

REPORT

Level 1 and Level 2 Water Report

Site Plan Licence Application for a Class 'A' Quarry Below Water Proposed Stittsville 2 Quarry Ottawa, Ontario

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Executive Summary

This hydrogeological and hydrological technical report was prepared in support of an application to license (under the *Aggregate Resources Act*) the R.W. Tomlinson Limited Stittsville 2 Quarry property as a quarry below the groundwater table. The proposed Stittsville 2 Quarry property is adjacent to licensed operational quarries to the south and west. It is proposed that the extraction of Bobcaygeon Formation and Gull River Formation limestone and dolostone bedrock would proceed to an average depth of approximately 36 metres below the existing ground surface on the proposed Stittsville 2 Quarry property.

As a consequence of the location of the proposed quarry in relation to the other licensed operational quarries nearby, the groundwater level drawdown at full development of the Stittsville Quarry and the proposed Stittsville 2 Quarry (combined) is similar in extent (to the north and east) to the total drawdown from all of the quarries at their full extent of development (based on the one metre groundwater level drawdown contour).

During the operational period, water collecting in the base of the existing Stittsville Quarry and the proposed Stittsville 2 Quarry will be directed to the same sump and discharged off-site in accordance with the existing Environmental Compliance Approval (Industrial Sewage Works) for the Stittsville Quarry.

Development of the proposed Stittsville 2 Quarry will result in modifications to the local surface water drainage patterns. Specifically with respect to the proposed Stittsville 2 Quarry footprint, the estimated incremental discharge from that footprint is expected to increase during operations and decrease following rehabilitation. Based on the impact assessment, it is not expected that the development of the proposed Stittsville 2 Quarry will have a negative impact on surface water receptors (Goulbourn Wetland Complex) or groundwater receptors (private water supply wells) during the operational life of the quarry. A comprehensive surface water and groundwater monitoring program will be in place during the operational life of the proposed Stittsville 2 Quarry to provide confirmation that local receptors are not negatively impacted.

Following the extraction of the bedrock at the proposed Stittsville 2 Quarry, the excavation area will be rehabilitated by filling the site such that the property returns to similar grading and land use as currently exists. The long-term groundwater levels in the bedrock surrounding the site are predicted to increase above the existing levels. Consequently, it is not expected that the development of the proposed Stittsville 2 Quarry will have a negative impact on surface water receptors (Goulbourn Wetland Complex) or groundwater receptors (private water supply wells) under rehabilitated conditions.



SPECIAL REPORT NOTE

R.W. Tomlinson Limited (Tomlinson), Lafarge Canada Inc. (Lafarge) and Thomas Cavanagh Construction Limited (Cavanagh) have entered into a data-sharing agreement whereby all three parties would have access to the comprehensive geological and hydrogeological database for the Jinkinson Road study area. This comprehensive geological and hydrogeological database includes work previously conducted on, and in the vicinity of, the Tomlinson Moore Quarry, Tomlinson Stittsville Quarry, Lafarge Bell Quarry, Cavanagh Henderson Quarry and the Cavanagh Beagle Club Quarry in addition to data collected as part of the Voluntary Monitoring Program. These quarry properties in the Jinkinson Road study area are shown on Figure 4. The comprehensive geological and hydrogeological data database includes detailed rock core logs, borehole logs, monitoring well installation records, geophysical logs, groundwater level data, hydraulic conductivity data, etc. The borehole locations that are included in the data-sharing agreement are shown on Figure 4. The total number of boreholes and monitoring wells that comprise the database for the Jinkinson Road study area are 100 and 158, respectively.

Through the data-sharing agreement, the geological and hydrogeological data are made available to WSP Canada Inc. (by Tomlinson, Lafarge and Cavanagh) for use by either of the three aggregate producers in the context of the quarry licensing projects under the *Aggregate Resources Act* and/or applications for Permits to Take Water or Environmental Compliance Approvals – Industrial Sewage Works under the *Ontario Water Resources Act*. This comprehensive geological and hydrogeological database (i.e., Paleozoic bedrock stratigraphy, hydraulic conductivity data and groundwater level data) has been used in the development of the conceptual and numerical hydrogeological model for the study area as presented in this document. In this report prepared specifically for Tomlinson, the detailed rock core logs, borehole logs, monitoring well installation records, geophysical logs, groundwater level data, hydraulic conductivity data, etc. belonging to Lafarge and Cavanagh are not presented, however, these data were used in the development of the conceptual and numerical hydrogeological model for the Jinkinson Road study area. This report does include the detailed site-specific geological and hydrogeological investigation data (borehole logs, monitoring well installation records, geophysical logs, groundwater level data, hydraulic conductivity data, etc.) for work conducted by Tomlinson as it relates to the studies completed since 1999 on, and in the vicinity of, the Tomlinson Stittsville Quarry and Tomlinson Moore Quarry.



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1.0 INTRODUCTION

1.1 Background

R.W. Tomlinson Limited (Tomlinson) operates a number of pits and limestone quarries in the Ottawa area. The materials are used in the Ottawa area for road construction and in site preparation for commercial and residential developments. As part of the long-term business plan in the Ottawa area, Tomlinson wishes to license, under the *Aggregate Resource Act* (ARA), a property adjacent to the existing licensed Tomlinson Stittsville Quarry in order to supply the western end of Ottawa with aggregate products into the future.

WSP Canada Inc. (WSP) was retained by Tomlinson to complete the necessary hydrogeological and hydrological studies to support an application under the ARA and the *Planning Act*. This report presents the combined results of the hydrogeological and hydrological studies completed in support of a site plan license application for a Class 'A' license for a quarry below the ground water table, under Ontario Regulation 244/97 under the ARA. These studies were conducted for the purpose of addressing the requirements for the Level 1 and Level 2 Water Report studies 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 proposed Stittsville 2 Quarry and neighbouring Tomlinson Stittsville and Moore Quarries during investigations and monitoring programs conducted between 2000 and 2022.

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

1.2 Site Description

The proposed Stittsville 2 Quarry is located in the Geographic Township of Goulbourn in the City of Ottawa, Ontario. The proposed quarry property is located in Lots 15 and 16, Concession XI. The location of the proposed Stittsville 2 Quarry is shown on Figure 1. The proposed extraction area covers an area of approximately 109.8 hectares (ha). The property is bounded by Jinkinson Road and the existing Tomlinson Stittsville Quarry to the north, the Goulbourn Wetland Complex to the east, the Trans-Canada Trail to the south and the Lafarge Canada Inc. (Lafarge) Bell Quarry property to the west. Access to the site is currently from Jinkinson Road. The Stittsville 2 Quarry will be developed in three lifts. The final quarry floor for the proposed Stittsville 2 Quarry will slope from approximately 123 metres above sea level (asl) in the southwest to approximately 101 metres asl in the northeast which generally follows the contact between the Bobcaygeon Formation and Gull River Formation. The base of the quarry excavation is below the average position of the groundwater table.

The nearest permanent residents to the site are located northeast along Jinkinson Road and across Highway 7. The site area is comprised largely of a limestone plain with shallow overburden. More detailed information concerning the Stittsville 2 Quarry can be found in Section 3.0.

In addition to the proposed Stittsville 2 Quarry, a number of licensed aggregate quarries also exist in the area. Three properties, the Lafarge Bell Quarry, the Tomlinson Stittsville Quarry and the Thomas Cavanagh Construction Limited (Cavanagh) Henderson Quarry are located to the west side of the site. The Taggart Fernbank Quarry and Cavanagh Beagle Club Quarry are located to the south of the site. The Tomlinson Moore Quarry is located to the northwest of the proposed Stittsville 2 Quarry across Highway 7.



1.3 Proposed Quarry Development and Rehabilitation Plan

The development of the Stittsville 2 Quarry is anticipated to occur simultaneously to the operation of the existing Stittsville Quarry. Extraction activities will proceed east and south from the common boundary with the existing Stittsville Quarry. Once excavation to the southern limit has been reached, any remaining bedrock in the extraction area to the north (along Jinkinson Road) will be removed. During the initial phases of quarry development, a sump will be located in the existing Stittsville Quarry, and this sump would be relocated (as required) within the extraction area during the operational life of the proposed Stittsville 2 Quarry. The proposed quarry will be developed in three lifts, which may operate simultaneously depending on rock quality and market demand. The depth of each lift is dependent on bedrock formation thickness. The anticipated lowest quarry floor elevation will be approximately 101 metres asl.

Following the extraction of material, the property will be rehabilitated by backfilling the excavation. It is anticipated that the excavation will be backfilled to the original grade throughout the limit of extraction allowing for future potential development in the area near Jinkinson Road and a naturalized area and wetland in the southern portion of the site.

1.4 Scope of Hydrogeological and Hydrological Studies

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

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

The work program consisted of the following:

- Data review and compilation;
- Receptor identification;
- Bedrock percussion drilling program;
- Borehole geophysical investigation program;
- Groundwater level, surface water level and surface water flow monitoring programs; and,
- Groundwater and surface water flow modelling and impact assessment.

2.0 REGIONAL SETTING

2.1 Topography and Physiography

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



2.2 Geology and Hydrogeology

2.2.1 Surficial Geology

Published information (Belanger, 2008) indicates the surficial geology within the area surrounding the Stittsville Quarry consists primarily of bedrock with thin unconsolidated Quaternary sediments or organic deposits (Figure 2). The organic deposits are primarily composed of muck and peat.

2.2.2 Bedrock Geology

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

Based on the OGS mapping, the bedrock of the area surrounding the Stittsville Quarry is mapped as the Gull River Formation at surface (refer to Figure 3). A small area of the Bobcaygeon Formation is mapped at surface on the southwest corner of the guarry site (Figure 3).

2.2.2.1 Bobcaygeon Formation

The youngest of the Paleozoic Formations in the study area is the Bobcaygeon Formation. The formation consists of limestone with shaley partings (Williams, 1991). The thickness of the Bobcaygeon Formation in the Ottawa area is approximately 87 metres thick (Williams, 1991).

2.2.2.2 Gull River Formation

The lower member of the Gull River Formation is made up of interbedded limestone and dolostone with shaley partings. Interbeds of sandstone and shale also occur. The upper member of the Gull River Formation consists of limestone with shaley partings (Williams, 1991). The thickness of the formation in the Ottawa area is approximately 51 metres thick (Williams, 1991).

2.2.2.3 Shadow Lake Formation

The Shadow Lake Formation consists of dolostone with shaley partings and thin interbeds of sandstone (Williams, 1991). The Formation is a somewhat constant thickness across the Ottawa - St. Lawrence Lowland ranging from 2.5 to 2.8 metres thick (Williams, 1991). The Shadow Lake Formation is disconformably underlain by the Rockcliffe Formation.

2.2.2.4 Rockcliffe Formation

The Rockcliffe Formation is sub-divided into lower and upper members. The lower member of the formation contains interbedded shale and sandstone, while the upper portion contains additional interbeds of limestone and dolostone (Williams, 1991). The Rockcliffe Formation unconformably overlies the Oxford Formation.

2.2.2.5 Oxford Formation

The Oxford Formation consists primarily of thin to thickly bedded dolostone. Shaley interbeds up to 30 centimetres in thickness occur within the Oxford Formation (Williams, 1991). The Oxford Formation was fully penetrated during the installation of the King's Park sentinel wells in the Village of Richmond (Golder, 2005). The borehole logs for the sentinel wells indicate that the Oxford Formation is between 57.45 metres and 62.5 metres thick within the Village of Richmond located approximately 12.5 kilometres southeast of the Stittsville 2 Quarry.



The thickness of the Oxford Formation was found to be about 42 metres in TW09-1 adjacent to the Stittsville 2 Quarry.

2.2.2.6 March Formation

The March Formation is characterized by interbedded quartz sandstone and dolostone. The lithology of the quartz sandstone beds of the March Formation are similar to those of the underlying Nepean Formation, while the lithology of the dolostone beds of the March Formation are similar to those of the overlying Oxford Formation (Williams, 1991). As a result, the March Formation is referred to as a transitional unit between the Nepean and Oxford Formations. The contact between the March and Oxford Formations is marked by the upper limit of the common occurrence of quartz sand (Williams, 1991).

2.2.2.7 Nepean Formation

The Nepean Formation sandstone overlies the unevenly eroded Precambrian granitic basement within the study area. Williams (1991) describes the Nepean Formation as white to cream coloured, weathering to grey. It is generally thick-bedded; however, portions are thinly-bedded and water-bearing. The cementing minerals include both calcite and quartz. The thickness of the Nepean Formation is difficult to ascertain precisely as there are few drillholes that have been reported to fully penetrate it. Two wells were completed at Canadian Golf and Country Club, located approximately 2.5 kilometres southwest of the Stittsville 2 Quarry that fully penetrated the Nepean Formation into the underlying Precambrian granite. At this location, the Nepean Formation had a total thickness between 31.7 metres and 35.65 metres (Golder, 2007). The thickness of the Nepean Formation was found to be about 21 metres in TW09-1 adjacent to the Stittsville 2 Quarry.

2.2.3 Hydrogeology

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 Stittsville 2 Quarry. For this reason, the bedrock aquifers are considered the principal aquifers for water supply.

2.2.3.2 Bedrock Formations

The Nepean, March and Oxford Formations are considered to be the primary aquifers (i.e., potentially capable of supplying adequate quantities of groundwater for domestic use) within the study area however, these formations may be too deep to access. The Rockcliffe, Shadow Lake, Gull River and Bobcaygeon Formations, located above the primary aquifers are considered marginally adequate for domestic consumption.

2.2.3.2.1 Nepean Formation (Sandstone)

A deep bedrock aquifer is interpreted to be present within the lower part of the March Formation and within the Nepean Formation. This aquifer is generally associated with sandstone rather than dolostone or limestone. Flow within this aquifer is mainly through fractures, since the primary porosity of the sandstone has been reduced by cementation. The aquifer tends to be most productive at the contact between the Nepean Formation and overlying March Formation and at the contact of the Nepean Formation with the underlying Precambrian rock (Brandon, 1960).

Within the Village of Manotick, Raven Beck (1996) measured a transmissivity of approximately 600 square metres per day (m²/day) over the upper 50 metres of the Nepean Formation using five metre test-interval straddle packers and found enhanced permeability at the March Formation/Nepean Formation contact. Available data



indicate that sustainable yields in the deep aquifer are high, ranging from 150 to 4,450 Litres per minute (L/min; Brandon, 1960; Oliver, Mangione, McCalla & Associates 1990, 1991; Geo-Analysis and J.L. Richards and Associates Limited, 1992).

The deep aquifer is regionally extensive and is the primary source of water for large residential/municipal groundwater supply systems including the municipal wells in Almonte, Kemptville, King's Park (Richmond), Hyde Park (Richmond), Merrickville and Munster. Aquifer testing completed on the communal wells at these locations have demonstrated high sustainable well yields (i.e., as high as 4,450 L/min in Almonte). The range in transmissivity of the lower March and Nepean Formations measured during aquifer testing at these locations was between 27 and 6,048 m²/day, with a typical transmissivity for the lower March and Nepean Formations aquifer of greater than 600 m²/day (Golder, 2000, 2001, 2003, 2004, Oliver, Mangione, McCalla & Associates 1990, 1991, 2000).

2.2.3.2.2 March and Oxford Formation (Limestone/Dolostone)

Typical well yields reported for the aquifer in the Oxford Formation are between 45 to 115 L/min (Geo-Analysis and J.L. Richards and Associates Limited, 1992). Drillers' records indicate that water bearing zones occur at distinct depths within the formation, with water being found within a network of fractures, possibly enhanced by carbonate dissolution, and possibly associated with shale partings (Williams, 1991).

Aquifer testing of three wells completed in the Oxford Formation found a range in transmissivity between 9 m²/day and 248 m²/day, with an average of 90 m²/day (Golder, 2006). A study completed by Geo-Analysis Inc. in 1991 consisting of aquifer testing of eleven test wells found the transmissivity of the Oxford Formation aquifer in the Village of Richmond ranged between 5 m²/day to greater than 100 m²/day, with an average of 46 m²/day.

A bedrock aquitard is interpreted to lie within the lower part of the Oxford Formation and the upper part of the March Formation (Raven Beck, 1996). Its presence is indicated by strong vertical gradients across this zone and by flowing artesian conditions observed in some wells completed below the aquitard, (i.e., the Alfred Street municipal well in Kemptville (Oliver, Mangione, McCalla and Associates Ltd., 2000) and the Village of Richmond sentinel wells (Golder, 2005).

2.2.3.2.3 Rockcliffe, Shadow Lake, Gull River and Bobcaygeon Formations

The well yields in these formations typically range from <14 to 22 m²/day and are considered marginally acceptable for domestic consumption. Golder (2003a) reports that the yield of the wells in these formations typically decreases with depth. These aquifers are usually only used where the better aquifers such as the Nepean and March Formations are too deep to access.

2.3 Hydrology

The study area, as shown in Figure 1, is within the Flowing Creek catchment, which is a part of the Jock River sub-watershed. The Flowing Creek catchment has a drainage area of approximately 50 square kilometres (km²) and the Jock River sub-watershed has a drainage area of 555 km² (Rideau Valley Conservation Authority, 2016).

The most prominent surface water feature in the local area is the provincially significant Goulbourn Wetland Complex, located on and to the east of the Stittsville 2 Quarry property. Under existing conditions, the surface runoff from the proposed Stittsville 2 Quarry property either drains towards the western wetland or the eastern wetland (Goulbourn Wetland Complex) which are connected by a drainage pathway, as seen in Figure 1. The Goulbourn Wetland Complex drains from northwest to southeast from its headwaters directly northwest of Speedway Road, approximately 1.5 kilometres northwest of the proposed quarry site, to its confluence with a



branch of the Flowing Creek southeast of Fallowfield Road, approximately 6 kilometres southeast of the proposed quarry site. Flowing Creek then drains to the Jock River near the Town of Richmond, Ontario.

2.4 Ecological Context

A detailed description of the ecosystem and an impact assessment analysis are provided in the Natural Environment Report (WSP, 2023).

2.5 Surrounding Land Use - Existing Quarries

As previously described, a number of licensed aggregate quarries currently exist in the area of the proposed Stittsville 2 Quarry. Tomlinson owns the Stittsville Quarry and the Moore Quarry located to the west and northwest of the proposed Stittsville 2 Quarry, respectively. Lafarge owns the Bell Quarry located to the west of the proposed quarry site. Further to the west, across Jinkinson Road is the Cavanagh Henderson Quarry. To the southeast of the site are the Taggart Fernbank Quarry and the Cavanagh Beagle Club Quarry. Locations of the existing quarries are shown on Figure 4.

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

Table 1: Summary of Existing Quarries

Quarry Operator	Quarry Name	Approximate Licensed Area (hectares)	Approved Quarry Floor Elevation (metres above sea level)	Rehabilitation Plan
Tomlinson	Stittsville Quarry	55.4	108 (minimum)	Rehabilitate to a lake with level at 141 metres asl.
	Moore Quarry	49	112 to 126	Rehabilitate to a lake with level at 134.5 metres asl.
Cavanagh	Henderson Quarry	124.7	112	Rehabilitate to a lake with level at 135.5 metres asl.
	Beagle Club Quarry	20.9	117	Rehabilitate to a lake with level at 135 metres asl.
Lafarge	Bell Quarry	59.1	132	Rehabilitate to a lake with level at 141 metres asl.
Taggart	Fernbank Quarry	115.1	126.5	Rehabilitate to a lake with level at 135 metres asl.

In considering the potential hydrogeological impacts from quarry dewatering at the proposed Stittsville 2 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 Name Operator		Simulated Floor Elevation		
Tomlinson	Stittsville Quarry	Quarry floor elevations within the excavated area were set at 120 metres asl		
	Moore Quarry	There is currently no excavation on the property.		
Cavanagh	Henderson Quarry	Quarry floor elevations within the excavated area were set at 121 metres asl		
	Beagle Club Quarry	Quarry excavation is flooded		
Lafarge	Bell Quarry	Quarry floor elevations within the excavated area were set at 135 metres asl		
Taggart	Fernbank Quarry	Quarry floor elevations within the excavated area were set at 136 metres asl		

As the majority of the sites are being operated independently, it is not possible to predict depth and breadth of excavation at any given future point. For that reason, cumulative impacts are assessed with all quarries at full development or, for cumulative rehabilitation, once final rehabilitation has been completed at all sites.

For the purposes of the assessment presented in this report, rehabilitated conditions are assumed as follows:

Table 3: Summary of Existing Quarries Under Rehabilitated Conditions

Quarry Operator	Quarry Name	Rehabilitation Plan
Tomlinson	Stittsville Quarry	Entire site rehabilitated to a lake with a level of 141 metres asl.
	Moore Quarry	Entire site rehabilitated to a lake with a level of 134.5 metres asl.
Cavanagh	Henderson Quarry	Entire site rehabilitated to a lake with a level of 135.5 metres asl.
	Beagle Club Quarry	Entire site rehabilitated to a lake with a level of 135 metres asl.
Lafarge	Bell Quarry	Entire site rehabilitated to a lake with a level of 141 metres asl.
Taggart	Fernbank Quarry	Entire site rehabilitated to a lake with a level of 135 metres asl.

3.0 STUDIES AT THE SITE AND ADJACENT TOMLINSON PROPERTIES

Various studies have been conducted at the proposed Stittsville 2 Quarry and other nearby Tomlinson properties for the purposes of licensing and obtaining the necessary permits to operate the various quarries. The other nearby properties include the Moore Quarry (on the north side of Hwy. 7) and the Stittsville Quarry, adjacent to the proposed Stittsville 2 Quarry.

The following sections provide a summary of the studies and data collected from the proposed Stittsville 2 Quarry site as well as the Stittsville Quarry and the Moore Quarry.



3.1 Geological Studies

3.1.1 Bedrock Drilling

3.1.1.1 Stittsville Quarries

Tomlinson has drilled a number of boreholes over time in the area of the proposed Stittsville 2 Quarry site and the adjacent Stittsville Quarry. The original on-site drilling program at the Stittsville Quarry was conducted in 1999. The drilling was carried out in order to identify bedrock stratigraphy, to obtain rock core samples for aggregate quality testing, to provide locations for undertaking subsurface geophysical logging and to permit monitoring well installations to allow for measurement of groundwater levels, collection of groundwater samples, and hydraulic conductivity testing of the bedrock beneath the site. The borehole locations are shown on Figure 1. Well logs/well records for the wells located on the proposed Stittsville 2 Quarry property and the Stittsville Quarry property are attached in Appendix B.

