REPORT

Level 1 and Level 2 Water Report in Support of an Aggregate Resources Act Amendment Application

R.W. Tomlinson Limited, Brechin Quarry, City of Kawartha Lakes, Ontario

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EXECUTIVE SUMMARY

Tomlinson is currently applying for an amendment under the Aggregate Resources Act (ARA) to deepen their existing Brechin Quarry (ARA License #624846) as part of their long-term strategy to supply aggregates to local construction projects and projects in the Greater Toronto Area. WSP was retained by Tomlinson to complete the necessary hydrogeological/hydrological study to support an application under the ARA. This study was conducted for the purpose of addressing the requirements for the Level 1 and Level 2 Water Report as described in “Aggregate Resources of Ontario: Technical reports and information standards”, dated August 2020.

The existing limits of extraction for the north and south extraction areas will remain unchanged under the proposed site plan amendment. The proposed final quarry floor elevation would be lowered to the top of the green beds of the Gull River Formation. This corresponds to a lowering of the proposed final quarry floor by approximately 6 metres beyond the presently approved quarry floor.

The deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry by limiting the depth of the proposed quarry to the top of the green beds of the Gull River Formation rather than extending through the entire Gull River Formation. The deepened quarry floor would slope form east to west and the final quarry floor would be between 216 and 223 mASL.

The development of the proposed deepened Brechin Quarry can affect potential receptors mainly via quarry water management (e.g., quarry dewatering) and the area of groundwater level drawdown. The proposed quarry deepening <u>does not</u> result in additional land use changes or surface water drainage alterations (i.e., there are no additional changes beyond those assessed as part of the impact assessment completed for the currently licensed Brechin Quarry presented in the Golder 2007 report).

The potential impacts as a result of the deepening of the Brechin Quarry during the operational phase of the quarry life were assessed separately from the rehabilitated conditions. Based on the results of the groundwater modelling, during operations, there are no water supply wells located within the one-metre incremental drawdown contour associated with the deepened Brechin Quarry. As such, negative impacts to water supply wells are not predicted as a result of the proposed deepening. Follow rehabilitation of the Brechin Quarry, groundwater levels rise in the Bobcaygeon Formation and Gull River Formation compared to current conditions. As such, impacts to water supply wells as a result of the rehabilitation of the Brechin Quarry are not predicted.

The deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry. This results in the area where the deepened Brechin Quarry is contributing 10% or greater of the cumulative drawdown not extending to any private water supply wells in the vicinity of the Brechin Quarry. As such, the modelling results indicate that the deepened Brechin Quarry will not significantly contribute to cumulative groundwater level drawdown at private wells when all of the quarries in the vicinity of the site are fully extracted.

There are three primary surface water receptors in the vicinity of the site. These include the north drainage feature, the south drainage feature and the wetland located along the eastern periphery of the property. Trigger levels and trigger periods have been developed and incorporated onto the existing Permit to Take Water (PTTW) for the site to limit the potential for adverse impacts to the adjacent wetland and the quarry water management plan has been designed to maintain flow in the north and south drainage features.

The proposed Brechin Quarry deepening will not affect the drawdown in the weathered bedrock beyond that which can be expected by the currently approved quarry development plan, thus, the surface water impact assessment from the original hydrogeological/hydrological study for Brechin Quarry (Golder 2007) remains valid. Therefore, no additional surface water impact assessment is required at this time as it relates to the proposed deepening of the Brechin Quarry.

The current monitoring program, trigger levels, quarry water distribution plan, and approved mitigation measures under the existing license and PTTW will remain in place for the deepened Brechin Quarry. The existing PTTW would be amended to recognize the proposed deepened Brechin Quarry in the impact assessment for the PTTW, and to add the monitoring wells completed as part of this study into the monitoring program associated with the PTTW.

The existing quarry sump dewatering system in the north extraction area is presently operated consistently at below 100 Litres per second. This is below the maximum permissible discharge rate under the current sump configuration of 149 Litres per second and well below the final sump configuration which allow offsite discharge at a rate of 211 Litres per second. There is currently no excavation in the south extraction area and there is no off-site discharge. As such, it is envisaged that the management of water collecting within the confines of the deepened Brechin Quarry excavation could be accommodated initially within the constraints imposed by the existing Brechin Quarry ECA (Industrial Sewage Works) without requiring a technical amendment to the ECA.

An annual performance report will continue to be a requirement of the existing ECA; this annual report would be submitted to the MECP for review and comment. In addition, Tomlinson will continue to prepare an annual report that provides an assessment and interpretation of the groundwater level data that is collected in accordance with the monitoring program defined on the amended PTTW. These monitoring data would ensure that quarry development is undertaken in a manner that does not negatively impact surface water and groundwater receptors in the area of the site.

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1.0 INTRODUCTION

1.1 Background

R.W. Tomlinson Limited (Tomlinson) operates a number of pits and limestone quarries in Ontario. Tomlinson is currently applying for an amendment under the *Aggregate Resource Act* (ARA) to deepen their existing Brechin Quarry (ARA License #624846). WSP Canada Inc. (WSP) was retained by Tomlinson to complete the necessary hydrogeological/hydrological study to support an application under the ARA. This study was conducted for the purpose of addressing the requirements for the Level 1 and Level 2 Water Report as described in “Aggregate Resources of Ontario: Technical reports and information standards”, dated August 2020.

The site-specific geological, hydrogeological and hydrological data presented in this report were collected for the Brechin Quarry during investigations and monitoring programs conducted between 2004 and 2024.

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

1.2 Site Description

The Brechin Quarry site is owned and operated by Tomlinson, and the limestone bedrock from the quarry is extracted and crushed to provide aggregates to service local construction projects and projects in the Greater Toronto Area. The Brechin Quarry is located on the western half of Lot 5, Concession II, and Lot 6 and Lot 7, Concession II, in the Geographic Township of Carden, now part of the City of Kawartha Lakes. The general location of the Brechin Quarry is shown on Figure 1.

The licensed area is approximately 207 hectares, of which the area to be extracted is approximately 131 hectares. The extraction area is divided into a north extraction area and a south extraction area, which measure approximately 92 hectares and 39 hectares, respectively. The licenced boundary and the limits of the north and south extraction areas are shown on Figure 2. Under the current ARA license, the north and south extraction areas would be operated in two lifts, and the base of the quarry extends approximately 10 metres into the Bobcaygeon Formation and remains approximately 5.8 metres above the top of the “green beds” of the Gull River Formation.

As shown on Figure 2, the quarry property is bounded on the west by Miller Road, and there are licensed quarries owned by Miller Paving and Dufferin Aggregates located to the north, southwest and southeast (see quarry locations on Figure 2). The Cranberry Lake Provincially Significant Wetland (wetland) exists on, and adjacent to, the south and east boundaries of the Tomlinson property. There are no private wells located within 500 metres of the north and south extraction areas. As part of the hydrogeological study completed for the original ARA licence application, a survey was completed within 1.5 kilometres of the site to identify all private water supply wells (Golder, 2007). The locations of the private water supply wells identified during the survey are shown on Figure 2. The closest private water supply wells (identified as SCOT-71 and MARA-3405) are approximately 600 to 650 metres from the extraction areas.

At this time, Tomlinson is operating within an area in the western half of the north extraction area. The approximate location of the existing extracted area and the existing north quarry sump are shown on Figure 2. To date, there has been no extraction within the south extraction area. The Brechin Quarry has a Permit to Take Water (PTTW) P-300-4187597913 that authorizes water taking at the site and an Environmental Compliance Approval (Industrial Sewage Works) No. 5012-BRWLWN that authorizes the discharge of water from the site.

1.3 Proposed Quarry Development and Rehabilitation Plan

The existing limits of extraction for the north and south extraction areas shown on Figure 2 will remain unchanged under the proposed site plan amendment. The proposed final quarry floor elevation would be lowered to the top of the “green beds” of the Gull River Formation. This corresponds to a lowering of the proposed final quarry floor by approximately 6 metres beyond the presently approved quarry floor. The deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry by limiting the depth of the proposed quarry to the top of the green beds of the Gull River Formation rather than extending through the entire Gull River Formation like the other quarries located in the vicinity of the site. The deepened quarry floor would slope form east to west and the final quarry floor would be between 216 and 223 metres above sea level (mASL). Additional details of the final floor elevations are provided in the amended ARA site plan (MHBC, 2025). The quarry sumps within the north and south extraction areas would be relocated as necessary as the quarry excavations progress. The proposed deepened quarry will be developed in three lifts, which may operate simultaneously depending on rock quality and market demand.

The rehabilitation for the deepened quarry will be the same as the rehabilitation plan for the existing licensed quarry. Rehabilitation at the Brechin Quarry will occur on a progressive basis, as permitted by the extractive, mitigative and processing facets of the operation. As described on the existing site plan, the final rehabilitation concept involves creating lake, wetland, shoreline, aquatic, alvar and forested habitats. The plan will require the creation of a variety of sloped shoreline areas around the perimeter of the excavation including some areas of exposed cliff face and overhangs. The shoreline perimeter will exhibit a varying geometry, substrate and gradient, designed to sustain the specific natural environment features which form part of the ecological aspects of the rehabilitation plan. Overburden material and rock rubble piles will be left on above water areas. The creation of differing substrate environments will result in a variation to the types of flora and fauna that will re-populate the area once rehabilitation is complete. Setback areas will be rehabilitated to include alvar and forestation areas, and the buffer along the retained watercourse (i.e., the South Drainage Feature) will be enhanced with riparian cover.

1.4 Scope of Water Report

The main objectives of the Water Report were to:

- Document the existing hydrogeological and hydrological conditions of the quarry property and surrounding lands; and,
- Assess potential impacts on groundwater and surface water associated with operation and rehabilitation of the proposed deepened Brechin Quarry.

The work program consisted of the following:

- Data review and preparing a summary of the hydrogeological and hydrological investigations completed in support of the original license application for the Brechin Quarry and the monitoring data collected to date under the PTTW monitoring program
- Bedrock drilling program
- Borehole geophysical logging program
- Monitoring well installation program
- Hydraulic conductivity testing

- Groundwater level monitoring program
- Groundwater flow modelling and impact assessment

2.0 LOCAL SETTING

2.1 Topography

The topography of the area is generally flat with a series of broad low hills and shallow valleys with a strong northeast to southwest orientation. Generally, the elevation difference between adjacent valleys and hills is less than approximately 20 metres. On the Tomlinson property, the elevation ranges from approximately 254 mASL near the intersection of Miller Road and Scotts Road to 237 mASL in the northwest part of the site.

2.2 Geology and Hydrogeology

2.2.1 Surficial Geology

The surficial geology in the vicinity of the site is shown on Figure 3. The Carden Plain typically has very little or no overburden over the Palaeozoic bedrock. The majority of the Brechin Quarry site is identified as Palaeozoic bedrock at surface. There is a large deposit of organic material (peat, muck, marl) along the east side of the property associated with the Cranberry Lake Wetland. Till material (unit 5b), fine textured glaciolacustrine deposits (Unit 8a) and some coarse textured glaciolacustrine deposits (units 9b, 9c and 14c) are found further to the east/southeast and west of the site. A number of the linear overburden deposits shown on Figure 3 have a northeast/southwest orientation.

2.2.2 Bedrock Geology

The sequence of Paleozoic sedimentary rock underlying the study area (from oldest to youngest and deepest to shallowest) is Shadow Lake Formation (dolostone/sandstone/shale), Gull River Formation (limestone/dolostone/shale), Bobcaygeon Formation (limestone/shale) and Verulam Formation (limestone/shale).

The bedrock geology in the vicinity of the site is shown on Figure 4. The published mapping identifies the Verulam Formation as the upper bedrock unit within the majority of the south extraction area. The majority of the north extraction area identifies the upper bedrock unit as Bobcaygeon Formation. The Gull River Formation is mapped as the upper bedrock unit approximately 2.3 kilometres to the northwest of the site.

2.2.3 Hydrogeology

Water supplies are obtained from the overburden, limestone bedrock and crystalline bedrock in the area surrounding the Brechin Quarry. As part of the original licensing application, supply wells within 1.5 kilometre of the property were visited to confirm their locations (Golder, 2007). The locations of the private wells within 1.5 kilometres of the site are shown on Figure 2.

2.2.3.1 Overburden Deposits

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 Brechin Quarry. For this reason, the bedrock formations are considered the principal units for water supply. Given the marginal quality of the bedrock for water supply in the vicinity of the site, dug wells are present in some localized areas having greater thickness of coarse-grained overburden deposits (i.e., in the area surrounding the intersection of Scotts Road and Mara Carden Boundary Road).

2.2.3.2 Bedrock Formations

The majority of the wells in the vicinity of the site that are completed in bedrock and obtain their groundwater supplies from the limestone bedrock. The Shadow Lake, Gull River, Bobcaygeon and Verulam Formations are considered marginally adequate for domestic consumption. The groundwater within these formations tends to be moderately alkaline and hard to very hard. Ontario Drinking Water Standards aesthetic objectives are typically exceeded for DOC and TDS, and occasionally for iron and sodium depending on which formation the groundwater is derived. The ODWS aesthetic objective for manganese is consistently exceeded in the Bobcaygeon Formations. Most metals appear at very low concentrations, or fall below the method detection limit of the analysis. However, elevated levels of boron and iron have been measured (Golder, 2007).

2.3 Hydrology

The local surface water drainage is dominated by flow to Lake Dalrymple often following a long, circuitous route. Lake Dalrymple lies in the southern arm of a broad horseshoe shaped depression that opens toward the southeast. Lake Dalrymple drains to the north and is part of the Black River drainage basin. Black River eventually drains to the Severn River at Washago approximately 25 km north of the Brechin Quarry.

To the south of Cranberry Lake, an upland area forms a drainage divide between the Lake Dalrymple drainage basin and the Talbot River drainage basin. Canal Lake is a flooded part of the Talbot River and is one lock below the maximum height of the Trent Severn canal system. The surface water divide in the Trent Severn Canal is just to the east of the Kirkfield liftlock approximately seven kilometres to the east of the Brechin Quarry. Canal Lake is on the west side of the divide and water flow is toward Lake Simcoe through the canal and the Talbot River. Surface water flow in the canal system to the east side of the Kirkfield lock is toward Lake Ontario. All drainage in the immediate vicinity of the Tomlinson property flows to Lake Dalrymple.

Surface water inflow onto the Brechin Quarry property originates from two sources, one of which is the wetland along the south and east property boundaries and flows through an agricultural swale, referred to as the “south drainage feature”. The location of the south drainage feature is shown on Figure 2. The second location is from surface water runoff along the north boundary adjacent to the Miller Aggregates Quarry which ultimately drains to Miller Road. This is referred to as the “north drainage feature”. The location of the north drainage feature is shown on Figure 2.

2.4 Ecological Context

The area on and around the Brechin Quarry has a relatively long-standing history of use for agricultural purposes. However, because of shallow, infertile soils, agricultural production quickly focused on livestock, with fields being sown to permanent pasture for use as grazing land. Also, because of the shallow depth of overburden and relatively soft bedrock resource, the local area has had a long history of resource extraction.

The flat and featureless plain that stretches east from the Brechin Quarry is known as the Carden Plain (Chapman and Putnam, 1984). Where present, the Carden Plain supports a distinctive group of plant communities that are more or less restricted to limestone barrens. These communities of limestone plains are known as ‘alvars’ and are characterized by species that can tolerate extremes in the moisture regime (from very wet to very dry), high soil calcium levels, and limited nutrient availability (Reschke *et al.*, 1999). Often, these species have very restricted distributions but are abundant where they do occur, due to the large but localized patches of limestone plain that occur in southern Ontario and the absence of competition from more common and aggressive colonizing plants.

The Brechin Quarry is located within one of the tributary systems of the Lake Dalrymple watershed and a shallow bedrock basin at the east edge of the property has developed as the Cranberry Lake Wetland, a wetland that is designated as 'provincially significant' (Haxton *et al*., 1992). A portion of this 280-hectare wetland occurs on the Tomlinson property, at the eastern and southeastern edges. Here, a mix of swamps, marshes, peatland and open water habitats are present.

2.5 Surrounding Land Use - Existing Quarries

As previously described, several licensed aggregate quarries currently exist in the vicinity of the Brechin Quarry. Miller Aggregates owns the quarry immediately to the north of the Brechin Quarry, and Dufferin owns the quarries located to the southeast and southwest of the Brechin Quarry (see quarry locations on Figure 2).

Details regarding the general properties of the existing quarry sites are included in the following table:

Table 1: Summary of Approved Quarry Extraction Areas and Final Floor Elevations

Quarry Operator	Quarry Name	Approximate Extraction Area (hectares)	Approved Quarry Floor Elevation (metres above sea level)
Tomlinson	Brechin Quarry	131 (92 north extraction area and 39 south extraction area)	222 to 229
Miller Aggregates	Carden Township Quarry	226	217
Dufferin Aggregates	Carden Quarry	196.7	187
	Campbell Quarry	75	206

In considering the potential hydrogeological impacts from quarry dewatering at the proposed deepened Brechin Quarry, a cumulative impacts assessment including all of the quarries in the area was completed. For the existing conditions, the quarry floor elevations were assumed as follows:

Table 2: Summary of Existing Quarries Under Existing Conditions

Quarry Operator	Quarry Name	Simulated Floor Elevation
Tomlinson	Brechin Quarry	Quarry floor elevations within the excavated area were set at between 225 and 235 mASL
Miller Aggregates	Carden Township Quarry	Quarry floor elevations within the excavated area were set at 225 mASL
Dufferin Aggregates	Carden Quarry	Quarry floor elevations within the excavated area were set between 212 and 225 mASL
	Campbell Quarry	There is no significant extraction at the Campbell Quarry under existing conditions.

3.0 SUMMARY OF PREVIOUS INVESTIGATIONS

3.1 Golder 2007 – Hydrogeological and Hydrological Study

As part of the original ARA licensing application an extensive hydrogeology and hydrology assessment was completed between 2004 and 2007. The study consisted of the following items:

- Data review and compilation
- Receptor identification
- Bedrock coring program and aggregate resource evaluation
- Bedrock percussion drilling program
- Pumping test wells and observation borehole array drilling program
- Geophysical logging program
- Monitoring well installation program
- Hydraulic conductivity and transmissivity testing program (packer testing, well response tests and pumping tests)
- Groundwater level monitoring program
- Groundwater quality monitoring program
- Surficial geological mapping program and wetland investigation
- Surface water flow monitoring program
- Surface water quality sampling program
- Water balance assessments and impact analysis
- Groundwater flow modelling and impact assessment

The results of the study were presented in a report entitled *Hydrogeological and Hydrological Assessments in Support of a Category 2 Class "A" Quarry Below Water, R.W. Tomlinson Limited Proposed Brechin Quarry, Former Township of Carden, City of Kawartha Lakes, Ontario*. This report is referred to as the Golder 2007 report within this document. A summary of the data collected and major findings of the Golder 2007 report are provided in the sections below.

3.1.1 Bedrock Drilling and Geophysical Logging Program

In support of the original licensing application four boreholes were cored to provide detailed characterization of the limestone bedrock of the Verulam, Bobcaygeon and Gull River Formations, as well as the underlying Shadow Lake Formation and Precambrian bedrock (Golder, 2007). The locations MW-1 to MW-4 are shown on Figure 5. An assessment of lithology and stratigraphy was completed using the bedrock core recovered from MW-1 to MW-4. The assessment involved a systematic description of the core including: weathered state; structure; colour; grain size; bedding; texture; material type; and, the location of open bedding planes/voids.

A total of 45 air percussion observation wells were advanced by Tomlinson using a track mounted rig. Two drillholes were completed at locations OW-1 through OW-22, and a single drillhole was completed at location OW-23. Where two drillholes were completed, the holes were drilled to depths of approximately 35 and 15 metres below ground surface (mbgs). OW-23 was drilled to a depth of 35 mbgs. The locations of the observation wells are shown on Figure 5.

Three additional air percussion drillholes (PW-1 to PW-3) were drilled in strategic locations to be used as pumping wells during the aquifer testing program. PW1, PW2 and PW3 were completed as 127 mm open boreholes to depths of 35, 28.5 and 31.7 mbgs, respectively. The locations of the pumping wells are shown on Figure 5.

After drilling was completed at the MW series cored boreholes, the OW series drillholes (except OW-23), and the PW series pumping wells, each location was geophysically logged. The log suite included both apparent conductivity and natural gamma logs. The conductivity and gamma logs were used in conjunction with the knowledge of the bedrock formations obtained from logging the core retrieved from cored boreholes MW1 to MW4 to assess the bedrock stratigraphy across the site.

The geological contacts and rock types identified in MW-1 to MW-4 were logged in conjunction with records of the geophysical logs. During this core logging evaluation, geophysical signatures of each of the geological formations were developed and refined. The method for identifying the formation contacts that was developed using the MW series wells was applied to the uncored OW and PW series wells to identify geological contacts. The results of the geophysical logging are provided on the geophysical logs in Appendix B.

3.1.1.1 Site Bedrock Geology

The following provides a summary of the site bedrock geology based on the results of the bedrock drilling program and geophysical logging.

The bedrock surface at the site is primarily defined by the interbedded limestone and shale of the upper Bobcaygeon Formation. The younger Verulam Formation was only encountered at OW-1 which is located on a local topographic high on the west side of the site south of Scotts Road. It is interpreted that the Verulam Formation has been removed by erosional processes over the remainer of the site. The Gull River Formation is encountered beneath the Bobcaygeon Formation at all borehole locations. The Shadow Lake Formation overlies the Precambrian basement. A description of the stratigraphic sequence based on site data is provided below.

3.1.1.1.1 Verulam Formation

At OW-1 the Verulam Formation was 6.5 metres thick. This is the only location on the site where the Verulam Formation was encountered. At this location, the Verulam Formation was described as shaly nodular micritic to calcarenitic limestone with medium grey shale.

3.1.1.1.2 Bobcaygeon Formation

The Bobcaygeon Formation is a series of interbedded limestones and shales. The limestone is argillaceous, non-porous, thinly bedded with shaley zones and partings. The amount of shale within the formation varies with depth. The Bobcaygeon Formation was encountered in all boreholes at the site. The thickness of the Bobcaygeon Formation varies from 9.0 to 27.5 m on the property, with an average thickness of 21.6 m. The thickest portion of the formation is found in the southern portion of the site. The base of the Bobcaygeon Formation slopes to the west at a rate of approximately 4.4 metres per kilometre (m/km), and ranges in elevation from 227.5 in the northeast corner of site to 218.5 mASL in the southwest corner of the site.

3.1.1.1.3 Gull River Formation

The entire thickness of the Gull River Formation was intersected at boreholes MW-1, MW-3 and MW-4. The thickness of the Gull River Formation at the site ranges from 16.7 metres to 16.9 metres, and forms a transitional contact with the overlying Bobcaygeon Formation. The upper part of the formation includes fine grained lime mudstone and coarse grained wackestone or packstone lithofacies. The lower portion of the formation contains silica rich beds that contribute to alkali-carbonate reactivity. There are “green beds” in the Gull River Formation that are known to be associated with water bearing zones, and are composed of silicate minerals.

The upper green bed in the Gull River Formation slopes from the east to the west at a rate of 4.0 m/km on the site and ranges in elevation from 223.5 to 215 mASL. The base of the currently licensed Brechin Quarry terminates approximately 5.8 metres above the upper green beds.

3.1.1.1.4 Shadow Lake Formation

The Shadow Lake Formation rests above the Precambrian bedrock. The formation consists of red and green shale, sandstone and arkose. The Shadow Lake Formation was intersected in three boreholes (MW-1, MW-3 and MW-4) at the site, and fully penetrated by two boreholes (MW-1 and MW-3). Using the data from MW-1 and MW-3, the Shadow Lake Formation has an average thickness of 8 metres at the site. Due to its high clast and shale content, it is not a target for quarrying.

3.1.2 Monitoring Well Installation Program

Groundwater monitoring intervals were constructed to allow for the measurement of groundwater levels (and determination of groundwater elevations), horizontal hydraulic conductivity, and vertical gradients within the various bedrock formations encountered at the site. The details of the monitoring interval installations in the cored boreholes and observation wells are shown on the geophysical logs in Appendix B.

3.1.3 Hydraulic Conductivity Testing Program

The hydrogeological characteristics of the bedrock formations beneath the site were investigated through an extensive program of hydraulic testing that was originally presented in the Golder 2007 report. The hydraulic testing program was designed to identify hydrostratigraphic units at the site, and to identify hydraulically conductive zones to be targeted for monitoring well installations. The in-situ hydraulic conductivity testing program consisted of packing testing, well response testing, stepped rate pumping tests, and constant rate pumping tests. A total of 100 packer tests were completed, 69 single well response tests were completed and three pumping tests were completed.

The data collected as part of the hydraulic conductivity testing program allowed for the identification of the hydrostratigraphic units at the site. Based on the available data, the overburden and the upper weathered bedrock together represent a moderately permeable upper horizon; while the remainder of the Bobcaygeon Formation and the Gull River Formation above the green beds represent a thick, competent aquitard. Beneath the aquitard lies the thin, but permeable green beds with approximately four orders of magnitude higher hydraulic conductivity than the overlying rocks. The rocks beneath the green beds are again relatively impermeable. This hydrostratigraphy is consistent with the results of the pumping tests which showed independence-of-response (to pumping) between the upper and lower water bearing zones, widespread response to pumping within the fully confined lower water bearing zone (i.e., green beds of the Gull River Formation), and high flows coupled with de-saturation effects within the unconfined upper water bearing zone (i.e., upper weathered bedrock).

Table 3 below summarizes the results of the packer tests and single well response tests and is presented by hydrostratigraphic unit.

Table 3: Packer Testing and Response Testing Hydraulic Conductivity Results by Hydrostratigraphic Unit

Hydrostratigraphic Unit Description	Approximate Thickness (m)	Packer Testing		Response Testing	
		Number of Tests	Geometric Mean (m/sec)	Number of Tests	Geometric Mean (m/sec)
Overburden	Variable	0	NA	1	2×10^{-6}
Upper Weathered Bedrock	Upper 5 m of bedrock	3	7×10^{-5}	21	3×10^{-6}
Bobcaygeon Formation plus Gull River Formation above the Green Beds	4 m to 22.5	34	5×10^{-8}	23	3×10^{-7}
Green Beds of the Gull River Formation	2 m	10	1×10^{-5}	15	1×10^{-7}
Gull River Formation below the Green Beds	14 m	21	6×10^{-7}	4	9×10^{-9}
Shadow Lake Formation	9 m	11	2×10^{-7}	0	NA

Constant rate pumping tests were completed using PW-1, PW-2 and MW-4. Table 4 below summarizes the estimated average transmissivity and storativity for the pumping tests.

Table 4: Average Transmissivity and Storativity for Pumping Tests at PW-1, PW-2 and MW-4

Pumping Well	Average Transmissivity (m^2/day)	Average Storativity
PW-1	51	4×10^{-3}
PW-2	30	3×10^{-2}
MW-4	8	5×10^{-6}

3.1.4 Groundwater Level Monitoring Program

Monitoring of groundwater levels was conducted in the monitoring intervals installed during the field investigation. Depths were measured relative to the surveyed top of the casing, or PVC pipe, if no casing existed, and were recorded to the nearest centimetre. The water elevations in the monitoring wells were calculated by subtracting the measured depth to water from the top of pipe reference elevations. Monthly groundwater level monitoring was completed between August 2004 and August 2006 as part of the Golder 2007 report.

The water table is present in the Bobcaygeon Formation across the site, except at OW-1 where the Verulam Formation is found at surface and in the northwest corner of the site (MW-4B) where the water table is found in the overburden. The water level data measured as part of the licensing application indicates that groundwater in the upper Bobcaygeon Formation (i.e., at the water table) flows from areas of topographic high to topographic low. It is inferred from this observation that the majority of the water in the upper weathered portion of this formation is both recharged and discharged locally. Generally, the groundwater flows across much of the Brechin Quarry property towards the north/northwest. The exception is in the area of the knoll near the intersection of Scotts Road and Miller Road. The relatively high water level in OW-1C, compared to the surrounding monitoring points, again provides evidence of local and topographically controlled recharge. During the groundwater level monitoring between August 2024 and August 2006, the maximum range in the water table water levels was 17.6 metres (i.e., the difference between the head at OW-1C and MW-4B).

The water level data for the Gull River Formation, with a range of 3.1 metres clearly indicates a more subdued influence of topography on groundwater flow directions in this formation. This is consistent with the hydrostratigraphic sequence described in the previous section, and with the presence of the thick aquitard separating this highly permeable horizon from the ground surface. The groundwater flow direction within the Gull River Formation is generally towards the west and northwest portion of the site.

A significant groundwater level database has been developed for the Brechin Quarry as part of the ongoing groundwater level monitoring program included on the PTTW. This additional groundwater level data is discussed in Section 3.2.

3.1.5 Wetland Assessment

Probeholes along three transects were completed within the wetland located along the eastern and southern side of the Brechin Quarry property. The probeholes were completed to allow for an assessment of the overburden material within the wetland. A total of 30 probeholes were completed to identify the type of overburden material present and the total depth of the overburden.

The overburden material encountered within the wetland typically consists of varying depths of organic material over a sandy marl. The organic material consists mainly of sphagnum peat that becomes denser with depth. The marl may overlay a thin, discontinuous layer of fine sand or rubble at the contact with the bedrock. The overburden depths along transects were typically between 1 metre and 2 metres. The maximum overburden depths were found along the eastern end of transects (greater than 3 metres at some locations).

3.1.6 Surface Water Evaluation

As part of the Golder 2007 report, the surface water evaluation for the area surrounding the site was conducted through a review of available topographic mapping and site reconnaissance to observe drainage features in the area. A field investigation was undertaken to complete a baseline characterization of stream flows and surface water quality within the study area.

All drainage in the immediate vicinity of the Brechin Quarry flows to Lake Dalrymple. Inflow onto the Brechin Quarry property originates from two sources, one of which is the wetland along the south and east property through the south drainage feature. The location of the south drainage feature is shown on Figure 5. The south drainage feature generally lacks any riparian vegetation such as grasses, shrubs or trees likely due to historical intrusion by cattle grazing. The substrate is mainly bedrock with some portions containing muck. It appears that a portion of the south drainage feature was excavated and manipulated several decades ago to allow gravity flow through a bedrock ridge to Miller Road. The south drainage feature exits the Brechin Quarry property near monitoring well OW-3.

Inflow onto the Tomlinson property also originates from surface water runoff along the north boundary adjacent to the Miller Aggregates Quarry which ultimately drains to Miller Road. The location of the north drainage feature is shown on Figure 5. The north drainage feature consists of a trapezoidal ditch located adjacent to the north property boundary (adjacent to the Miller Aggregates property). The base of the upstream portion of this reach is generally located on bedrock, but portions are covered with sand and silt substrate. At Miller Road, the north drainage feature flows south along the Miller Road.

3.1.7 Water Balance

As part of the Golder 2007 report, a water balance analysis of existing and proposed conditions was completed to assess water availability under various quarry conditions. The water balance analysis also evaluated the adequacy of water supplies to support mitigation water requirements, should it be determined that mitigation works are required. The water balance assessment was completed based on the site-specific flow monitoring of local streams, meteorological data (precipitation, lake evaporation), Meteorological Service of Canada water balances, Environment Canada stream flow monitoring, existing and proposed operational and rehabilitation plans, topographic mapping, land uses, surficial soils and similar studies.

The water balance presented in Golder 2007 quantifies the effects of the catchment area alterations, land use changes, water management strategies and groundwater flow changes on average annual flows. Based on the water balance, it was concluded that during operational conditions the quarry surplus flow can be manipulated in a manner to incur average annual flow increases where the north drainage feature exits the Brechin Quarry property, at the wetland outflow (where discharge from the wetland enters the south drainage feature) and where the south drainage feature exits the Brechin Quarry property assuming a 40% diversion of the north extraction sump discharge to the south drainage feature.

During operations, excess water from the south extraction area will discharge to the wetland and flow through the wetland and south drainage feature. Forty percent of the north extraction area will discharge to the south drainage feature at Miller Road and 60% to the north drainage feature at Miller Road.

Based on the water balance assessment, following rehabilitation, there will be a reduction in flow in the wetland and south drainage feature (approximately 4 L/s, or 10% reduction in the surplus average annual flow from the wetland to the on-site south drainage feature, and approximately 8 L/s, or 16% reduction in average annual flow in the south drainage feature downstream of the site to its confluence with the north drainage feature). Both the storm flow and base flow portions of the average annual flow are anticipated to decrease. The decrease in average annual flows is mainly due to the diversion of drainage area to the north extraction area, but also due to decreased groundwater discharge to the wetland. The 8 L/s flow reduction in the south drainage feature downstream of Miller Road will partially be compensated for by an approximately 9 L/s, or 60% increase in average annual flows in the north drainage feature downstream of Miller Road. Due to the attenuating effect of the rehabilitation lakes, this increase should primarily occur in the base flow component of the stream flow and storm flows should be less than or similar to existing conditions.

Following rehabilitation, there may be a subtle increase in average annual flows downstream of the confluence with the north and south drainage features due to capture, and discharge of groundwater from the rehabilitation lakes. Due to the attenuating effects of the rehabilitation lakes, a reduction is expected to occur in the storm flow component of the stream flow and base flows should be similar to or slightly larger than existing conditions.

