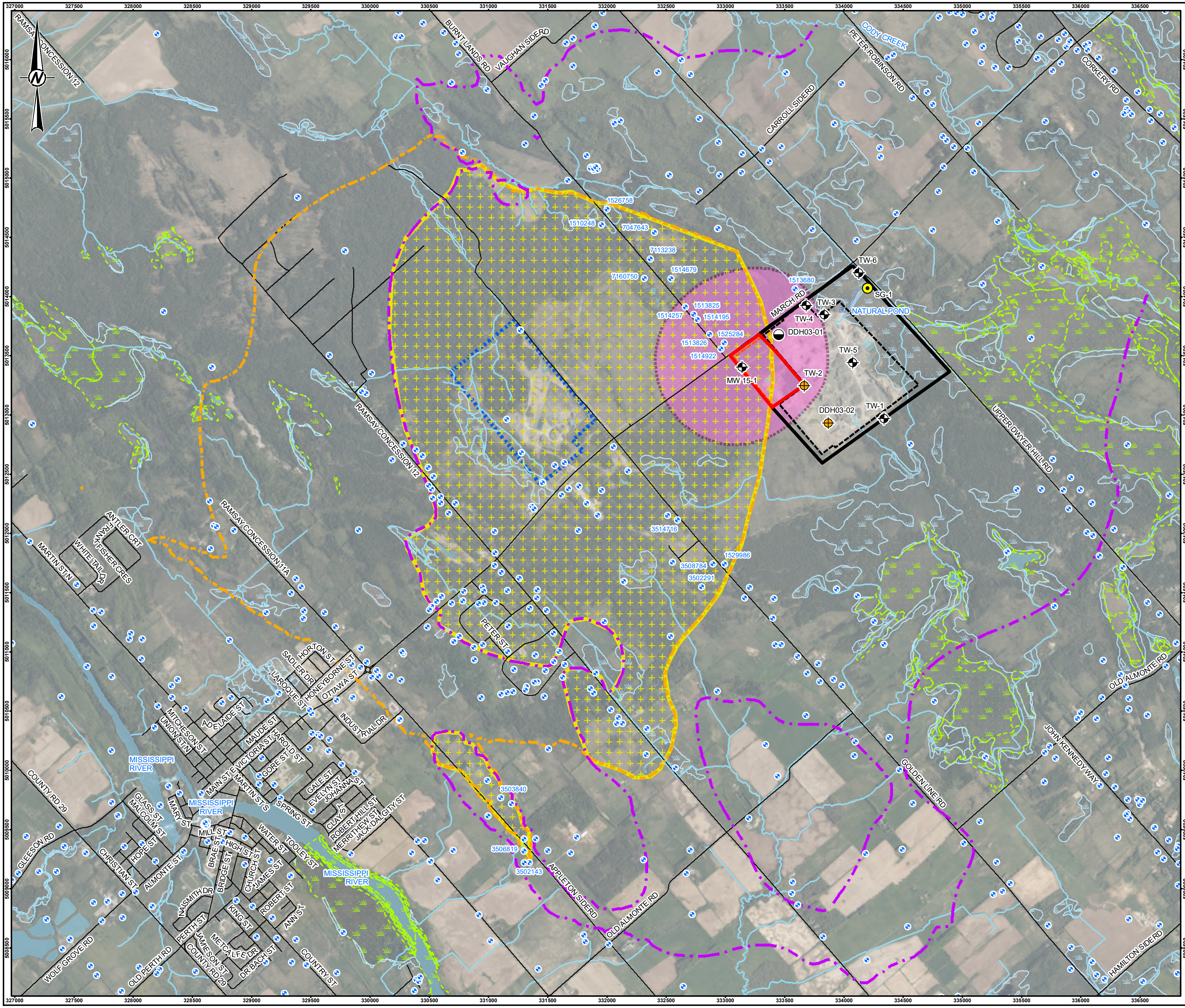
PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS-
PROPOSED WEST CARLETON QUARRY EXTENSION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-07-14
PREPARED	HW
DESIGN	HW
REVIEW	XX
APPROVED	XX

TITLE
SIMULATED RANGE IN INCREMENTAL DRAWDOWN RESULTING FROM SENSITIVITY ANSLYSIS

PROJECT No.	Rev.	FIGURE
1899975	0	19



LEGEND

- ● WATER WELL LOCATION (AS PER MECP WWIS)
- ⊙ STAFF GAUGE LOCATION
- ⊕ TEST WELL
- ◓ DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)
- ⊕ TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT
- 🟥 PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- ⬚ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
- ⬛ EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- ⬚ EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION
- ⬚ BURNT LANDS QUARRY LICENSE BOUNDARY
- — ROADWAY
- — WATERCOURSE
- ▭ WATERBODY
- ▭ WETLAND
- ▨ SIGNIFICANT WETLAND
- -·- 1-m DRAWDOWN CONTOUR - FULL DEVELOPMENT OF EXISTING ALMONTE QUARRY PLUS EXTENSION LANDS
- -·- 1-m DRAWDOWN CONTOUR - FULL DEVELOPMENT OF BURNT LANDS QUARRY
- ▨ ZONE OF CUMULATIVE IMPACT
- ▨ ZONE OF INCREMENTAL DRAWDOWN

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. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 300 600 1,200

1:32,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
WATER SUPPLY IMPACT ASSESSMENT

CONSULTANT

GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0007	0	**20**

Path: N:\Active\Spatial_IM\ThomasCavanagh\Almonte\99_PROJ\1899975_ThomasCavanagh_ARA_Application\40_PROD\0007_CH_HydroG_Hydrological_Assessments\1899975-0007-CH-0020.mxd

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

0 25mm

APPENDIX A

Water Well Records (TW-1, TW-2 and TW-3)

Ontario Ministry of the Environment

The Ontario Water Resources Act
WATER WELL RECORD

Print only in spaces provided.
Mark correct box with a checkmark, where applicable.

11 1531919

Municipality 15005 Con. CON 09

County or District Ottawa Carleton	Township/Borough/City/Town/Village West Carleton	Con block tract survey, etc. 9	Lot 15
Owner's surname First Name Thomas Cavanagh Const. Ltd.	Address R. R. # 2, Ashton ON. KOA 1BO	Date completed 01 day 05 month 01 year	

21 UTM Zone Easting Northing RC Elevation RC Basin Code ii iii iv

LOG OF OVERBURDEN AND BEDROCK MATERIALS (see instructions)

General colour	Most common material	Other materials	General description	Depth - feet From	Depth - feet To
Grey	Limestone	shale	med. hard	0	190
Grey & Green	limestone	sandstone		190	250
	refer to Geological Report for detailed bedrock				

31
32

41 WATER RECORD

Water found at - feet	Kind of water
215	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
238	NOT TESTED
	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas

51 CASING & OPEN HOLE RECORD

Inside diam inches	Material	Wall thickness inches	Depth - feet From	Depth - feet To
6 1/4	1 ☒ Steel 2 ☐ Galvanized 3 ☐ Concrete 4 ☐ Open hole 5 ☐ Plastic	.188	0	21
6 1/8	1 ☐ Steel 2 ☐ Galvanized 3 ☐ Concrete 4 ☒ Open hole 5 ☐ Plastic		21	250
	1 ☐ Steel 2 ☐ Galvanized 3 ☐ Concrete 4 ☐ Open hole 5 ☐ Plastic			

SCREEN

Sizes of opening (Slot No.)	Diameter inches	Length feet
Material and type	Depth at top of screen feet	

61 PLUGGING & SEALING RECORD

☒ Annular space ☐ Abandonment

Depth set at - feet From	To	Material and type (Cement grout, bentonite, etc.)
21	0	Grouted-cement (3)

71 PUMPING TEST

Pumping test method 1 ☒ Pump 2 ☐ Bailer		Pumping rate 12 GPM		Duration of pumping 2 Hours Mins	
Static level	Water level end of pumping	Water levels during 1 ☒ Pumping 2 ☐ Recovery			
		15 minutes	30 minutes	45 minutes	60 minutes
72 feet	76 feet	75 feet	76 feet	76 feet	76 feet
If flowing give rate GPM		Pump intake set at feet		Water at end of test ☐ Clear ☐ Cloudy	
Recommended pump type ☐ Shallow ☒ Deep		Recommended pump setting 150 feet		Recommended pump rate 5 GPM	

FINAL STATUS OF WELL

1 ☒ Water supply
2 ☐ Observation well
3 ☐ Test hole
4 ☐ Recharge well
5 ☐ Abandoned, insufficient supply
6 ☐ Abandoned, poor quality
7 ☐ Abandoned (Other)
8 ☐ Dewatering
9 ☐ Unfinished
10 ☐ Replacement well

WATER USE

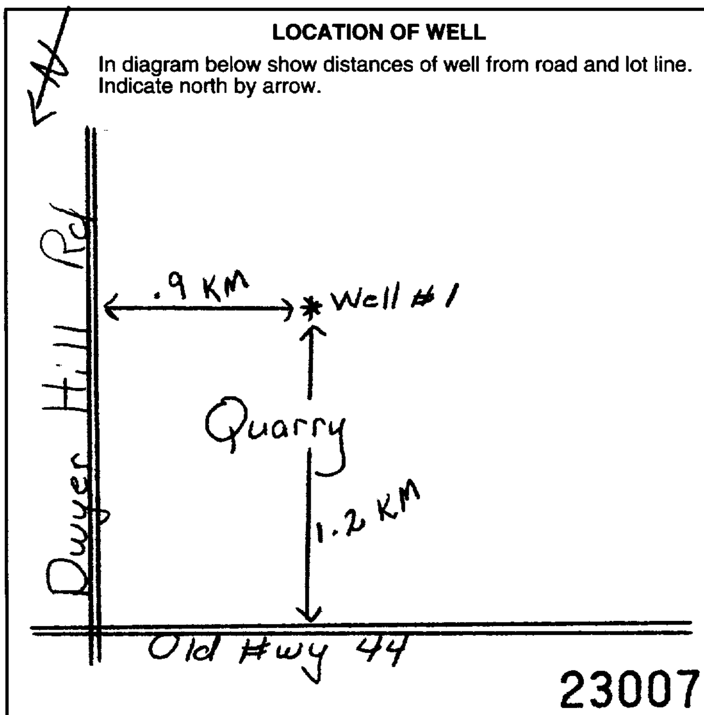
1 ☐ Domestic
2 ☐ Stock
3 ☐ Irrigation
4 ☐ Industrial
5 ☐ Commercial
6 ☐ Municipal
7 ☐ Public supply
8 ☐ Cooling & air conditioning
9 ☐ Not use
10 ☐ Other observation

METHOD OF CONSTRUCTION

1 ☐ Cable tool
2 ☐ Rotary (conventional)
3 ☐ Rotary (reverse)
4 ☒ Rotary (air)
5 ☐ Air percussion
6 ☐ Boring
7 ☐ Diamond
8 ☐ Jetting
9 ☐ Driving
10 ☐ Digging
11 ☐ Other

LOCATION OF WELL

In diagram below show distances of well from road and lot line. Indicate north by arrow.



230079

Name of Well Contractor Capital Water Supply Ltd.	Well Contractor's Licence No. 1558
Address Box 490, Stittsville, ON K2S 1A6	
Name of Well Technician S. Miller	Well Technician's Licence No. T0097
Signature of Technician/Contractor Kavanagh	Submission date day 01 mo 05 yr 01

MINISTRY USE ONLY

Data source	Contractor 1558	Date received JUN 15 2001
Date of inspection	Inspector	
Remarks	CSS.ES1	

2 - MINISTRY OF THE ENVIRONMENT COPY

0506 (07/00) Front Form 9

Ontario Ministry of the Environment

The Ontario Water Resources Act
WATER WELL RECORD

Print only in spaces provided.
Mark correct box with a checkmark, where applicable.

11 1531920 Municipality 15005 Con. CON 11

County or District	Township/Borough/City/Town/Village	Con block tract survey, etc.	Lot
Ottawa Carleton	West Carleton	11	15

Owner's surname / First Name	Address	Date completed
Thomas Cavanagh Const. Ltd.	R. R. #2, Ashton ON. K0A 1B0	02 day 05 month 01 year

21 UTM Zone Easting Northing RC Elevation RC Basin Code ii iii iv

LOG OF OVERBURDEN AND BEDROCK MATERIALS (see instructions)

General colour	Most common material	Other materials	General description	Depth - feet From	Depth - feet To
Brown	Soil	Broken Rock		0	3
Grey	Limestone	Shale	med hard	3	200
Grey & Green	Limestone	Sandstone		200	248

refer to Geological Report for detailed bedrock

31

32

41 WATER RECORD

Water found at - feet	Kind of water
225	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
248	NOT TESTED ☐ Salty ☐ Minerals ☐ Gas
	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas

51 CASING & OPEN HOLE RECORD

Inside diam inches	Material	Wall thickness inches	Depth - feet From	Depth - feet To
6 1/4	☒ Steel ☐ Galvanized ☐ Concrete ☐ Open hole ☐ Plastic	.188	0	21
6 1/8	☐ Steel ☐ Galvanized ☐ Concrete ☒ Open hole ☐ Plastic		21	248
	☐ Steel ☐ Galvanized ☐ Concrete ☐ Open hole ☐ Plastic			

SCREEN

Sizes of opening (Slot No.)	Diameter	Length
	inches	feet

Material and type	Depth at top of screen
	feet

61 PLUGGING & SEALING RECORD

☒ Annular space ☐ Abandonment

Depth set at - feet From	To	Material and type (Cement grout, bentonite, etc.)
21	0	Grouted Cement (3)

71 PUMPING TEST

Pumping test method: ☒ Pump ☐ Bailer		Pumping rate 12 GPM		Duration of pumping 2 Hours Mins	
Static level	Water level end of pumping	Water levels during ☒ Pumping ☐ Recovery			
		15 minutes	30 minutes	45 minutes	60 minutes
79 feet	80 feet	80 feet	80 feet	80 feet	80 feet
If flowing give rate GPM		Pump intake set at 120 feet		Water at end of test ☐ Clear ☒ Cloudy	
Recommended pump type ☐ Shallow ☒ Deep		Recommended pump setting 150 feet		Recommended pump rate 5 GPM	

FINAL STATUS OF WELL

- ☒ Water supply
- ☐ Observation well
- ☐ Test hole
- ☐ Recharge well
- ☐ Abandoned, insufficient supply
- ☐ Abandoned, poor quality
- ☐ Abandoned (Other)
- ☐ Dewatering
- ☐ Unfinished
- ☐ Replacement well

WATER USE

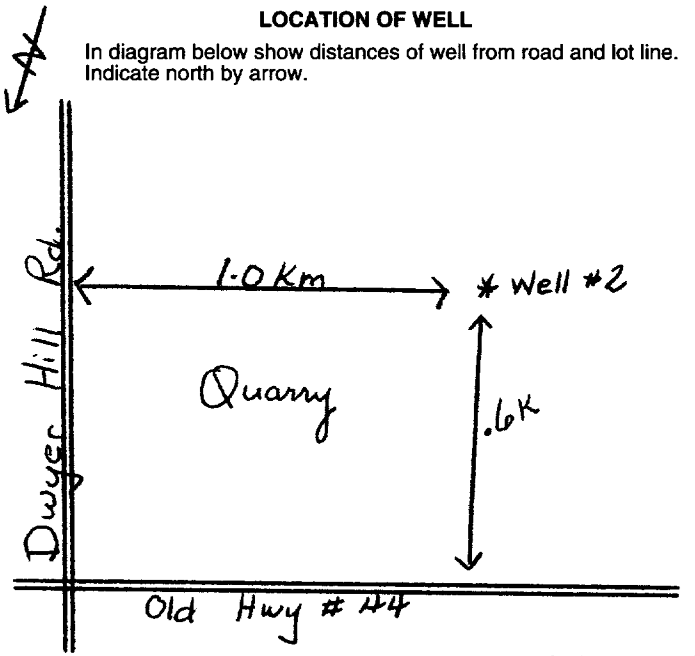
- ☐ Domestic
- ☐ Stock
- ☐ Irrigation
- ☐ Industrial
- ☐ Commercial
- ☐ Municipal
- ☐ Public supply
- ☐ Cooling & air conditioning
- ☐ Not use
- ☐ Other observation

METHOD OF CONSTRUCTION

- ☐ Cable tool
- ☐ Rotary (conventional)
- ☐ Rotary (reverse)
- ☒ Rotary (air)
- ☐ Air percussion
- ☐ Boring
- ☐ Diamond
- ☐ Jetting
- ☐ Driving
- ☐ Digging
- ☐ Other

LOCATION OF WELL

In diagram below show distances of well from road and lot line.
Indicate north by arrow.



230080

Name of Well Contractor	Well Contractor's Licence No.
Capital Water Supply Ltd	1558

Address
Box 490, Stittsville, ON K2S 1A6

Name of Well Technician	Well Technician's Licence No.
S. Miller	T0097

Signature of Technician/Contractor: Kavanagh

Submission date day 01 mo 05 yr 01

MINISTRY USE ONLY

Data source	Contractor	Date received
	1558	JUN 15 2001

Date of inspection

Inspector

Remarks CSS.ES1

2 - MINISTRY OF THE ENVIRONMENT COPY

0506 (07/00) Front Form 9

Ontario Ministry of the Environment

The Ontario Water Resources Act
WATER WELL RECORD

Print only in spaces provided.
Mark correct box with a checkmark, where applicable.

11 1531921 Municipality 15005 Con. CON

County or District Ottawa Carleton	Township/Borough/City/Town/Village West Carleton	Con block tract survey, etc. 11	Lot 15
Owner's surname / First Name Thomas Cavanagh Const. Ltd.	Address R. R. #2, Ashton ON/ K0A 1B0	Date completed 02 day 05 month 01 year	

21 UTM Zone Easting Northing RC Elevation RC Basin Code ii iii iv

LOG OF OVERBURDEN AND BEDROCK MATERIALS (see instructions)

General colour	Most common material	Other materials	General description	Depth - feet From	Depth - feet To
Grey	Limestone	shale		0	165
Grey & Green	Limestone	red limestone		165	250
Grey	Limestone	sandstone		250	255
	refer to Geological Report for detailed		bedrock		

31

32

41 WATER RECORD

Water found at - feet	Kind of water
195	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
235	NOT TESTED 1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas
	1 ☐ Fresh 2 ☐ Salty 3 ☐ Sulphur 4 ☐ Minerals 6 ☐ Gas

51 CASING & OPEN HOLE RECORD

Inside diam inches	Material	Wall thickness inches	Depth - feet From	Depth - feet To
6 1/4	1 ☒ Steel 2 ☐ Galvanized 3 ☐ Concrete 4 ☐ Open hole 5 ☐ Plastic	.188	0	21
6 1/8	1 ☐ Steel 2 ☐ Galvanized 3 ☐ Concrete 4 ☒ Open hole 5 ☐ Plastic		21	250
5 3/4	1 ☐ Steel 2 ☐ Galvanized 3 ☐ Concrete 4 ☒ Open hole 5 ☐ Plastic		250	255

SCREEN

Sizes of opening (Slot No.)	Diameter inches	Length feet

Material and type | Depth at top of screen feet

61 PLUGGING & SEALING RECORD

☒ Annular space ☐ Abandonment

Depth set at - feet From	To	Material and type (Cement grout, bentonite, etc.)
21	0	Grouted-cement (3)

71 PUMPING TEST

Pumping test method 1 ☒ Pump 2 ☐ Bailer		Pumping rate 5 GPM		Duration of pumping Hours 55 Mins	
Static level	Water level end of pumping	Water levels during 1 ☒ Pumping 2 ☐ Recovery			
		15 minutes	30 minutes	45 minutes	60 minutes
3 feet	102 feet	53 feet	75 feet	92 feet	102 feet
If flowing give rate GPM		Pump intake set at 120 feet		Water at end of test ☐ Clear ☒ Cloudy	
Recommended pump type ☐ Shallow ☒ Deep		Recommended pump setting 150 feet		Recommended pump rate 5 GPM	

FINAL STATUS OF WELL

1 ☒ Water supply
2 ☐ Observation well
3 ☐ Test hole
4 ☐ Recharge well
5 ☐ Abandoned, insufficient supply
6 ☐ Abandoned, poor quality
7 ☐ Abandoned (Other)
8 ☐ Dewatering
9 ☐ Unfinished
10 ☐ Replacement well

WATER USE

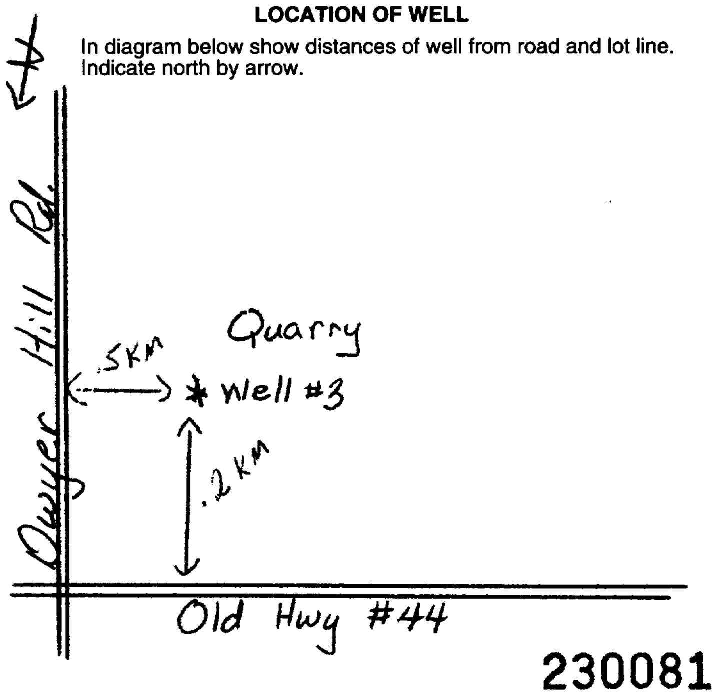
1 ☐ Domestic
2 ☐ Stock
3 ☐ Irrigation
4 ☐ Industrial
5 ☐ Commercial
6 ☐ Municipal
7 ☐ Public supply
8 ☐ Cooling & air conditioning
9 ☐ Not use
10 ☐ Other Observation

METHOD OF CONSTRUCTION

1 ☒ Cable tool 250
2 ☐ Rotary (conventional)
3 ☐ Rotary (reverse)
4 ☒ Rotary (air)
5 255 Air percussion
6 ☐ Boring
7 ☐ Diamond
8 ☐ Jetting
9 ☐ Driving
10 ☐ Digging
11 ☐ Other

LOCATION OF WELL

In diagram below show distances of well from road and lot line. Indicate north by arrow.



230081

Name of Well Contractor Capital Water Supply Ltd.	Well Contractor's Licence No. 1558
Address Box 490, Stittsville, ON. K2S 1A6	
Name of Well Technician S. Miller	Well Technician's Licence No. T0097
Signature of Technician/Contractor Kavanagh	Submission date day 2 mo 05 yr 01

MINISTRY USE ONLY

Data source	Contractor 1558	Date received JUN 15 2001
Date of inspection	Inspector	
Remarks	CSS.ES1	

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APPENDIX B

Borehole Logs

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-1

SHEET 1 OF 5

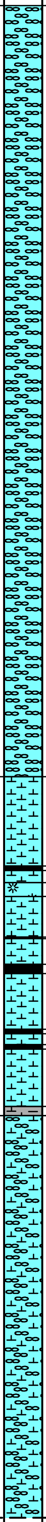
LOCATION: N 5013679.6 ;E 333450.4

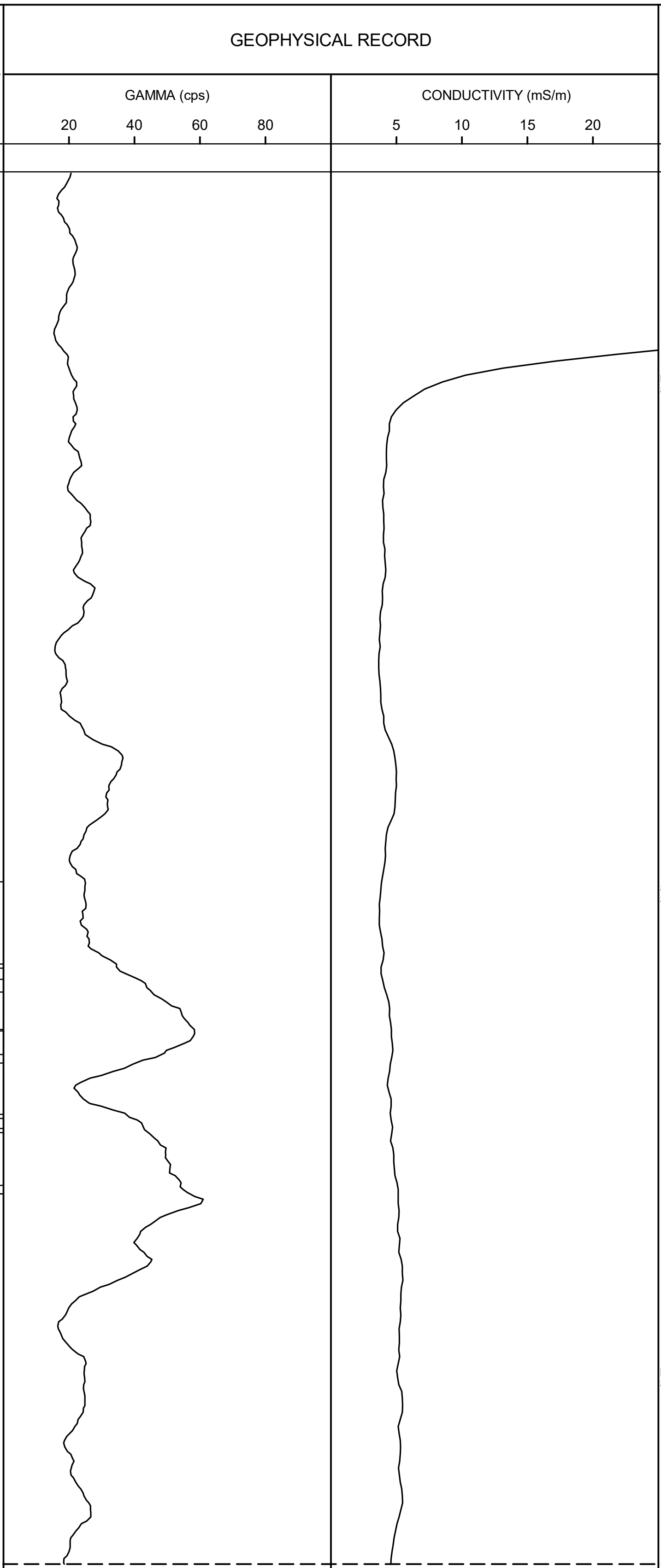
INCLINATION: -90° AZIMUTH: ---

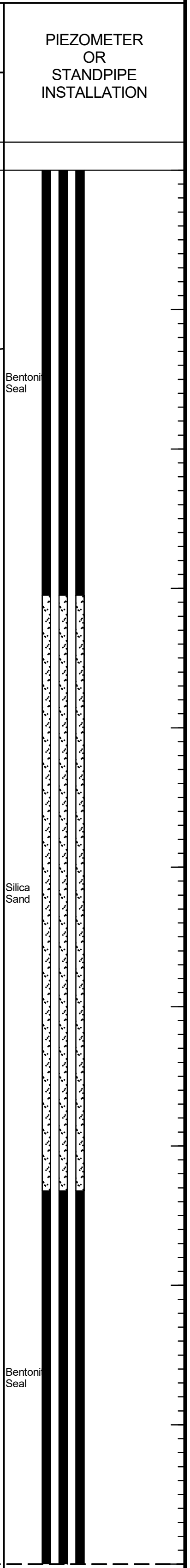
DRILLING DATE: November 2003
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		GROUND SURFACE		149.99
0		**Lower Bobcaygeon Formation, 0.0 m to 30.96 m** **Unit 3, 0.0 m to 17.27 m** **From 0.0 m to 5.10 m,** fresh, weathered on bedding partings to 12.62 m, medium brownish grey, fine grained, partly crystalline, non-porous, thinly to medium bedded **NODULAR MICRITIC LIMESTONE** with localized birds eye calcite crystals.		0.00
5		**From 5.10 m to 7.34 m,** fresh, medium brownish grey, fine grained, partly crystalline, non-porous, thinly bedded **ARGILLACEOUS TO SHALEY MICRITIC LIMESTONE** with individual dark grey to black shale partings at 5.69-.72m, 6.16-.17m, 6.34-.40m, 6.77-.80m, 6.87-.90m and 7.28-.34m. Thin bed of medium grained calcarenitic limestone at 5.80-.89m.		144.89 5.10 144.30 5.72 5.80 5.89 143.83 6.17 6.40 143.22 6.90 142.71 142.65
7		**From 7.34 m to 14.47 m,** fresh, medium brownish grey, fine grained, partly crystalline, non-porous, thinly to medium bedded **NODULAR ARGILLACEOUS MICRITIC LIMESTONE** with argillaceous bedding partings. Sharp basal contact. (No core available between 8.31 m and 13.92 m due to previous sampling.)		7.34
10		*CONTINUED NEXT PAGE*		







OTTAWA-GEO 1899975.GPJ GAL-GTA.GDT 7/21/20 JM

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-1

SHEET 2 OF 5

LOCATION: N 5013679.6 ;E 333450.4

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 2003

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

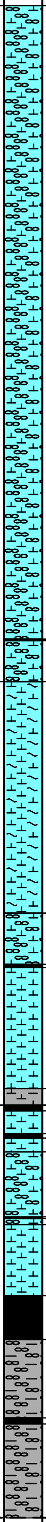
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	GEOPHYSICAL RECORD	PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

From 7.34 m to 14.47 m, fresh, medium brownish grey, fine grained, partly crystalline, non-porous, thinly to medium bedded **NODULAR ARGILLACEOUS MICRITIC LIMESTONE** with argillaceous bedding partings. Sharp basal contact. (No core available between 8.31 m and 13.92 m due to previous sampling.)

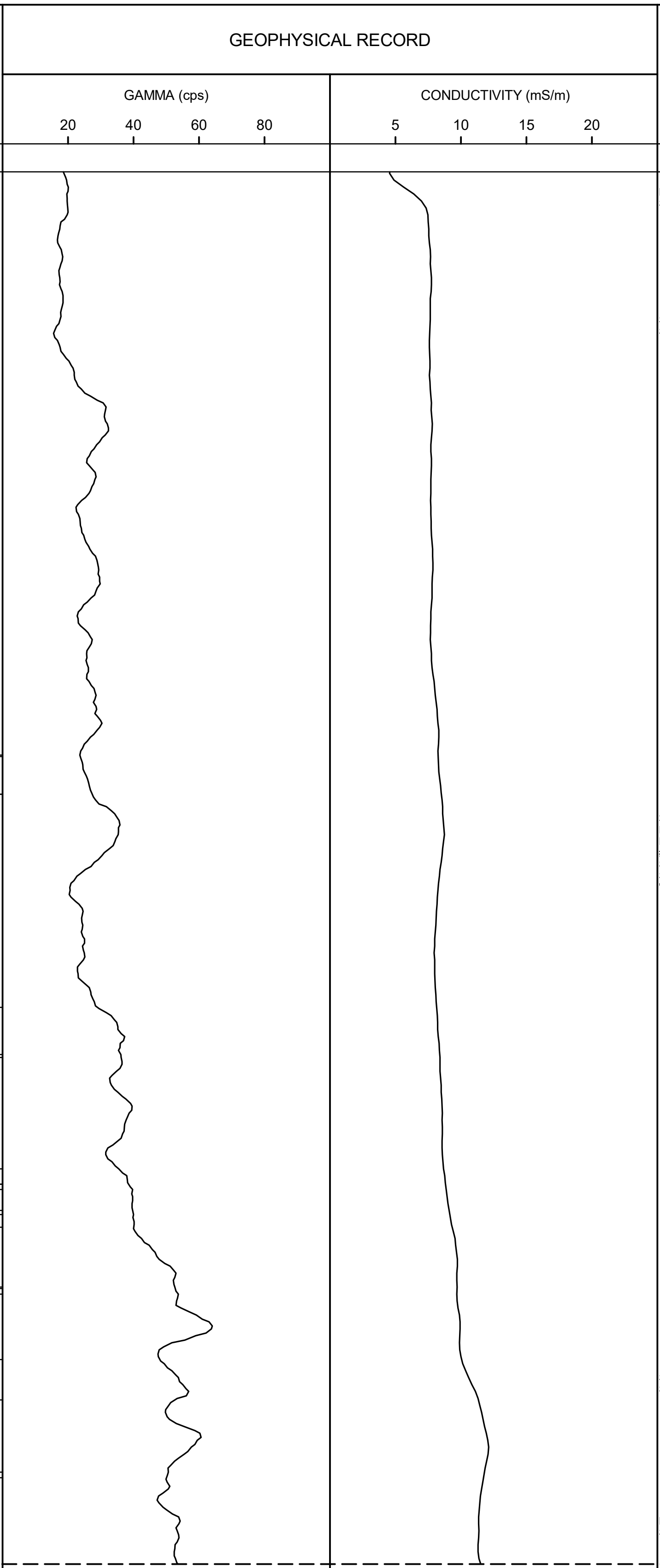
From 14.47 m to 17.27 m, fresh, medium brownish grey, fine grained crystalline, non-porous, thinly to medium bedded, laminar textured **MICRITIC LIMESTONE** with moderately developed fine stylolites and 0.5-2.0mm black argillaceous partings. Interbed of argillaceous lithoclastic limestone at 16.00-.08m and nodular argillaceous micritic limestone at 16.00-.36m with black shaley partings at 16.08-.09m and 16.34-.36m and thin bed of argillaceous to shaley limestone at 17.16-.27m. Transitional basal contact.

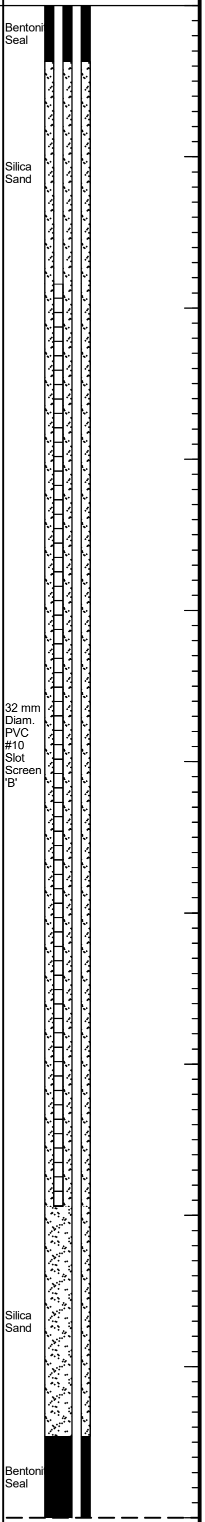
Unit 2, 17.27 m to 20.32 m
Fresh medium brownish grey, fine grained crystalline, non-porous, thinly to medium bedded, laminar textured **NODULAR ARGILLACEOUS MICRITIC LIMESTONE** with thin interbeds of **MICRITIC LIMESTONE** at 17.31-.58m and 18.06-.53m and black **SHALE and SHALEY LIMESTONE** at 18.53-.82m and 20.06-.27m and black shaley partings at 17.27-.31m, 17.46-.49m, 18.01-.02m, 19.34-.38m and 20.27-.32m. Fossil shell fragments occur in the nodular beds. Sharp basal contact.