Borehole BH99-1 was drilled to obtain rock core samples for aggregate quality testing. It was drilled by Marathon Drilling, under the direction of Tomlinson, to a total depth of approximately 31 metres. Borehole BH99-2 was also drilled by Marathon Drilling under the direction of Tomlinson to obtain rock core samples for aggregate quality testing. Borehole BH99-3 was cored to a total depth of approximately 31 metres below ground surface.

The three additional boreholes (BH99-4, BH99-5 and BH99-6) were drilled by Capital Water Supply Ltd. using air rotary percussion drilling techniques, at a diameter of 150 millimetres (6 inches).

An assessment of lithology and stratigraphy was completed using the bedrock core recovered from DDH2001-1 and DDH2001-2. 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.

Boreholes BH99-4, BH99-5 and BH99-6 were decommissioned in August 2004 and replaced with new monitors BH03-7, BH03-8 and BH03-9 (respectively) in order to accommodate the reconstruction of Highway 7. A new borehole (BH13-16) was drilled in October 2013 to replace BH03-8 which was removed in June 2014 by progressive quarry development.

Boreholes TW05-10, TW05-11 and TW05-12 were drilled using air rotary percussion drilling techniques at a diameter of 150 millimetres (6 inches). The boreholes were drilled for a resource evaluation of a portion of the Stittsville 2 Quarry property.

Borehole BH18-17 was installed at the request of the Ministry of Environment, Conservation and Parks (MECP) in order to provide an additional location for groundwater level monitoring under the Permit to Take Water (PTTW) monitoring program for the Stittsville Quarry.

Boreholes SQAT18-01 to SQAT18-20 were completed at the Stittsville Quarry site by means of an air track drill rig. These boreholes were used in a resource assessment/mining plan for the Stittsville Quarry.

Boreholes SQAT20-21 to SQAT20-31 were completed at the proposed Stittsville 2 Quarry site by means of an air track drill rig. These boreholes were used in a resource assessment for the proposed Stittsville 2 Quarry.

A number of water supply wells exist or have existed on the site. Water Well TW03-1 was drilled as a water supply well for the original scalehouse in 2003 but was destroyed in 2013 due to quarry extraction in the area of the well. Water wells TW09-1, TW09-2 and TW09-3 are all used to supply the Tomlinson Ready Mix concrete plant that exists on the Stittsville 2 Quarry site.



The following table provides a summary of the boreholes on the Stittsville Quarry and Stittsville 2 Quarry sites:

Table 4: Stittsville Quarry Properties Borehole Summary

Well Name	Comments
DDH2001-1 (T-EXPL) ¹	Rock core recovered for resource evaluation. Borehole has been destroyed.
DDH2001-2 ¹	Rock core recovered for resource evaluation. Borehole has been destroyed.
BH99-1	BH99-1 was cored as part of the original geological/hydrogeological investigation of the Stittsville Quarry site.
BH99-2	BH99-2 was cored as part of the original geological/hydrogeological investigation of the Stittsville Quarry site. Borehole was decommissioned in 2019 due to progressive quarry development.
BH99-3 ¹	BH99-3 was cored as part of the original geological/hydrogeological investigation of the Stittsville Quarry site.
BH99-4	BH99-4 was drilled as part of the original geological/hydrogeological investigation of the Stittsville Quarry site. Borehole was decommissioned in 2004 to allow for expansion of Hwy 7.
BH99-5	BH99-5 was drilled as part of the original geological/hydrogeological investigation of the Stittsville Quarry site. Borehole was decommissioned in 2004 to allow for expansion of Hwy 7.
BH99-6 ¹	BH99-6 was drilled as part of the original geological/hydrogeological investigation of the Stittsville Quarry site. Borehole was decommissioned in 2004 to allow for expansion of Hwy 7.
BH03-7	BH99-7 was drilled in 2003 as a replacement for BH99-4 to allow for expansion of Hwy 7. Borehole was decommissioned in 2020 due to progressive quarry development.
BH03-8	BH99-8 was drilled in 2003 as a replacement for BH99-5 to allow for expansion of Hwy 7. Borehole was decommissioned in 2014 due to progressive quarry development.
BH03-9 ¹	BH03-9 was drilled in 2003 as a replacement for BH99-6 to allow for expansion of Hwy 7.
TW05-10 ¹	TW05-10 was drilled as part of a resource evaluation for the Stittsville 2 Quarry site.
TW05-11 ¹	TW05-11 was drilled as part of a resource evaluation for the Stittsville 2 Quarry site.
TW05-12 ¹	TW05-12 was drilled as part of a resource evaluation for the Stittsville 2 Quarry site.
BH13-16 ²	BH13-16 was drilled in 2013 as a replacement for BH03-8 due to removal through progressive quarry development.
BH18-17 ¹	BH18-17 was drilled in 2018 as a requirement of the Permit to Take Water groundwater level monitoring program for the Stittsville Quarry.
TW03-1	TW03-1 was drilled as a water supply well for the original scalehouse. The well has been destroyed



Well Name	Comments		
TW09-1 ¹	TW09-1 was drilled as a water supply well for Tomlinson Ready Mix concrete plant. The well is still in use.		
TW09-2 ¹	TW09-2 was drilled as a water supply well for Tomlinson Ready Mix concrete plant. The well is still in use.		
TW09-3 ¹	TW09-3 was drilled as a water supply well for Tomlinson Ready Mix concrete plant. The well is still in use.		
SQAT18-01 to SQAT18-20	SQAT18-01 to SQAT18-20 were drilled as part of a resource evaluation conducted on the Stittsville Quarry property.		
SQAT20-21 to SQAT20-31 were drilled as part of a resource evaluation conducted proposed Stittsville 2 Quarry property.			
Notes: ¹ - Borehole located on the proposed Stittsville 2 Quarry property ² - Borehole located on the Moore Quarry property			

3.1.1.2 Moore Quarry

The original percussion drilling program at Moore Quarry was conducted on October 19 and 27, 2005 by Capital Water Supply Ltd. using an air percussion water well rig. The boreholes are identified as BH05-13, BH05-14 and BH05-15, and were drilled to provide access for subsurface geophysical logging and observation points for the collection of water levels and hydraulic conductivity data.

The three boreholes were 152 millimetres in diameter and drilled to depths of approximately 35 metres each. The depths of any large fractures or water producing zones in the wells were recorded by personnel from Golder Associates Ltd. at the time of drilling. The method of drilling did not allow for a direct assessment of the lithology and rock conditions. The borehole locations are shown on Figure 1.

Additional borehole installations were carried out on July 4 and 7, 2014 at the Moore Quarry site. During that time, a total of three boreholes (numbered BH14-17, BH14-17A and BH14-18) were put down at the locations shown on Figure 1. The boreholes were advanced using a track-mounted hollow-stem auger drill rig supplied and operated by Marathon Drilling Company of Ottawa, Ontario. These boreholes were advanced to depths ranging from 2.0 to 9.1 metres below the existing ground surface and boreholes BH14-17 and BH14-18 were terminated after advancing 7 metres into bedrock.

A total of four mini-piezometers (MP14-19, MP14-20, MP14-21 and MP14-22) were installed on July 2, 2014, at the locations shown on Figure 1. Each mini-piezometer (MP) was installed by hand-augering a hole to the depth of auger refusal, then installing a 51 mm diameter PVC screen and riser in the augered hole.

Borehole BH18-18 (refer to Figure 1) was installed at the request of MECP during development of the groundwater monitoring program under the PTTW for the site.

Boreholes MQAT18-01 to MQAT18-06 (refer to Figure 1) were completed at the site by means of an air track drill rig. These boreholes were used in a resource assessment/mining plan for the Moore Quarry.

Well logs for the Moore Quarry on-site wells are attached in Appendix B.



3.1.2 Geophysical Logging

Many open cored boreholes and air rotary boreholes were geophysically logged following completion of the drilling operations by geophysicists from Golder Associates Ltd. The log suite included both apparent conductivity and natural gamma logs. The conductivity and gamma logs were used in conjunction with the logging of the rock core to assess the bedrock stratigraphy beneath the site.

Natural Gamma

The natural gamma log provides a measurement (recorded in counts per second – cps) that is proportional to the natural radioactivity of the formation. The sample volume for the γ_n log is typically a 25 to 30 cm radius. The log is used principally for lithologic identification and stratigraphic correlation.

The tool used for logging employs a scintillation sodium iodide (NaI) detector. The gamma-emitting radio isotopes that naturally occur in geologic materials are Potassium 40 and nuclides in the Uranium 238 and Thorium 232 decay series. Potassium 40 occurs with all potassium minerals including potassium feldspars. Uranium 238 is typically associated with dark shale and uranium mineralization. Thorium 232 is typically associated with biotite, sphene, zircon and other heavy minerals.

The usual interpretation of the γ_n log is that measured counts are proportional to the quantity of clay minerals (shale) present. This assumes that the natural radioisotopes of potassium, uranium and thorium occur as exchange ions attached to the clay particles, so that the correlation is between gamma counts and the cation exchange capacity (CEC).

Electromagnetic Induction (Apparent Conductivity)

Apparent conductivity is a measure of the bulk apparent conductivity of the subsurface, which is primarily a function of interconnected porosity, clay content, moisture content and the dissolved ion concentration in the pore fluid. Temperature, phase state of the pore water and the amount and composition of any suspended colloids in the pore water also contribute to conductivity but to a lesser degree. An increase in any of these properties would result in an elevated apparent conductivity.

However, changes in clay content can also significantly alter instrument response. Clay particles have a relatively large number of ions adsorbed to their surface. When clays are saturated, these adsorbed ions can become partially dissociated and available for ionic conductivity. Since clay particles have a relatively large surface area, the presence of small amounts of clay can significantly increase bulk apparent conductivity.

Typically, the apparent conductivity of carbonate bedrock is low (<1 or 2 millisiemens per metre; mS/m) due to low porosity and clay content. Shaley or clay rich lithologies within carbonate rock show as natural gamma highs but may or may not have an associated apparent conductivity high although usually a shale layer will have a higher apparent conductivity than limestone or dolomite. Metamorphic rocks (slates and marbles) also produce very low apparent conductivity due to low porosity. Reported values are generally around 4 mS/m for these rock types.

Metal objects, such as steel casing in the borehole, will show as an anomalous response in the apparent conductivity log, either as large positive or negative deflections.



3.1.2.1 Stittsville Quarries

The geophysical logging at the boreholes drilled on the Stittsville Quarry property was conducted in several phases as boreholes were drilled between 1999 and 2020. The geophysical log suite included both apparent conductivity and natural gamma logs. To date, all of the wells on the Stittsville Quarry site have been geophysically logged. The geophysical logs for each borehole are presented on the logs in Appendix B.

After drilling was completed, boreholes BH05-10, BH05-11 and BH05-12 were geophysically logged. The geophysical logging program was conducted in December 2005. The log suite included both apparent conductivity and natural gamma logs. Geophysical logging, including apparent conductivity and natural gamma logs, has also been completed on DDH2001-1 and DDH2001-2. Geophysical logging of boreholes SQAT20-21 through SQAT20-31 was completed in 2020. The geophysical logs for each of these nearby borehole locations are presented on the logs in Appendix B.

3.1.2.2 Moore Quarry

After drilling was completed, boreholes BH05-13, BH05-14 and BH05-15 were geophysically logged. In addition, geophysical logging was completed in boreholes BH18-18 and MQAT-01 through MQAT18-06 (where possible). The log suite included both apparent conductivity and natural gamma logs and the geophysical logs for each borehole are presented on the logs in Appendix B.

3.1.2.3 Discussion

The conductivity and gamma logs were used in conjunction with WSP's knowledge of the bedrock formations obtained from the core retrieved from cored borehole DDH2001-1, DDH2001-2 and other detailed core logging from sites in the area of the proposed Stittsville 2 Quarry to create composite geological and geophysical reference logs for the Jinkinson Road Area including the proposed Stittsville 2 Quarry, the Stittsville Quarry and the Moore Quarry properties.

The Composite Geological Reference Log – Jinkinson Road Area is presented on Figure 5 and was developed based on WSP's experience to date in the logging of rock core in this area. Based on the examination of the Composite Geological Reference Log – Jinkinson Road Area on Figure 5, WSP has logged rock core (in the Jinkinson Road Area) that represents the upper part of the Bobcaygeon Formation through to the upper Rockcliffe Formation. The limitation of quarry coring programs to the Bobcaygeon Formation and the Gull River Formation is based on the fact that it is these two rock formations that represent the target aggregate resource materials in this area. The penetration of some cored boreholes into the top of the Rockcliffe Formation occasionally occurs at locations where the upper rock unit is the Gull River Formation and the depth to the top of the Rockcliffe Formation is minimal. The top of the Rockcliffe Formation represents a significant change in the geology and is accompanied by a dramatic shift in the natural gamma signal (see Figure 5) and, as such, this stratigraphic position is a significant geological marker horizon in this area. With reference to Figure 5, the top of the Rockcliffe Formation is identified as one of the two regional "Horizontal Correlation Lines" (the other being the geological contact between the Bobcaygeon Formation and the Gull River Formation with the top of the Gull River Formation being marked by the "first dolostone marker bed").

The Geophysical Log for TW09-1 (Figure 5) includes the entire Paleozoic stratigraphic sequence (in the Jinkinson Road Area) from the upper part of the Bobcaygeon Formation through to the Precambrian basement.



In an effort to relate the Paleozoic stratigraphy of the Jinkinson Road Area to the stratigraphy of the Ottawa area, two additional boreholes (with geological and/or geophysical data) are presented on Figure 5. These two additional boreholes are as follows:

- 1) GSC Dominion Observatory #1 borehole
- 2) GSC Lebreton borehole

Both of these boreholes were drilled by the Geological Survey of Canada and the approximate locations of these boreholes are shown on the inset on Figure 5.

The GSC Dominion Observatory #1 borehole was drilled to an approximate depth of 265 metres and penetrated the entire Paleozoic sequence from the lower Bobcaygeon Formation to the Precambrian basement. This borehole was geophysically logged by the Geological Survey of Canada.

The GSC Lebreton borehole was drilled to a depth of 476.2 metres and penetrated the entire Paleozoic sequence from the Verulam Formation to the Precambrian basement. Only the upper 395.5 metres of this borehole is illustrated on Figure 5 as this was sufficient to display the entire Paleozoic sequence and the upper part of the Precambrian basement. This borehole was geophysically logged by the Geological Survey of Canada to a depth of 438 metres. In November 2000, Golder Associates Ltd. geophysically logged the upper 200 metres of this same borehole. Golder Associates Ltd. has also logged the rock core over the depth from ground surface to 395.5 metres.

The GSC Dominion Observatory #1 borehole and the GSC Lebreton borehole are shown on Figure 5 as a means of illustrating how the geology of the Jinkinson Road Area fits into the regional context.

3.1.3 On-Site Surficial Geology

Quaternary-aged sediments in the study area were deposited during the Wisconsinan glaciation by the Laurentide Ice Sheet approximately 10,000 years before present (BP). The surficial geology mapping indicates that there is generally a thin layer of overburden on the Tomlinson sites. The surficial deposits generally consist of glacial till and topsoil in the area of the Tomlinson properties (Figure 2). Organic muck and peat deposits are mapped in the area of the wetlands.

Based on the borehole data, there is limited overburden on the proposed Stittsville 2 Quarry and the Stittsville Quarry sites (with a maximum of 2.6 metres of overburden at SQAT20-30). Overburden thicknesses on the Moore Quarry site ranges from 0.15 metres at 14-18 to 2.8 metres at BH18-18.

3.1.4 On-Site Bedrock Geology

The upper Paleozoic bedrock formations that have been cored/geophysically logged in the vicinity of the existing Stittsville Quarry and Moore Quarry are, from top to bottom, the Bobcaygeon Formation, Gull River Formation and the Rockcliffe Formation (see Composite Geological Reference Log – Jinkinson Road Area on Figure 5). On the Tomlinson properties, the lower Bobcaygeon was encountered in all boreholes. The Gull River Formation underlies the Bobcaygeon Formation, and it was encountered in all boreholes (with geophysical information) on the Tomlinson properties with the exception of BH99-5, BH99-6, SQAT18-05, SQAT18-06, SQAT18-07, SQAT18-11, SQAT18-13, SQAT18-14, SQAT18-15, SQAT18-16, SQAT18-17, SQAT18-18, SQAT18-20, SQAT20-21, SQAT20-22, SQAT20-23, SQAT20-24, SQAT20-25 and SQAT20-27. The Bobcaygeon Formation and the Gull River Formation are the two bedrock formations that represent the target aggregate resource materials in this



area. The Rockcliffe Formation underlies the Gull River Formation and was encountered in boreholes BH13-16 and TW09-1 on the Tomlinson properties.

A summary of the Bobcaygeon Formation and Gull River Formation stratigraphic sequence on the Tomlinson quarry properties is presented below based on the on-site geological and geophysical investigations, other studies in the Jinkinson Road Area and regional geological data. To assist in this discussion, reference should be made to the discussion presented in Section 3.1.2.3 and the Composite Geological Reference Log – Jinkinson Road Area and Composite Geophysical Reference Log – Jinkinson Road Area which are presented on Figure 5.

3.1.4.1 Bobcaygeon Formation

The Bobcaygeon Formation is identified in all boreholes (with geophysical information) drilled on the properties. The thickness of the Bobcaygeon formation ranges from 8.3 to 36.2 metres. The thickest portion of the Bobcaygeon Formation lies along the easternmost boundary of the Stittsville Quarry at boreholes BH99-6, BH03-9, BH18-17, DDH2001-1 and TW09-1. The Bobcaygeon Formation is a medium grey, very fine grained non-crystalline to fine grained, faintly crystalline, thinly to medium bedded, nodular textured limestone.

3.1.4.2 Gull River Formation

The Gull River Formation underlies the Bobcaygeon Formation. The upper portion of the formation is light to medium grey, very fine to fine grained, faintly crystalline, thinly to medium bedded, argillaceous limestone interbedded with dolostone and shale. The full thickness of the Gull River Formation, based on the results of geophysical testing at BH13-16 and BH09-1, beneath the guarry is approximately 38 metres.

3.2 Physical Hydrogeology

The hydrogeological characteristics of the bedrock formations beneath the site were investigated through various hydraulic testing programs. The hydraulic testing programs were developed to identify hydrostratigraphic units at the sites, and to identify hydraulically conductive zones to be used for monitoring well installations.

3.2.1 Monitoring Well Installation

Groundwater monitoring intervals were constructed in many of the boreholes 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 sites. The positions of the screened intervals in each borehole were selected based on the reported water bearing zone(s) as noted during drilling and results from geophysical testing, where available.

The monitoring wells were developed following their installation in order to remove drill cuttings from the sand filter pack. The development was carried out by evacuating the standing water in the wells to the surface using Waterra foot valves, flushing silt-sized drill cuttings in the sand filter pack out at the surface. Between one and three well volumes were evacuated from each well, prior to carrying out the hydraulic conductivity testing. The development ensures that the groundwater level measurements and hydraulic conductivity tests are accurate.

3.2.1.1 Stittsville Quarry Properties

Boreholes (BH99-1 to BH99-7, BH03-7 to BH03-9, BH13-16 and BH18-17) were instrumented with nested monitoring well installations at different depth intervals. These multi-level installations enable the determination of individual water levels and vertical hydraulic gradients within the various rock strata encountered beneath the site. The details of the well installations are shown on the Summary Logs in Appendix B.



Boreholes BH05-10 and BH05-12 were each instrumented with three nested monitoring well installations at specific depth intervals. The construction details of monitoring intervals are presented in Appendix B. Borehole BH05-11 was left as an open hole, with steel casing set just into the surface of the bedrock.

3.2.1.2 Moore Quarry

Boreholes BH05-13, BH05-14 and BH05-15 were each instrumented with three nested monitoring well installations at specific depth intervals. The construction details of these monitoring wells are presented in Appendix B.

A groundwater monitor was installed in borehole BH14-17A to allow subsequent measurement of the groundwater levels in the overburden adjacent to borehole BH14-17. Borehole BH14-17A is located approximately 2 metres from borehole BH14-17. There was insufficient thickness of overburden at borehole BH14-18 to allow the installation of an adjacent overburden groundwater monitor. Boreholes BH14-17 and BH14-18 were left as open holes, with steel casings set just into the surface of the bedrock.

Borehole BH18-18 was instrumented with 4 nested monitoring well installations at specific depth intervals. The construction details of these monitoring wells are presented in Appendix B.

3.2.2 Hydraulic Conductivity Testing

A total of 20 well response tests were carried out in the monitoring intervals installed in the boreholes 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 response testing was either performed by quickly removing water from the monitoring well with a Waterra foot valve and tubing or displacing water by inserting/removing a plastic slug and monitoring the recovery to the static water level by measuring the depth to the water using a water level tape and/or pressure transducer and datalogger at frequent intervals.

For analysis, the intervals for response testing were defined as the sand pack interval (zone filled with sand surrounding the screens) between the bentonite seals. This definition of screen length is applicable in the bedrock formations encountered in the area of the site since inflow to the sand pack is fairly slow and thus the assumption for horizontal flow over the entire length of the sand pack is preserved. The details regarding the locations of the test intervals for each monitoring well are provided on the borehole logs in Appendix B. The well response test graphs and interpretations are provided in Appendix C. The hydraulic conductivity value from each test was calculated using the Hvorslev (1951) method.

A summary of the well response testing results is provided in the following table:

Table 5: Summary of Well Testing Results

Monitoring Well	Geophysical Unit(s) Tested	Date Tested	Calculated Hydraulic Conductivity (m/s)
BH99-2A	Bobcaygeon/Gull River Contact	January 24, 2000	9×10 ⁻⁷
BH99-2B	Bobcaygeon	January 24, 2000	1×10 ⁻⁶
BH99-3A	Gull River	January 24, 2000	2×10 ⁻⁶
BH99-3B	Bobcaygeon	January 24, 2000	1×10 ⁻⁶
BH99-4A	Gull River	January 24, 2000	5×10 ⁻⁷



Monitoring Well	Geophysical Unit(s) Tested	Date Tested	Calculated Hydraulic Conductivity (m/s)
BH99-4C	Bobcaygeon	January 24, 2000	1×10 ⁻⁶
BH99-4D	Bobcaygeon	January 24, 2000	2×10 ⁻⁸
BH05-10A	Bobcaygeon/Gull River Contact	June 23, 2006	Could not draw water down
BH05-10B	Bobcaygeon	June 23, 2006	Could not draw water down
BH05-10C	Bobcaygeon	June 23, 2006	4x10 ⁻⁹
BH05-12B	Bobcaygeon/Gull River Contact	June 24, 2016	Well was dry
BH05-12C	Bobcaygeon	June 24, 2006	Could not draw water down
BH05-13A	Bobcaygeon/Gull River Contact	June 24, 2006	Could not draw water down
BH05-13B	Bobcaygeon	June 24, 2006	3×10 ⁻⁶
BH05-13C	Bobcaygeon	June 24, 2006	4×10 ⁻⁹
BH05-14A	Gull River	June 22, 2006	2×10 ⁻⁸
BH05-14B	Bobcaygeon/Gull River Contact	June 22, 2006	Could not draw water down
BH05-14C	Bobcaygeon	June 22, 2006	3×10 ⁻⁸
BH05-15A	Gull River	June 23, 2006	7×10 ⁻⁸
BH05-15B	Gull River	June 23, 2006	Could not draw water down
BH05-15C	Bobcaygeon/Gull River Contact	June 23, 2006	Could not draw water down

Four successful well response tests were completed in the Gull River Formation. The hydraulic conductivity values for the Gull River Formation range from 2×10⁻⁸ m/s to 2×10⁻⁶ m/s. The geometric mean for the Gull River Formation is 2×10⁻⁷ m/s and the arithmetic mean is 6×10⁻⁷ m/s. The water level could not be drawn down during a testing attempt on BH05-15B indicating a hydraulic conductivity greater than 10⁻⁴ m/s.