3.1.8 Groundwater Flow Modelling

Within the Golder 2007 report, groundwater flow modelling was performed in order to assess the potential impacts on local water resources and ecological receptors associated with the planned operation of the Brechin Quarry. A three-dimensional, steady-state, finite-difference numerical model of groundwater flow were prepared in order to calculate the following:

- quarry-induced groundwater level drawdown in the upper weathered bedrock and in the green beds of the Gull River Formation;
- changes in groundwater seepage rate to surface water; and,
- potential reduction in available drawdown at local water supply wells.

The numerical modelling of groundwater flow was also used to provide an assessment of the effectiveness of specific measures developed for the purpose of mitigating potential groundwater level drawdown beneath the wetland.

The modelling included operational scenarios for full extraction of the quarry and the flooded rehabilitated quarry under post-closure conditions, and mitigation options. A water balance analysis of existing and proposed conditions was undertaken in order to provide input into the groundwater model calibration and to assess water availability under various quarry development conditions.

3.1.9 Golder 2007 Impact Assessment and Issuance of Approvals

The results of the groundwater flow modelling and surface water balance assessment were used to complete an impact assessment for the operational period and post rehabilitation period for the Brechin Quarry property. The main conclusions of the impact assessment completed as part of the Golder 2007 report are presented in Sections 3.1.9.1.1 and 3.1.9.1.2 for the operational period and rehabilitation period, respectively.

3.1.9.1.1 Operational Period

Based on the results of the Golder 2007 impact assessment, it was concluded that during operational conditions:

- The quarry surplus flow can be manipulated in a manner to incur average annual flow and base flow increases in the wetland, and in the south and north drainage feature where they exit the site. As such, negative impacts to these features are not predicted during the operational period.
- The storm flows from the Brechin Quarry and in the downstream drainage features are predicted to be reduced.
- Erosion in the downstream receiving system is not expected to increase.
- The elevation of the Brechin Quarry floor was chosen in large part to minimize impacts to local water supply wells due to the depressurization of the permeable green beds of the Gull River Formation. Based on the groundwater modelling results impacts to surrounding water supply wells as a result of the development of the Brechin Quarry is not predicted.
- Based on the results of the impact assessment presented in the Golder 2007 report, it would be expected that mitigation measures will be required during the latter part of the operational period. The need for mitigation

measures and the timing for implementation of mitigation measures would be based on the data obtained from the site-specific monitoring programs.

3.1.9.1.2 Rehabilitated Conditions

Based on the results of the Golder 2007 impact assessment, it was concluded that during rehabilitated conditions:

- There will be a reduction in flow in the wetland and south drainage feature (approximately 4 L/s, or 10% reduction in the surplus average annual flow from the wetland to the on-site south drainage feature, and approximately 8 L/s, or 16% reduction in average annual flow in the south drainage feature downstream of the site to its confluence with the north drainage feature). Both the storm flow and base flow portions of the average annual flow are anticipated to decrease. The decrease in average annual flows is mainly due to the diversion of drainage area to the north extraction area, but also due to decreased groundwater discharge to the wetland.
- The 8 L/s flow reduction in the south drainage feature downstream of Miller Road will partially be compensated for by an approximately 9 L/s, or 60% increase in average annual flows in the north drainage feature downstream of Miller Road. Due to the attenuating effect of the rehabilitation lakes, this increase should primarily occur in the base flow component of the stream flow and storm flows should be less than or similar to existing conditions.
- There may be a subtle increase in average annual flows downstream of the confluence with the north and south drainage features due to capture, and discharge of groundwater from the rehabilitation lakes. Due to the attenuating effects of the rehabilitation lakes, a reduction is expected to occur in the storm flow component of the stream flow and base flows should be similar to or slightly larger than existing conditions.
- The storm flows from the Brechin Quarry property and in the downstream drainage features are predicted to be reduced.
- Erosion in the downstream receiving system is not expected to increase.
- Based on the results of the groundwater modelling and the review of local water supply wells, it was concluded that there will be no potential for adverse impacts to local water supply wells as the residual groundwater level drawdown following rehabilitation will be minimal.
- Based on the results of the impact assessment presented in the Golder 2007 report, it would be expected that mitigation measures will be required during the post rehabilitated period at the proposed Brechin Quarry. The need for mitigation measures and the timing for implementation of mitigation measures would be based on the data obtained from the site-specific monitoring programs.

Following the review of the Golder 2007 report and the associated satisfactory responses to agency comments, the MNR issued the Tomlinson Brechin Quarry Licence 624846 on September 23, 2009 and approved the final version of the Site Plans on October 1, 2009. Following issuance of the licence, Tomlinson commenced the process of obtaining a PTTW and ECA (Industrial Sewage Works). These applications were reviewed and approved by the MECP. The original PTTW Number 7251-7ZGPEF was issued by the MECP on June 14, 2010. The current amended PTTW Number P-300-4187597913 was issued on November 9, 2022. The original ECA Number 7458-842L3X was issued by the MECP on July 23, 2010. The current amended ECA Number 5012-BRWLWN was issued on September 28, 2020. The Brechin Quarry started operations in March 2011 and annual performance monitoring reports under the PTTW and ECA have been prepared and submitted to the MECP for review for the 2011 through 2024 site operations. WSP is currently undertaking the 2025 PTTW and ECA monitoring programs.

3.1.9.2 Long-Term Monitoring Program

As part of the Golder 2007 report, groundwater, surface water and ecological monitoring programs were developed to measure and evaluate the actual effects on water resources associated with long-term quarry development, and to allow a comparison between the actual effects measured during the monitoring program with those predicted as part of the impact assessment. The groundwater, surface water and natural environment monitoring programs have been implemented under the PTTW monitoring program for the Brechin Quarry. Additional details about the water level data collected to date under the PTTW monitoring program are provided in Section 3.2.1 and 3.2.2, and the wetland vegetation monitoring program is summarized in Section 3.2.3.

3.2 Permit to Take Water Monitoring and Reporting 2011 Through 2024

In September 2009, an application was submitted for a PTTW to facilitate operation of the then recently licensed Brechin Quarry. The hydrogeological/hydrological technical study completed for the licensing of the Brechin Quarry was used to support the application for the Brechin Quarry PTTW. Following review of the PTTW application package by the Ministry of the Environment, Conservation and Parks (MECP), the original PTTW for the Brechin Quarry was issued on June 14, 2010, and included the groundwater, surface water and ecological monitoring programs that were developed through collaboration with the Ministry of Natural Resources (MNR) and MECP during the quarry licensing process.

Dewatering started at the Brechin Quarry in March 2011, and to date, PTTW monitoring reports have been prepared each year between 2011 and 2024. The monitoring program for the PTTW includes the measurement of groundwater and surface water levels and a wetland vegetation monitoring program. The wetland vegetation monitoring is required during selected years as described on the PTTW. Prior to 2015, the site-specific monitoring program also included water quality sampling at selected monitoring wells. The requirement for groundwater quality sampling at the site and at off-site monitor OW-32 was removed in September 2015.

Condition ‘f’ on the Operational Plan and Condition 4.4 on the original PTTW required the development of trigger levels and mitigation plans prior to extraction within Phase 2 (A or B) in the north extraction area or Phase 3B or Phase 4 in the south extraction area (phase boundaries are identified on Figure 2). The intention of the site plan and PTTW conditions was to establish trigger levels and mitigation plans to limit the potential for adverse impacts to the adjacent wetland. The trigger levels and mitigation plans were developed in consultation with the MECP and MNR. After addressing comments from the MECP and MNR, a final version of the trigger levels and mitigation measures document was submitted in June 2019 (Golder 2019a). Through discussions with the MECP and MNR, it was agreed that the existing PTTW would be amended to incorporate the newly developed trigger levels, and the reporting associated with the triggers would be included in the PTTW annual report.

The amended PTTW for the Brechin Quarry was issued in February 2020, and the 2020 PTTW annual report presented the first trigger assessment using the established trigger levels. Each year since 2020, the annual water level trigger assessment has been presented in the PTTW annual monitoring report. A summary of the components of the PTTW monitoring program and the information collected to date, including a discussion of the most recent trigger assessment presented in the 2024 monitoring report, is provided in the sections below.

3.2.1 PTTW Groundwater Level Monitoring Program

The PTTW groundwater level monitoring program was designed to evaluate groundwater level drawdown effects as the Brechin Quarry develops. The monitoring locations include selected on-site monitoring wells installed as part of the ARA application, as well as seven additional shallow on-site monitoring wells completed within the weathered zone, three additional multilevel monitoring wells constructed in the adjacent wetland and two off-site multilevel monitoring locations installed during 2010 and 2011 to satisfy PTTW monitoring requirements. In July 2017, two new shallow monitoring wells (OW-34 and OW-35) were installed near the wetland in the area between the extraction limits of the north and south extraction areas (see well locations on Figure 5). These wells were installed to assist with delineating the extent of drawdown in the shallow bedrock.

The on-site and off-site PTTW groundwater level monitoring locations are shown on Figure 5. Not all monitoring wells drilled at the site are included in the PTTW monitoring program. The logs for the monitoring wells included in the groundwater level monitoring program are included with the borehole logs provided in Appendix B. The borehole logs for OW-34 and OW-35 have been added to Appendix B.

In June 2006, data loggers were installed in the monitoring intervals in on-site boreholes OW-3, OW-4 and OW-10. As part of the PTTW groundwater monitoring program, additional data loggers were installed in all monitoring intervals of on-site boreholes OW-29, OW-30 and OW-31 located in the wetland, and off-site boreholes OW-32 and OW-33. Table 5 provides a list of the monitoring locations with data loggers and the geological formation monitored.

Table 5: Monitoring Locations with Data Loggers and the Formation Monitored

Location	Formation Monitored
OW-3A	Gull River
OW-3B	Bobcaygeon
OW-3C	Bobcaygeon (water table)
OW-4A	Gull River
OW-4B	Bobcaygeon
OW-4C	Bobcaygeon (water table)
OW-10A	Bobcaygeon/Gull River
OW-10B	Bobcaygeon
OW-10C	Bobcaygeon (water table)
OW-29A	Gull River
OW-29B	Bobcaygeon
OW-29C	Bobcaygeon
OW-29D	overburden (water table)
OW-30A	Gull River
OW-30B	Bobcaygeon
OW-30C	Bobcaygeon
OW-30D	overburden (water table)
OW-31A	Gull River
OW-31B	Bobcaygeon

Location	Formation Monitored
OW-31C	Bobcaygeon
OW-31D	overburden (water table)
OW-32A*	Precambrian
OW-32B*	Shadow Lake/Precambrian
OW-32C*	Gull River
OW-32D	Bobcaygeon
OW-33A	Shadow Lake/Precambrian
OW-33B	Gull River
OW-33C	Bobcaygeon/overburden (water table)

* As of November 2022, Tomlinson no longer has permission to monitor water levels at off-site monitoring well location OW-32.

Plots of groundwater elevations collected between 2004 and 2024 for the monitoring wells drilled as part of the ARA license application that are included in the PTTW groundwater monitoring program are provided in Appendix C. Monitoring well locations MWPSW-3, MWPSW-4, OW-5C, OW-24, OW-25, OW-26, OW-27, OW-28, OW-29A, OW-29B, OW-29C, OW-29D, OW-30A, OW-30B, OW-30C, OW-30D, OW-31A, OW-31B, OW-31C and OW-31D were installed in December 2010 or early 2011. As a result, the groundwater elevation plots in Appendix C for these locations start either in December 2010 or in early 2011 depending on the installation dates for the wells.

OW-6C was damaged by cattle in late 2006. A replacement well for OW-6C was installed in January 2011. As a result, the groundwater elevation plot for OW-6C provided in Appendix C has data for October 2004 to October 2006, and then starts again on January 27, 2011. At the time of drilling, the groundwater level in MW-4A was approximately 3 metres above ground surface. Due to difficulties in obtaining manual readings from this location, the groundwater elevation plot for MW-4A in Appendix C has limited data before 2011. In 2011, this location was fitted with a vibrating wire piezometer to allow for more frequent, and more accurate, groundwater level measurements. In September 2014, monitoring well OW-9C was found to be blocked. In October 2014, a replacement monitoring well was constructed at the same location and to a similar depth. The available data from the original OW-9C and the replacement monitoring well are provided on same plot in Appendix C.

In late November 2022, the property owner where OW-32 is located requested that WSP no longer access their property for measuring groundwater levels. The available historical groundwater elevation data for OW-32 is presented in Appendix C.

In November 2023, OW-3A became blocked at a depth of approximately 11.2 metres. Groundwater levels can no longer be measured at this location. OW-3A is completed in the green beds of the Gull River Formation and is located along the western boundary of the site, just southwest of the existing excavation (see location on Figure 5).

The groundwater elevation plots in Appendix C also include a table below the plot displaying groundwater elevation data. For locations without loggers, the table includes several years of manual groundwater levels. For locations with data loggers, the table includes a couple of years of manual groundwater levels, as well as a representative weekly groundwater level taken from the daily groundwater levels collected by the data logger.

Detailed groundwater elevation plots for all PTTW monitoring locations containing data loggers are provided on Figure D1 through Figure D8 in Appendix D. These locations include OW-3, OW-4, OW-10, OW-29, OW-30, OW-31, OW-32 and OW-33. The plots in Appendix D display available manual groundwater elevations and representative daily groundwater elevations collected by the data loggers, as well as the precipitation record and pumping records for the Brechin Quarry.

3.2.1.1 Pre-Development Groundwater Level Trends

A discussion of pre-development groundwater level trends (i.e., before dewatering started at the Brechin Quarry) based on groundwater level data (manual readings and data loggers) for OW-3, OW-4 and OW-10 are summarized below. See Figures D1, D2 and D3 in Appendix D. For reference, the time when dewatering began at the site is identified on Figures D1, D2 and D3.

3.2.1.1.1 Bobcaygeon Formation (Water Table)

The intervals completed in the Bobcaygeon Formation at the water table (OW-3C, OW-4C and OW-10C) show rapid changes in groundwater levels on the order of 1 to 2 metres. There is little to no overburden at these locations, and the rapid increases in groundwater levels are interpreted to be the result of direct infiltration into the upper weathered zone during precipitation events and spring freshets. The increases in groundwater levels are followed by rapid decreases as the water drains from the upper weathered zone when the precipitation/freshet event ends.

3.2.1.1.2 Bobcaygeon Formation

When the effects of the testing completed as part of the ARA application are excluded (i.e., after October 2006), the intervals completed below the water table within the Bobcaygeon Formation in OW-3B, OW-4B and OW-10B have smooth groundwater level plots and show minimal change. Below the upper weathered zone, the Bobcaygeon Formation is interpreted to be an aquitard at the site and, as such, exhibits a limited response to seasonal variations.

3.2.1.1.3 Gull River Formation

When the effects of the testing completed as part of the ARA application are excluded (i.e., after October 2006), the intervals in OW-3, OW-4 and OW-10 completed in the Gull River Formation (OW-3A, OW-4A and OW-10A) are typically stable and show less than one metre of variation per year. However, in October 2010, there was a minor decrease in groundwater levels in the Gull River Formation intervals (i.e., less than one metre) followed by a sharp increase of approximately 4 to 5 metres. This was followed by an equally sharp decrease in groundwater levels. In mid-March to early-April, groundwater levels returned to normal in the Gull River Formation. During this period, two distinct peaks are observed at OW-4A. This sharp increase in groundwater levels followed by a sharp decrease in groundwater levels was also observed in the Gull River Formation intervals at OW-7 and OW-15 when manual groundwater levels were collected in October 2010 through March 2011 (see plots in Appendix C). As such, this is not interpreted to be related to a malfunction of the data logging equipment. The cause of the increase in groundwater levels in the Gull River Formation is not known, but it is not a result of activities at the Brechin Quarry (i.e., it occurred prior to the start of operations at the site). The spike in groundwater levels in the Gull River Formation has not reoccurred.

3.2.1.2 Post Development Groundwater Level Trends

The data used for the discussion of post development groundwater level trends is provided on the figures included in Appendix C and Appendix D. To assist with the interpretation of groundwater levels at the site, the relationship between snow melt, precipitation and pumping at the site is displayed in the graph at the top of the page for Figures D1 through D8 in Appendix D.

3.2.1.2.1 Overburden Monitoring Wells (Water Table)

The PTTW monitoring program required the installation of three multilevel monitoring wells in the adjacent wetland. These monitoring locations are identified as OW-29, OW-30 and OW-31 (see locations on Figure 5). Each multilevel monitor included a shallow monitor completed in the overburden beneath the wetland. The overburden monitors are identified as OW-29D, OW-30D and OW-31D. As shown on the plots for OW-29D, OW-30D and OW-31D in Appendix C and D, the groundwater elevations are generally stable and typically vary by 0.5 to 1 metre or less. Based on the groundwater elevation data gathered between 2011 and 2024, the groundwater elevations at OW-29D, OW-30D and OW-31D display seasonal variations and are not being influenced by quarry dewatering.

Groundwater elevations at MW-4B begin to decline in mid-2014 and decline beyond the previously measured range in groundwater elevations during 2016 through August 2019 (see plot in Appendix C). After August 2019, the groundwater elevations at this location display seasonal variations, but the steady decline in groundwater elevations was no longer occurring. MW-4B is an overburden water table monitor located in the northwest portion of the site immediately adjacent to the existing excavation (see location on Figure 5). During 2024, the groundwater levels at MW-4B were generally stable and remained approximately 1.5 metres below the typical levels observed prior to 2014.

3.2.1.2.2 Bobcaygeon Formation (Water Table)

As observed in the pre-development data, the intervals completed in the Bobcaygeon Formation at the water table in OW-3, OW-4 and OW-10 continue to show rapid changes in groundwater elevations on the order of 0.5 to 2.5 metres following development of the Brechin Quarry (see Figures D1 through D3 in Appendix D and plots in Appendix C). This rapid response in the shallow Bobcaygeon Formation is not observed in the wetland monitors (OW-29 through OW-31). The presence of overburden above the Bobcaygeon Formation at these locations is interpreted to dampen the infiltration effects of precipitation/snow melt events.

During 2012, shallow groundwater elevations at monitoring locations OW-9C, OW-25, OW-26 and OW-27 declined during the late-spring and summer and did not display the typical rise in groundwater elevations in the fall (see plots in Appendix C). During 2013 through 2024, the shallow groundwater elevations at OW-9C, OW-26 and OW-27 remained one to two metres below the typical range observed prior to 2012. OW-25 was removed by progressive quarry development in December 2023.

A slow downward trend in the groundwater elevations is observed at OW-6C between 2015 and 2022 (see plot in Appendix C). The total gradual decline in the groundwater elevations at this location over the past eight years has been approximately 1.5 metres. The decline in the groundwater elevations at OW-6C is not as rapid or pronounced as the declines observed at OW-26 and OW-27. As such, it is interpreted that OW-6C is positioned near the edge of the radius of influence associated with the existing quarry. The groundwater elevations at this location did not decline further in 2024.

The groundwater elevations at OW-34 installed in July 2017 display a slight downward trend (see plot in Appendix C). OW-34 is located approximately 400 metres from the existing quarry excavation. The decline in groundwater elevations at this location between 2018 and 2024 is approximately 0.5 metres. Given the proximity to the quarry excavation, and the steady decline in water levels observed at OW-34, this groundwater levels at this location are interpreted to be influenced by quarry dewatering. Given the small magnitude of the decline in the groundwater elevations, OW-34 is interpreted to be located near the edge of the radius of influence associated with the quarry dewatering.

A gradual decline in groundwater elevations at OW-31C has been observed since September 2022 (see plot in Appendix C). Between August 2023 and January 2024, the groundwater elevation at OW-31C declined below the level typically observed at this location. The groundwater elevation returned to typical range in April/May 2024. Between June 2024 and December 2024, the groundwater elevation at OW-31C again declined below the typical range observed at this location. Based on data gathered up to May 2025, the groundwater elevation at OW-31C has not returned to typical levels observed at this location. OW-31C is located approximately 500 metres from the current quarry excavation and the groundwater level at this location is interpreted to be influenced by quarry dewatering. The decline in groundwater elevations at OW-31C between September 2022 and December 2024 is approximately 0.5 metres. Given the small magnitude of the decline in the groundwater elevations, OW-31C is interpreted to be located near the edge of the radius of influence associated with the quarry dewatering.

OW-35 installed in July 2017 was damaged in November 2021 and no groundwater levels could be measured in 2022, 2023 and 2024.

3.2.1.2.3 Estimated Radius of Influence (Water Table)

Monitoring locations MW-4B, OW-6C, OW-9C, OW-26, OW-27, OW31C and OW-34 are located between 30 metres and 500 metres from the existing extraction area. Based on the groundwater level data collected in 2012 through 2024, the groundwater levels at these monitoring locations are interpreted to be influenced by quarry dewatering (the maximum decline in water level is interpreted to be 1 to 2 metres).

Based on the above assessment, the drawdown cone associated with the dewatering of the existing excavation at the site is interpreted to extend in the upper bedrock approximately 400 to 500 metres to the east from the limits of the existing quarry extraction area (i.e., in the direction of the adjacent wetland). Based on the location of the monitoring wells currently influenced by quarry dewatering, the radius of influence in the shallow bedrock associated with dewatering of the quarry excavation extends beneath the western edge of the wetland.

With the exception of MW-4B, OW-6C, OW-9C, OW-26, OW-27, OW31C and OW-34, the groundwater level trends observed in the Bobcaygeon Formation and overburden monitoring wells installed at the water table are not interpreted to be influence by quarry dewatering and are considered to represent seasonal variations.

3.2.1.2.4 Bobcaygeon Formation (Below the Water Table)

As shown on the plots in Appendix C and Appendix D, the groundwater elevations from the Bobcaygeon Formation at depth (i.e., not at the water table) measured following development of the Brechin Quarry are generally smooth at most locations. The groundwater levels in the Bobcaygeon Formation at the site typically vary by less than one to two metres. This is similar to what was observed at OW-3, OW-4 and OW-10 in the review of pre-development groundwater levels in the Bobcaygeon Formation.

OW-1A and OW-7B are two monitoring intervals completed in the Bobcaygeon Formation at depth that have displayed more variation than is typically observed within this formation at the site (see plots in Appendix C). At both locations, the increase in variability begins after the quarry floor buckling that occurred in March 2017. The impacts of the quarry floor buckling are discussed further in Section 3.2.1.2.5 below.

OW-31B displays very slow recovery following groundwater quality sampling completed annually between 2011 and 2014 (see Figure D6 in Appendix D). Once groundwater quality sampling was stopped, the groundwater elevation at OW-31B recovered to near pre-sampling levels in 2015. This was followed by a decline in groundwater elevations between June 2015 and May 2017. The groundwater elevation at OW-31B has been relatively stable between October 2017 and December 2024. The variation in the groundwater elevations observed at OW-31B are not typical of monitoring wells completed at the site in the Bobcaygeon Formation at depth.

Overall, the available groundwater elevation data for monitoring wells completed in the Bobcaygeon Formation below the water table show no response to the water taking at the site and most locations show no response to the quarry floor buckle that occurred in March 2017. The groundwater levels in the Bobcaygeon Formation below the water table are interpreted to represent natural variation in groundwater elevations at the site except at OW-1A and OW-7B.

3.2.1.2.5 Gull River Formation

The post development groundwater elevation data for the Gull River Formation monitoring locations are shown on the groundwater level plots in Appendix C, as well as on the detailed groundwater level plots included as Figures D1 through D8 in Appendix D. Figure D1 through Figure D6 present the groundwater elevation data for the on-site monitoring wells (OW-3, OW-4, OW-10, OW-29, OW-30 and OW-31). Figures D7 and D8 present the groundwater elevation data for the off-site monitoring locations (OW-32 and OW-33).

3.2.1.2.5.1 On-Site Monitoring Wells

As shown on the plots in Appendix C and Appendix D, groundwater elevations from the Gull River Formation measured prior to April 2014 are generally smooth at all locations, and the groundwater elevations in the Gull River Formation at the site typically varied by less than 2 metres. During 2014, the groundwater elevations in the on-site monitoring wells completed in the green beds of the Gull River Formation (i.e., MW-4A, OW-3A, OW-4A, OW-10A, OW-29A, OW-30A, OW-31A) were slightly lower than previously observed at most locations starting in September and October. As shown on the plots in Appendix C and Appendix D, in 2015, 2016 and the early portion of 2017 (i.e., prior to the quarry floor buckling) the groundwater elevations in the Gull River Formation monitors continued to decline. Occasional increases in groundwater elevations were observed (i.e., October 2014 and November 2015), but the overall trend in groundwater elevations was downward.

As discussed in detail in the 2017 PTTW annual monitoring report for the Brechin Quarry (Golder, 2018), most of the on-site monitoring wells completed in the green beds of the Gull River Formation displayed a rapid decline in groundwater level following the quarry floor buckling in March 2017. The approximate location where the quarry floor buckle occurred is shown on Figure 5. For reference, the time when the buckling of the quarry floor occurred is indicated on the plots provided in Appendix C and D. As shown in the groundwater level plots in Appendix C and D, since the buckling occurred, the on-site Gull River Formation groundwater elevations have remained generally stable at the groundwater elevations measured following the quarry floor buckling. Once groundwater elevations stabilized following the buckling, the groundwater elevations in the majority of Gull River Formation monitors displayed fluctuations that are typically less than two metres. The downward trend that was observed at OW-7A during 2021 and 2022 stabilized during 2023 and 2024 (see plot in Appendix C).

The groundwater elevation trends observed in monitoring wells completed in the green beds of the Gull River Formation on the Brechin Quarry property through the end of 2024 confirm that the initial groundwater elevation decline in the green beds in March 2017 was immediate and permanent and with little evidence of groundwater elevation recovery in the green beds of the Gull River Formation following the quarry floor buckling (see Figures D1 through D6 in Appendix D). As shown in Figures D1 through D5 in Appendix D, the changes in the groundwater elevations observed in the green beds of the Gull River Formation do not result in significant changes in the groundwater elevations measured in the overlying Bobcaygeon Formation monitors.

3.2.1.2.5.2 Off-Site Monitoring Wells

As discussed in detail in the 2017 PTTW annual monitoring report for the Brechin Quarry (Golder, 2018), the Gull River Formation monitors located in off-site monitoring locations OW-32 and OW-33 displayed no change in groundwater elevations as a result of the quarry floor buckling in March 2017 (see Figures D7 and D8 in Appendix D). The groundwater elevation trends within the green beds of the Gull River Formation at OW-32C and OW-33B are interpreted to represent seasonal variations and are not influenced by progressive development of the quarry.

In late November 2022, the property owner where OW-32 is located requested that WSP no longer access their property for measuring groundwater levels.

3.2.2 Surface Water Level Monitoring Program

The surface water component of the monitoring program includes water level measurements in the wetland at four staff gauge locations. The four staff gauges are identified at SG06-1, SG06-2, SG09-3 and SG09-4, and the staff gauge locations are shown on Figure 5. As necessary, the tops of the staff gauges are resurveyed to improve elevation control. The collection of water level data prior to 2011 in the wetland was infrequent, and the resolution did not allow for recording of short-term variations in water levels (i.e., during and following precipitation events). The quality of the water level data from the wetland significantly improved with the installation of data loggers at the staff gauge locations in April 2011. A detailed plot of surface water levels collected using the data loggers in 2011 through 2024 is provided on Figure E1 in Appendix E. This plot provides the surface water elevation data, as well as the pumping records and precipitation record for the site.

All four staff gauges installed in the wetland typically show similar general trends in water levels. The staff gauge data shows higher water levels in early-April followed by a gradual decline in water levels into summer. All four staff gauges have historically gone dry. Because there is no impact from quarry dewatering on overburden groundwater elevations in monitoring wells completed within the wetland (see Section 3.2.1.2.1), the surface water elevations collected at the staff gauges to date are interpreted to be representative of the natural variation of water levels in the wetland. Moving forward, the data loggers will continue to measure daily water levels during periods of ice-free conditions.

3.2.3 Wetland Vegetation Monitoring Program

The natural environment wetland monitoring program focused on the area of the wetland adjacent to the eastern portion of the Brechin Quarry. Vegetation monitoring in the wetland began in 2011. The data collected during 2011 was baseline data and represents the reference conditions against which future conditions are assessed. Based on the PTTW monitoring program, wetland monitoring is required to be completed annually for the first two years of quarry operations and subsequently at increasing intervals, assuming that negative impacts due to the quarry operations are not identified.

In 2011, a vascular plant species inventory transect and two associated fixed location sample plots were established in the wetland. The survey transect was 360 metres long, 2 metres wide and was positioned on a direct line between two groundwater monitoring wells, identified as OW-30 and OW-31 (see locations on Figure 5). Flagging tape was used to demarcate the centerline of the transect at 10-metre intervals. The first 5 metres and the last 5 metres of the transect are on rock rubble that was originally placed to permit the drill rig access to the well locations and were excluded from the survey. All vascular plants within one metre of the transect centerline were identified for the length of the transect.

The fixed sample plots were established at distances of 15 metres and 25 metres from each transect end point; one fixed plot was located between 15 metres and 25 metres southwest of OW-30, and a second fixed plot was located between 15 metres and 25 metres northeast of OW-31 (see locations on Figure 5). Each sample plot was a 10-metre x 10-metre square, with the corners marked by wooden stakes, with one side of the plot aligned with the transect centerline. Within each fixed plot, all vascular plants were identified, and cover values were estimated. Cover values were estimated for the tree canopy (more than 5 metres above the ground surface), the tall shrub layer (2 metres to 5 metres above the ground surface), the low shrub and tall herb layer (0.2 metres to 2 metres above the ground surface) and the ground layer (0 metres to 0.2 metres above the ground surface). Cover percentages for standing water, organic detritus and bare substrate were estimated for each fixed sample plot. Cover estimates were also made for ground-dwelling bryophytes, mosses and liverworts although individual species were not identified. It is expected that the vascular plants are as sensitive to changes in the moisture regime as are the mosses, and to simplify and streamline the monitoring process, no attention was directed to the identification of moss species, except to search for the presence of sphagnum moss.

Photographs are taken at the center of each fixed plot to document conditions at the time of the survey and provide representative images for future comparisons. Photographs are taken using a camera level of approximately 1.7 metres above the ground surface and facing in each of the four cardinal points of the compass (i.e., north, west, south and east) for a total of four photographs in each fixed plot.

To date, the vegetation monitoring program has been completed using the established transect and fixed sample plots in 2011, 2012, 2013, 2015, 2017 and 2021. The next vegetation monitoring session will be in summer 2025.

The results of the most recent vegetation monitoring session (summer 2021) are summarized below.

3.2.3.1 Results

3.2.3.1.1 Plant Community

The plant community intersected by the survey transect and the fixed sample plots is classified as a thicket swamp, based on Ecological Land Classification (ELC) for southern Ontario (Lee *et al*. 1998). The wetland community is dominated by shrubs, with a moderately high diversity of species. Different dominants occur along different sections of the survey transect, forming a mosaic of different community patches. Speckled alder (*Alnus incana* ssp. *rugosa*) is the most abundant shrub in this community and is a frequent but patchy dominant. Patches of red osier dogwood (*Cornus stolonifera*) and of pussy willow (*Salix discolor*) are also scattered through the thicket community and are locally dominant in smaller areas than those occupied by the speckled alder. Trees occur frequently in the community but mostly as scattered individuals and occasionally as small clusters of two or three stems. Generally, the trees are associated with small, irregular hummocks. The hummocks generally support species of plants that are less tolerant of extended flooding and, occasionally host upland plants, as mentioned in the discussion of vascular plants, below.

The community canopy is relatively open and there is a high diversity of ferns, graminoids (plants with a grass-like appearance) and forbs (flowering herbaceous plants that are not graminoids) in the ground cover layer of this community. However, many of the species that contribute to this diversity have a low frequency, meaning that they occur mainly as single scattered stems and are not abundant in the wetland. Because the diversity of ground cover species is high, a distinction has been made between the tall herb layer (0.2 metres to 2 metres high) and the low herb and creeping shrub layer (0 metres to 0.2 metres high) in the compilation of species cover values. Mosses and liverworts are a patchy component of the ground cover and make a relatively limited contribution to the biomass. Based upon the fixed plots, bryophytes may represent about 25 percent of the live ground cover. No sphagnum mosses were observed on the transect or in the fixed plots in any of the years of monitoring.

The estimated cover values observed in the fixed sample plots in 2011, 2012, 2013, 2015, 2017, and 2021 are summarized in the table below.

Table 6: Estimated Vegetation Cover in Fixed Sample Plots During the Wetland Monitoring Program from 2011 to 2021

Year	2011		2012		2013		2015		2017		2021	
Vegetation Layer	Plot #1	Plot #2	Plot #1	Plot #2	Plot #1	Plot #2	Plot #1	Plot #2	Plot #1	Plot #2	Plot #1	Plot #2
Canopy (>5 m)	8%	6%	10%	12%	5%	9%	5%	10%	4%	15%	5%	10%
Understorey (2 m - 5 m)	38%	22%	28%	20%	38 %	40%	35%	40%	45%	35%	50%	50%
Tall ground cover (0.2 m - 2 m)	49%	57%	40%	55%	25 %	20%	25%	25%	45%	29%	45%	40%
Low ground cover (<2 m)	6%	5%	12%	8%	36 %	40%	35%	40%	35%	15%	30%	15%
Organic detritus	5%	10%	10%	8%	5%	5%	5%	5%	3%	5%	2%	6%
Open water	1%	2%	>1%	0%	1%	2%	1%	2%	5%	4%	4%	3%

Because there is overlap between each layer of vegetation and each layer was estimated independently, the values total to more than 100 percent. This is not uncommon in communities with an open canopy where shading is limited, and plants can grow under the tree and shrub canopy. The composition, structure and spatial distribution of plants in the thicket swamp are characteristic for the community-type in this area of the province (eco district 6E-9 [Lindsay 1986]).