ELEV. / DEPTH (m):

135.80
14.20
135.52
14.47
133.99
16.00
133.65
16.36
132.83
132.76
17.27
17.31
17.49
17.58
131.98
18.06
131.46
18.53
131.17
18.82
130.65
19.38





Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

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DEPTH SCALE
1 : 50

GOLDER

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-1

SHEET 3 OF 5

LOCATION: N 5013679.6 ;E 333450.4

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 2003

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | GEOPHYSICAL RECORD | PIEZOMETER OR STANDPIPE INSTALLATION

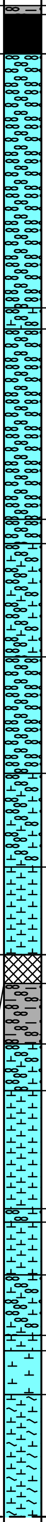
--- CONTINUED FROM PREVIOUS PAGE ---

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

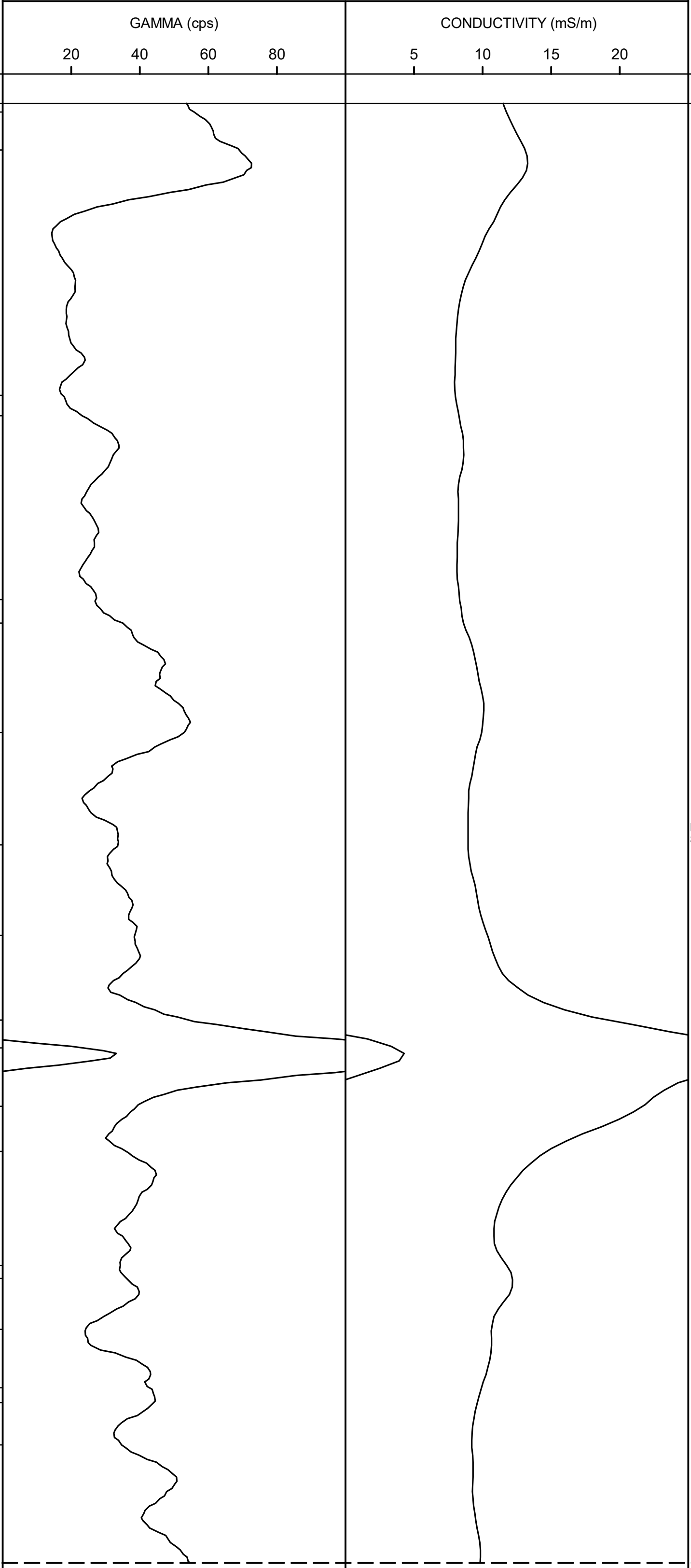
Unit 1, 20.32 m to 30.80 m
From 20.32 m to 26.28 m, fresh, medium brownish grey, fine grained crystalline, non-porous, medium to thickly bedded **NODULAR MICRITIC LIMESTONE** with interbeds of nodular argillaceous micritic limestone at 22.00-.14m, 23.56-24.31m (argillaceous to shaley at 23.56-.66m) and 25.08-.70m. Medium bedded argillaceous micritic limestone at 25.70-26.24m with shaley micrite at 26.24-.28m. Sharp basal contact.

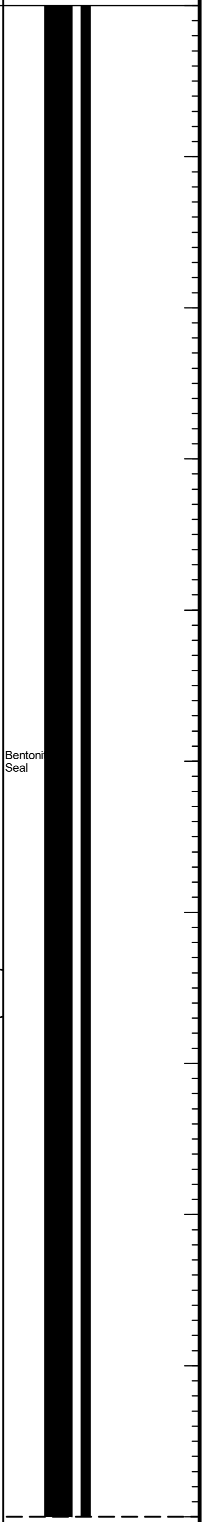
From 26.28 m to 26.47 m, soft, light grey bentonitic clay layer associated with large natural gamma and apparent conductivity geophysical spikes, possible volcanic ash bed.

From 26.47 m to 30.96 m, fresh, fine grained crystalline, non-porous, thinly to medium bedded, wavy laminar textured **NODULAR ARGILLACEOUS MICRITIC LIMESTONE** including interbeds of shaley nodular micrite at 26.47-.87m (shaley with brachiopod fossils), 27.96-28.05m (argillaceous to shaley) and 28.40-.80m (argillaceous to shaley) with medium beds of micritic limestone at 27.18-.96 m, 28.05-.40m and 28.80-29.19m. Thinly to medium bedded, laminar textured **MICRITIC LIMESTONE** from 29.19 m to 31.80 m. Basal thin bed of dark grey shaley limestone at 30.80-.96m overlying the first dolostone marker bed at the top of the Gull River Formation.



ELEV.	DEPTH (m)
129.93	20.06
129.67	20.32
127.99	22.00
	22.14
126.59	23.40
	23.56
125.68	24.31
124.91	25.08
124.29	25.70
123.71	26.28
123.52	26.47
123.12	26.87
122.81	27.18
122.03	27.96
	28.05
121.59	28.40
121.19	28.80
	28.90
120.80	29.19





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DEPTH SCALE

1 : 50

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-1

SHEET 4 OF 5

LOCATION: N 5013679.6 ;E 333450.4

DRILLING DATE: November 2003

DATUM: Geodetic

DRILL RIG: CME 55

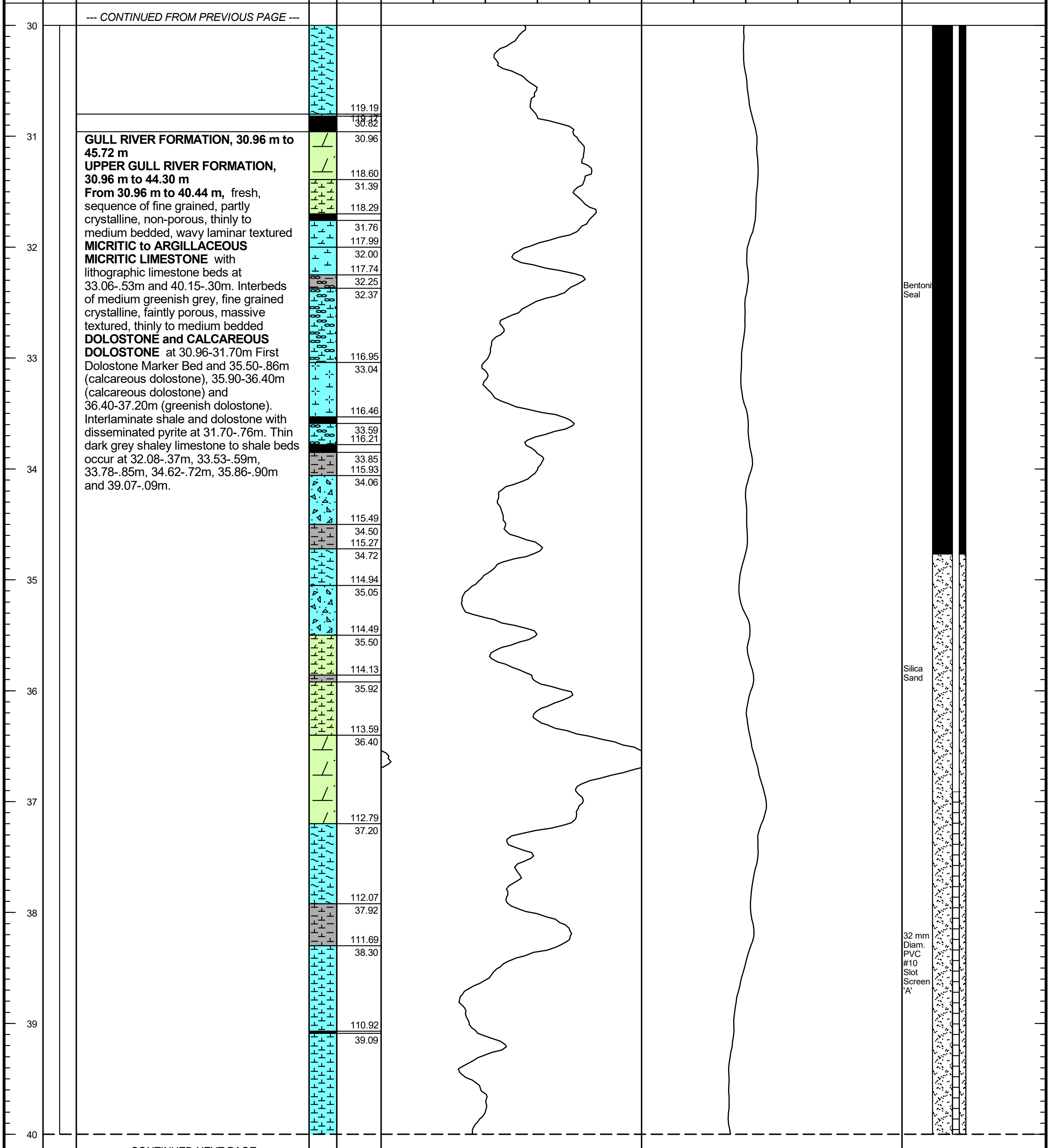
INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Marathon Drilling

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | GEOPHYSICAL RECORD | PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

GULL RIVER FORMATION, 30.96 m to 45.72 m
UPPER GULL RIVER FORMATION, 30.96 m to 44.30 m
From 30.96 m to 40.44 m, fresh, sequence of fine grained, partly crystalline, non-porous, thinly to medium bedded, wavy laminar textured **MICRITIC to ARGILLACEOUS MICRITIC LIMESTONE** with lithographic limestone beds at 33.06-.53m and 40.15-.30m. Interbeds of medium greenish grey, fine grained crystalline, faintly porous, massive textured, thinly to medium bedded **DOLOSTONE and CALCAREOUS DOLOSTONE** at 30.96-31.70m First Dolostone Marker Bed and 35.50-.86m (calcareous dolostone), 35.90-36.40m (calcareous dolostone) and 36.40-37.20m (greenish dolostone). Interlaminate shale and dolostone with disseminated pyrite at 31.70-.76m. Thin dark grey shaley limestone to shale beds occur at 32.08-.37m, 33.53-.59m, 33.78-.85m, 34.62-.72m, 35.86-.90m and 39.07-.09m.



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DEPTH SCALE
1 : 50

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-1

SHEET 5 OF 5

LOCATION: N 5013679.6 ;E 333450.4

INCLINATION: -90° AZIMUTH: ---

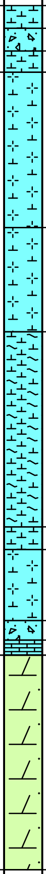
DRILLING DATE: November 2003

DRILL RIG: CME 55

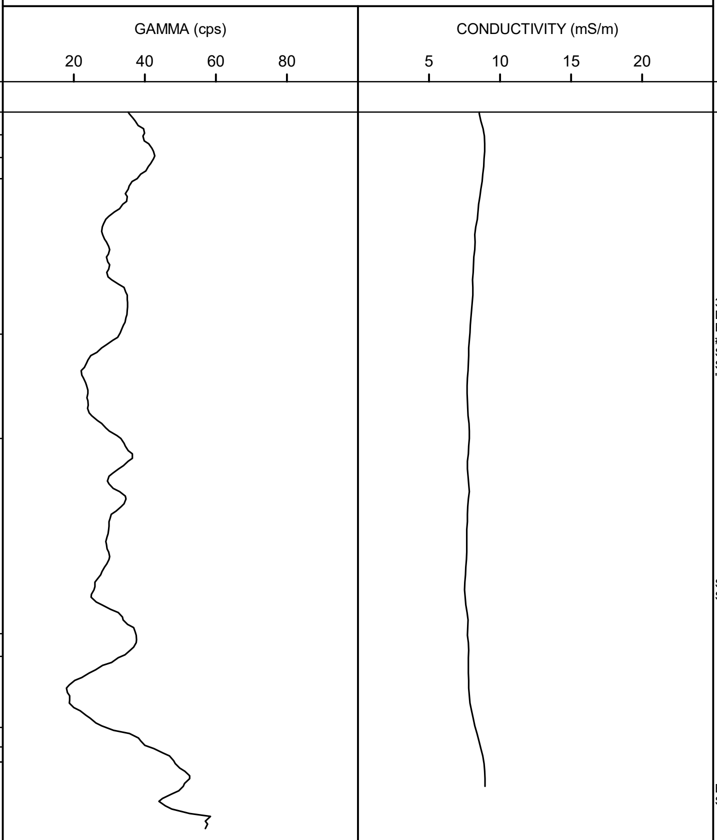
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

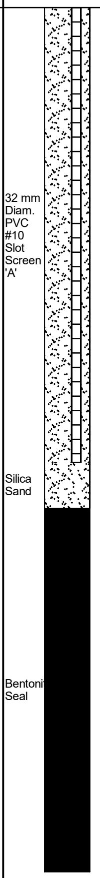
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		--- CONTINUED FROM PREVIOUS PAGE ---		
40				109.84 40.15 40.30 109.55 40.44
		From 40.44 m to 44.30 m, fresh, light to medium grey, very fine grained, non-porous, medium bedded **LITHOGRAPHIC LIMESTONE** with interbed of medium grey, laminar textured **MICRITIC LIMESTONE** at 42.16-43.48m grading to argillaceous micrite at 43.48-.60m. Laths of selenite occur in lithoclastic limestone bed at 44.07-.20m.		108.52 41.47 107.83 42.16 106.54 43.45 43.60 105.92 44.07 105.69 44.20
41				
42				
43				
44				
		Lower Gull River Formation Unit 5, 44.30 m to 45.72 m Fresh, medium grey to greenish grey, fine grained crystalline, faintly porous, medium bedded **CALCAREOUS DOLOSTONE** marking the top of the approximately 10 m thick Unit 5 dolostone sequence.		44.30
45				104.27
		End of Borehole, 45.72 m		45.72
46				
47				
48				
49				
50				



GEOPHYSICAL RECORD



PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE

1 : 50

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-2

SHEET 1 OF 5

LOCATION: N 5012872.5 ;E 333890.6

INCLINATION: -90° AZIMUTH: ---

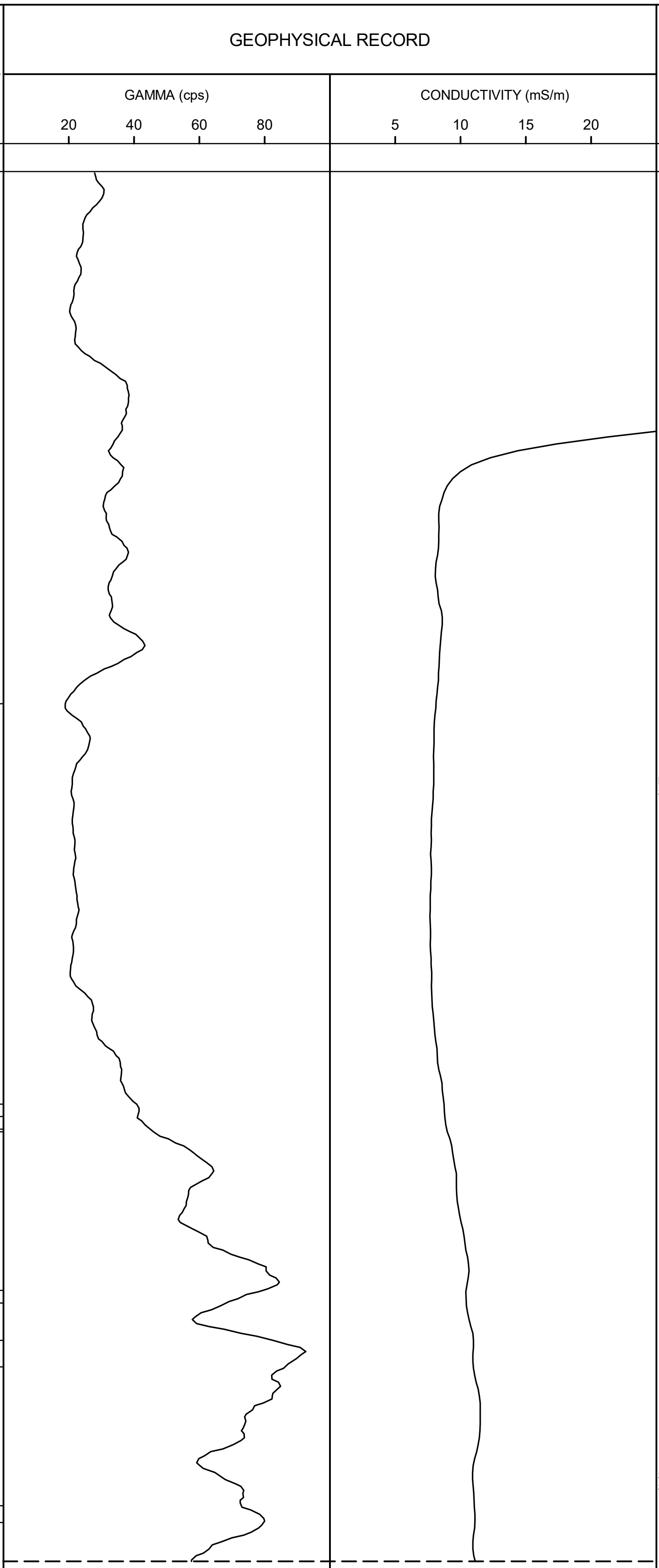
DRILLING DATE: November 2003

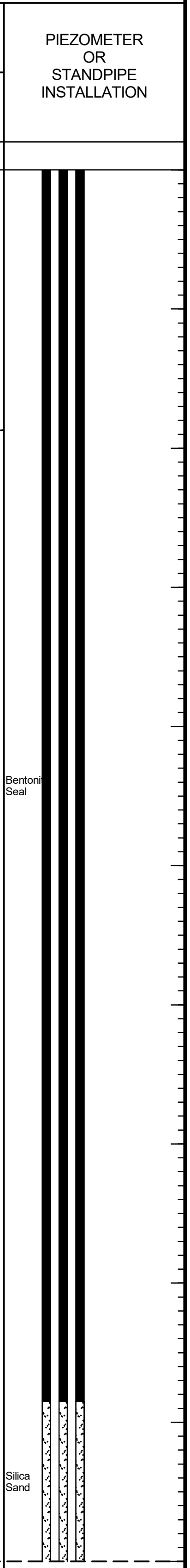
DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		GROUND SURFACE		150.05
0		**LOWER BOBCAYGEON FORMATION, 0.0 m to 20.88 m** **Bedrock Surface, 0.0 m** **UNIT 3, 0.0 m to 6.80 m** **From 0.0 m to 3.84 m** Fresh, medium brownish grey, very fine grained with disseminated calcite crystals, non-porous, thinly bedded **NODULAR LIMESTONE** with occasional fossil burrow casts, less than 1 % shale.		0.00
				146.22 3.83
4		**From 3.84 m to 6.89 m,** Fresh, light brownish grey, faintly porous, medium grained crystalline, medium to thickly bedded, stylolitic **CALCARENITIC LIMESTONE** with sharp top and gradational bottom contacts, no shale. Thin Fine grained, thin bed of argillaceous limestone occurs at 6.71 m to 6.80 m.		
				143.34 6.71 6.80
7		**UNIT 2, 6.89 m to 10.70 m** Fresh, medium to dark grey with dark grey to black shaley partings, fine grained, non porous, thinly to medium bedded, laminar to nodular textured **ARGILLACEOUS to SHALEY NODULAR LIMESTONE** with fossil burrow casts infilled with calcarenite with occasional mollusc fossils. Black calcareous shale partings occur at 6.89 m to 6.91 m, 8.05 m to 8.14 m, 8.41 m to 8.60 m, 9.60 m to 9.72 m and 10.64 m to 10.70 m. Sharp basal contact on shale parting at 10.70 m.		6.89 6.91
8				142.00 8.05 8.14
				141.64 8.41
				141.45 8.60
				140.45 9.60 9.72
10		*CONTINUED NEXT PAGE*		





DEPTH SCALE

1 : 50

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-2

SHEET 2 OF 5

LOCATION: N 5012872.5 ;E 333890.6

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 2003

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION

--- CONTINUED FROM PREVIOUS PAGE ---

UNIT 1, 10.71 m to 20.88 m
Fresh, medium grey, very fine grained non crystalline to fine grained faintly crystalline, non porous, thinly to medium bedded, faintly stylolitic **ARGILLACEOUS NODULAR LIMESTONE** with very fine laminar argillaceous partings and fossil burro casts infilled with calcarenite and occasional disseminated medium calcite crystals in fine grained matrix.
Black shale partings at 13.87 m to 13.88 m, 15.15 m to 15.17 m and 15.24 m to 15.26 m.
Between 16.15 m and 16.40 m, light grey, bleached, faintly weathered limestone with open fractures at 20 degrees TCA with central 4 cm light grey layer of very fine grained porous clayey calcareous residue at 16.26 m to 16.30 m corresponding to natural gamma and apparent conductivity log spikes.
Sharp basal contact on dolostone bed.

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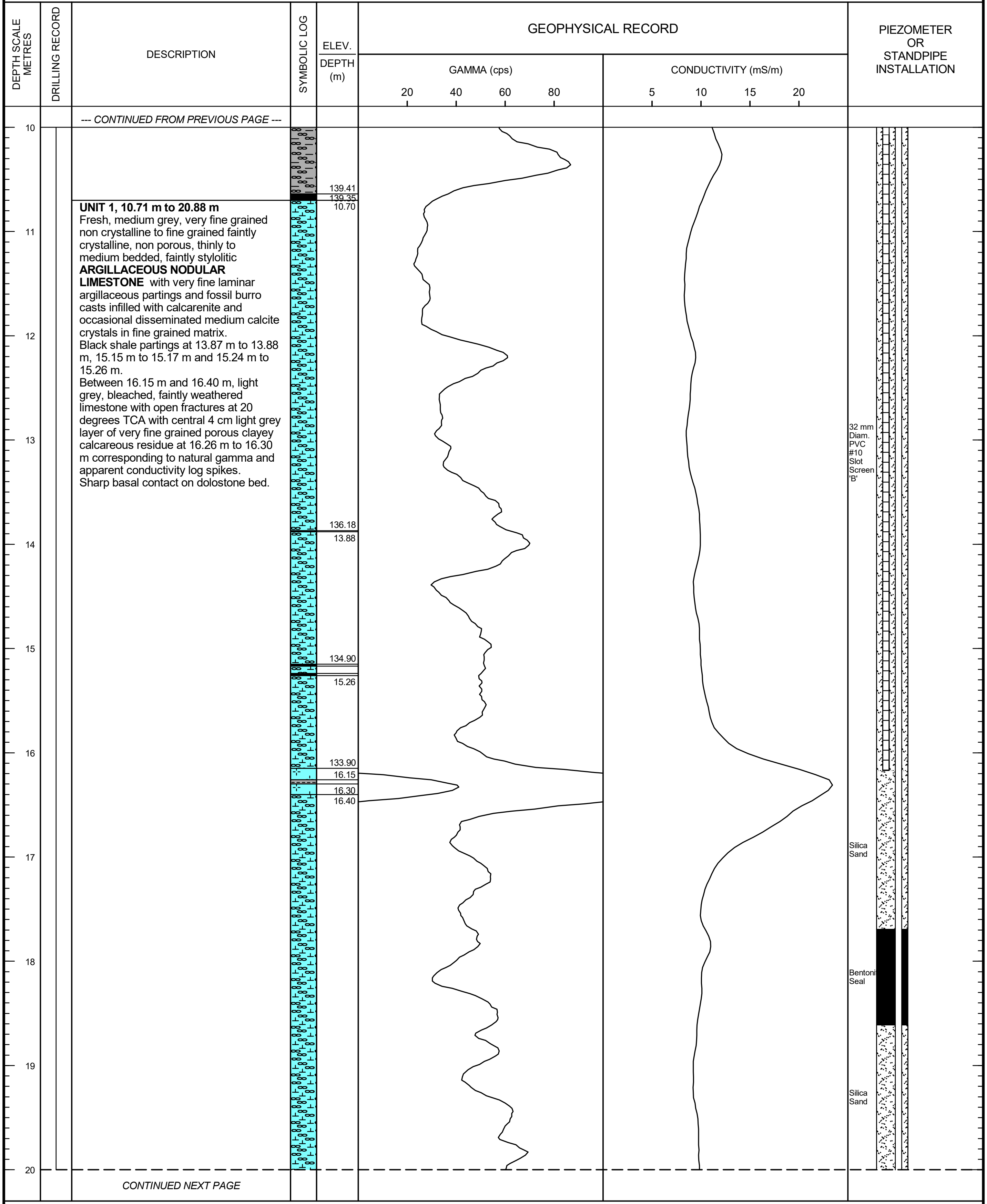


DEPTH SCALE
1 : 50

GOLDER

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-2

SHEET 3 OF 5

LOCATION: N 5012872.5 ;E 333890.6

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 2003

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | GEOPHYSICAL RECORD | PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

GULL RIVER FORMATION, 20.88 m to 47.50 m

UPPER GULL RIVER FORMATION, 20.88 m to 33.07 m

Fresh, light to medium grey, very fine to fine grained faintly crystalline, thinly to medium bedded **LAMINAR TEXTURED ARGILLACEOUS LIMESTONE** with occasional weakly developed stylolites and laminar argillaceous partings and interbeds of dolostone, lithographic limestone beds, oolitic beds and lithoclastic limestone beds. Sharp basal contact on dolostone bed. Individual interbeds occur at;

20.88 m to 21.67 m, Light greenish grey, fine to medium grained, faintly porous **first dolostone marker bed** with sharp top and bottom contacts.

22.28 m to 22.31 m, Black shale parting.

22.71 m to 22.80 m, Lithoclastic limestone bed.

23.77 m to 24.00 m, Oolitic limestone bed.

24.38 m to 25.91 m, Light greenish grey, fine grained, faintly porous, argillaceous dolostone bed, sharp top and bottom contacts with interbed of dark grey lithoclastic limestone from 24.84 m to 24.99 m.

26.21 m to 26.33 m, Dark grey dolostone bed.

Dark grey to black shaley partings at 27.07 m to 27.19 m and 27.68 m to 27.69 m.

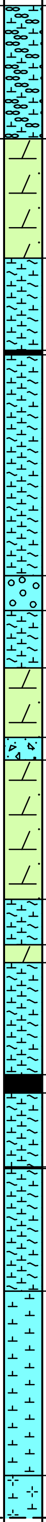
28.50 m to 29.72 m, Medium grey fine grained medium bedded limestone.

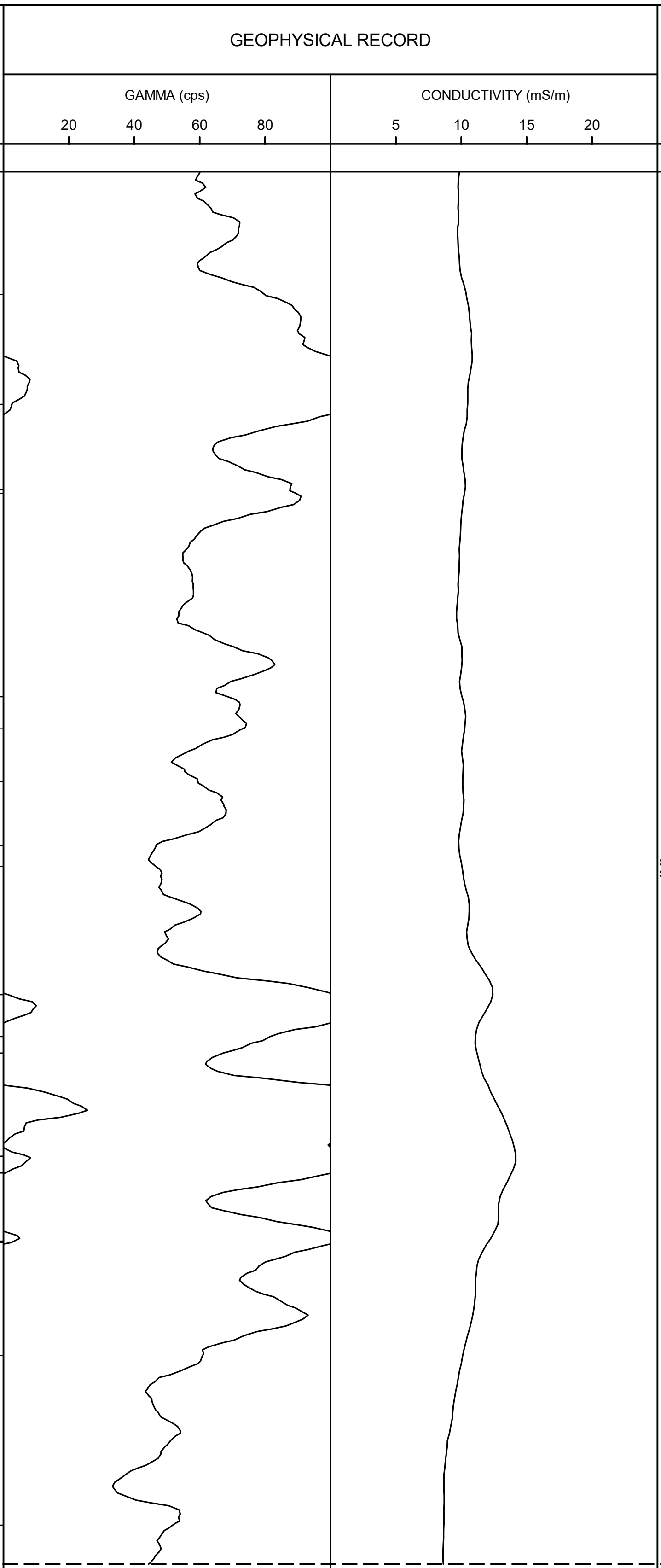
29.72 m to 31.42 m, Very fine grained medium bedded lithographic limestone bed.

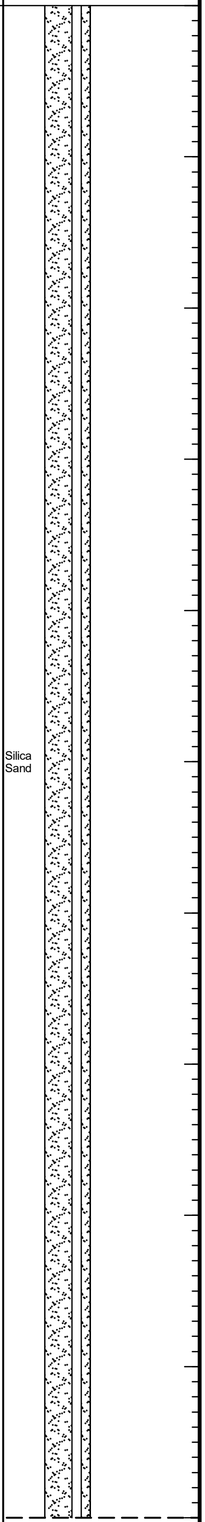
31.42 m to 32.34 m, Fresh, dark grey, fine grained, faintly porous, thick dolostone bed with sharp top and bottom contacts.

32.34 m to 33.07 m, Fresh, light grey, faintly stylolitic, lithographic limestone.

ELEV.	DEPTH (m)
129.17	20.88
128.38	21.67
127.77	22.31
126.28	23.77
126.05	24.00
125.67	24.38
125.21	24.84
	24.99
124.14	25.91
123.84	26.21
	26.33
122.98	27.07
	27.19
122.37	27.69
121.55	28.50
120.33	29.72







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DEPTH SCALE

1 : 50

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-2

SHEET 4 OF 5

LOCATION: N 5012872.5 ;E 333890.6

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 2003
DRILL RIG: CME 55
DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION

--- CONTINUED FROM PREVIOUS PAGE ---

LOWER GULL RIVER FORMATION, 33.07 m to 47.50 m
Fresh, light to medium greenish grey, fine grained, faintly porous, medium to thickly bedded **DOLOSTONE** with minor thin interbeds of limestone and oolitic and lithoclastic dolostone.
33.07 m to 39.84 m, Medium to thickly bedded dolostone with some comparatively soft weathered sections with thin 1 cm shale partings at 34.90 m, 35.36 m, 37.19 m and 37.49 m.

36.76 m to 36.94 m, Oolitic dolostone bed.

38.19 m to 38.34 m, Lithoclastic dolostone bed.

39.84 m to 40.23 m, Laminar textured argillaceous limestone.

40.23 m to 43.95 m, Fine grained, faintly porous, thickly bedded, massive textured dolostone with laminar textured argillaceous dolostone between 42.85 m and 42.98 m.

43.95 m to 44.44 m, Laminar textured argillaceous limestone bed.

44.44 m to 45.06 m, Argillaceous dolostone bed.