Six well response tests were attempted using monitors that straddled the contact between the Bobcaygeon Formation and the Gull River Formation (BH99-2A, BH05-10A, BH05-12B, BH05-13A, BH05-14B and BH05-15C). The water level could not be drawn down during the tests on BH05-10A, BH05-13A, BH05-14B and BH05-15C indicating a hydraulic conductivity greater than 10⁻⁴ m/s, and the hydraulic conductivity value for this zone in monitoring well BH99-2A was 9×10⁻⁷ m/s.

Eight successful well response tests were completed in the Bobcaygeon Formation. The hydraulic conductivity values for the Bobcaygeon Formation range from 4×10⁻⁹ m/s to 3×10⁻⁶ m/s. The geometric mean for the Bobcaygeon Formation is 1×10⁻⁷ m/s and the arithmetic mean is 8×10⁻⁷ m/s.

3.2.3 Groundwater Level Monitoring

Monitoring of groundwater levels was conducted in the monitoring intervals installed in the on-site boreholes as well as in open boreholes. Depths to water were measured relative to the surveyed top of the casing and were recorded to the nearest centimetre. The water elevations in the monitoring wells and open boreholes were calculated by subtracting the measured depth to water from the top of pipe reference elevations.



3.2.3.1 Stittsville Quarry Properties

Groundwater level measurements for the monitoring intervals installed within the monitoring wells and in the open boreholes began in March 2000 and have continued through July 2022. During each monthly session, water levels were measured in all accessible intervals. A summary of the groundwater elevations measured through July 2022 are provided in Appendix D, following the text of the report.

Pre-development Water Level Trends

The pre-development groundwater elevation data for the exiting Stittsville Quarry are presented in Appendix D and shown on Figures 6 through 10. The pre-development groundwater elevations measured between January 28, 2000 and October 2, 2002 represent baseline groundwater elevation conditions in the vicinity of the Stittsville Quarry before development. Figures 6 through 10 show that, with the exception of the monitoring wells installed in borehole BH99-6, groundwater elevations at the Stittsville Quarry were generally consistent during the pre-development period. The trends in the groundwater levels in the monitoring wells installed in borehole BH99-6 are related to the slow recovery of the water levels after construction of the monitoring wells and following groundwater sampling events (see Figure 10). It is noted that groundwater elevations increased from about 141 metres above sea level (asl) to about 146 metres asl in monitoring well BH99-4C in June 2001 (see Figure 8). A drop in groundwater elevations is generally noted in monitoring wells after sampling events due to well purging (refer to Figures 8 and 10).

Post-Development Water Level Trends

Groundwater elevation data are presented in Appendix D and shown on Figures 6 through 18. These figures show that the post-development (of the existing Stittsville Quarry) groundwater elevations at many locations are comparable to those observed prior to existing Stittsville Quarry dewatering. The monitoring wells in boreholes BH99-1 and BH99-3 (Figures 6 and 7) are the only remaining locations with water level data that extends prior to existing Stittsville Quarry dewatering (October 14, 2002). Figure 6 shows that groundwater elevations in monitoring wells BH99-1 and BH99-2B have remained relatively consistent (within the historical range) between the pre-development and post-development monitoring programs at the Stittsville Quarry. The deeper monitoring intervals, BH99-2A, BH99-3A and BH99-3B show a decrease in groundwater elevations as compared to the recorded pre-development groundwater elevations. Groundwater elevations in monitoring wells BH99-3C and BH99-3D are more variable when compared to pre-development groundwater elevations (Figure 7).

Monitoring wells that were installed after quarry dewatering began (BH03-7, BH03-8, BH03-9, BH05-10, BH05-12, BH13-16 and BH18-17) generally show the same trend with the exception of the monitoring wells in BH03-9 and BH18-17. It should be noted the BH05-11, SQAT20-25, SQAT20-26, SQAT20-27 and SQAT20-29 are open boreholes with no monitoring wells installed. The deeper monitoring intervals ("A" and "B" intervals) at the various locations show a decreasing water level trend over time whereas the shallower intervals ("C" and "D" intervals) are relatively stable (Figures 8, 9, 11, 12, 14, 15 and 16). The water levels in the deeper monitoring wells in BH03-9 have increased over time such that they are at the same elevation as the upper monitor (Figure 13). The water levels in the monitoring wells in BH18-17 do not show the same decrease in the deeper intervals.

The decline in water levels at the deeper intervals appears in early 2006 at most monitoring well locations and continued until mid-2012. After that time, water levels have been generally stable, but variable from one monitoring session to the next. The groundwater level in BH99-1 (Figure 6) dropped in July 2020 and has remained at approximately the same level ever since.



In plan view (Figure 1), borehole BH99-3 is the closest remaining borehole to the quarry excavation and, as such, should show the greatest decrease in water levels. The deep intervals at this location show the greatest decrease in groundwater elevations. The shallower intervals at this location, as well as the deep intervals at BH99-2, BH03-7, BH05-10 and BH13-16 farther from the quarry excavation, show less decrease in groundwater elevations. The overall decline in groundwater levels at BH99-1, BH99-2A, BH99-3A, BH99-3B, BH03-7A and BH03-7B, BH05-10A, BH05-10B, BH05-10C, BH05-12A, BH05-12B, BH13-16A and BH13-16B is interpreted to be related to quarry dewatering activities in the area.

3.2.3.2 Moore Quarry

Monitoring of groundwater levels has been conducted in the monitoring intervals installed on-site. Quarterly groundwater level measurements for the monitoring intervals installed within the monitoring wells (intervals "A", "B" and "C") began in June 2006, or when additional monitors were installed. Monthly groundwater level monitoring began in September 2012. During each session, water levels were measured in all accessible intervals. A summary of the groundwater elevations measured to date are provided in Appendix D and presented on Figures 18 to 24.

The recorded values show that water levels in the monitoring wells are typically consistent over time however some monitors show a general decline since May 2008. Monitoring wells BH05-15A and BH05-15B show a decreasing trend of approximately 3 metres in groundwater levels between May 2008 and January 2016, after which water levels have leveled off (Figure 21). Monitoring wells BH05-13A, BH05-13C, BH05-14A, BH05-14B, BH05-14C and BH05-15C have generally remained consistent over the period from June 2006 to July 2022. Water levels in monitoring well BH05-15B increased by approximately 4.7 metres between May and August 2014. The reason for this increase is unknown, however water levels have remained consistent since that time. Groundwater levels in the shallow bedrock and overburden monitors installed in 2014 (BH14-17, BH14-17A, BH14-18, BH18-18 and MP14-19 through MP14-22) have remained consistent since monitoring began at those locations.

The drop in water levels at monitors BH05-15A and BH05-15B is likely due to quarry dewatering in the area. Groundwater elevation monitoring at Stittsville Quarry indicates that the drawdown due to quarry operations is more significant in the deeper monitoring wells surrounding the quarry.

3.2.3.3 Groundwater Flow Directions

The groundwater elevation data presented on Figures 6 through 24 along with the borehole locations presented on Figure 1 and the water levels recorded in the MECP Water Well information System (WWIS) indicate that groundwater flow is generally from east to west across the Moore Quarry site and from west to east across the Stittsville Quarry and proposed Stittsville 2 Quarry site. The figures also indicate that there are generally recharging conditions at all of the multi-level monitoring wells on-site. At the Moore Quarry site, the vertical gradient appears to decrease near the wetland (BH05-14 and BH05-15) as the difference in groundwater elevations in the different monitors at these locations is smaller than at BH05-13.

Based on the results of the groundwater elevations collected at the site, at the shallow intervals, groundwater flow generally flows from west to east. In the shallow intervals, the highest groundwater elevations are found in monitoring wells installed on the western side of the site (i.e., BH99-1, BH99-3D, BH03-9C, BH05-10C and BH13-16D) and the lower groundwater elevations are found in the monitoring wells installed along the eastern edge of the proposed extraction area (BH18-17D and SQAT20-27).



In the deeper intervals, groundwater flow is generally from east to west likely due to the existing dewatered quarry on the western side of the proposed Stittsville 2 Quarry site. The highest groundwater elevations are found in the monitoring wells located on the east edge of the proposed extraction area (BH18-17A). The lowest groundwater elevations are located on the western side of the site (BH05-10A, BH99-3A, BH13-16A and BH03-9A).

3.2.3.4 Identification of Hydrostratigraphic Units

The data presented on the borehole logs, along with the data collected during the well response tests and WSP's experience in the area forms the basis for the identification of hydrostratigraphic units. The hydraulic conductivity data presented in Section 3.2.2 illustrates the degree of variability of measured hydraulic conductivity values. The degree of variability is related to the scale of the hydraulic testing which, relative to the scale of the quarry is small. At larger scales, particularly at the scale of a grid block in a numerical groundwater flow model, the degree of variability is significantly reduced. For this reason, it is appropriate to take averages of smaller scale data and apply them to larger volumes. The geometric mean, which minimizes bias towards the high or low end of the large range in measured values, is appropriate for this task.

Based on the results of the on-site single well response testing and the responses (to quarry dewatering over the last decade) observed in monitoring wells in the Jinkinson Road Area, it is interpreted that there is a regionally significant transmissive zone (TZ) that exists in the subsurface in close proximity to the contact between the Bobcaygeon Formation and the Gull River Formation and is most likely associated with the dolostone beds in the upper part of the Gull River Formation. This regionally significant feature is referred to herein as the "Transmission Zone" or "TZ" and is characterized by a higher horizontal hydraulic conductivity as compared to the overlying Bobcaygeon Formation and underlying Gull River Formation. This TZ feature is recognized as a distinct hydrostratigraphic unit in the Jinkinson Road Area and has been subject to depressurization over time as a result of quarry development in the area.

Seven hydrostratigraphic units were identified on the basis of the hydraulic testing and the geological formations of the bedrock in the area. In order of increasing depth, the hydrostratigraphic units are: 1) the overburden; 2) the upper weathered bedrock; 3) the Bobcaygeon Formation; 4) a Transmissive Zone (TZ) between the Bobcaygeon Formation and the Gull River Formation; 5) the Gull River Formation; 6) the Rockcliffe Formation; and, 7) the Oxford Formation.

In summary, the overburden and the upper weathered bedrock together represent a moderately permeable upper horizon; while the Bobcaygeon Formation, the Gull River Formation and the Rockcliffe Formation represent an aquitard with a TZ at the contact between the Bobcaygeon and Gull River Formations.

3.3 Surface Water Studies

3.3.1 Monitoring Stations

Pursuant to the monitoring required by the Environmental Compliance Approval (ECA) and the PTTW for the existing Stittsville Quarry, a number of water level monitoring locations have been established for the existing Stittsville Quarry, as well as, and more recently, to increase the understanding of the Goulbourn Wetland Complex hydrological characteristics. A list of the monitoring stations, their locations and their installation dates are provided in Table 6.



Table 6: Surface Water Level Monitoring Locations

Station Name	Zone	Northing	Easting	Installation Date	Measurements ²
SG-1	18	5009419	423182	September 26, 2002	Water Level (Continuous and Manual)
SG-2	18	5009475	423980	April 23, 2003	Water Level (Manual Only)
SG-4	18	5009429	423993	April 13, 2018	Water Level (Continuous and Manual)
SS-3	18	5009142	424418	July 21, 2020	Water Level (Continuous and Manual)
SS-7	18	5010001	423986	July 21, 2020	Water Level (Continuous and Manual)
SS-8	18	5010247	423400	April 9, 2021	Water Level (Continuous and Manual)
SW-A	18	5008093	425198	July 22, 2020	Water Level (Continuous and Manual)

Notes:

3.3.2 Surface Water Level Monitoring

Surface water stations (SG1, SG-2, SG-4, SS-3, SS-7, SS-8, and SW-A) were previously installed to assess seasonal water level and storage characteristics in the western and eastern wetlands within the existing quarry discharge drainage path which is also within the proposed Stittsville 2 Quarry boundary as well as to assess the Goulbourn Wetland Complex. Water level transducer dataloggers along with manual staff gauges were installed at the surface water stations detailed above with the exception of SG-2. The dataloggers were programmed to record water levels on a 15-minute interval. Where present, the pressure transducer (datalogger) is removed at the end of each season before winter and re-installed in the spring. The elevations of the staff gauges are surveyed annually relative to the Canadian Geodetic Vertical Datum of 1928 (1978 adjustment), or a nearby temporary benchmark, which was also surveyed relative to the Geodetic Datum. Water levels were manually recorded at the staff gauge locations monthly, during unfrozen periods, to verify continuous water level measurements recorded with the datalogger.

The ranges in water levels for the monitoring stations for the period of 2018 – 2022 are presented in the tables below. Any water levels recorded before 2018 at SG-1 and SG-2 are provided in Figures 25 and 26, respectively. These water level ranges are based on the continuous logger data.



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

⁽²⁾ All continuous and manual measurements at each station are seasonal (no winter measurements).

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Table 7: Maximum and Minimum Water Levels at the Surface Water Stations

Period of Record		Surface Water Monitoring Stations							
		SG-1 ⁽¹⁾	SG-2 ⁽¹⁾	SG-4 ⁽¹⁾	SS-3 ⁽¹⁾	SS-7 ⁽¹⁾	SS-8 ⁽¹⁾	SW-A (1)	
2018	Minimum (masl)	139.85	132.91	133.65	_ (2)	_ (2)	_ (2)	_ (2)	
	Average (masl)	139.94	139.94	133.79	_ (2)	_ (2)	_ (2)	_ (2)	
	Maximum (masl)	140.22	132.91	133.99	_ (2)	_ (2)	_ (2)	_ (2)	
	Minimum (masl)	139.79	132.96	132.76	_ (2)	_ (2)	_ (2)	_ (2)	
2019	Average (masl)	139.92	132.99	132.96	_ (2)	_ (2)	_ (2)	_ (2)	
	Maximum (masl)	140.13	133.05	133.11	_ (2)	_ (2)	_ (2)	_ (2)	
	Minimum (masl)	139.85	132.94	132.71	131.85	133.24	_ (2)	126.06	
2020	Average (masl)	139.87	132.99	132.89	132.20	133.77	_ (2)	126.56	
	Maximum (masl)	140.09	133.01	133.03	132.33	133.88	_ (2)	126.80	
	Minimum (masl)	139.85	132.97	132.75	132.24	_ (3)	136.38	126.56	
2021	Average (masl)	139.88	133.00	132.94	132.38	_ (3)	136.55	126.67	
	Maximum (masl)	140.09	140.09	133.08	132.46	_ (3)	136.87	126.86	
	Minimum (masl)	139.90	139.90	132.89	132.15	_ (3)	136.35	126.53	
2022	Average (masl)	139.93	139.93	132.95	132.20	_ (3)	136.42	126.61	
	Maximum (masl)	140.06	133.03	133.02	132.25	_ (3)	136.52	126.78	
Continuous Fluctuation (m)		0.43	0.17	1.28	0.61	0.64	0.52	0.79	



Note:

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

(2) Surface water loggers had not been installed at these locations yet, therefore, no continuous data was available during these years.

(3) No continuous data available during these years.

Table 8: Summary of Range of Water Levels in Quarry Surface Water Receptors

Minimum Water Elevation (masl)	Maximum Water Elevation (masl)	Range of Water Levels (m)					
Western Wetland (SG-1)							
139.79	140.22	0.43					
Eastern Wetland (SG-2 and SG-4 (Post 2019))							
132.71	132.91	0.20					
Goulbourn Wetland Complex North of the Rail Line (SS-3 and SS-7)							
131.85	132.25	0.40					
Goulbourn Wetland Complex North of Fernbank Road (SW-A)							
126.06	126.86	0.79					
Goulbourn Wetland Complex South of Highway 7 (SS-8)							
136.35	136.87	0.52					

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

As detailed in Tables 7 and 8 above, variations in water elevation at the surface water stations within the western and eastern wetland pockets on site were observed to be 0.43 m and 0.2 m, respectively, over the period of record. Variations in water elevation at the surface water stations within the Goulbourn Wetland Complex were observed to range from 0.4 m to 0.79 m over the period of record within the different sections of the complex.

Figures 25 through 31 show the continuous water level data for each monitoring station with the exception of SG-2 (detailed on Figure 26) which only shows manual measurements. Fluctuations in water elevation in the Goulbourn Wetland Complex, as measured at SG-2 (Figure 26), and in the western wetland pocket, as measured at SG-1 (Figure 24), have remained relatively consistent since 2008 at SG-1 and 2010 at SG-2. Based on the data collected at the two staff gauges to date, with the exception of a decrease in water levels at SG-1 between 2002 and 2007, there is no evidence of general increases or decreases in water levels at SG-1 or SG-2. Water elevations at SG-4 have also remained relatively stable since 2019.

Generally, water level records at the surface water stations are marked by low levels during the summer and early fall. Water levels through the spring were moderate to high following the freshet. Water levels in the fall were marked with responses to large precipitation events. As the majority of the stations were operated seasonally, no trends for the winter water levels were observed. Changes in water levels in SG-1 and SG-4, as detailed in Figures 25 and 27, respectively, are influenced by rainfall and quarry pumping events as these events tend to coincide (i.e., rainfall and snowmelt that enter the quarry excavation area is pumped out to maintain the quarry in a dewatered state). The staff gauge and data logger for SG-4 was moved in the spring of 2019 to better capture water levels within the Goulbourn Wetland Complex (i.e., within the eastern wetland pocket onsite) and, as such, water levels recorded in 2018 cannot be directly compared to 2019 through 2022.



3.3.3 Surface Water Flow Monitoring

Instantaneous flow measurements were collected seasonally at surface water stations SW-A, SS-3, and SS-8 (as seen on Figure 1) over the period of 2020 – 2022 and were used to verify the hydrological model. Continuous flow data were collected by a MACE Agriflo XCI flowmeter (MACE flowmeter), located in a culvert on the Stittsville 2 Quarry property downstream of the existing Stittsville Quarry effluent discharge location (shown in Figure 1) which provides continuous water level and velocity data (i.e., collected at 15-minute intervals) using acoustic Doppler velocity sensor technology. Continuous flow measurements were collected seasonally, and the MACE flowmeter was reinstalled yearly as early as April and retrieved before frost as late as December over the period of 2018 to 2022. Instantaneous flow measurements for SWA, SS-3, and SS-8 are summarized in Table 9. A summary of the continuous flow measurements at the MACE flowmeter is detailed in Table 10 and is displayed on Figure 32.

Table 9: Instantaneous Flow Measurements at SW-A, SS-3, and SS-8

	Flow (L/s)							
SW Station	Period of Record							
	Nov. 26, 2020	Dec. 02, 2020	Apr. 30, 2021	Sep. 24, 2021	April 8, 2022			
SW-A	_(3)	206.9	106.9	189.2	934.9			
SS-3	4.2	_(2)	_(2)	_(2)	46.7			
SS-8	_(3)	_(3)	_(1)	_(1)	0.0			

Note: L/s = Liters per second

Table 10: Summary of Continuous Flow Data at the MACE Flowmeter

Continuous Flows	Flow (L/s)						
	Period of Record						
	2018	2019	2020	2021	2022		
Minimum	-0.04	-0.01	-0.01	-0.002	0.00		
Average	0.36	0.64	0.08	0.02	0.18		
Maximum	7.44	10.16	1.59	0.45	4.18		

Note: L/s = Liters per second

The continuous flow record at the MACE flowmeter is marked by low flows during the summer and early fall. Precipitation events and quarry pumping seem to drive the majority of the flow through the culvert as the channel remains dry for extended periods of the year. It was noted that the flow data shows sudden spikes in flow and then quickly drops back down to zero. These trends can likely be attributed to the position of the flowmeter within the culvert. As demonstrated during field investigations, when the culvert is half full, the MACE flowmeter records



⁽¹⁾ No flow was observed.

⁽²⁾ Flow measurement was not recorded.

⁽³⁾ Instantaneous flow measurements began during December 2020 field visit for SW-A and SS-8 during the April 2021 field visit.

zero flow even though water is still flowing around it. It is likely that the MACE flowmeter can only record data above a certain flow before the meter is unable to get a proper reading.

3.3.4 Water Quality Monitoring

Water quality monitoring for the existing Stittsville Quarry under the existing ECA has been taking place since 2000. Water quality where surface water from the Tomlinson property enters the Goulbourn Wetland Complex (SS-6), and at the outlet of the western wetland (SS-5), is typically similar to background (SS-2, SS-7, SS-8) parameter concentrations with the exception of general increases in concentrations of boron, hardness, nitrate, potassium, strontium and sulphate and general decreases in concentrations of chloride and sodium. These results indicate that the quarry discharge may be having an effect on downstream surface water quality in the Goulbourn Wetland Complex with respect to boron, hardness, nitrate, potassium, strontium and sulphate. With respect to these six parameters, only boron has a Provincial Water Quality Objective (PWQO) and both boron and nitrate have objectives for the Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life. Although quarry discharge may be resulting in an increase in the boron concentration in the Goulbourn Wetland Complex, the boron concentrations do not exceed the interim PWQO value of 0.2 mg/L or the short-and long-term CCME objectives of 15 mg/l and 29 mg/L, respectively. Nitrate concentrations also do not exceed the short-and long-term CCME objectives of 550 mg/l and 13 mg/L, respectively. Water Quality results are presented in Appendix E.

4.0 GROUNDWATER FLOW MODELLING

4.1 Conceptual Model Development

A conceptual model describes the essential features of the hydrogeological system and identifies the principal processes affecting the potential impacts due to quarry dewatering. Since the potential impacts must account for uncertainty, an assessment of the usefulness of the available data to describe the hydrogeological system, and an identification of the uncertainties in the hydrogeological system is a critical part of the conceptual model.