The slight differences between the values estimated in 2011 and 2012 are not considered to represent any significant difference in the community structure. However, the values estimated in 2013 and 2015 are quite different from those determined in the previous two years. This is largely a function of the late date of the 2013 and 2015 surveys which allowed the ground cover layers more time to develop. The 2017 and 2021 surveys were also conducted towards the end of August similar to the surveys conducted in 2013 and 2015. The values estimated in 2021 are not significantly different from those estimated in 2015 and 2017, with the exceptions of a slight increase in understory vegetation and tall ground cover in the plots.

There are no trees in the two sample plots, but there are trees close to the boundaries of both plots. It is difficult to accurately estimate how much of each of the plot areas is covered by the portion of the tree canopies. There are similar difficulties in estimating the tall shrub canopy. Combined with seasonal variation in the progress of the season from one year to the next, the variation in cover estimates between years can be relatively high. Nonetheless, the values are sufficiently similar to indicate that no structural change has occurred between 2011 and 2021. This conclusion is also supported by the general observations that were made during the perimeter survey of the wetland and during the examination along the survey transect. The community appearance, structure and general composition in 2021, overall were unchanged from the conditions observed in 2011.

3.2.3.1.2 Vascular Plants

In 2021, the plants identified along the vegetation transect and in the two fixed plots include 10 species of trees, 19 species of shrubs and woody vines, 6 species of ferns and fern allies, 9 species of graminoids and 37 species of forbs (see Table F1 in Appendix F). The most abundant and frequent species documented are characteristic of wetlands such as speckled alder, dwarf birch (*Betula pumila*), red osier dogwood and slender willow (*Salix petiolaris*). However, as in past surveys, a few infrequent and widely scattered upland species, such as Canada mayflower (*Maianthemum canadense*), red raspberry (*Rubus idaeus*) and starflower (*Trientalis borealis*), were also present due to raised hummocks where soils were sufficiently dry to permit the establishment of upland plants.

The number of species documented in 2021 (81) is similar to the numbers documented in 2015 (86) and 2017 (79). These minor discrepancies are considered a reflection of a typical variation in observations and are not considered to represent significant changes in species composition from one survey event to another. Also, although the corners of the fixed plots have been staked and the segments of the survey transect have been flagged, there are slight year to year discrepancies in the boundaries of the survey units. Emphasis is placed on the general similarity of year-over-year data rather than on these small discrepancies.

None of the species documented on the survey transect or in the fixed sample plots are uncommon in the province and none have special conservation status. Four new species were documented on the transect and within the sample plots in 2021 including: an unknown oak species (*Quercus sp.*), limber honeysuckle (*Lonicera dioica*), three-way sedge (*Dulichium arundinaceum*) and Loesel's twayblade (*Liparis loeselii*). Only three species of the 107 documented in the survey plots and transect are non-native species, reflecting the relatively limited extent to which non-native plants have established in this portion of the wetland.

3.2.3.1.3 Reference Photographs

The photographs taken at the center of each fixed plot during the 2021 assessment are included in Appendix F. As well as documenting conditions in the fixed plots at the time of the survey, they are considered representative of the general community. The photographs taken in 2021 do not show any marked difference from those taken in previous years. Like the photographs taken in previous years, those from 2021 will be archived to provide a basis for visual comparisons with those taken in future monitoring programs.

3.2.3.2 Discussion

Conditions in the wetland have not demonstrated a measurable change since the wetland monitoring began in 2011. Conditions at the time of the 2021 survey were similar to 2017 with some areas of standing water. There were no distinctive changes in the vegetation types or structure. The slight compositional changes that appear in the transect segments on a year-over-year basis are attributed to the slight yearly differences in the seasonal development of the vegetation at time of each survey and the small discrepancies that occur with respect to the location and width of the transect between each survey. Although every effort is made to maintain consistency between surveys, plants at the edge of a survey plot may sometimes be considered ‘in’ and other times may be considered ‘out.’ As well, species that are in flower at the time of the survey are invariably more distinctive and readily identified than are those that are not in flower. However, the variability resulting from this latter circumstance was considered minor.

3.2.3.3 Conclusions and Future Monitoring

Based upon the wetland monitoring surveys conducted between 2011 and 2021, no identifiable change has occurred in the surveyed area of the wetland adjacent to the Brechin Quarry.

Using the survey locations and protocols described above, the next monitoring will be conducted in 2025 to collect data that can be compared to those collected in the previous years of monitoring. Where possible, WSP will schedule future wetland monitoring surveys around the same time as the 2021 wetland monitoring survey. A summary of the conditions and results of the 2025 vegetation monitoring will be provided in the PTTW annual monitoring report.

3.2.4 Trigger Assessment

Trigger levels were previously established at the site in consultation with the MNR and MECP to limit the potential for adverse impacts to the adjacent wetland. Table 7 provides a list of the trigger locations, the formation monitored at each location and the approximate proximity to the mapped wetland boundary.

Table 7: Trigger Locations

Location	Monitoring Zone	Approximate Proximity to Mapped Wetland Boundary
OW-4C	Bobcaygeon Formation (water table)	20 metres outside wetland
OW-10C	Bobcaygeon Formation (water table)	90 metres outside wetland
OW-15C	Bobcaygeon Formation (water table)	60 metres outside wetland
OW-19C	Bobcaygeon Formation (water table)	80 metres outside wetland
OW-28	Bobcaygeon Formation (water table)	60 metres outside wetland
OW-29C	Bobcaygeon Formation	130 metres inside wetland
OW-29D	Overburden (water table)	130 metres inside wetland
OW-30C	Bobcaygeon Formation	120 metres inside wetland

Location	Monitoring Zone	Approximate Proximity to Mapped Wetland Boundary
OW-30D	Overburden (water table)	120 metres inside wetland
OW-31C	Bobcaygeon Formation	130 metres inside wetland
OW-31D	Overburden (water table)	130 metres inside wetland
PW-3	Bobcaygeon Formation (water table)	160 metres outside wetland
MWPSW-3	Overburden (water table)	5 metres inside wetland
MWPSW-4	Overburden (water table)	5 metres inside wetland
SG06-1	Surface water	75 metres inside wetland
SG06-2	Surface water	25 metres inside wetland
SG09-3	Surface water	25 metres inside wetland
SG09-4	Surface water	25 metres inside wetland

The trigger locations were primarily selected based on their proximity to the wetland. Monitoring well locations OW-4C, OW-10C, OW-15C, OW-19C and OW-28 represent the monitoring wells closest to the wetland boundary, but still outside the wetland. Monitoring well/staff gauge locations OW-29C, OW-29D, OW-30C, OW-30D, OW-31C, OW-31D, MWPSW-3, MWPSW-4, SG06-1, SG06-2, SG09-3 and SG09-4 are the available shallow monitoring wells (i.e., shallow bedrock or overburden) and surface water monitoring locations found within the wetland.

3.2.4.1 Trigger Levels

Detailed water level plots, including precipitation data and pumping records for the quarry are provided for each monitoring well trigger location in Appendix G. The detailed water level plot for the staff gauge locations is provided in Appendix E.

3.2.4.1.1 Safety Trigger Level

As shown on the detailed water elevation plots in Appendix G, 'safety trigger level' has been assigned at each trigger location based on the available water elevation data. The elevation of the safety trigger level is set equal to the lowest recorded water elevation at each location, except for locations OW-15C and OW-31C where a slightly higher, more representative safety trigger level was selected. For locations MWPSW-3, MWPSW-4 and SG06-1, SG06-2, SG09-3 and SG09-4, the safety trigger level is set at the 'dry' level because all of these locations have gone dry in the past as a result of natural variations in water levels at the site.

The purpose of the safety trigger level is to act as an early alert trigger. If the water level at any of the trigger locations drops below the lowest level observed during the previous natural variations at that location, it would trigger the review of the available water level data and local precipitation data to confirm if the low water level is the result of site operations, or a wide-spread low-water condition unrelated to site operations. In addition, to assist in assessing the cause of the observed lower water level at the trigger location(s), a groundwater level review of the data for all monitoring wells included in the PTTW monitoring program would be used to interpret the current extent of the groundwater level drawdown cone associated with the dewatering of the existing on-site quarry.

If the results of the water level assessment indicate that the drop in water level at the trigger location is the result of a wide-spread seasonal low-water condition, and a review of the on-site groundwater data confirms the drawdown cone has not reached the triggering location(s), no immediate action is required, and ongoing monitoring would continue to follow the program specified in the PTTW. In this situation, the groundwater level data would be considered to represent natural variations, and the associated safety trigger level would be adjusted accordingly. If the water level at the trigger location continues to decline to the 'action trigger level', then additional actions will be required.

3.2.4.1.2 Action Trigger Level

As shown on the detailed water level plots in Attachment G, an 'action trigger level' has been assigned at each trigger location based on the available water level data with the exception MWPSW-3, MWPSW-4, SG06-1, SG06-2, SG09-3 and SG09-4 (discussed further below). The action trigger level was set equal to 0.5 metres below the safety trigger level for all locations having at least one metre of total variation observed in the historical water level record. For locations having less than one metre of total variation, the action trigger level was set at a level equal to half the total variation observed at the location below the safety trigger level.

Action Trigger levels cannot be assigned at locations MWPSW-3, MWPSW-4, SG06-1, SG06-2, SG09-3 and SG09-4 because these locations have historically gone dry. As a result, the safety trigger is at the dry level, and the development of a lower trigger level is not feasible; however, an action trigger period can be developed (as discussed in Section 3.2.4.2).

It should be noted that if the review of available on-site water level data indicates that the drawdown cone associated with the on-site quarry has not reached the trigger location that is below the action trigger level, no further action is required, and the action trigger levels would be adjusted accordingly to reflect the additional baseline groundwater level data. If it is determined that the decrease in water level to below the action trigger level is due to on-site quarry operations, the required actions described in Table 4 of Golder (2019a) will be initiated. For reference, a copy of Table 4 from Golder 2019a is provided in Appendix H.

3.2.4.2 Trigger Periods

The safety trigger periods and action trigger periods have specific activities that are required when the water level at the trigger location has been below 'normal' for a prolonged period of time, or for trigger locations that have gone dry in the past, the dry period extends longer than previously observed. The trigger periods were proposed in response to the MNR recommendation received on May 28, 2019.

The trigger periods are defined for a subset of trigger locations (trigger period locations) that are in direct contact with the wetland (i.e., shallow overburden monitoring wells within the wetland and staff gauge locations) where the potential exists for impacts to the wetland if the water levels are depressed below 'normal' for a prolonged period (i.e., significantly beyond what has been observed in the historical water level record). The locations where the safety and action trigger periods will be assigned are OW-29D, OW-30D, OW-31D, MWPSW-3, MWPSW-4, SG06-1, SG06-2, SG09-3 and SG09-4. Trigger locations found outside the wetland, or at depth in the wetland (i.e., bedrock monitoring intervals in the wetland), will not have assigned trigger periods.

Additional details about the safety and action trigger periods (including tables providing the safety and action period durations and required actions) taken from Section 4.0 of the Trigger Levels and Mitigation Measure Document (Golder 2019a) are provided in Appendix H.

3.2.4.3 PTTW Trigger Assessment

Detailed water level plots, including precipitation data and pumping records for the quarry are provided for each monitoring well trigger location in Appendix G. The detailed water level plot for the staff gauge locations is provided in Appendix E. The most recent trigger assessment (2024) is summarized in Table 8.

Table 8: Trigger Assessment

Location	Safety Trigger Level (mASL)	Action Trigger Level (mASL)	Minimum 2024 Water Elevation (mASL)	Safety Trigger Period (days)	Action Trigger Period (days)	2024 Maximum Duration Below Average Water Level or Maximum Dry Period
OW-4C	246.13	245.63	246.20	NA	NA	NA
OW-10C	246.68	246.18	246.66	NA	NA	NA
OW-15C	245.69	245.19	245.99	NA	NA	NA
OW-19C	246.32	245.82	247.02	NA	NA	NA
OW-28	245.48(1)	245.07	246.60	NA	NA	NA
OW-29C	246.01	245.51	246.43	NA	NA	NA
OW-29D	246.28	245.84	246.66	238	357	0
OW-30C	246.12	245.65	246.31	NA	NA	NA
OW-30D	246.33	245.92	246.69	243	364	0
OW-31C	245.61(2)	245.46	245.38	NA	NA	NA
OW-31D	246.02	245.63	246.47	234	351	0
PW-3	247.09	246.59	246.92	NA	NA	NA
MWPSW-3	dry	NA	246.45	275	365	0
MWPSW-4	dry	NA	246.78	190	285	0
SG06-1	dry	NA	246.89	71	106	0
SG06-2	dry	NA	dry	172	258	62
SG09-3	dry	NA	dry	173	260	94
SG09-4	dry	NA	246.54	160	240	0

Notes:

- location below safety trigger level (yellow)

- location below action trigger level (green)

(1) The safety trigger level at OW-28 was changed from 245.57 mASL to 245.48 mASL during 2019. The water level at OW-28 dropped to 245.48 mASL and was interpreted to be the result of natural variations and not to be the result of quarry dewatering (i.e., the drawdown associated with quarry dewatering has not reached this location).

(2) The safety trigger level at OW-31C was changed from 245.66 mASL to 245.61 mASL during 2021. The water level at OW-31C dropped to 245.60 mASL and was interpreted to be the result of natural variations and not to be the result of quarry dewatering (i.e., the drawdown associated with quarry dewatering has not reached this location).

3.2.4.3.1 Trigger Levels

As shown in Table 8 and on Figures G1 through G13, and Figure E1 (staff gauge locations), the safety trigger level was reached at OW-10C, OW-31C, PW-3, SG06-2 and SG09-3 during 2024 and the safety and action triggers were reached at OW31-C. The water levels at all other locations remained above the safety trigger.

3.2.4.3.1.1 SG06-2 and SG09-3

SG06-2 was dry for August and September 2024 and SG09-3 was dry for September through December 2024. Based on historical data, these locations typically go dry for a portion of each year. Based on a review of groundwater levels at the site, the drawdown cone from the existing quarry extends in the shallow bedrock between 400 and 500 metres from the extraction area. No drawdown associated with the quarry dewatering is observed at the overburden monitors within the wetland. Because there is no impact on overburden groundwater levels as a result of quarry dewatering in the vicinity of the wetland, the surface water elevations collected at the staff gauges in 2024 are interpreted to be representative of the natural variation of water levels in the wetland. Overall, the dry conditions at SG06-2 and SG09-3 locations during 2024 were not attributed to the ongoing dewatering at the Brechin Quarry and no further action was required.

3.2.4.3.1.2 OW-31C

A gradual decline in groundwater elevations at OW-31C has been observed since September 2022. Between August 2023 and January 2024, the groundwater elevation at OW-31C declined below the level typically observed at this location. The groundwater elevation returned to typical range in April/May 2024. Between June 2024 and December 2024, the groundwater elevation at OW-31C declined below the safety and action trigger levels. Based on data gathered up to May 2025, the groundwater elevation at OW-31C has increased to above the action trigger level, but has not returned to typical levels and remains below the safety trigger level. The total decline in groundwater elevations at OW-31C between September 2022 and December 2024 is approximately 0.5 metres. OW-31C is located approximately 500 metres from the current quarry excavation. The observed lack of rise in the groundwater elevation at OW-31C following the spring melt in 2025 indicates that the groundwater level at this location is likely being influence by quarry dewatering.

Because the groundwater level decline at OW-31C is interpreted to be the result of quarry dewatering, and because the groundwater elevation has fallen below the action trigger level, the required actions listed in Table 4 of the Golder (2019a) trigger report must be initiated (see copy of Table 4 in Appendix H). Table 4 (Golder, 2019a) states the if the groundwater elevation at OW-31C falls below the action trigger level, the frequency of the data logger download at the overlying overburden monitoring interval (OW-31D) would be increased from quarterly to monthly. The data logger data for OW-31D confirms that the groundwater elevation at OW-31D remains stable and is well above the safety trigger (see Figure G11 in Appendix G). Because the groundwater elevation at OW-31D remains stable, the only action required at this time is ongoing monthly downloading of the data logger at OW-31D.

3.2.4.3.1.3 PW-3

During 2024, the groundwater level at PW-3 was slightly below the safety trigger level of 247.09 mASL during the August and October monitoring sessions. The lowest groundwater level during this period was 246.92 mASL. The groundwater elevations at this location in November and December 2024 were well above the safety trigger level (see Figure G12 in Appendix G).

Based on the assessment of water levels at the site, the drawdown cone associated with the dewatering of the existing excavation at the site is interpreted to extend in the upper bedrock approximately 400 to 500 metres to the east from the limits of the existing quarry extraction area (i.e., in the direction of the adjacent wetland). PW-3 is located approximately 350 metres from the current excavation. Monitoring well locations that have been impacted by quarry dewatering at the site typically show a rapid decline in groundwater elevation of one to two metres, and the groundwater elevation typically does not return to pre-impact levels observed at the location. The groundwater elevation plots for OW-26 and OW-27 in Appendix C display the typical response of a well location impacted by quarry dewatering. Because the groundwater elevation at PW-3 has rapidly risen above the safety trigger level and remained above the safety trigger level for November and December 2024 and January through March 2025, this location is not interpreted to be influence by quarry dewatering. At this time, the safety trigger is not being lowered at PW-3 until additional information is gathered to confirm if the observed decline in water levels in the result of natural variations at this location.

3.2.4.3.1.4 OW-10C

During 2024, the groundwater elevation at OW-10C was slightly below the safety trigger level of 246.68 mASL for one day on November 11, 2024. The groundwater elevation at OW-10C on November 11, 2024 was 246.66 mASL. For the remainder of 2024, the groundwater elevation at OW-10C was well above the safety trigger level (see Figure G2 in Appendix G). Based on the assessment of water levels at the site, the drawdown cone associated with the dewatering of the existing excavation at the site is interpreted to extend in the upper bedrock approximately 400 to 500 metres from the limits of the existing quarry extraction area. OW-10C is located greater than 750 metres from the existing extraction at the site and the groundwater elevation at this location is not interpreted to be influenced by quarry dewatering. During 2024, the summer and fall were quite dry. The measured groundwater level at OW-10C slightly below the safety trigger is interpreted to be the result of natural variations and not to be the result of quarry dewatering. As such, the safety trigger level should be adjusted accordingly (see Section 3.2.4.3.3 below).

3.2.4.3.2 Trigger Periods

As shown in Table 8 and in Figures G1 through G13 and Figure E1 (staff gauge locations), no safety or action trigger periods were exceeded during 2024.

3.2.4.3.3 Proposed Modifications to Trigger Levels or Trigger Periods

The measured groundwater elevation at OW-10C on November 11, 2024 was slightly below the safety trigger and is interpreted to be the result of natural variations and not to be the result of quarry dewatering. As such, the safety trigger level at this location will be reduced from 246.68 mASL to 246.66 mASL moving forward. There are no other proposed modifications to trigger levels or trigger periods as part of the 2024 assessment.

3.2.5 2024 PTTW Impact Assessment

The following provides the most recent impact assessment (2024) based on the available PTTW monitoring data. The impact assessment considers the potential impact to existing groundwater users as well as the adjacent wetland based on the groundwater levels measured to date at the Brechin Quarry.

3.2.5.1 Existing Groundwater Users

The following provides an impact assessment focused on potential impacts to existing groundwater users in the vicinity of the Brechin Quarry. The impact assessment is based on the available well completion details for nearby private wells and the currently available groundwater level data.

As part of the hydrogeological assessment completed in support of the ARA license application for the Brechin Quarry, a private well survey was completed in 2006 for wells within 1.5 kilometres of the site (Golder, 2007). Figure 3 shows the locations of the private wells identified as part of the private well survey. The wells are located to the west of the site, and are primarily found along Scotts Road, Mara Carden Boundary Road and Concession Road 6.

The closest water supply wells to the site are identified as MARA-3405 and SCOT-71 on Figure 3 and are located approximately 600 metres from the Brechin Quarry. Based on available information, MARA-3405 is a drilled well that is 17.37 metres deep. Based on the regional dip of the rock formations in the vicinity of the site, the depth to the green beds (i.e., transmissive unit within the upper part of the Gull River Formation) at MARA 3405 is 13.8 metres, and the green beds are assumed to be about 2 metres thick. As such, based on the available information, MARA-3405 is interpreted to intersect the Gull River Formation green beds and have a bottom elevation of about 219.6 m ASL.

As shown on Figure 3, off-site monitoring well OW-32 is ideally located for assessing potential impacts to MARA 3405. Monitoring interval 'C' at OW-32 is completed in green beds of the Gull River Formation. In late November 2022, the property owner where OW-32 is located requested that WSP no longer access their property for measuring groundwater levels. As such, groundwater levels were not measured at this location in 2024. Based on a review of the 2017 through 2022 groundwater level data collected at OW-32C following the quarry floor buckling, the groundwater level at OW-32C remained within the typical range observed at this location. During 2024, the on-site monitoring well locations completed in the green beds of the Gull River Formation along the western side of the site (i.e., OW-38A, OW-39 and MW-4A) did not display significant declines in groundwater elevations. As such, it is not expected that the groundwater elevation at OW-32C would have declined during 2024. As a result, interference with the water supply at MARA-3405 is not anticipated.

Based on a review of available information, SCOT-71 is a drilled well that is 16.15 metres deep. Based on the regional dip of the rock formations in the vicinity of the site, the depth to the top of the Gull River Formation is approximately 22.3 metres, and the depth to the top of the overlying Bobcaygeon Formation is approximately 11.4 metres. As such, based on the available information, SCOT-71 is interpreted to be completed in the Bobcaygeon Formation. The available groundwater level data from the on-site and off-site monitoring wells indicate groundwater levels in the Bobcaygeon Formation have not been significantly influenced by the decline in groundwater levels at the site in the green beds of the Gull River Formation or as a result of quarry dewatering at the site. As a result, interference with the water supply at SCOT-71 is not anticipated.

Many of the remaining identified locations (i.e., Con6-1018, MARA-3263, MARA-3248, MARA-3225, SCOT-19 and SCOT-23) were supplied by dug wells at the time of the private well survey in 2006. Interference with dug wells is not predicted as a result of the buckling at the Brechin Quarry or progressive development of the quarry over time.

MARA-3546 is located close to off-site monitoring well OW-33. All monitoring well intervals at OW-33 are within the typical range of water levels observed at the monitoring intervals prior to the buckling. As a result, interference with the water supply at MARA 3546 is not expected as a result of the buckling at the site or progressive development of the quarry over time.

Overall, based on the analysis of the available groundwater level data and our current understanding of the completion details for water supply wells in the vicinity of the site, it is WSP's opinion that the decline in groundwater levels in the green beds of the Gull River Formation at the Brechin Quarry property poses a low risk in terms of interfering with local private water supply wells. In the five years since the buckling occurred at the site, Tomlinson has received no complaints from local residents relating to water supply.

3.2.5.2 Local Surface Water Receptors

The primary surface water receptor in the vicinity of the Brechin Quarry is the wetland located along the eastern periphery of the property. As described in Section 3.2.4, trigger levels and trigger periods have been developed to limit the potential for adverse impacts to the adjacent wetland.

Based on a review of available groundwater level data for the monitoring wells completed in the vicinity of the wetland, the drawdown cone associated with the dewatering of the Brechin Quarry is not impacting water levels in the overburden beneath the wetland (i.e., the material in direct contact with the water within the wetland). As such, impacts to the water level in the wetland as a result of the progressive development of the Brechin are not occurring at this time.

3.2.6 PTTW Monitoring Conclusions

Based on monitoring data collect to date, the dewatering at the site has not resulted in an identifiable lowering of groundwater elevations in the deeper Bobcaygeon Formation monitors (i.e., below the water table at the site). Given that the available groundwater level data for monitoring wells completed in the deeper portion of the Bobcaygeon Formation show no response to the water taking at the site, it is interpreted that the groundwater elevations in these monitoring wells represent natural variation in groundwater levels within this hydrostratigraphic unit.

There was a widespread measured decline in groundwater elevations within the green beds of the Gull River Formation following the quarry floor bucking in March 2017. This widespread decline stabilized shortly after the quarry floor buckling occurred and there has been no indication that the progressive development of the Brechin Quarry since March 2017 has had any appreciable additional effect on groundwater levels in the green beds of the Gull River Formation.

Based on the analysis of the available groundwater level data and our current understanding of the completion details for water supply wells in the vicinity of the site, it is WSP’s interpretation that the buckling that occurred on the Brechin Quarry property in March 2017 posed a low risk in terms of interfering with local private water supply wells. Similarly, the ongoing progressive development of the Brechin Quarry and the development of the groundwater level drawdown (in the upper bedrock) associated with quarry dewatering also poses a low risk in terms of interfering with local private water supply wells. To date, Tomlinson has received no complaints from local residents relating to water supply since the buckling occurred.

The drawdown cone associated with the dewatering of the existing excavation at the site is interpreted to extend in the upper bedrock approximately 400 to 500 metres to the east from the limits of the existing quarry extraction area (i.e., in the direction of the adjacent wetland). The extent of the drawdown cone in the upper bedrock is interpreted to be beneath the western edge of the wetland. Based on a review of available groundwater level data and the results of the 2024 trigger assessment, there is no indication that progressive development of the quarry over time has impacted overburden groundwater levels or surface water levels within the wetland. As such, impacts to the wetland are not predicted.

4.0 CURRENT INVESTIGATION METHODS AND RESULTS

4.1 Hydrogeological Investigation

As part of the current investigation, a hydrogeological/hydrological assessment in support of the ARA amendment application for deepening the existing Brechin Quarry was completed. The assessment involved the following tasks:

- Reviewing and compiling the results of previous work completed at the site (see Sections 2.0 and 3.0)
- Borehole drilling program and geophysical logging
- Monitoring well installation program
- Hydraulic conductivity testing
- Groundwater level monitoring program
- Groundwater flow modelling
- Assessment of potential impacts to surrounding receptors related to the development and rehabilitation of the proposed deepened Brechin Quarry

The investigation methods and results for the current study are presented in the sections below.

4.1.1 Borehole Drilling Program and Geophysical Logging

Four new boreholes were completed to support the Brechin Quarry deepening amendment application. The new boreholes are identified as OW-38 through OW-41 and the borehole locations are shown on Figure 5. The boreholes allow for additional assessment of the geological formations (through geophysical logging), and provided locations for undertaking in-situ hydraulic testing and installation of groundwater monitoring wells.

OW-38 was drilled southeast of the intersection of Scotts Road and Miller Road near existing monitoring well OW-1. OW-1 was terminated above the Gull River Formation. OW-38 was completed deeper than OW-1 to provide an opportunity to install a monitoring well in the green beds of the Gull River Formation at this location. OW-39 was completed along the western boundary of the existing quarry extraction in the north extraction area. OW-40 was completed in the central portion of the northern extraction area and OW-41 was completed in the central portion of the northern boundary of the northern extraction area.

Table 9 below summarizes the borehole drilling details for OW-38 through OW-41.

Table 9: Borehole Drilling Details (OW-38 through OW-41)

Location	Overburden Thickness	Total Depth (m)	Ground Surface Elevation (mASL)	Bottom Elevation of Borehole (mASL)
OW-38	0.5	46	254.43	208.43
OW-39	NA*	20	225.31	205.31
OW-40	0.5	32	245.41	213.41
OW-41	0.5	30	242.42	212.42

* OW-39 was completed on the floor of the existing quarry.

After drilling was completed at OW-38 through OW-41 each location was geophysically logged. The logging suite included apparent conductivity and natural gamma logs. The conductivity and gamma logs were used in conjunction with WSP's knowledge of the geophysical signatures of the bedrock formations obtained during the preparation of the original licensing application to assess the bedrock stratigraphy at the new borehole locations. The results of the geophysical logging are provided on the logs in Appendix I and are summarized in Table 10 below.

Table 10: Formation Thickness and Contact Elevations (OW-38 through OW-41)

Location	Ground Surface Elevation (mASL)	Top of Verulam Formation (mASL)	Thickness of Verulam Formation (m)	Top of Bobcaygeon Formation (mASL)	Thickness of Bobcaygeon Formation (m)	Top of Gull River Formation (mASL)	Top of Green Beds of Gull River Formation (mASL)
OW-38	254.43	253.93	5.3	248.63	26.9	221.73	216.43
OW-39	225.31	not present	NA	NA*	NA*	223.41	217.81
OW-40	245.41	not present	NA	244.91	19.2	225.71	220.21
OW-41	242.42	not present	NA	241.92	14.6	227.32	221.92

* OW-39 is completed on the floor of the existing quarry and most of the Bobcaygeon Formation has been removed.

As shown in Table 10, the Verulam Formation was not encountered at OW-39, OW-40 and OW-41. This is consistent with the previous boreholes completed at the site. The thickness of the Bobcaygeon Formation and elevation of the green beds of the Gull River Formation at OW-38 through OW-41 were consistent with the previously interpreted geology for the Brechin Quarry property.

4.1.2 Monitoring Well Installation and Elevation Surveying

Following borehole drilling, groundwater monitoring wells were constructed in each borehole to allow for the measurement of groundwater levels and to obtain estimates of horizontal hydraulic conductivity and gradients within the bedrock encountered at each location. The preferred locations for the screened intervals of the monitoring wells within the boreholes were determined based on the interpretation of the geophysical logging. The intension was to install monitoring wells in the upper weathered bedrock and in the green beds of the Gull River Formation. Two monitoring wells were installed at OW-38, OW-40 and OW-41. Because OW-39 was drilled on the floor of the existing quarry the upper weather bedrock had been removed, so one monitoring well was installed in the green beds at this location. The conversion of the boreholes into monitoring wells was completed by WSP's licensed well contractor.

All monitoring wells were constructed of 32-mm diameter, threaded, PVC slot #10 screen and solid risers. Clear stone supplied by Tomlinson was placed in the boreholes around the screened portions of the monitors and bentonite was used to provide seals between the screened intervals. A near surface bentonite seal was installed within each borehole. A survey of the ground surface and top of casing for the monitoring wells was completed by Tomlinson (see elevation data in Table 11 below).

The deepest monitoring well installation at each drilling location is designated as monitoring well "A", and where present the shallower monitoring well was designated as monitoring well "B". The monitoring wells were developed following their installation prior to undertaking hydraulic conductivity testing and groundwater level measurements. The monitoring well installation details are shown on the borehole logs in Appendix I, and a summary of the monitoring well completion details for OW-38 through OW-41 is provided below.

Table 11: Monitoring Well Installation Details (OW-38 through OW-41)

Location	Ground Surface Elevation (mASL)	TOP Elevation (mASL)	Screened Interval (mASL)
OW-38A	254.43	254.65	210.43 – 219.43
OW-38B	254.43	254.67	247.43 – 252.93
OW-39	225.31	226.62	212.81 – 220.81
OW-40A	245.41	246.61	213.51 – 222.51
OW-40B	245.41	246.60	237.41 – 243.41
OW-41A	242.42	243.65	216.92 – 223.42
OW-41B	242.42	243.67	234.42 – 240.42

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

4.1.3 Hydraulic Conductivity Testing

Well response tests were carried out in the monitoring intervals installed in OW-38 through OW-41. The testing was completed using the rising/falling head method. The well response tests provide an estimate of the horizontal hydraulic conductivity of the bedrock adjacent to the monitoring well interval.

The falling-head test consists of rapidly inserting a slug of known volume into the monitoring well. The subsequent decline in groundwater level within the well is then monitored over time. Once the groundwater level returned to the original static level, or close to the original static level, the rising-head test was initiated. The rising-head test consists of rapidly removing the slug and monitoring the subsequent rise in groundwater level within the monitoring well over time.

Well response tests were conducted on September 27 and 28, 2022. The results of the in-situ hydraulic conductivity testing are summarized in Table 12. The screened interval elevation and comments relating to the interval tested are also provided.

Table 12: Hydraulic Conductivity Testing Results (OW-38 through OW-41)

Location	Screened Interval (mASL)	Analysis Method	Hydraulic Conductivity (m/sec)	Formation Tested	Notes
OW-38A	210.43 – 219.43	Horslev	7×10^{-8}	Gull River	rising-head test presented
OW-38B	247.43 – 252.93	Bouwer and Rice	1×10^{-7}	Verulam and Upper Bobcaygeon	rising-head test presented
OW-39	212.81 – 220.81	Horslev	2×10^{-8}	Gull River	rising-head test presented
OW-40A	213.51 – 222.51	Butler	3×10^{-4}	Gull River	falling-head test presented
OW-40B	237.41 – 243.41	Bouwer and Rice	4×10^{-6}	Bobcaygeon	falling-head test presented

Location	Screened Interval (mASL)	Analysis Method	Hydraulic Conductivity (m/sec)	Formation Tested	Notes
OW-41A	216.92 – 222.92	Horslev	2×10^{-5}	Gull River	rising-head test presented
OW-41B	234.42 – 240.42	Horslev	2×10^{-5}	Bobcaygeon	falling-head test presented

For all monitoring intervals with the exception of OW-38B, OW-40A and OW-40B, the hydraulic testing data was analyzed using the Hvorslev method (1951). The Butler (1998) method was used to analyze the data for OW-40A due to the oscillating response observed in the early portion of the testing data. The Bouwer and Rice (1976) method was used to analyze the data from OW-38B and OW-40B because the initial static water level was within the sand pack interval. To remain conservative, if the falling- and rising-head tests provided different results, the higher value was reported. The results of the hydraulic conductivity analyses are provided in Appendix J.