45.06 m to 45.20 m, Laminar textured argillaceous limestone bed.

45.20 m to 47.50 m, Dark grey dolostone from with lithoclastic dolostone bed from 45.63 m to 45.72 m.

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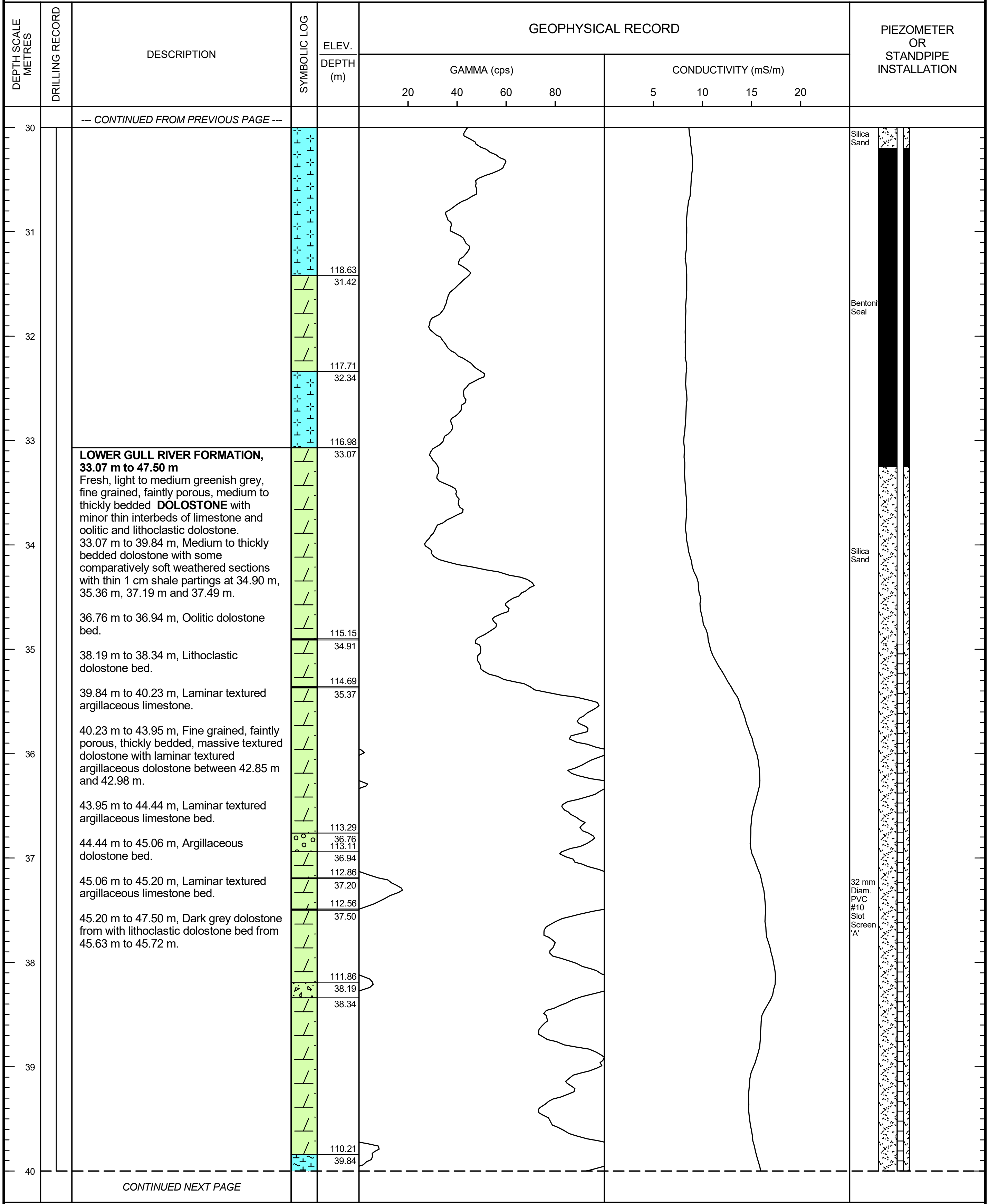


OTTAWA-GEO 1899975.GPJ GAL-GTA.GDT 7/21/20 JM

DEPTH SCALE
1 : 50

GOLDER

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: DDH03-2

SHEET 5 OF 5

LOCATION: N 5012872.5 ;E 333890.6

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 2003

DRILL RIG: CME 55

DRILLING CONTRACTOR: Marathon Drilling

DATUM: Geodetic

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | GEOPHYSICAL RECORD | PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

LOWER GULL RIVER FORMATION, 33.07 m to 47.50 m

Fresh, light to medium greenish grey, fine grained, faintly porous, medium to thickly bedded **DOLOSTONE** with minor thin interbeds of limestone and oolitic and lithoclastic dolostone.

33.07 m to 39.84 m, Medium to thickly bedded dolostone with some comparatively soft weathered sections with thin 1 cm shale partings at 34.90 m, 35.36 m, 37.19 m and 37.49 m.

36.76 m to 36.94 m, Oolitic dolostone bed.

38.19 m to 38.34 m, Lithoclastic dolostone bed.

39.84 m to 40.23 m, Laminar textured argillaceous limestone.

40.23 m to 43.95 m, Fine grained, faintly porous, thickly bedded, massive textured dolostone with laminar textured argillaceous dolostone between 42.85 m and 42.98 m.

43.95 m to 44.44 m, Laminar textured argillaceous limestone bed.

44.44 m to 45.06 m, Argillaceous dolostone bed.

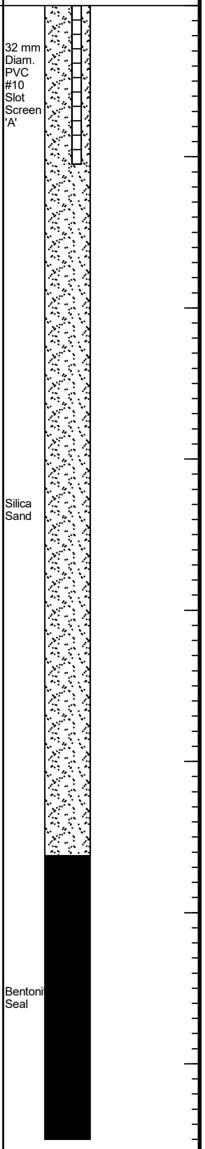
45.06 m to 45.20 m, Laminar textured argillaceous limestone bed.

45.20 m to 47.50 m, Dark grey dolostone from with lithoclastic dolostone bed from 45.63 m to 45.72 m.

End of Borehole, 47.50 m

ELEV.	DEPTH (m)
109.82	40.23
107.20	42.85
	42.98
106.10	43.95
105.61	44.44
104.99	45.06
	45.20
104.42	45.63
	45.72
102.55	47.50

Depth scale: 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50



DEPTH SCALE

1 : 50

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-1

SHEET 1 OF 4

LOCATION: N 5012969.8 ;E 334338.0

INCLINATION: -90° AZIMUTH: ---

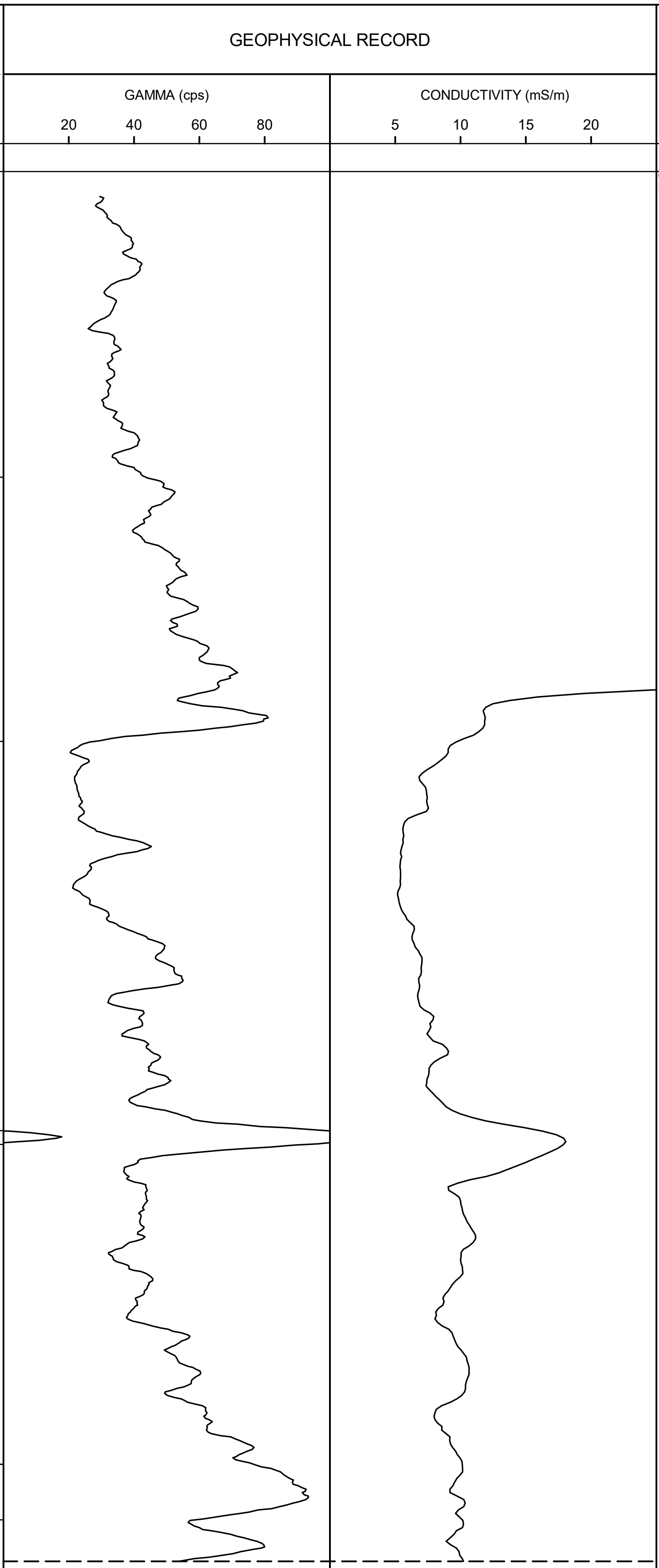
DRILLING DATE: May 1, 2001

DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	145.95	
0	**Bedrock Surface, 0.0 m** **LOWER BOBCAYGEON FORMATION, 0.0 m to 18.6 m** **UNIT 3, 0.0 m to 4.4 m** interbedded light to medium brownish grey, fine to medium grained crystalline, non-porous, finely stylolitic, medium bedded **CALCARENITIC LIMESTONE** with bioturbated sections associated with mollusk burrow casts becoming more evident within lower half of section. Transitional to sharp basal contact.	0.00	Open Hole
4	**UNIT 2, 4.4 m to 8.2 m** dark grey, fine grained, non-porous, thinly bedded, partly bioturbated and fossiliferous (gastropod and pelecypod debris) **ARGILLACEOUS NODULAR LIMESTONE and SHALEY NODULAR LIMESTONE.** Slake susceptible dark grey to black beds of **SHALE** comprise approximately 10-40% of sequence. Transitional to sharp basal contact.	141.55 4.40	
8	**UNIT 1, 8.2 m to 18.6 m** medium grey to brownish grey, fine to medium grained, micritic to partly crystalline, non-porous, thinly bedded with nodular to wavy textured argillaceous partings, extensively bioturbated **ARGILLACEOUS NODULAR LIMESTONE.** Burrow casts tend to be infilled with medium grained crystalline calcarenite. Section contains laterally variable thicknesses of **MICRITIC LIMESTONE, CALCARENITIC LIMESTONE** occasional very fine grained thin to medium beds of **LITHOGRAPHIC LIMESTONE,** medium grained beds of **OOLITIC LIMESTONE** and widely spaced black shaley partings 5 to 30 mm thick. Grey bentonitic clay layer at 13.8-14.0 m.	137.75 8.20	
14		132.15 13.80 14.00	
18		127.35 18.60	
		126.55 19.40	
20	*CONTINUED NEXT PAGE*		



DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

GEOPHYSICAL LOG OF: TW-1

PROJECT: 1899975

SHEET 2 OF 4

LOCATION: N 5012969.8 ;E 334338.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 1, 2001

DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	GEOPHYSICAL RECORD	PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

GULL RIVER FORMATION, 18.6 m to 55.4 m

UPPER GULL RIVER FORMATION, 18.6 m to 31.8 m
Medium grey, very fine to fine grained, nonporous, micritic, thinly bedded **ARGILLACEOUS LIMESTONE** with laminar to very thin slake susceptible argillaceous bedding partings 1 to 10 mm thick with thin to medium interbeds of lithoclastic limestone, oolitic limestone and greenish grey argillaceous to calcareous dolostone with thin shaley caps and bases. Top of the unit is marked by the first appearance of greenish dolostone with a dark grey to black thin shaley cap, the **first dolostone marker bed",** at 18.6 m to 19.4 m with second dolostone beds between 23.4 m and 26.1 m.

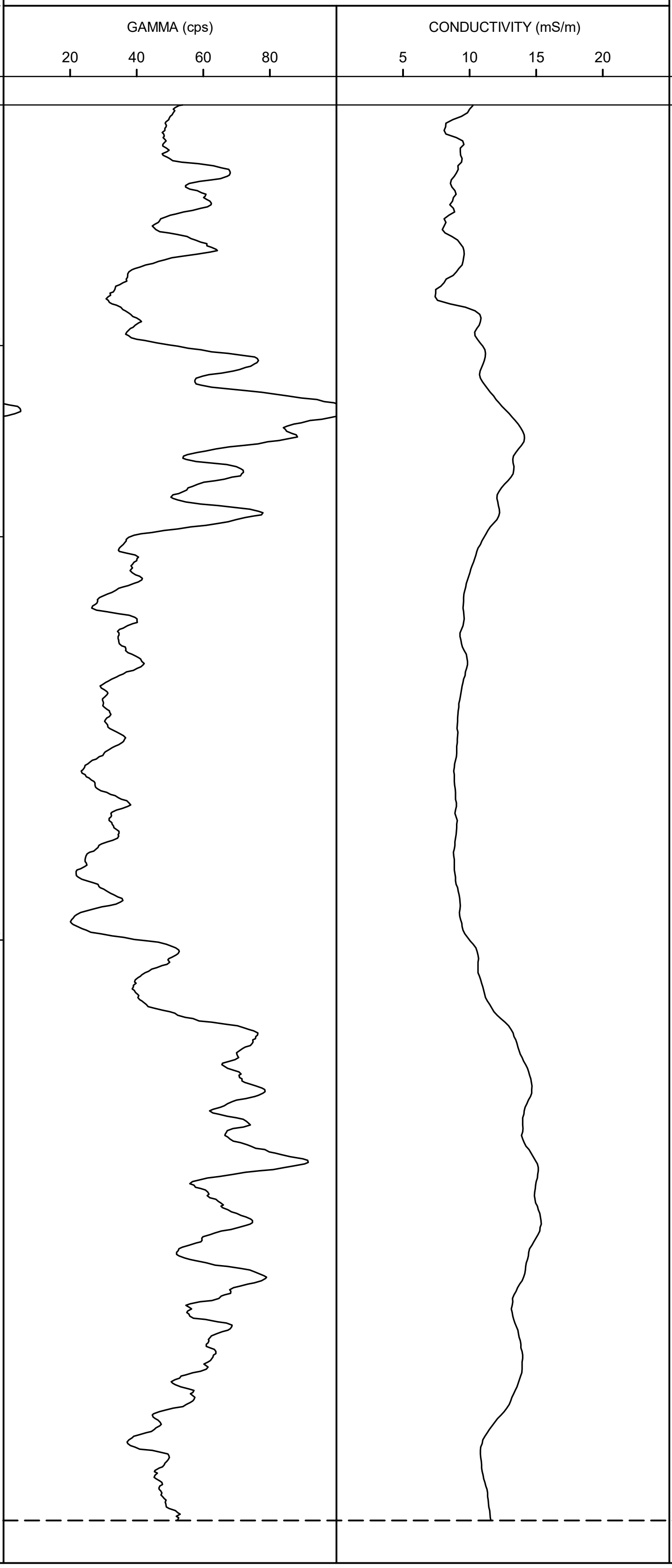
122.55
23.40

119.85
26.10

114.15
31.80

LOWER GULL RIVER FORMATION, 31.8 m to 55.4 m

UNIT 5, 31.8 m to 42.1 m The Lower Gull River Formation marks the transition into predominately dolostone with subordinate limestone units. Light to medium grey and greenish grey, fine grained, faintly porous, medium to very thickly bedded, laminar to massive textured **DOLOSTONE.** Black argillaceous to shaley bedding partings 1 to 10 mm thick, minor interbeds of laminar textured argillaceous limestone beds with occasional stylolites, calcareous dolostone and nodular, mottled calcareous dolostone occur. Very thickly bedded dolostone beds are partly bioturbated noted by burrow casts.



Depth scale: 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40

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DEPTH SCALE
1 : 100

LOGGED: RB
CHECKED: KAM

OTTAWA-GEO 1899975.GPJ GAL-GTA.GDT 7/21/20 JM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-1

SHEET 3 OF 4

LOCATION: N 5012969.8 ;E 334338.0

INCLINATION: -90° AZIMUTH: ---

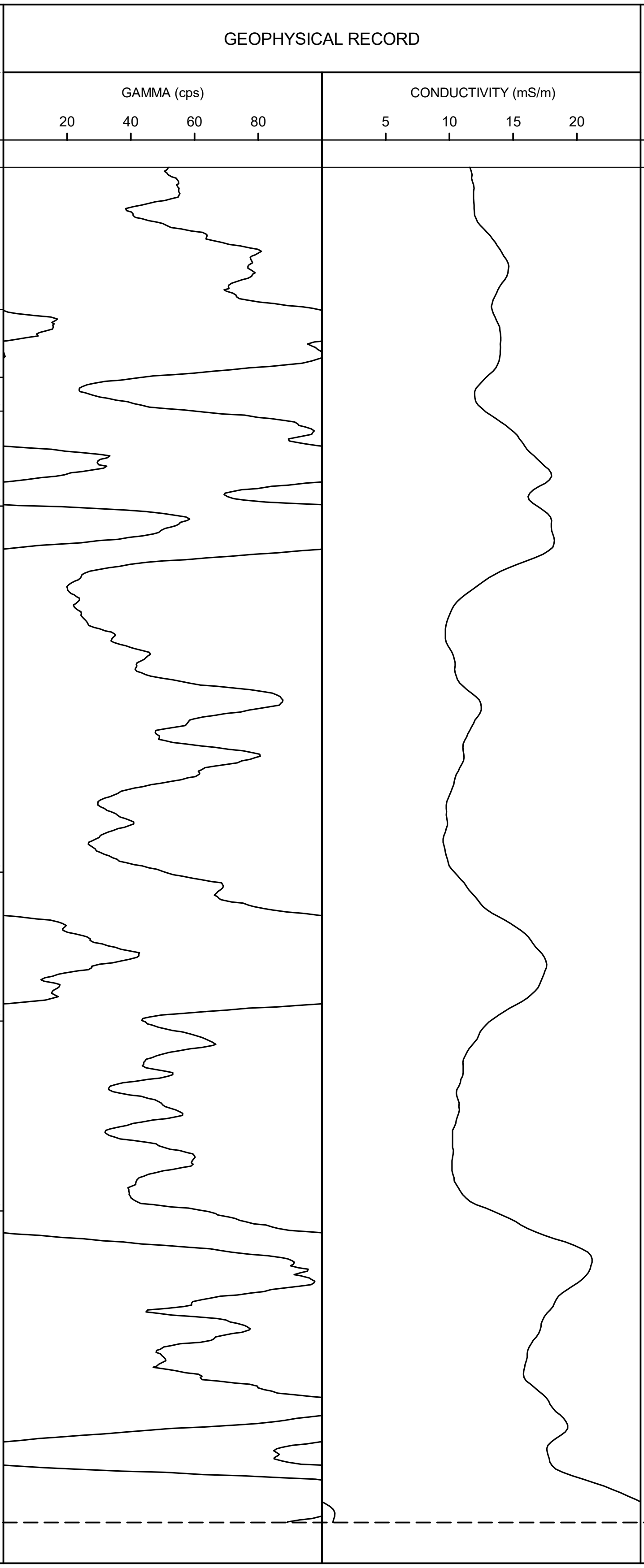
DRILLING DATE: May 1, 2001

DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---			
40			🟩		
42 44		**UNIT 4, 42.1 m to 45.0 m** interbedded sequence of light to medium grey to greenish grey and dark grey, fine grained, faintly porous, thinly to medium bedded, massive textured, argillaceous to shaley **DOLOSTONE** and medium grey **DOLOMITIC LIMESTONE.** Thin interbeds of laminar to nodular textured limestone and thin oolitic limestone beds occur with medium bed of limestone at 43.1 m to 43.6 m. Unit also includes light to medium grey and greenish grey, medium grained, thinly to medium bedded, calcareous to dolomitic cemented, partly bioturbated **QUARTZ SANDSTONE** and minor black **SHALE.**	🟩 🟦 🟩	103.85 42.10 102.85 43.10 102.35 43.60	
46 48 50		**UNIT 3, 45.0 m to 50.4 m** medium grey to brownish grey, fine grained, non-porous, laminated to thinly bedded **ARGILLACEOUS LIMESTONE.** Unit includes interbeds of medium brownish grey, very fine grained lithographic limestone with numerous fine argillaceous partings, thin beds of oolitic limestone, weakly developed lithoclastic limestone, minor burrow bioturbated limestone, with lesser amounts of calcareous dolostone, dark grey dolomitic shale, shaley dolostone. Black argillaceous to shaley bedding partings occur.	🟦	100.95 45.00	
52		**UNIT 2, 50.4 m to 52.6 m** interbedded sequence of medium grey to greenish grey, fine grained, faintly porous, thinly to medium bedded, argillaceous **DOLOSTONE and CALCAREOUS DOLOSTONE** with thinly interbedded black **SHALE, SHALEY DOLOSTONE and DOLOMITIC SILTSTONE** with localized burrowed bioturbation.	🟩	95.55 50.40	
54		**UNIT 1, 52.6 m to 55.4 m** medium grey, fine grained, non-porous, thinly bedded **ARGILLACEOUS LIMESTONE** weakly nodular in part with interbeds of medium brownish grey, very fine grained lithographic limestone with numerous fine argillaceous partings and very thin beds of black calcareous shale. Sharp basal contact locally marked by thin black shaley parting.	🟦	93.35 52.60	
56 58 60			🟩	90.55 55.40	
		CONTINUED NEXT PAGE			



DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-1

SHEET 4 OF 4

LOCATION: N 5012969.8 ;E 334338.0

INCLINATION: -90° AZIMUTH: ---

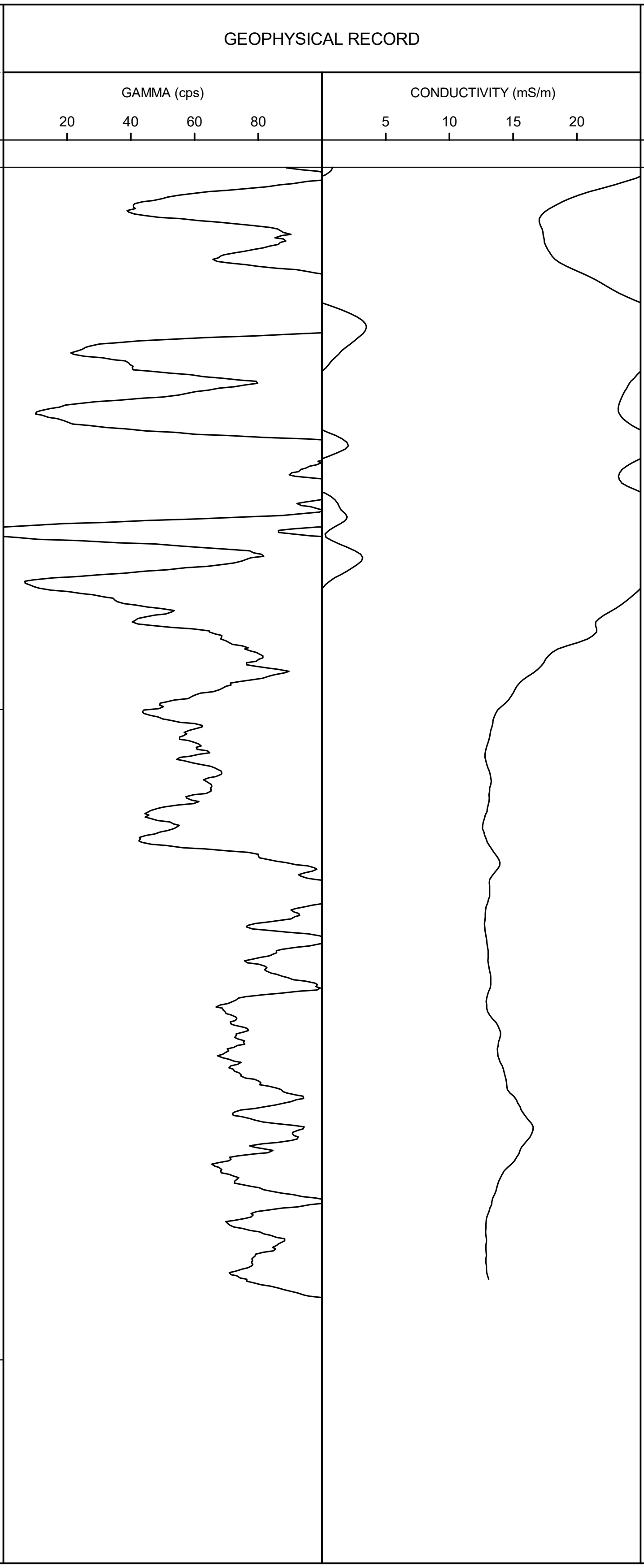
DRILLING DATE: May 1, 2001

DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	GEOPHYSICAL RECORD	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---				
60		**ROCKCLIFFE FORMATION, 55.4 m to 77.6 m** **UPPER ROCKCLIFFE FORMATION, 55.4 m to 68.0 m** Interbedded sequence composed of medium grey, fine grained, non-porous to faintly porous, massive textured to mottled, medium to thick beds of **DOLOSTONE and CALCAREOUS DOLOSTONE,** dark grey to black, slake susceptible **SHALE,** medium grey, mottled to laminar textured, fine grained, thin to medium beds of **ARGILLACEOUS LIMESTONE** with light grey, fine grained, calcareous cemented, medium to thick beds of **QUARTZ SANDSTONE.** Individual lithological sequences such as shale beds typically vary in thickness from approximately 0.25 m to 2.0 m. Upper Rockcliffe Formation is transitional with the underlying Lower Rockcliffe Formation noted by transition from predominately dolostone and shale in the upper sequence to predominately sandstone in the lower sequence.	🟩			
62						
64						
66						
68		**LOWER ROCKCLIFFE FORMATION, 68.0 m to 77.6 m** Light whitish grey, fine grained (0.1-0.3 mm), laminar textured to rippled and cross bedded, thin to thick bedded **QUARTZ SANDSTONE** with thin to thick interbeds of medium to dark grey slake susceptible **SHALE** with fine laminations of siltstone and fine calcareous sandstone and light to medium grey, laminar textured, thin to medium beds of **SILTSTONE to SANDY SILTSTONE.** Sandstone is largely silica cemented subangular to subrounded quartz grains with minor beds having varying amounts of calcareous cement. Contact with the underlying Oxford Formation is transitional to sharp erosional.	🟨	77.95 68.00		
70						
72						
74						
76						
		End of Borehole, 77.6 m		68.35 77.60		
78						
80						



DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-2

SHEET 1 OF 4

LOCATION: N 5013251.4 ;E 333663.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 2, 2001

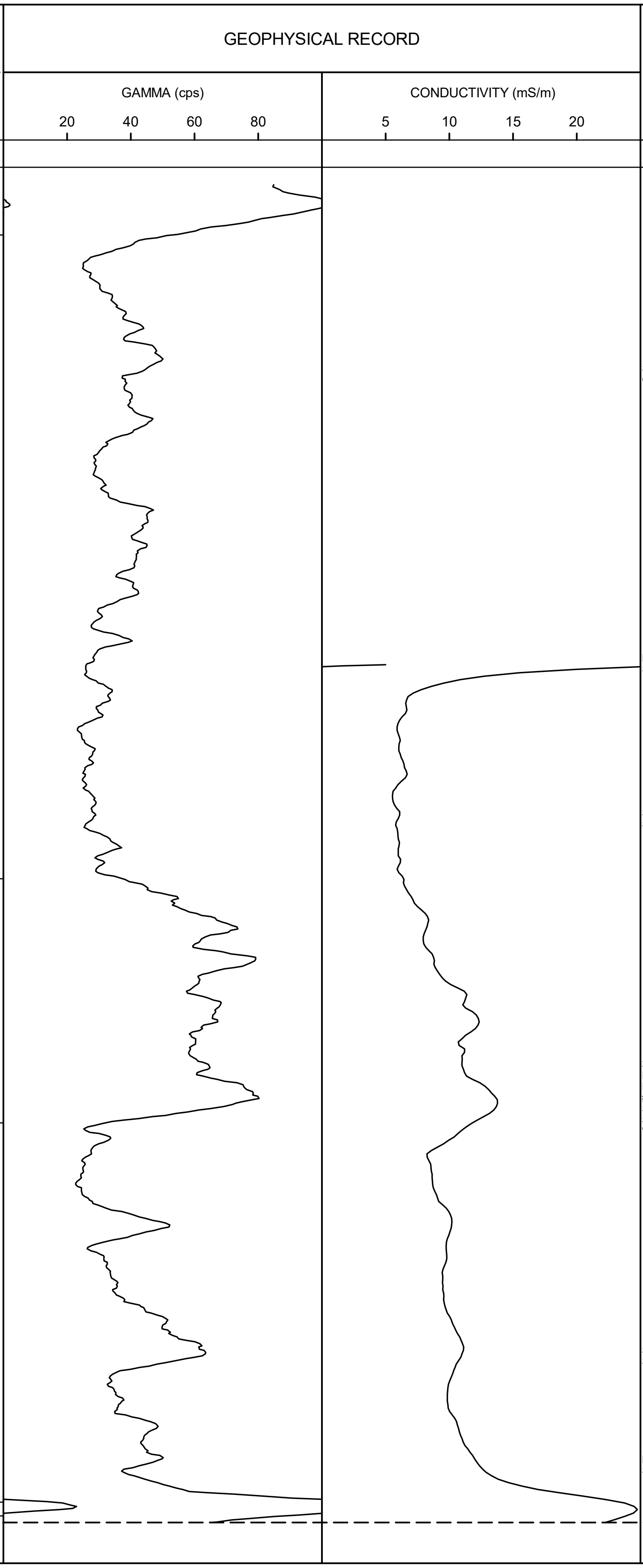
DRILL RIG: Water Well Rig

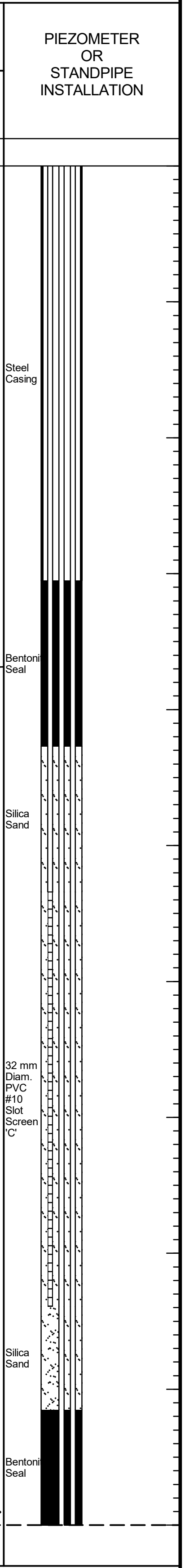
DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		GROUND SURFACE		150.08
0		**Overburden, 0.0 m to 1.0 m**	▨	0.00
		Bedrock Surface, 1.0 m **LOWER BOBCAYGEON FORMATION, 1.0 m to 24.2 m** **UNIT 3, 1.0 m to 10.5 m** interbedded light to medium brownish grey, fine to medium grained crystalline, non-porous, finely stylolitic, medium bedded **CALCARENITIC LIMESTONE** with bioturbated sections associated with mollusk burrow casts becoming more evident within lower half of section. Transitional to sharp basal contact.	🟦	149.08 1.00
		UNIT 2, 10.5 m to 14.1 m dark grey, fine grained, non-porous, thinly bedded, partly bioturbated and fossiliferous (gastropod and pelecypod debris) **ARGILLACEOUS NODULAR LIMESTONE and SHALEY NODULAR LIMESTONE.** Slake susceptible dark grey to black beds of **SHALE** comprise approximately 10-40% of sequence. Transitional to sharp basal contact.	▩	139.58 10.50
		UNIT 1, 14.1 m to 24.2 m medium grey to brownish grey, fine to medium grained, micritic to partly crystalline, non-porous, thinly bedded with nodular to wavy textured argillaceous partings, extensively bioturbated **ARGILLACEOUS NODULAR LIMESTONE.** Burrow casts tend to be infilled with medium grained crystalline calcarenite. Section contains laterally variable thicknesses of **MICRITIC LIMESTONE, CALCARENITIC LIMESTONE** occasional very fine grained thin to medium beds of **LITHOGRAPHIC LIMESTONE,** medium grained beds of **OOLITIC LIMESTONE** and widely spaced black shaley partings 5 to 30 mm thick. Grey bentonitic clay layer at 19.7-19.9 m.	🟦	135.98 14.10
			▨	130.38 19.70
20		*CONTINUED NEXT PAGE*		