A numerical model was developed to simulate the 3-D distribution of groundwater hydraulic head in the study area, using MODFLOW (Harbaugh, 2005). A base case calibrated flow model was developed through the establishment of a finite difference grid, distribution of hydraulic conductivity, distribution of boundary conditions, with adjustments, as necessary, to match the output of the model to observed conditions (i.e., the observed static water levels in the MECP WWIS in combination with groundwater elevations from the Jinkinson Road study area wells and quarry effluent discharge). The calibrated flow model was used to estimate future conditions surrounding the quarry site. Visual MODFLOW Version 4.6.0.169 was used as a pre- and post-processor for MODFLOW.

4.1.1 Data Considered

Data from a variety of sources are considered in this study. Mapping data includes Natural Resources Values Information System (NRVIS) maps from the MNRF, OGS maps from Ontario Ministry of Northern Development and Mines, and maps from the Geological Survey of Canada (GSC). Subsurface information was obtained from the MECP WWIS. At the watershed scale, reference documents include the Renfrew County – Mississippi – Rideau Groundwater Study (Golder, 2003a), the Wellhead Protection Study for Munster Hamlet and Kings Park Communal Wells (Golder, 2003), and the updates to that report (Golder, 2008 and 2009). At the local scale, references include various annual monitoring summary reports for quarries in the area and quarry licensing and permitting application documents for quarries in the area.



Tomlinson, Lafarge and Cavanagh have entered into a data-sharing agreement whereby all three parties would have access to the comprehensive geological and hydrogeological database for the Jinkinson Road study area. This comprehensive geological and hydrogeological database includes work previously conducted on, and in the vicinity of, the Tomlinson Moore Quarry, Tomlinson Stittsville Quarry, Lafarge Bell Quarry, Cavanagh Henderson Quarry and the Cavanagh Beagle Club Quarry in addition to data collected as part of the Voluntary Monitoring Program. These quarry properties in the Jinkinson Road study area are shown on Figure 4. The comprehensive geological and hydrogeological data database includes detailed rock core logs, borehole logs, monitoring well installation records, geophysical logs, groundwater level data, hydraulic conductivity data, etc. The borehole locations that are included in the data-sharing agreement are shown on Figure 4. The total number of boreholes and monitoring wells that comprise the database for the Jinkinson Road study area are 100 and 158, respectively.

Through the data-sharing agreement, the geological and hydrogeological data is made available to WSP (by Tomlinson, Lafarge and Cavanagh) for use by either of the three aggregate producers in the context of the quarry licensing projects under the *Aggregate Resources Act* and/or applications for Permits to Take Water or Environmental Compliance Approvals – Industrial Sewage Works under the *Ontario Water Resources Act*. This comprehensive geological and hydrogeological database (i.e., Paleozoic bedrock stratigraphy, hydraulic conductivity data and groundwater level data) has been used in the development of the conceptual and numerical hydrogeological model for the study area as presented in this document. In this report prepared specifically for Tomlinson, the detailed rock core logs, borehole logs, monitoring well installation records, geophysical logs, groundwater level data, hydraulic conductivity data, etc. belonging to Lafarge and Cavanagh are not presented, however, these data were used in the development of the conceptual and numerical hydrogeological model for the Jinkinson Road study area. This report does include the detailed site-specific geological and hydrogeological investigation data (borehole logs, monitoring well installation records, geophysical logs, groundwater level data, hydraulic conductivity data, etc.) for work conducted by Tomlinson as it relates to the studies completed since 1999 on, and in the vicinity of, the Tomlinson Stittsville Quarry and Tomlinson Moore Quarry.

4.1.2 Data Review and Processing

Based on a preliminary review of the available data, a fourteen kilometre by thirteen-kilometre study area was chosen, centred on the quarry operations in the Jinkinson Road area. Within this area, water well records were obtained from the WWIS, combined with available data from other sources, and examined to determine subsurface geological and hydrogeological conditions. The data was reviewed and processed as follows:

- Presentation of the geological information ("formations" as described by the GSC Mat1 Code in the WWIS, or
 equivalent in other data sets) and hydrogeological information (elevation of water found and elevation of static
 water level in the WWIS).
- Development of a "layer cake" model of subsurface geology (i.e., from the ground surface down) consistent with the geological information contained within the WWIS, geological mapping and data obtained from the various guarry field programs.
- Assessment of the data gaps.

The hydrogeological information contained in the WWIS represents water level data collected during different years, different seasons and from different formations depending on the depth of the well. The reported static water levels may not be representative of actual static conditions as they are likely measured shortly after completion of the drilling of the well. On an individual basis, the information cannot be relied upon to be representative of actual current conditions; however, when multiple wells are considered together, trends in water



levels can be observed and outliers can be identified. It is recognized that the information in the WWIS should be used with an acknowledgement of its limitations.

4.1.3 Hydrostratigraphy

Based on the information in the WWIS and mapped geology, two general hydrostratigraphic units, were postulated for the regional hydrogeological system under investigation:

- 1) Sand or glacial till overburden (typically 2 metres thick)
- 2) Limestone bedrock (up to 150 metres thick)

The top of the model was set equal to ground surface elevation taken from the NRVIS digital elevation model.

The overburden hydrostratigraphic unit (glacial till and sand) was assumed to be present over the entire area with a constant thickness of 2 metres. The distribution of the various overburden types was based on the existing mapping (refer to Figure 2). Based on shallow subsurface data collected in the vicinity of the quarries, it was assumed that glacial till was present everywhere where other units, such as sand, were not mapped.

Bedrock in the area of the quarry includes (from depth to top of bedrock) the Precambrian basement, the Nepean Formation, the March Formation, the Oxford Formation, the Rockcliffe Formation, the Gull River Formation and the Bobcaygeon Formation. The rock units slope towards the northeast consistent with the strike and dip of the layered bedrock. The proposed Stittsville 2 Quarry will extract bedrock from the Bobcaygeon Formation.

Based on the results of the geophysical analysis, hydraulic conductivity testing, and pumping tests conducted in the monitoring wells located in the vicinity of the quarries as well as WSP's experience in the surrounding area, the limestone bedrock general hydrostratigraphic unit was further divided into seven separate units.

The lowest unit included in the conceptual model was the Oxford Formation (up to 100 metres thick). Hydraulic conductivities in the formation generally range from 10⁻¹⁰ to 10⁻⁴ metres per second (Golder, 2003a). Above this unit is the Rockcliffe Formation (up to 30 metres thick), that generally has lower hydraulic conductivity and poor domestic well yields. Based on the water levels and model calibration, a more transmissive unit of the Rockcliffe Formation was defined in the southern portion of the model domain (refer to Figure 33). This more transmissive zone of the Rockcliffe Formation is located south of the proposed Stittsville 2 Quarry and is not expected to significantly impact any of the simulations. Above the Rockcliffe Formation is the Gull River Formation. This unit ranges in thickness from 0 to 30 metres depending on the location within the model domain.

In close proximity to the contact between the Bobcaygeon Formation and the Gull River Formation was a more transmissive unit (TZ) that was assumed to have a thickness of five metres. The TZ is a regionally significant feature that exists in the subsurface in close proximity to the contact between the Bobcaygeon Formation and the Gull River Formation and is most likely associated with the dolostone beds in the upper part of the Gull River Formation. This regionally significant feature is characterized by a higher horizontal hydraulic conductivity as compared to the overlying Bobcaygeon Formation and underlying Gull River Formation. This TZ feature is recognized as a distinct hydrostratigraphic unit in the Jinkinson Road Area and has been subject to depressurization over time as a result of quarry development in the area. The TZ 'daylights' (directly beneath the weathered bedrock) to the south and west of the proposed Stittsville 2 Quarry. The TZ does not exist to the south of the daylight area, as the formation has been weathered away due to geological erosional processes in the past (refer to Figure 33).



The TZ is overlain by the less permeable upper unit ranging in thickness from 0 to 55 metres (Bobcaygeon Formation). A weathered bedrock layer at the top of the bedrock surface (3 metres thick) was assumed over the entire model domain.

4.1.4 Groundwater Recharge, Discharge and Flow Direction

Based on the water well information in the WWIS and the on-site monitoring well data, it was assumed that local groundwater flow in the area of the proposed Stittsville 2 Quarry is recharged at the local topographic high located immediately to the west of the quarry site along Jinkinson Road. Shallow groundwater discharges at the surrounding lowlands including wetlands, and streams. Deeper groundwater likely follows the general west to east regional flow. An important discharge location includes the Goulbourn Wetland Complex located to the east of the Site.

4.1.5 Finite Difference Grid

The grid block size for the area surrounding the proposed Stittsville 2 Quarry and the other quarries was set equal to 20 metres and was increased to a maximum value of 150 metres as the distance from the quarries to the edge of the domain increased (refer to Figure 34). There was a total of 17 layers in the model. Figure 35 illustrates the relationship between the 17 numerical model layers and the hydrostratigraphic units present in the vicinity of the proposed Stittsville 2 Quarry. Layer thicknesses ranged from 0.25 metres to 25 metres. Overburden (glacial till and sand) was represented with a single two-metre thick layer (from ground surface) and the weathered bedrock had a thickness of 3 metres (from the bottom of the surficial overburden layer). The lower bedrock layers outside of the area immediately surrounding the quarries followed the general dip and strike of the bedrock. Within the area surrounding the quarries, the lower bedrock layers were defined by surfaces generated based on the results of the geophysical testing and core logging that has taken place in the boreholes/monitoring wells. The resulting finite difference grid consisted of 403 rows, 313 columns, and 17 layers. A total of 2,144,363 grid blocks were defined within the model domain.

4.1.6 Boundary Conditions

Boundary conditions are assigned to the model to match the boundaries of the flow system as defined in the conceptual model.

Recharge boundary conditions were established on the top layer (overburden) based on the mapped surficial geology units. Overburden (glacial till and sand) was assumed to be present over the entire area with a constant thickness of 2 metres. As indicated previously, it was assumed that glacial till was present everywhere where other units, such as sand, were not mapped. Because no vertical differentiation of the overburden units was considered, and because the model domain is dominated by the presence of the glacial till unit, a single value of 150 millimetres per year (mm/yr) was assigned for surficial recharge. This recharge rate is consistent with that used in previous models for this area (Golder, 2018).

Constant head boundary conditions were applied to the outside edges of the model domain based on the static water levels obtained from the WWIS. The values were then adjusted during model calibration to those indicated on Figure 36. The model domain of thirteen kilometres by fourteen kilometres, centred on the Proposed Stittsville 2 Quarry and the other nearby quarries, was chosen so that boundary conditions assigned to the outside edge of the model would not directly impact the centre of the model.

Drain boundary conditions were applied to the upper surface of the model at the locations shown on Figure 36. Such boundary conditions were applied to mapped streams and rivers within the model domain as well as the



mapped wetlands, with the drain elevation set equal to the model-top elevation (ground surface). The conductance for the drain boundary conditions used at groundwater discharge locations were set at 25 m²/day.

The quarry excavations are simulated using drain boundary conditions in the cells surrounding the excavation and at the bottom of the excavation. The elevation of the drain boundary conditions for the cells representing the bottom of the quarry excavation are set equal to the base elevation of the quarry. The elevation of the drain boundary conditions used to represent the sides of the quarry excavation are set equal to the bottom of the cell block plus one tenth of the total thickness of the block. The conductance for the drain boundary conditions used to represent the quarry excavations is set at 25 m²/day. The boundary conditions for the quarry excavations are shown on Figure 35.

4.1.7 Hydraulic Conductivity and Storativity

Hydraulic conductivity is assigned to the individual grid blocks based on their location within the assumed hydrostratigraphic model. Initial hydraulic conductivity values are assigned based on measured values, typical ranges and professional experience with the specific hydrostratigraphic units. Adjustments are considered during the model calibration exercise.

The numerical model is run to steady state conditions (as a conservative approach) and, as such, storativity is not required for the numerical model.

Details regarding the hydraulic conductivity values assigned for the numerical model are provided in Section 4.1.8, where the calibration of the model is discussed.

4.1.8 Model Calibration

In general terms, model calibration is the exercise of adjusting model properties and boundary conditions (generally referred to as "parameters"), within reasonable bounds, to best match the model output to the observed conditions. In the case of steady state groundwater flow modelling, the model output is limited to groundwater elevations and groundwater discharge rates. In this case, both were considered in the model calibration.

Observed groundwater elevations (i.e., hydraulic heads) considered during model calibration were calculated by subtracting the depth-to-water from the ground surface elevation, while the measuring point (i.e., elevation head) was inferred from information about the well, as shown in the following table.

Table 11: Groundwater Calibration Data

Data Source	Ground Surface Elevation	Depth to Water	Measurement Point (i.e., Elevation Head)
WWIS	Interpolated from digital elevation model	In database	Lowest elevation of "water found"
Jinkinson Road Study Area Monitoring Wells	Surveyed to Geodetic datum	Measured using water level tape	Centre of monitoring interval

For comparison to the observed values, simulated groundwater elevations (from the numerical model) at each measurement point were interpolated from the simulated groundwater elevations in the surrounding grid blocks. The match between the observed and simulated groundwater elevations was assessed from plots of simulated



versus observed groundwater elevations and from calibration statistics: maximum over-prediction, maximum under-prediction, residual mean, absolute residual mean, root mean square (RMS) and normalized RMS.

The strategy employed for model calibration was to first adjust hydraulic conductivities of the hydrostratigraphic layers and recharge rates as inferred from the conceptual model in order to best match simulated to observed groundwater elevations on a regional scale (i.e., throughout the model), prior to any quarry development (Scenario 1). Starting values and reasonable ranges for these parameters were inferred from the available data and from tabulated values (i.e., published typical values and from WSP's experience with similar formations).

The Scenario 1 model was then used to develop the Scenario 2 model where existing conditions at the Bell Quarry, Henderson Quarry, Stittsville Quarry, Moore Quarry, Beagle Club Quarry and the Fernbank Quarry were simulated. The parameters obtained from the calibration of Scenario 1 were applied to Scenario 2 to determine if the presence of the existing quarries, as observed in the drawdown from the Jinkinson Road study area wells, was captured by the numerical model. Adjustments to the hydraulic conductivities and recharge were again considered to best match both the pre-development water levels (Scenario 1) and the existing conditions (Scenario 2) in the area. The observed groundwater elevations used for the calibration included all the records in the WWIS and water levels collected from the Jinkinson Road study area monitoring wells. For the existing conditions scenario, all available records from the WWIS were used along with the 2021 average water levels for the Jinkinson Road study area monitoring wells.

To achieve the best calibration, it was determined that the hydraulic conductivity anisotropy ratio $(K_h:K_v)$ of the weathered bedrock layer, the TZ, located between the Gull River and Bobcaygeon Formations, and the permeable layer at the bottom of the model (Oxford Formation) in the numerical model was 10:1, whereas the other bedrock layers in the model had an anisotropy ratio of 100:1.

The hydraulic conductivity of the sand unit was assumed to be within the typical range of a silty sand (1x10⁻⁴ m/s; Freeze and Cherry, 1979), while the hydraulic conductivity of the glacial till unit was based on the results of the model calibration process.

The input parameters of the calibrated model (for both Scenario 1 and Scenario 2) that produced the modelling results presented in this report are shown in cross section on Figure 37 and summarized in the following table:

Table 12: Calibrated Input Parameters

Model Parameter	Horizontal Hydraulic Conductivity (m/s)	K _h :K _v
Sand and Gravel	1x10 ⁻⁴	1:1
Glacial Till	2x10 ⁻⁶	1:1
Upper Weathered Bedrock	2x10 ⁻⁵	10:1
Bobcaygeon Formation	9x10 ⁻⁸	100:1
Transmissive Zone	6x10 ⁻⁶	10:1
Gull River Formation	1x10 ⁻⁷	100:1
Rockcliffe Formation	1x10 ⁻⁷	100:1
Transmissive Rockcliffe Formation	6x10 ⁻⁶	100:1
Oxford Formation	3x10 ⁻⁵	10:1



The hydraulic conductivity of the TZ was the primary parameter that has been adjusted from previous instances of this model being calibrated. The hydraulic conductivity was lowered from 5x10⁻⁵ m/s in previous calibrations to 6x10⁻⁶ m/s. The adjustment was made to better match the water level trends in the Jinkinson Road monitoring wells and the most recent pumping records for the quarries.

Contours of simulated water table elevations without the existence of any of the quarries, and with the existing quarries (as of 2021) are illustrated on Figures 38 and 39, along with calibration plots and statistics for the groundwater elevations from the WWIS and monitoring wells (Jinkinson Road study area wells).

The results of the calibration of Scenario 1 and Scenario 2 indicate a reasonable agreement between the simulated groundwater elevations and the observed groundwater elevations, based on the following observations:

- As shown on Figures 38 and 39, the majority of the simulated groundwater elevations are within 5 metres of the observed elevations, with an absolute residual mean error of 3.13 metres for Scenario 1 (pre-quarry conditions Figure 38), and 3.37 metres for Scenario 2 (existing conditions Figure 39). A strong bias was not present in the simulated groundwater elevations, as indicated by the residual mean, which was 0.96 metres for Scenario 1 and 0.87 metres for Scenario 2. The normalized root mean squared error (nRMS) was 6.70% for Scenario 1, and 7.33% for Scenario 2.
- Recent water levels measured from the Jinkinson Road study area monitoring wells generally compare well to the simulated values at these locations.
- Groundwater flow directions simulated by the model are similar to those inferred from the measured water levels across the model area (Figures 38 and 39).
- Groundwater seepage into the existing Stittsville and Henderson quarries was simulated to be 510 cubic metres per day (m³/day) and 500 m³/day, respectively. Although direct measurements of groundwater inflow are not available at the existing quarries, these values are within the range of values noted in the available pumping records during periods of low precipitation (when surface water / runoff inflow to the quarries should be minimal).

4.2 Forecast Simulations

Once calibration was complete, the existing conditions model (Scenario 2) was used as a predictive tool to assess the potential drawdown associated with the development and rehabilitation of the proposed Stittsville 2 Quarry. Predictive scenarios were developed to assess the drawdown from existing conditions associated with the proposed development and rehabilitation of the Stittsville 2 Quarry. The different calibration and predictive scenarios are as follows:

Calibration Scenarios:

- Scenario 1 Pre-quarry Conditions (Calibration Run) no quarry development in Jinkinson Road study area.
- Scenario 2 Existing Conditions (Calibration Run) Bell Quarry, Henderson Quarry, Stittsville Quarry,
 Beagle Club Quarry and Fernbank Quarry at existing conditions (as of 2021).



Forecast Scenarios:

 Scenario 3 – Stittsville Quarry and Proposed Stittsville 2 Quarry at Full Development – Stittsville Quarry and proposed Stittsville 2 Quarry fully extracted and dewatered with remaining quarries at existing (2021) level of development.

- Scenario 4 Existing Quarries Full Development All licensed quarries fully extracted and dewatered with the proposed Stittsville 2 Quarry remaining at existing (undeveloped) conditions.
- Scenario 5 All Quarries at Full Development All licensed quarries fully extracted and dewatered including the proposed Stittsville 2 Quarry.
- Scenario 6 Stittsville Quarry and Proposed Stittsville 2 Quarry at Full Rehabilitation Stittsville Quarry and proposed Stittsville 2 Quarry fully developed and rehabilitated with remaining quarries at existing (2021) level of development.
- Scenario 7 Existing Quarries at Full Rehabilitation All licensed quarries fully developed and rehabilitated with the proposed Stittsville 2 Quarry remaining at existing (undeveloped) conditions.
- Scenario 8 All Quarries at Full Rehabilitation All licensed quarries fully developed and rehabilitated including the proposed Stittsville 2 Quarry.

Table 13 describes the full development and rehabilitation states of the proposed Stittsville 2 Quarry and each currently licensed quarry considered in the model. The full development and rehabilitation conditions for the proposed Stittsville 2 Quarry were selected based on the proposed quarry development plan outlined in Section 1.3.

As previously discussed in Section 1.2, the final quarry floor for the proposed Stittsville 2 Quarry will slope from approximately 123 metres asl in the southwest to 101 metres asl in the northeast which generally follows the contact between the Bobcaygeon Formation and Gull River Formation. For modelling purposes and as a conservative measure, the final quarry floor for the proposed Stittsville 2 Quarry was set at a constant elevation of 108 metres asl.

Table 13: Quarry Development and Rehabilitation Summary

Quarry Operator	Quarry Name	Approved Quarry Floor Elevation (metres above sea level)	Rehabilitation Plan
Tomlinson	Proposed Stittsville 2 Quarry	101 to 123	Backfill excavation to original grade
	Stittsville Quarry	108 (minimum)	Rehabilitate to a lake with level at 141 metres asl.
	Moore Quarry	112 to 126	Rehabilitate to a lake with level at 134.5 metres asl.
Cavanagh	Henderson Quarry	112	Rehabilitate to a lake with level at 135.5 metres asl.
	Beagle Club Quarry	117	Rehabilitate to a lake with level at 135 metres asl.



Quarry Operator	Quarry Name	Approved Quarry Floor Elevation (metres above sea level)	Rehabilitation Plan
Lafarge	Bell Quarry	132	Rehabilitate to a lake with level at 141 metres asl.
Taggart	Fernbank Quarry	126.5	Rehabilitate to a lake with level at 135 metres asl.

For the rehabilitation scenarios where backfilling will be completed, the backfilled material was assumed to have a hydraulic conductivity value of $1x10^{-5}$ m/s ($K_h=K_v$)

4.3 Forecast Simulation Results

4.3.1 Existing Groundwater Levels

Simulated pre-quarry and existing quarry (as of 2021) water table elevations are shown in plan view on Figures 38 and 39, respectively. In general, the direction of groundwater flow in the vicinity of the Proposed Stittsville 2 Quarry site is from northwest to southeast, which corresponds to the interpreted groundwater elevation data.

4.3.2 Predicted Groundwater Drawdown

The results of the predictive groundwater flow model simulations for each of the scenarios are presented on Figures 40 through 47 and illustrate the simulated groundwater level drawdown due to the development and rehabilitation of the proposed Stittsville 2 Quarry. The results are presented as drawdown contours from the weathered bedrock (Layer 2 of the numerical model), the TZ (Layer 8 of the numerical model), and the Gull River Formation (Layer 10 of the numerical model). The maximum extent of drawdown discussed is based on the 1-meter drawdown contour.