Based on the hydraulic testing at OW-38 through OW-41, the hydraulic conductivity of the near surface bedrock Verulam/upper Bobcaygeon measured at OW-38B, OW-40B and OW-41B ranged between 1×10^{-7} metres per second (m/sec) and 2×10^{-5} m/sec and the geometric mean was 2×10^{-6} m/sec. The hydraulic conductivity of the Gull River Formation measured at OW-38A, OW-39, OW-40A and OW-41A ranged between 7×10^{-8} m/sec and 3×10^{-4} m/sec and the geometric mean was 1×10^{-6} m/sec.

The hydraulic conductivity results for OW-38 through OW-41 fall within the range previously observed for the shallow bedrock and Gull Rivier Formation for the ARA licensing investigations (Golder, 2007).

4.1.4 Groundwater Level Monitoring

As discussed in Section 3.2.1 above, there is an extensive PTTW groundwater level monitoring program that has been undertaken at the Brechin Quarry. Although not included in the PTTW monitoring program, monthly groundwater level monitoring was initiated at OW-38 through OW-41 in July 2022. In September 2022, data loggers were installed in the Gull River Formation monitoring intervals (OW-38A, OW-39, OW-40A and OW-41A) to record daily groundwater levels.

Plots of groundwater elevations measured between July 2022 and December 2024 for the monitoring wells installed in OW-38 through OW-41 are provided in Appendix C. The groundwater elevation plots in Appendix C also include a table below the plot displaying groundwater elevation data. For locations without loggers, the table includes available manual groundwater levels. For locations with data loggers, the table includes a couple of years of manual groundwater levels, as well as a representative weekly groundwater level taken from the daily groundwater levels collected by the data logger.

4.1.4.1 OW-38

As shown on the plots in Appendix C, the groundwater elevations at OW-38A typically range between approximately 228 mASL and 232 mASL and the groundwater elevations at OW-38B typically range between 252 mASL and 254 mASL. At both locations, the highest groundwater elevations are typically measured in spring and the lowest groundwater elevations are typically measured in late summer. The groundwater elevations at both monitoring intervals are not interpreted to be impacted by quarry dewatering and the measured groundwater elevations represent seasonal variations.

4.1.4.2 OW-39

As shown on the plot in Appendix C, the groundwater elevations at OW-39 vary between approximately 225.8 mASL and 223.7 mASL. The groundwater elevations are generally stable and varied by approximately 1 metre until summer 2024 where the groundwater elevation dropped approximately 1 metre below the typical range observed at this location. Summer 2024 was quite dry, and a similar 1 metre decline was observed at other Gull River Formation monitors across the site. The groundwater elevations at OW-39 are not interpreted to be impacted by quarry dewatering and the measured groundwater elevations represent seasonal variations.

In November 2023, OW-3A became blocked at a depth of approximately 11.2 metres. Groundwater levels can no longer be measured at this location. OW-3A is completed in the green beds of the Gull River Formation and is located along the western boundary of the site, just southwest of the existing excavation (see location on Figure 5). Based on a review of the available groundwater elevation data, OW-39 has similar groundwater elevations to OW-3A. As such, the groundwater elevation data for OW-39 has been added to Figure D1 in Appendix D to allow for continuation of the assessment of the changes in groundwater elevations along the western side of the property in the Gull River Formation.

4.1.4.3 OW-40

As shown on the plots in Appendix C, the groundwater elevations at OW-40A vary between approximately 223.9 mASL and 226 mASL and the groundwater elevations at OW-40B vary between approximately 244 mASL and 245 mASL. The groundwater elevations at OW-40A are generally stable and varied by approximately 1 metre until summer 2024 where the groundwater elevation dropped approximately 1 metre below the typical range observed at this location. Summer 2024 was quite dry, and a similar 1 metre decline was observed at other Gull River Formation monitors across the site.

The groundwater elevations at OW-40B are generally stable and have historically varied by approximately one metre. The groundwater elevations at OW-40A and OW-40B are not interpreted to be impacted by quarry dewatering and the measured groundwater elevations represent seasonal variations.

4.1.4.4 OW-41

As shown on the plots in Appendix C, the groundwater elevations at OW-41A vary between approximately 223.8 mASL and 226.1 mASL and the groundwater elevations at OW-41B vary between approximately 240.5 mASL and 242 mASL. The groundwater elevations at OW-41A are generally stable and varied by approximately 1.25 metres until summer 2024 where the groundwater elevation dropped approximately 0.75 metres below the typical range observed at this location. Summer 2024 was quite dry, and a similar decline was observed at other Gull River Formation monitors across the site.

The groundwater elevations at OW-41B are generally stable and have historically varied by approximately 1.5 metres. The groundwater elevations at OW-41A and OW-41B are not interpreted to be impacted by quarry dewatering and the measured groundwater elevations represent seasonal variations.

4.1.5 Groundwater Flow Directions

Figure 6 and Figure 7 provide groundwater elevation contour plots for the water table (typically associated with the upper weathered portion of the bedrock) and the Gull River Formation (including the green beds layer), respectively. Based on previous investigations completed during the ARA application, these two hydrostratigraphic units were identified as having the greatest potential for impacting surrounding receptors if groundwater levels were lowered as a result of quarry dewatering (Golder, 2007). The groundwater elevation data presented on Figure 6 and Figure 7 are from December 11, 2024.

The groundwater elevations for OW-38 through OW-41 were added to the PTTW groundwater elevation data set to assist with developing the groundwater elevation contours for Figure 6 and Figure 7.

Figure 6 shows a groundwater elevation high in the vicinity of OW-1C and OW-38B, with shallow groundwater flow moving radially away from this location in the southern portion of the site. For the remainder of the site, the shallow groundwater flow direction is generally towards the west/northwest. As expected, there is some local shallow groundwater flow towards the quarry in the vicinity of the existing excavation.

Figure 7 shows the interpreted horizontal groundwater flow direction in the green beds of the Gull River Formation. Figure 9 shows a groundwater elevation high in the vicinity of OW-38A, with groundwater flow moving radially away from this location in the southern portion of the site. The groundwater elevation at OW-4A (edge of wetland in the central portion of the site) is higher than the other nearby on-site monitors completed in the green beds. As such, groundwater flow is generally away from this location.

Historically, along the western side of the site, the interpreted groundwater flow direction is towards the west/northwest due to the lower off-site groundwater elevation at OW-32C. In late November 2022, the property owner where OW-32 is located requested that WSP no longer access their property for measuring groundwater levels. As such, groundwater levels were not measured at this location in 2024. The absence of a groundwater elevation data for OW-32C (i.e., using only on-site groundwater elevation data) would result in an interpreted northerly flow direction along the western boundary. Based on historical assessments, this interpretation is not considered consistent with the actual groundwater flow direction within this area. To address this issue, a representative average groundwater elevation for OW-32C was used to draw the contours shown on Figure 9. The average value was calculated using all the available historical groundwater elevation data for OW-32C. This results in the interpreted groundwater flow direction in the northeastern portion of the site, and west of the site, being towards the west/northwest. This interpretation is considered to be more representative of actual groundwater flow conditions.

5.0 RECEPTOR IDENTIFICATION

5.1 Water Supply Wells

The area surrounding the Brechin Quarry is not serviced by a municipal water supply and thus is reliant upon groundwater supply wells for water. Extensive deposits of coarse grained and permeable overburden, capable of supplying sufficient quantities of groundwater for domestic use are typically not present within the vicinity of the site. As such, the bedrock is considered the principal unit for water supply. Given the marginal quality of the bedrock for water supply in the vicinity of the site, dug wells are present in some localized areas having greater thickness of coarse-grained overburden deposits (i.e., in the area surrounding the intersection of Scotts Road and Mara Carden Boundary Road).

As part of the hydrogeological assessment completed in support of the ARA license application for the Brechin Quarry, a private well survey was completed in 2006 for wells within 1.5 kilometres of the site (Golder, 2007). Figure 2 shows the locations of the private wells identified as part of the private well survey. The wells are located to the west of the site, and are primarily found along Scotts Road, Mara Carden Boundary Road and Concession Road 6.

The primary hydrogeological consideration with respect to nearest water supply wells is the development of the groundwater drawdown cone that is associated with quarry operations, and the potential for drawdown (depressurization) to cause an interruption of the water supply as a result of the lowering of water levels in the water supply wells. The potential for impacts to existing groundwater users are assessed as part of the impact assessment presented in Section 7.0.

5.2 Surface Water Receptors

There are three primary surface water receptors in the vicinity of the site. These include the north drainage feature, the south drainage feature and the Cranberry Lake Provincially Significant Wetland located along the eastern periphery of the property. As described in Section 3.2.4, trigger levels and trigger periods have been developed to limit the potential for adverse impacts to the adjacent wetland. The potential for impacts to surface water features are discussed in the impact assessment presented in Section 7.0.

6.0 GROUNDWATER FLOW MODELLING

As part of the hydrogeological assessment completed in support of the ARA application for the Brechin Quarry (Golder, 2007), a conceptual model was developed and then used as the basis for the creation of the numerical model. This conceptual model was updated in 2019 following the Tomlinson floor buckle that occurred in March 2017 and used as part of a numerical model in support of an Environmental Compliance Approval (ECA) industrial sewage works amendment application (Golder, 2019b). The conceptual model for these applications was adopted for this work. As part of the current study, refinements to the conceptual model, particularly within the Gull River Formation Unit 3 (green beds), were made based on a review of the monitoring well response to historical quarry dewatering and the Brechin Quarry floor buckle including data from surrounding quarries, where available. A summary of the conceptual model and details regarding the updated green beds representation is provided below.

6.1 Conceptual Model

The thickness of the overburden, where present, is variable, and was inferred from the drillers' observations as noted in the MECP water well database and from on-site borehole, drillhole, and augerhole data. The contacts between the Verulam Formation and Bobcaygeon Formation, between the Bobcaygeon Formation and Gull River Formation, between the Gull River Formation and Shadow Lake Formation, and between the Shadow Lake Formation and the Precambrian basement rock were assumed to form smooth surfaces whose elevation across the site could be inferred from the most recent geological interpretation of the borehole/drillhole logs (see Appendix B). The dip of these surfaces on the property is approximately 4 metres per 1,000 metres to the southwest. This south-westerly dip direction is consistent with the regional dip for the Palaeozoic rocks as described in Liberty (1969). The lines of intersection between the various contacts and the ground surface were found to compare favourably with the geological boundaries on Armstrong and Anastas (1993).

Based on the most recent geological interpretations and the hydraulic conductivity testing carried out at the site, the following hydrostratigraphic units were identified:

- The overburden
- The upper weathered bedrock
- The Verulam Formation
- The Bobcaygeon Formation

- The Gull River Formation above the green beds (Gull River Formation Unit 4)
- The green beds (Unit 3 of the Gull River Formation)
- The Gull River Formation below the green beds (Unit 2 and 1 of the Gull River Formation)
- The Shadow Lake Formation

Time-averaged groundwater levels measured at the site in monitoring wells and static water levels measured by drillers at off-site water wells (as noted in the MECP database) were assumed to represent average conditions that are independent of seasonal variations in precipitation. On average, groundwater was assumed to recharge at topographic highs and discharge at topographic lows. It was assumed that quarry dewatering will have no effect on average water levels in Dalrymple Lake and Canal Lake. These lakes were assumed to be regional groundwater discharge points, thus making the traverse of groundwater beneath them unlikely. It was assumed that groundwater flow is parallel to the contact between the Shadow Lake Formation and the Precambrian basement rock (i.e., a no-flow boundary).

6.1.1 Conceptual Model Update – Gull River Formation Green Beds

The hydrogeological interpretation of the green beds of the Gull River Formation was further refined from the 2019 groundwater model based on WSP's local experience and discussions with the MECP regarding the response in monitoring wells at the Dufferin Aggregates Carden Quarry and the Miller Quarry following the quarry floor buckle at the Brechin Quarry. This information in combination with the monitoring data collected for the Brechin Quarry was used to define interpreted zones of impact related to the Brechin Quarry floor buckle and to the dewatering of the surrounding quarries. The interpreted conductivity zones in the green beds are presented in Figure 8 and described below.

To define the hydraulic conductivity zones in the green beds, it is important to understand the timeline of quarry dewatering within the study area. Both the Miller Quarry to the north and the Dufferin Carden Quarry to the south were well established quarries prior to the beginning of operations at the Tomlinson Brechin Quarry in 2011. In the case of the Dufferin Carden Quarry, it is likely given the depth of the excavation, that the quarry floor was close to the top of the green beds and resulted in depressurization of the green beds prior to 2011. This is evidenced by the head of approximately 222 mASL measured in off-site green bed monitor OW-32C which is located approximately 650 metres to the west of the Brechin Quarry. The head of 222 mASL is approximately 5 meters lower than the elevation of the interpreted discharge point at Dalrymple Lake to the north (227 mASL) suggesting that there has been some depressurization with the Dufferin Carden Quarry being the most likely influence. Based on discussions with the MECP, this assumption is consistent with observed drawdown in the green bed monitoring wells at the north end of that site prior to 2011. The historical depressurization from the Dufferin Carden Quarry has had a limited impact on the green bed monitors located on the Brechin Quarry property with the heads in these monitors being generally around 240 mASL in 2011 despite being a similar distance away from the Dufferin Carden Quarry as OW-32C.

In March 2017, a buckle occurred in the Brechin Quarry floor which resulted in a decrease in heads in green bed monitors across the Brechin Quarry property. The heads in this formation decreased to between approximately 225 and 230 mASL which is close to the elevation of the Brechin Quarry floor at 225 mASL. A similar impact from the quarry floor buckling was not observed at the off-site Tomlinson green bed monitors to the west and northwest of the site (OW-32C and OW-33B, respectively) or at the Dufferin Carden Quarry to the southwest. Based on discussions with the MECP, the impact of the quarry floor buckling was observed in the monitors located at the south end of the Miller property, but not at the monitors located within the central or north parts of the property.

Overall, the data suggests that the green beds are a well connected and high hydraulic conductivity formation beneath the Brechin Quarry property, but that this connection is not necessarily consistent regionally. There are areas to the west, south and north of the Brechin Quarry which appear to have a limited connection to the green beds beneath the Brechin Quarry. From the monitoring data reviewed, two higher hydraulic conductivity zones which are separated from the regional green bed formation have been interpreted. One zone is related to depressurization from the Dufferin Carden Quarry and the other is related to the depressurization following the Brechin Quarry floor buckle.

The interpretation of these higher conductivity zones within the green beds is based on head responses in monitoring wells and is not connected with a specific geological feature, and it is recognized that there is uncertainty in this interpretation.

The primary receptors that may be impacted by the extent of the higher conductivity zones in the green beds are supply wells completed in the green beds. Surface water features (i.e., wetland east/south of the site and the north and south drainage features) and supply wells completed above the green beds are considered unlikely to be impacted by the interpretation of the high hydraulic conductivity zones in the green beds. Based on monitoring results following the buckling at the Brechin Quarry, there has been limited observed changes in monitoring wells completed above the Gull River Formation to date and no impact on the shallow bedrock beneath the wetland and drainage features as a result of the buckling. The potential impacts to the nearest supply wells located to the west and northwest of the property will be monitored with off-site monitoring wells OW-32 (if access can be regained) and OW-33. If access cannot be regained to OW-32, Tomlinson will work with additional private landowners and the City of Kawartha Lakes to identify an appropriate location for a new monitoring well to replace OW-32. The monitoring data at the on-site and off-site Tomlinson wells will allow for observed impacts to be evaluated as it relates to the interpretations made in the conceptual model (see Section 9.0 for a discussion of monitoring program).

6.2 Model Approach

The groundwater flow model developed previously for the Brechin Quarry was used as a staring point and updated to represent recent (post-buckling) groundwater conditions. The recalibrated model was then modified to represent the proposed deepened extraction area to evaluate the potential influence of the proposed deepening on the local groundwater conditions.

The groundwater modelling was completed using MODFLOW-USG (Panday *et al.*, 2017). Groundwater Vistas® (Version 8.3) was used as a pre- and post-processor for MODFLOW-USG. The use of MODFLOW implies that an equivalent porous media approach was adopted for this work. Although groundwater flow in bedrock aquifers is typically governed by the presence of fractures, such individual discrete features are not explicitly defined in the model. Rather, the bulk material properties are established based on large scale characteristics of the bedrock. Additional modelling assumptions are provided below.

Numerical Model (MODFLOW)

- Flow is laminar and steady and is governed by Darcy's Law.
- Groundwater flow is represented by an equivalent porous media.

- 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).
- The conceptual model was based upon geologic data compiled as of 2024, including boreholes completed in the bedrock and overburden local to the site.

Calibration

- Calibration was evaluated using steady-state model results.
- 2022 average groundwater levels from Brechin Quarry monitoring wells were used as target elevations in the calibration process. These are assumed to be representative of post-buckling conditions. These data were supplemented with MECP water well information system (WWIS) data throughout the model domain.
- 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. The exception to this was for Unit 3 of the Gull River Formation (green beds) where zones of higher and lower hydraulic conductivity were established based on the response to Brechin Quarry floor buckle, and dewatering of surrounding quarries.

6.2.1 Model Extents and Layering

The model grid and layering are illustrated on Figure 9. The model domain covers an area of 15 kilometres by 25 kilometres and is centered on the Brechin Quarry. Model grid cell spacing was specified as 100 metres on the model periphery and refined to 10 metres in the vicinity of the Brechin Quarry floor buckle where gradients are expected to be high.

The model extends from Lake Simcoe at the westernmost portion of the domain, following a low in the topographic surface northeast towards Dalrymple Lake. The northeastern model boundary extends from the Community of Lake Dalrymple following a topographic low to an upland region. The boundary then trends south along a valley through Canal Lake and follows the Talbot River at the exit of Canal Lake towards Lake Simcoe. The groundwater model boundary is consistent with the previous modelling for the Tomlinson Brechin Quarry (Golder, 2019b).

There are 259 columns and 400 rows in the model with a total of 959,160 total active grid blocks defined in the model. A total of 15 numerical model layers were specified to represent the overburden and bedrock within the model with thickness ranging between approximately 0.2 metres and 30 metres. These were based on the regional hydrostratigraphic units identified during the initial conceptualization of the regional hydrogeological setting and are consistent with the modelling completed for the site in 2019 except for an additional layer added to represent Gull River Unit 2 and Unit 1 as separate units to be consistent with the most recent geological interpretations of the boreholes on site. Figure 10 illustrates the relationship between the 15 numerical model layers and the hydrostratigraphic units.

- **Layer 1 – Overburden.** A thin veneer of overburden is present over the majority of the study area, with thicker deposits found in isolated pockets. The overburden is composed of a mix of organic deposits, alluvium, fine grained glaciolacustrine deposits, glacial tills, stratified drift and occasional sand deposits. Regionally, the overburden deposits were represented as a bulk unit with a hydraulic conductivity value that was ultimately determined through the calibration process (discussed in Section 6.2.4). In some places within the model domain, no overburden is present at surface. In these areas, the underlying weathered bedrock is defined at surface. The top surface of Layer 1 is defined by topography, based on Provincial digital elevation model data. The bottom surface of this layer is defined as the top of bedrock, which was defined based on all available borehole and MECP WWIS information.
- **Layers 2 and 3 – Upper Weathered Bedrock.** These layers represent a zone of enhanced fracturing as a result of weathering that is typically found within the upper 3 metres to 6 metres of bedrock throughout the study area. The top surface of these layers was defined as the top of rock. As it is not possible to map the thickness of this unit with the amount of data currently available, this layer was specified with a minimum total thickness of approximately 4 metres. However, the material properties of the upper weathered bedrock were extended into lower model layers where geological surfaces “pinch-out” and minimum numerical layer thicknesses were specified, effectively extending the thickness of the weathered zone in these areas.
- **Layer 4 – Verulam Formation.** This layer represents the Verulam Formation bedrock. The thickness of this unit is variable and increases towards the south. In areas where the Verulam Formation is not present (such as over most of the Brechin Quarry), the material properties of the overlying (weathered bedrock) unit were applied.
- **Layers 5 to 8 – Bobcaygeon Formation.** Generally found throughout the study area, this layer is considered to be a thick (up to approximately 27 metres at the Brechin Quarry), continuous and relatively impermeable unit.
- **Layer 9 and 10 – Gull River Formation Unit 4.** This layer represents the Gull River Formation above the green beds and is approximately 5 metres thick in the area of the Brechin Quarry. This unit is considered to be an aquitard with hydraulic properties similar to those of the overlying Bobcaygeon Formation.
- **Layer 11 – Gull River Formation Unit 3.** Layer 11 represents the green beds unit, found approximately 5 metres to 6 metres below the Gull River-Bobcaygeon formational contact. This unit is approximately 1 metre to 4 metres thick across the study area. Despite its limited thickness, this unit generally represents an aquifer.
- **Layer 12 – Gull River Formation Unit 2.** This layer represents the Gull River Formation below the green beds and primarily consists of limestone similar to Unit 4 of the Gull River Formation and is approximately 3 metres to 4 metres thick at the Brechin Quarry. This unit is interpreted to be an aquitard.
- **Layer 13 – Gull River Formation Unit 1.** This layer represents the lowest unit of the Gull River Formation and consists primarily of dolostone and is approximately 6 metres thick at the Brechin Quarry. It is considered to be slightly more permeable than the overlying limestone of Gull River Formation Unit 2.
- **Layer 14 – Shadow Lake Formation.** This layer represents the Shadow Lake Formation of relatively consistent (8 metres to 12 metres) thickness across the study area. This unit is interpreted to be an aquitard.
- **Layer 15 – Shadow Lake / Precambrian Contact.** A zone of enhanced fracturing is sometimes found at the contact between the Shadow Lake Formation and the underlying Precambrian basement rock and is

considered as a continuous aquifer across the study area. Layer 15 was specified as a constant 5-metre thick layer draped below the top of the Precambrian rock surface to represent this zone. The top of the Precambrian surface is irregular across the study area, and cuts through the overlying formations in places. The base of this layer forms the base of the numerical model, as it is assumed that the competent Precambrian rock found below the weathered zone at the Shadow Lake contact is impermeable relative to the overlying formations.

6.2.2 Boundary Conditions

Figure 11 illustrates the boundary conditions applied in the model. The boundary conditions were kept consistent with the previous modelling for the site (Golder, 2019b), except for updating the size and depth of the active quarry excavations based on topography and aerial imagery.

The perimeter of the model generally follows regional topographic and surface water divides and assumes that these are consistent with groundwater flow divides. Unless otherwise specified, the outer edges of the groundwater model were defined as no-flow boundaries; groundwater flow does not occur across these boundaries.

Drain boundaries were specified in the upper layers of the model to represent the various streams, creeks, tributaries and wetlands found within the study area. At these boundaries, groundwater discharge can occur during the simulation depending on the local gradients simulated in the model. Once groundwater discharge occurs at a drain boundary, the water is removed from the model and is not reapplied at subsequent downstream boundaries. Therefore, it is assumed that these surface water features are locations of groundwater discharge, and do not recharge the deeper groundwater flow system on an average annual basis. The elevation assigned to each drain boundary was based on topography.

Constant head boundaries were used to represent the lakes and rivers and were based on ground surface elevation data.

Operating quarries within the study area were simulated using drain boundaries specified over the extraction footprint and floor elevation based on the available data (aerial imagery and topography). The nearest active extraction areas are located approximately 0.9 kilometres to the north (Miller Quarry), 1.7 kilometres to the southwest (Dufferin Carden Quarry) and 1.8 km to the south (Dufferin Campbell Quarry) of the current Brechin Quarry excavation.

Recharge was applied to the top surface of the model to simulate annual average infiltration to the groundwater flow system from precipitation. The recharge distribution for the model is shown on Figure 11. This considers two primary areas of recharge: where overburden is present at ground surface, 75 mm per year (mm/year) is used, and where weathered bedrock is present at ground surface 100 mm/year is used. The recharge zones are consistent with previous modelling (Golder, 2019b), but were increased through the calibration process to better match the observed pumping data for the quarry (discussed in Section 6.2.4).

6.2.3 Hydraulic Conductivity

Estimates of hydraulic conductivity for the hydrostratigraphic units were derived from Golder 2007. Additional hydraulic conductivity testing was completed as part of this study within the upper weathered bedrock and the green beds of the Gull River Formation. The results of this testing were generally consistent with previous estimates for these formations from Golder 2007. A summary of the hydraulic conductivity testing completed at the Brechin Quarry site is provided in Section 3.1.3.

Estimates of hydraulic conductivity typically range within several orders of magnitude for a given hydrostratigraphic unit. The wide range in hydraulic conductivity estimates may be due to the local variability in the degree of fracturing within a given unit. The estimates provided in Section 3.1.3 and Section 4.1.3 are representative of the horizontal hydraulic conductivity of the principal hydrostratigraphic units. There are no supporting field data to describe the vertical hydraulic conductivity of these units. Due to the nature of their deposition, sedimentary rocks (such as those found within the study area) often exhibit stratification that results in the horizontal hydraulic conductivity being an order of magnitude or greater than the vertical hydraulic conductivity.

Initial estimates of hydraulic conductivity were based on the calibrated model values used in Golder 2019b. Adjustments were made from these initial values to better match the recent observed heads and quarry discharge while maintaining the hydraulic conductivities within reasonable bounds based on the measured values on site. A summary of the adjustments made during the calibration process are presented below:

- Increase the hydraulic conductivity of the weathered bedrock to better match the quarry inflows.
- Increase in the hydraulic conductivity of the Bobcaygeon Formation to better match heads within this formation.
- Decrease in the vertical conductivity for Unit 4 of the Gull River Formation (above the green beds) to better match the heads in the hydrostratigraphic units above the Gull River Formation.
- Zones of higher and lower conductivity within Gull River Formation Unit 3 (green beds) were used to better match the head response to the quarry floor buckle and surrounding quarry dewatering (as discussed in Section 6.1.1 and shown on Figure 8).
- The Gull River Formation below the green beds was represented as two separate units (Gull River Formation Unit 1 and 2) based on the most recent geological interpretation of the Gull River Formation. Gull River Formation Unit 1 was assigned a hydraulic conductivity consistent with the previous modelling and Gull River Formation Unit 2 was assigned a lower hydraulic conductivity to better match the head response in the overlying green beds.

The Brechin Quarry buckle that occurred on March 9, 2017, was represented in the model as a vertical high hydraulic conductivity feature (1×10^{-3} m/sec) specified between the quarry floor and the green beds in the location where this feature was mapped in the field (see location on Figure 5).

Details regarding the hydraulic conductivity values assigned for the calibrated numerical model are provided in Figure 10.

6.2.4 Model Calibration

Calibration of the groundwater model involved the refinement of the recharge rates and the material properties of the hydrostratigraphic units until the simulated hydraulic head distribution and groundwater seepage rates into the quarry compared reasonably well with the measured conditions. A spatial comparison of the distribution of error was also considered throughout the calibration process.

Water level data obtained during groundwater monitoring at the Tomlinson Brechin Quarry were used as the primary dataset in the calibration process, which was comprised of measurements from 82 monitoring locations taken in 2022. The year 2022 was selected because this was the last year of monitoring completed at off-site monitoring location OW-32. To account for the areas outside of the quarry (i.e., not covered by the water level monitoring program) the static water levels recorded in the MECP WWIS were utilized as discrete points of comparison. A total of 473 WWIS points were used. A comparison of the simulated and measured groundwater elevations for all calibration data is illustrated on Figure 12 including residual plots showing the spatial distribution of error. A review of the results allows the following observations:

- Simulated groundwater elevations are typically within 5 metres of measured values; 89% of calibration points have a calculated value within 5 metres of the observed value.
- The absolute mean was 2.0 metres for site-specific data, and 2.6 metres when data from the WWIS was included. The residual error was -0.2 metres for site-specific data, and 1.1 metres when data from the WWIS was included, indicating that there is no significant bias in the simulated groundwater elevation.
- The normalized root mean square error was 10.2% for site-specific data and 5.2% when the WWIS data was included.
- The spatial residual plot of the model domain (Figure 12) does not show a significant spatial bias in the distribution of error. The spatial residual plots of the Brechin Quarry monitoring wells completed both above and below the top of the green beds also have a good match to the observed data. This shows that there is a reasonable match in both the shallow and deeper groundwater flow systems on site.

Approximations of the groundwater component of quarry pumping are estimated based on total pumping during extended periods of low precipitation. For example, the total inflow rate based on pumping between August 9, 2022 and August 20, 2022 (a period over which there was negligible precipitation) was approximately 650 cubic metres per day (m^3/day). As another example, the total inflow rate based on pumping between August 31, 2022 and September 11, 2022 (a period over which there was negligible precipitation) was approximately 720 m^3/day. By comparison, the simulated groundwater inflow to the quarry in the calibrated model was 710 m^3/day.

The calibrated model is referred to as Scenario 0.

6.3 Forecast Simulations

Following calibration, the model was used to simulate the potential drawdown associated with the development and rehabilitation of the proposed deepened Brechin Quarry. To evaluate potential cumulative impacts from quarry development in the area, the development of the Miller Quarry to the north and the two Dufferin quarries to the south were considered. The calibrated model, which represents existing conditions, was used as the reference scenario (Scenario 0) to calculate drawdown for the following forecast simulation scenarios:

- Scenario 1 – Full development of the Tomlinson Brechin Quarry based on currently approved license with other quarries remaining at existing conditions.
- Scenario 2 – Full development of the Tomlinson Brechin Quarry including proposed deepening with other quarries remaining at existing conditions.
- Scenario 3 – Full development of the Tomlinson Brechin Quarry including the proposed deepening with the other quarries (Miller and two Dufferin quarries) fully developed.
- Scenario 4 - Tomlinson Brechin Quarry remaining at existing conditions with the other quarries (Miller and two Dufferin quarries) fully developed. This Scenario was used only as a reference to evaluate the Brechin Quarry's contribution to the total cumulative drawdown in Scenario 3.

- Scenario 5 – Full rehabilitation of the deepened Tomlinson Brechin Quarry as a lake with the other quarries remaining at existing conditions.

Table 13 below describes the full development states of the Brechin Quarry and the three nearby quarries which were considered in the cumulative impact assessment.

Table 13: Full Development Quarry Floor Elevations

Quarry Operator	Quarry Name	Approved Quarry Floor / Proposed Deepening (metres above sea level)
Tomlinson	Brechin Quarry	222 to 229 / 216 to 223
Miller Aggregates	Carden Township Quarry	217
Dufferin Aggregates	Carden Quarry	187
Dufferin Aggregates	Campbell Quarry	206

Table 14 below describes the lake level based on the approved rehabilitation plan for the Brechin Quarry which was used for the rehabilitation forecast simulation (Scenario 5). For the rehabilitation simulation, the quarry lake is represented with drain boundaries specified within the extracted bedrock draining to the elevation presented in Table 14.

Table 14: Brechin Quarry Rehabilitated Lake Elevations

Quarry	Extraction Area	Lake Level on Approved Site Plan (metres above sea level)
Tomlinson Brechin	North	235.5
	South	242.5

6.4 Forecast Simulation Results

6.4.1 Predicted Groundwater Drawdown

The results of the groundwater flow model simulations are presented on Figures 13 through 17. The results are presented as the change in hydraulic head (drawdown) in the weathered bedrock (Layer 3 of the numerical model), the Bobcaygeon Formation (Layer 8 of the numerical model) and the Gull River Formation Unit 3 (green beds; Layer 11 of the numerical model). The maximum extent of drawdown discussed is based on the 1-metre drawdown contour.

6.4.1.1 Scenario 1

Figure 13 shows the contours of simulated groundwater level drawdown in the weathered bedrock (Layer 3), Bobcaygeon Formation (Layer 8) and Gull River Formation Unit 3 (Layer 11) of the numerical model, induced by the full development of the Tomlinson Brechin Quarry based on the currently approved depth with the surrounding quarries remaining at their existing level of development. The contours are produced by subtracting the simulated groundwater elevations in Scenario 1 from the simulated groundwater elevations in the calibrated model (Scenario 0).

The simulated drawdown in the weathered bedrock and the Bobcaygeon Formation extends a maximum of approximately 500 metres from the Brechin Quarry excavation. There is approximately one metre of drawdown in the Gull River Formation Unit 3 which extends a maximum of 1,300 metres to the east of the Brechin Quarry excavation.

6.4.1.2 Scenario 2

Figure 14 shows the contours of simulated groundwater level drawdown in the weathered bedrock (Layer 3), Bobcaygeon Formation (Layer 8) and Gull River Formation Unit 3 (Layer 11) of the numerical model, induced by the full development and deepening of the Tomlinson Brechin Quarry with the surrounding quarries remaining at their existing level of development. The contours are produced by subtracting the simulated groundwater elevations in Scenario 2 from the simulated groundwater elevations in the calibrated model (Scenario 0). Because Scenario 2 assumes that the Miller Quarry and the two Dufferin quarries remain at existing conditions and the Brechin Quarry is deepened and fully extracted, this is the scenario where the Brechin Quarry has the greatest potential to impact groundwater level drawdown. As such, Scenario 2 is considered the worst-case scenario for groundwater level drawdown resulting from the development of the Brechin Quarry.

The simulated drawdown in the weathered bedrock extends a maximum of approximately 500 metres from the Brechin Quarry excavation (i.e., no change from Scenario 1 – current licensed condition). The simulated drawdown in the Bobcaygeon Formation extends a maximum of approximately 1400 metres from the Brechin Quarry excavation. There is up to 10 metres of drawdown in the Gull River Formation Unit 3 in close proximity to the Brechin Quarry and the 1-metre drawdown extends a maximum of 1600 metres from the Brechin quarry excavation.