Depth scale markings: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20





OTTAWA-GEO 1899975.GPJ GAL-GTA.GDT 7/21/20 JM

DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-2

SHEET 2 OF 4

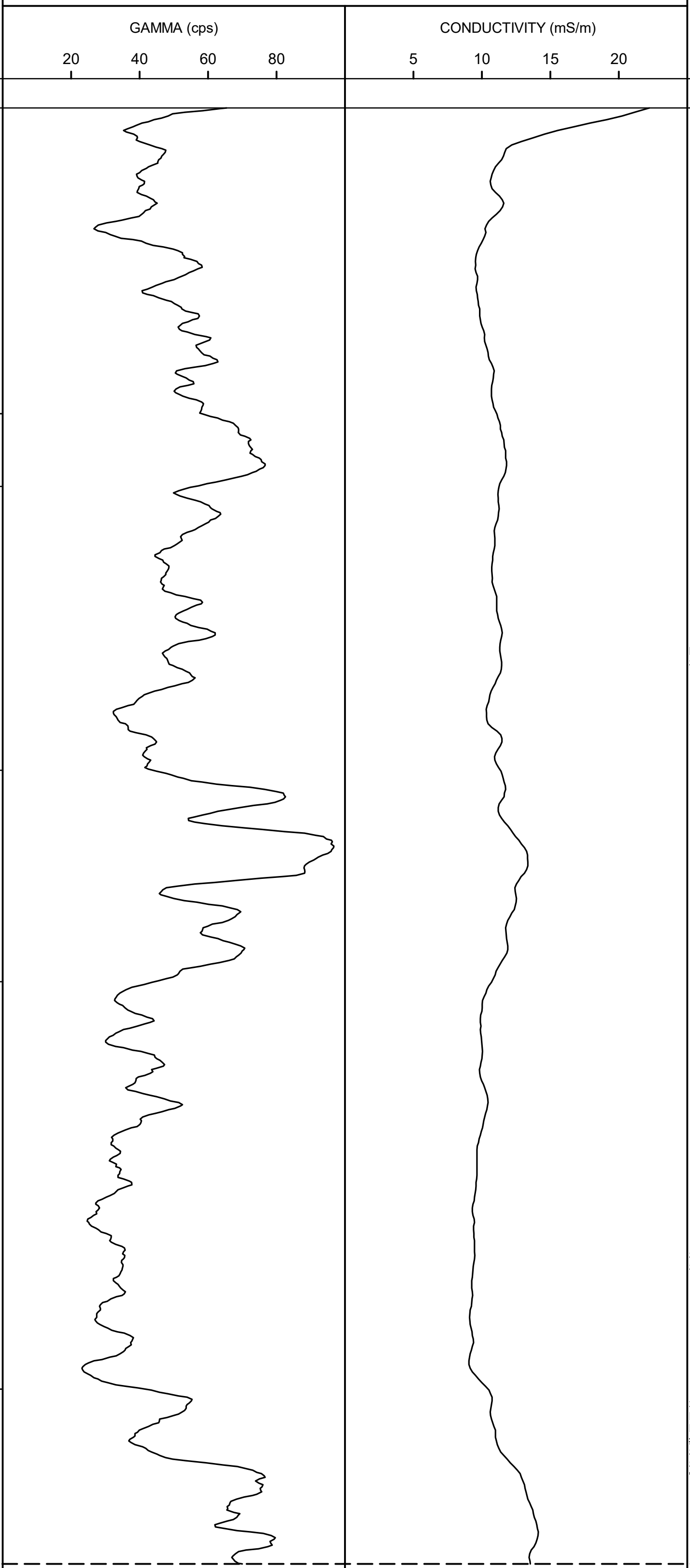
LOCATION: N 5013251.4 ;E 333663.5
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 2, 2001
DRILL RIG: Water Well Rig
DRILLING CONTRACTOR: Capital Water Supply

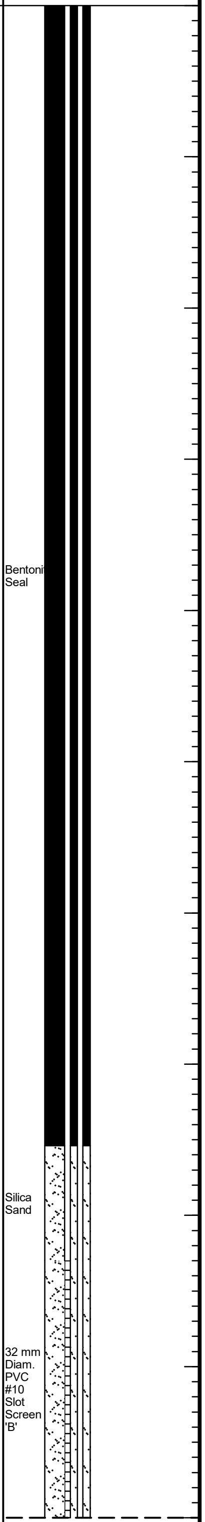
DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		--- CONTINUED FROM PREVIOUS PAGE ---		
20				19.90
24		**GULL RIVER FORMATION, 24.2 m to 61.1 m** **UPPER GULL RIVER FORMATION, 24.2 m to 37.6 m** Medium grey, very fine to fine grained, nonporous, micritic, thinly bedded **ARGILLACEOUS LIMESTONE** with laminar to very thin slake susceptible argillaceous bedding partings 1 to 10 mm thick with thin to medium interbeds of lithoclastic limestone, oolitic limestone and greenish grey argillaceous to calcareous dolostone with thin shaley caps and bases. Top of the unit is marked by the first appearance of greenish dolostone with a dark grey to black thin shaley cap, the **first dolostone marker bed",** at 24.2 m to 25.2 m with second dolostone beds between 29.1 m and 32.0 m.		125.88 24.20
				124.88 25.20
				120.98 29.10
				118.08 32.00
				112.48 37.60
40		*CONTINUED NEXT PAGE*		

GEOPHYSICAL RECORD



PIEZOMETER OR STANDPIPE INSTALLATION



DEPTH SCALE
1 : 100

GOLDER

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-2

SHEET 3 OF 4

LOCATION: N 5013251.4 ;E 333663.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 2, 2001

DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | GEOPHYSICAL RECORD | PIEZOMETER OR STANDPIPE INSTALLATION

--- CONTINUED FROM PREVIOUS PAGE ---

LOWER GULL RIVER FORMATION, 37.6 m to 61.1 m

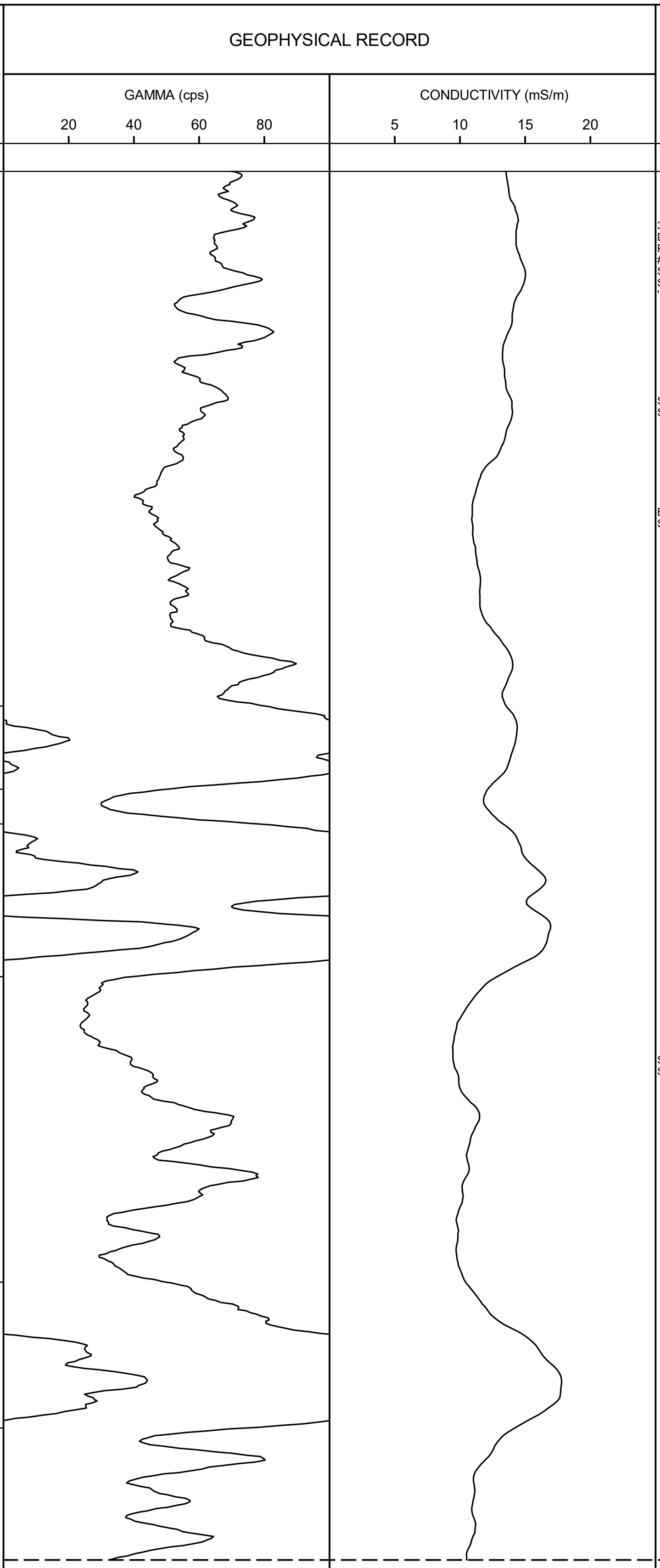
UNIT 5, 37.6 m to 47.7 m The Lower Gull River Formation marks the transition into predominately dolostone with subordinate limestone units. Light to medium grey and greenish grey, fine grained, faintly porous, medium to very thickly bedded, laminar to massive textured **DOLOSTONE.** Black argillaceous to shaley bedding partings 1 to 10 mm thick, minor interbeds of laminar textured argillaceous limestone beds with occasional stylolites, calcareous dolostone and nodular, mottled calcareous dolostone occur. Very thickly bedded dolostone beds are partly bioturbated noted by burrow casts.

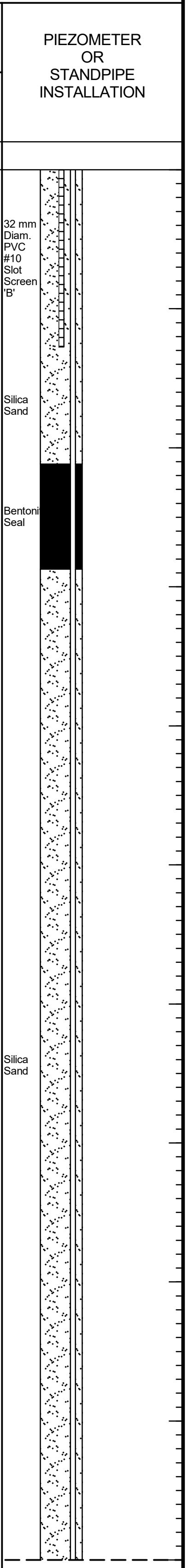
UNIT 4, 47.7 m to 51.6 m interbedded sequence of light to medium grey to greenish grey and dark grey, fine grained, faintly porous, thinly to medium bedded, massive textured, argillaceous to shaley **DOLOSTONE** and medium grey **DOLOMITIC LIMESTONE.** Thin interbeds of laminar to nodular textured limestone and thin oolitic limestone beds occur with medium bed of limestone at 48.9 m to 49.4 m. Unit also includes light to medium grey and greenish grey, medium grained, thinly to medium bedded, calcareous to dolomitic cemented, partly bioturbated **QUARTZ SANDSTONE** and minor black **SHALE.**

UNIT 3, 51.6 m to 56.0 m medium grey to brownish grey, fine grained, non-porous, laminated to thinly bedded **ARGILLACEOUS LIMESTONE.** Unit includes interbeds of medium brownish grey, very fine grained lithographic limestone with numerous fine argillaceous partings, thin beds of oolitic limestone, weakly developed lithoclastic limestone, minor burrow bioturbated limestone, with lesser amounts of calcareous dolostone, dark grey dolomitic shale, shaley dolostone. Black argillaceous to shaley bedding partings occur.

UNIT 2, 56.0 m to 58.1 m interbedded sequence of medium grey to greenish grey, fine grained, faintly porous, thinly to medium bedded, argillaceous **DOLOSTONE and CALCAREOUS DOLOSTONE** with thinly interbedded black **SHALE, SHALEY DOLOSTONE and DOLOMITIC SILTSTONE** with localized burrowed bioturbation.

ELEV.	DEPTH (m)
102.38	47.70
101.18	48.90
100.68	49.40
98.48	51.60
94.08	56.00
91.98	58.10





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DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-2

SHEET 4 OF 4

LOCATION: N 5013251.4 ;E 333663.5

INCLINATION: -90° AZIMUTH: ---

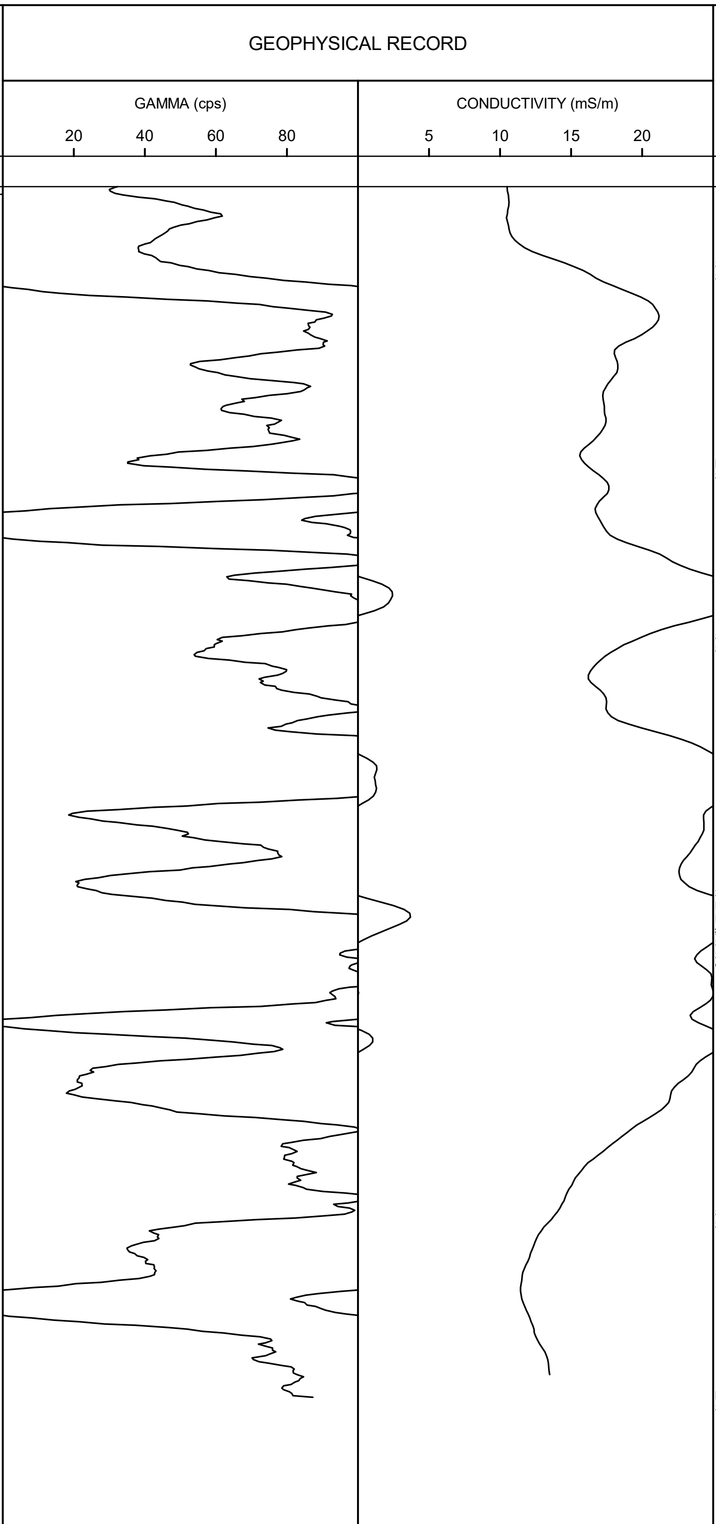
DRILLING DATE: May 2, 2001

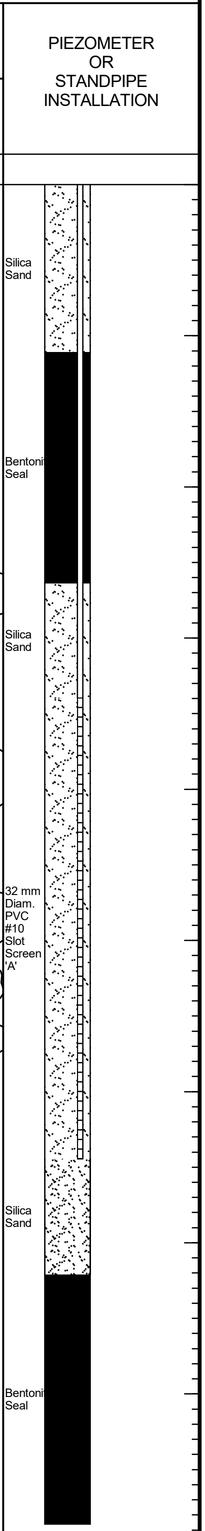
DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		--- CONTINUED FROM PREVIOUS PAGE ---		
60		**UNIT 1, 58.1 m to 60.1 m** medium grey, fine grained, non-porous, thinly bedded **ARGILLACEOUS LIMESTONE** weakly nodular in part with interbeds of medium brownish grey, very fine grained lithographic limestone with numerous fine argillaceous partings and very thin beds of black calcareous shale. Sharp basal contact locally marked by thin black shaley parting.	🟦	89.98 60.10
62		**ROCKCLIFFE FORMATION, 60.1 m to 77.7 m**	🟩	
		UPPER ROCKCLIFFE FORMATION, 60.1 m to 77.7 m Interbedded sequence composed of medium grey, fine grained, non-porous to faintly porous, massive textured to mottled, medium to thick beds of **DOLOSTONE and CALCAREOUS DOLOSTONE,** dark grey to black, slake susceptible **SHALE,** medium grey, mottled to laminar textured, fine grained, thin to medium beds of **ARGILLACEOUS LIMESTONE** with light grey, fine grained, calcareous cemented, medium to thick beds of **QUARTZ SANDSTONE.** Individual lithological sequences such as shale beds typically vary in thickness from approximately 0.25 m to 2.0 m. Upper Rockcliffe Formation is transitional with the underlying Lower Rockcliffe Formation noted by transition from predominately dolostone and shale in the upper sequence to predominately sandstone in the lower sequence.	🟩	
64				
66				
68				
70				
72				
74				
76				72.38
78		**End of Borehole, 77.7 m**		77.70
80				





DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-3

SHEET 1 OF 4

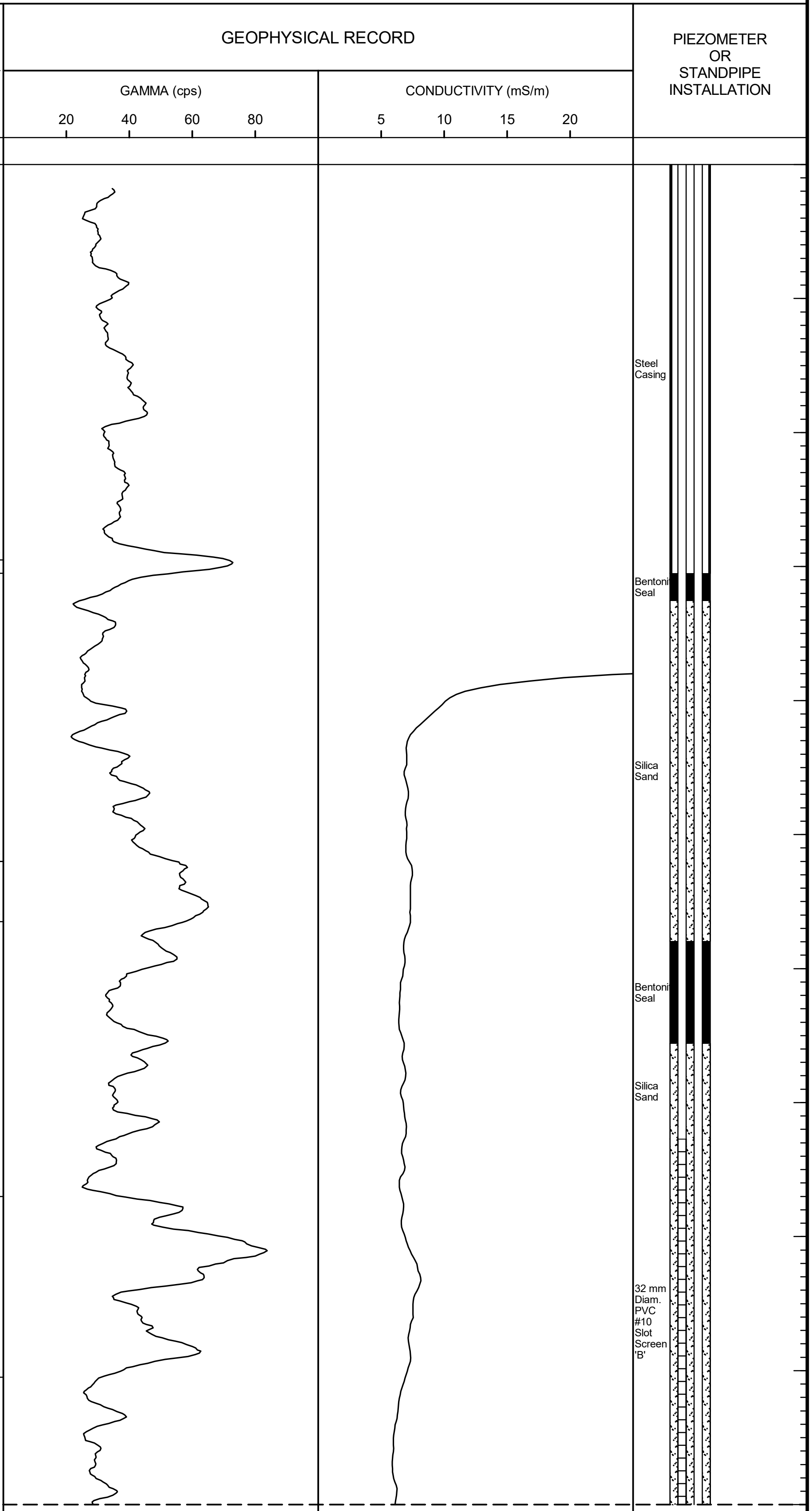
LOCATION: N 5013846.8 ;E 333832.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 2, 2001
DRILL RIG: Water Well Rig
DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		GROUND SURFACE		126.30
0		**Bedrock Surface, 0.0 m** **LOWER BOBCAYGEON FORMATION, 0.0 m to 10.4 m** **UNIT 1, 0.0 m to 10.4 m** medium grey to brownish grey, fine to medium grained, micritic to partly crystalline, non-porous, thinly bedded with nodular to wavy textured argillaceous partings, extensively bioturbated **ARGILLACEOUS NODULAR LIMESTONE.** Burrow casts tend to be infilled with medium grained crystalline calcarenite. Section contains laterally variable thicknesses of **MICRITIC LIMESTONE, CALCARENITIC LIMESTONE** occasional very fine grained thin to medium beds of **LITHOGRAPHIC LIMESTONE,** medium grained beds of **OOLITIC LIMESTONE** and widely spaced black shaley partings 5 to 30 mm thick. Grey bentonitic clay layer at 5.9-6.1 m.		0.00
				120.40 5.90
6				6.10
10				115.90
		GULL RIVER FORMATION, 10.4 m to 47.3 m **UPPER GULL RIVER FORMATION, 10.4 m to 23.8 m** Medium grey, very fine to fine grained, nonporous, micritic, thinly bedded **ARGILLACEOUS LIMESTONE** with laminar to very thin slake susceptible argillaceous bedding partings 1 to 10 mm thick with thin to medium interbeds of lithoclastic limestone, oolitic limestone and greenish grey argillaceous to calcareous dolostone with thin shaley caps and bases. Top of the unit is marked by the first appearance of greenish dolostone with a dark grey to black thin shaley cap, the **first dolostone marker bed",** at 10.4 m to 11.3 m with second dolostone beds between 15.4 m and 18.1 m.		10.40
				115.00 11.30
				110.90 15.40
18				108.20 18.10
20		*CONTINUED NEXT PAGE*		



DEPTH SCALE
1 : 100

GOLDER

LOGGED: RB
CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-3

SHEET 2 OF 4

LOCATION: N 5013846.8 ;E 333832.5

INCLINATION: -90° AZIMUTH: ---

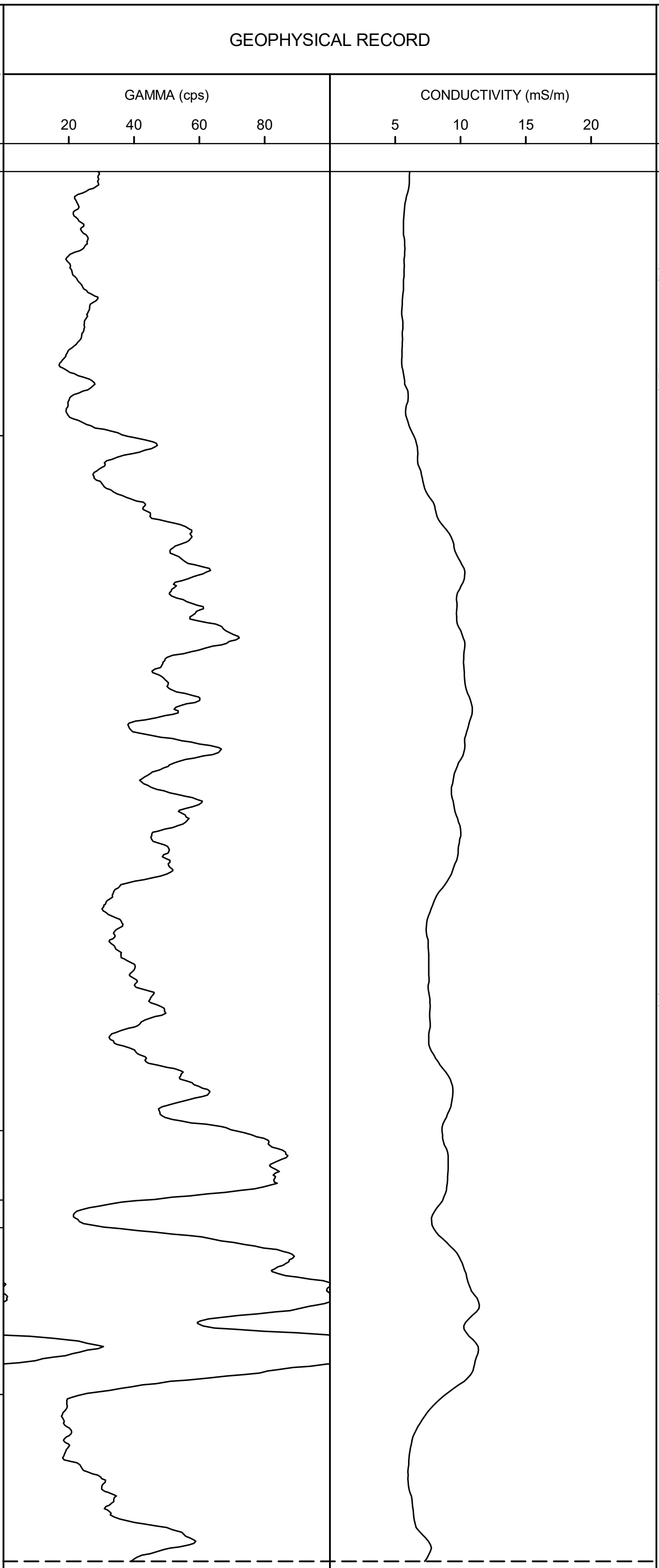
DRILLING DATE: May 2, 2001

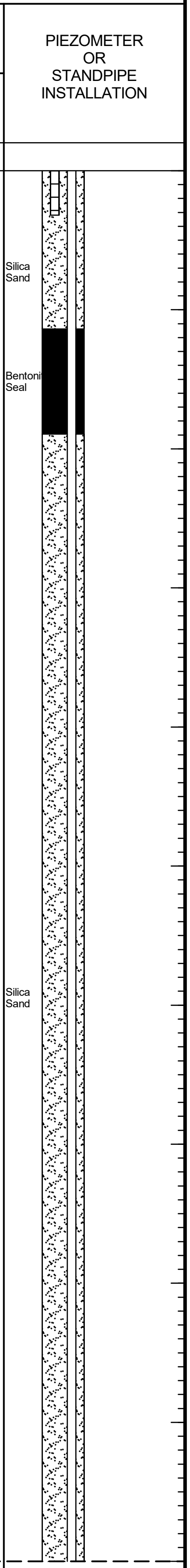
DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		--- CONTINUED FROM PREVIOUS PAGE ---		
20				
24		**LOWER GULL RIVER FORMATION, 23.8 m to 47.3 m** **UNIT 5, 23.8 m to 33.8 m** The Lower Gull River Formation marks the transition into predominately dolostone with subordinate limestone units. Light to medium grey and greenish grey, fine grained, faintly porous, medium to very thickly bedded, laminar to massive textured **DOLOSTONE.** Black argillaceous to shaley bedding partings 1 to 10 mm thick, minor interbeds of laminar textured argillaceous limestone beds with occasional stylolites, calcareous dolostone and nodular, mottled calcareous dolostone occur. Very thickly bedded dolostone beds are partly bioturbated noted by burrow casts.		102.50 23.80
34		**UNIT 4, 33.8 m to 37.6 m** interbedded sequence of light to medium grey to greenish grey and dark grey, fine grained, faintly porous, thinly to medium bedded, massive textured, argillaceous to shaley **DOLOSTONE** and medium grey **DOLOMITIC LIMESTONE.** Thin interbeds of laminar to nodular textured limestone and thin oolitic limestone beds occur with medium bed of limestone at 34.8 m to 35.2 m. Unit also includes light to medium grey and greenish grey, medium grained, thinly to medium bedded, calcareous to dolomitic cemented, partly bioturbated **QUARTZ SANDSTONE** and minor black **SHALE.**		92.50 33.80 91.50 34.80 91.10 35.20 88.70 37.60
40		*CONTINUED NEXT PAGE*		





DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-3

SHEET 3 OF 4

LOCATION: N 5013846.8 ;E 333832.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 2, 2001

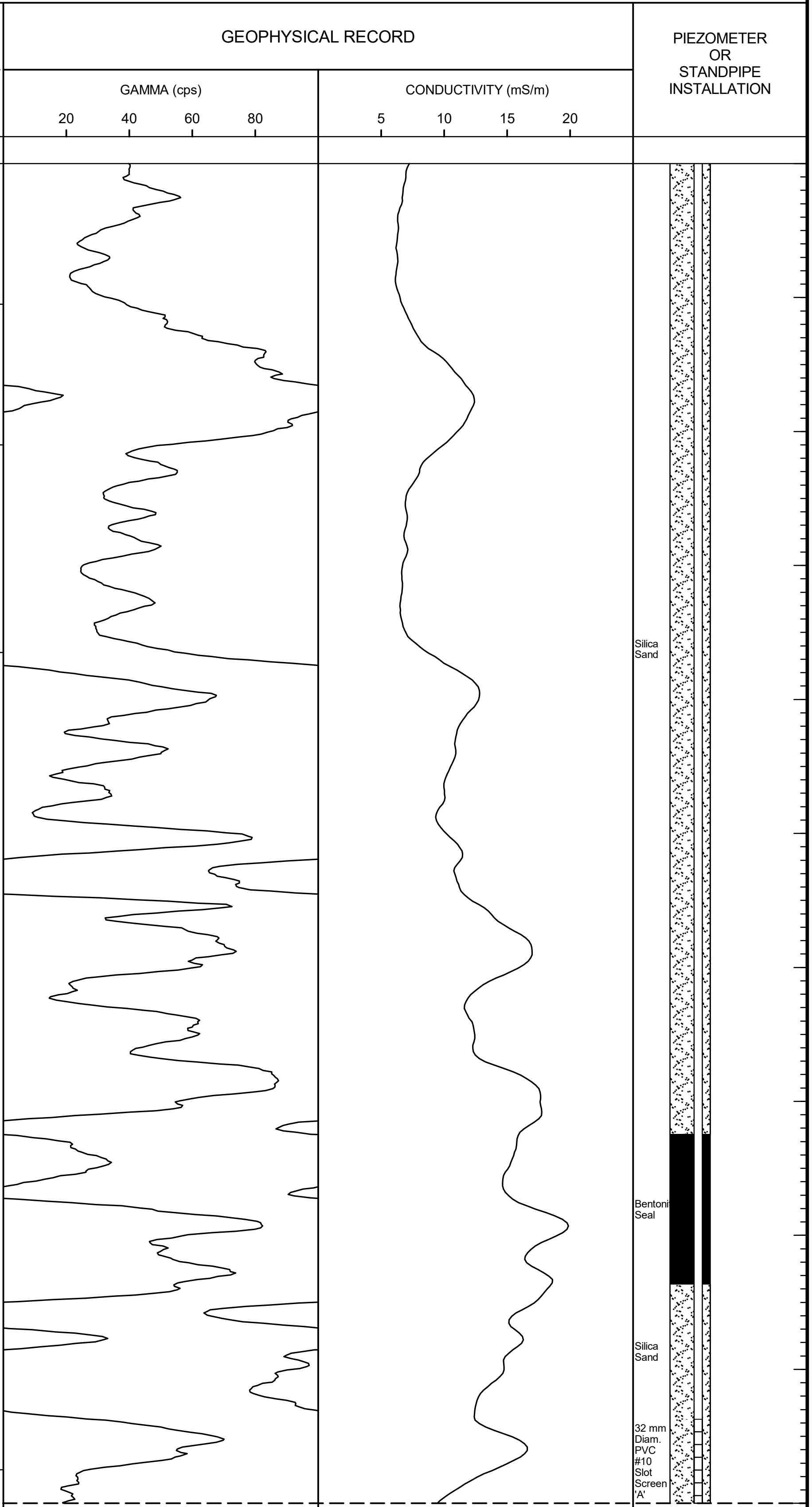
DRILL RIG: Water Well Rig

DRILLING CONTRACTOR: Capital Water Supply

DATUM: Geodetic

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
40	**UNIT 3, 37.6 m to 42.1 m** medium grey to brownish grey, fine grained, non-porous, laminated to thinly bedded **ARGILLACEOUS LIMESTONE.** Unit includes interbeds of medium brownish grey, very fine grained lithographic limestone with numerous fine argillaceous partings, thin beds of oolitic limestone, weakly developed lithoclastic limestone, minor burrow bioturbated limestone, with lesser amounts of calcareous dolostone, dark grey dolomitic shale, shaley dolostone. Black argillaceous to shaley bedding partings occur.	🟦	84.20 42.10
42	**UNIT 2, 42.1 m to 44.2 m** interbedded sequence of medium grey to greenish grey, fine grained, faintly porous, thinly to medium bedded, argillaceous **DOLOSTONE and CALCAREOUS DOLOSTONE** with thinly interbedded black **SHALE, SHALEY DOLOSTONE and DOLOMITIC SILTSTONE** with localized burrowed bioturbation.	🟩	82.10 44.20
44	**UNIT 1, 44.2 m to 47.3 m** medium grey, fine grained, non-porous, thinly bedded **ARGILLACEOUS LIMESTONE** weakly nodular in part with interbeds of medium brownish grey, very fine grained lithographic limestone with numerous fine argillaceous partings and very thin beds of black calcareous shale. Sharp basal contact locally marked by thin black shaley parting.	🟦	79.00 47.30
48	**ROCKCLIFFE FORMATION, 47.3 m to 71.5 m** **UPPER ROCKCLIFFE FORMATION, 47.3 m to 59.5 m** Interbedded sequence composed of medium grey, fine grained, non-porous to faintly porous, massive textured to mottled, medium to thick beds of **DOLOSTONE and CALCAREOUS DOLOSTONE,** dark grey to black, slake susceptible **SHALE,** medium grey, mottled to laminar textured, fine grained, thin to medium beds of **ARGILLACEOUS LIMESTONE** with light grey, fine grained, calcareous cemented, medium to thick beds of **QUARTZ SANDSTONE.** Individual lithological sequences such as shale beds typically vary in thickness from approximately 0.25 m to 2.0 m. Upper Rockcliffe Formation is transitional with the underlying Lower Rockcliffe Formation noted by transition from predominately dolostone and shale in the upper sequence to predominately sandstone in the lower sequence.	🟩	66.80 59.50
60		🟨	