Scenario 3: Stittsville Quarry and Proposed Stittsville 2 Quarry Development

Figure 40 shows the contours of simulated groundwater level drawdown in the weathered bedrock (Layer 2), TZ (Layer 8) and Gull River Formation (Layer 10) of the numerical model, induced by the full extraction of the Stittsville Quarry and the proposed Stittsville 2 Quarry as compared to current conditions. The contours are produced by subtracting the simulated groundwater elevations in Scenario 3 from those in Scenario 2 (existing conditions, i.e., 2021 estimate).

The simulated drawdown in the TZ and the Gull River Formation have similar extent with the one metre drawdown contour extending between approximately 800 metres (to the south and west) and 2,100 metres (to the north and east) of the proposed Stittsville 2 Quarry excavation footprint. The more extensive drawdown to the north and east corresponds with where the TZ is present. The simulated drawdown in the weathered bedrock extends to a maximum of approximately 350 metres from the proposed Stittsville 2 Quarry excavation footprint.

Incremental Drawdown Associated with Stittsville 2 Quarry under Full Development Conditions

The contours of simulated groundwater level drawdown in the weathered bedrock (Layer 2), TZ (Layer 8) and Gull River Formation (Layer 10) of the numerical model for Scenario 4 (all quarries except Stittsville 2 Quarry at full development) and Scenario 5 (all quarries at full development) are shown on Figures 41 and 42, respectively. Figure 43 shows the incremental drawdown associated with the proposed Stittsville 2 Quarry under full development conditions calculated by subtracting the drawdown contours of Scenario 5 from those of Scenario 4.



As shown on Figure 43, the simulated additional drawdown related to the development of the proposed Stittsville 2 Quarry is the highest in the TZ (Layer 8) and extends to the north and east a maximum of approximately 1,900 metres from the proposed Stittsville 2 Quarry excavation footprint. The simulated incremental drawdown in the weathered bedrock extends to a maximum of approximately 200 metres from the proposed Stittsville 2 Quarry excavation footprint.

Scenario 6: Stittsville Quarry and Proposed Stittsville 2 Quarry Rehabilitation

Figure 44 shows the contours of simulated groundwater level drawdown in the weathered bedrock (Layer 2), TZ (Layer 8) and Gull River Formation (Layer 10) of the numerical model, induced by the full extraction and rehabilitation of the Stittsville Quarry and the proposed Stittsville 2 Quarry as compared to current conditions. The contours are produced by subtracting the simulated groundwater elevations in Scenario 6 from those in Scenario 2 (existing conditions, i.e., 2021 estimate).

As shown in the negative drawdown contours in Figure 44, groundwater levels simulated for the rehabilitation of the Stittsville Quarry and proposed Stittsville 2 Quarry are generally higher than the simulated groundwater levels in the Existing Conditions Model.

Incremental Drawdown Associated with Stittsville 2 Quarry under Full Rehabilitation Conditions

The contours of simulated groundwater level drawdown in the weathered bedrock (Layer 2), TZ (Layer 8) and Gull River Formation (Layer 10) of the numerical model for Scenario 7 (all quarries except Stittsville 2 Quarry at full rehabilitation) and Scenario 8 (all quarries at full rehabilitation) are shown on Figures 45 and 46, respectively. Figure 47 shows the incremental drawdown associated with the proposed Stittsville 2 Quarry under full rehabilitation conditions calculated by subtracting the drawdown contours of Scenario 8 from those of Scenario 7.

As shown in the incremental drawdown contours on Figure 47, the simulation generally predicts a negligible change or an increase in groundwater levels related to the rehabilitation of the proposed Stittsville 2 Quarry.

4.3.3 Predicted Quarry Inflow

The table below shows the simulated groundwater inflows to the proposed Stittsville 2 Quarry, the Stittsville Quarry, other nearby quarries and the Goulbourn Wetland Complex. For the purposes of this model, the Goulbourn Wetland Complex was defined as the drain cells within the area mapped as the Goulbourn Wetland Complex in the MNRF wetland mapping and watercourses that were interpreted to be discharging to it based on topography.

Table 14: Simulated Groundwater Inflow Results

		Simulated Groundwater Inflow (m³/d)			
Simulation	Proposed Stittsville 2 Quarry	Stittsville Quarry	Other Quarries	Goulbourn Wetland Complex	
Scenario 1 – pre- quarry conditions	-	-	-	12,450	
Scenario 2 – existing conditions	-	513	719	12,245	
Scenario 3 – Stittsville Quarry and Proposed Stittsville 2 Quarry at full development	1,238	501	657	11,298	



		Simulated Groundwater Inflow (m³/d)			
Simulation	Proposed Stittsville 2 Quarry	Stittsville Quarry	Other Quarries	Goulbourn Wetland Complex	
Scenario 4 – all quarries except the proposed Stittsville 2 Quarry at full development	-	650	2,336	11,713	
Scenario 5 – all quarries at full development	1,185	392	2,208	11,003	

Based on this assessment, full development of the Stittsville Quarry and the proposed Stittsville 2 Quarry while the other quarries remain in the existing (2021) level of development (Scenario 3) will cause a reduction in groundwater inflow to the Goulbourn Wetland Complex of approximately 8% as compared to existing conditions. Development of the proposed Stittsville 2 Quarry with all other quarries fully developed (Scenario 5) results in a 6% (710 m³/day) decrease in groundwater inflow to the Goulbourn Wetland Complex compared to the full development of the currently licensed quarries (Scenario 4).

Should the Stittsville Quarry and the Proposed Stittsville 2 Quarry develop to the full extent (while the surrounding quarries remain in the current level of development – Scenario 3), groundwater inflow to the proposed Stittsville 2 Quarry excavation will be approximately 1,238 m³/day. Should all of the surrounding quarries be developed to their full extent (Scenario 5), the predicted groundwater inflow to the proposed Stittsville 2 Quarry is 1,185 m³/day.

4.4 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 where six additional simulations were completed with variations on the model input parameters. These six sensitivity runs were completed specifically to test the parameters that were thought to have the most impact on the proposed Stittsville 2 Quarry. The sensitivity scenarios are summarized as follows:

- Sensitivity Run 1 (SR1) Higher hydraulic conductivity in the TZ. For this simulation, the hydraulic conductivity of the TZ was increased to 5x10⁻⁵ m/s which is what has been used in previous calibrations of this model (Golder, 2018).
- Sensitivity Run 2 (SR2) Lower hydraulic conductivity in the TZ. For this simulation, the hydraulic conductivity of the TZ was decreased to 1x10⁻⁶ m/s.
- Sensitivity Run 3 (SR3) Higher hydraulic conductivity in the Gull River Formation. For this simulation, the hydraulic conductivity of the Gull River Formation was increased to 1x10⁻⁶ m/s (compared to 1x10⁻⁷ m/s for the base case).
- Sensitivity Run 4 (SR4) Lower hydraulic conductivity in the Gull River Formation. For this simulation, the hydraulic conductivity of the Gull River Formation was decreased to 5x10⁻⁸ m/s.
- Sensitivity Run 5 (SR5) Lower recharge. For this simulation, the recharge was halved.



Sensitivity Run 6 (SR6) – Higher recharge. For this simulation, the recharge was increased by 50%.

All sensitivity runs were completed for Scenario 2 (existing conditions) and Scenario 3 (Stittsville Quarry and proposed Stittsville 2 Quarry at full development). Results are summarized in terms of the simulated rates of groundwater inflow in the table below.

Table 15: Simulated Groundwater Inflow Results - Sensitivity Analysis

Scenario 3 – Stittsville Quarry and Proposed Stittsville 2		Simulated Ground	Groundwater Inflow (m³/d)			
Quarry Full Development (Other Quarries at Existing Conditions)	Proposed Stittsville 2 Quarry	Stittsville Quarry	Other Quarries	Goulbourn Wetland Complex		
Base Case	1,238	501	657	11,298		
SR1 – Higher K TZ	2,364	833	461	10,479		
SR2 – Lower K TZ	995	399	682	11,477		
SR3 – Higher K Gull River	1,450	661	767	10,663		
SR4 – Lower K Gull River	1,224	491	654	11,477		
SR5 – Lower Recharge	826	326	297	5,016		
SR6 – Higher Recharge	1,588	666	1,005	17,606		

Note: K = Hydraulic Conductivity

A review of results of the sensitivity analysis (Table 15) allows the following observations:

- The maximum extent of drawdown across the sensitivity simulations was similar to what was predicted by the simulation results from Scenario 3 except for sensitivity run 1 (higher K TZ).
- Increasing the hydraulic conductivity of the TZ to what has been used in previous calibrations of this model (5x10⁻⁵ m/s) caused an increase in the maximum extent of drawdown (approximately 2,000 metres). This higher conductivity for the TZ was not considered a good fit during the calibration process due to a poor match with the available quarry pumping records and the recent groundwater level trends.
- Simulated groundwater inflow to the proposed Stittsville 2 Quarry is sensitive to the hydraulic conductivity of the TZ. Increasing the hydraulic conductivity of the TZ to what has been used in previous calibrations of this model (5x10⁻⁵ m/s) resulted in an approximate 91% increase in flow to the proposed Stittsville 2 Quarry, whereas decreasing the hydraulic conductivity of the TZ by a factor of 6 resulted in an approximate 20% decrease in the amount of flow to proposed Stittsville 2 Quarry. Simulated groundwater inflow to the Goulbourn Wetland Complex is relatively insensitive to the hydraulic conductivity of the TZ. Increasing the hydraulic conductivity of the TZ to what has been used in previous calibrations of this model (5x10⁻⁵ m/s) resulted in an approximate 7% decrease in flow to the Goulbourn Wetland Complex, whereas decreasing the hydraulic conductivity of the TZ by a factor of 6 resulted in an approximate 2% increase in flow to the Goulbourn Wetland Complex.
- The sensitivity of the hydraulic conductivity of the Gull River Formation on the simulated groundwater inflows are relatively minor. Increasing the hydraulic conductivity of the Gull River Formation by one order of magnitude resulted in an approximate 17% increase in flow to the proposed Stittsville 2 Quarry and a 6%



reduction in flow to the Goulbourn Wetland Complex, whereas decreasing the hydraulic conductivity of the Gull River Formation by a factor of 2 resulted in an approximate 1% decrease in flow to the proposed Stittsville 2 Quarry and a 2% increase in groundwater flow to the Goulbourn Wetland Complex.

All groundwater inflows are sensitive to changes in recharge. Reducing the recharge by a factor of 2 resulted in an approximate 33% decrease in flow to the proposed Stittsville 2 Quarry and a 56% reduction in flow to the Goulbourn Wetland Complex, whereas increasing the recharge by 50% resulted in an approximate 28% increase in flow to the proposed Stittsville 2 Quarry and a 56% increase in groundwater flow to the Goulbourn Wetland Complex.

5.0 HYDROLOGICAL ASSESSMENT

Within the vicinity of the proposed Stittsville 2 Quarry, several wetlands (delineated as western and southern wetlands in Figure 1) and the Goulbourn Wetland Complex (which includes the on-site eastern wetland) may experience changes due to surface water drainage alterations, changed land uses, quarry water management (e.g., quarry dewatering) and the propagation of groundwater level drawdown beneath the surface water features as a result of quarry dewatering. These changes have some potential to affect the receptor flow regimes (e.g., distribution of base flow and storm flow/flooding), channel erosion and water quantity at a local scale, but are not expected to significantly change the annual site water budget.

Under existing conditions, the area around the proposed Stittsville 2 Quarry was separated into 13 sub-catchments, including the existing Stittsville quarry, based on a convergence point selected at a culvert located downstream of the site at Fernbank Road, as detailed in Figure 48. Discharge from the existing quarry (i.e., sub-catchment 3) is pumped directly into the western wetland (i.e., sub-catchment 1C and 4A). Drainage from these sub-catchments as well as 5C then flows east to a small drainage pathway with a culvert crossing, located within the proposed extraction area, before continuing to the Goulbourn Wetland Complex. Ultimately, all the sub-catchments detailed in Figure 48 drain to the Goulbourn Wetland Complex.

As a result of the proposed quarry, the western and southern wetlands will be removed, and drainage will be captured by the quarry footprint and will ultimately continue to report to the Goulbourn Wetland Complex via a quarry discharge point directed towards Sub-catchment 4B under operational conditions.

Under rehabilitated conditions, the quarry will be backfilled. It is anticipated that the excavation will be backfilled to original grade throughout the limit of extraction, allowing for future potential development in the area near Jinkinson Road and a naturalized area in the southern portion of the property. The proposed naturalized area will include forests, wetlands, meadow and thicket. This area will be planted with mixed native species and will provide a range of habitats for wildlife. The ultimate drainage directions and sub-catchments areas are expected to closely resemble existing pre-development conditions.

The purpose of the hydrological assessment was to evaluate the potential implications of the proposed Stittsville 2 Quarry operations on surface water flows in the key surface water receptors. The points of analysis to conduct the hydrologic assessment were selected at the drainage outlet of the western wetland pocket (at the MACE flowmeter modelled as Junction 1) and where the Goulbourn Wetland Complex drains under Fernbank Road (at surface water station SW-A modelled as Junction 4). The model schematic representing the linkages between sub-catchments and location of calibration stations (where applicable), modelled as junctions, is presented on Figures 48 through 50.



The hydrologic model assesses the differences in infiltration, runoff and peak flows within the surface water subcatchments for the following scenarios (as defined in Section 4.2):

- Scenario 2: Existing Conditions (Calibration Run) All quarries in the area including Bell Quarry, Henderson Quarry, Stittsville Quarry, Beagle Club Quarry and Fernbank Quarry as well as the proposed Stittsville 2 Quarry site at existing conditions (as of 2021), sub-catchments for this scenario are shown on Figure 48;
- Scenario 4: Existing Conditions at Full Development All licensed quarries fully extracted and dewatered with the proposed Stittsville 2 Quarry remaining at existing (undeveloped) conditions, sub-catchments for this scenario are shown on Figure 49;
- Scenario 5: All Quarries at Full Development All licensed quarries fully extracted and dewatered including the proposed Stittsville 2 Quarry, sub-catchments for this scenario are shown on Figure 50; and,
- Scenario 8: All Quarries at Full Rehabilitation All licensed quarries fully developed and rehabilitated including the proposed Stittsville 2 Quarry with the assumption that the proposed Stittsville 2 Quarry site will be filled, graded, and vegetated. Sub-catchments for this scenario are shown on Figure 50. Both the existing Stittsville Quarry and Bell Quarry will be rehabilitated as a lake and will continue to contribute surplus to the Goulbourn Wetland Complex.

The assessment focused on quantifying changes within the surface water sub-catchments. As the evaluation point moves further downstream the magnitude of the changes predicted becomes smaller as available surplus and storage capacity from unaffected sub-catchments may contribute maintaining pre-existing conditions. The surface water catchment areas contributing to the points of analysis and estimated groundwater capture zones, defined as the areas where shallow groundwater flows to the guarry, are provided on Figures 48 through 50.

5.1 Hydrologic Model Methodology

A hydrologic model was prepared as a tool to help quantify effects and to assess their impacts under the operational and rehabilitated conditions to the key surface water receptors that receive discharge from the proposed quarry site, including the Goulbourn Wetland Complex. Results of the model are provided in Section 6.0. For the purposes of the model, it was assumed that, under rehabilitated conditions, the proposed Stittsville 2 Quarry would be modelled as a filled quarry that had an area for future potential development in the area near Jinkinson Road (seeded area) and a naturalized area and wetland in the southern portion of the site.

A HEC-HMS model was developed for the study area, simulating hydrologic conditions on a continuous basis. HEC-HMS was developed by U.S. Army Corps of Engineers to simulate the precipitation-runoff processes of natural and urban watershed systems (Scharffenberg, 2016). For this application, the model was designed to run on a continuous basis to capture the long-term average effects of proposed development, considering the following parameters:

- Meteorological data (precipitation and potential evapotranspiration)
- Canopy interception
- Surface depression storage
- Infiltration
- Baseflow
- Runoff transform



Four HEC-HMS models were developed to represent the Existing Conditions (Scenario 2 - Calibration), Existing Conditions at Full Development (Scenario 4), All Quarries at Full Development (Scenario 5) and All Quarries at Full Rehabilitation (Scenario 8) of the surface water system. The models include both surface water and groundwater inputs during full development conditions. Each model scenario was simulated using an hourly time step, spanning January 1, 1991, to September 22, 2022, to correspond with available meteorological data. Calibration of the model was conducted using an hourly timestep, spanning from January 1, 2018, to September 22, 2022, to correspond with available discharge pumping records.

Land use in the sub-catchment areas was interpreted from Southern Ontario Land Resource Information System (SOLRIS), and includes grassed and forested land, sand/gravel areas, wetlands including swamps and marshes, as well as impervious areas including roads, built-up areas, and existing extraction areas. Topography data and site boundaries were used to help delineate the various sub-catchments within the Goulbourn Wetland Complex at Fernbank Road. These estimated sub-catchments form the basis of the HEC-HMS model.

The model was split into various elements to help represent sub-catchments, wetlands, and adjacent quarries. Specifically, the following elements were considered:

- Sub-Basins (used to represent sub-catchments) → parameters including area, land uses, baseflow, slope, and canopy/surface depression storage were used to characterize the sub-catchments response to precipitation events in relation to runoff and infiltration.
- Reservoirs (used to represent large wetland areas) → storage discharge relationships were developed based on available outlet specifications/assumptions and wetland surface areas for each applicable subcatchment to properly characterize the storage capacity in each wetland section and its role on dampening outflow.
- Junctions (used to represent the points of analysis)
- Sources (used to represent available quarry discharge over the period of record)
- Sinks (used to represent the final point of analysis, i.e., SW-A)

Please see Appendix F which shows a model schematic figure of the HEC-HMS model described above.

5.1.1 Meteorological Data

Meteorological data for use in the HEC-HMS model consisted of composite hourly precipitation data collected at the Environment Canada (EC) Ottawa MacDonald Cartier International Airport (ID 6106000) monitoring station from 1950 to 2005 and EC Ottawa CDA RCS (ID 6105978) monitoring station from 2005 to 2022. Potential evaporation (PE) data from the Meteorological Service of Canada (MSC) Thornthwaite water budgets for Ottawa MacDonald Cartier International Airport (ID 6106000) with a period of 1939 – 2021 was also used. HEC-HMS requires hourly precipitation and average monthly PE. Hourly precipitation from EC was used in the HEC-HMS model. The PE rate (mm per month) for each month was obtained by taking average values over the period of record (1950 to 2013) for Scenarios 4, 5, and 8 while PE rates for each month were taken from 2018 to 2021 for Scenario 2. Monthly PE values for each sub-catchment are listed in Appendix F.

Evapotranspiration (ET) refers to water losses from soil surfaces to the atmosphere. The term combines evaporation (i.e., water lost from the soil surface) and transpiration (i.e., water lost from plants and trees) because of the difficulties involved in separating these processes. PE refers to the loss of water from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of evapotranspiration is typically less than the potential rate under dry conditions (e.g., during the summer months when there is a soil moisture deficit).



5.1.2 Canopy Interception

The Simple Canopy Method was used to calculate canopy interception. Inputs to the Simple Canopy Method include initial storage (%) and maximum storage (mm) within the canopy. For all sub-catchments, initial storage was set to zero, while maximum storage values were prorated based on land uses percentages in each sub-catchment using an assumed maximum storage value of 1 mm to represent the canopy within the forested and wetland areas, based on a typical range of 0.5 to 2 mm (Shuttleworth, 1989). Canopy storage values for each sub-catchment are listed in Appendix F.

5.1.3 Surface Depression Storage

The Simple Surface Method was used to calculate depression storage. Inputs to the Simple Surface Method include initial storage (%) and maximum storage (mm) on the surface. Initial storage was set to zero for all subbasins. Maximum storage was based on land use impervious percentages assuming a depression storage on impervious areas would equal 2 mm while natural land types would fall between 5-10 mm (depending on slope). Maximum storage values were then prorated based on percentage of wetland and impervious area. Storage values for each sub-catchment are listed in Appendix F.

5.1.4 Infiltration

The Soil Moisture Accounting Method was used to model infiltration losses. The Soil Moisture Accounting Method represents the movement of water through and the storage of water in three layers: the soil layer, and upper and lower groundwater layers. This method is well suited for continuous simulation including both wet and dry conditions.

Inputs to the Soil Moisture Accounting Method are listed in Appendix F and are based on surficial geology mapping for the sub-basins (Belanger, 2008), as seen in Figure 2.

5.1.5 Groundwater Inflows (Baseflow)

The Constant Monthly Method was used to represent baseflow. This method utilizes simulated groundwater discharge estimates assuming a vertical hydraulic conductivity of 2x10⁻⁶ m/s for overburden and bedrock and a groundwater recharge rate of 150 mm/yr. Groundwater inflow to existing quarries with effluent discharge records (i.e., Stittsville Quarry) were omitted from the model as the discharge records would include any contribution from groundwater inflow. Other existing quarries within the model (i.e., Bell Quarry) considered the contribution from groundwater discharge estimates in place of available effluent discharge records. Baseflow estimates for each sub-catchment are listed in Appendix F.

5.1.6 Runoff Transform

The Soil Conservation Service (SCS) Unit Hydrograph was used to transform excess precipitation to runoff. This is a parametric unit hydrograph based upon averages of unit hydrographs derived from gauged rainfall and runoff for a large number of small agricultural watersheds (Feldman, 2000). Lag time was assumed to be 0.6 of the time of concentration, which was calculated according to the velocity method, for each sub-catchment, as the sum of estimated travel times for sheet flow, shallow flow and channel flow (NRCS, 2010). Times of concentration and lag times for each sub-catchment are listed in Appendix F.

5.2 Hydrologic Model Validation

The baseline hydrologic model flows were validated at two separate locations (i.e., Junction 1 and Junction 4) from 2018 – 2019 due to the sparse observed data record at Junction 1 during 2020 to 2022. Continuous flow data recorded over this period at Junction 1 was either missing a substantial portion of the year or showed several



gaps between months. The methods and assumptions for the validation process for both locations are detailed in the sections below.

5.2.1 Hydrologic Model Assumptions

The following assumptions were utilized in the calibration of the hydrological model.

- The western wetland was modelled as a sub-basin with a reservoir. While the sub-basin would direct outflow into the reservoir, the reservoir would direct its outflow towards Junction 1 utilizing the rating curve developed for Junction 1, which was also utilized in the flow hydrograph for Junction 1 as seen in Figure 32. The storage capacity and outflow curve in the wetland was adjusted for verification purposes. The remaining wetland areas were also modelled as sub-basins with reservoirs. Similar to above, the reservoirs would outlet to the downstream junction, however, for these reservoirs, a storage-discharge relationship via a culvert outlet was created to model the outflow.
- For verification purposes for Junction 1, baseflow contributions from Sub-catchments 1C and 5C were
 omitted to avoid double counting, as it was assumed that any baseflow or infiltration within those subcatchments would be recirculated back into the existing Stittsville or Bell Quarries. The annual discharge
 from the quarries, would include any baseflow or recirculated infiltration contributions to these subcatchments.
- Discharge flow contributions from the existing and fully operational Bell Quarry to SS-3 were considered
 in Scenarios 2, 4, and 5 of the HEC-HMS models, respectively, through a simplified surplus estimation
 using a water budget for the quarry footprint. A Water Holding Capacity (WHC) of 10 mm was assumed
 for the quarry footprints under both scenarios. The annual surplus was then used to estimate an average
 annual discharge rate that would act as the existing and proposed pumping rates for the Bell Quarry in
 the HEC-HMS models.