6.4.1.2.1 Incremental Increase in Drawdown Caused by the Deepening of the Tomlinson Brechin Quarry

Figure 15 shows the contours of simulated incremental increase in groundwater level drawdown in the weathered bedrock (Layer 3), Bobcaygeon Formation (Layer 8) and Gull River Formation Unit 3 (Layer 11) of the numerical model, induced by the full development and deepening of the Brechin Quarry with the surrounding quarries remaining at their existing level of development (i.e., the scenario with the worst-case for drawdown contribution from the proposed deepened Brechin Quarry). The contours are produced by subtracting the simulated groundwater elevations in Scenario 2 from the simulated groundwater elevations in Scenario 1.

The simulated incremental increase in drawdown caused by the deepening is less than 0.1 metres in the weathered bedrock. The simulated incremental increase in drawdown caused by the deepening in the Bobcaygeon Formation is between 1 and 3 metres and extends a maximum of approximately 1400 metres from the Brechin Quarry excavation. There is a simulated incremental increase of up to 10 metres caused by the deepening in the Gull River Formation Unit 3 and the 1-metre incremental drawdown contour extends a maximum of 1600 metres from the Brechin Quarry excavation.

The incremental drawdown contours on Figure 15 identify the areas within the formations where the development of the proposed deepened Brechin Quarry will have the greatest impact on groundwater levels (i.e., will impact groundwater levels by one metre or more). The ‘zone of incremental drawdown’ is defined as the area within the 1-metre incremental drawdown contour. As shown on Figure 15, for Scenario 2, largest zone of incremental drawdown is found in the most transmissive unit in the groundwater model (i.e., Gull River Formation Unit 3 – green beds).

6.4.1.3 Scenario 3 and 4

Figure 16 shows the contours of simulated cumulative groundwater level drawdown in the weathered bedrock (Layer 3), Bobcaygeon Formation (Layer 8) and Gull River Formation Unit 3 (Layer 11) of the numerical model, induced by the full development and deepening of the Tomlinson Brechin Quarry with the three surrounding quarries also fully developed. The contours are produced by subtracting the simulated groundwater elevations in Scenario 3 from the simulated groundwater elevations in the calibrated model (Scenario 0). Also presented on this figure is the percent contribution to the cumulative drawdown caused by the deepened Brechin Quarry. The percent contribution from the deepened Brechin Quarry is determined by subtracting the drawdown produced by the surrounding quarries without the development of the Brechin Quarry (Scenario 4) from the total cumulative drawdown (Scenario 3) then dividing this number by the total cumulative drawdown (Scenario 3). The areas where the deepened Brechin Quarry is contributing 10% or greater of the cumulative drawdown are highlighted on Figure 16.

The areas where the Tomlinson contribution to the simulated cumulative drawdown in the weathered bedrock is greater than 10% is generally within 500 metres of the deepened Brechin Quarry excavation. The areas where the deepened Brechin Quarry contribution to the simulated cumulative drawdown in the Bobcaygeon Formation and Gull River Formation Unit 3 is greater than 10% is generally within 1500 metres of the Brechin Quarry excavation, and the greatest extent is towards the southeast.

As noted previously, the deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry by limiting the depth of the proposed quarry to the top of the green beds of the Gull River Formation rather than extending through the entire Gull River Formation like the other quarries located in the vicinity of the site. This results in the area where the deepened Brechin Quarry is contributing 10% or greater of the cumulative drawdown (area highlighted in Figure 16) does not extend to any private water supply wells in the vicinity of the Brechin Quarry.

6.4.1.4 Scenario 5

Figure 17 shows the contours of simulated groundwater level drawdown in the weathered bedrock (Layer 3), Bobcaygeon Formation (Layer 8) and Gull River Formation Unit 3 (Layer 11) of the numerical model, induced by the full rehabilitation of the deepened Brechin Quarry with the surrounding quarries remaining at their existing level of development. The contours are produced by subtracting the simulated groundwater elevations in Scenario 5 from the simulated groundwater elevations in the calibrated model (Scenario 0).

Following rehabilitation, the simulated drawdown in the weathered bedrock extends a maximum of approximately 500 metres from the Brechin Quarry excavation. There is predicted to be a general increase in simulated groundwater elevations in the Bobcaygeon Formation of up to approximately 2 metres compared to current conditions. There is predicted to be a general increase in simulated groundwater elevations in the Gull River Formation Unit 3 of up to approximately 8 metres compared to current conditions.

It is noted that as part of the updated modelling the final lake level for the south extraction area is simulated to not reach the 242.5 mASL which is specified on the approved site plans for the Brechin Quarry. The final lake level in the south extraction area is predicted to be similar to the north extraction area due to the connection through Gull River Formation Unit 3 to the north extraction area which is draining to a level of 235.5 mASL.

6.4.2 Modelled Groundwater Balance

The overall water balance for the calibration and forecast simulations was checked and is presented in Figure 18. The simulation for each scenario converged and had a low mass balance error (< 0.01 %).

The simulated groundwater discharge to the Brechin Quarry increased from 710 m^3/day under current conditions (Scenario 0) to a maximum of 1300 m^3/day when the Brechin Quarry was deepened and fully extracted (Scenario 2). There is a simulated increase of 50 m^3/day for the deepened quarry when compared to currently approved depth (Scenario 1).

The Cranberry Lake Wetland, which is the surface water receptor located to the east of the Brechin Quarry excavation, is predicted to see a decrease in groundwater discharge from 1310 m^3/day under current conditions (Scenario 0) to 995 m^3/day when the Brechin Quarry is deepened and fully extracted (Scenario 2). This is similar to the groundwater discharge of 1010 m^3/day to the Cranberry Lake Wetland which is predicted for the development of the Brechin Quarry to the currently approved depth (Scenario 1). If the three surrounding quarries and the deepened Brechin Quarry are all fully developed (Scenario 3) the groundwater discharge to the Cranberry Lake Wetland is predicted to be 800 m^3/day.

6.5 Sensitivity Analysis

It is recognized that there is inherently some uncertainty associated with the calibrated groundwater model, which stems from limitations in the available subsurface information and can be related to variability in the aquifer properties and uncertainties with the conceptual model. To gain some understanding of the potential impact of this uncertainty in the groundwater model forecasts, a sensitivity analysis was completed.

Four sensitivity runs were completed which involved varying the hydraulic conductivity assigned regionally to Gull River Formation Unit 3 (green beds) and the weathered bedrock by a factor of 5 (SR1a and SR1b) and varying the recharge rate applied in the model by 20% (SR2a and SR2b). The incremental increase in drawdown caused by the Brechin Quarry deepening compared to the currently approved condition was calculated (i.e., Scenario 2 – Scenario 1) and compared to the results of the base case calibrated model. Additional details and the results of the sensitivity runs compared to the base case model are presented in Figure 19. The results showed a negligible incremental drawdown in the weathered bedrock for each of the four sensitivity runs which was similar to the base case model results. In the Bobcaygeon Formation, the extent of the incremental drawdown was generally similar or within 300 metres when comparing the base case to the sensitivity runs. In Gull River Formation Unit 3, the extent of the incremental drawdown was generally similar or within 700 metres when comparing the base case to the sensitivity runs. The groundwater discharge to the deepened Brechin Quarry was between 50 to 60 m^3/day higher than the currently licensed depth for the base case and all four sensitivity runs. The groundwater discharge to the Cranberry Lake Wetland was between 5 to 15 m^3/day less when the Brechin Quarry was deepened compared to the currently licensed depth for the base case and all four sensitivity runs.

7.0 IMPACT ASSESSMENT

This section provides an assessment of the potential water resources impacts associated with the development of the proposed deepened Brechin Quarry. The development of the proposed deepened quarry can affect potential receptors mainly via quarry water management (e.g., quarry dewatering) and the area of groundwater level drawdown. The proposed quarry deepening does not result in additional land use changes or surface water drainage alterations (i.e., there are no additional changes beyond those assessed as part of the impact assessment completed for the currently licensed Brechin Quarry presented in the Golder 2007 report).

7.1 Groundwater Supply Impact Assessment

7.1.1 Operational Period

As discussed in Section 6.4.1.3, because the proposed deepened Brechin Quarry is relatively shallow, when the adjacent Miller Quarry and the two Dufferin quarries are at full development the contribution of the deepened Brechin Quarry to groundwater level drawdown under Scenario 3 is minimal. This is illustrated by the results presented on Figure 16 that show the area where the deepened Brechin Quarry is contributing 10% or greater of the cumulative drawdown (area highlighted in Figure 16) does not extend to any private water supply well in the vicinity of the Brechin Quarry.

Due to the limited contribution of the deepened Brechin Quarry to the predicted drawdown under Scenario 3, the impact assessment presented below focuses on Scenario 2 where the deepened Brechin Quarry has the greatest influence on groundwater levels in the vicinity of the site (see discussion in Section 6.4.1.2). This scenario assumes that the deepened Brechin Quarry proceeds to full development while the Miller Quarry and two Dufferin quarries remain at existing conditions. The impact assessment focuses on the area within the one-metre incremental drawdown contour shown on Figure 15. This is the area where the deepened Brechin Quarry will influence groundwater levels by one metre or greater compared to the already approved current license for the Brechin Quarry.

7.1.1.1 Water Supply Wells West of the Brechin Quarry

The closest existing water supply wells are located approximately 600 to 650 metres west of the Brechin Quarry (see well locations MARA-3405 and Scott-71 on Figure 5). Monitoring well OW-32 is located to the west of the site between the quarry and the private well closest to the current excavation at the site (see location on Figure 5). As noted previously, changes in groundwater elevations associated with the development of the proposed deepened Brechin Quarry are most pronounced in the green beds of the Gull River Formation. The typical groundwater elevations measured at monitoring well OW-32 within the green beds of the Gull River Formation are about 222 mASL (see Figure D7 in Appendix D).

The proposed final quarry floor elevation for the deepened Brechin Quarry would be lowered to the top of the green beds of the Gull River Formation. The quarry floor would slope form east to west and the final quarry floor would be between 216 and 223 mASL. The deepened Brechin Quarry would be a maximum of seven metres below the groundwater elevation in the vicinity of the nearest private wells. Given this minimal depth below the existing off-site groundwater elevation in the Gull River Formation green beds, and the distance to the nearest private wells (600 to 650 metres), impacts to surrounding water supply wells would not be expected as a result of the proposed deepening of the Brechin Quarry. This interpretation is consistent with the modelling results presented on Figure 15. The largest one-metre incremental drawdown contour is found within Unit 3 of the Gull River Formation (i.e., the green beds). A review of Figure 15 also shows there are no water supply wells located within the one-metre incremental drawdown contour for the green beds. As such, negative impacts to water supply wells are not predicted as a result of the proposed deepening of the Brechin Quarry.

Prior to the deepening of the Brechin Quarry, additional attempts will be made to regain access to monitoring well OW-32 to allow for measurement of off-site groundwater elevations in the vicinity of the nearest private wells. If access cannot be obtained to OW-32, Tomlinson will work with additional private landowners and the City of Kawartha Lakes to identify an appropriate location for a new monitoring well to replace OW-32. Further details about the proposed monitoring program are provided in Section 9.0.

7.1.1.2 Water Supply Wells Southeast of the Brechin Quarry

As noted previously, there is uncertainty in the extent/orientation of the higher hydraulic conductivity zones within the green beds of the Gull River Formation, particularly east/southeast of the Brechin Quarry. As shown on Figure 8, there is no off-site control for the extent of the higher hydraulic conductivity zone to the east/southeast of the site. Based on the available information to the west and north of the site, the higher hydraulic conductivity zone on the Brechin Quarry property appears to have a limited areal extent. The on-site zone is not connected to OW-32 and is not interpreted to connect with the monitoring wells in the central portion of the Miller Quarry to the north (see Figure 8).

As shown on Figure 13, there are numerous private wells located in the vicinity of Canal Lake to the southeast of the Brechin Quarry. In the southeast direction, the closest private wells are approximately two kilometres from the Brechin Quarry. It is highly unlikely that the higher hydraulic conductivity zone on the Brechin Quarry property extends two kilometres to the southeast. In addition, as shown on Figure 13, most of the wells in the vicinity of Canal Lake are completed in the Bobcaygeon Formation above the green beds. Based on groundwater elevation data collected following the buckling that occurred at the Brechin Quarry, changes in the groundwater elevation in the green beds does not result in significant changes in the groundwater elevations in the Bobcaygeon Formation. As such, given the distance to the private wells located to the southeast of the Brechin Quarry, and because the wells are primarily completed above the green beds, negative impacts to water supply wells to the southeast are not predicted as a result of the proposed deepening of the Brechin Quarry.

Monitoring wells OW-29, OW-30 and OW-31 are located in the wetland to the east of the Brechin Quarry extraction areas (see well locations on Figure 5). Each of these monitoring wells has a monitoring interval in the green beds of the Gull River Formation, and in the Bobcaygeon Formation. Groundwater level monitoring at these locations will continue as part of the monitoring program proposed for the deepened Brechin Quarry. If significant drawdown is observed in the Bobcaygeon Formation intervals at these locations (i.e., greater than 7 metres) an assessment would be completed to determine if an additional monitoring well should be established to the southeast of the site (i.e., within a road allowance or on private property) between the Brechin Quarry and the private wells located two kilometres southeast of the site.

7.1.2 Following Rehabilitation

Follow rehabilitation of the Brechin Quarry, groundwater levels rise in the Bobcaygeon Formation and Gull River Formation compared to current conditions (see Figure 17). As such, impacts to water supply wells as a result of the rehabilitation of the Brechin Quarry are not predicted.

7.2 Cumulative Impact Assessment

As noted previously, the deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry by limiting the depth of the proposed quarry to the top of the green beds of the Gull River Formation rather than extending through the entire Gull River Formation like the other quarries located in the vicinity of the site. This results in the area where the deepened Brechin Quarry is contributing 10% or greater of the cumulative drawdown (area highlighted in Figure 16) not extending to any private water supply wells in the vicinity of the Brechin Quarry. As such, the modelling results indicate that the deepened Brechin Quarry will not significantly contribute to cumulative groundwater level drawdown at private wells when all of the quarries in the vicinity of the site are fully extracted.

7.3 Potential for Impacts to Local Surface Water Features

There are three primary surface water receptors in the vicinity of the site. These include the north drainage feature, the south drainage feature and the wetland located along the eastern periphery of the property. Trigger levels and trigger periods have been developed to limit the potential for adverse impacts to the adjacent wetland, and the quarry water management plan has been designed to maintain flow in the north and south drainage features.

The proposed quarry deepening does not result in additional land use changes or surface water drainage alterations (i.e., there are no additional changes beyond those assessed as part of the impact assessment completed for the currently licensed Brechin Quarry). In addition, the proposed Brechin Quarry deepening will not affect the drawdown in the weathered bedrock beyond that which can be expected by the currently approved quarry development plan. The predicted drawdown in the weathered bedrock for the currently licensed quarry (Figure 13) matches that of the deepened Brechin Quarry (Figure 14). As shown on Figure 15, the incremental drawdown in the weathered bedrock is less than 0.1 metres. Thus, the surface water impact assessment from the original hydrogeological/hydrological study for Brechin Quarry (Golder 2007) remains valid. The current monitoring program, trigger levels, quarry water distribution plan, and approved mitigation measures under the existing license and PTTW will remain in place for the deepened Brechin Quarry. Therefore, no additional surface water impact assessment is required at this time as it relates to the proposed deepening of the Brechin Quarry.

7.4 Source Water Protection

The Brechin Quarry is located north of the boundary for the Lake Simcoe Region Conservation Authority and is not within an identified source protection region. The Brechin Quarry is within the City of Kawartha Lakes. The City of Kawartha Lakes has mapped the wellhead protection areas for municipal wellheads and intake protection zones for municipal surface water supplies. The Brechin Quarry is outside of the mapped wellhead Protection areas (A through D) and intake protection zones 1 and 2 for all municipal water supplies. As such, impacts to source water quality or quantity as a result of the proposed deepening of the Brechin Quarry are not predicted.

8.0 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 proposed deepened Brechin Quarry 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 Tomlinson, the Complaints Response Program detailed below shall be initiated. As soon as can be arranged, a representative of Tomlinson or their agent will visit the site to make an initial assessment of 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 geoscientist/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 geoscientist/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 generic measures which are considered 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). The feasibility of well replacement would be based on a test drilling program. 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.
- Water Treatment Considerations – Appropriate water treatment will be incorporated into any restored water supply as discussed above. Tomlinson 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.

9.0 PROPOSED MONITORING PROGRAM

If Tomlinson is successful in obtaining an amendment under the ARA from the MNR for the deepening of the Brechin Quarry, this technical document would be used as supporting documentation to apply to the MECP for an amendment to the existing PTTW. This PTTW amendment would be required to recognize the proposed deepened Brechin Quarry in the impact assessment for the PTTW, and to add the monitoring wells completed as part of this study into the monitoring program associated with the PTTW. It is anticipated that any water collecting in the base of the deepened Brechin Quarry (i.e., within the sump in the north extraction area or in the sump in the south extraction area) will discharge off-site in accordance with the existing ECA for the Brechin Quarry.

The existing quarry sump dewatering system in the north extraction area is presently operated consistently at below 100 Litres per second. This is below the maximum permissible discharge rate under the current sump configuration of 149 Litres per second and well below the final sump configuration which allow offsite discharge at a rate of 211 Litres per second. There is currently no excavation in the south extraction area and there is no off-site discharge. As such, it is envisaged that the management of water collecting within the confines of the deepened Brechin Quarry excavation could be accommodated initially within the constraints imposed by the existing Brechin Quarry ECA (Industrial Sewage Works) without requiring a technical amendment to the ECA.

The objectives of the groundwater and surface water monitoring programs will be to measure and evaluate the actual effects on water resources associated with long term development of the deepened quarry, and to allow a comparison between the actual effects measured during the monitoring program with those predicted as part of the impact assessment (refer to Section 7.0). It is proposed that the groundwater and surface water monitoring programs defined on the existing PTTW and the ECA for the existing Brechin Quarry will be continued during the development of the proposed deepened Brechin Quarry.

The existing Brechin Quarry ECA/PTTW groundwater and surface water monitoring programs consist of the following activities:

Table 15: Existing Brechin Quarry Permit to Take Water Monitoring Program

Groundwater Level Monitoring
<u>Monthly Manual Groundwater Levels Locations:</u> MW-3A, OW-1A, OW-1B, OW-1C, OW-2C, OW-5C*, OW-6C, OW-7A, OW-7B, OW-7C, OW-8C, OW-9C, OW-15A, OW-15B, OW-15C, OW-19A, OW-19B, OW-19C, OW-24, OW-25*, OW-26, OW-27, OW-28, PW-3A, MWPSW-3 and MWPSW-4 *monitoring well has been removed by progressive quarry development <u>Quarterly Monitoring Well Locations with Transducers and Data Loggers:</u> OW-3A, OW-3B, OW-3C, OW-4A, OW-4B, OW-4C, OW-10A, OW-10B, OW-10C, OW-29A, OW-29B, OW-29C, OW-29D, OW-30A, OW-30B, OW-30C, OW-30D, OW-31A, OW-31B, OW-31C, OW-31D, OW-32A**, OW-32B**, OW-32C** and OW-32D** ** Tomlinson currently does not have permission to access monitoring location OW-32 <u>Monitoring Well Location with Vibrating Wire Piezometer:</u> MW-4A <u>Permanent Groundwater Monitoring Locations:</u> MW-3, MW-4A, OW-1A, OW-1B, OW-1C, OW-3A, OW-3B, OW-3C, OW-4A, OW- 4B, OW-4C, OW-10A, OW-10B, OW-10C, OW-15A, OW-15B, OW-15C, OW-19A, OW-19B, OW-19C, OW-29A, OW-29B, OW-29C, OW-29D, OW-30A, OW-30B, OW- 30C, OW-30D, OW-31A, OW-31B, OW-31C, OW-31D, OW-32A, OW-32B, OW-32C, OW-32D, PW-3A, MWPSW-3 and MWPSW-4 <u>Temporary Groundwater Monitoring Locations (will be removed by progressive quarry development):</u> OW-2C, OW-5C*, OW-6C, OW-7A, OW-7B, OW-7C, OW-8C, OW-9C, OW-24, OW- 25*, OW-26, OW-27, OW-28 *monitoring well has been removed by progressive quarry development

Surface Water Level Monitoring
<u>Quarterly Manual Surface Water Measurements:</u> SG06-1, SG06-2, SG09-3 and SG09-4 <u>Permanent Staff Gauge Location with Transducers and Data Loggers:</u> SG06-1, SG06-2, SG09-3 and SG09-4 Frequency: data logger readings during ice free conditions
Wetland Vegetation Monitoring
<u>Vegetation Assessment Transect:</u> Approximately 400 metres in length located within the wetland between OW-30 and OW-31 – all vascular plants within one metre of the centreline will be identified and their cover contribution, in successive ten-metre intervals along the transect, will be tabulated. <u>Fixed Vegetation Community Plots:</u> Two ten-metre by ten-metre fixed vegetation community plots will be established near the endpoints of the vegetation assessment transect. Within each community plot, all vascular plants will be identified, and cover values will be determined. <u>Frequency:</u> During the first 10 years of water taking at the site the frequency for the vegetation monitoring is once in each year during: year zero, year one, year two, year four, year six, and year ten. After the first ten years, the frequency of vegetation monitoring will remain at every four years unless a significant change is observed. If a significant change is observed between sampling events, the vegetation monitoring would return to an annual frequency.
Trigger Level Assessment
<u>Trigger Level Locations:</u> OW-4C, OW-10C, OW-15C, OW-19C, OW-28, OW-29C, OW-29D, OW-30C, OW-30D, OW- 31C, OW-31D, MWPSW-3, MWPSW-4, PW-3, SG06-1, SG06-2, SG09-3 and SG09-4 <u>Trigger Level Required Actions:</u> As described in Golder Associates Ltd. report "*Revised Report, Phase 2 Development: Trigger Levels and Mitigation Measures Document, R.W. Tomlinson Limited, Brechin Quarry, Kawartha Lakes, Ontario. June 2019*"

Table 16: Existing Brechin Quarry Environmental Compliance Approval (Industrial Sewage Works) Monitoring Program

Surface Water Quality Monitoring
■ Monthly effluent quality sampling during months that discharge occurs at SW2 or SW5 for the following parameter: oil and grease, total suspended solids, total ammonia, pH (field) and temperature (field).
■ Quarterly surface water quality sampling of the effluent (SW2 or SW5) and at surface water locations SW11, SW12 and SW13 during periods of effluent discharge for the following parameters: oil and grease, total suspended solids, total ammonia, pH (field), temperature (field), 2,4-dinitrotoluene, 2,6-dinitrotoluene, conductivity, hardness, alkalinity, BOD5, DOC, TDS, chloride, phenol, total phosphorus, nitrate, nitrite, TKN, sulphate and metal scan (Ca, Mg, K, Al, Ba, B, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se, Ag, Zn, U, As).

It is proposed that the groundwater and surface water monitoring programs continue as described in Tables 15 and 16, except where an existing monitoring component will be removed as the quarry is developed (e.g., monitoring well removed by progressive quarry development), with the addition of the following components to the monitoring program on the current PTTW:

Table 17: Proposed Additional Monitoring Program

Groundwater Level Monitoring
■ Monthly groundwater level monitoring in monitoring wells OW-38A, OW-38B, OW-39, OW-40A, OW-40B OW-41A and OW-41B.
■ If significant drawdown is observed in the Bobcaygeon Formation intervals at OW-29, OW-30 or OW-31 (i.e., greater than 7 metres) an assessment would be completed to determine if an additional monitoring well should be established to the southeast of the site (i.e., within a road allowance or on private property) between the Brechin Quarry and the private wells located two kilometres southeast of the site.
■ Prior to the deepening of the Brechin Quarry, additional attempts shall be made to regain access to monitoring well OW-32 to allow for measurement of off-site groundwater elevations in the vicinity of the nearest private wells. If access cannot be obtained to OW-32, Tomlinson will work with additional private landowners and the City of Kawartha Lakes to identify an appropriate location for a new monitoring well to replace OW-32.

The ultimate need for mitigation measures and the timing for implementation of mitigation measures would be based on the data obtained from the groundwater and surface water monitoring programs.

The annual performance report will continue to be required as they operate under the existing ECA; this annual report would be submitted to the MECP for review and comment. In addition, Tomlinson will continue to prepare an annual report that provides an assessment and interpretation of the water level data that is collected in accordance with the monitoring program defined on the amended PTTW. This includes an annual assessment of established surface water and groundwater trigger levels. These monitoring data would ensure that quarry development is undertaken in a manner that does not negatively impact surface water and groundwater receptors in the area of the site.

Where appropriate, comments received from the regulatory agencies (as part of this ARA amendment application process) that relate to the monitoring of the groundwater would be considered in the context of preparing the future monitoring program that takes into account the proposed development of the deepened Brechin Quarry.

10.0 SITE PLAN RECOMMENDATIONS

The following recommendations are provided for inclusion on the site plans for the deepened Brechin Quarry:

- The proposed groundwater, surface water and vegetation monitoring program presented in Section 9.0 should be referenced on the site plans. This can be accomplished by including the following text in the Water Report recommendation section on the Operations Plan:

  > *The Licensee shall implement the groundwater, surface water and vegetation monitoring program as described in Section 9.0 of the Level 1 and 2 Water Report prepared in support of the Aggregate Resources Act amendment application for the Tomlinson Brechin Quarry.*

- The *Complaints Response Program* presented in Section 8.0 should be referenced on the site plans. This can be accomplished by including the following text in the Water Report recommendation section on the Operations Plan:

  > *In the event of a well interference complaint, the Licensee shall follow the protocol set out in Section 8.0 of the Level 1 and 2 Water Report prepared in support of the Aggregate Resources Act amendment application for the Tomlinson Brechin Quarry*.

11.0 SUMMARY AND CONCLUSIONS

Tomlinson operates a number of pits and limestone quarries in Ontario. Tomlinson is currently applying for an amendment under the ARA to deepen their existing Brechin Quarry (ARA License #624846) as part of their long-term strategy to supply aggregates to local construction projects and projects in the Greater Toronto Area. WSP was retained by Tomlinson to complete the necessary hydrogeological/hydrological study to support an application under the ARA. This study was conducted for the purpose of addressing the requirements for the Level 1 and Level 2 Water Report as described in “Aggregate Resources of Ontario: Technical reports and information standards”, dated August 2020.

The site-specific geological, hydrogeological and hydrological data presented in this report were collected for the Brechin Quarry during investigations and monitoring programs conducted between 2004 and 2024.

The Brechin Quarry is located on the western half of Lot 5, Concession II, and Lot 6 and Lot 7, Concession II, in the Geographic Township of Carden, now part of the City of Kawartha Lakes. The Brechin Quarry licensed area is approximately 207 hectares, of which the area to be extracted is approximately 131 hectares. The extraction area is divided into a north extraction area and a south extraction area, which measure approximately 92 hectares and 39 hectares, respectively. Under the current ARA license, the north and south extraction areas would be operated in two lifts, and the bottom of the quarry extends approximately 10 metres into the Bobcaygeon Formation and remains approximately 5.8 metres above the top of the green beds of the Gull River Formation.

The existing limits of extraction for the north and south extraction areas will remain unchanged under the proposed site plan amendment. The proposed final quarry floor elevation would be lowered to the top of the green beds of the Gull River Formation. This corresponds to a lowering of the proposed final quarry floor by approximately 6 metres beyond the presently approved quarry floor. The deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry by limiting the depth of the proposed quarry to the top of the green beds of the Gull River Formation rather than extending through the entire Gull River Formation like the other quarries located in the vicinity of the site. The deepened quarry floor would slope form east to west and the final quarry floor would be between 216 and 223 mASL.

The quarry property is bounded on the west by Miller Road, and there are licensed quarries owned by Miller Paving and Dufferin Aggregates located to the north, southwest and southeast (see quarry locations on Figure 2). The Cranberry Lake Provincially Significant Wetland exists on, and adjacent to, the south and east boundaries of the Tomlinson property. There are no private wells located within 500 metres of the north and south extraction areas.

The main objectives of the current study were to:

- Review and compile the results of previous work completed at the site between 2004 and 2024
- Borehole drilling program and geophysical logging
- Monitoring well installation program
- Hydraulic conductivity testing
- Groundwater level monitoring program
- Groundwater flow modelling
- Assessment of potential impacts to surrounding receptors related to the development and rehabilitation of the proposed deepened Brechin Quarry

The additional geologic and hydrogeological data gathered as part of the current study were used to refine the existing Brechin Quarry numerical groundwater model to estimate the groundwater level drawdown associated with operations at the proposed deepened Brechin Quarry. The numerical model was developed and calibrated based on the site-specific data, the monitoring data collected from all the nearby quarry operations and the information in the MECP WWIS.

A number of model scenarios were developed to assess additional drawdown associated with operational and rehabilitated conditions at the proposed deepened Brechin Quarry as compared to the already licensed quarries in the immediate area. The scenarios included:

- Scenario 0 – Existing Conditions (Calibration Run)
- Scenario 1 – Full development of the Tomlinson Brechin Quarry based on currently approved license with other quarries remaining at existing conditions.
- Scenario 2 – Full development of the Tomlinson Brechin Quarry including proposed deepening with other quarries remaining at existing conditions.
- Scenario 3 – Full development of the Tomlinson Brechin Quarry including the proposed deepening with the other quarries (Miller and two Dufferin quarries) fully developed.

- Scenario 4 - Tomlinson Brechin Quarry remaining at existing conditions with the other quarries (Miller and two Dufferin quarries) fully developed. This Scenario was used only as a reference to evaluate the Brechin Quarry's contribution to the total cumulative drawdown in Scenario 3.
- Scenario 5 – Full rehabilitation of the deepened Tomlinson Brechin Quarry as a lake with the other quarries remaining at existing conditions.

The development of the proposed deepened Brechin Quarry can affect potential receptors mainly via quarry water management (e.g., quarry dewatering) and the area of groundwater level drawdown. The proposed quarry deepening does not result in additional land use changes or surface water drainage alterations (i.e., there are no additional changes beyond those assessed as part of the impact assessment completed for the currently licensed Brechin Quarry presented in the Golder 2007 report).

The potential impacts as a result of the deepening of the Brechin Quarry during the operational phase of the quarry life were assessed separately from the rehabilitated conditions. Based on the results of the groundwater modelling, during operations, there are no water supply wells located within the one-metre incremental drawdown contour associated with the deepened Brechin Quarry. As such, negative impacts to water supply wells are not predicted as a result of the proposed deepening. Follow rehabilitation of the Brechin Quarry, groundwater levels rise in the Bobcaygeon Formation and Gull River Formation compared to current conditions. As such, impacts to water supply wells as a result of the rehabilitation of the Brechin Quarry are not predicted.

The deepened Brechin Quarry has been specifically designed to limit the potential contribution to cumulative impacts on water supply wells in the vicinity of the quarry. This results in the area where the deepened Brechin Quarry is contributing 10% or greater of the cumulative drawdown not extending to any private water supply wells in the vicinity of the Brechin Quarry. As such, the modelling results indicate that the deepened Brechin Quarry will not significantly contribute to cumulative groundwater level drawdown at private wells when all of the quarries in the vicinity of the site are fully extracted.

There are three primary surface water receptors in the vicinity of the site. These include the north drainage feature, the south drainage feature and the wetland located along the eastern periphery of the property. Trigger levels and trigger periods have been developed to limit the potential for adverse impacts to the adjacent wetland and the quarry water management plan has been designed to maintain flow in the north and south drainage features.

The proposed quarry deepening of the Brechin Quarry does not result in additional land use changes or surface water drainage alterations (i.e., there are no additional changes beyond those assessed as part of the impact assessment completed for the currently licensed Brechin Quarry). In addition, the proposed Brechin Quarry deepening will not affect the drawdown in the weathered bedrock beyond that which can be expected by the currently approved quarry development plan, Thus, the surface water impact assessment from the original hydrogeological/hydrological study for Brechin Quarry (Golder 2007) remains valid. Therefore, no additional surface water impact assessment is required at this time as it relates to the proposed deepening of the Brechin Quarry.

The current monitoring program, trigger levels, quarry water distribution plan, and approved mitigation measures under the existing license and PTTW will remain in place for the deepened Brechin Quarry. The existing PTTW would be amended to recognize the proposed deepened Brechin Quarry in the impact assessment for the PTTW, and to add the monitoring wells completed as part of this study into the monitoring program associated with the PTTW.

The existing quarry sump dewatering system in the north extraction area is presently operated consistently at below 100 Litres per second. This is below the maximum permissible discharge rate under the current sump configuration of 149 Litres per second and well below the final sump configuration which allow offsite discharge at a rate of 211 Litres per second. There is currently no excavation in the south extraction area and there is no off-site discharge. As such, it is envisaged that the management of water collecting within the confines of the deepened Brechin Quarry excavation could be accommodated initially within the constraints imposed by the existing Brechin Quarry ECA (Industrial Sewage Works) without requiring a technical amendment to the ECA.

An annual performance report will continue to be a requirement of the existing ECA; this annual report would be submitted to the MECP for review and comment. In addition, Tomlinson will continue to prepare an annual report that provides an assessment and interpretation of the groundwater level data that is collected in accordance with the monitoring program defined on the amended PTTW. These monitoring data would ensure that quarry development is undertaken in a manner that does not negatively impact surface water and groundwater receptors in the area of the site.