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DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

OTTAWA-GEO 1899975.GPJ GAL-GTA.GDT 7/21/20 JM

PROJECT: 1899975

GEOPHYSICAL LOG OF: TW-3

SHEET 4 OF 4

LOCATION: N 5013846.8 ;E 333832.5

DRILLING DATE: May 2, 2001

DATUM: Geodetic

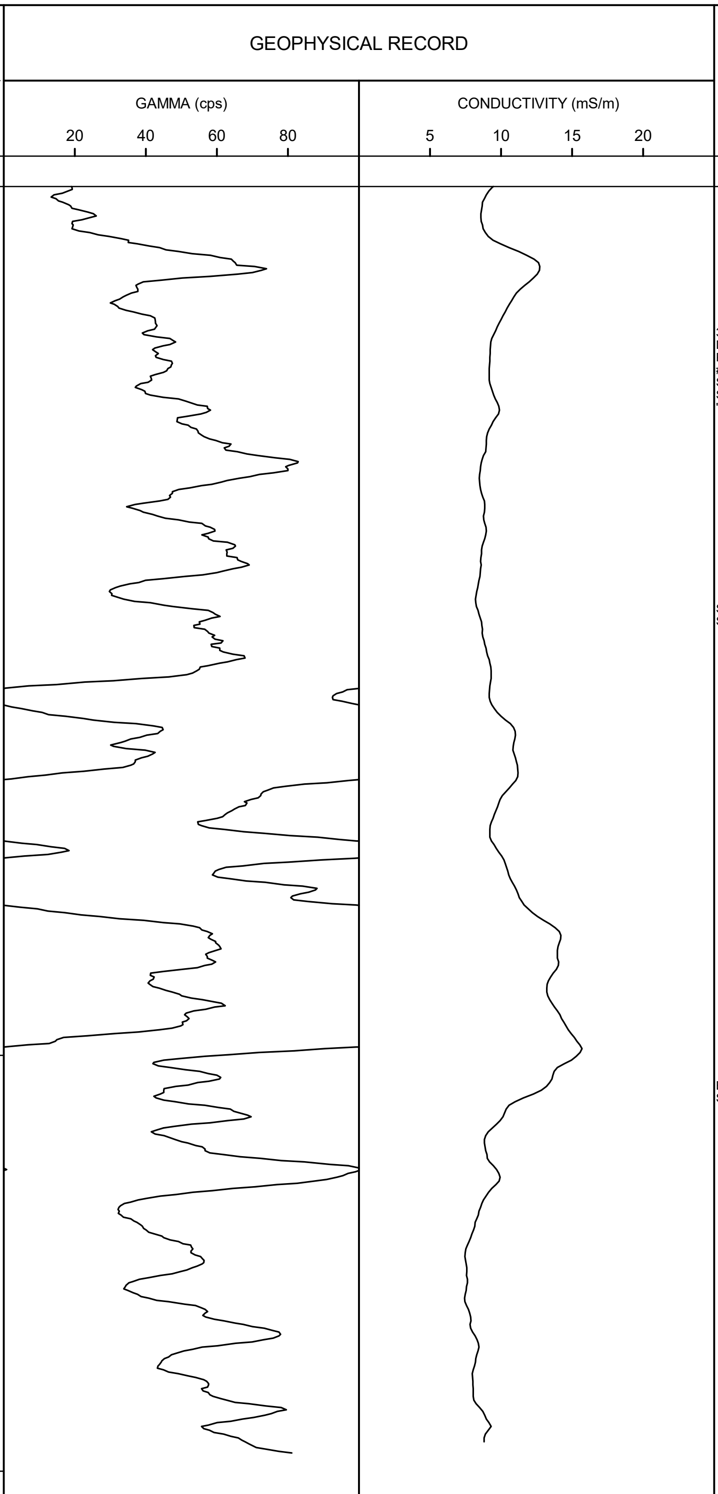
DRILL RIG: Water Well Rig

INCLINATION: -90° AZIMUTH: ---

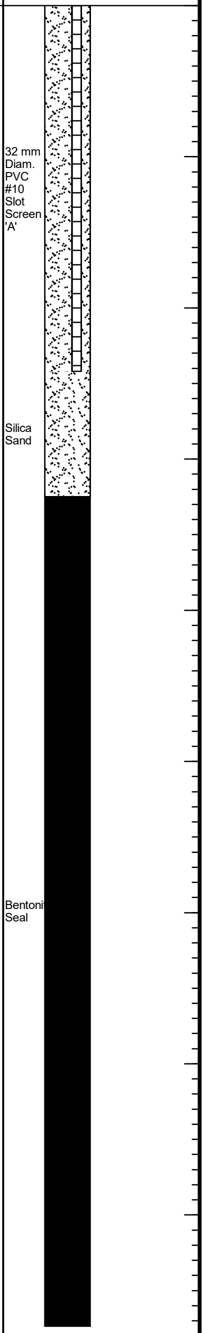
DRILLING CONTRACTOR: Capital Water Supply

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)
		--- CONTINUED FROM PREVIOUS PAGE ---		
60		**LOWER ROCKCLIFFE FORMATION, 59.5 m to 71.5 m** Light whitish grey, fine grained (0.1-0.3 mm), laminar textured to rippled and cross bedded, thin to thick bedded **QUARTZ SANDSTONE** with thin to thick interbeds of medium to dark grey slake susceptible **SHALE** with fine laminations of siltstone and fine calcareous sandstone and light to medium grey, laminar textured, thin to medium beds of **SILTSTONE to SANDY SILTSTONE.** Sandstone is largely silica cemented subangular to subrounded quartz grains with minor beds having varying amounts of calcareous cement. Contact with the underlying Oxford Formation is transitional to sharp erosional.	🟨	54.80 71.50
72		**UPPER OXFORD FORMATION 71.5 m to 77.0 m** Medium grey, fine grained micritic, medium bedded, argillaceous **DOLOSTONE and CALCAREOUS DOLOSTONE** with 0.01-0.50 m thick interbeds of dark grey to black, slake susceptible **SHALE and SHALEY DOLOSTONE.**	🟩	49.30 77.00
		End of Borehole, 77.0 m		

Depth scale: 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80



PIEZOMETER OR STANDPIPE INSTALLATION



OTTAWA-GEO 1899975.GPJ GAL-GTA.GDT 7/21/20 JM

DEPTH SCALE

1 : 100

GOLDER

LOGGED: RB

CHECKED: KAM

PROJECT: 05-1120-993-3000

RECORD OF TEST WELL: TW-6

SHEET 1 OF 2

LOCATION: N 5014201.38 ;E 334126.01

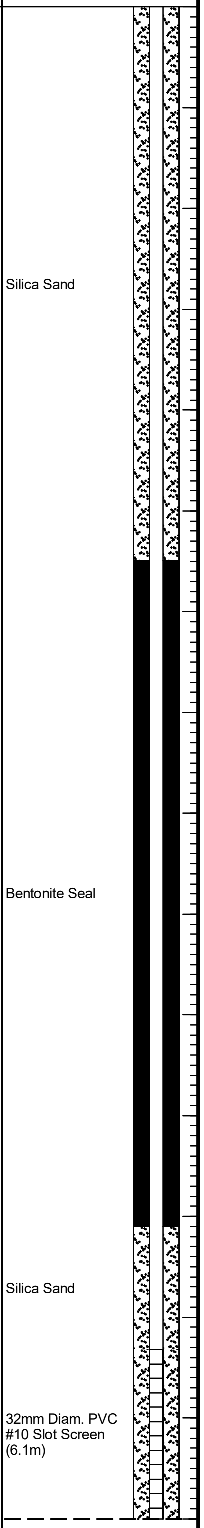
BORING DATE: July 12, 2006

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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		124.50							
0	Air Rotary	Loose brown TOPSOIL		0.00							
1		Grey SAND		123.29 1.21							
2											
3		Grey CLAY		121.76 2.74							Silica Sand
4											
5											
6											
7											
8											
9											Bentonite Seal
10		Medium grey and white SANDSTONE BEDROCK		114.75 9.75							
11											
12											
13											Silica Sand
14											32mm Diam. PVC #10 Slot Screen (6.1m)
15											



CONTINUED NEXT PAGE

DEPTH SCALE

1 : 75

LOGGED: S.M.

CHECKED: C.A.M.C.

PROJECT: 05-1120-993-3000

RECORD OF TEST WELL: TW-6

SHEET 2 OF 2

LOCATION: N 5014201.38 ;E 334126.01

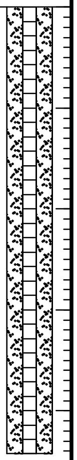
BORING DATE: July 12, 2006

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: 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
		--- CONTINUED FROM PREVIOUS PAGE ---									
15 16 17 18 19	Air Rotary	Medium grey and white SANDSTONE BEDROCK		105.08 19.42							32mm Diam. PVC #10 Slot Screen (6.1m)
20 21 22 23 24 25 26 27 28 29 30		End of Test Well									Water level in screen at elev. 123.73 m on Nov. 18, 2019



DEPTH SCALE

1 : 75

GOLDER

LOGGED: S.M.

CHECKED: C.A.M.C.

MIS-BHS 001 05-1120-993-3000.GPJ GAL-MIS.GDT 7/20/20 JM

PROJECT: 07-1122-0039-8000

RECORD OF BOREHOLE: MW15-1

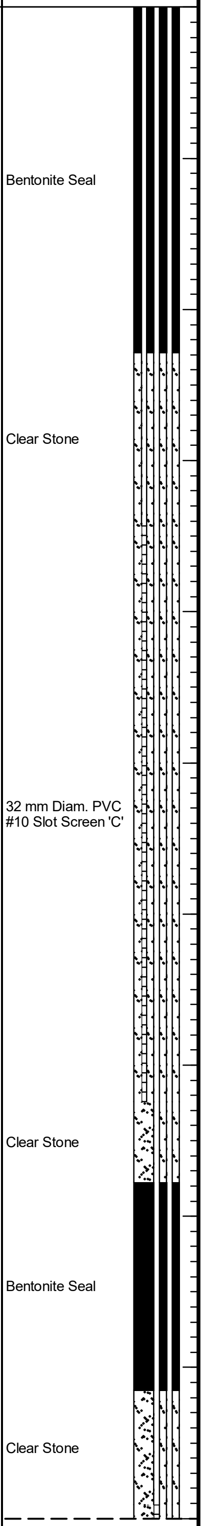
SHEET 1 OF 3

LOCATION: N 5013403.72 ;E 333139.46

BORING DATE: December 16, 2015

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		152.08							
0	Air Rotary 150 mm	Limestone		0.00							
20		*CONTINUED NEXT PAGE*									



DEPTH SCALE
1 : 100

LOGGED: CA
CHECKED: JPAO

PROJECT: 07-1122-0039-8000

RECORD OF BOREHOLE: MW15-1

SHEET 2 OF 3

LOCATION: N 5013403.72 ;E 333139.46

BORING DATE: December 16, 2015

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
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	Air Rotary 150 mm	Limestone									
22											
24											32 mm Diam. PVC #10 Slot Screen 'B'
26											
28											Clear Stone
30											Bentonite Seal
32											Clear Stone
34											
36											
37											32 mm Diam. PVC #10 Slot Screen 'A'
38											
40		*CONTINUED NEXT PAGE*									

DEPTH SCALE
1 : 100

GOLDER

LOGGED: CA
CHECKED: JPAO

PROJECT: 07-1122-0039-8000

RECORD OF BOREHOLE: MW15-1

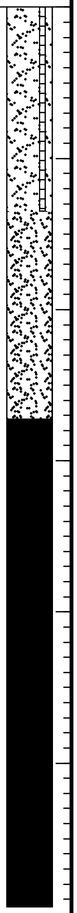
SHEET 3 OF 3

LOCATION: N 5013403.72 ;E 333139.46

BORING DATE: December 16, 2015

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
		--- CONTINUED FROM PREVIOUS PAGE ---									
40	Air Rotary 150 mm	Limestone									32 mm Diam. PVC #10 Slot Screen 'A'
42											
44											Clear Stone
46											
48											Bentonite Seal
50											
52		End of Drillhole		100.18 51.90							
54											
56											
58											
60											



MIS-BHS 001 0711220039.GPJ GAL-MIS.GDT 7/20/20 JM

DEPTH SCALE
1 : 100

GOLDER

LOGGED: CA
CHECKED: JPAO

APPENDIX C

Hydraulic Conductivity Results

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST MW15-1A

INTERVAL (metres below ground surface)

Top of Interval =	**33.55**
Bottom of Interval =	**42.70**

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

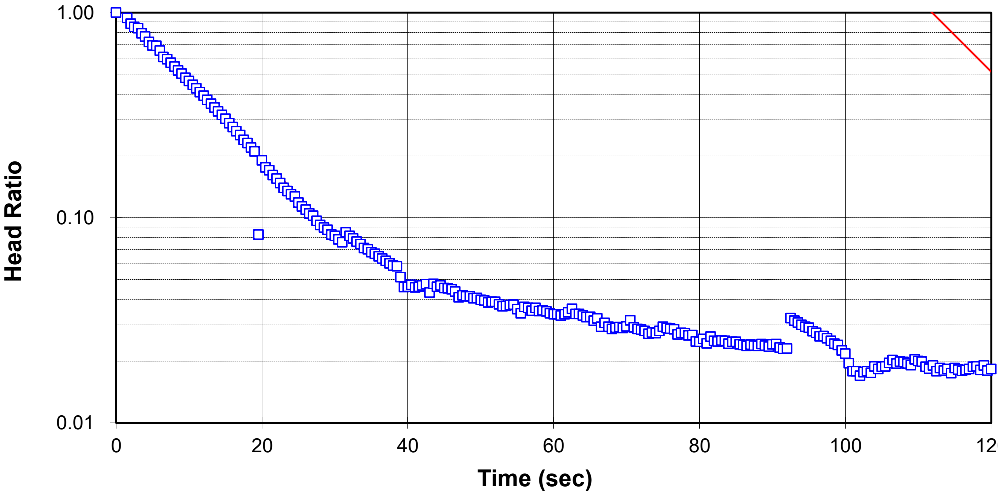
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	**1.6E-02**
R_e =	**7.6E-02**
L_e =	**9.2**
t_1 =	**5**
t_2 =	**31**
h_1/h_0 =	**0.70**
h_2/h_0 =	**0.08**

RESULTS

K=	**6E-06**	**m/sec**
K=	**6E-04**	**cm/sec**



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 16/07/2019

Analysis By: SPS
Checked By: CWT
Analysis Date: 25/07/2019

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST MW15-1B

INTERVAL (metres below ground surface)

Top of Interval = 19.82
Bottom of Interval = 27.43

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

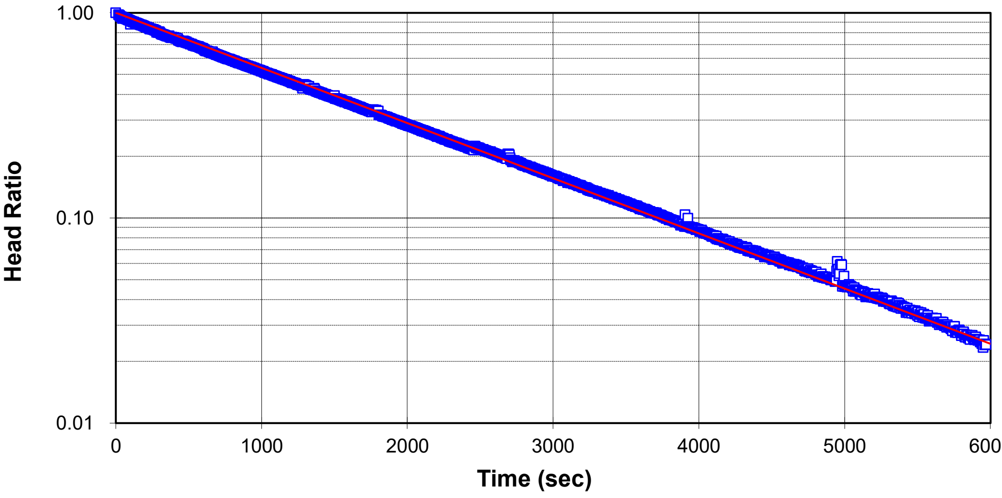
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c = **1.6E-02**
R_e = **7.6E-02**
L_e = **7.6**
t_1 = **0**
t_2 = **5460**
h_1/h_0 = **1.00**
h_2/h_0 = **0.03**

RESULTS

K=	**5E-08**	**m/sec**
K=	**5E-06**	**cm/sec**



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 16/07/2019

Analysis By: SPS
Checked By: CWT
Analysis Date: 25/07/2019

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST MW15-1C

INTERVAL (metres below ground surface)

Top of Interval = 6.83
Bottom of Interval = 14.44

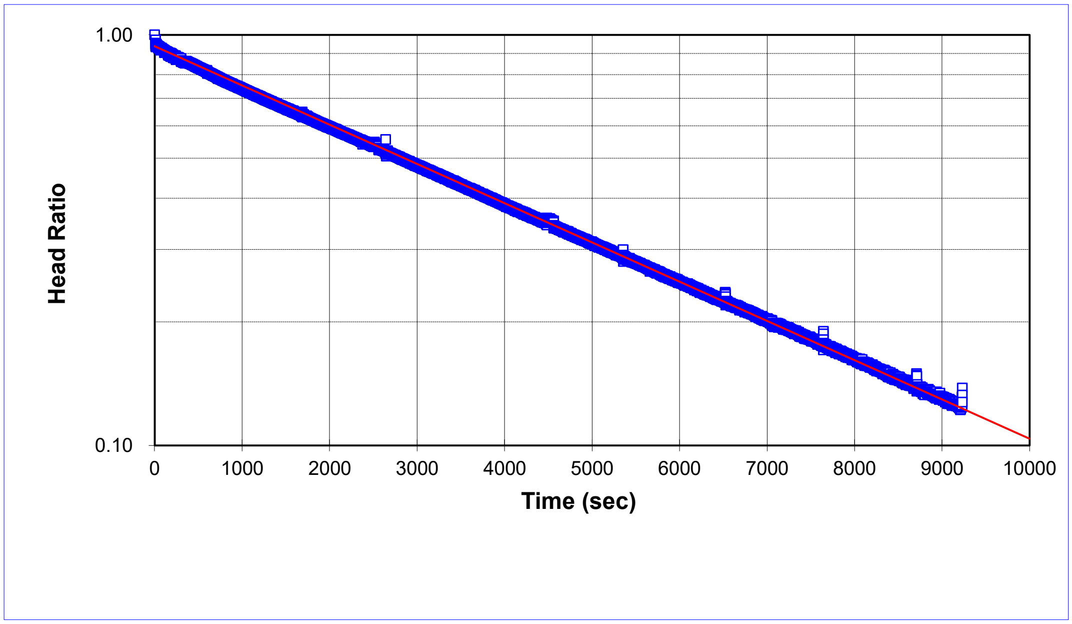
$$K = \frac{r_c^2}{2L_e} \ln\left[\frac{L_e}{2R_e} + \sqrt{1+\left(\frac{L_e}{2R_e}\right)^2}\right]\left[\frac{\ln\left(\frac{h_1}{h_2}\right)}{(t_2 - t_1)}\right]$$ where K = (m/sec)

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 =	1.6E-02
R_e =	7.6E-02
L_e =	7.6
t_1 =	45
t_2 =	8512
h_1/h_0 =	0.93
h_2/h_0 =	0.14

RESULTS

K=	2E-08	m/sec
K=	2E-06	cm/sec



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 16/07/2019

Analysis By: SPS
Checked By: CWT
Analysis Date: 25/07/2019

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST DDH03-1A

INTERVAL (metres below ground surface)

Top of Interval = 36.80
Bottom of Interval = 42.90

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

where K = (m/sec)

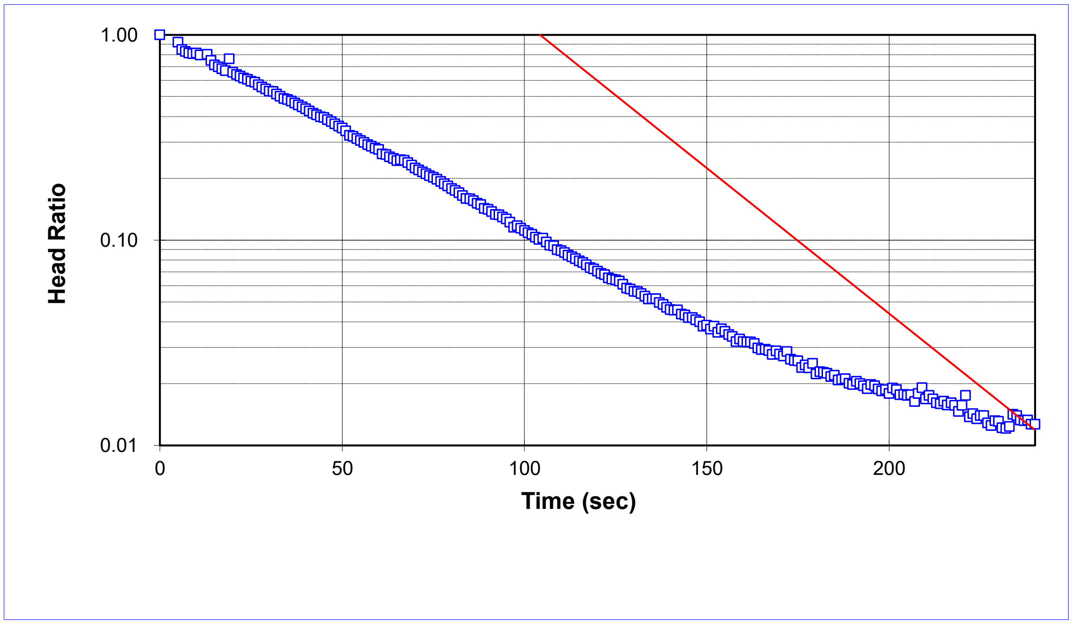
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c = 1.6E-02
R_e = 7.6E-02
L_e = 6.1
t_1 = 63
t_2 = 150
h_1/h_0 = 0.25
h_2/h_0 = 0.04

RESULTS

K=	2E-06	m/sec
K=	2E-04	cm/sec



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 17/07/2019

Analysis By: SPS
Checked By: CWT
Analysis Date: 25/07/2019

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
FALLING HEAD TEST DDH03-1B

INTERVAL (metres below ground surface)

Top of Interval = **11.90**
Bottom of Interval = **18.00**

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

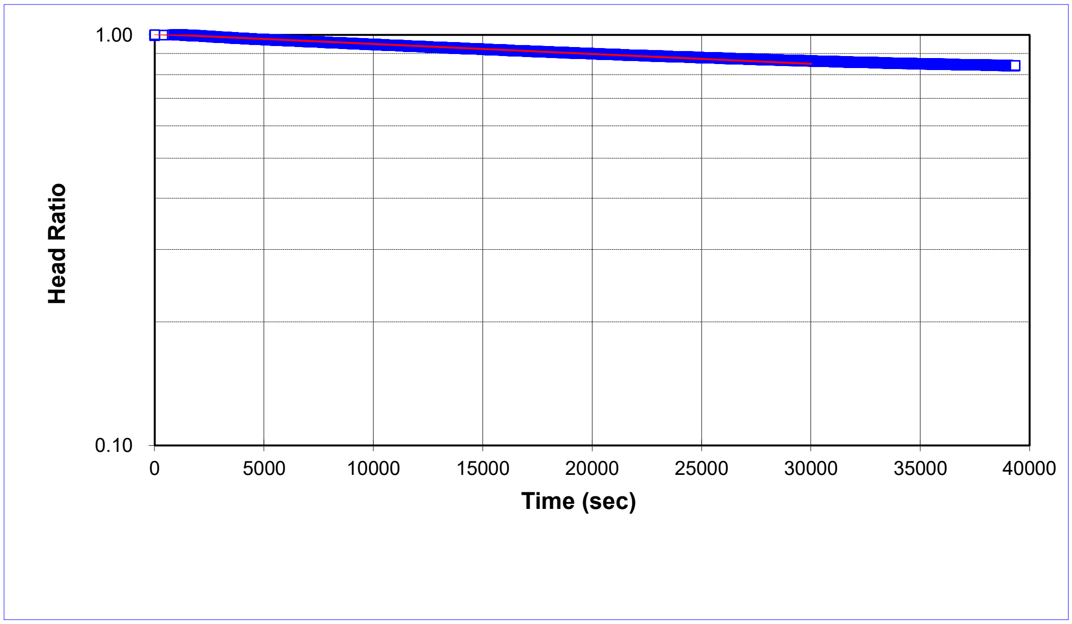
where:

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 =	**1.6E-02**
R_e =	**4.8E-02**
L_e =	**6.1**
t_1 =	**2351**
t_2 =	**20005**
h_1/h_0 =	**0.99**
h_2/h_0 =	**0.90**

RESULTS

K=	**6E-10**	**m/sec**
K=	**6E-08**	**cm/sec**



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 02/03/2020

Analysis By: SPS
Checked By: CWT
Analysis Date: 24/03/2020

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST TW-3A

INTERVAL (metres below ground surface)

Top of Interval = 58.80
Bottom of Interval = 64.90

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

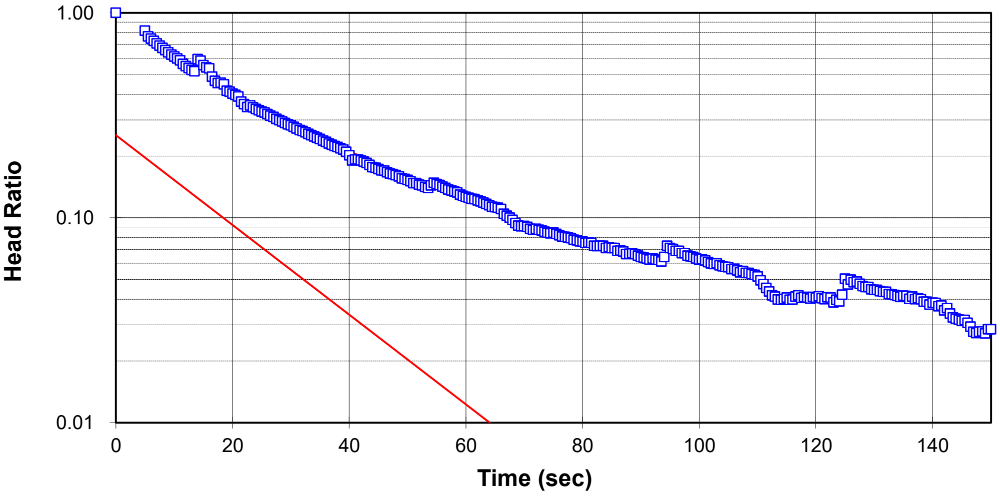
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c =	1.6E-02
R_e =	7.6E-02
L_e =	6.1
t_1 =	22
t_2 =	54
h_1/h_0 =	0.36
h_2/h_0 =	0.14

RESULTS

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



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 17/07/2019

Analysis By: SPS
Checked By: CWT
Analysis Date: 25/07/2019

Golder Associates Ltd.

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST TW-3B

INTERVAL (metres below ground surface)

Top of Interval = 14.75
Bottom of Interval = 20.85

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

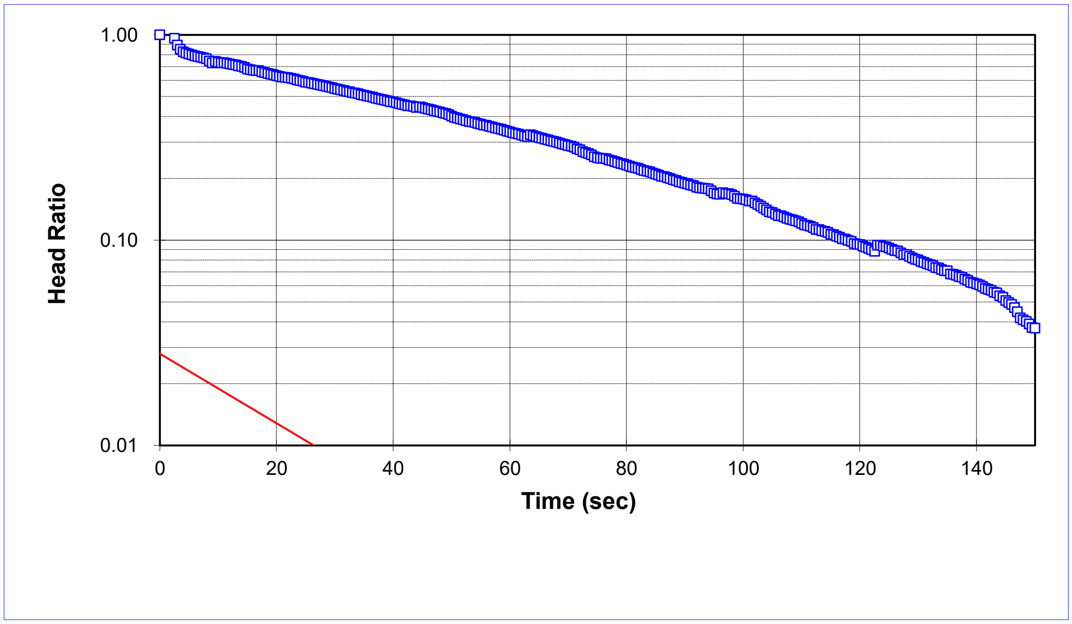
where:
r_c = casing radius (metres)
R_e = filter pack radius (metres)
L_e = length of screened interval (metres)
t = time (seconds)
h_t = head at time t (metres)

INPUT PARAMETERS

r_c = 1.6E-02
R_e = 7.6E-02
L_e = 6.1
t_1 = 4.5
t_2 = 63
h_1/h_0 = 0.82
h_2/h_0 = 0.32

RESULTS

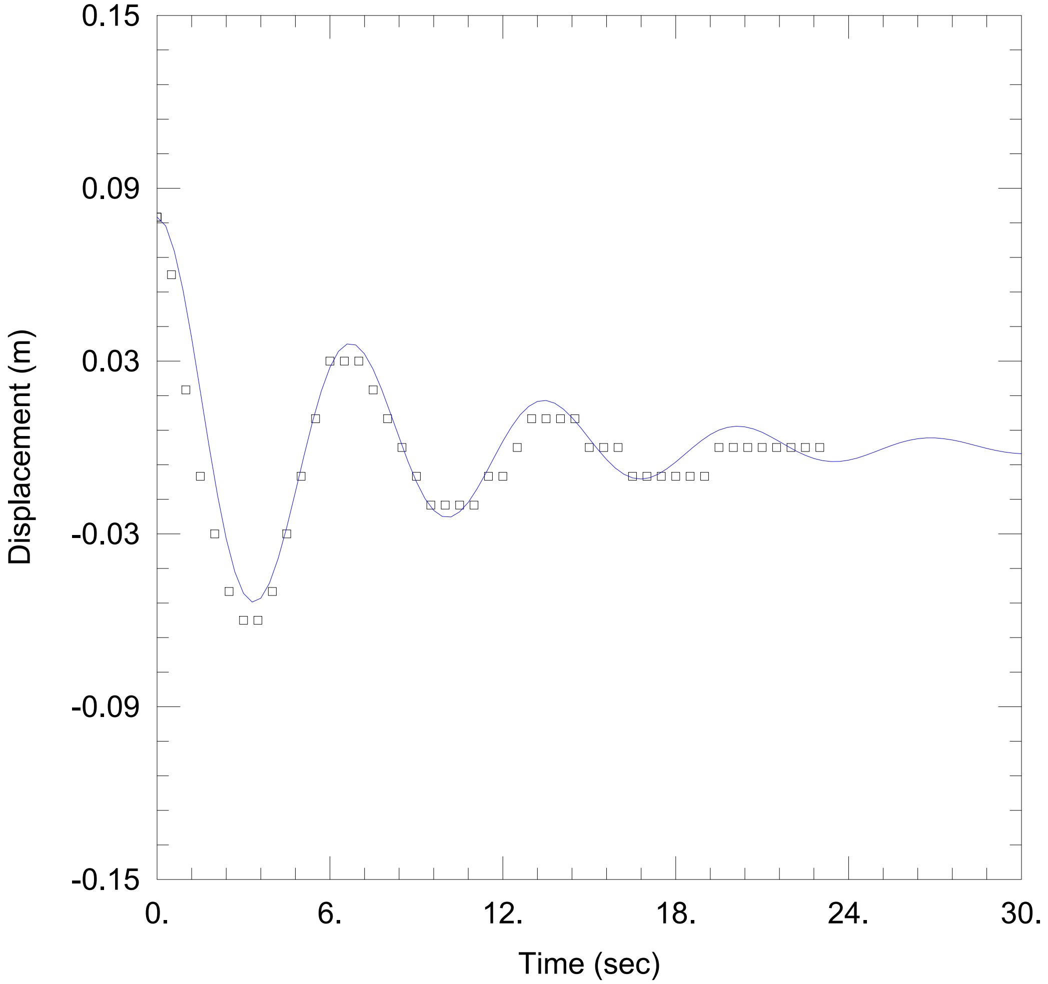
K=	**1E-06**	**m/sec**
K=	**1E-04**	**cm/sec**



Project Name: Cavanagh/ARA Application/Almonte
Project No.: 1899975
Test Date: 17/07/2019

Analysis By: SPS
Checked By: CWT
Analysis Date: 25/07/2019

Golder Associates Ltd.