5.2.2 Hydrologic Model Verification – Junction 1

Hydrologic flows at Junction 1 were validated against the continuous flow data captured by the MACE flowmeter from 2018 - 2019. Based on these flow records, the simulated model flow output was adjusted through the manipulation of wetland storage capacities and outflows (i.e., using the reservoir functions). The results of the verifications for Junction 1 are shown in Table 16 below:

Table 16: Verification of Continuous Stream Flow Measurements – Junction 1 (Average Annual Flow)

Flows at Junction 1	Available Period of Flow Data			
Flows at Juliction 1	2018	2019	Total Period	
Average Annual Observed Flow (m³/s)	0.0055	0.0088	0.0074	
Average Annual Simulated Flow (m³/s)	0.0062	0.0081	0.0073	
% Difference from Observed	12%	-8%	-2%	

As seen in Table 16 above, the average annual simulated flows were within +/-12% of the average annual observed flows at Junction 1 and were within +/- 2% of the average annual observed flows across the entire period. Overall, the discrepancy in average annual flows seen in Table 16 can be partially attributed to the placement of the MACE flowmeter within the culvert as discussed above in Section 3.3.3. For calibration purposes, zero and negative flows captured by the flow meter were omitted from the average annual observed



and modelled flow estimates detailed above as there was little confidence in the MACE flowmeters' ability to properly estimate low flows through the culvert.

5.2.3 Hydrologic Model Verification – Junction 4

Hydrologic flows at Junction 4 were verified against a combination of catchment-area-prorated average monthly flows captured downstream at the WSC flow gauge "Jock River Near Richmond (ID: 02LA007)" between 2018 – 2019 as well as average monthly flow estimates from water balance calculations across the 13 sub-catchments including Bell Quarry. This method of verification differs from the Junction 1 verification method detailed above due to the availability and credibility of the manual flow measurements at Junction 4 from 2020 – 2022. As detailed in Table 9 in Section 3.3.3, the manual flow measurements for Junction 4 (SW-A) vary greatly in value over a two-year period and could likely be impacted by beaver activity in the area. Due to this, it is determined that the water balance estimates and proration from the WSC gauge would be more representative of average monthly and annual surplus contributing downstream to the Goulbourn Wetland Complex. The methodology used for the water balance and WSC gauge proration estimates are detailed in the sections below.

5.2.3.1 Water Balance Methodology

5.2.3.1.1 Meteorological Data

A water balance assessment related to the 13 sub-catchments with consideration of the Bell Quarry flow input under existing conditions was carried out to characterize the average monthly surplus estimates contributing downstream to Junction 4. The water balance assessment was based on meteorological data from the EC Thornthwaite water budgets (Environment Canada Ottawa MacDonald Cartier International Airport (ID 6106000) between 2018 and 2019), watershed boundaries, land use data, and the existing soil types.

The Thornthwaite method describes water flux in a unit area of soil on a monthly basis based on a balance of precipitation (rainfall and snowmelt), evapotranspiration (ET), soil storage, and surplus.

The water budget can be summarized as follows:

$$P = S + ET + R + I$$

Where: P = precipitation;

S = change in soil water storage;

ET = evapotranspiration;

R = surface runoff; and,

I = infiltration (infiltration below the root zone and available for groundwater recharge).

The various water budget components associated with catchment areas are typically presented in millimetres (mm) per time step over their respective sub-catchments and represent the amount of water per unit of watershed area.

The water budget model combines accumulated rainfall and snowmelt to estimate total precipitation. Rainfall represents precipitation when monthly mean temperatures are greater than 0° C. Snowmelt is initiated when snow is on the ground and monthly mean temperatures are greater than 0° C. Hence, snowmelt is based on the depletion of snow storage (accumulated precipitation during periods of sub-zero temperatures). Composite precipitation data collected at the Ottawa MacDonald Cartier International Airport meteorological station (2018 to 2019) indicated a mean annual precipitation (P) of 947 mm/y.



The potential or maximum ET is estimated, in this case, by the empirical Thornthwaite equation (using average monthly temperature and hours of daylight) and represents the amount of water that would be evaporated or transpired under saturated soil-water scenarios. The actual ET is the total evapotranspiration for the period of study based on evapotranspiration demand, available soil-water storage, and the rate at which soil water is drawn from the ground (as defined by an established drying curve specific to the soil type). Wintertime sublimation was assumed to approach zero in all evaluated scenarios. As this assumption was applied to all scenarios, it is not expected to significantly affect the presented effects assessment, which is based on comparison of the scenarios. The mean annual potential ET for the site is approximately 608 mm/y based on data provided by EC.

Annual water surplus is the difference between P and the actual ET assuming year to year changes in soil moisture storage are negligible. The water surplus represents the total amount of water available for either surface runoff (R) or groundwater infiltration (I) on an annual basis. On a monthly basis, surplus water remains after actual evapotranspiration has been removed from the sum of rainfall and snowmelt, and maximum soil or snowpack storage is exceeded. Maximum soil storage is quantified using a WHC specific to the soil type and land use. WHC is defined as the difference in soil moisture content between the field capacity and wilting point and is assigned across the site based on soil type and vegetation cover.

5.2.3.1.2 Water Balance Parameters

Soils within the 13 sub-catchment areas consist primarily of bedrock or organic deposits with sections of fine sandy loam present within sub-catchment 7. Land uses were separated out based on differing soil classifications based available surficial geology mapping. The maximum soil storage is quantified using a WHC that is based on guidelines provided in Table 3.1 of the MECP Stormwater Management Planning and Design Manual (MECP, 2003; MECP SWM Manual).

The water balance analyses were developed under the following assumptions:

- WHCs were chosen based on Table 3.1 in the MECP SWM Manual (2003) corresponding to the specific soil types and existing land uses for the 13 sub-catchment area water balances.
 - Forested Area (Mature Forest): 100 mm WHC on bedrock, 250 mm WHC on fine sandy loam, and 400 mm WHC on organic deposits.
 - Meadow / Grasslands (Pasture and Shrubs): 100 mm WHC on bedrock or fine sandy loam and 250 mm WHC on organic deposits.
 - Quarry Extraction Area / Stripped Areas (Dewatered Quarry / Operational Areas): 10 mm WHC (utilized for Bell Quarry and sections of overlapping quarry area on other sub-catchments while the existing Stittsville Quarry surplus was estimated using available effluent discharge records).
 - Exposed Sand / Gravel Deposits (Bare Area): 75 mm WHC on bedrock and 100 mm WHC on fine sandy loam.
 - Wetlands (Swamp Area): 100 mm WHC on bedrock and 150 mm WHC on fine sandy loam or organic deposits.
 - Impervious Built-Up Areas (i.e., compacted operational roadways and buildings): 3 mm WHC on all soil types.
- Net surplus was estimated by multiplying the estimated monthly surplus (mm/month) for the assumed WHC by the associated drainage area. Annual evapotranspiration and surplus values were obtained from the



meteorological data from the Ottawa MacDonald Cartier International Airport EC Meteorological Station based on the WHC assigned to each land use area.

Runoff was calculated as the difference between surplus and infiltration.

The results of the water balance surplus estimations for the 13 sub-catchments and Bell Quarry under existing conditions are provided in Appendix G.

5.2.3.2 WSC Gauge Proration Methodology

To perform a comparative analysis of the simulated HEC-HMS model flow outputs to the WSC "Jock River Near Richmond" flow gauge, daily average flows from 2018 – 2019 were prorated to match catchment size at the downstream point of analysis (Junction 4). A summary of the catchment areas at each location are provided in Table 17 below. Prorated average monthly flows for Junction 4 are detailed in the section below.

Table 17: Summary of Catchment Areas for Each Flow Location

Flow Locations	Catchment Areas (km²)
"Jock River Near Richmond" Flow Gauge ¹	526
Downstream Point of Analysis (Junction 4) ²	5.65

Note:

5.2.3.3 Junction 4 Calibration Results

Similar to the Junction 1 calibration method, the simulated model flow output was calibrated through the manipulation of wetland storage capacities and outflows (i.e., using the reservoir functions) as well as reestimating baseflow contributions to account for recirculating infiltration. The results of this calibration on a monthly basis are shown in Table 18 below.

Table 18: Calibration of Prorated WSC Flow Gauge Data and Water Balance Surplus Estimates – Junction 4

	Average Monthly Surplus -	Average Monthly Surplus -	Average Monthly Surplus -
	HEC-HMS Model	Water Balance	Jock River
	(m³/s)	(m³/s)	(m³/s)
Surplus Flow	0.093	0.097	0.084

As seen in Table 18 above, the average annual simulated flow was estimated to be 0.093 m³/s which is within +/-5% of the water balance surplus flow estimate (i.e., 0.097 m³/s) and +/-9% of the Jock River flow proration estimate (i.e., 0.084 m³/s).



⁽¹⁾ The catchment area was taken from the total drainage area provided within the summary of the WSC flow gauge.

⁽²⁾ The catchment area is the total drainage area of the 13 sub-catchments.

These results from the verification exercises for Junctions 1 and 4 are within an acceptable range for existing predevelopment conditions. Therefore, the parameters manipulated in the calibration exercise were applied to predict total discharge to the point of interest under the modelled baseline, operational, and rehabilitation conditions.

6.0 HYDROLOGIC MODEL RESULTS

The hydrologic model assesses the differences in total discharge for Existing Conditions at Full Development (Scenario 4), Operational Condition (Scenario 5), and the Rehabilitated Condition (Scenario 8) models of the proposed Stittsville 2 Quarry. The area of study for the analysis focuses on the drainage area reporting to the points of analysis, which correspond to Junction 4.

A summary of the estimated average annual discharge at the point of analysis is included in the following table. The average annual discharge was developed from the results of the daily hydrologic model.

Table 19: Estimated Average Annual Discharge in Flowing Creek (m³/year) at Fernbank Road (Junction 4)

	Junction 4 – Goulbourn Wetland Complex at Fernbank Road		
Scenario	Estimated Average Annual Surface Water Volume ¹ (m³/yr)	Change from Existing Condition Scenario 4 (%)	
Existing Conditions at Full Development (Scenario 4)	2,836,915	-	
All Quarries at Full Development (Scenario 5)	3,119,911	+10%	
All Quarries at Full Rehabilitation (Scenario 8)	2,164,146	-24%	

Notes: 1 - Corresponding to estimated average annual amounts for the 626 ha draining to Junction 4 in these scenarios

Based on the cumulative effect of all the quarries together (i.e., Scenario 5), the estimated discharge at the point of analysis on Fernbank Road (Junction 4) is expected to increase by approximately 283,000 m³/year (or 10%) over Existing Conditions at Full Development (Scenario 4).

Under Rehabilitated Conditions (Scenario 8 – All quarries at full rehabilitation including the proposed Stittsville 2 Quarry), the estimated cumulative discharge will decrease by approximately 673,000 m³/yr (or 24%) as compared to Existing Conditions at Full Development (Scenario 4 - All quarries at full development excluding the proposed Stittsville 2 Quarry). The effect of the proposed Stittsville 2 Quarry alone on average annual discharge at Junction 4 under rehabilitated conditions represents a decrease of approximately <1% as compared to existing conditions (Scenario 4).

The increase and subsequent decrease in estimated average annual surface water volume (see Table 19) in large part, is the result of changes in the amount of groundwater captured in the quarry excavations and discharged to surface in the existing condition (as compared to rehabilitation) with some changes in evaporative losses.

7.0 IMPACT ASSESSMENT

This section provides an analysis of the data in the context of the potential water resources impacts associated with the development of the proposed Stittsville 2 Quarry. The development of the proposed Stittsville 2 Quarry can affect potential receptors mainly via land use changes, surface water drainage alterations (mainly catchment area changes as the drainage features themselves will not be altered), quarry water management (e.g., quarry



dewatering) and the area of groundwater level drawdown ("drawdown cone") and residual groundwater level drawdown.

Ecological implications of the development of the proposed Stittsville 2 Quarry are discussed in the Natural Environment Report (WSP, 2023).

7.1 Groundwater Impact Assessment

7.1.1 Groundwater Receptors

Water supplies in the area surrounding the quarry are typically obtained from the limestone bedrock. Based on WSP's experience in the area, and the data in the Ministry of the Environment, Conservation and Parks (MECP) Water Well Information System (WWIS), a limited number of water supply wells are located near the licensed extraction area.

The primary hydrogeological concern with respect to nearest water supply wells is the development of the groundwater drawdown cone that is associated with quarry dewatering, and the potential for drawdown to cause an interruption of the water supply at nearby homes as a result of the lowering of water levels in the water supply wells and/or to reduce the groundwater contribution to local surface water features and wetlands.

There are many licensed aggregate quarries in the area of the Stittsville Quarry. As illustrated by the modelling results in Section 4.3, the predicted drawdown (from existing conditions) from the Stittsville Quarry and the proposed Stittsville 2 Quarry combined (refer to Figure 40) or the drawdown associated with the proposed Stittsville 2 Quarry with all of the nearby licensed quarries (refer to Figure 43) is similar. Thus, the potential impacts to groundwater users from the proposed Stittsville 2 Quarry (combined with the existing Stittsville Quarry) will be similar with or without the contributions of the other licensed guarries in the area.

There are a total of 42 water supply wells listed in the MECP WWIS, with a known location of within 300 metres or less, that fall within the predicted zone of influence in the TZ due to quarry dewatering at the combined Stittsville and the Stittsville 2 Quarries (refer to Figure 51). Appendix H provides the details from the WWIS for the wells identified within the predicted zone of influence in the TZ (based on the one metre drawdown contour).

The depths of the wells range from 9.1 to 200.9 metres and static water levels range from 0.6 to 23.5 metres below ground surface (where static water levels are available in the WWIS). Total available drawdown in the wells range from 6.1 to 171.3 metres (where data is available for calculation in WWIS) based on the difference between the recorded static water level and the deepest water found elevation. It is noted that a minor reduction in available drawdown in a local supply well does not necessarily result in a negative impact on the well user as the minor reduction may not be perceptible to the user.

Of the 42 wells identified within the predicted radius of influence in the TZ, seven have a predicted drawdown of 20% or greater of the available drawdown. When examining the historical air photos at the locations of these wells (1502597, 1502824, 1502939, 1511033, 7132600, 7132601 and 7314134), the following comments regarding the status of the wells can be made.



Table 20: Status of Water Supply Wells

Well ID	Date Drilled	Observations regarding water well use
1502597	1950	Based on historical air photos, no building or development has been present nearby the well location since 1976. The well is likely no longer in use.
1502824	1960	Based on historical air photos, there may have been a structure in close proximity to where the well is located (1976). The structure is no longer present as of 1999. The well is likely no longer in use.
1502939	1964	The well was originally drilled for use as a water supply for a trailer. Based on historical air photos, no structure was present in the area of the well in 1976 however a house was built on the lot in the intervening time between 1976 and 1991. The well may be in use by the existing house.
1511033	1971	Based on historical air photos, no building or development has been present nearby the well location since 1976. The well plots on a wetland area and the street name on the well record does not match up with current or historical street names. The well likely does not exist at the location, or if it does it is likely no longer in use.
7132600	2009	The well is located on the proposed Stittsville 2 Quarry site and is used as a water supply for the concrete plant
7132601	2009	The well is located on the proposed Stittsville 2 Quarry site and is used as a water supply for the concrete plant
7314134	2018	The well is likely in use by the commercial building present on the property.

Of the wells that are likely still in use, two of them (1502939 and 7132601) are completed above the TZ and, as such, the predicted drawdown in the TZ is greater than what would be predicted for the actual depth of the well (less than 0.5 metres of drawdown at each well location). Wells 7132600 and 7132601 are both owned and operated by Tomlinson for use as a water supply at their on-site concrete plant. Should issues arise with these wells, Tomlinson will seek other sources of water supply (i.e., deeper wells).

The remaining well, 7314134, predicts 8.7 metres of drawdown from an available drawdown of 36.7 metres (24%). In all likelihood, the well owner would not perceive the reduction in available drawdown in the well. The well plots in the property adjacent to the proposed Stittsville 2 Quarry where a commercial building is currently located. Monitoring well (BH18-17) exists in close proximity to this water well and monitoring well BH18-17A is screened at approximately the same depth as the bottom of the private well. The results of monitoring data from monitoring well BH18-17A can be used to determine if dewatering from the proposed Stittsville 2 Quarry could impact the well.

7.1.2 Potential for Impacts to Local Surface Water Features

This section discusses the potential of groundwater level (water table) drawdown in the upper weathered bedrock during the operational period and the associated potential to underdrain and thus affect local surface water features and wetlands. The nearest significant surface water feature to the proposed Stittsville 2 Quarry is the western wetland, the southern wetland and Goulbourn Wetland Complex. It should be noted that the western wetland and the southern wetland are both within the proposed excavation area of the proposed Stittsville 2 Quarry and, as such, will be removed during operations.



As it relates to the ongoing development of the Stittsville Quarry, comprehensive, multi-disciplinary surface water, groundwater and biological monitoring programs have been ongoing at the quarry properties for many years for the purpose of assessing the potential effects of quarry development on the various surface water features. These monitoring programs are stipulated on the PTTW and the ECA (industrial sewage works) for the Stittsville Quarry and compliance reports are prepared and submitted to the MECP on an annual basis. To date, no negative impacts to the surface water features have been observed.

With the addition of the proposed Stittsville 2 Quarry, numerical modelling (refer to Section 4.3 and Figure 43) indicates that there will be limited additional drawdown in the upper weathered bedrock beneath the Goulbourn Wetland Complex (based on the one-metre outer drawdown contour) beyond that which would be experienced by the existing operational quarries under current conditions. That being said, a decrease in the groundwater flow to the Goulbourn Wetland Complex has been predicted. Under full development of the Stittsville Quarry and the proposed Stittsville 2 Quarry, while the other quarries remain in the existing (2021) level of development (Scenario 3), a reduction in groundwater inflow to the Goulbourn Wetland Complex of approximately 8% as compared to existing conditions is predicted. Development of the proposed Stittsville 2 Quarry with all other quarries fully developed (Scenario 5) results in a 6% (710 m³/day) decrease in groundwater inflow to the Goulbourn Wetland Complex compared to the full development of the currently licensed quarries (Scenario 4). It is anticipated that the increased volume being pumped to the Goulbourn Wetland Complex will compensate for the reduction in groundwater inflow to the Goulbourn Wetland Complex. Water level data collected in the wetland pocket to date does not indicate any reduction in water levels over time as the existing Stittsville Quarry developed.

The results of groundwater level monitoring over time indicates that there is hydraulic separation between the shallow and deeper bedrock. This lower permeability layer will serve to slow down the infiltration of water from the wetland to the underlying bedrock. As such, based on the results of the groundwater and surface water monitoring data collected at the site, the following conclusions are presented with respect to the potential effects of groundwater level (water table) drawdown in the upper weathered bedrock on the Goulbourn Wetland Complex during the operational period of the proposed Stittsville 2 Quarry:

- During the operational period for the proposed Stittsville 2 Quarry, there will be limited additional drawdown in the upper weathered bedrock beneath the Goulbourn Wetland Complex (based on the one metre outer drawdown contour) beyond that which would be experienced by the existing operational quarries under current conditions.
- The results of monitoring data collected to date indicate that groundwater level drawdown within the upper weathered bedrock is not expected to induce significant downward movement of groundwater ("under draining") from the wetland/overburden that would have the potential to cause a negative impact to the Goulbourn Wetland Complex.
- Given that the quarry sump water will continue to be discharged to the Goulbourn Wetland Complex during the operational period for the Stittsville and Stittsville 2 Quarries, any potential effects associated with the propagation of the drawdown cone beneath the Goulbourn Wetland Complex during the operational period would be mitigated. In fact, as discussed in Section 6.0, an increase in the average annual flow volume in the receiving drainage features is predicted during the operational period.

7.1.3 Source Water Protection

The proposed Stittsville 2 Quarry falls outside of the mapped Wellhead Protection Areas (A through D) within the Mississippi-Rideau Source Protection Region protection plans. Impacts to groundwater quality or quantity at the



water supply wells, where Wellhead Protection Areas have been established, as a result of the proposed development of the proposed Stittsville 2 Quarry are not predicted.

The site lies within a Highly Vulnerable Aquifer due to the thin layer of overburden that currently exists in the area. No Significant Groundwater Recharge Areas have been identified on the site. The status of the Highly Vulnerable Aquifer will remain unchanged following the addition of the proposed quarry.

7.2 Surface Water Features

7.2.1 Surface Water Receptors

The main surface water receptor of concern is the Goulbourn Wetland Complex located along the east quarry boundary (Figure 1). This feature is mainly of concern for its ecological function.

The primary concerns with respect to the wetlands are the surface water drainage alterations (mainly catchment area changes as the drainage features themselves will not be altered), quarry water management (e.g., quarry dewatering) and the propagation of the groundwater level drawdown cone beneath the wetlands as a result of quarry dewatering. These changes could affect the receptor flow regimes (base flow and storm flow/flooding), channel erosion and water quality.

The following sections describe the changes (as compared to the existing quarry development conditions) that are anticipated to occur in the downstream receiving drainage features during the proposed operational and rehabilitated stages of the site.

7.2.2 Average Annual Stream Flow

Under the proposed fully operational conditions (Scenario 5), a reduction in evapotranspiration, increased groundwater input, and a corresponding increase in the amount of surface water runoff collecting within the proposed Stittsville 2 Quarry is expected to occur. During operations, surface water runoff and groundwater inflow will be directed to a quarry sump within the proposed Stittsville 2 Quarry and discharged off-site towards the Goulbourn Wetland Complex (likely via the on-site eastern wetland shown on Figure 1).