Where appropriate, comments received from the regulatory agencies (as part of this ARA amendment application process) that relate to the monitoring of the groundwater would be considered in the context of preparing the future monitoring program that takes into account the proposed development of the deepened Brechin Quarry.

12.0 LIMITATIONS AND USE OF REPORT

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

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

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

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

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

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

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

13.0 CLOSURE

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

WSP Canada Inc.

PROFESSIONAL GEOSCIENTISTS
JAIME P. A. OXTOBEE
PRACTISING MEMBER
1095
16/10/2025
ONTARIO

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Senior Hydrogeologist

Kris Marentette, M.Sc., P.Geo.
Senior Hydrogeologist

JPAO/SPS/KAM/rk

https://wsponline.sharepoint.com/sites/gld-139625/project files/6 deliverables/water report/20449322-r-rev0_brechin quarry_water_report_16oct2025.docx

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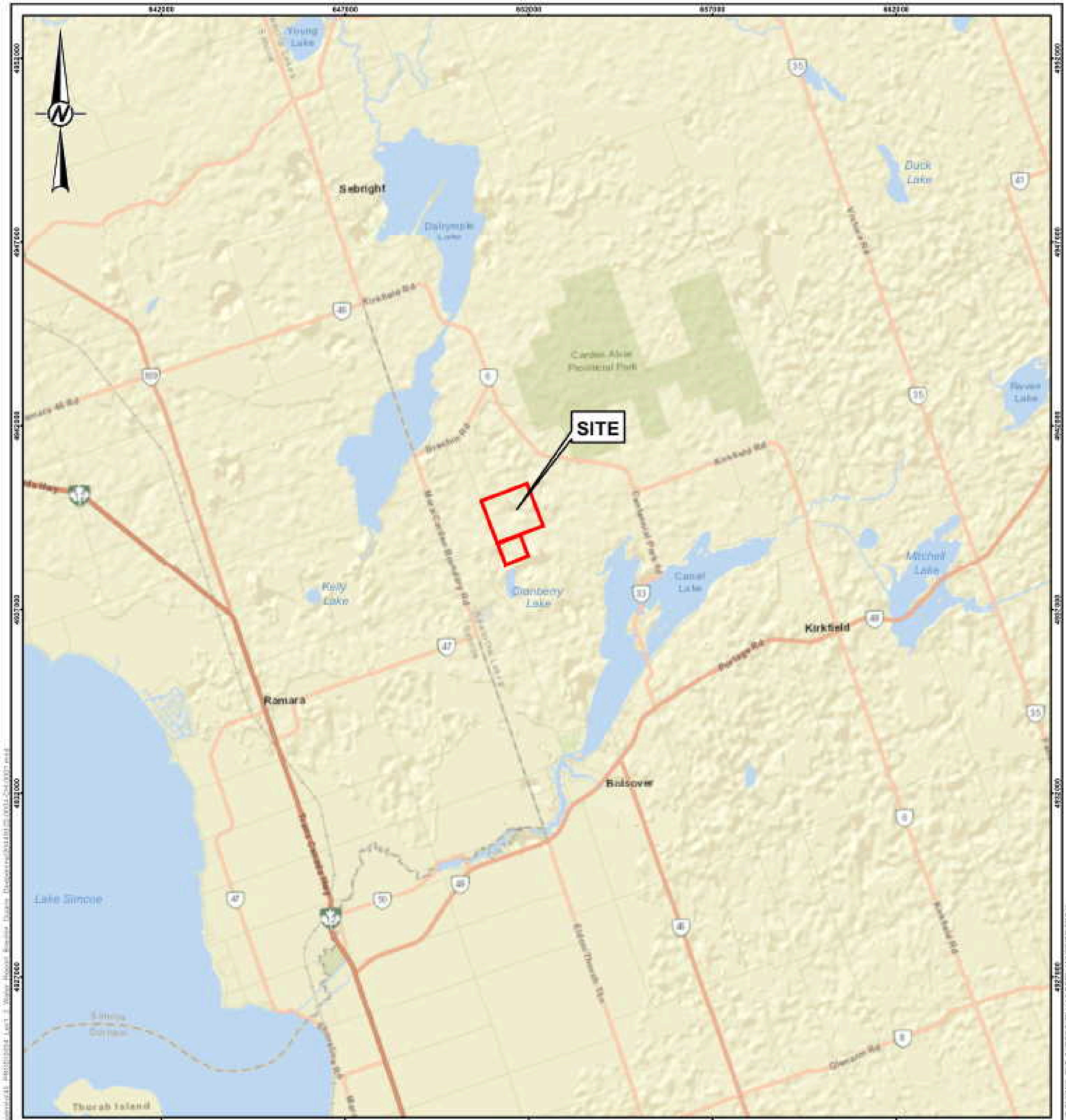


CLIENT

R.W. TOMLINSON LIMITED

PROJECT

LEVEL 1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

TITLE

KEY PLAN

0 1,500 3,000 6,000

1:150,000 METRES

CONSULTANT

YYYY-MM-DD	8/13/2025
DESIGNED	JPAO
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

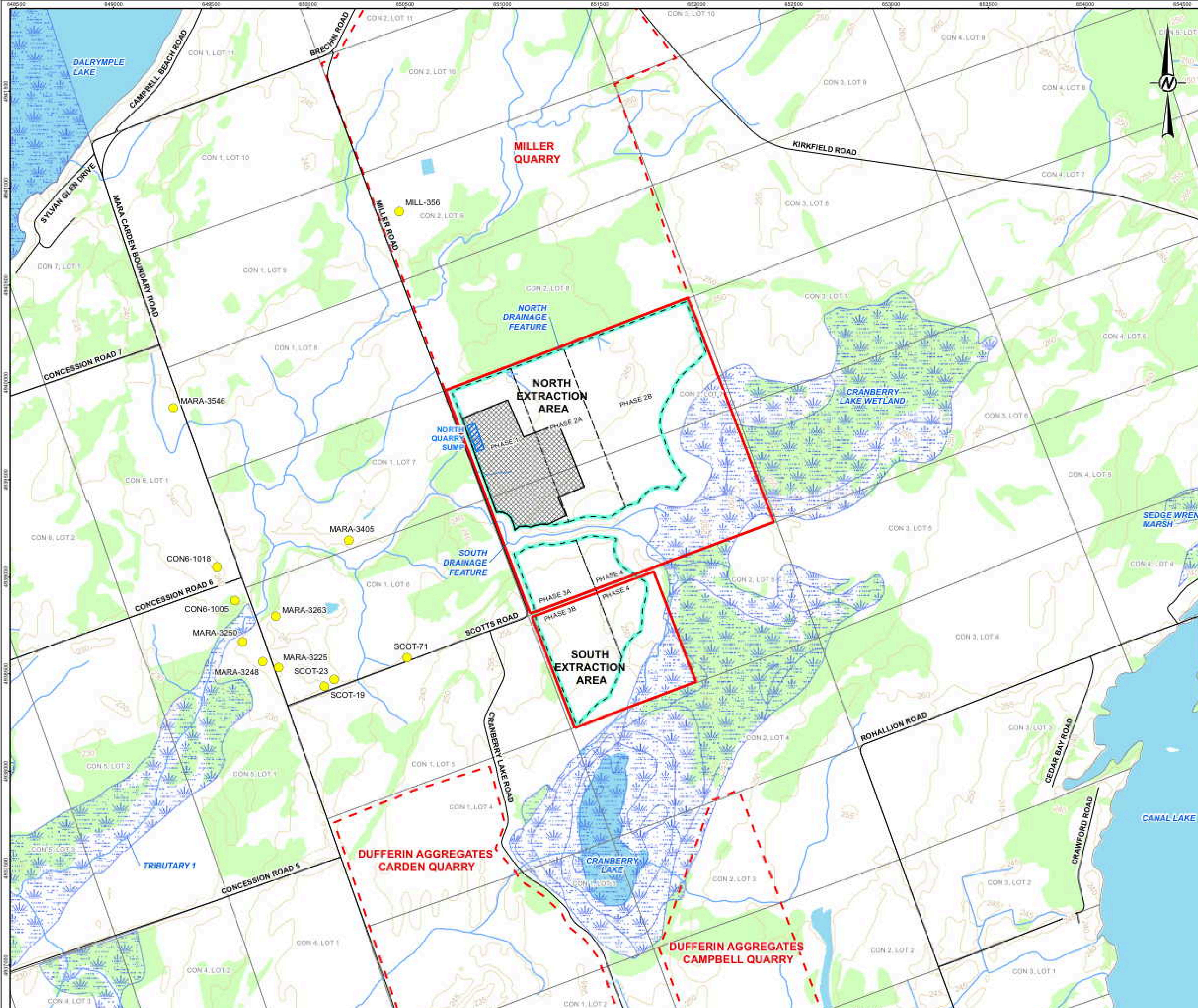
PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0004	0	1

NOTE(S)

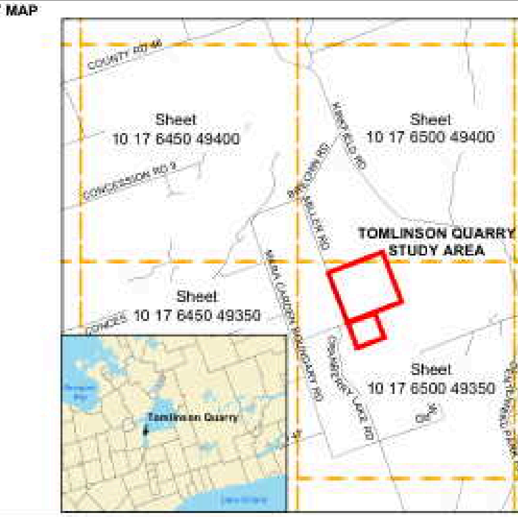
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. IMAGERY 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
3. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N



KEY MAP



LEGEND

- WATER WELL INCLUDED IN PRIVATE WELL SURVEY
- APPROXIMATE BOUNDARY OF EXISTING QUARRY
- NORTH QUARRY SUMP
- CONCESSION/LOT
- PHASE BOUNDARY
- SURROUNDING QUARRY LOCATIONS
- TOMLINSON BRECHIN QUARRY LICENSED BOUNDARY
- EXTRACTION FOOTPRINT
- ROAD
- TOPOGRAPHIC CONTOUR, metres (5 m INTERVAL)
- DRAINAGE FEATURE
- PROVINCIALLY SIGNIFICANT WETLAND BASED ON MNR DATA
- WATERBODY
- WOODED AREA

0 200 400 800

1:20,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N

CLIENT
R.W. TOMLINSON LIMITED

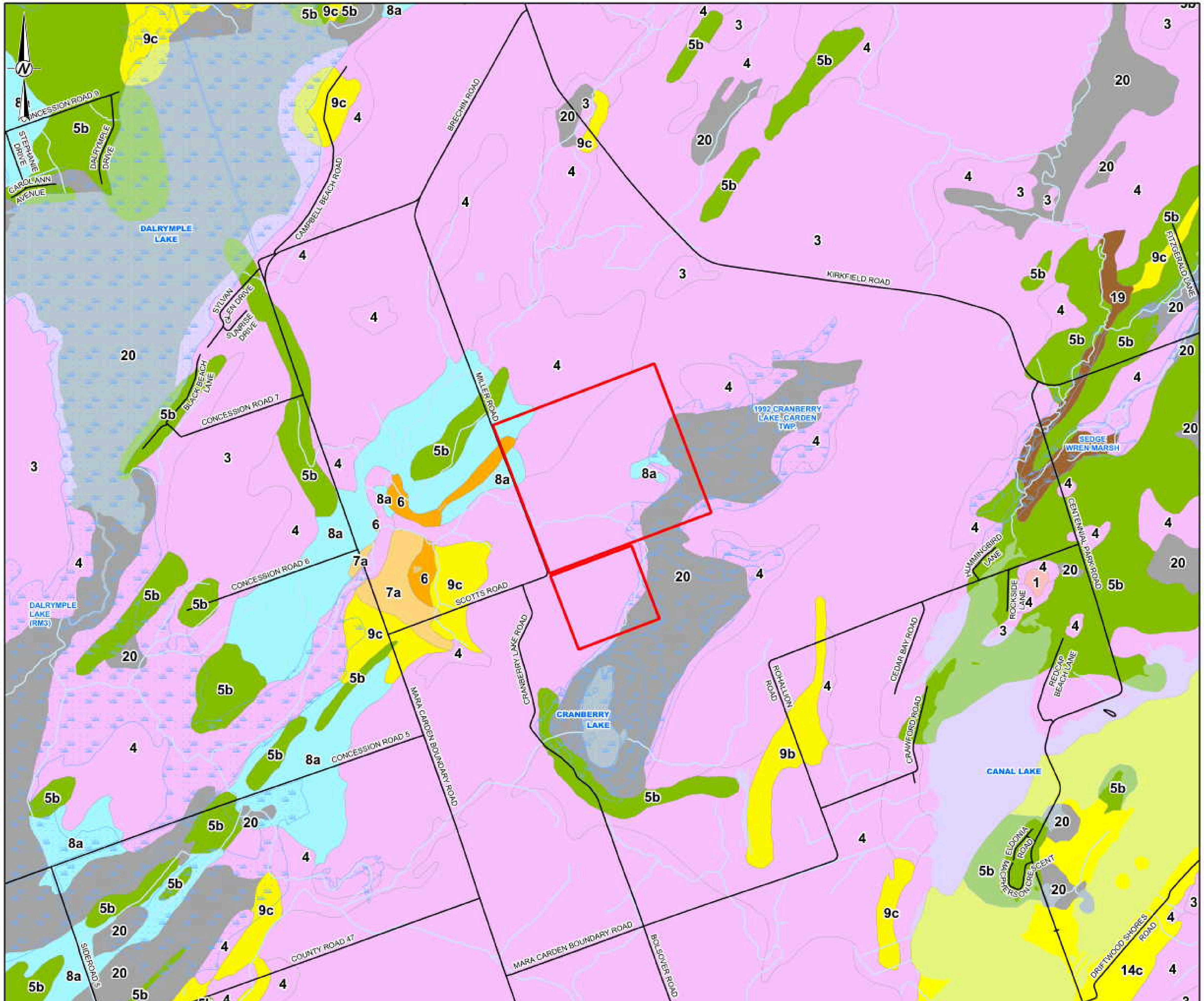
PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

TITLE
SITE PLAN

CONSULTANT

YYYY-MM-DD	6/13/2025
DESIGNED	JPAO
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0004	0	2



KEY MAP

SCALE: 1:1,250,000

LEGEND

- TOMLINSON BRECHIN QUARRY LICENSED BOUNDARY
- ROADWAY
- WATERCOURSE
- PROVINCIALLY SIGNIFICANT WETLAND BASED ON MNR DATA
- WATERBODY
- 1. **PRECAMBRIAN BEDROCK**
- 3. **PALEOZOIC BEDROCK**
- 4. **BEDROCK-DRIFT COMPLEX IN PALEOZOIC TERRAIN:**
- 5b. **TILL:** STONE-POOR, SANDY SILT TO SILTY SAND-TEXTURED TILL ON PALEOZOIC TERRAIN
- 6. **ICE-CONTACT STRATIFIED DEPOSITS:** SAND AND GRAVEL MINOR, SILT, CLAY AND TILL
- 7a. **GLACIOFLUVIAL DEPOSITS:** RIVER DEPOSITS AND DELTA TOPSET FACIES; SANDY DEPOSITS
- 8a. **FINE-TEXTURED GLACIOLACUSTRINE DEPOSITS:** SILT AND CLAY, MINOR SAND AND GRAVEL; MASSIVE TO WELL LAMINATED
- 9b. **COARSE-TEXTURED GLACIOLACUSTRINE DEPOSITS:** SAND, GRAVEL, MINOR SILT AND CLAY; LITTORAL DEPOSITS
- 9c. **COARSE-TEXTURED GLACIOLACUSTRINE DEPOSITS:** SAND, GRAVEL, MINOR SILT AND CLAY; FORESHORE AND BASINAL DEPOSITS
- 14c. **COARSE-TEXTURED LACUSTRINE 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

0 250 500 1,000

1:30,000 METRES

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. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
3. BASE MAP: ESRI, CGIAR, USGS. SOURCES: ESRI, TOMTOM, GARMIN, FAO, NOAA, USGS, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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R.W. TOMLINSON LIMITED

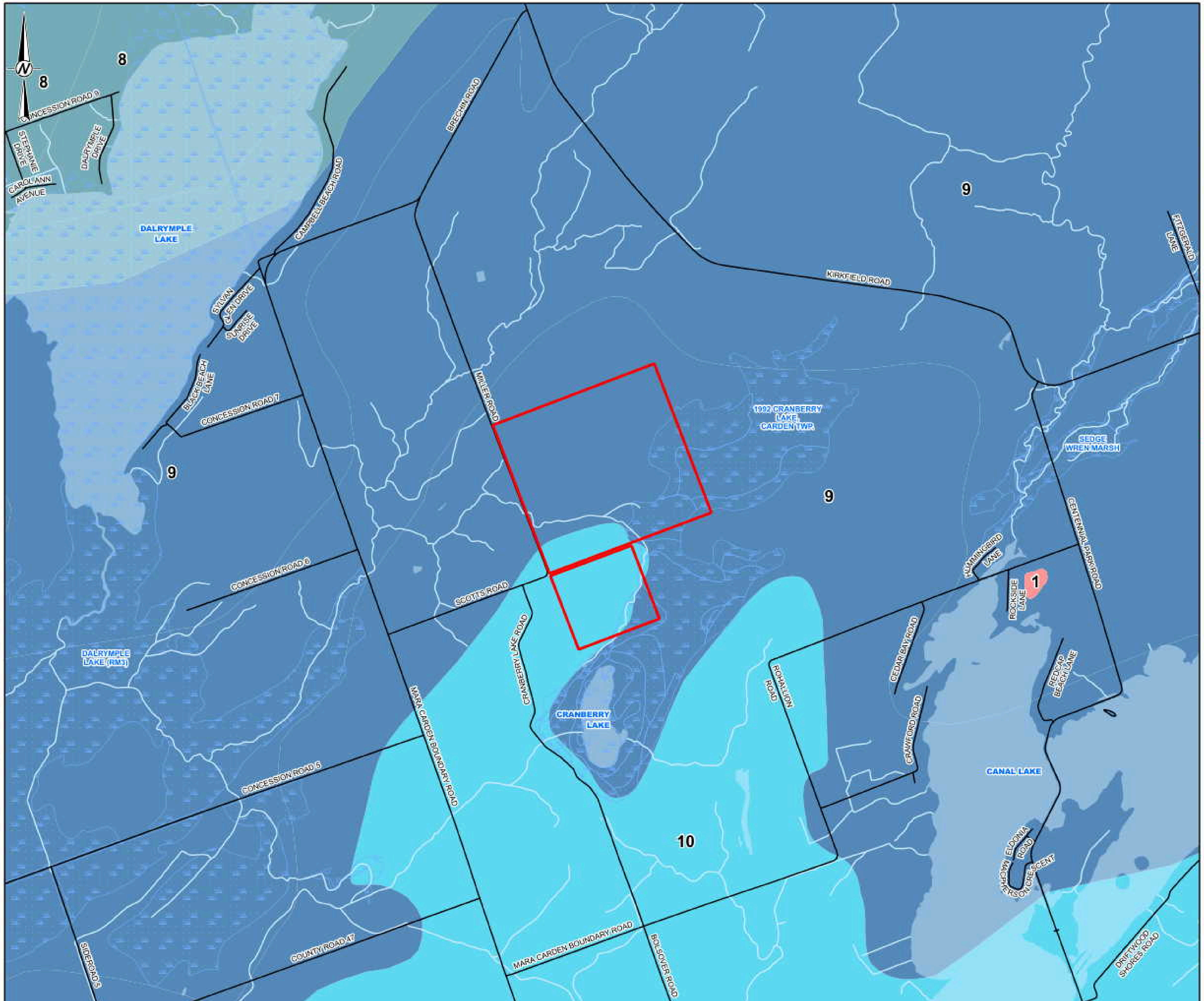
PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

TITLE
SURFICIAL GEOLOGY

CONSULTANT

YYYY-MM-DD	2025-06-13
DESIGNED	JPAO
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0004	0	3



KEY MAP

SCALE: 1:1,250,000

LEGEND

- TOMLINSON BRECHIN QUARRY LICENSED BOUNDARY
- ROADWAY
- WATERCOURSE
- PROVINCIALLY SIGNIFICANT WETLAND BASED ON MNR DATA
- WATERBODY

OGS BEDROCK GEOLOGY

- 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
- 1: PRECAMBRIAN

0 250 500 1,000

1:30,000 METRES

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. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
3. BASE MAP: ESRI, CGIAR, USGS, SOURCES: ESRI, TOMTOM, GARMIN, FAO, NOAA, USGS, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 17N

CLIENT

R.W. TOMLINSON LIMITED

PROJECT

LEVEL 1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

TITLE

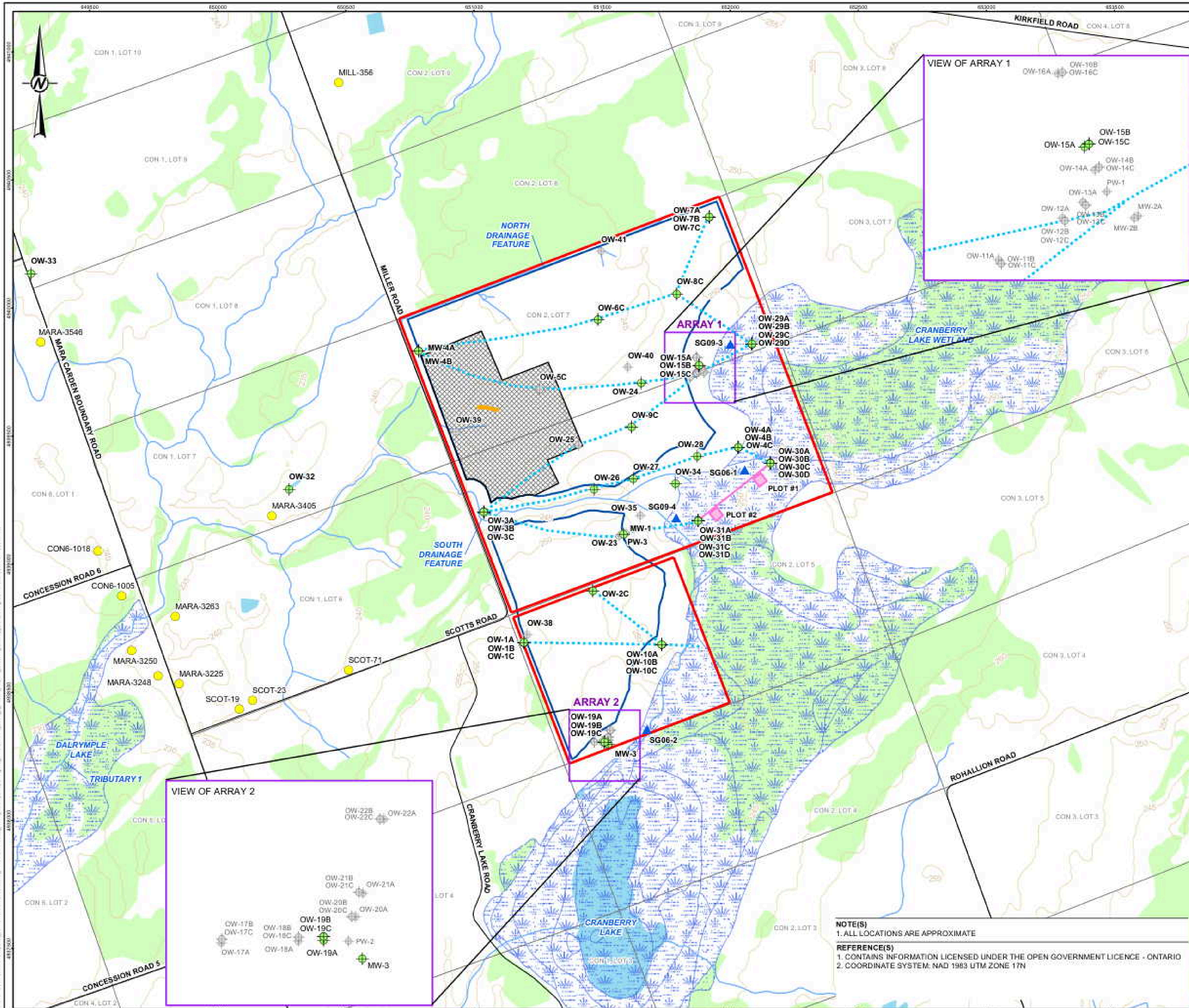
BEDROCK GEOLOGY

CONSULTANT

wsp

YYYY-MM-DD	2025-06-13
DESIGNED	JPAO
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0003	0	4



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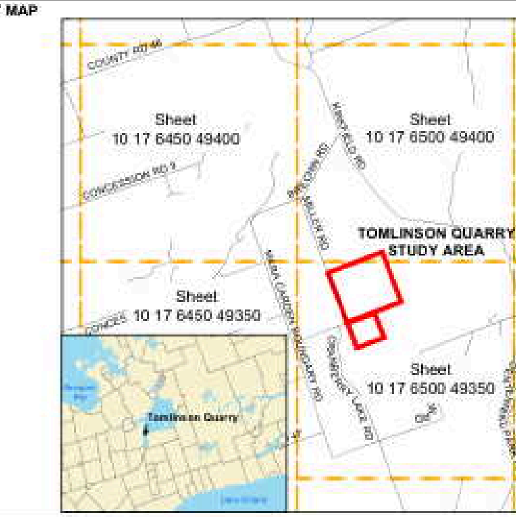


LEGEND

- EXISTING BOREHOLE INCLUDED IN PTTW MONITORING PROGRAM
- STAFF GAUGE LOCATION
- EXISTING BOREHOLE / DRILLHOLE (NOT INCLUDED IN PROGRAM)
- MONITORING WELL (NOT INCLUDED IN PROGRAM)
- WATER WELL INCLUDED IN PRIVATE WELL SURVEY
- APPROXIMATE LOCATION OF QUARRY FLOOR BUCKLE
- ALIGNMENT OF MONITORING WELL INSTALLATIONS BETWEEN ADVANCING QUARRY FACE AND WETLAND
- VEGETATION ASSESSMENT
- FIXED VEGETATION COMMUNITY PLOTS
- TOMLINSON BRECHIN QUARRY LICENSED BOUNDARY
- PUMP TEST LOCATION
- APPROXIMATE BOUNDARY OF EXISTING QUARRY
- EXTRACTION FOOTPRINT
- CONCESSION/LOT
- ROAD
- TOPOGRAPHIC CONTOUR, metres (5 m INTERVAL)
- DRAINAGE FEATURE
- PROVINCIALLY SIGNIFICANT WETLAND BASED ON MNR DATA
- WATERBODY
- WOODED AREA

0 150 300 600
1:15,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N

CLIENT
R.W. TOMLINSON LIMITED

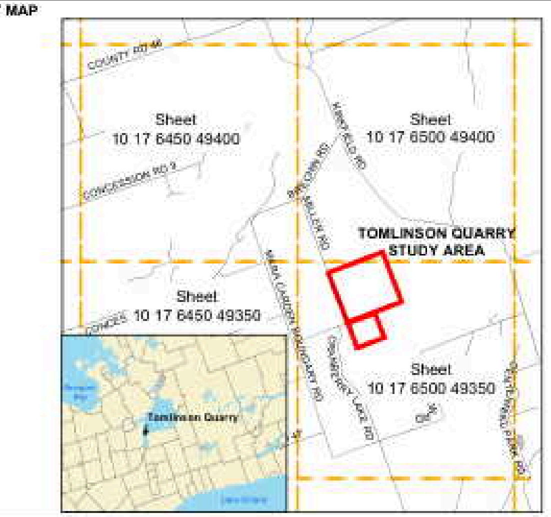
PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

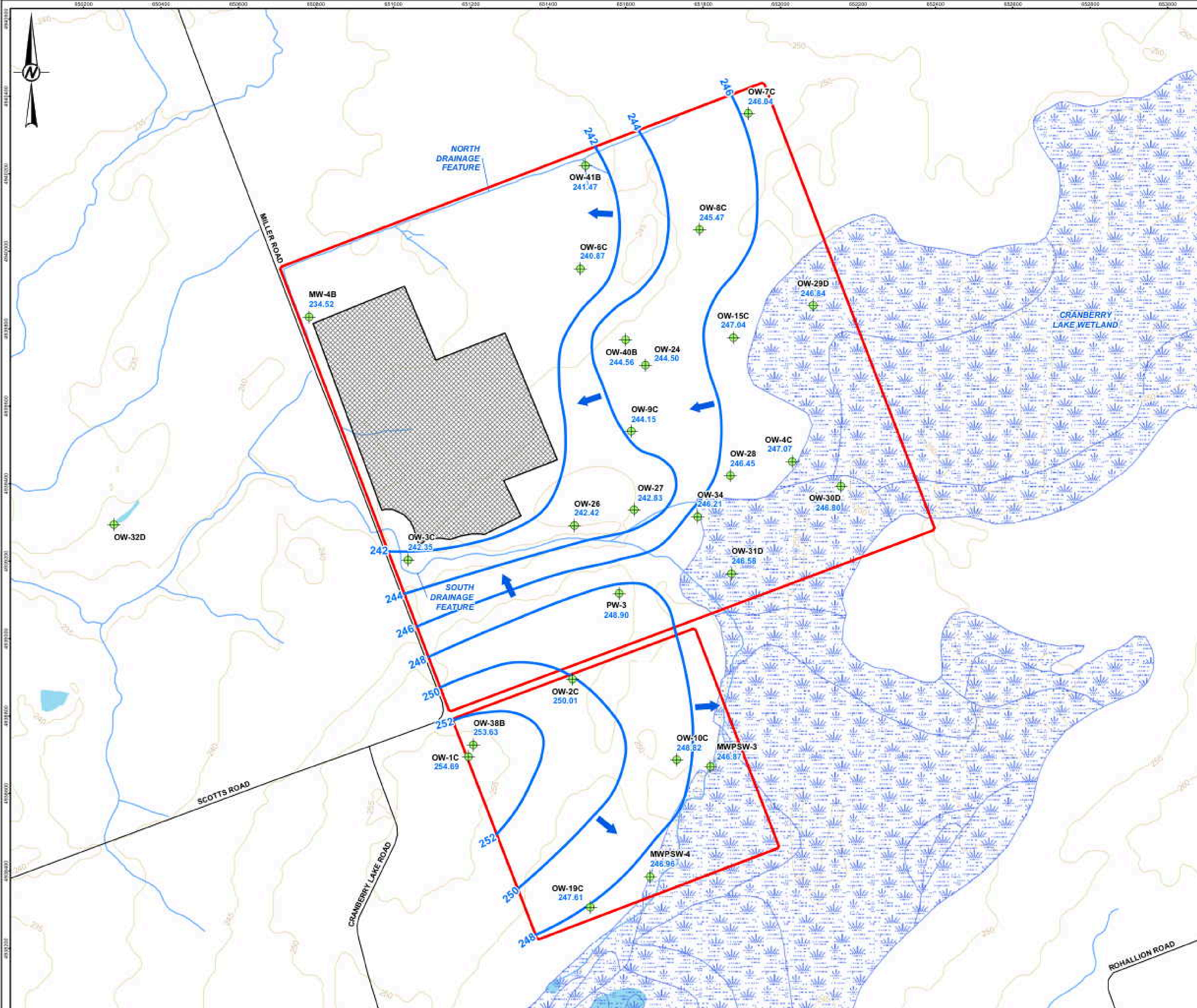
TITLE
MONITORING LOCATIONS

CONSULTANT		
WSP	YYYY-MM-DD	6/13/2025
	DESIGNED	JPAO
	PREPARED	BR
	REVIEWED	JPAO
	APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0004	0	5

KEY MAP





LEGEND

- BOREHOLE/DRILLHOLE LOCATION
- ROAD
- TOPOGRAPHIC CONTOUR, metres (5 m INTERVAL)
- DRAINAGE FEATURE
- WATERBODY
- PROVINCIALLY SIGNIFICANT WETLAND BASED ON MNR DATA
- APPROXIMATE BOUNDARY OF EXISTING QUARRY
- TOMLINSON BRECHIN QUARRY LICENSED BOUNDARY
- 238.35 GROUNDWATER ELEVATION
- INTERPRETED GROUNDWATER ELEVATION CONTOUR (DECEMBER 11, 2024)
- INTERPRETED GROUNDWATER FLOW DIRECTION