PROJECT INFORMATION

Project: 18106557
Test Well: 19-25
Test Date: 2019-05-28

AQUIFER DATA

Saturated Thickness: 20. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (TW-6)

Initial Displacement: 0.08 m
Total Well Penetration Depth: 18.56 m
Casing Radius: 0.016 m
Static Water Column Height: 18.56 m
Screen Length: 6.1 m
Well Radius: 0.076 m

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

K = 0.000346 m/sec
Le = 11.01 m

APPENDIX D

Water Elevation Data

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	11-Aug-06		29-Aug-06		6-Jan-07		15-Mar-07		13-Sep-07		9-Jul-08		23-Sep-08		17-Nov-08	
			Depth to water (m)*	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.28	138.32	12.58	138.02	10.28	140.32	11.42	139.18	13.08	137.52	11.89	138.71	12.25	138.35	12.38	138.22
DD 03-1B	149.99	150.65	8.45	142.20	8.04	142.61	8.02	142.63	8.08	142.57	8.48	142.17	8.49	142.16	9.08	141.57	9.12	141.53
DD 03-2A	148.30	149.21	11.15	138.06	13.71	135.50	12.08	137.13	13.04	136.17	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	2.16	147.05	3.70	145.51	0.94	148.27	1.39	147.82	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	10.38	135.69	11.08	134.99	11.13	134.94
TW-2A	148.33	148.86	24.63	124.23	25.38	123.48	22.61	126.25	25.00	123.86	25.46	123.40	- -	- -	24.77	124.09	24.81	124.05
TW-2B	148.33	148.86	12.81	136.05	13.18	135.68	11.14	137.72	11.88	136.98	13.63	135.23	11.78	137.08	12.09	136.77	12.11	136.75
TW-2C	148.33	148.86	5.81	143.05	7.27	141.59	1.79	147.07	2.52	146.34	7.95	140.91	3.31	145.55	3.49	145.38	3.57	145.29
TW-3A	126.30	126.67	2.58	124.09	3.31	123.36	0.55	126.12	- -	- -	3.42	123.25	1.18	125.49	1.32	125.35	1.41	125.26
TW-3B	126.30	126.69	0.46	126.23	0.78	125.91	- -	- -	- -	- -	0.72	125.97	0.12	126.57	0.17	126.52	0.28	126.41
TW-6	124.50	125.60	2.03	123.57	3.33	122.27	1.51	124.09	1.78	123.82	2.46	123.14	3.31	122.29	3.24	122.36	3.35	122.25
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	14-Apr-09		30-Jun-09		17-Sep-09		17-Nov-09		9-Apr-10		12-Jul-10		24-Sep-10		9-Nov-10	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	10.26	140.34	11.36	139.24	13.55	137.05	13.49	137.11	10.40	140.20	13.67	136.93	13.51	137.09	13.48	137.12
DD 03-1B	149.99	150.65	5.97	144.68	6.72	143.93	8.29	142.36	8.24	142.42	7.15	143.50	8.94	141.71	8.63	142.02	8.59	142.06
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	10.99	135.08	11.06	135.01	13.69	132.38	13.58	132.49	16.49	129.58	19.07	127.00	18.90	127.17	18.97	127.10
TW-2A	148.33	148.86	- -	- -	25.03	123.83	26.10	122.76	25.95	122.91	- -	- -	- -	- -	25.68	123.18	26.61	122.25
TW-2B	148.33	148.86	- -	- -	12.04	136.82	14.21	134.65	14.15	134.72	- -	- -	- -	- -	14.09	134.77	14.10	134.76
TW-2C	148.33	148.86	- -	- -	3.61	145.25	4.68	144.18	4.49	144.37	- -	- -	- -	- -	4.39	144.47	4.33	144.53
TW-3A	126.30	126.67	- -	- -	1.06	125.61	2.33	124.35	2.31	124.37	0.88	125.79	4.26	122.41	2.81	123.86	3.14	123.53
TW-3B	126.30	126.69	- -	- -	0.11	126.58	0.56	126.13	0.52	126.17	0.00	126.69	0.95	125.74	0.51	126.18	0.67	126.02
TW-6	124.50	125.60	1.43	124.17	2.84	122.76	2.23	123.37	2.31	123.29	1.35	124.25	1.94	123.66	2.06	123.54	2.00	123.60
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	12-Apr-11		3-Jun-11		7-Sep-10		14-Nov-11		3-Apr-12		12-Jun-12		29-Aug-12		17-Oct-12	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	10.29	140.31	13.54	137.06	13.69	136.91	13.74	136.86	12.03	138.57	9.24	141.36	13.16	137.44	13.06	137.54
DD 03-1B	149.99	150.65	7.08	143.57	8.64	142.01	8.98	141.67	9.00	141.65	9.12	141.53	12.10	138.55	10.31	140.34	10.20	140.45
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	16.46	129.61	18.69	127.38	19.39	126.68	19.41	126.66	10.54	135.53	10.80	135.27	9.54	136.53	9.23	136.84
TW-2A	148.33	148.86	- -	- -	26.04	122.82	27.04	121.82	27.07	121.79	25.29	123.57	25.36	123.50	27.04	121.82	26.83	122.03
TW-2B	148.33	148.86	- -	- -	14.16	134.70	14.49	134.37	14.54	134.32	13.89	134.97	13.94	134.92	15.08	133.78	14.99	133.87
TW-2C	148.33	148.86	- -	- -	4.41	144.45	4.71	144.15	4.77	144.09	3.96	144.90	4.02	144.84	4.87	144.00	4.80	144.06
TW-3A	126.30	126.67	0.78	125.89	4.09	122.58	3.66	123.01	3.68	122.99	0.40	126.27	0.61	126.06	3.24	123.43	3.11	123.56
TW-3B	126.30	126.69	0.00	126.69	1.01	125.68	1.18	125.51	1.23	125.46	1.34	125.35	1.51	125.18	1.19	125.50	1.09	125.60
TW-6	124.50	125.60	1.33	124.27	2.02	123.58	2.91	122.69	2.93	122.67	1.29	124.31	1.48	124.12	1.92	123.68	1.80	123.80
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	3-May-13		21-Jun-13		23-Aug-13		3-Oct-13		30-Apr-14		4-Jun-14		29-Aug-14		6-Oct-14	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.78	137.82	12.86	137.74	13.06	137.54	13.01	137.59	12.74	137.86	12.89	137.71	12.96	137.64	13.01	137.59
DD 03-1B	149.99	150.65	9.67	140.98	9.73	140.92	9.92	140.73	9.88	140.77	9.60	141.05	9.84	140.81	9.91	140.74	9.97	140.68
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	9.12	136.95	9.19	136.88	10.03	136.04	9.64	136.43	9.29	136.78	9.64	136.43	10.04	136.03	10.40	135.67
TW-2A	148.33	148.86	26.78	122.08	26.84	122.02	27.11	121.75	27.04	121.82	26.56	122.30	26.92	121.94	27.03	121.83	27.08	121.78
TW-2B	148.33	148.86	14.88	133.98	14.93	133.93	15.10	133.77	15.06	133.80	14.79	134.07	15.04	133.82	15.08	133.78	15.13	133.73
TW-2C	148.33	148.86	4.62	144.24	4.69	144.17	4.82	144.04	4.78	144.08	4.54	144.32	4.77	144.09	4.84	144.02	4.80	144.06
TW-3A	126.30	126.67	2.03	124.64	2.00	124.67	2.49	124.18	2.44	124.23	1.62	125.05	2.10	124.57	2.14	124.53	2.20	124.47
TW-3B	126.30	126.69	1.15	125.54	1.19	125.50	1.87	124.82	1.31	125.38	0.80	125.89	1.23	125.46	1.29	125.40	1.61	125.08
TW-6	124.50	125.60	1.53	124.07	1.59	124.01	1.83	123.77	1.74	123.86	1.44	124.16	1.69	123.91	1.88	123.72	1.93	123.67
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	24-Apr-15		8-Jun-15		21-Aug-15		29-Oct-15		6-Apr-16		29-Jun-16		4-Aug-16		7-Oct-16	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	n (m ASL)	Depth to water (m)	n (m ASL)	Depth to water (m)	n (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.99	137.61	13.89	136.71	14.56	136.04	14.50	136.10	12.17	138.43	15.12	135.48	15.07	135.53	15.03	135.57
DD 03-1B	149.99	150.65	10.14	140.51	11.23	139.42	11.40	139.25	11.38	139.27	10.18	140.47	11.11	139.54	11.29	139.36	10.91	139.74
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	8.66	137.41	8.78	137.29	9.09	136.98	9.09	136.98	7.93	138.14	9.15	136.92	9.06	137.01	9.36	136.71
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	1.58	125.09	2.87	123.80	3.89	122.78	3.27	123.40	1.10	125.57	3.88	122.79	3.82	122.85	3.72	122.95
TW-3B	126.30	126.69	0.78	125.91	1.96	124.73	2.18	124.51	2.00	124.69	0.82	125.87	2.51	124.18	2.45	124.24	3.07	123.62
TW-6	124.50	125.60	1.45	124.15	1.71	123.89	2.19	123.41	2.12	123.48	1.47	124.13	2.32	123.28	2.47	123.13	2.39	123.21
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	5.10	148.54	11.60	142.04	12.07	141.57	10.70	142.94
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	2.01	151.65	2.95	150.71	2.67	150.99	2.34	151.32
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	1.94	151.70	2.87	150.77	2.54	151.10	2.30	151.34

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

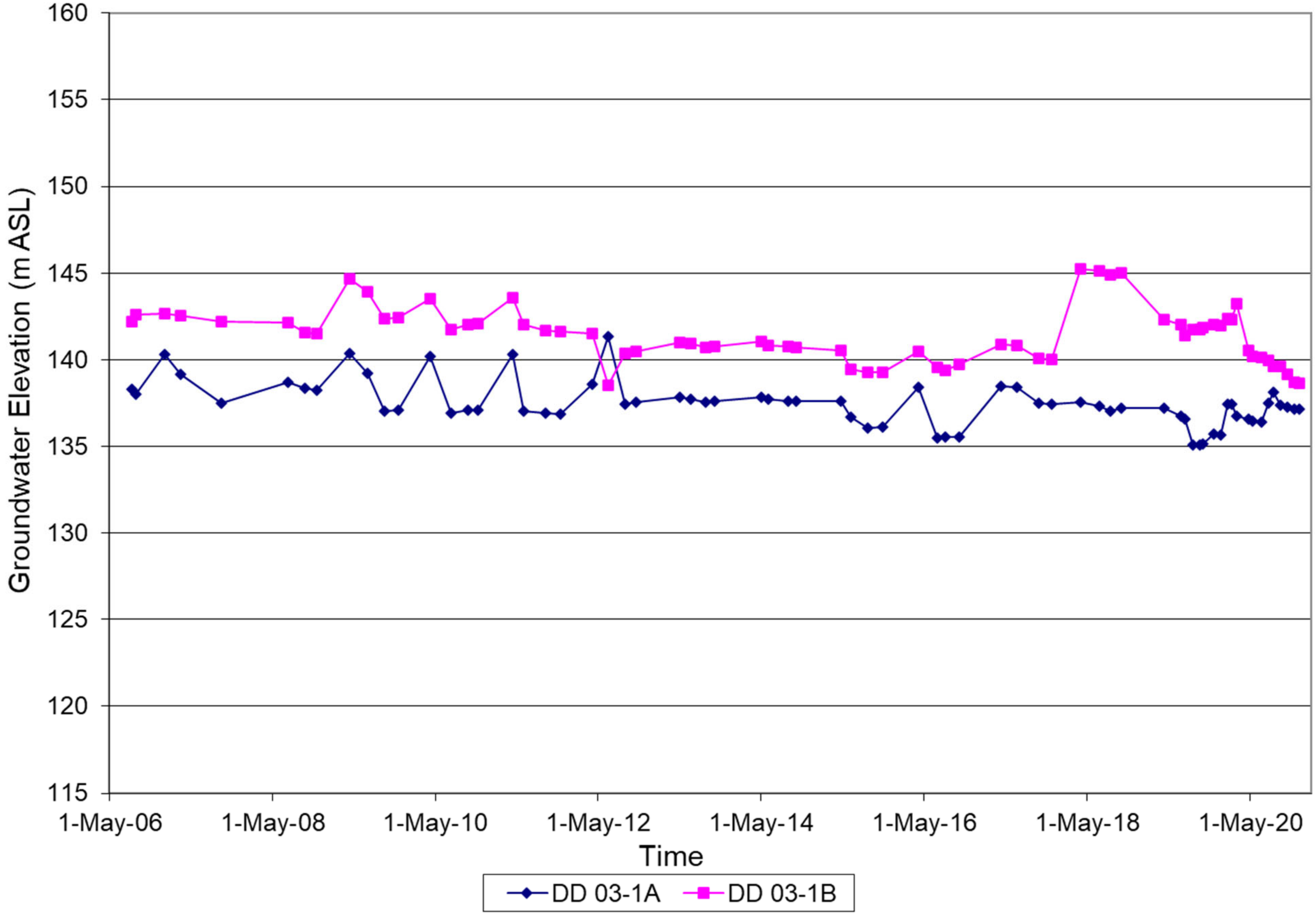
Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	10-Apr-17		21-Jun-17		28-Sep-17		23-Nov-17		3-Apr-18		27-Jun-18		14-Aug-18		2-Oct-18		13-Apr-19	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.12	138.48	12.18	138.42	13.10	137.50	13.16	137.44	13.06	137.54	13.26	137.34	13.57	137.03	13.39	137.21	13.40	137.20
DD 03-1B	149.99	150.65	9.75	140.90	9.83	140.82	10.60	140.05	10.63	140.02	5.41	145.24	5.55	145.10	5.78	144.87	5.64	145.01	8.33	142.32
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	3.12	142.95	3.40	142.67	3.89	142.18	4.01	142.06	0.20	145.87	2.92	143.15	3.25	142.82	3.16	142.91	12.13	133.94
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	0.97	125.70	2.74	123.93	3.66	123.01	2.94	123.73	1.79	124.88	2.08	124.59	2.52	124.15	2.39	124.28	0.71	125.96
TW-3B	126.30	126.69	0.64	126.05	1.69	125.00	2.14	124.55	1.79	124.90	1.12	125.57	1.49	125.20	1.72	124.97	1.64	125.05	0.33	126.36
TW-6	124.50	125.60	1.29	124.31	1.37	124.23	1.77	123.83	1.80	123.80	1.44	124.16	1.64	123.96	1.98	123.62	1.88	123.72	1.32	124.28
MW15-1A	152.08	153.64	4.57	149.07	4.65	148.99	5.01	148.63	5.04	148.60	5.76	147.88	5.88	147.76	6.15	147.49	6.01	147.63	7.41	146.23
MW15-1B	152.08	153.66	1.84	151.82	1.94	151.72	2.30	151.36	2.33	151.33	1.97	151.69	2.18	151.48	2.46	151.20	2.30	151.36	1.98	151.68
MW15-1C	152.08	153.64	1.78	151.86	1.88	151.76	2.21	151.43	2.24	151.40	1.90	151.74	2.12	151.52	2.29	151.35	2.26	151.38	1.90	151.74

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	28-Jun-19		16-Jul-19		20-Aug-19		18-Sep-19		3-Oct-19		18-Nov-19		20-Dec-19		23-Jan-20		7-Feb-20	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	13.82	136.78	14.02	136.58	15.54	135.06	15.52	135.08	15.48	135.12	14.89	135.71	14.94	135.66	13.18	137.42	13.16	137.44
DD 03-1B	149.99	150.65	8.62	142.03	9.28	141.37	8.91	141.74	8.92	141.73	8.80	141.85	8.64	142.01	8.67	141.98	8.29	142.36	8.31	142.34
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	13.80	132.27	8.64	137.43	8.79	137.28	8.73	137.34	8.94	137.13	8.75	137.32	8.90	137.17	8.42	137.65	8.31	137.76
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	2.21	124.46	2.62	124.05	2.74	123.94	2.70	123.97	2.65	124.02	2.33	124.34	2.44	124.23	2.01	124.66	2.08	124.59
TW-3B	126.30	126.69	1.71	124.98	1.57	125.12	2.60	124.09	2.54	124.15	2.50	124.19	1.83	124.86	2.01	124.68	1.35	125.34	1.4	125.29
TW-6	124.50	125.60	1.71	123.89	1.86	123.74	2.28	123.32	2.23	123.37	2.34	123.26	1.87	123.73	1.97	123.63	1.58	124.02	1.63	123.97
MW15-1A	152.08	153.64	7.62	146.02	8.74	144.90	11.58	142.06	11.59	142.05	12.07	141.57	10.55	143.09	10.61	143.03	8.71	144.93	8.7	144.94
MW15-1B	152.08	153.66	2.17	151.49	2.22	151.44	2.45	151.21	2.43	151.23	2.45	151.21	2.04	151.62	2.09	151.57	2.07	151.59	2.11	151.55
MW15-1C	152.08	153.64	2.11	151.53	2.17	151.47	2.40	151.24	2.38	151.26	2.40	151.24	2.00	151.64	2.02	151.62	2.00	151.64	2.05	151.59

TABLE D1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	2-Mar-20		10-Apr-20		13-May-20		23-Jun-20		24-Jul-20		12-Aug-20		14-Sep-20		15-Oct-20		16-Nov-20		9-Dec-20	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	13.82	136.78	14.01	136.59	14.14	136.46	14.20	136.40	13.08	137.52	12.49	138.11	13.24	137.36	13.31	137.29	13.46	137.14	13.44	137.16
DD 03-1B	149.99	150.65	7.42	143.23	10.11	140.55	10.48	140.17	10.53	140.12	10.70	139.95	11.04	139.61	11.03	139.62	11.48	139.17	11.96	138.69	12.03	138.62
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	8.69	137.38	8.04	138.03	8.34	137.73	8.46	137.61	8.38	137.69	8.33	137.74	8.22	137.85	8.36	137.71	8.26	137.81	8.58	137.49
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	2.04	124.63	1.74	124.93	2.03	124.64	2.09	124.58	2.30	124.37	2.64	124.03	2.97	123.70	3.01	123.66	2.88	123.79	2.69	123.98
TW-3B	126.30	126.69	1.30	125.39	1.14	125.55	1.35	125.34	1.42	125.27	1.50	125.19	1.46	125.23	1.43	125.26	1.50	125.19	1.39	125.30	1.20	125.49
TW-6	124.50	125.60	1.49	124.11	1.56	124.04	1.80	123.80	2.01	123.59	1.94	123.66	1.88	123.72	1.82	123.78	1.74	123.86	1.78	123.82	1.61	123.99
MW15-1A	152.08	153.64	8.80	144.84	8.80	144.84	10.02	143.62	10.14	143.50	9.49	144.15	8.69	144.95	6.62	147.02	6.16	147.48	6.08	147.56	5.58	148.06
MW15-1B	152.08	153.66	2.01	151.65	2.01	151.65	2.30	151.36	2.39	151.27	2.20	151.46	1.99	151.67	2.05	151.61	2.12	151.54	2.10	151.56	2.03	151.63
MW15-1C	152.08	153.64	1.94	151.70	1.94	151.70	2.24	151.40	2.36	151.28	2.23	151.41	1.90	151.75	1.98	151.66	2.02	151.62	2.00	151.65	1.98	151.66



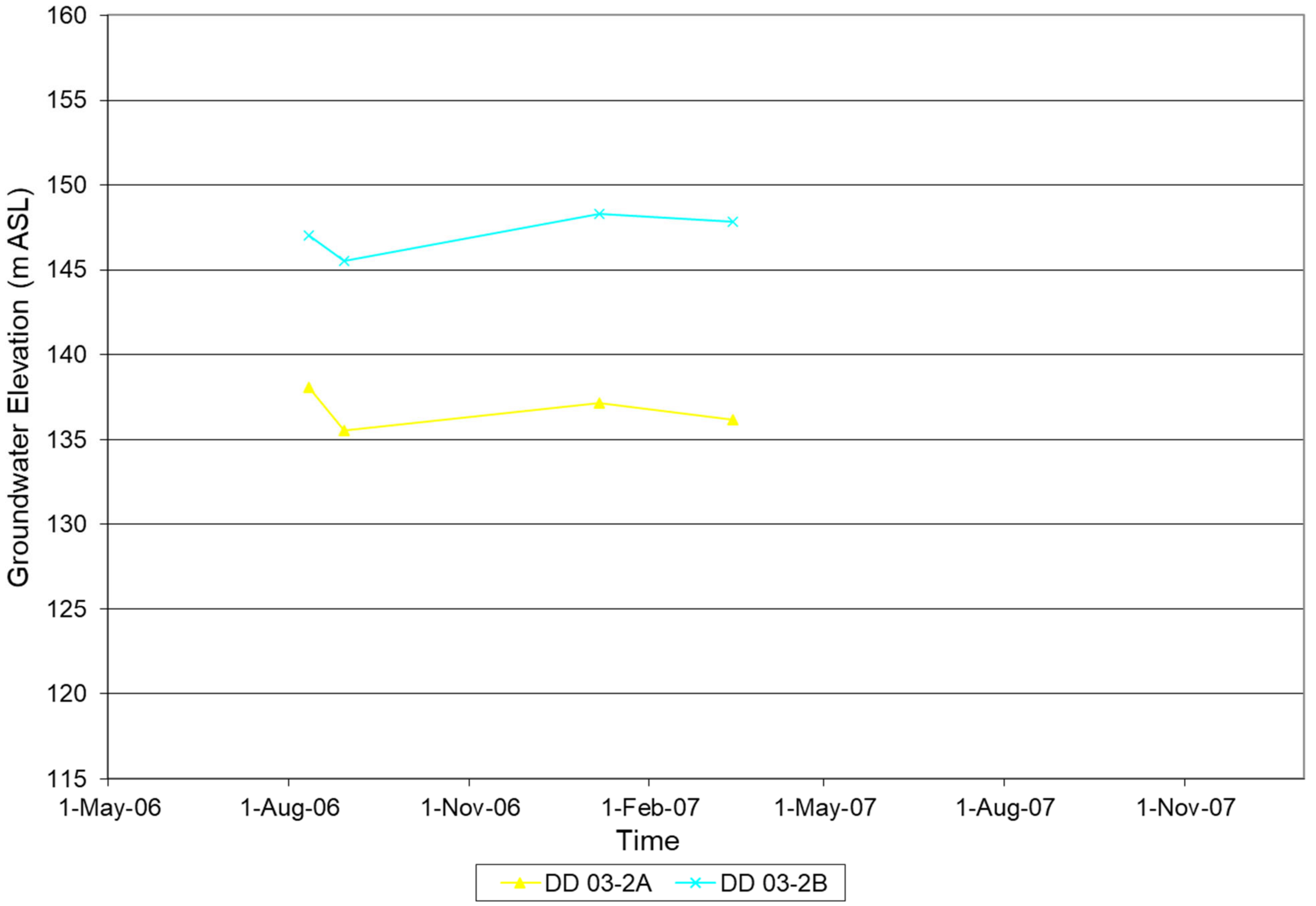
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

DDH03-1 Groundwater Elevation Data
August 11, 2006 to December 9, 2020

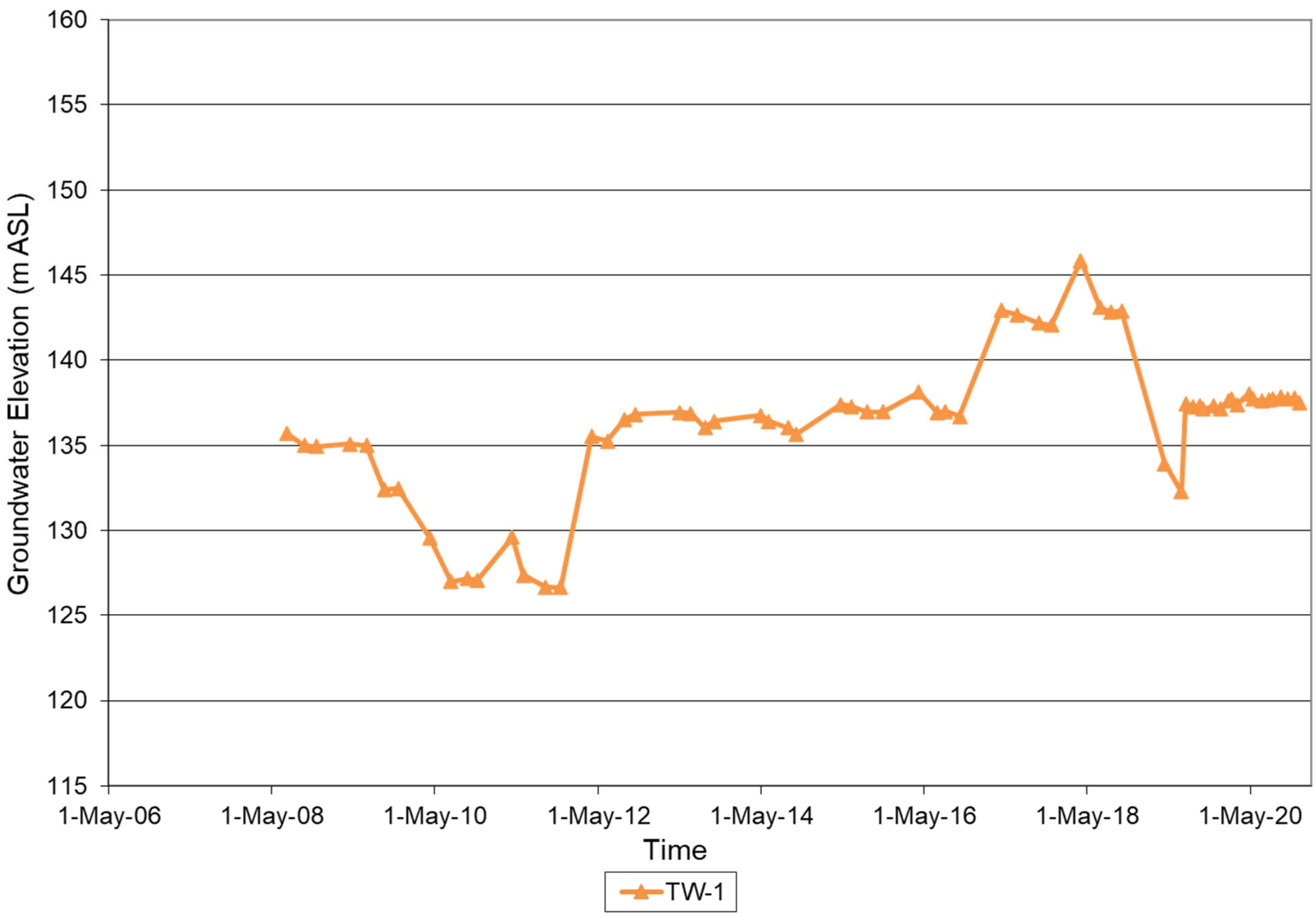
FIGURE D1



Date: December 2020	Drawn: JPAO	
Project: 1899975	Checked: KAM	

DDH03-2 Groundwater Elevation Data
August 11, 2006 to March 15, 2007

FIGURE D2



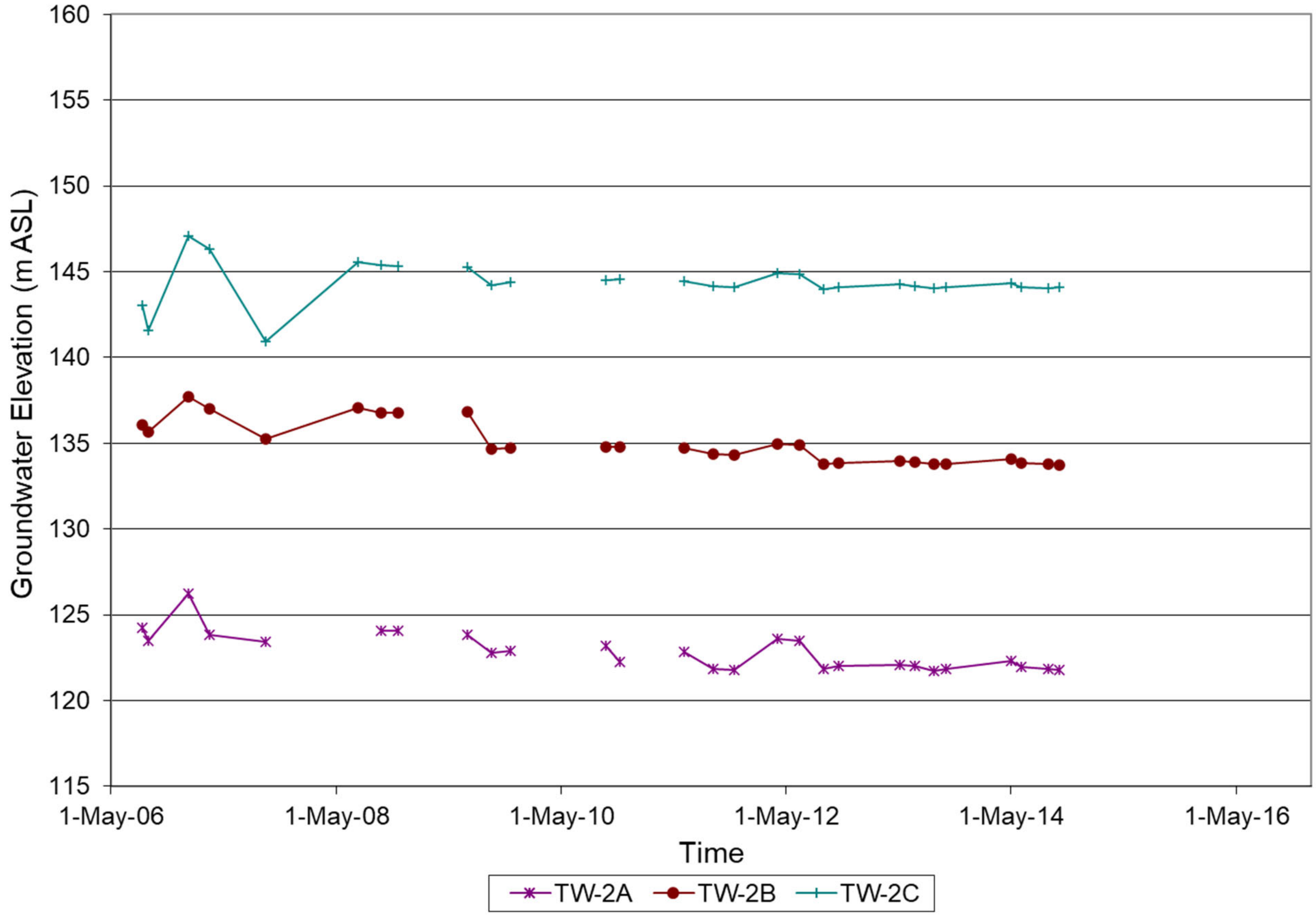
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

TW-1 Groundwater Elevation Data
July 9, 2008 to December 9, 2020

FIGURE D3



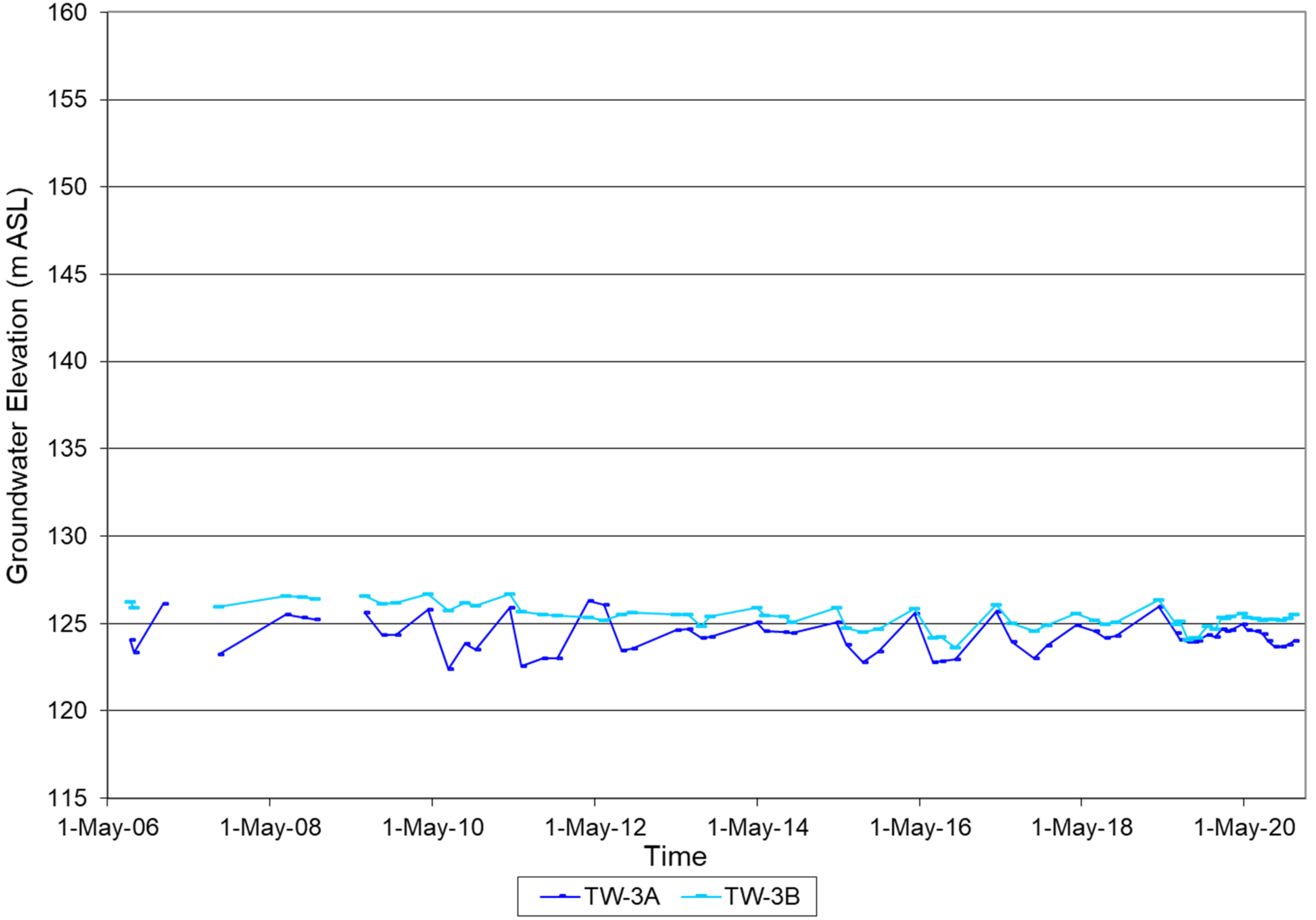
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