The estimated average annual discharge from the proposed Stittsville 2 Quarry would be 1,014,103 m³/year [i.e., the sum of surface water runoff (581,578 m³/year) and groundwater inflow (432,525 m³/year) within the Stittsville 2 Quarry catchment]. Overall, an increase of approximately 10% in average annual total discharge volume through the point of analysis on Fernbank Road within the Goulbourn Wetland Complex (Junction 4) compared to the Existing Conditions at Full Development (Scenario 4) is predicted. It is noted that the overall surplus draining from other catchments decreased under operational conditions due to groundwater drawdown from quarry excavations. This is due to the change in land use across the proposed Stittsville 2 Quarry footprint to represent dewatered quarry floor which will increase overall surplus reporting to the point of analysis. However, these estimates are under an assumption that the outflow from the proposed Stittsville 2 Quarry is unmitigated. It should also be noted that flows estimated for Bell Quarry are under unmitigated conditions as no knowledge of the existing pumping records for Bell Quarry are available for use in this model. Under mitigated operational conditions, the quarry surplus will be collected within the quarry sump and discharged towards the Goulbourn Wetland Complex under an appropriate maximum discharge rate that will be designed with consideration of potential impacts including flow increase. During the rehabilitated stage of the proposed Stittsville 2 Quarry, average annual total discharge at Junction 4 will decrease to within 26% of existing conditions as the site will be rehabilitated to similar grading.



The estimated changes in overall average annual flow volume to the Goulbourn Wetland Complex during the operational phase of the proposed Stittsville 2 Quarry is not predicted to significantly change flows and water levels, which are highly influenced by external factors under mitigated conditions. The incremental surface flow will be diffused in the connecting water bodies and the change in flows are expected to be minimal. Based on calculations and visual observations in the field, it is expected that there will be no change to the form or function of the receiving features in comparison to current conditions.

7.2.3 Water Quality

The proposed Stittsville 2 Quarry will extract aggregate from the same geological units as the existing Stittsville Quarry, and similar operational procedures are expected to be followed. For these reasons, the quality of the quarry effluent from the proposed Stittsville 2 Quarry is expected to be similar to existing Stittsville Quarry effluent. It is expected that the existing Stittsville Quarry effluent monitoring program will be continued under the existing ECA (Industrial Sewage Works) with the addition of the proposed Stittsville 2 Quarry.

The water quality samples collected from the water sampling locations where surface water from the Tomlinson property enters the Goulbourn Wetland Complex and the outlet of the western wetland as part of the ongoing monitoring program under the existing ECA (Industrial Sewage Works) for the site indicate that no parameters exceed the PWQO or CCME guidelines and are similar to background parameter values. While general increases in concentrations of boron, hardness, nitrate, potassium, strontium and sulphate and general decreases in concentrations of chloride and sodium have been observed, only boron has a PWQO which has not exceeded the interim value of 0.2 mg/L. Additionally, only nitrate (550 mg/L for short-term and 13 mg/L for long-term) and boron (15 mg/L for short-term and 29 mg/L for long-term) have CCME objectives. Concentrations of these parameters will continue to be monitored during the operational phase of the proposed Stittsville 2 Quarry.

7.2.4 Hydrological Function and Flooding

As detailed in Section 3.3, the water levels within the Goulbourn Wetland Complex have remained fairly consistent at SG-2 since 2010 and at SG-4 since 2019, noting that SG-4 was moved into the Goulbourn Wetland Complex during 2019 to better characterize the seasonal water levels. Through this time, impacts to water levels within the Goulbourn Wetland Complex were largely correlated with precipitation. Hence, the interception of contributing catchment area and addition of quarry discharge from the proposed Stittsville 2 Quarry would have a minimal impact on overall water levels.

Development of the proposed Stittsville 2 Quarry will result in the removal of approximately 10 ha of existing wetland that is not provincially significant. The hydrological function of these wetland areas, i.e., temporary retention and moderated outflow, will be replaced with the quarry water management system for the quarry. The quarry excavation will intercept precipitation inputs and behave like a large extended detention pond during events. Following runoff events, water will be pumped from the quarry at a controlled rate, as required to maintain dry working conditions, and the quarry will have the ability to temporarily store a significant volume of runoff during large events. Therefore, the peak storm flow rates during large events are expected to be lower during operations than under Existing Conditions (Scenario 2), and the proposed Stittsville 2 Quarry is not expected to negatively contribute to flooding issues within the receiving water features. Storage detention and pumped discharge rates will vary as the quarry is developed and will be governed by the existing ECA or an amended ECA issued by the MECP. As the proposed Stittsville 2 Quarry property will return to similar conditions as seen during existing conditions after rehabilitation, the proposed Stittsville 2 Quarry is not anticipated to contribute to flooding during the rehabilitation period.



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 Stittsville 2 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, a representative of Tomlinson or their agent will visit the site to make an initial assessment within three days of receiving the complaint. This will include a well/system inspection (where accessible) by a licensed pump maintenance contractor to determine the groundwater level, pump depth setting and condition of the well system. The available groundwater level data from the existing onsite 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;



Connect to Existing City of Ottawa Municipal Water Supply – Municipal water is not currently available within
the area of the proposed Stittsville 2 Quarry however, connection to the City water supply could be an option
in the future should well interference occur due to dewatering of the proposed quarry if the municipal water
supply extends to the area;

- Communal Water Supplies In specific situations, the communal water supply option is also available for consideration. The communal well water supply could be developed by tapping water bearing formations beyond the quarry influence along with the installation of water distribution lines to the affected property(ies). The communal well(s) could be developed on Tomlinson property and the distribution system could be placed along public right-of-ways. The water from the communal well(s) could be distributed to plumbing in homes with pipelines. Although communal water supplies are a viable option to address well interference, it is not likely that this would be a practical option for addressing confirmed well interference due to the remote nature of water supply wells in the area; and,
- 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 MONITORING PROGRAM FOR PROPOSED STITTSVILLE 2 QUARRY

If Tomlinson is successful in obtaining a license under the ARA from the MNRF for the proposed Stittsville 2 Quarry, this technical document would be used as supporting documentation to apply to the MECP for an amendment to the existing PTTW for the Stittsville Quarry. This PTTW amendment would be required to recognize the proposed Stittsville 2 Quarry in the impact assessment of the PTTW and to add some existing monitoring wells at the proposed Stittsville 2 Quarry into the monitoring program associated with the PTTW. It is anticipated that any water collecting in the base of the Stittsville Quarry, and the proposed Stittsville 2 Quarry will be collected in the same sump and discharged off-site in accordance with the existing ECA for the Stittsville Quarry. The existing quarry sump dewatering system is presently operated relatively infrequently at about 80 Litres per second which is below the maximum permissible discharge rate of 90 Litres per second. As such, it is envisaged that the management of water collecting within the confines of the proposed Stittsville 2 Quarry excavation could be accommodated (at least during the early stages of the development of the proposed Stittsville 2 Quarry) within the constraints imposed by the existing Stittsville 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 quarry development on the combined quarry properties, 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 Stittsville Quarry be continued during the development of the proposed Stittsville 2 Quarry.

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



Table 21: Existing Stittsville Quarry Permit to Take Water Monitoring Program

Groundwater Level Monitoring

Monthly groundwater level monitoring (during operational periods) in monitoring wells BH99-1, BH99-3A, BH99-3B, BH99-3C, BH99-3D, BH03-9A, BH03-9B, BH03-9C, BH13-16A, BH13-16B, BH13-16C, BH13-16D, BH18-17A, BH18-17B, BH18-17C and BH18-17D and monitoring wells BH05-13A, BH05-13B, BH15-13C located on the Tomlinson Moore Quarry Property. Monitoring frequency reverts to quarterly during non-operational periods at the Stittsville Quarry.

Groundwater Quality Monitoring

- Annual groundwater quality sampling at the "Spruce Ridge Residence".
- Groundwater quality samples shall be analysed for alkalinity, aluminum, ammonia, barium, beryllium, boron, chemical oxygen demand (COD), chloride, cadmium, chromium, cobalt, conductivity (field), copper, dissolved organic carbon (DOC), hardness (calcium and magnesium), iron, lead, manganese, molybdenum, nickel, nitrate, nitrite, pH (field), potassium, silver, sodium, strontium, sulphate, temperature (field), thallium, titanium, total dissolved solids (TDS), total Kjeldahl nitrogen (TKN), total phosphorus, total suspended solids (TSS), vanadium and zinc.

Surface Water Level Monitoring

Monthly staff gauge and continuous surface water level measurements (during ice-free conditions) at SG-1 and SG-4.

Surface Water Flow Monitoring

Measurement of the water flow downstream of the outlet of the western wetland (at the culvert beneath the on-site road) by measuring water levels upstream of the culvert inlet on a daily basis during ice-free conditions and converting to daily discharge flows using calculations based on the culvert dimensions.

Table 22: Existing Stittsville Quarry Environmental Compliance Approval (Industrial Sewage Works) Monitoring Program

Surface Water Quality Monitoring

- Monthly surface water quality sampling during periods of effluent discharge at stations SS-1, SS-3, SS-4, SS-5, SS-6 and SS-8.
- Surface water quality samples are analysed for alkalinity, ammonia, barium, biochemical oxygen demand, boron, chloride, chromium, chromium III, hexavalent chromium, cobalt, chemical oxygen demand, copper, dissolved organic carbon, hardness (calcium and magnesium), iron, manganese, potassium, silicon, silver, sodium, strontium, sulphur, thallium, mercury, nitrate, nitrite, sulphate, total dissolved solids, total suspended solids, total Kjeldahl nitrogen and total phosphorus.



Surface Water Level Monitoring

Monthly staff gauge and continuous surface water level measurements (during ice-free conditions) at SG-1.

Monthly staff gauge measurements (during ice-free conditions) at SG-2.

It is proposed that the groundwater and surface water monitoring programs continue as described in Tables 21 and 22, 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 23: Proposed Additional Monitoring Program

Groundwater Level Monitoring

- Monthly groundwater level monitoring (during operational periods) in monitoring wells BH05-10A, BH05-10B, BH05-10C, BH05-11, BH05-12A*, BH05-12B*, BH05-12C*, SQAT20-25, SQAT20-26, SQAT20-27 and SQAT20-29. Monitoring frequency reverts to quarterly during non-operational periods at the Stittsville and Stittsville 2 Quarries.
- Note: * Monitoring wells installed in BH05-12 should either be repaired or replaced prior to operations commencing at the Stittsville 2 Quarry.

Surface Water Level Monitoring

- Monthly staff gauge and continuous surface water level measurements (during ice-free conditions) at a background station upstream of the proposed quarry discharge for Stittsville 2 Quarry (i.e., SS-8), at the convergence of the proposed quarry discharge and the Goulbourn Wetland Complex (e.g. SS-6 but subject to changes during operational conditions), at the rail trail (i.e., SS-3), and at Fernbank Road (i.e., SW-A).
- Water quality sampling at the above locations, as required by the ECA.

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.

It is expected that an annual performance report will continue to be a requirement of an amended 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 operations on the combined quarry properties (i.e., proposed Stittsville 2 Quarry and Stittsville Quarry) are 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 licensing application process) that relate to the monitoring of the groundwater and surface water would be considered in the context of preparing the future monitoring program that takes into account the proposed development of the Stittsville 2 Quarry.



10.0 SUMMARY AND CONCLUSIONS

Tomlinson operates a number of pits and limestone quarries in the Ottawa area. The materials are used in the Ottawa area for road construction and in site preparation for commercial and residential developments. As part of the long-term business plan in the Ottawa area, Tomlinson wishes to license, under the *Aggregate Resource Act* (ARA), a property adjacent to the existing licensed Tomlinson Stittsville Quarry in order to supply the western end of Ottawa with aggregate products into the future.

WSP was retained by Tomlinson to complete the necessary hydrogeological and hydrological studies to support an application under the ARA and the *Planning Act*. This report presents the combined results of the hydrogeological and hydrological studies completed in support of a site plan license application for a Class 'A' license for a quarry below the ground water table, under Ontario Regulation 244/97 under the ARA. These studies were conducted for the purpose of addressing the requirements for the Level 1 and Level 2 Water Report studies as described in "Aggregate Resources of Ontario: Technical reports and information standards", dated August 2020.

The results of the ecological studies are presented in a separate Natural Environment Report (WSP, 2023).

The proposed Stittsville 2 Quarry is located in the Geographic Township of Goulbourn in the City of Ottawa, Ontario. The proposed quarry property is located in Lots 15 and 16, Concession XI. The proposed extraction area covers an area of approximately 108 ha. The property is bounded by Jinkinson Road and the existing Tomlinson Stittsville Quarry to the north, the Goulbourn Wetland Complex to the east, the Trans-Canada Trail to the south and the Lafarge Bell Quarry property to the west. Access to the site is currently from Jinkinson Road. The proposed Stittsville 2 Quarry will be developed in three lifts. The final quarry floor for the proposed Stittsville 2 Quarry will slope from approximately 123 metres asl in the southwest to 101 metres asl in the northeast which generally follows the contact between the Bobcaygeon Formation and Gull River Formation. The base of the quarry excavation is below the average position of the groundwater table.

A number of licensed aggregate quarries also exist in the area. Three properties, the Lafarge Bell Quarry, the Tomlinson Stittsville Quarry and the Cavanagh Henderson Quarry are located to the west side of the site. The Taggart Fernbank Quarry and Cavanagh Beagle Club Quarry are located to the south of the site. The Tomlinson Moore Quarry is located to the northwest of the proposed Stittsville 2 Quarry across Highway 7.

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

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

The work program consisted of the following:

- Data review and compilation;
- Receptor identification;
- Bedrock percussion drilling program;
- Borehole geophysical investigation program;



- Groundwater level, surface water level and surface water flow monitoring programs; and,
- Groundwater and surface water flow modelling and impact assessment.

The on-site hydrogeological and hydrological data for the proposed Stittsville 2 Quarry were supplemented by the existing available data associated with the Stittsville Quarry. These data were used to develop the conceptual model for the proposed Stittsville 2 Quarry property.

A regional numerical groundwater model was developed to estimate the groundwater level drawdown associated with operations at the proposed Stittsville 2 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 hydrologic model was prepared as part of an impact assessment under the operational and rehabilitated conditions for the key receptors that receive discharge from the proposed quarry site, including the Goulbourn Wetland Complex at Fernbank Road.

A number of model scenarios were developed to assess additional drawdown associated with operational and rehabilitated conditions at the proposed Stittsville 2 Quarry as compared to the already licensed quarries in the immediate area. The scenarios included:

- Scenario 1 Pre-quarry Conditions (Calibration Run) no quarry development in the study area.
- Scenario 2 Existing Conditions (Calibration Run) Bell Quarry, Henderson Quarry, Stittsville Quarry, Beagle Club Quarry and Fernbank Quarry at existing conditions (as of 2021).
- Scenario 3 Stittsville Quarry and Proposed Stittsville 2 Quarry at Full Development Stittsville Quarry and proposed Stittsville 2 Quarry fully extracted and dewatered with remaining quarries at existing (2021) level of development.
- Scenario 4 Existing Quarries Full Development All licensed quarries fully extracted and dewatered with the proposed Stittsville 2 Quarry remaining at existing (undeveloped) conditions.
- Scenario 5 All Quarries at Full Development All licensed quarries fully extracted and dewatered including the proposed Stittsville 2 Quarry.
- Scenario 6 Stittsville Quarry and Proposed Stittsville 2 Quarry at Full Rehabilitation Stittsville Quarry and proposed Stittsville 2 Quarry fully developed and rehabilitated with remaining quarries at existing (2021) level of development.
- Scenario 7 Existing Quarries at Full Rehabilitation All licensed quarries fully developed and rehabilitated with the proposed Stittsville 2 Quarry remaining at existing (undeveloped) conditions.
- Scenario 8 All Quarries at Full Rehabilitation All licensed quarries fully developed and rehabilitated including the proposed Stittsville 2 Quarry.

The development of the proposed Stittsville 2 Quarry can affect potential receptors mainly via land use changes, surface water drainage alterations (mainly catchment area changes as the drainage features themselves will not be altered), quarry water management (e.g., quarry dewatering) and the area of groundwater level drawdown ("drawdown cone") and residual groundwater level drawdown.



The primary hydrogeological concern with respect to nearest water supply wells is the development of the groundwater drawdown cone that is associated with quarry dewatering, and the potential for drawdown to cause an interruption of the water supply at nearby homes as a result of the lowering of water levels in the water supply wells and/or to reduce the groundwater contribution to local surface water features and wetlands. The main surface water receptor of concern is the Goulbourn Wetland Complex located along the east property boundary of the proposed Stittsville 2 Quarry.

The potential impacts of the operational phase of the quarry life were assessed separately from the rehabilitated conditions.

Operational Period

Based on the results of the impact assessment, the following can be concluded during operational conditions:

- Forty-two (42) private wells are located within the area where at least one-metre of additional drawdown due to the operation of the proposed Stittsville 2 Quarry is expected (refer to Figure 51). It is noted that a minor reduction in available drawdown in a local supply well does not necessarily result in a negative impact on the well user as the minor reduction may not be perceptible to the user. Of those wells, seven have a predicted drawdown (in the TZ) of 20% or greater of the available drawdown in the wells. Two of the identified wells are likely no longer in use and two of the identified wells are used by Tomlinson for the water requirements associated with their concrete plant. Two of the wells are completed above the TZ and, as such, the predicted drawdown in the TZ is greater than what would be predicted for the actual depth of the well (less than 0.5 metres of drawdown at each well location).
- The remaining well has a predicted decrease in total available drawdown of 24%. In all likelihood, the well owner would not perceive the reduction in available drawdown in the well. In the event that the groundwater level monitoring program indicates that there is a potential for the progressive development of the proposed Stittsville 2 Quarry to adversely interfere with water supply wells in the local area, a complaints response program has been developed for the site that outlines a number of mitigative actions that can be undertaken (Section 8.0).
- As the extent of additional groundwater drawdown in the shallow bedrock due to the proposed Stittsville 2 Quarry is limited off of the site, impacts to the identified surface water features are not anticipated during the operational stage of the proposed Stittsville Quarry.
- During the Full Development of all Quarries including proposed Stittsville 2 Quarry (Scenario 5), an increase of approximately 10% in average annual total discharge volume at the point of analysis on Fernbank Road at the Goulbourn Wetland Complex (SW-A) is anticipated compared to Existing Conditions at Full Development (Scenario 4). This is due to the decrease in evapotranspiration from land use changes within the quarry as well as the quarry dewatering limiting any potential evaporation of pooled water before discharging to the point of analysis.
- The estimated changes in overall average annual flow volume to the Goulbourn Wetland Complex during the operational phase of the proposed Stittsville 2 Quarry is not predicted to significantly change flows and water levels, which are highly influenced by external factors. The incremental surface flow will be diffused in the connecting water bodies and the change in flows are expected to be minimal. Based on calculations and visual observations in the field, it is expected that there will be no change to the form or function of the receiving features in comparison to current conditions.



While this site is operational, the proposed Stittsville 2 Quarry excavation will act as a large extended detention pond during storms due to the collection of water in the excavation. Therefore, the peak storm flow rates during large events are expected to be lower during operations than under Existing Conditions (Scenario 2), and the proposed Stittsville 2 Quarry is not expected to negatively contribute to flooding issues within the receiving water feature.

In summary, it is not expected that the development of the proposed Stittsville 2 Quarry will have a negative impact on surface water or groundwater receptors during the operational period, and it is not expected that the implementation of mitigation measures will be required during the operational period. During the operational period, it is anticipated that a monitoring program will be implemented for the purpose of verifying that the operation of the proposed Stittsville 2 Quarry does not adversely impact surface water or groundwater receptors.

Rehabilitated Conditions

Based on the results of the impact assessment, the following can be concluded during rehabilitated conditions:

- As the extent of long term additional residual groundwater drawdown due to the proposed Stittsville 2 Quarry is limited off of the site (water levels will increase in comparison to existing conditions), impacts to the identified surface water features and groundwater users are not anticipated following rehabilitation of the proposed Stittsville 2 Quarry (and surrounding quarries); and,
- As per the rehabilitation plan for the proposed Stittsville 2 Quarry, the proposed Stittsville 2 Quarry will be backfilled to the original grade throughout the limit of extraction, allowing for future potential development in the area near Jinkinson Road and a naturalized area in the southern portion of the property. The proposed naturalized area will include forests, wetlands, meadow and thicket. This area will be planted with mixed native species and will provide a range of habitats for wildlife. The ultimate drainage directions and subcatchments areas are expected to closely resemble existing pre-development conditions. Runoff from the rehabilitated Stittsville 2 Quarry will then flow east off the property towards the Goulbourn Wetland Complex.
- Under Rehabilitated Conditions (Scenario 8 All quarries at full rehabilitation including the proposed Stittsville 2 Quarry), the estimated cumulative discharge will decrease by approximately 673,000 m³/yr (or 24%) as compared to Existing Conditions at Full Development (Scenario 4 All quarries at full development excluding the proposed Stittsville 2 Quarry). The effect of the proposed Stittsville 2 Quarry alone on average annual discharge at Junction 4 under rehabilitated conditions represents a decrease of approximately <1% as compared to existing conditions (Scenario 4).

In summary, it is not expected that the development of the proposed Stittsville 2 Quarry will have a negative impact on surface water or groundwater receptors under rehabilitated conditions, and it is not expected that the implementation of mitigation measures will be required.

Comprehensive Site-Specific Monitoring Programs

Proposed groundwater and surface water monitoring programs are presented in Section 9.0 of this report. 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 quarry development on the combined quarry properties, 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). Given that the combined quarries will continue to be developed over a period of several decades, these monitoring programs will permit the development of a



comprehensive groundwater and surface water database prior to any potential impacts on local receptors including local private water supply wells.

If Tomlinson is successful in obtaining a license under the ARA from the MNRF for the proposed Stittsville 2 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 Stittsville 2 Quarry in the impact assessment of the PTTW and to add some existing monitoring wells at the proposed Stittsville 2 Quarry into the monitoring program associated with the PTTW. It is anticipated that any water collecting in the base of the Stittsville Quarry and the proposed Stittsville 2 Quarry will be collected in the same sump and discharged off-site in accordance with the existing ECA for the Stittsville Quarry. As noted above, the existing quarry sump dewatering system is presently operated relatively infrequently at about 80 Litres per second which is below the maximum permissible discharge rate of 90 Litres per second. As such, it is envisaged that the management of water collecting within the confines of the proposed Stittsville 2 Quarry excavation could be accommodated (at least during the early stages of the development of the proposed Stittsville 2 Quarry) within the constraints imposed by the existing ECA (Industrial Sewage Works) without requiring a technical amendment to the ECA.

It is expected that an annual performance report will continue to be a requirement of a future amended 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 operations on the combined quarry properties (i.e., Stittsville Quarry and proposed Stittsville 2 Quarry) are 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 licensing application process) that relate to the monitoring of the groundwater and surface water would be considered in the context of preparing the future monitoring program that takes into account the proposed development of the Stittsville 2 Quarry.

11.0 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.