0 100 200 400
1:10,000 METRES

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N

CLIENT
R.W. TOMLINSON LIMITED

PROJECT
LEVEL1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

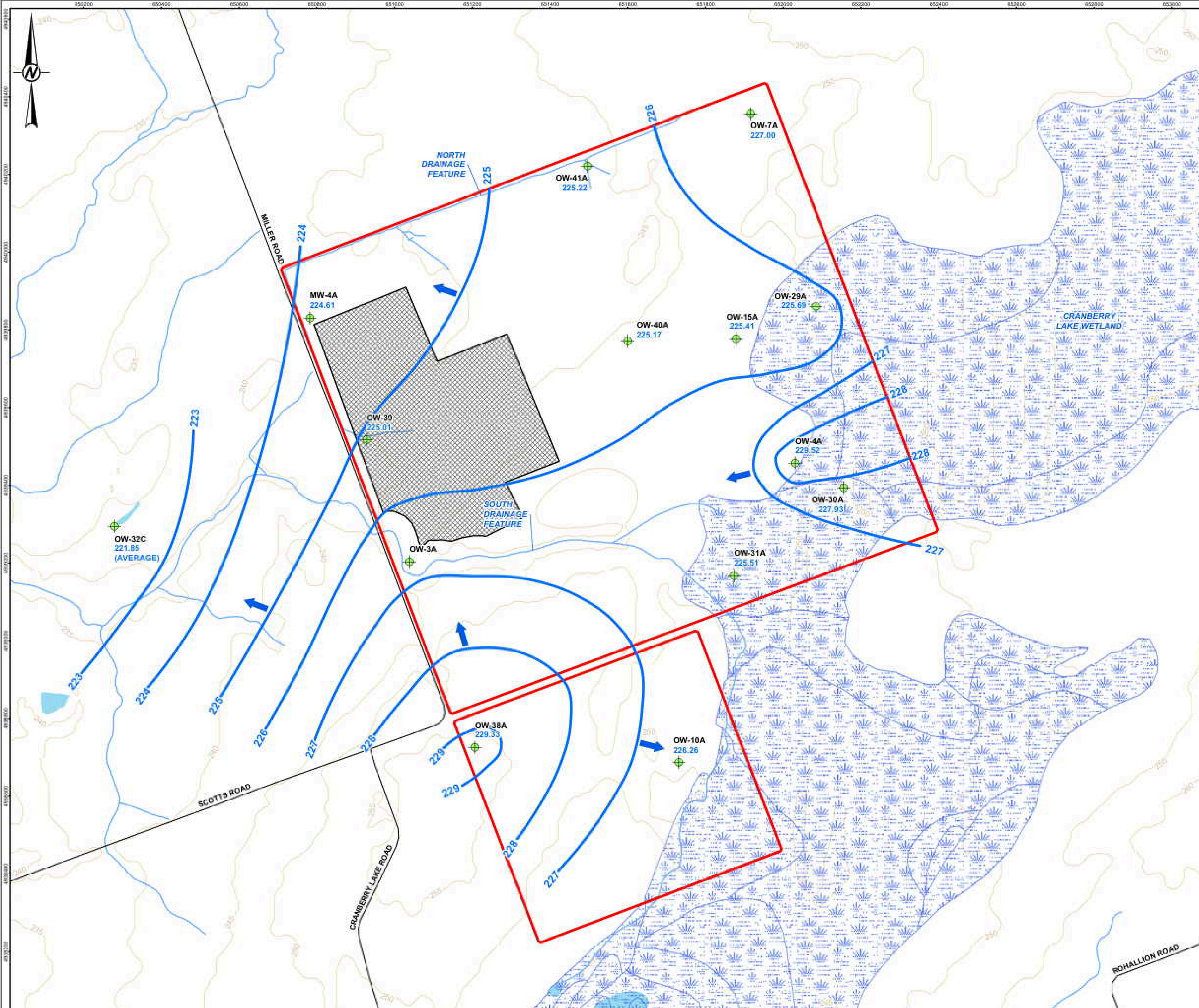
TITLE
GROUNDWATER TABLE ELEVATION CONTOURS (DECEMBER 11, 2024)

CONSULTANT

wsp

YYYY-MM-DD	6/13/2025
DESIGNED	JPAO
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0004	0	6



KEY MAP

LEGEND

- BOREHOLE/DRILLHOLE LOCATION
- ROAD
- TOPOGRAPHIC CONTOUR, metres (5 m INTERVAL)
- DRAINAGE FEATURE
- WATERBODY
- PROVINCIALLY SIGNIFICANT WETLAND BASED ON MNR DATA
- APPROXIMATE BOUNDARY OF EXISTING QUARRY
- TOMLINSON BRECHIN QUARRY LICENSED BOUNDARY
- 238.35 GROUNDWATER ELEVATION
- INTERPRETED GROUNDWATER ELEVATION CONTOUR (DECEMBER 11, 2024)
- INTERPRETED GROUNDWATER FLOW DIRECTION

NOTE(S)
1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)
1. CONTAINS INFORMATION LICENSED UNDER THE OPEN GOVERNMENT LICENCE - ONTARIO
2. COORDINATE SYSTEM: NAD 1983 UTM ZONE 17N

0 100 200 400
1:10,000 METRES

CLIENT
R.W. TOMLINSON LIMITED

PROJECT
LEVEL1 AND LEVEL 2 WATER REPORT – BRECHIN QUARRY DEEPENING

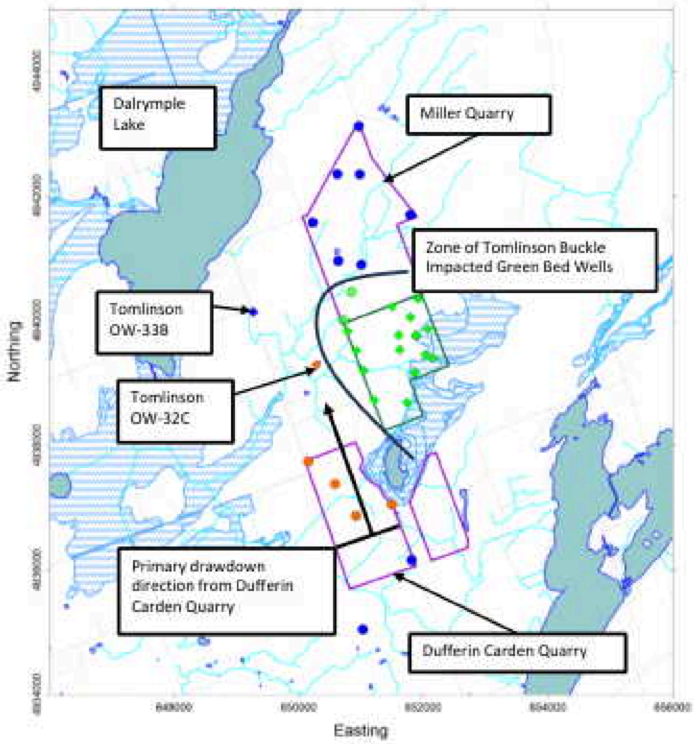
TITLE
GROUNDWATER ELEVATION CONTOURS FOR GULL RIVER FORMATION (GREEN BEDS) WELLS (DECEMBER 11, 2024)

CONSULTANT

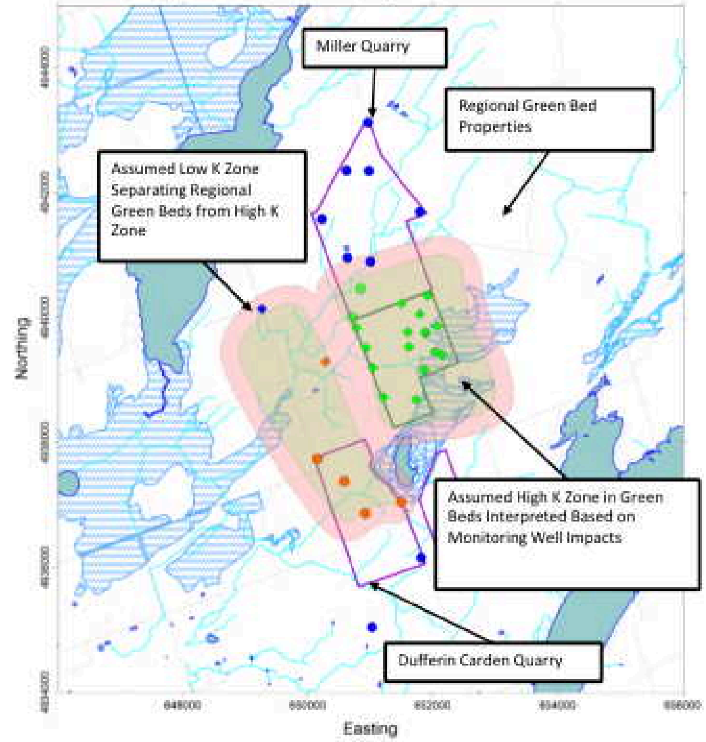
YYYY-MM-DD	6/13/2025
DESIGNED	JPAO
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
20449322	0004	0	7

Impacted Green Bed Monitoring Wells



Interpreted Conductivity Zones In Green Beds



- Tomlinson Monitoring Well Impacted by Buckle
- Tomlinson Monitoring Well Interpreted to be Impacted by Dufferin Carden Quarry Dewatering Prior to Tomlinson Beginning Operations
- Tomlinson Monitoring Well With Limited Interpreted Impact From Buckle and Tomlinson/Dufferin Quarry Operations
- Other Quarry Monitoring Well Impacted by Buckle
- Other Quarry Monitoring Well Interpreted to be Impacted by Dufferin Carden Quarry Dewatering Prior to Tomlinson Beginning Operations
- Other Quarry Monitoring Well With Limited Interpreted Impact From Buckle and Tomlinson/Dufferin Quarry Operations

LEGEND

- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road

Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
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CLIENT: R.W. TOMLINSON LIMITED

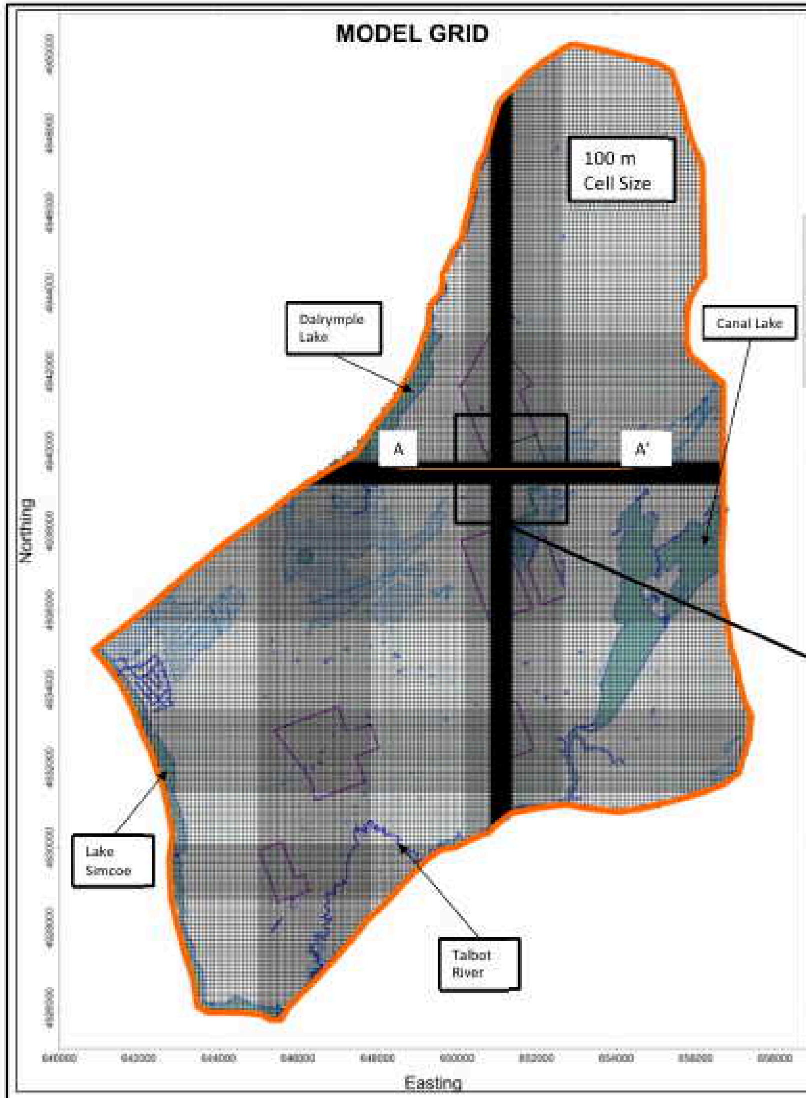
PROJECT: LEVEL 1 AND LEVEL 2 WATER REPORT BRECHIN QUARRY DEEPENING

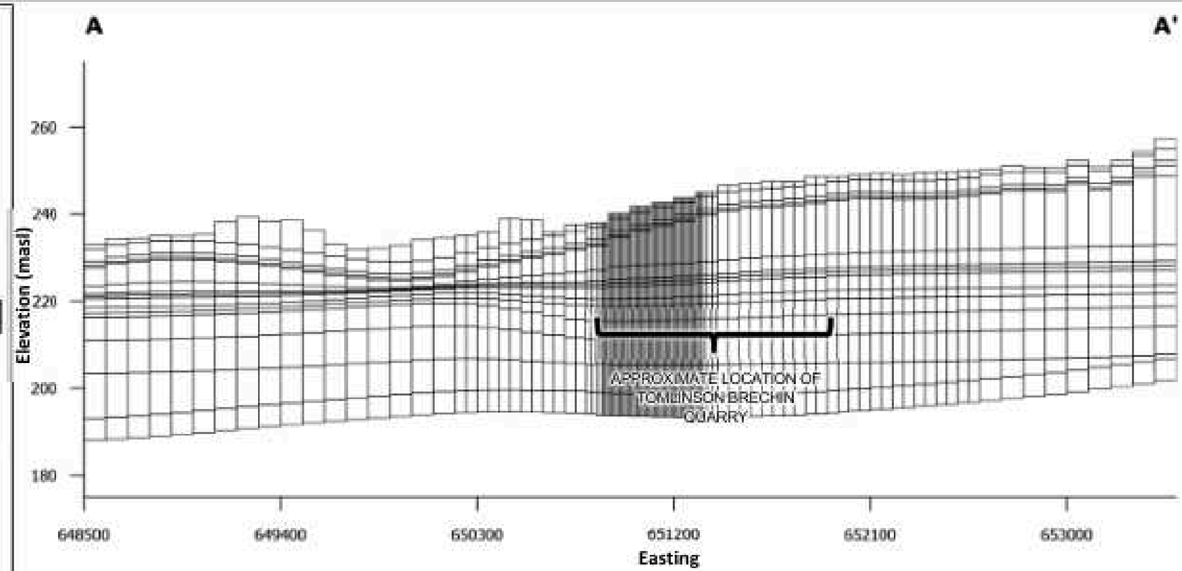
CONSULTANT: wsp

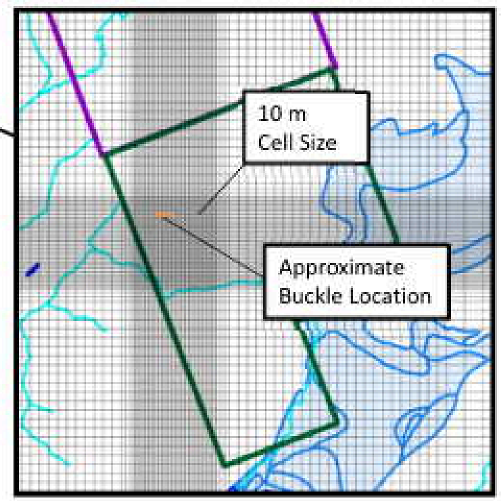
YYYY-MM-DD	2024-11-13
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM

TITLE: GREEN BED MONITORING WELLS IMPACTED BY BRECHIN QUARRY BUCKLE AND/OR LOCAL QUARRY OPERATIONS

PROJECT NO. 20449322 REV. FIGURE 8







Model Information

- 259 columns, 400 rows
- 15 layers
- 959,160 active cells
- 10 m to 100 m cell size
  - Grid refined around quarries and the Tomlinson Brechin quarry floor buckle
- 0.2 m to 30 m layer thicknesses

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse

Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. Vertical exaggeration of 20 in cross-section

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R.W. TOMLINSON LIMITED

PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
PROPOSED BRECHIN QUARRY DEEPENING

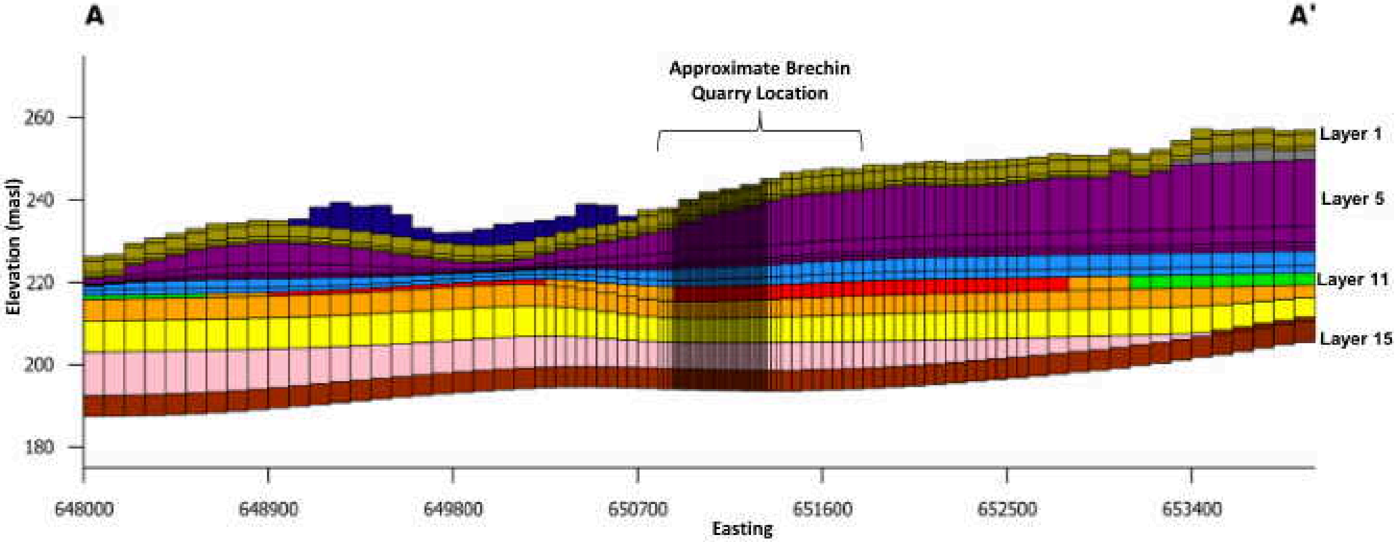
CONSULTANT
wsp

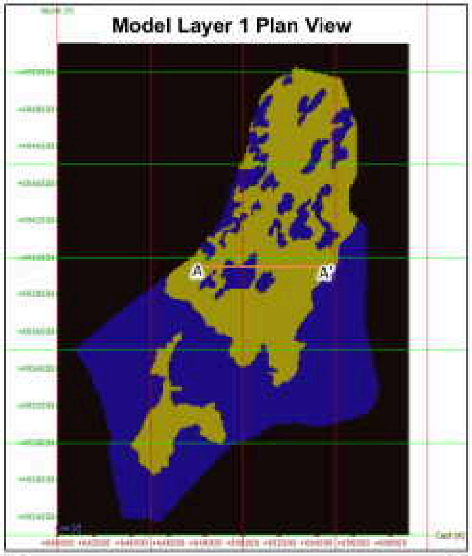
YYYY-MM-DD	2024-11-13
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM

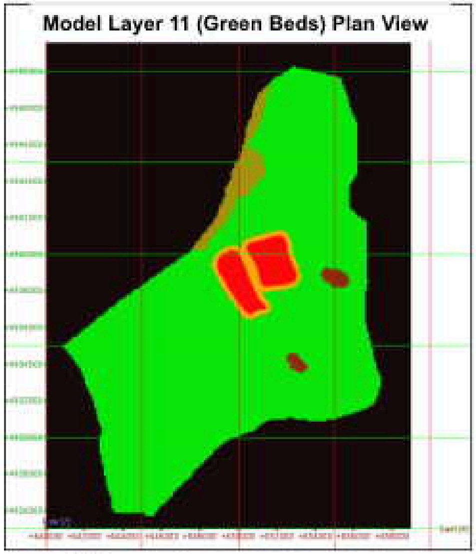
TITLE
GROUNDWATER MODEL GRID AND LAYERING

PROJECT NO. 20449322 REV. FIGURE 9

Cross-Section A-A'







	Hydrostratigraphic Unit	K_H (m/s)	K_V (m/s)
(dark blue)	Overburden	5×10^{-6}	5×10^{-7}
(olive)	Weathered Bedrock	5×10^{-5}	2.5×10^{-5}
(grey)	Verulam Formation	1×10^{-8}	1×10^{-9}
(purple)	Bobcaygeon Formation	5×10^{-9}	5×10^{-10}
(blue)	Gull River Unit 4	5×10^{-9}	5×10^{-11}
(green)	Gull River Unit 3 (Green Beds) Regional	1×10^{-5}	5×10^{-6}
(red)	Gull River Unit 3 (Green Beds) High K Zone	1×10^{-4}	5×10^{-5}
(orange)	Gull River Unit 2 / (Green Beds) Low K Zone	1×10^{-8}	1×10^{-10}
(yellow)	Gull River Unit 1	5×10^{-7}	5×10^{-8}
(pink)	Shadow Lake Formation	2×10^{-7}	2×10^{-8}
(brown)	Precambrian Contact	5×10^{-6}	5×10^{-7}

Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Vertical exaggeration of 20 in cross-section
3. See report Section 6.11 and Figure 8 for further details regarding the assignment of the hydraulic conductivity zones within layer 11.

CLIENT
R.W. TOMLINSON LIMITED

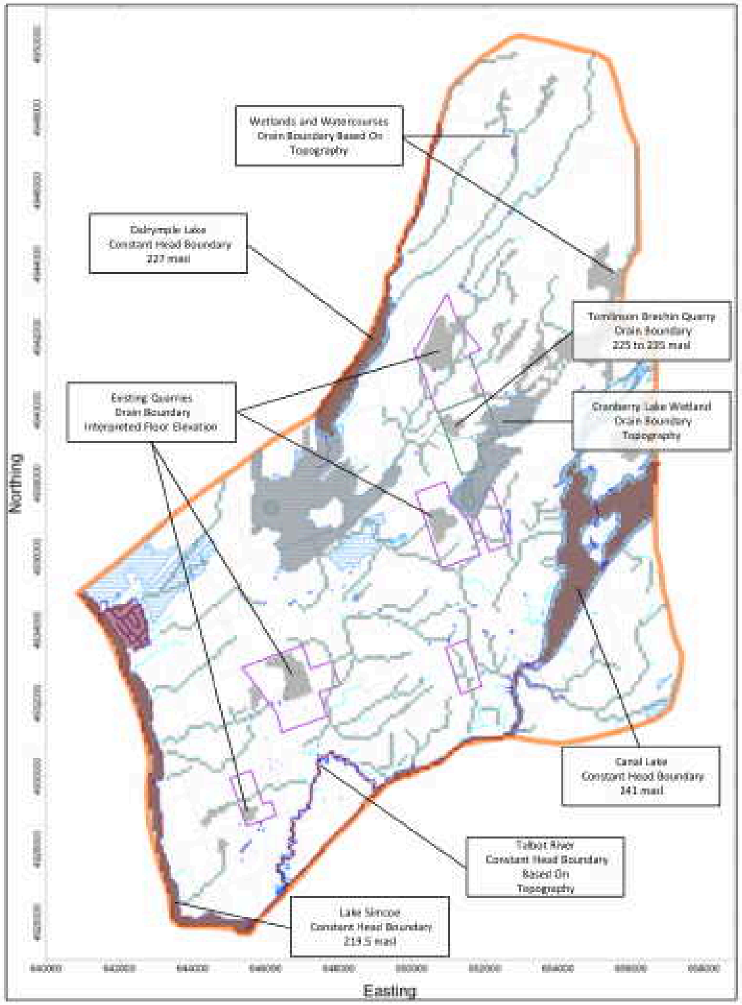
PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

CONSULTANT
wsp

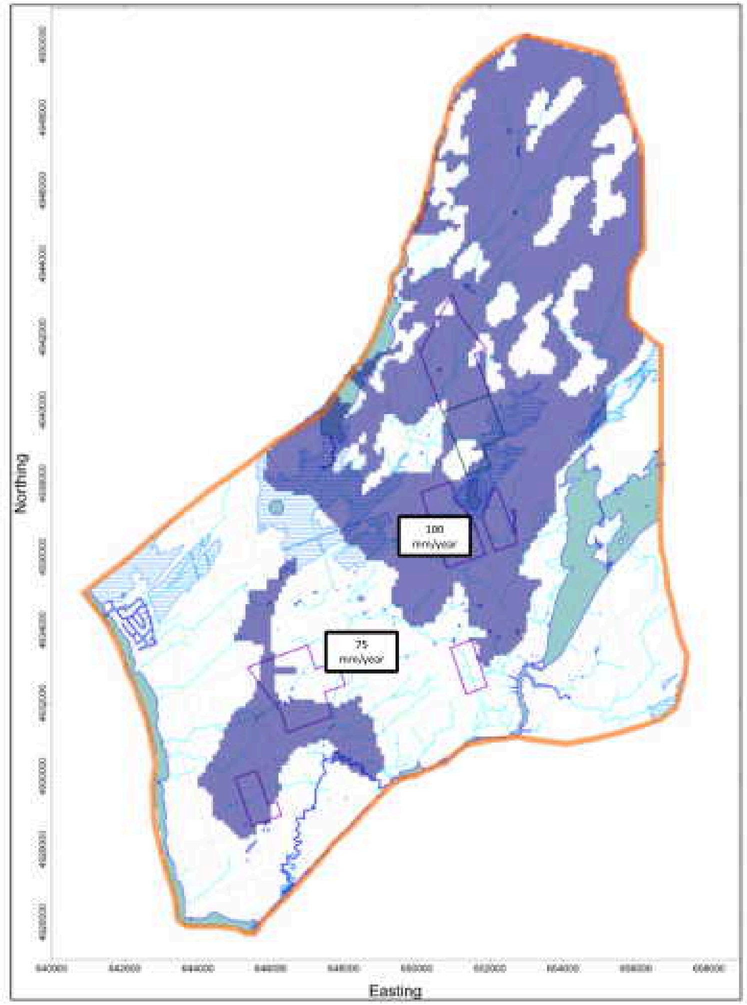
YYYY-MM-DD	2024-11-11
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAG
APPROVED	KAM

TITLE
GROUNDWATER MODEL CROSS SECTION AND HYDRAULIC CONDUCTIVITY VALUES

PROJECT NO. 20449322 | REV. | FIGURE 10



BOUNDARY CONDITIONS



RECHARGE

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Constant Head Boundary
- Drain Boundary

Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. Boundary conditions represent calibrated model to current conditions

CLIENT
R.W. TOMLINSON LIMITED

CONSULTANT
wsp

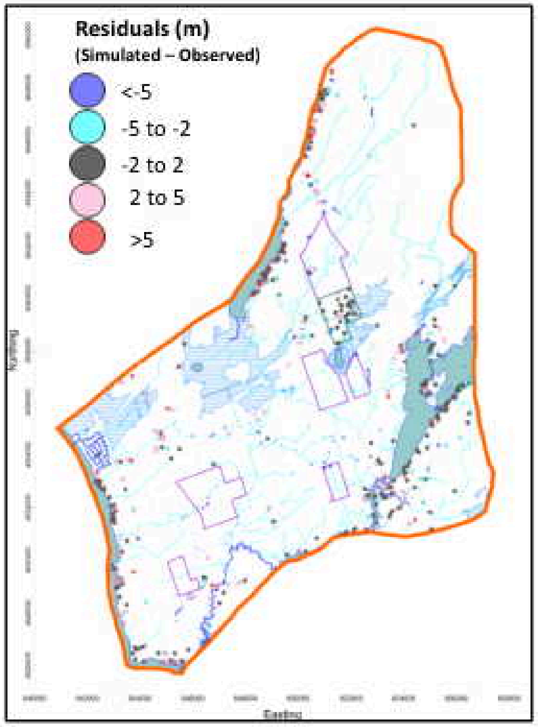
YYYY-MM-DD	2024-11-13
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAO
APPROVED	KAM

PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

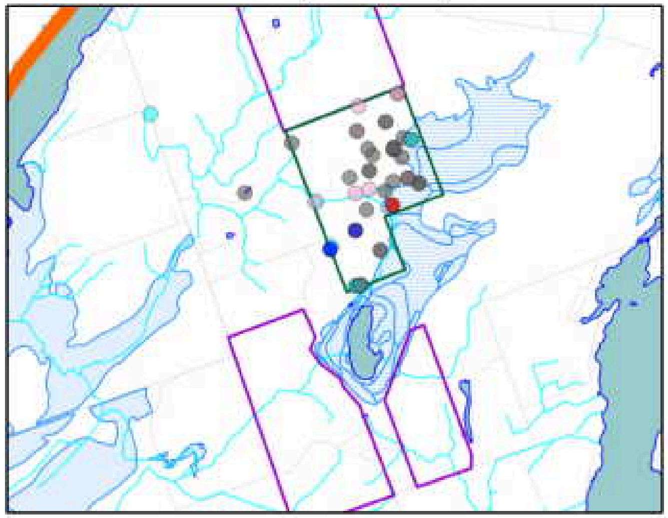
TITLE
GROUNDWATER MODEL BOUNDARY CONDITIONS AND RECHARGE

PROJECT NO. 20449322 REV. FIGURE 11

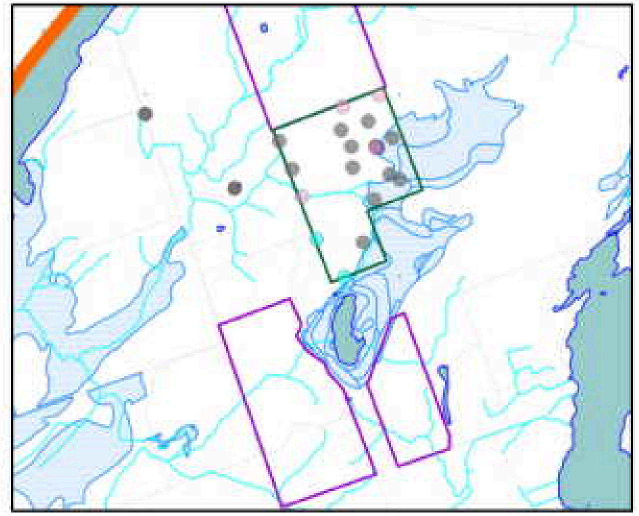
WWIS and Tomlinson Wells

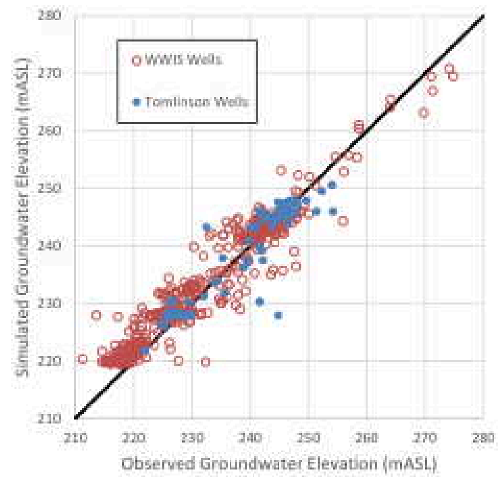


Tomlinson Wells Completed Above Top of Green Beds



Tomlinson Wells Completed Below Top of Green Beds





Tomlinson Wells
Residual Mean (m) = -0.2
Abs. Residual Mean (m) = 2.0
Root Mean Squared (m) = 3.3
Normalized RMS (%) = 10.2

Tomlinson and WWIS Wells
Residual Mean (m) = 1.1
Abs. Residual Mean (m) = 2.6
Root Mean Squared (m) = 3.4
Normalized RMS (%) = 5.2

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road

Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. Tomlinson Wells based on 2022 average water levels
4. WWIS data sourced from the MECP WWIS database accessed in 2023

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PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

CONSULTANT
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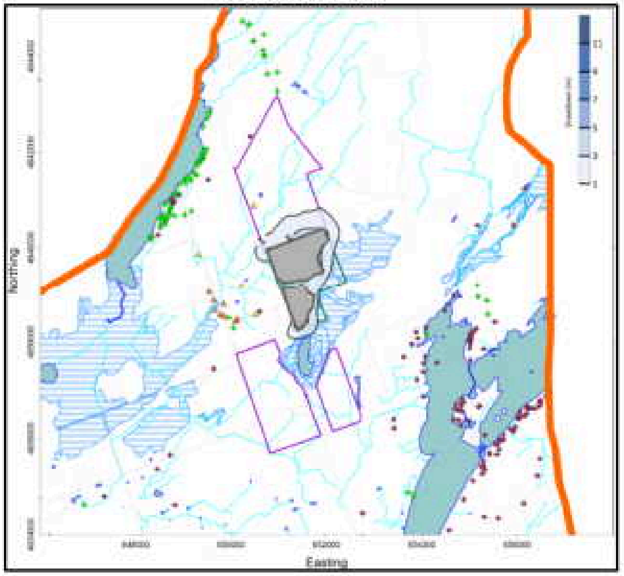
YYYY-MM-DD 2024-11-11
PREPARED SPS
DESIGNED SPS
REVIEWED JPAD
APPROVED KAM