TW-2 Groundwater Elevation Data
August 11, 2006 to December 9, 2020

FIGURE D4



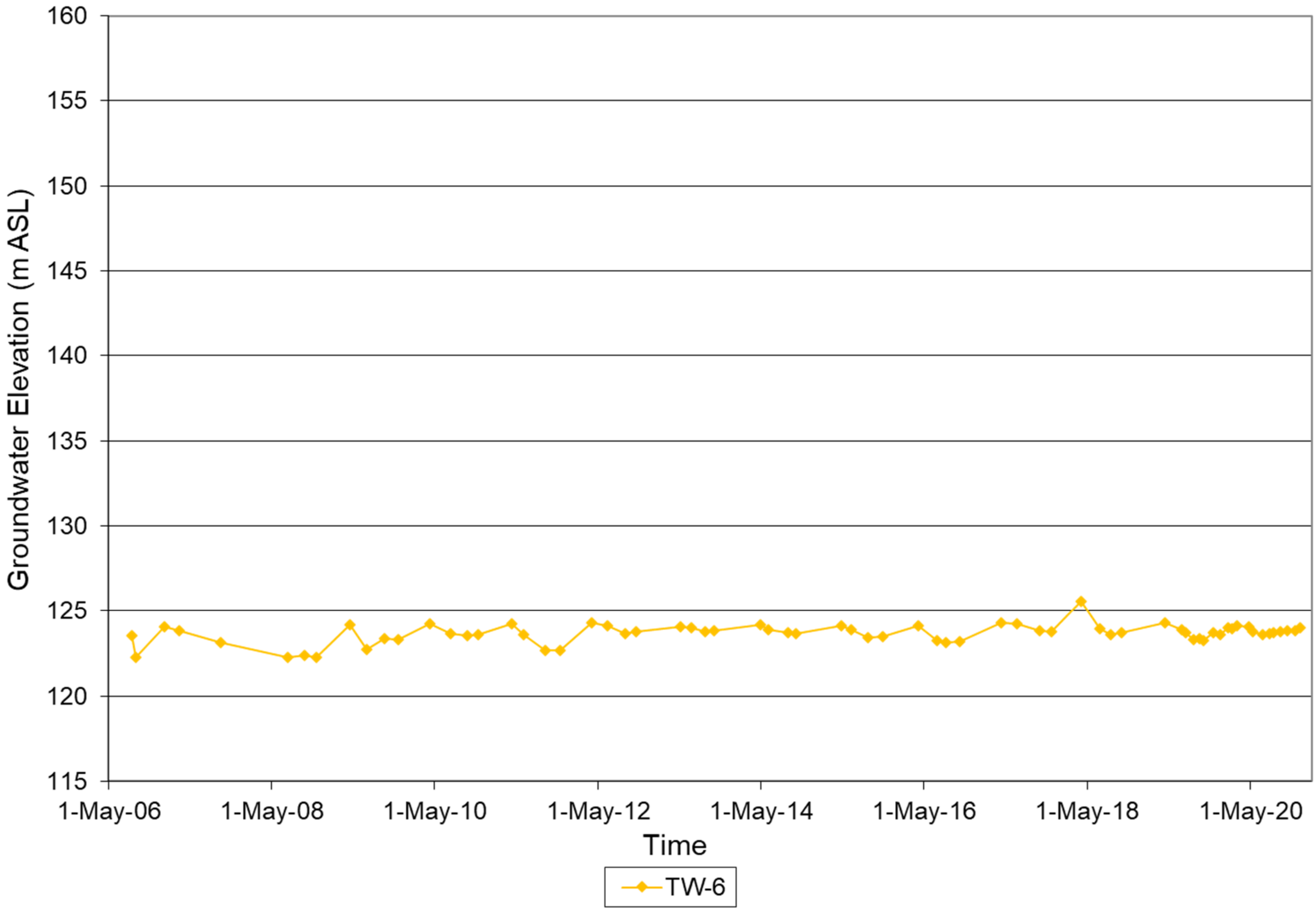
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

TW-3 Groundwater Elevation Data
August 11, 2006 to December 9, 2020

FIGURE D5



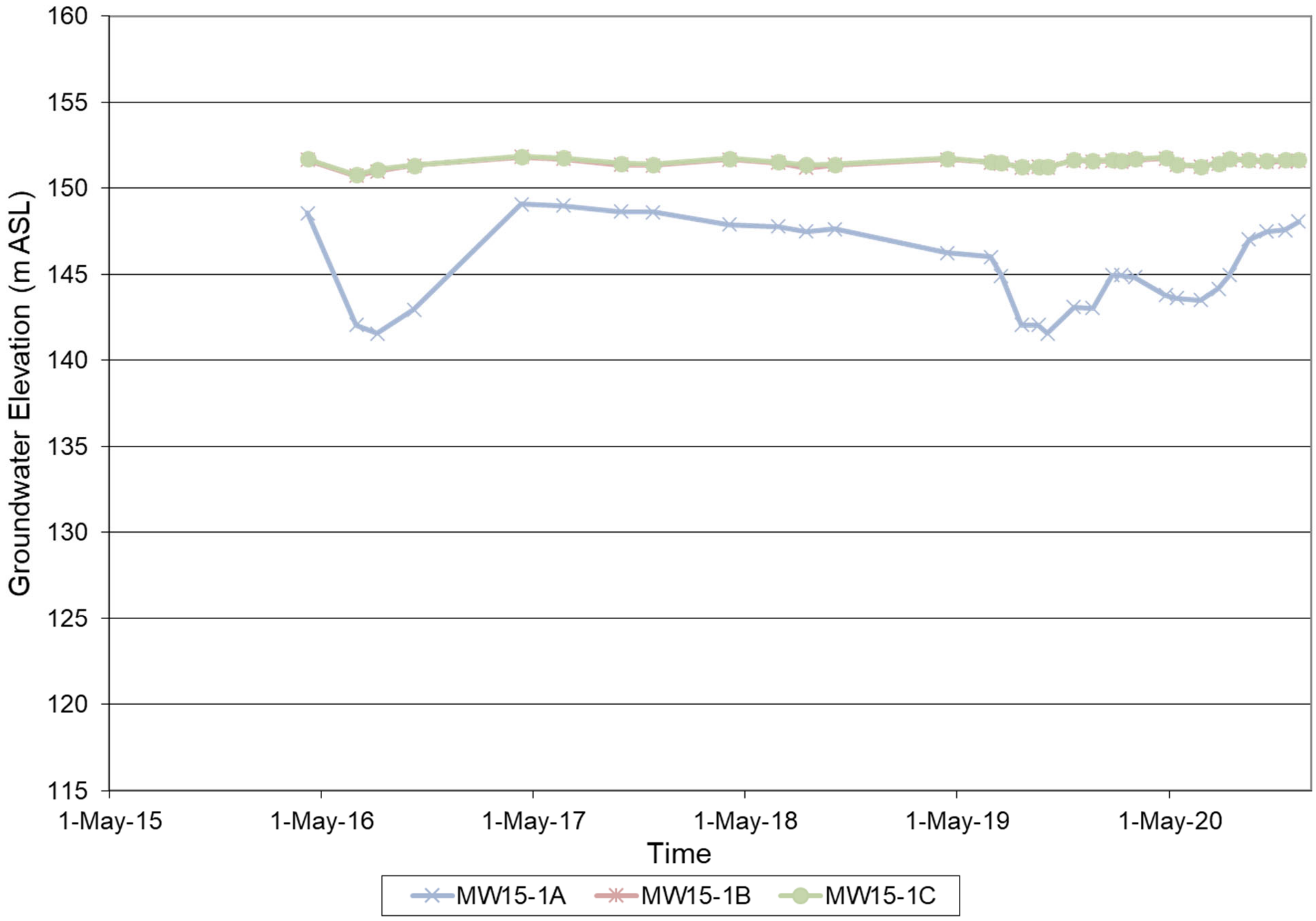
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

TW-6 Groundwater Elevation Data
August 11, 2006 to December 9, 2020

FIGURE D6



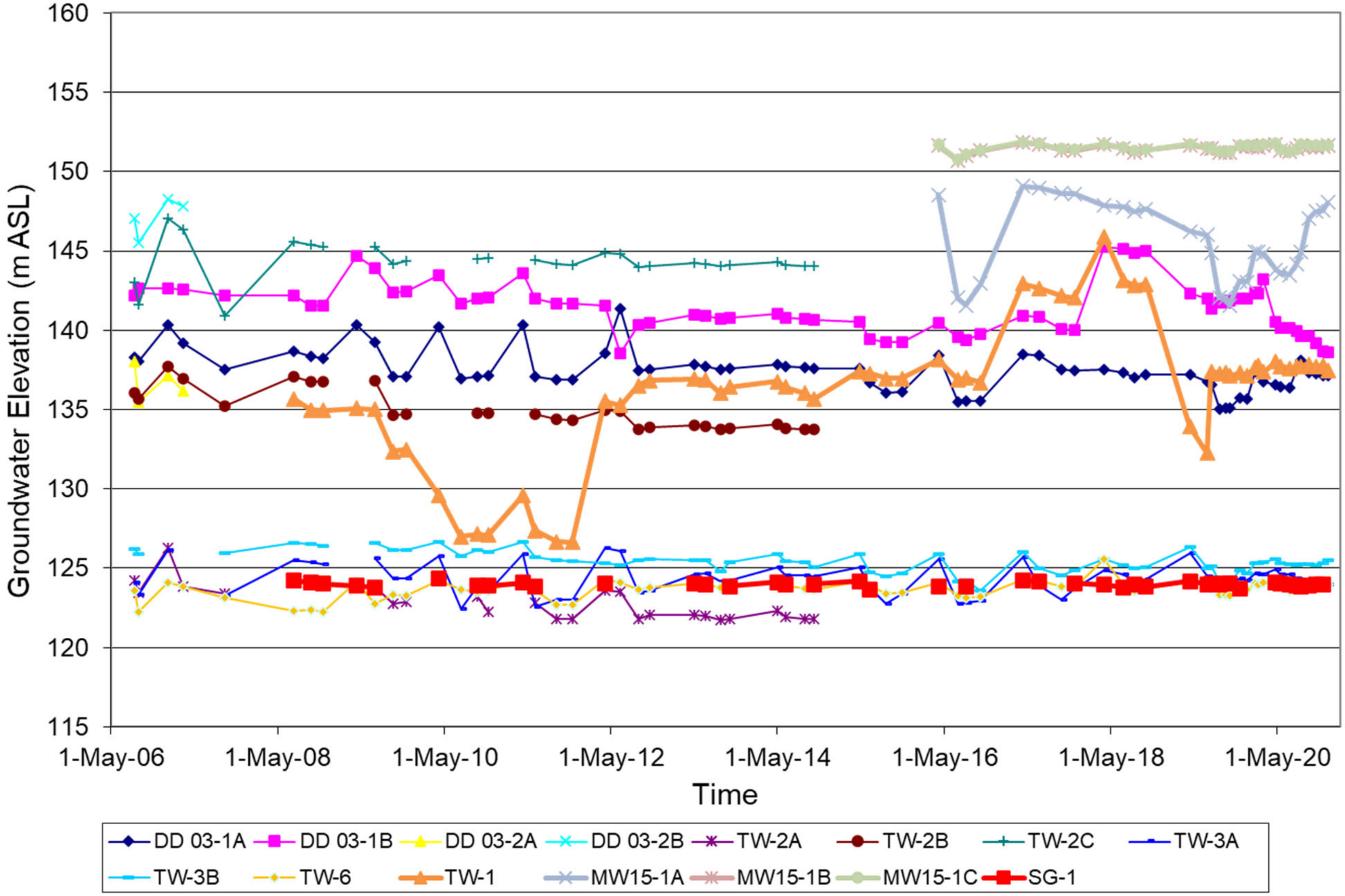
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

MW15-1 Groundwater Elevation Data
April 6, 2016 to December 9, 2020

FIGURE D7



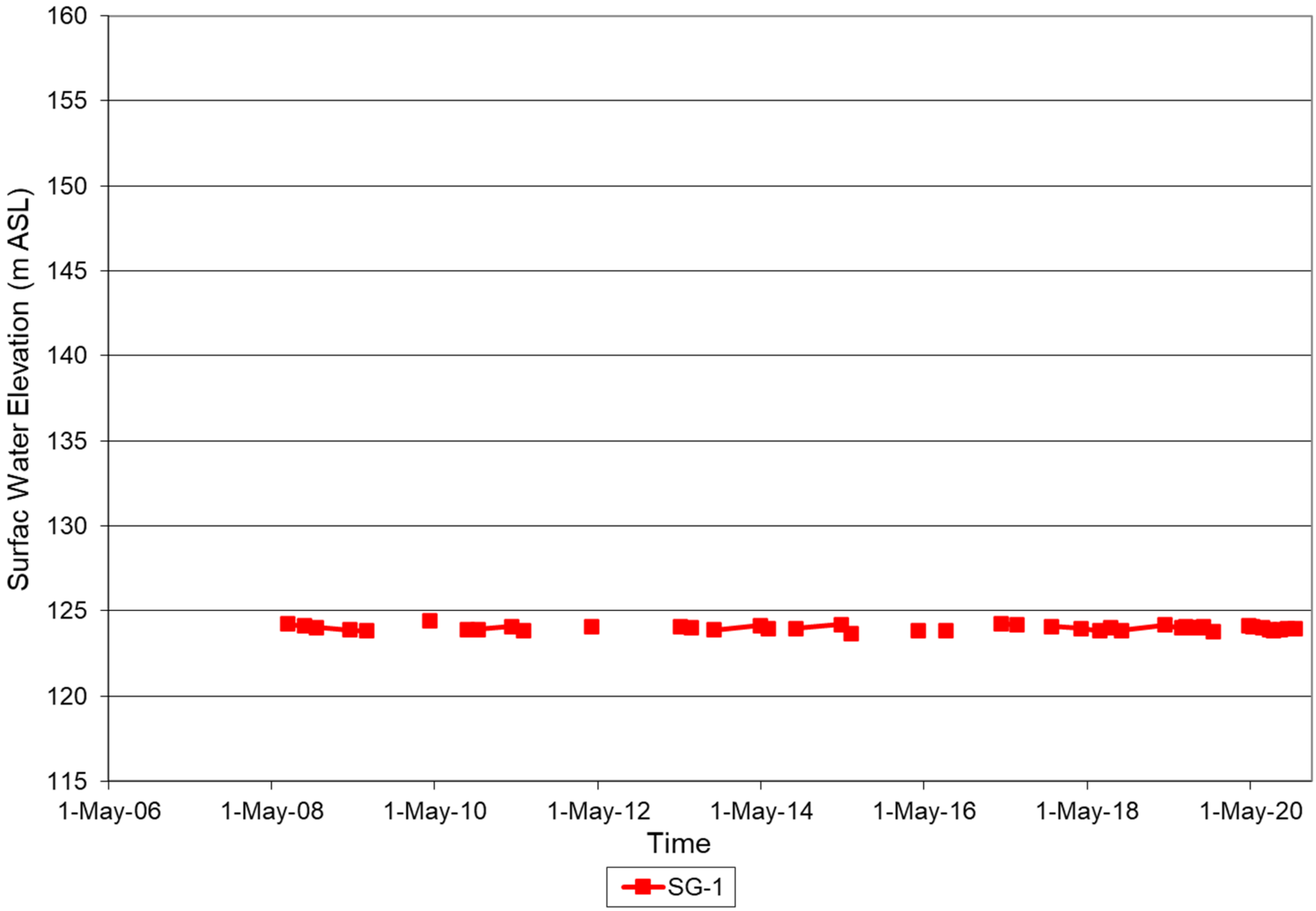
GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

Groundwater Elevation Data
All Monitoring Locations

FIGURE D8



GOLDER

Date: December 2020 Drawn: JPAO

Project: 1899975 Checked: KAM

SG-1 Water Elevation Data
July 9, 2008 to December 9, 2020

FIGURE D9

APPENDIX E

Supply Well Completion Details and Predicted Loss in Available Drawdown

Table E1
Supply Well Completion Details, Predicted
Available Drawdown and Forcast Scenario Results

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
								Drawdown Relative to Predevelopment Conditions (m)								
								Scenario 1	**Scenario 2**		**Scenario 3**	**Scenario 4**	**Scenario 5**			**Scenario 6**
Water Well Record Number	**Easting**	**Northing**	**Ground Surface Elevation (m ASL)**	**Well Depth (m)**	**Well Bottom Elevation (m ASL)**	**Static Water Elevation (m ASL)**	**Available Drawdown (m) (calculated using the static measured at time of drilling as per the water well record)**	**Predicted Drawdown Associated With Existing Almonte Quarry - Full Development**	**Predicted Drawdown Associated With Existing Almonte Quarry and Extension Lands - Full Development**	**Incremental Additional Drawdown Associated with the Development of the Extension Lands (Scenario 2 minus Scenario 1)**	**Predicted Drawdown Associated With Existing Almonte Quarry and Extension Lands - Full Development**	**Predicted Drawdown Associated With Existing Almonte Quarry and Extension Lands - Predevelopment**	**Predicted Drawdown Associated With Existing Almonte Quarry and Extension Lands - Full Development**	**Percent Drawdown Attributed to Existing Almonte Quarry and Extension Lands**	**Predicted Available Drawdown Following Full Development of the Existing Almonte Quarry, the Extension Lands, and the Burnt Lands Quarry to Final Floor Elevation (m) (available drawdown Column 8 minus Scenario 5 drawdown Column 15)**	**Existing Almonte Quarry and Extension Lands Rehabilitated**
								Burnt Lands Quarry - Current Conditions	**Burnt Lands Quarry - Current Conditions**		**Burnt Lands Quarry - Predevelopment**	**Burnt Lands Quarry - Full Development**	**Burnt Lands Quarry - Full Development**			**Burnt Lands Quarry - Rehabilitated**
1525284	410498.5	5012676	154.2	49.7	104.5	148.06	43.52	7.04	10.09	3.05	9.93	1.66	11.42	87%	32.10	5.22
1514922	410468.5	5012626	154.1	77.4	76.9	146.44	69.53	6.88	9.91	3.04	9.75	1.74	11.34	86%	58.19	5.21
1513826	410375.5	5012752	152.6	60.4	92.2	138.93	46.74	5.99	8.10	2.11	7.91	1.89	9.70	82%	37.04	4.41
1514195	410274.5	5012880	152.5	53.3	99.1	135.36	36.30	5.14	6.64	1.50	6.43	2.03	8.39	77%	27.90	3.68
1513825	410245.5	5012922	152.7	24.4	128.2	150.84	22.61	4.91	6.27	1.36	6.06	2.06	8.05	75%	14.56	3.48
1513680	411098	5013031	143.0	44.2	98.7	130.84	32.10	9.02	10.24	1.22	10.18	0.83	10.85	94%	21.25	3.98
1514257	410175.5	5012986	152.0	75.6	76.3	136.71	60.38	4.47	5.61	1.14	5.39	2.17	7.49	72%	52.89	3.15
1514679	410059.5	5013228	153.3	72.5	80.7	144.24	63.51	3.65	4.39	0.74	4.18	2.13	6.21	67%	57.31	2.41
7160750	409833	5013235	146.1	31.4	114.9	138.49	23.59	3.06	3.63	0.57	3.37	2.66	5.89	57%	17.70	2.14
7113238	409888	5013397	150.2	62.0	88.1	140.69	52.55	3.02	3.53	0.51	3.31	2.25	5.40	61%	47.15	1.96
7047643	409926	5013621	146.4	53.3	93.5	134.54	41.06	2.88	3.30	0.42	3.12	1.89	4.85	64%	36.21	1.71
3514716	410075	5011191	161.2	91.4	70.0	141.98	71.94	2.40	2.68	0.29	2.44	2.06	4.91	50%	67.03	1.77
1510248	409480.5	5013692	135.2	32.9	102.3	132.48	30.15	2.22	2.48	0.25	2.27	2.42	4.36	52%	25.78	1.47
1526758	409529.5	5013824	133.4	32.0	101.4	127.92	26.51	2.23	2.45	0.22	2.29	1.87	3.91	59%	22.61	1.28
3508784	410369	5010813	158.6	38.1	120.5	147.96	27.43	2.26	2.42	0.16	2.27	1.23	3.86	59%	23.57	1.55
3503840	408540.5	5008873	136.2	23.5	112.7	130.39	17.66	2.12	2.28	0.16	2.12	2.25	4.02	53%	13.63	1.23
1529986	410466.5	5010811	157.2	35.1	122.2	146.53	24.37	2.41	2.56	0.15	2.42	1.12	3.89	62%	20.48	1.62
3502291	410270.5	5010622	154.9	30.5	124.4	144.26	19.85	1.84	1.98	0.14	1.83	1.21	3.42	54%	16.43	1.27
3506819	408729.5	5008421	130.5	26.2	104.3	124.88	20.58	1.23	1.34	0.11	1.24	1.15	2.44	51%	18.14	0.75
3502143	408770.5	5008322	129.8	18.9	110.9	123.89	13.01	1.15	1.24	0.09	1.16	1.06	2.15	54%	10.87	0.72

APPENDIX F

Water Well Records – Predicted Available Drawdown Less Than 15 Metres

ONTARIO

B

MINISTRY OF THE ENVIRONMENT

The Ontario Water Resources Act

WATER WELL RECORD

31F/8

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11

1513825.

MUNICIP. 15005 CON. CON 11

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON., BLOCK, TRACT, SURVEY, ETC.	LOT
[redacted]	Huntley	Con 11	016

[redacted] Richmond Ont.

DATE COMPLETED DAY 18 MO. 08 YR. 73

012700 RC 4 ELEVATION 0505 RC 5 BASIN CODE 26

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
grey	clay	shale		0	7
grey	limestone			7	80

31 0007205 17 0080215

32

41 WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
0080	1 ☒ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL

51 CASING & OPEN HOLE RECORD

INSIDE DIAM. INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
05	1 ☒ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	.188	0	0020
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER INCHES	LENGTH FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN FEET

61 PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	DEPTH SET AT - FEET TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

71 PUMPING TEST

PUMPING TEST METHOD 1 ☐ PUMP 2 ☑ BAILER

PUMPING RATE 0006 GPM.

DURATION OF PUMPING 01 HOURS 00 MINS.

WATER LEVELS DURING 1 ☒ PUMPING 2 ☐ RECOVERY

STATIC LEVEL	WATER LEVEL END OF PUMPING	15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
006 FEET	060 FEET	055 FEET	060 FEET	060 FEET	060 FEET

IF FLOWING GIVE RATE GPM.

PUMP INTAKE SET AT FEET

WATER AT END OF TEST 1 ☐ CLEAR 2 ☑ CLOUDY

RECOMMENDED PUMP TYPE ☐ SHALLOW ☑ DEEP

RECOMMENDED PUMP SETTING 060 FEET

RECOMMENDED PUMPING RATE 005 GPM.

000.1 GPM./FT. SPECIFIC CAPACITY

FINAL STATUS OF WELL

1 ☑ WATER SUPPLY
2 ☐ OBSERVATION WELL
3 ☐ TEST HOLE
4 ☐ RECHARGE WELL
5 ☐ ABANDONED, INSUFFICIENT SUPPLY
6 ☐ ABANDONED, POOR QUALITY
7 ☐ UNFINISHED

WATER USE 01

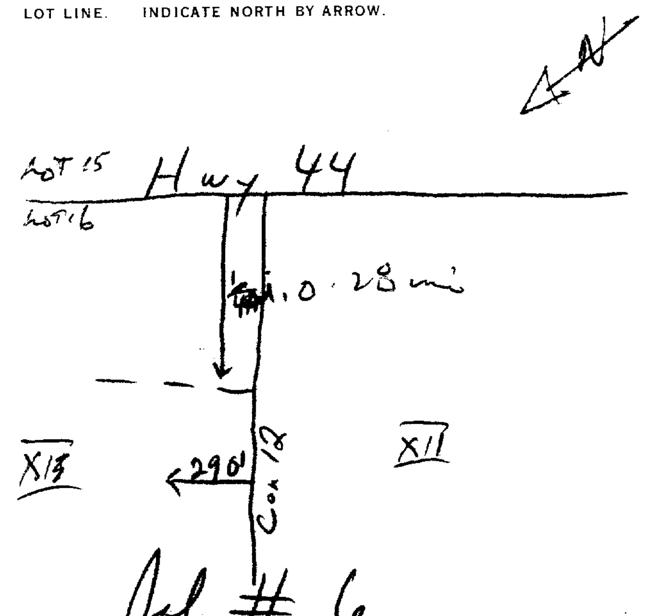
1 ☑ DOMESTIC
2 ☐ STOCK
3 ☐ IRRIGATION
4 ☐ INDUSTRIAL
☐ OTHER
5 ☐ COMMERCIAL
6 ☐ MUNICIPAL
7 ☐ PUBLIC SUPPLY
8 ☐ COOLING OR AIR CONDITIONING
9 ☐ NOT USED

METHOD OF DRILLING

1 ☑ CABLE TOOL
2 ☐ ROTARY (CONVENTIONAL)
3 ☐ ROTARY (REVERSE)
4 ☐ ROTARY (AIR)
5 ☐ AIR PERCUSSION
6 ☐ BORING
7 ☐ DIAMOND
8 ☐ JETTING
9 ☐ DRIVING

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.



DRILLERS REMARKS: Job # 6,

CONTRACTOR

NAME OF WELL CONTRACTOR Henry Mains Well Drilling

LICENCE NUMBER 3644

ADDRESS Box 326, Richmond Ont.

NAME OF DRILLER OR BORER

LICENCE NUMBER

SIGNATURE OF CONTRACTOR Henry Mains

SUBMISSION DATE DAY 18 MO. 8 YR. 73

OFFICE USE ONLY

DATA SOURCE 1

CONTRACTOR 3644

DATE RECEIVED 110274

DATE OF INSPECTION

INSPECTOR K.

REMARKS:

P R

WI

MINISTRY OF THE ENVIRONMENT COPY

FORM 7 07-091

3/7/1 east

GW

UTM 18 Z 408740 E

5 R 5008100 N

Con X
Elev. 5 R 0426

Lot 2 5 2
Basin

35 № 2148

RECEIVED
SEP 14 1956
GEOLOGICAL BRANCH
DEPARTMENT of MINES

ONTARIO

The Water-well Drillers Act, 1954

Department of Mines

Water-Well Record

County or Territorial District LANARK Township, Village, Town or City RAMSAY

[redacted] Village, Town or City)

ddress CEDAR HILL ONT

(day) (month) (year)

Pipe and Casing Record		Pumping Test	
Casing diameter(s)	6 1/4	Static level	24'
Length(s)	9'	Pumping rate	10 GPM
Type of screen		Pumping level	30 FT
Length of screen		Duration of test	1 HR

Well Log | **Water Record**

Overburden and Bedrock Record	From ft.	To ft.	Depth(s) at which water(s) found	No. of feet water rises	Kind of water (fresh, salty, or sulphur)
CLAY	0	4	56	32	FRESH
LIMESTONE	4	62			

For what purpose(s) is the water to be used? DOMESTIC

Is water clear or cloudy? CLEAR

Is well on upland, in valley, or on hillside? UPLAND

Drilling firm C GOODBERRY

Address VERONA ONT

Name of Driller LOUIS CRONK

Address VERONA ONT

Licence Number 710

I certify that the foregoing statements of fact are true.

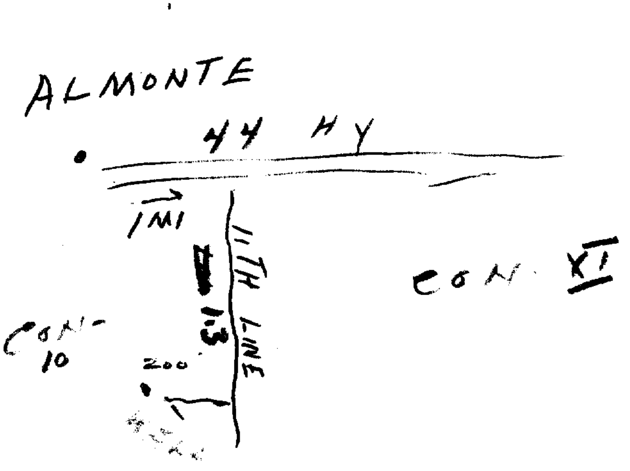
Date Je 20

Signature of Licensee

BW

Location of Well

In diagram below show distances of well from road and lot line. Indicate north by arrow.



CSS.S8

Form 5

MINISTRY OF THE ENVIRONMENT

The Ontario Water Resources Act

WATER WELL RECORD

31 F/E

Ontario

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11

3503840

MUNICIP. 35012 CON. CØN 11

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON., BLOCK, TRACT, SURVEY, ETC.	LOT 25-27
	RAMSAY	XI	013

[redacted]

Carleton Place

DATE COMPLETED 48-53 DAY 03 MO. 10 YR. 74

HING 00 8651 RC. 4 ELEVATION 0440 RC. 5 BASIN CODE 26

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	DEPTH - FEET TO
BROWN	DIRT			0	16
GRAY	LIMESTONE			16	77

31 0016601 0077215

32

WATER RECORD

41

WATER FOUND AT - FEET	KIND OF WATER
10-13 0050	14 1 ☑ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
15-18	19 1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
20-23	24 1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
25-28	29 1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
30-33	34 80 1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL

CASING & OPEN HOLE RECORD

51

INSIDE DIAM. INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	DEPTH - FEET TO
10-11 06	12 1 ☒ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	.187	0	13-16 0018
17-18 06	19 1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☑ OPEN HOLE			20-23 0077
24-25	26 1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			27-30

SCREEN

SIZE(S) OF OPENING 31-33 (SLOT NO.)	DIAMETER 34-38 INCHES	LENGTH 39-40 FEET

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN 41-44 FEET	80

PLUGGING & SEALING RECORD

61

DEPTH SET AT - FEET FROM	DEPTH SET AT - FEET TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
10-13	14-17	
18-21	22-25	
26-29	30-33	80

PUMPING TEST

71

PUMPING TEST METHOD 10: 1 ☐ PUMP 2 ☑ BAILER

PUMPING RATE 11-14: 0010 GPM.

DURATION OF PUMPING: 01 15-16 HOURS 00 17-18 MINS.

STATIC LEVEL 19-21: 024 FEET

WATER LEVEL END OF PUMPING 22-24: 060 FEET

25 WATER LEVELS DURING 1 ☐ PUMPING 2 ☐ RECOVERY

15 MINUTES 26-28	30 MINUTES 29-31	45 MINUTES 32-34	60 MINUTES 35-37
– FEET	– FEET	– FEET	– FEET

IF FLOWING, GIVE RATE 38-41: – GPM.

PUMP INTAKE SET AT: 60 FEET

WATER AT END OF TEST 42: 1 ☑ CLEAR 2 ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☑ SHALLOW ☐ DEEP

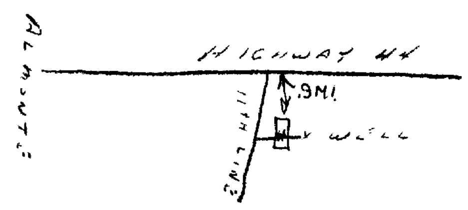
RECOMMENDED PUMP SETTING 43-45: 060 FEET

RECOMMENDED PUMPING RATE 46-49: 0010 GPM.

50-53 000.3 GPM./FT. SPECIFIC CAPACITY

LOCATION OF WELL 0808

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.



DRILLERS REMARKS: GR 084 087

FINAL STATUS OF WELL 54: 1
- 1 ☑ WATER SUPPLY
- 2 ☐ OBSERVATION WELL
- 3 ☐ TEST HOLE
- 4 ☐ RECHARGE WELL
- 5 ☐ ABANDONED, INSUFFICIENT SUPPLY
- 6 ☐ ABANDONED, POOR QUALITY
- 7 ☐ UNFINISHED

WATER USE 55-56: 01
- 1 ☑ DOMESTIC
- 2 ☐ STOCK
- 3 ☐ IRRIGATION
- 4 ☐ INDUSTRIAL
- ☐ OTHER
- 5 ☐ COMMERCIAL
- 6 ☐ MUNICIPAL
- 7 ☐ PUBLIC SUPPLY
- 8 ☐ COOLING OR AIR CONDITIONING
- 9 ☐ NOT USED

METHOD OF DRILLING 57: 1
- 1 ☑ CABLE TOOL
- 2 ☐ ROTARY (CONVENTIONAL)
- 3 ☐ ROTARY (REVERSE)
- 4 ☐ ROTARY (AIR)
- 5 ☐ AIR PERCUSSION
- 6 ☐ BORING
- 7 ☐ DIAMOND
- 8 ☐ JETTING
- 9 ☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR: McARTHUR DRILLING LTD — LICENCE NUMBER: 3568

ADDRESS: RR#1 RENFREW ONT

NAME OF DRILLER OR BORER: A. L. GEE — LICENCE NUMBER:

SIGNATURE OF CONTRACTOR:

SUBMISSION DATE: DAY 21 MO. 10 YR. 74

OFFICE USE ONLY

DATA SOURCE 58: 1

CONTRACTOR 59-62: 3568

DATE RECEIVED 63-68: 011174 80

DATE OF INSPECTION: 9 May 75

INSPECTOR: PF/RD

REMARKS: CSS.58

P

WI

MINISTRY OF THE ENVIRONMENT COPY

FORM 7 07-091

APPENDIX G

Water Balance Results

Table G1: Environment Canada Precipitation, Surplus Data,
Drummond Crentre (filled in with Carlton Place/Appleton data), Ontario

Drummond Centre (Filled in with Carleton Place/Appleton), ON WATER BUDGET MEANS - 1984 - 2019

Water Holding Capacity	3	mm
Heat Index	36.33	
Lower Zone	1	mm
A	1.074	
Date Range	1984	2019

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	3	301
28-Feb	-8.1	56	16	30	1	1	0	44	70	3	356
31-Mar	-2.1	61	31	77	8	8	0	101	22	3	416
30-Apr	6	76	71	27	33	32	-1	66	0	3	494
31-May	13.3	77	77	0	82	67	-14	11	0	1	571
30-Jun	17.9	95	95	0	114	83	-30	12	0	1	667
31-Jul	20.5	89	89	0	133	87	-46	3	0	0	757
31-Aug	19.3	79	79	0	116	76	-40	3	0	0	837
30-Sep	15	91	91	0	76	69	-8	21	0	2	928
31-Oct	8.2	86	86	1	37	36	0	49	0	3	87
30-Nov	1.5	76	60	11	10	10	0	61	5	3	163
31-Dec	-5.6	71	26	17	2	2	0	41	33	3	235
AVE	**6.3**										
TTL		**925**	**738**	**188**	**613**	**472**	**-139**	**453**			

Water Holding Capacity	10	mm
Heat Index	36.33	
Lower Zone	6	mm
A	1.074	
Date Range	1984	2019

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	10	301
28-Feb	-8.1	56	16	30	1	1	0	44	70	10	356
31-Mar	-2.1	61	31	77	8	8	0	101	22	10	416
30-Apr	6	76	71	27	33	33	0	66	0	9	494
31-May	13.3	77	77	0	82	70	-12	11	0	5	571
30-Jun	17.9	95	95	0	114	85	-28	12	0	4	667
31-Jul	20.5	89	89	0	133	89	-44	2	0	1	757
31-Aug	19.3	79	79	0	116	76	-40	2	0	2	837
30-Sep	15	91	91	0	76	69	-7	18	0	6	928
31-Oct	8.2	86	86	1	37	36	0	46	0	9	87
30-Nov	1.5	76	60	11	10	10	0	60	5	10	163
31-Dec	-5.6	71	26	17	2	2	0	41	33	10	235
AVE	**6.3**										
TTL		**925**	**738**	**188**	**613**	**480**	**-131**	**444**			

Water Holding Capacity	150	mm
Heat Index	36.33	
Lower Zone	90	mm
A	1.074	
Date Range	1984	2019

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**										
TTL		**925**	**738**	**188**	**613**	**580**	**-31**	**342**			

Table G1: Environment Canada Precipitation, Surplus Data,
Drummond Centre (filled in with Carlton Place/Appleton data), Ontario

Water Holding Capacity	400	mm
Heat Index	36.33	
Lower Zone	240	mm
A	1.074	
Date Range	1984	2019

DATE	TEMP (C)	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**										
TTL		**925**	**738**	**188**	**613**	**611**	**-2**	**309**			

Table G2: Estimation of Average Annual Rates
Proposed West Carleton Quarry Extension
Ottawa, Ontario

Estimated Average Annual Infiltration and Run-Off Rates - Pre-Development(WHC method)				
Land use	**Description**	**Soil Type**	**Water Holding Capacity**	**Surplus**
			(mm)	**(mm/a)**
Treed Swamp	Pervious	Organics	Precip - PET	312.0
Marsh	Pervious	Organics	Precip - PET	312.0
Transportation	Impervious	Gravel / Paved	3	453.0
Extraction-Aggregate	Impervious	Bedrock	10	444.0
Shallow and Exposed Bedrock	Impervious	Bedrock	10	444.0
Forest (Bedrock)	Pervious	Bedrock	150	342.0
Forest (Organics)	Pervious	Organics	400	309.0
Flooding	Pervious	Water	Precip - PET	312.0