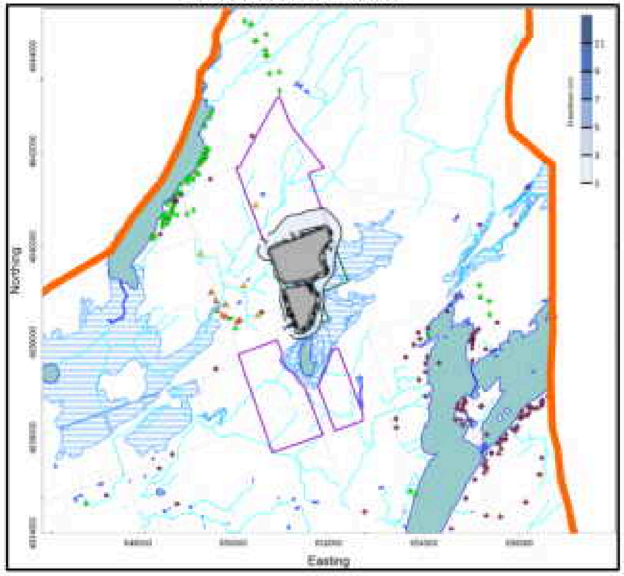
TITLE
GROUNDWATER FLOW MODEL CALIBRATION

PROJECT NO. 20449322
REV.
FIGURE 12

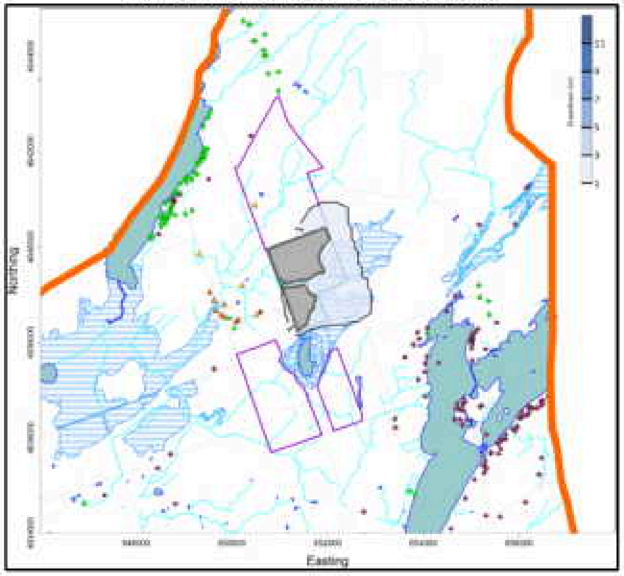
Weathered Bedrock



Bobcaygeon Formation



Gull River Formation Unit 3 (Green Beds)



Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
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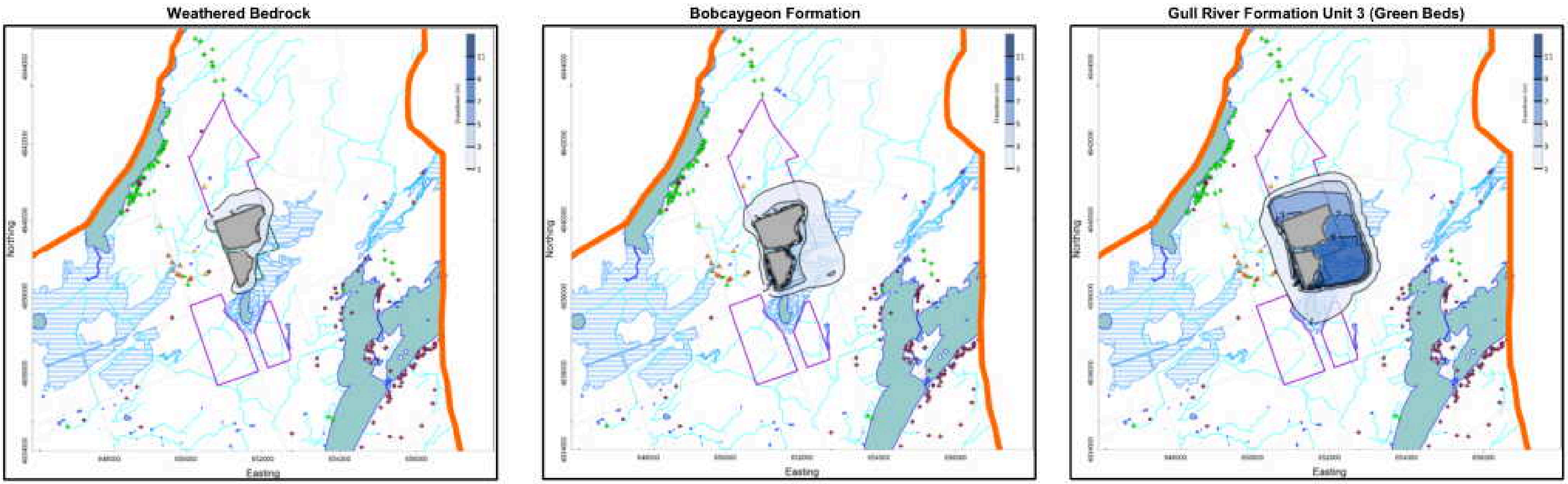
3. MECP listed supply wells (WWIS Final status code of 1) with good location accuracy (WWIS UTM reliability code < 6) presented

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Quarry Extraction
- Simulated Groundwater Drawdown Contour (m)
- MECP Supply Well Completed Above Green Beds
- MECP Supply Well Completed Below Green Beds
- Tomlinson Well Survey – Dug Well
- Tomlinson Well Survey – Drilled Well

CLIENT	R.W. TOMLINSON LIMITED
PROJECT	LEVEL 1 AND LEVEL 2 WATER REPORT BRECHIN QUARRY DEEPENING
YYYY-MM-DD	2024-11-13
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM
TITLE	SCENARIO 1: SIMULATED GROUNDWATER DRAWDOWN FROM EXISTING CONDITIONS – TOMLINSON BRECHIN QUARRY FULLY EXTRACTED TO CURRENTLY APPROVED DEPTH
PROJECT NO.	20449322
REV.	
FIGURE	13



Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. MECP listed supply wells (WWIS Final status code of 1) with good location accuracy (WWIS UTM reliability code < 6) presented

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Quarry Extraction
- Simulated Groundwater Drawdown Contour (m)
- MECP Supply Well Completed Above Green Beds
- MECP Supply Well Completed Below Green Beds
- Tomlinson Well Survey – Dug Well
- Tomlinson Well Survey – Drilled Well

R.W. TOMLINSON LIMITED

LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

YYYY-MM-DD	2024-11-13
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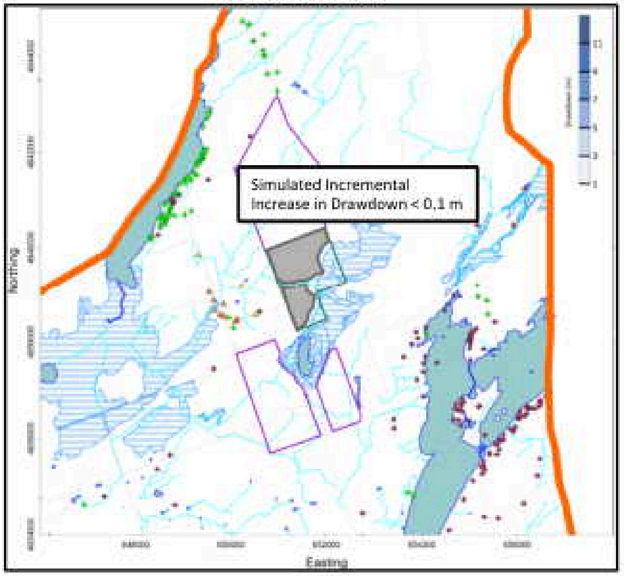
SCENARIO 2: SIMULATED GROUNDWATER DRAWDOWN FROM EXISTING CONDITIONS – TOMLINSON BRECHIN QUARRY FULLY EXTRACTED WITH PROPOSED DEEPENING

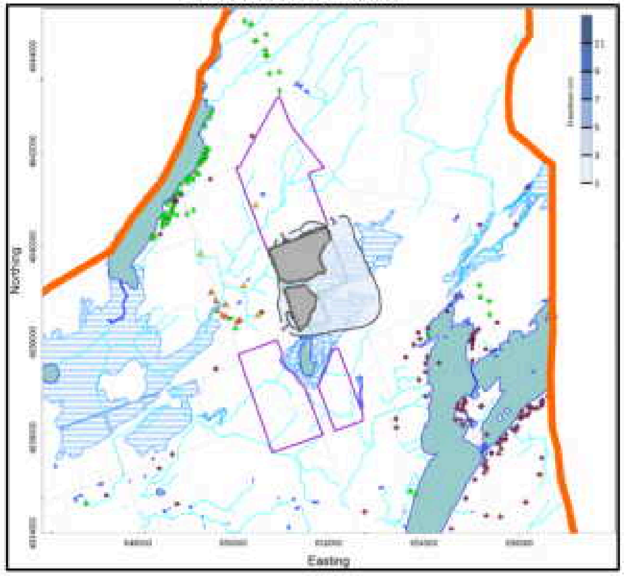
20449322

FIGURE 14

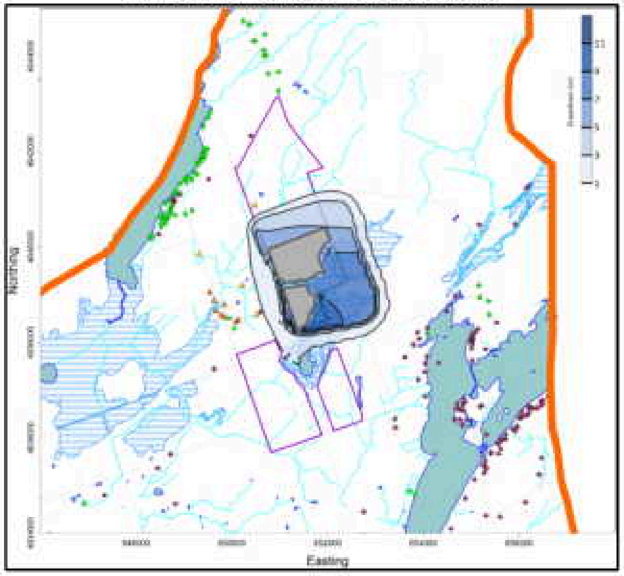
Weathered Bedrock



Bobcaygeon Formation



Gull River Formation Unit 3 (Green Beds)



Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
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3. MECP listed supply wells (WWIS Final status code of 1) with good location accuracy (WWIS UTM reliability code < 6) presented

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Quarry Extraction
- Simulated Groundwater Drawdown Contour (m)
- MECP Supply Well Completed Above Green Beds
- MECP Supply Well Completed Below Green Beds
- Tomlinson Well Survey – Dug Well
- Tomlinson Well Survey – Drilled Well

CLIENT
R.W. TOMLINSON LIMITED

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YYYY-MM-DD	2024-11-13
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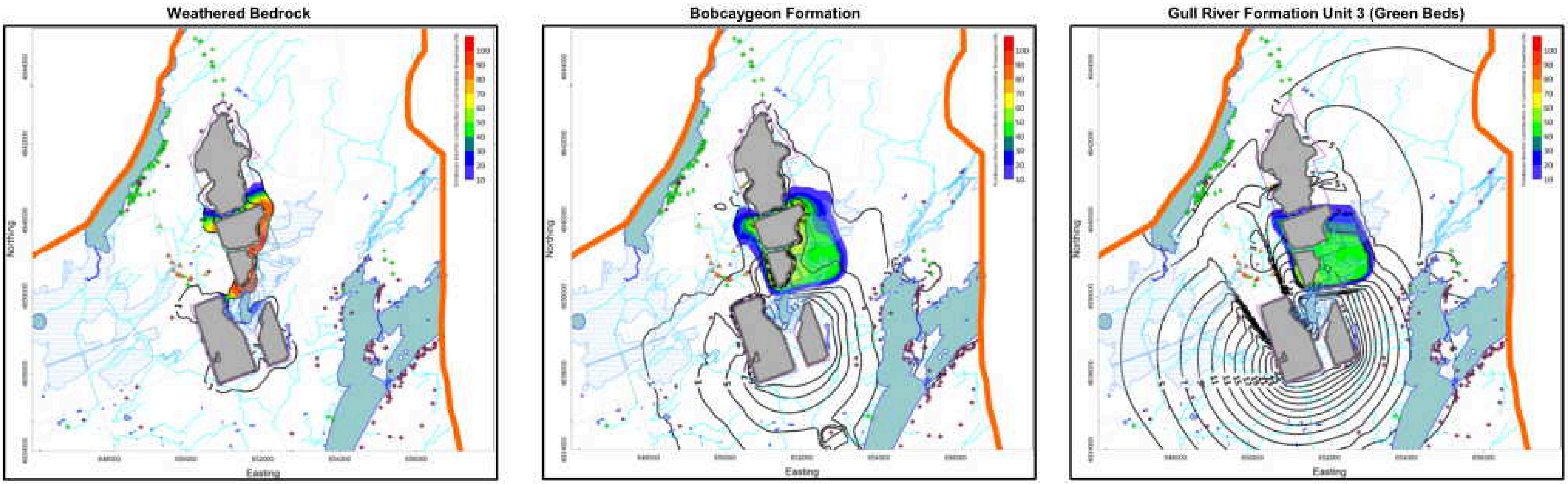
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM

PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

TITLE
SIMULATED INCREMENTAL INCREASE IN GROUNDWATER DRAWDOWN CAUSED BY TOMLINSON BRECHIN DEEPENING COMPARED TO CURRENTLY APPROVED QUARRY DEPTH

PROJECT NO. 20449322 REV. FIGURE 15



Notes

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3. MECP listed supply wells (WWIS Final status code of 1) with good location accuracy (WWIS UTM reliability code < 6) presented

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Quarry Extraction
- Simulated Groundwater Drawdown Contour (m)
- MECP Supply Well Completed Above Green Beds
- MECP Supply Well Completed Below Green Beds
- Tomlinson Well Survey – Dug Well
- Tomlinson Well Survey – Drilled Well

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PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

CONSULTANT

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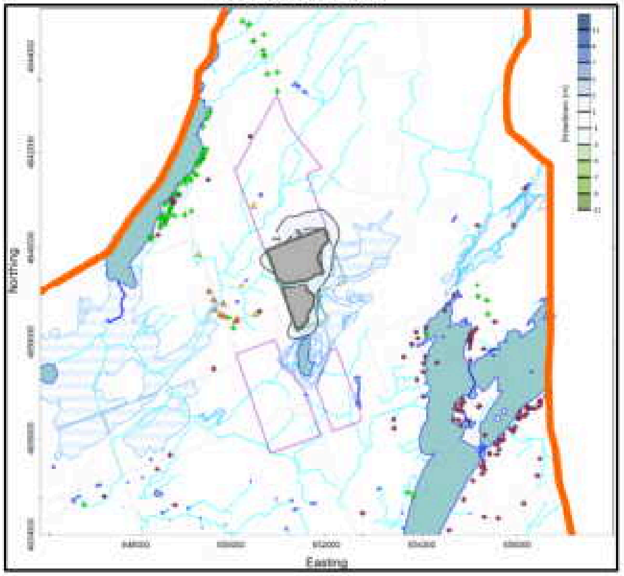
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM

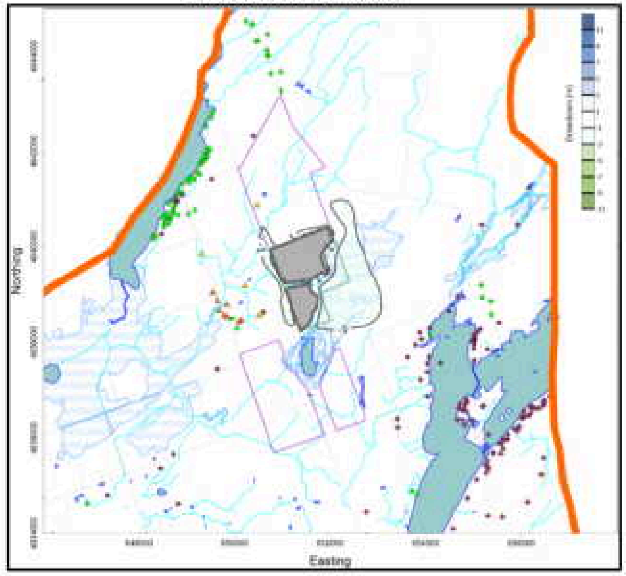
TITLE
SCENARIO 3: SIMULATED PERCENT CONTRIBUTION FROM DEEPENED TOMLINSON BRECHIN QUARRY TO CUMULATIVE DRADOWN WITH ALL SURROUNDING QUARRIES FULLY EXTRACTED

PROJECT NO. 20449322 REV. FIGURE 16

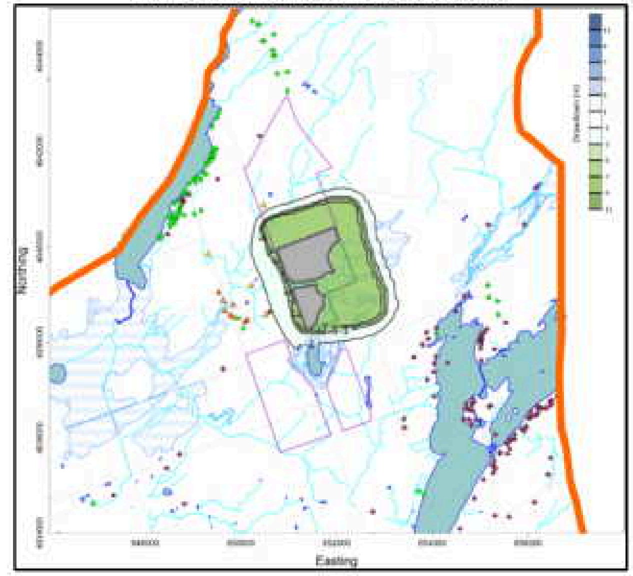
Weathered Bedrock



Bobcaygeon Formation



Gull River Formation Unit 3 (Green Beds)



Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. MECP listed supply wells (WWIS Final status code of 1) with good location accuracy (WWIS UTM reliability code < 6) presented
4. Negative drawdown indicates an increase in water levels compared to current conditions.

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Quarry Extraction
- Simulated Groundwater Drawdown Contour (m)
- MECP Supply Well Completed Above Green Beds
- MECP Supply Well Completed Below Green Beds
- Tomlinson Well Survey – Dug Well
- Tomlinson Well Survey – Drilled Well

CLIENT
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PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

CONSULTANT
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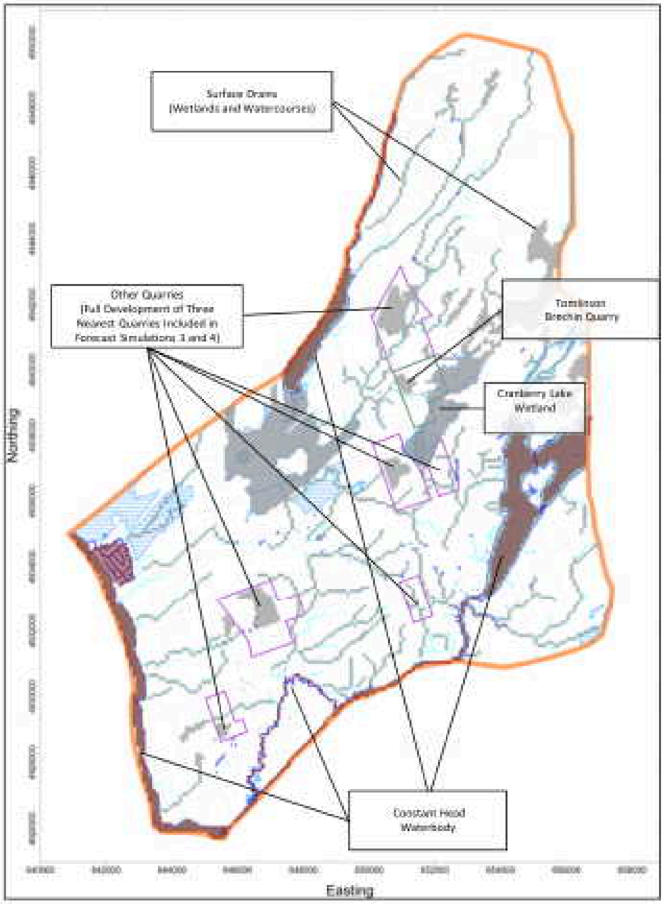
YYYY-MM-DD	2024-11-13
PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM

TITLE
SCENARIO 5: SIMULATED GROUNDWATER DRAWDOWN FROM EXISTING CONDITIONS – TOMLINSON BRECHIN QUARRY FULLY REHABILITATED AS A LAKE

PROJECT NO. 20449322 REV. FIGURE 17



	Scenario 0		Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	Inflow (m^3/day)	Outflow (m^3/day)	Inflow (m^3/day)	Outflow (m^3/day)	Inflow (m^3/day)	Outflow (m^3/day)	Inflow (m^3/day)	Outflow (m^3/day)	Inflow (m^3/day)	Outflow (m^3/day)	Inflow (m^3/day)	Outflow (m^3/day)
Recharge	46,900	--	46,900	--	46,900	--	46,900	--	46,900	--	46,900	--
Constant Head (Waterbody)	1,350	14,200	1,350	14,200	1,350	14,200	1,390	14,000	1,390	14,000	1,350	14,200
Cranberry Lake Wetland	--	1,310	--	1,010	--	995	--	800	--	1,060	--	1,020
Other Surface Drains (Watercourse and Wetland)	--	28,100	--	27,900	--	27,900	--	26,600	--	26,700	--	28,000
Tomlinson Brechin Quarry	--	710	--	1,250	--	1,300	--	1,060	--	470	--	1,060
Other Quarries	--	3,860	--	3,860	--	3,840	--	5,760	--	6,040	--	3,860
Mass Balance Error (%)	<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	

Scenario	Description
Scenario 0	Existing conditions scenario used for model calibration.
Scenario 1	Full development of the Tomlinson Brechin Quarry based on currently approved license with other quarries remaining at existing conditions.
Scenario 2	Full development of the Tomlinson Brechin Quarry including proposed deepening with other quarries remaining at existing conditions.
Scenario 3	Full development of the Tomlinson Brechin Quarry including proposed deepening with the other quarries fully developed.
Scenario 4	Tomlinson Brechin Quarry remaining at existing conditions with the other quarries fully developed.
Scenario 5	Full rehabilitation as a lake of the Tomlinson Brechin Quarry including deepening with other quarries remaining at existing conditions.

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Constant Head Boundary
- Drain Boundary

Notes

1. Coordinate System: UTM Zone 17 Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. Values presented in mass balance table are rounded to three significant digits.
4. Inflow to the quarries represents groundwater discharge and does not account for direct precipitation, surface water runoff or water released from storage.

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LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

GROUNDWATER FLOW MODEL WATER BALANCE

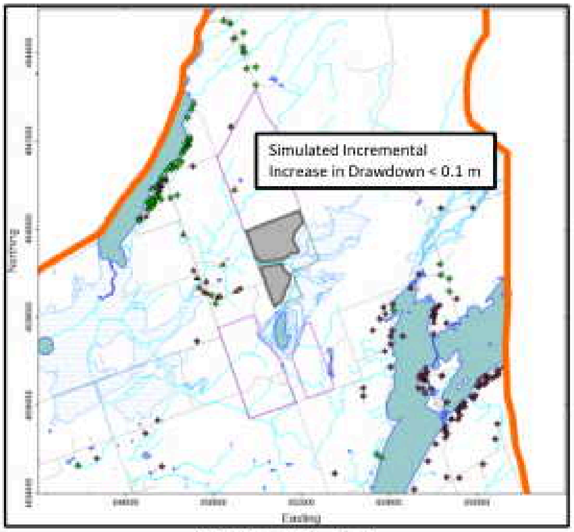
20449322

18

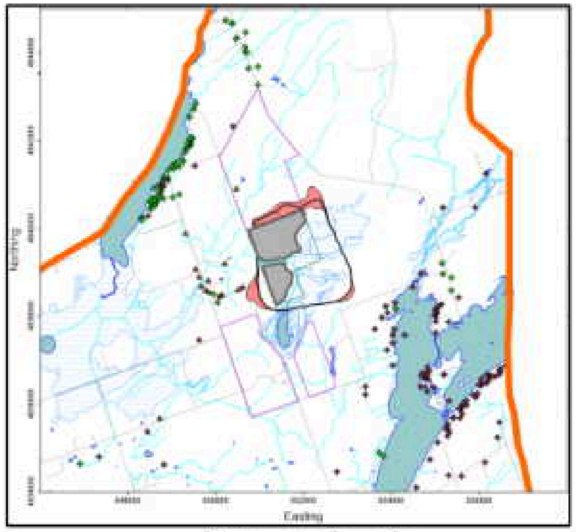
Sensitivity Run	Description
SR1a	5x increase in regional green bed and weathered bedrock K
SR1b	5x decrease in regional green bed and weathered bedrock K
SR2a	20% increase in recharge
SR2b	20% decrease in recharge

Groundwater Discharge

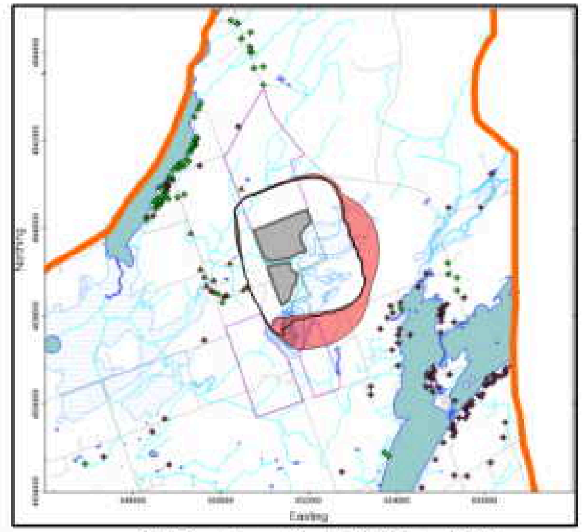
	Base Case		SR1a		SR1b		SR2a		SR2b	
	S1 (Current License)	S2 (Deepened)	S1 (Current License)	S2 (Deepened)	S1 (Current License)	S2 (Deepened)	S1 (Current License)	S2 (Deepened)	S1 (Current License)	S2 (Deepened)
Tomlinson Brechin Quarry (m^3/day)	1250	1300	1910	1960	915	975	1425	1475	1070	1120
Cranberry Lake Wetland (m^3/day)	1010	995	225	220	1460	1445	1290	1280	730	720



Weathered Bedrock



Bobcaygeon Formation



Gull River Formation Unit 3 (Green Beds)

LEGEND

- Model Domain
- Tomlinson Brechin Quarry License Boundary
- Other Quarry License Boundary
- Provincially Evaluated Wetland
- Waterbody
- Watercourse
- Road
- Quarry Extraction
- MECP Supply Well Completed Above Green Beds
- MECP Supply Well Completed Below Green Beds
- Tomlinson Well Survey – Dug Well
- Tomlinson Well Survey – Drilled Well
- Base Case 1 m Drawdown Contour
- Envelope of 1 m Drawdown Contours from Sensitivity Runs

Notes

1. Coordinate System: UTM Zone 17
   Datum: NAD 1983
2. Contains information licensed under the Open Government License – Ontario
3. MECP listed supply wells (WWIS Final status code of 1) with good location accuracy (WWIS UTM reliability code < 6) presented

CLIENT
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PREPARED	SPS
DESIGNED	SPS
REVIEWED	JPAD
APPROVED	KAM

PROJECT
LEVEL 1 AND LEVEL 2 WATER REPORT
BRECHIN QUARRY DEEPENING

TITLE
SENSITIVITY RUNS 1A AND 1B AND 2A AND 2B - SIMULATED INCREMENTAL INCREASE IN DRAWDOWN CAUSED BY TOMLINSON BRECHIN DEEPENING COMPARED TO CURRENTLY APPROVED DEPTH (VARYING GREEN BEDS HYDRAULIC CONDUCTIVITY AND MODEL RECHARGE)

PROJECT NO. 20449322 REV. FIGURE 19

APPENDIX A

Author Qualifications and Experience

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

WSP Canada Inc. – Ottawa

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./WSP Canada Inc. – Ottawa

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 (now WSP) 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/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 (now WSP) 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 (now WSP) 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 (now WSP) 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 (now WSP) 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 (now WSP) 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 (now WSP) 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 (now WSP) 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

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

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. 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

WSP Canada Inc. – Ottawa, Ontario

Employment History

Career Summary

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 WSP Canada Inc. (previously Golder Associates), and has 20 years of broad experience in the fields of water supply development, physical hydrogeological characterization studies, regional scale groundwater studies, waste management, contaminated sites assessment /remediation, aggregate resource evaluations and the licensing and permitting of quarry development and expansion projects. Kris is responsible for business development, project management, and senior technical review of hydrogeology, quarry and sand and gravel pit development and expansion, golf course irrigation, site assessment and remediation projects, and waste facility siting, design, operation and environmental compliance monitoring assignments from the Ottawa office.

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

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

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

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

Golder Associates Ltd. – Ottawa, Ontario
Hydrogeologist/Senior Hydrogeologist (1988 to 1997)

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

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

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

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

PROJECT EXPERIENCE – WATER RESOURCES MANAGEMENT

Village of Winchester Water Supply Project
Ontario, Canada

Project Hydrogeologist for the Village of Winchester Water Supply Expansion Project. This project included the preliminary evaluation of potential target aquifers followed by a comprehensive test well investigation and aquifer characterization program. Participated in the development of a comprehensive Water Resources Protection Strategy.

Rural Subdivision Development
Ontario, Canada

Supervised test well drilling programs for numerous residential, industrial and commercial private services subdivision developments including evaluation and selection of target aquifers, development of site specific well construction requirements, analysis and interpretation of physical hydrogeological data and groundwater chemical data and preparation and submission of detailed hydrogeological reports. Responsible for conducting many subsurface investigations as related to the installation of small and large subsurface septic sewage disposal systems for private services developments including projects subject to the Ontario Ministry of the Environment Reasonable Use Guideline B-7.

Communal / Commercial Water Supply Evaluation
Ontario, Canada

Project Manager for communal water supply investigations for non-profit housing developments in Elgin and Clayton, Ontario and time share condominium development in Cobden, Ontario; responsible for groundwater resource evaluation with respect to project specific water supply requirements. Conducted hydrogeological assessment of the Evergreen Spring Water Site in the Township of Sebastopol, Ontario for Cott Beverages Ltd.; assessment included characterization of geological setting, quantity, quality and age of spring water and evaluation of potential sources of contamination in the vicinity of the spring.

Township of Kingston Planning Study
Ontario

Conducted hydrogeological study and general terrain analysis of rural Kingston Township to characterize the present status of the Township's groundwater resources to assist in establishing planning policies for locating new developments on private services and to provide standards for water well construction within the Municipality.

Land Development Evaluation
Ontario

Conducted a preliminary hydrogeological and terrain evaluation of a 400 acre parcel of land south of the Ottawa International Airport with respect to the feasibility of developing the site as a rural residential subdivision on private services.

PROJECT EXPERIENCE – WASTE MANAGEMENT

Township of Clarence Landfill Buchanan Landfill
Bourget, Ontario/Chalk River, Ontario, Canada

Preparation and submission of documentation to the Ontario Ministry of the Environment to obtain an exemption from the Environmental Assessment Act and approval under the Environmental Protection Act for interim expansions of the Township of Clarence Landfill and Buchanan Landfill. Project involved detailed hydrogeological and geophysical site characterization studies, development of mitigation measures to address existing off-site impacts on groundwater and surface water resources and participation in the preparation of the site development and operations reports, trigger mechanisms, and contingency measures, site closure plans, public participation/presentations, document preparation and representation to regulatory agencies. Expert testimony at the Environmental Assessment Board hearings resulting in successful applications.

Dodge Landfill
Espanola, Ontario, Canada

Project Hydrogeologist responsible for hydrogeological studies of existing landfill in support of an application to the Ontario Ministry of Environment for a long-term site expansion.

Lanark County Waste Management Master Plan City/Township of Kingston Waste Management Master Plan
Ontario, Canada

Hydrogeological consultant on the master plan study teams involving technical aspects and document preparation, Environmental Assessment process, EA level field investigations and evaluation of site-specific engineered containment system requirements at the preferred sites and presentations to the steering committees and the public.

Armbro Mine Landfill Development
Marmora, Ontario, Canada

Project Hydrogeologist as part of the Metro Toronto area landfill site search, for hydrogeological assessment, conceptual design and technical feasibility evaluation of constructing a municipal landfill in the 250 metre deep former open pit iron ore mine.

Township of Clarence Waste Management Planning Study
Ontario, Canada

As part of a multi-disciplinary team, responsible for the hydrogeological aspects of a long term waste management planning study under the Environmental Assessment Act and Environmental Protection Act, including development and evaluation of alternative waste management components and systems, a systematic landfill site selection process and interaction with the Public Liaison Committee, municipal council and the public.

Municipal Waste Management Planning Studies
Ontario, Canada

Participated in hydrogeological aspects of waste management planning studies to identify potentially suitable areas for landfill development to satisfy the long term waste disposal requirements for the Township of Grattan, Township of Pittsburgh and the Townships of Palmerston, North and South Canonto.

Various Landfill Sites
Eastern and Northern Ontario, Canada

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

PROJECT EXPERIENCE – CONTAMINATED SITES INVESTIGATION AND REMEDIATION

Nation-Wide Environmental Site Assessments
Canada

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

Assessment of Rockcliffe Airbase Lands
Ottawa, Ontario, Canada

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

Environmental Site Assessments
Eastern Ontario, Canada

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

Assessment of Diesel Fuel Release
Smiths Falls, Ontario, Canada

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

Petroleum Hydrocarbon Releases
Eastern Ontario, Canada

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

Investigation of Salt Storage Facilities
Eastern Ontario, Canada

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

PROJECT EXPERIENCE – AGGREGATE INDUSTRY

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

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class “A” quarry license 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" quarry license for a 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 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