Table G2: Estimation of Average Annual Rates
Proposed West Carleton Quarry Extension
Ottawa, Ontario

Infiltration Factor	Infiltration	Run-Off
	(mm/a)	(mm/a)
0.00	0	312
0.00	0	312
0.00	0	453
0.00	0	444
0.00	0	444
0.50	171	171
0.60	185.4	123.6
0.00	0	312

Table G3: Summary of Water Budget Estimate
Proposed West Carleton Quarry Extension
Ottawa, Ontario

Average Annual Rates - Scenario 1a (Baseline Conditions - Existing Quarry Extracted / Extension Current Conditions)

Land use	Description	Water Holding Capacity	Area	Precipitation		Evapotranspiration		Surplus	
			(ha)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Treed Swamp	Pervious	Precip - PE	1.41	925	13,000	613	8,600	312	4,400
Marsh	Pervious	Precip - PE	32.85	925	303,900	613	201,400	312	102,500
Transportation	Impervious	3	0.90	925	8,300	472	4,200	453	4,100
Extraction-Aggregate	Impervious	10	90.20	925	834,400	480	433,000	444	400,500
Shallow and Exposed Rock	Impervious	10	14.56	925	134,700	480	69,900	444	64,600
Forest on Bedrock	Pervious	150	12.71	925	117,500	580	73,700	342	43,500
Forest on Organics	Pervious	400	4.54	925	42,000	611	27,700	309	14,000
		Total	**157.2**		**1,453,800**		**818,500**		**633,600**

Average Annual Rates - Scenario 1b (Baseline Conditions - Existing Quarry Flooded/ Extension Current Conditions)

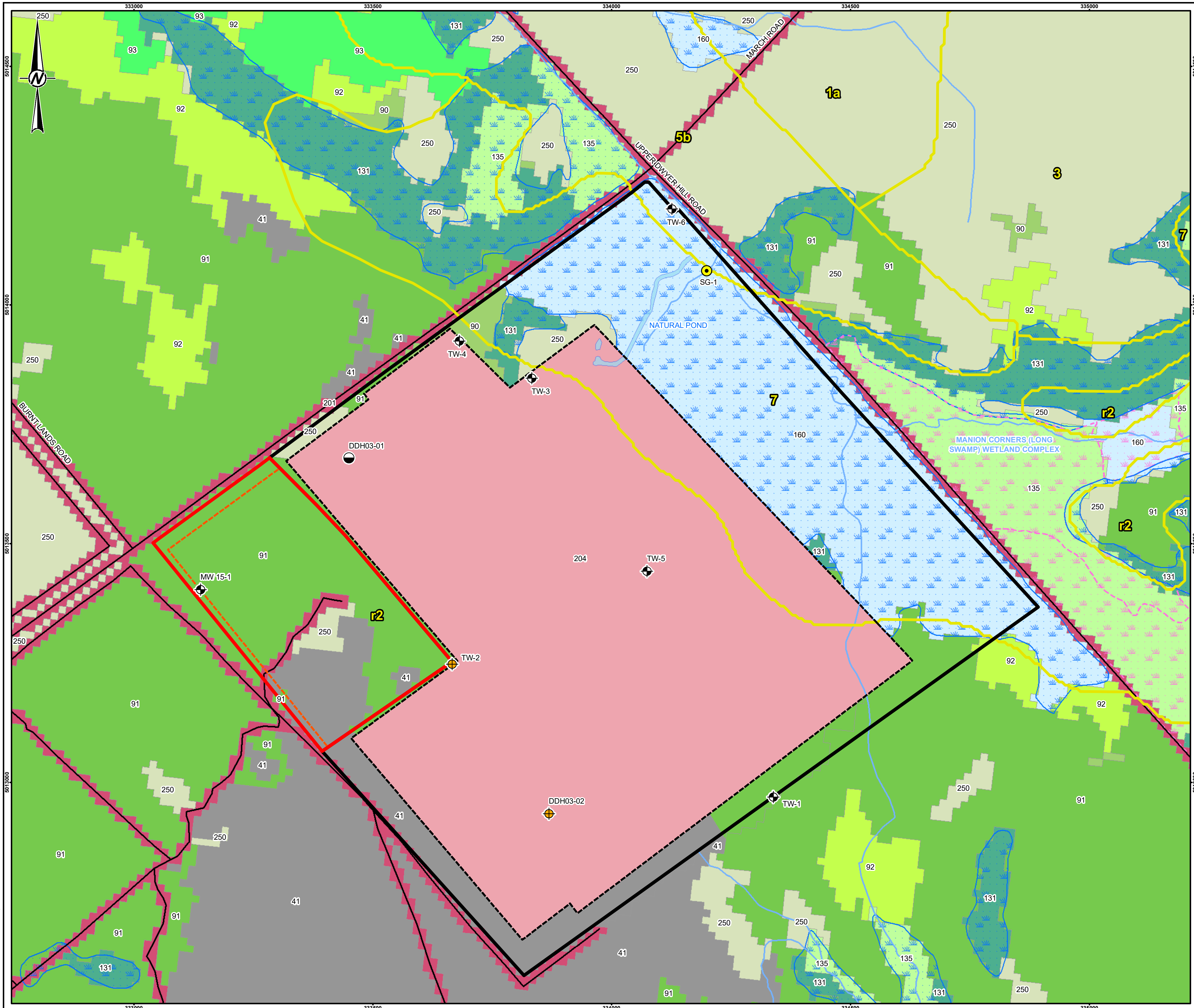
Land use	Description	Water Holding Capacity	Area	Precipitation		Evapotranspiration		Surplus	
			(ha)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Treed Swamp	Pervious	Precip - PE	1.41	925	13,000	613	8,600	312	4,400
Marsh	Pervious	Precip - PE	32.85	925	303,900	613	201,400	312	102,500
Transportation	Impervious	3	0.90	925	8,300	472	4,200	453	4,100
Extraction-Aggregate	Impervious	10	0.00	925	0	480	0	444	0
Shallow and Exposed Rock	Impervious	10	14.56	925	134,700	480	69,900	444	64,600
Forest on Bedrock	Pervious	150	12.71	925	117,500	580	73,700	342	43,500
Forest on Organics	Pervious	400	4.54	925	42,000	611	27,700	309	14,000
Flooded area	Impervious	Precip - PE	90.20	925	834,400	613	552,900	312	281,400
		Total	**157.2**		**1,453,800**		**938,400**		**514,500**

Average Annual Rates - Scenario 2 (Operational / Full Extraction Conditions)

Land use	Description	Water Holding Capacity	Area	Precipitation		Evapotranspiration		Surplus	
			(ha)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Treed Swamp	Pervious	Precip - PE	1.41	925	13,000	613	8,600	312	4,400
Marsh	Pervious	Precip - PE	32.85	925	303,900	613	201,400	312	102,500
Transportation	Impervious	3	0.25	925	2,300	472	1,200	453	1,100
Extraction-Aggregate	Impervious	10	106.71	925	987,000	480	512,200	444	473,800
Shallow and Exposed Rock	Impervious	10	9.76	925	90,300	480	46,800	444	43,300
Forest on Bedrock	Pervious	150	1.65	925	15,200	580	9,500	342	5,600
Forest on Organics	Pervious	400	4.54	925	42,000	611	27,700	309	14,000
		Total	**157.2**		**1,453,700**		**807,400**		**644,700**

Average Annual Rates - Scenario 6 (Rehabilitation - Existing Quarry and Extension Lands Flooded)

Land use	Description	Water Holding Capacity	Area	Precipitation		Evapotranspiration		Surplus	
			(ha)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)	(mm/a)	(m^3/a)
Treed Swamp	Pervious	Precip - PE	1.41	925	13,000	613	8,600	312	4,400
Marsh	Pervious	Precip - PE	32.85	925	303,900	613	201,400	312	102,500
Transportation	Impervious	3	0.25	925	2,300	472	1,200	453	1,100
Extraction-Aggregate	Impervious	10	0.00	925	0	480	0	444	0
Shallow and Exposed Rock	Impervious	10	9.76	925	90,300	480	46,800	444	43,300
Forest on Bedrock	Pervious	150	1.65	925	15,200	580	9,500	342	5,600
Forest on Organics	Pervious	400	4.54	925	42,000	611	27,700	309	14,000
Flooded area	Pervious	Precip - PE	106.71	925	987,000	613	654,100	312	332,900
		Total	**157.2**		**1,453,700**		**949,300**		**503,800**



LEGEND

- ◉ STAFF GAUGE LOCATION
- ⊕ TEST WELL
- ◒ DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)
- ⊕ TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT
- ▭ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- ⬚ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
- ▭ EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- ⬚ EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION
- — ROADWAY
- — WATERCOURSE
- ⬚ WETLAND
- ⬚ SIGNIFICANT WETLAND
- ▭ GSC SURFICIAL GEOLOGY

7. ORGANIC DEPOSITS: MUCK & PEAT

5b: NEARSHORE SEDIMENTS: FINE TO MEDIUM GRAINED SAND

3. OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT

1a. TILL, PLAIN WITH LOCAL RELIEF <5 m

r2. BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE

LAND COVER

- ■ 41. OPEN CLIFF AND TALUS
- ■ 90. FOREST
- ■ 91. CONIFEROUS FOREST
- ■ 92. MIXED FOREST
- ■ 93. DECIDUOUS FOREST
- ■ 131. TREED SWAMP
- ■ 135. THICKET SWAMP
- ■ 160. MARSH
- ■ 201. TRANSPORTATION
- ■ 204. EXTRACTION-AGGREGATE
- ■ 250. UNDIFFERENTIATED

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. BÉLANGER, J. R. 2008 URBAN GEOLOGY OF THE NATIONAL CAPITAL AREA, GEOLOGICAL SURVEY OF CANADA, OPEN FILE 5311, 1 DVD.
2. SOUTHERN ONTARIO LAND RESOURCE INFORMATION SYSTEM (SOLRIS) 3.0, ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAST UPDATED, 2019-05-21.
3. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 80 160 320
1:8,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
BASELINE CONDITIONS (SCENARIO 1A)

CONSULTANT
GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	MK
APPROVED	KMM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0008	0	**G1**

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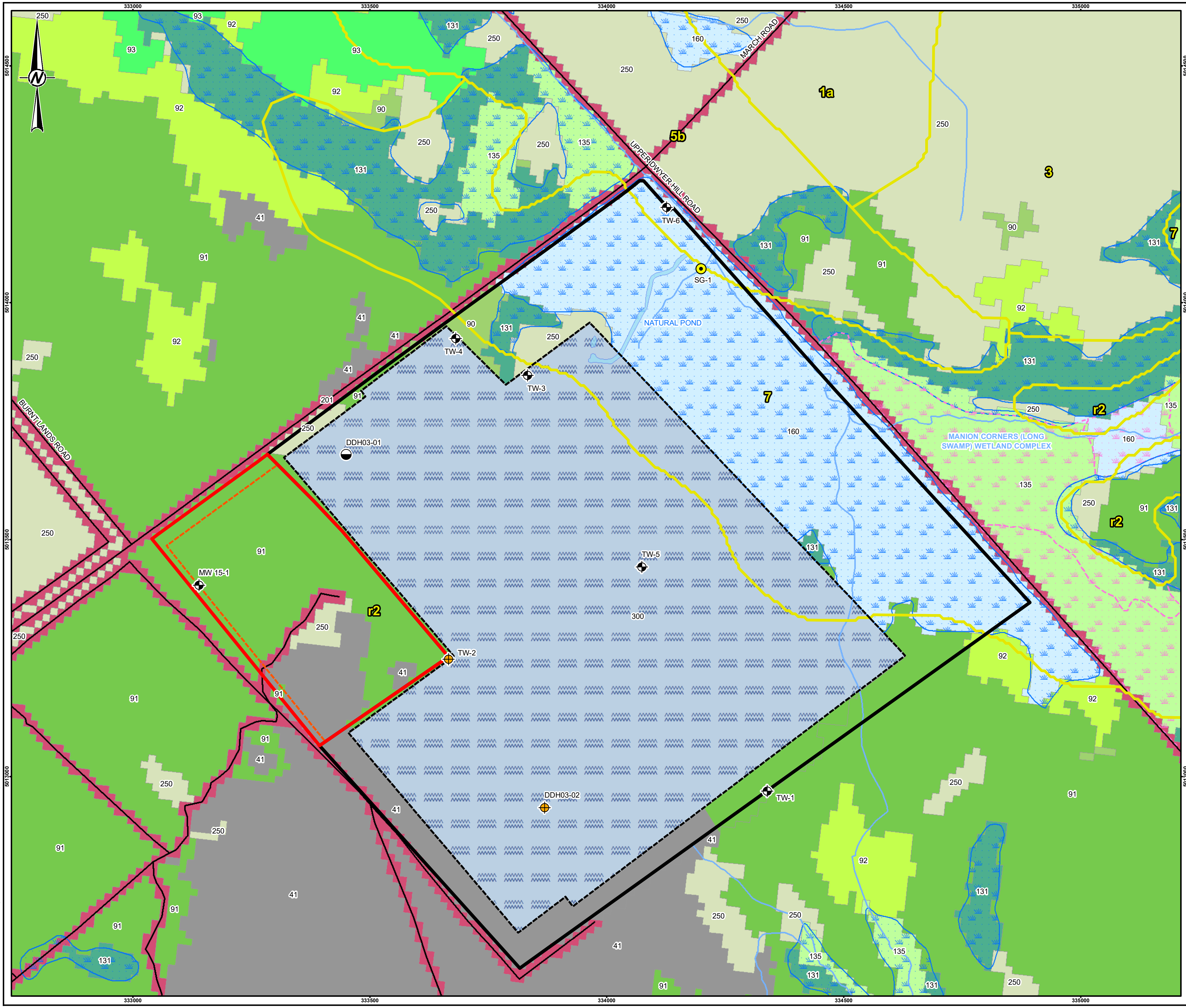

LEGEND

●	STAFF GAUGE LOCATION
⊕	TEST WELL
◒	DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)
⊕	TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT
🟥	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
⬚	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
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—	ROADWAY
—	WATERCOURSE
⬚	WETLAND
⬚	SIGNIFICANT WETLAND
🟨	GSC SURFICIAL GEOLOGY
	7. ORGANIC DEPOSITS: MUCK & PEAT
	5b: NEARSHORE SEDIMENTS: FINE TO MEDIUM GRAINED SAND
	3. OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT
	1a. TILL, PLAIN WITH LOCAL RELIEF <5 m
	r2. BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE

LAND COVER

⬛	41. OPEN CLIFF AND TALUS
🟩	90. FOREST
🟩	91. CONIFEROUS FOREST
🟩	92. MIXED FOREST
🟩	93. DECIDUOUS FOREST
🟩	131. TREED SWAMP
🟩	135. THICKET SWAMP
🟦	160. MARSH
🟥	201. TRANSPORTATION
⬜	250. UNDIFFERENTIATED
🟦	300. FLOODED

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4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 80 160 320
1:8,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
BASELINE CONDITIONS (SCENARIO 1B)

CONSULTANT

GOLDER

YYYY-MM-DD	2021-02-25
DESIGNED	----
PREPARED	BR
REVIEWED	MK
APPROVED	KMM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0008	0	G2

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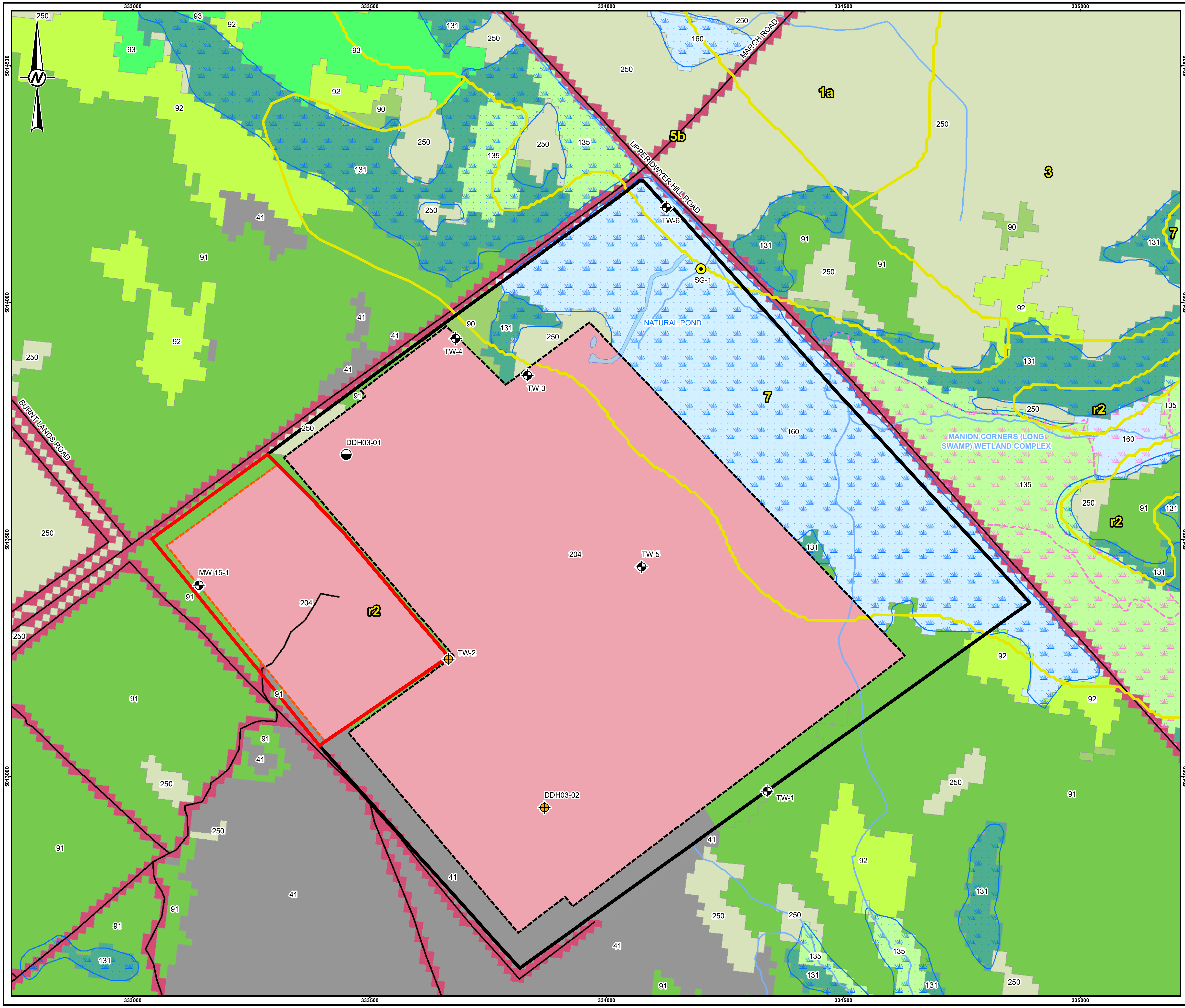

LEGEND

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⊕ TEST WELL

◒ DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)

⊕ TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT

▭ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY

▭ PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION

▭ EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY

▭ EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION

— ROADWAY

— WATERCOURSE

▭ WETLAND

▭ SIGNIFICANT WETLAND

▭ GSC SURFICIAL GEOLOGY

7. ORGANIC DEPOSITS: MUCK & PEAT

5b: NEARSHORE SEDIMENTS: FINE TO MEDIUM GRAINED SAND

3. OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT

1a. TILL, PLAIN WITH LOCAL RELIEF <5 m

r2. BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE

LAND COVER

■ 41. OPEN CLIFF AND TALUS

■ 90. FOREST

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■ 204. EXTRACTION-AGGREGATE

■ 250. UNDIFFERENTIATED

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4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
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0 80 160 320

1:8,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
OPERATIONAL CONDITIONS (SCENARIO 2)

CONSULTANT

GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	MK
APPROVED	KMM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0008	0	**G3**

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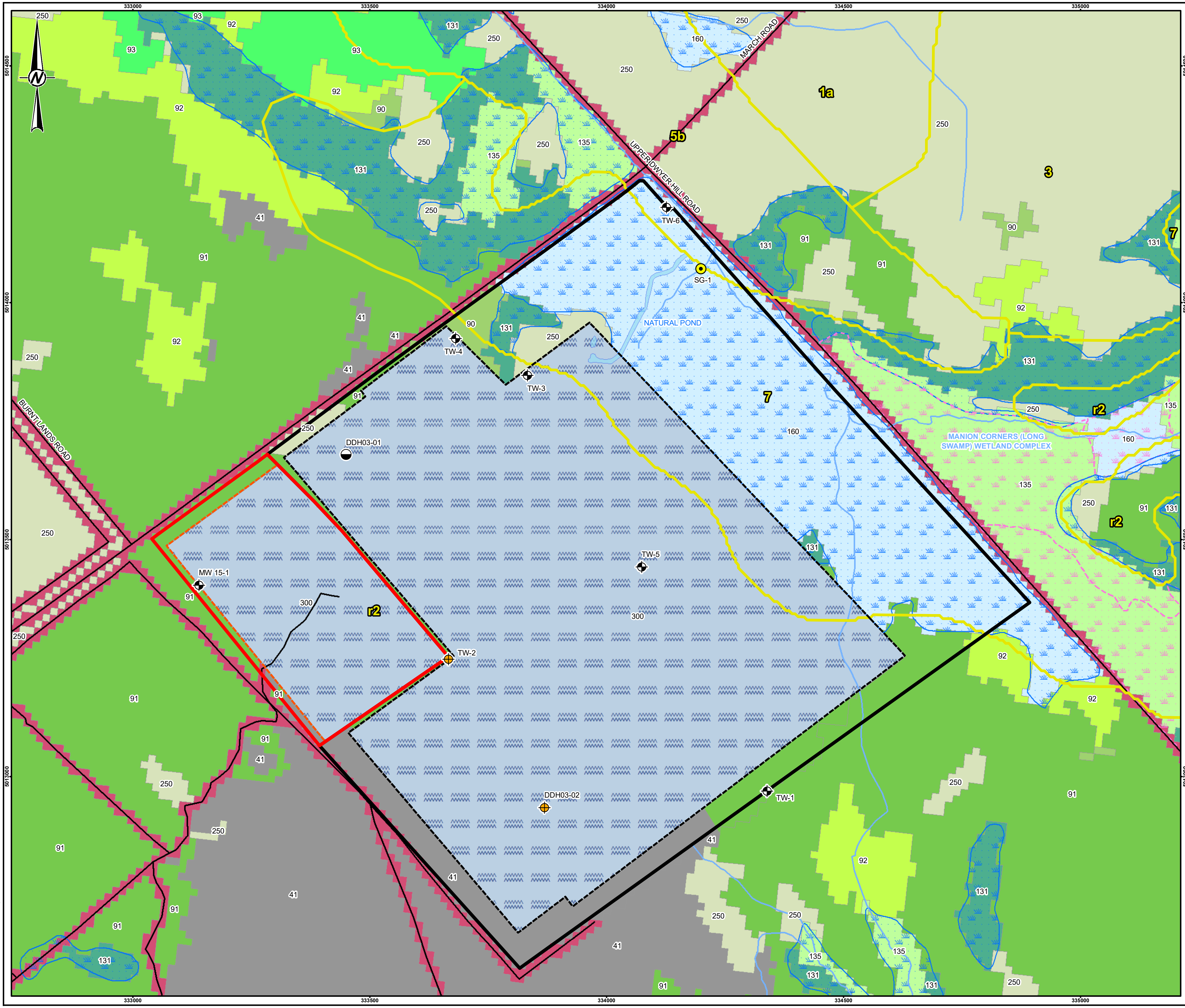

LEGEND

⊙	STAFF GAUGE LOCATION
⊕	TEST WELL
◒	DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)
⊕	TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT
🟥	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
⬚	PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
⬛	EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
⬚	EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION
—	ROADWAY
—	WATERCOURSE
▨	WETLAND
▨	SIGNIFICANT WETLAND
🟨	GSC SURFICIAL GEOLOGY
	7. ORGANIC DEPOSITS: MUCK & PEAT
	5b: NEARSHORE SEDIMENTS: FINE TO MEDIUM GRAINED SAND
	3. OFFSHORE MARINE DEPOSITS: CLAY, SILTY CLAY & SILT
	1a. TILL, PLAIN WITH LOCAL RELIEF <5 m
	r2. BEDROCK: LIMESTONE, DOLOMITE, SANDSTONE & LOCAL SHALE

LAND COVER

⬛	41. OPEN CLIFF AND TALUS
🟩	90. FOREST
🟩	91. CONIFEROUS FOREST
🟩	92. MIXED FOREST
🟩	93. DECIDUOUS FOREST
🟩	131. TREED SWAMP
🟩	135. THICKET SWAMP
🟦	160. MARSH
🟥	201. TRANSPORTATION
▨	250. UNDIFFERENTIATED
🟦	300. FLOODED

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. BÉLANGER, J. R. 2008 URBAN GEOLOGY OF THE NATIONAL CAPITAL AREA, GEOLOGICAL SURVEY OF CANADA, OPEN FILE 5311, 1 DVD.
2. SOUTHERN ONTARIO LAND RESOURCE INFORMATION SYSTEM (SOLRIS) 3.0, ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, LAST UPDATED, 2019-05-21.
3. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2020
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 80 160 320
1:8,000 METRES

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

PROJECT
HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENTS – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
REHABILITATED CONDITIONS (SCENARIO 6B)

CONSULTANT
GOLDER

YYYY-MM-DD	2021-07-07
DESIGNED	----
PREPARED	BR
REVIEWED	MK
APPROVED	KMM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0008	0	G4

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

Qualifications and Experience of Report Authors

Golder Associates Ltd. – Ottawa

Education

M.Sc. Civil Engineering: Hydrogeology
Queen's University
Kingston, Ontario, 2001

B.Sc. Environmental Science: Earth Sciences Stream, Honours
Brock University
St. Catharines, Ontario
1998

Certifications

Registered Professional Geoscientist Ontario

Senior Hydrogeologist

Jaime Oxtobee has over 20 years of broad experience in the field of physical hydrogeology that includes hydrogeological impact assessments in support of the licensing of pits and quarries under the *Aggregate Resources Act*, water supply development and regional scale groundwater studies.

Employment History

Golder Associates Ltd. – Ottawa

Associate and Senior Hydrogeologist (2001 to Present)

Jaime is responsible for project management, technical analysis and reporting for a variety of hydrogeological and environmental projects. Jaime is also often responsible for senior technical review of hydrogeological investigations.

Projects have included groundwater resources studies; hydrogeological investigation programs in support of licensing/permitting pits and quarries and in support of Permit to Take Water applications for local construction dewatering projects, ready-mix concrete plants, golf courses and quarries; communal water supply investigations; wellhead protection studies; contaminated site investigations; and, providing senior review for landfill, pit and quarry monitoring reports.

Queen's University – Kingston, Ontario

Teaching Assistant (2000 to 2001)

Teaching assistant for university courses relating to groundwater flow and contaminant transport in porous media and fractured rock environments.

Phase IV Bedrock Remediation Program – Smithville, Ontario

Project Manager (1999)

Coordinated and conducted a groundwater/surface water interaction study downgradient from the PCB-contaminated site in Smithville, Ontario. The study involved detailed numerical modelling, as well as an extensive field program including stream surveys, stream gauging, construction and installation of mini-piezometers, seepage meters and weirs, fracture mapping, groundwater and surface water sampling.

SELECTED PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Hydrogeological and Hydrological Assessments for Quarry Licensing
Township of Drummond-North Elmsley, Ontario, Canada

Golder carried out the necessary hydrogeological, hydrological ecological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing the extension of an existing quarry. The application was for two new below water quarries on either side of an existing below water quarry. Jaime led the hydrogeological and hydrological assessment component of the project, and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessments for Pit Licensing
Township of Lanark, Ontario, Canada

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing a new pit above the water table. Jaime led the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program and preparing the required reporting.

Hydrogeological and Hydrological Assessments for Quarry Licensing
Ramara, Ontario, Canada

Golder carried out the necessary hydrogeological, hydrological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing the extension of an existing quarry. The application was for one new below water quarry adjacent to an existing below water quarry. Jaime led the hydrogeological and hydrological assessment component of the project. Jaime was responsible for development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting.

Hydrogeological Assessments for Pit Licensing
Township of Leeds and Thousand Islands, Ontario, Canada

Golder carried out the necessary hydrogeological studies to support an application under the *Aggregate Resource Act* for licensing a new pit below the water table. Jaime led the hydrogeological assessment component of the project. Jaime was responsible for the development and execution of the hydrogeology field program and completing the hydrogeological impact assessment/reporting.

Hydrogeological Assessment for Quarry Permitting
Township of Bomby

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new quarry. The application was for a below water quarry located on Crown Land. Jaime led the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessment for Pit Permitting
District of Kenora, Ontario, Canada

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new pit. The application was for a below water pit located on Crown Land. Jaime provided input to the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development of the site conceptual model in the vicinity of the pit and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessment for Quarry Permitting
District of Kenora, Ontario, Canada

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new quarry. The application was for a below water quarry located on Crown Land. Jaime provided input to the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development of the site conceptual model in the vicinity of the quarry and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological and Hydrological Assessment for Quarry Licensing
City of Kawartha Lakes, Ontario, Canada

Golder carried out the necessary hydrogeological, hydrological and ecological studies to support an application under the *Aggregate Resource Act* for licensing a new quarry. The application was for a below water quarry located adjacent to a provincially significant wetland. Jaime provided input to the hydrogeological assessment component of the project, which included the installation of over 80 monitoring intervals and the completing of three pumping tests. Jaime was involved in data analysis and the completion of the impact assessment and reporting for the hydrogeology assessment.

TRAINING

Beyond Data: Conceptual Site Models in Environmental Site Assessments
Golder U, 2011

Health and Safety Modules 1, 2, 3 and 4
Golder U, various years

Critical Thinking in Aquifer Test Interpretation
Golder U, 2011

HydroBench (Proprietary Aquifer Test Interpretation Software)
Golder U, 2011

Project Management
Golder U, 2007

Short course: Environmental Isotopes in Groundwater Resource and Contaminant Hydrogeology
2007

Short course: Hydrogeology of Fractured Rock – Characterization, Monitoring, Assessment and Remediation
2002

OSHA 40 Hour Hazardous Waste Site Worker Training
2002

PROFESSIONAL AFFILIATIONS

Member, Association of Professional Geoscientist of Ontario

Member, Ottawa Geotechnical Group

PUBLICATIONS

Conference Proceedings	West, A.L., K.A. Marentette and J.P.A. Oxtobee. 2009. *Quantifying Cumulative Effects of Multiple Rock Quarries on Aquifers*. 2009 Joint Assembly, May. Toronto, Canada.
	Novakowski, K.S., P.A. Lapcivic, J.P.A. Oxtobee and L. Zanini. 2000. *Groundwater Flow in the Lockport Formation Underlying the Smithville Ontario Area*. 1st IAH-CNC and CGS Groundwater Specialty Conference, October. Montreal, Canada.
	Oxtobee, J.P.A. and K.S. Novakowski. 2001. *A Study of groundwater/Surface Water Interaction in a Fractured Bedrock Environment*. Fractured Rock 2001 Conference, March. Toronto, Canada.
Journal Articles	Oxtobee, J.P.A. and K.S. Novakowski. Groundwater/Surface Water Interaction in a Fractured Rock Aquifer. *Journal of Ground Water*, 41(5) (2003), 667-681.
	Oxtobee, J.P.A. and K.S. Novakowski. A Field Investigation of Groundwater/Surface Water Interaction in a Fractured Bedrock Environment. *Journal of Hydrology*, 269 (2002), 169-193.
Other	Oxtobee, J.P.A., 1998. Environmental Assessment of Grapeview, Francis and Richardson's Creeks, St. Catharines, Ontario. B.Sc. Thesis, Brock University, Earth Sciences Department pp.119.

Education

M.Sc. (Eng.) Water Resource Engineering, University of Guelph, Guelph, 1995

B.Sc. (Eng.) Water Resource Engineering, Minor: Environmental Engineering, University of Guelph, Guelph, 1993

Languages

English – Fluent

Golder Associates Ltd. – Cambridge

Employment History

Golder Associates Ltd. – Cambridge, Ontario
Water Resources Engineer, Principal (1997 to Present)

Responsible for management of water resources assessments including hydrology, hydraulics, upland and in stream erosion, water quality and water management for a wide variety of government, power generation, industrial, mining and aggregate producing clients. Being part of a comprehensive client service team for aggregate producers in Ontario has facilitated an excellent understanding of the aggregate business and how water management affects their operations. Water resources assessments have been completed in support of Environmental Assessments (EA) and Permitting and Approvals under Federal, provincial and international regulations. Peer reviewer for two Ontario Source Water Protection projects and water resources sections of a new international airport in Quito, Ecuador. Responsible for managing and implementing field data collection studies, including stream flow monitoring, meteorology and water quality. Other abilities include assessments of upland soil erosion, natural channel design and fluvial geomorphology.

University of Guelph – Guelph, Ontario
Hydrologist (1996 to 1996)

Responsible for collection and analysis of four large databases of rural hydrology parameters in Southern Ontario. Frequency distributions were found for event, daily and yearly runoff coefficients and detailed daily water budgets were synthesised for the duration of each record. Estimated evapo-transpiration in the absence of meteorological data required for the Penman equation.

University of Guelph – Guelph, Ontario
Research Assistant (1994 to 1996)

Responsible for designing and performing experiments concerning soil erosion by rainfall. Erosion rates from single drop impacts and 1.0 m^2 erosion plots were quantified and related to rainfall intensity and energy flux rate. A model of the inter-rill detachment process was developed for use in future large-scale erosion models.

University of Guelph – Guelph, Ontario
Teaching Assistant (1994 to 1996)

Taught weekly seminars on engineering mechanics (statics and dynamics) and on engineering design and report writing. Emphasis was placed on three-dimensional vector analysis and excellence in communicating technical information through text and verbal presentations.

PROJECT EXPERIENCE – HYDROLOGY/HYDRAULICS

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 MOE application forms and supporting studies and reports have been prepared for numerous aggregate sites across Southern Ontario. Applications have been completed for 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.

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.

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.
Brimley Road Slope Failure Toronto, Ontario	Detailed statistical analysis of the rainfall amounts in the 30 days prior to a major slope failure. Historical records of rainfall and snowmelt were analysed and compared to the precipitation in the days preceding the failure.

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 – 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

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.

PROFESSIONAL AFFILIATIONS

Professional Engineers Ontario

Engineers Nova Scotia

PUBLICATIONS AND PRESENTATIONS

Other

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.

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 and has 20 years of broad experience in the fields of water supply development, physical hydrogeological characterization studies, regional scale groundwater studies, aggregate resource evaluations and the licensing and permitting of quarry development and expansion projects, waste management and contaminated sites assessment /remediation. 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.

Kris has been the Golder 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.

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 – 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

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