12.0 CLOSURE

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

100110984

02/11/2023

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 $https://golder associates.share point.com/sites/115663/project files/6 deliverables/water report/final/19130670-r-rev0_stittsville_2_water_report_31oct2023.docx$

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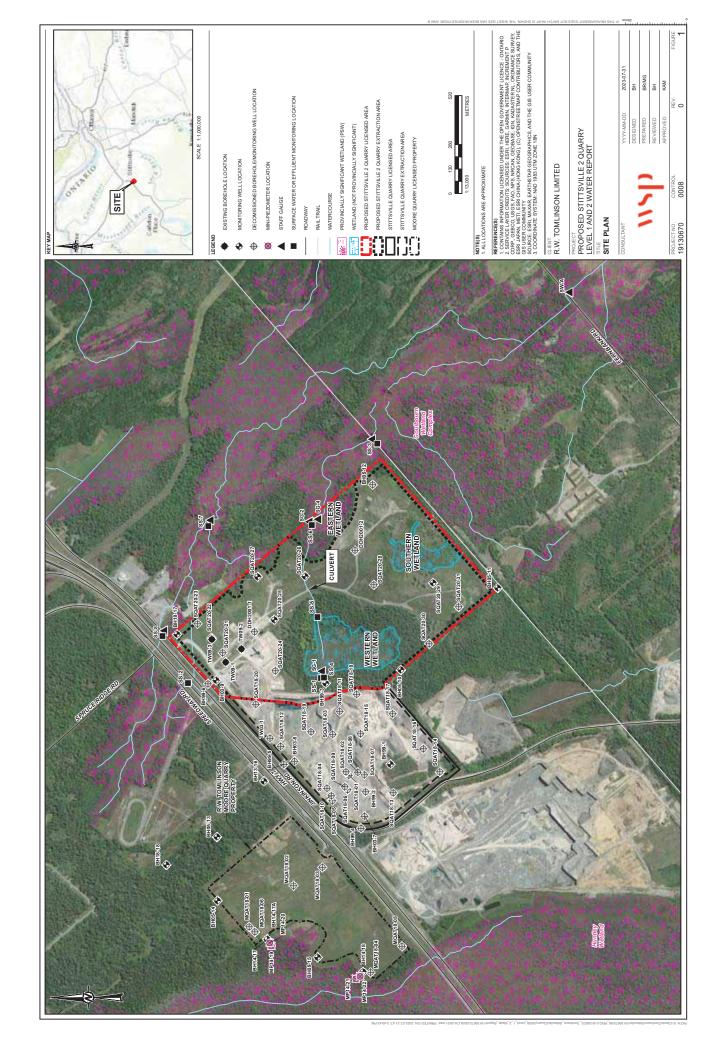


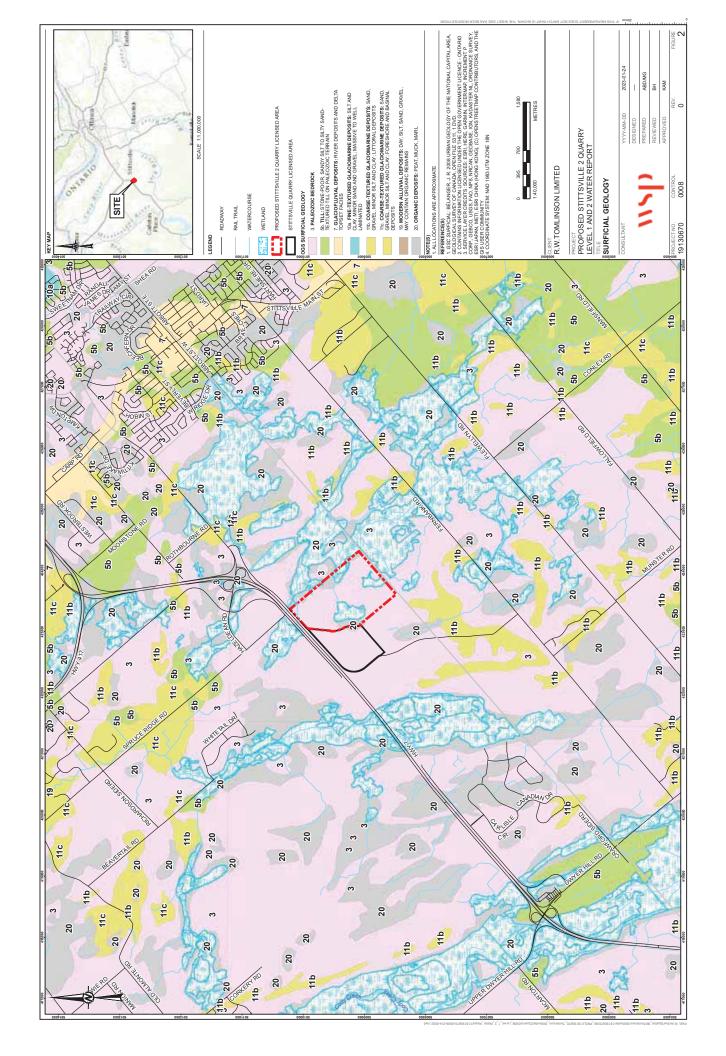
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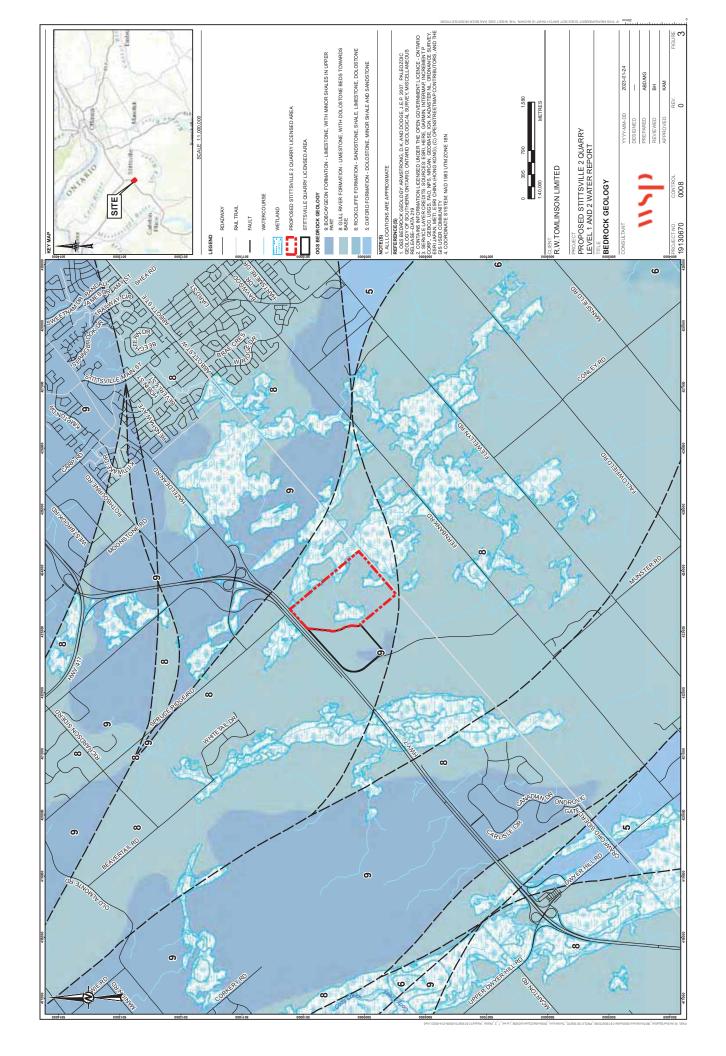
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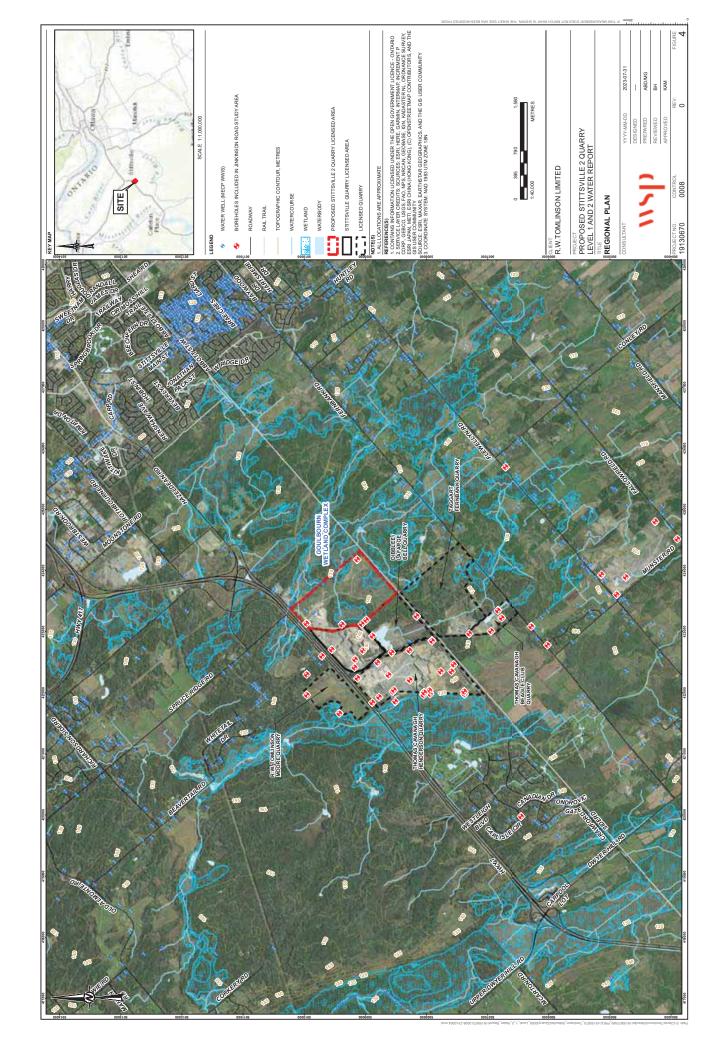
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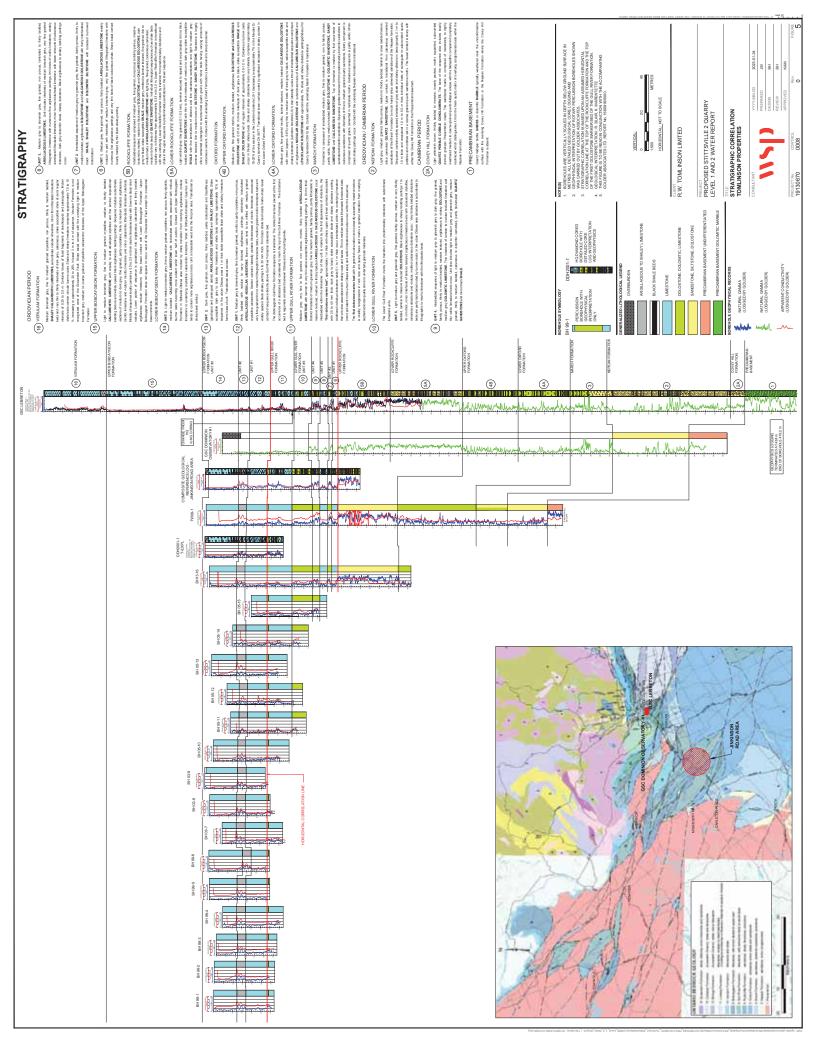


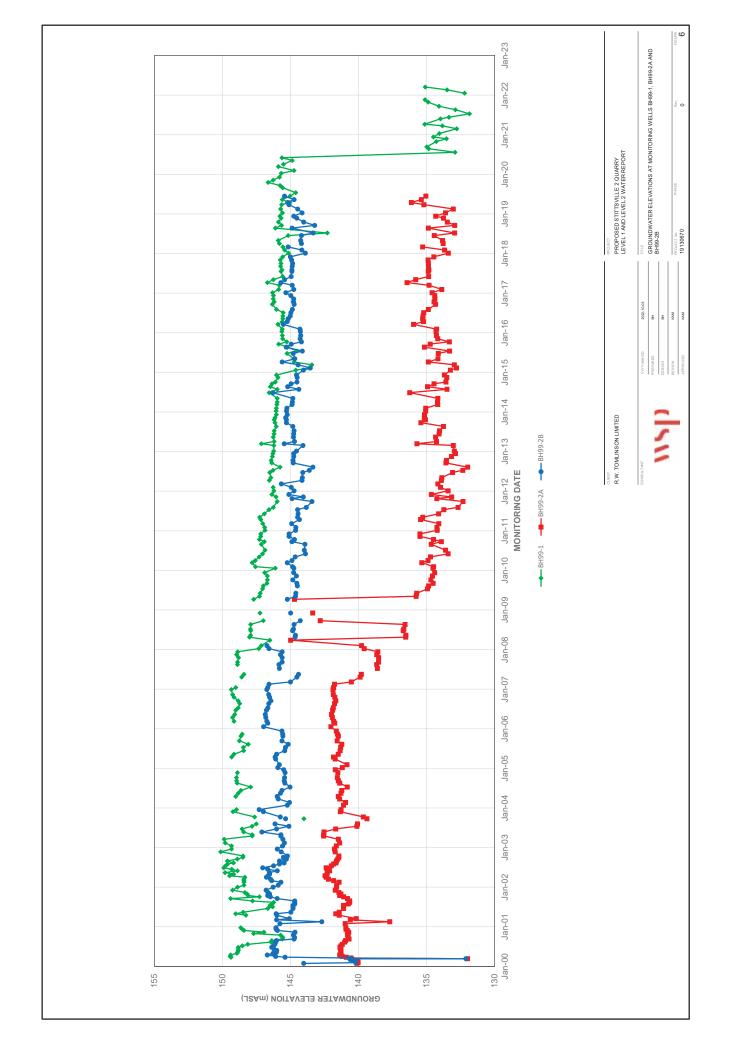


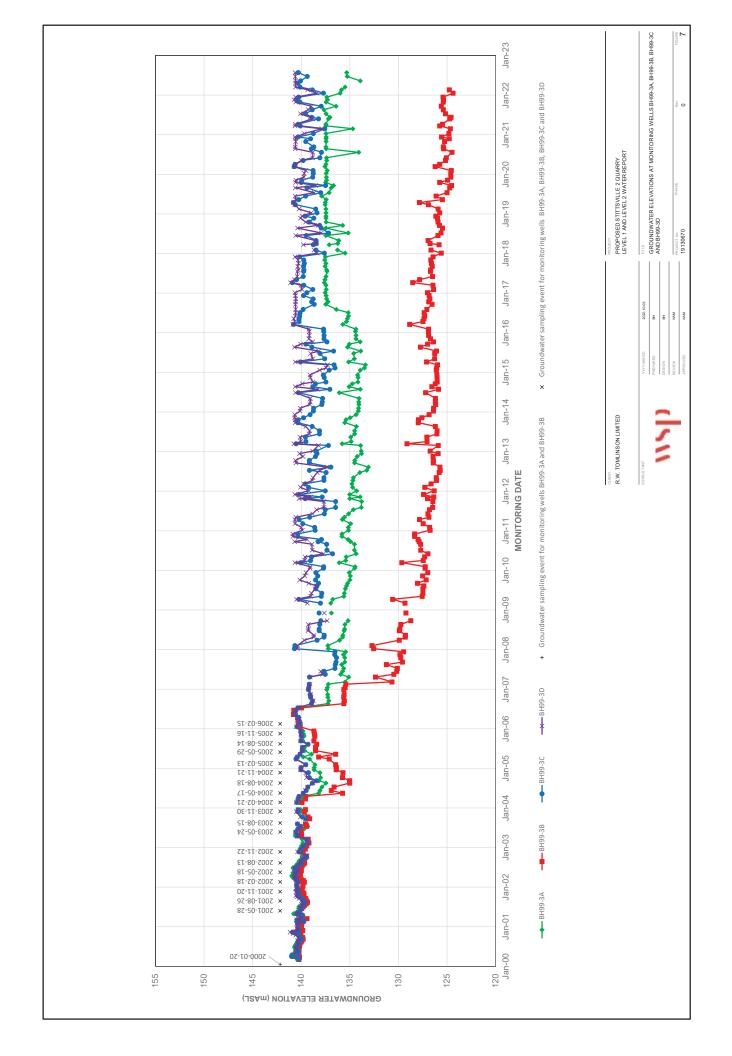


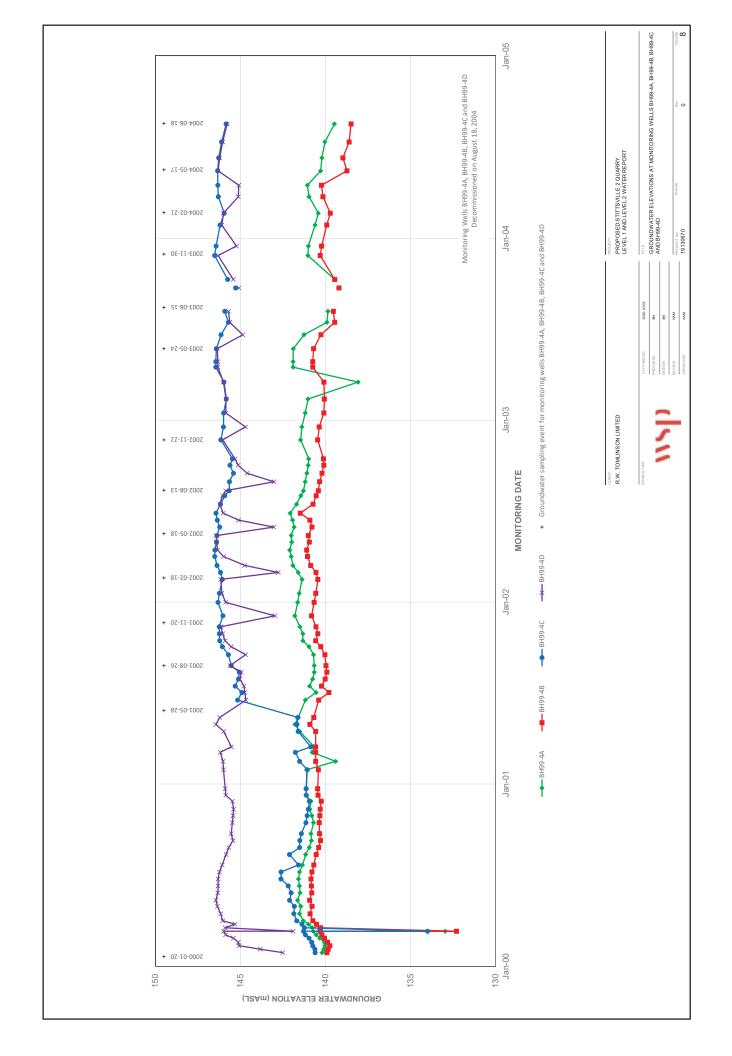


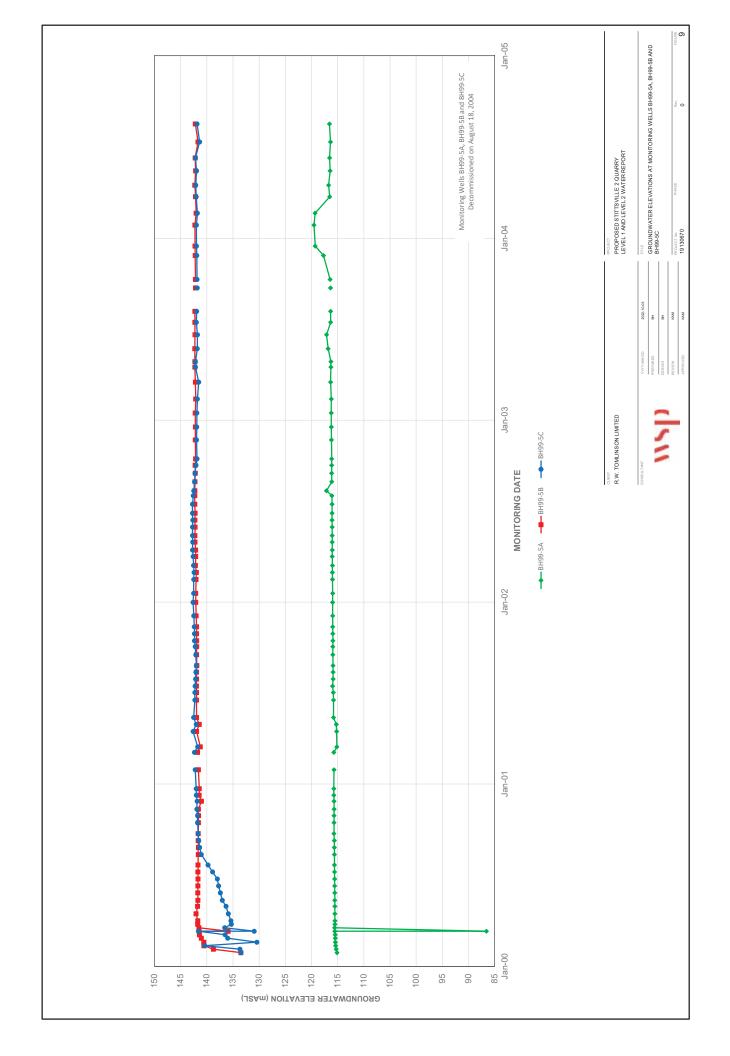


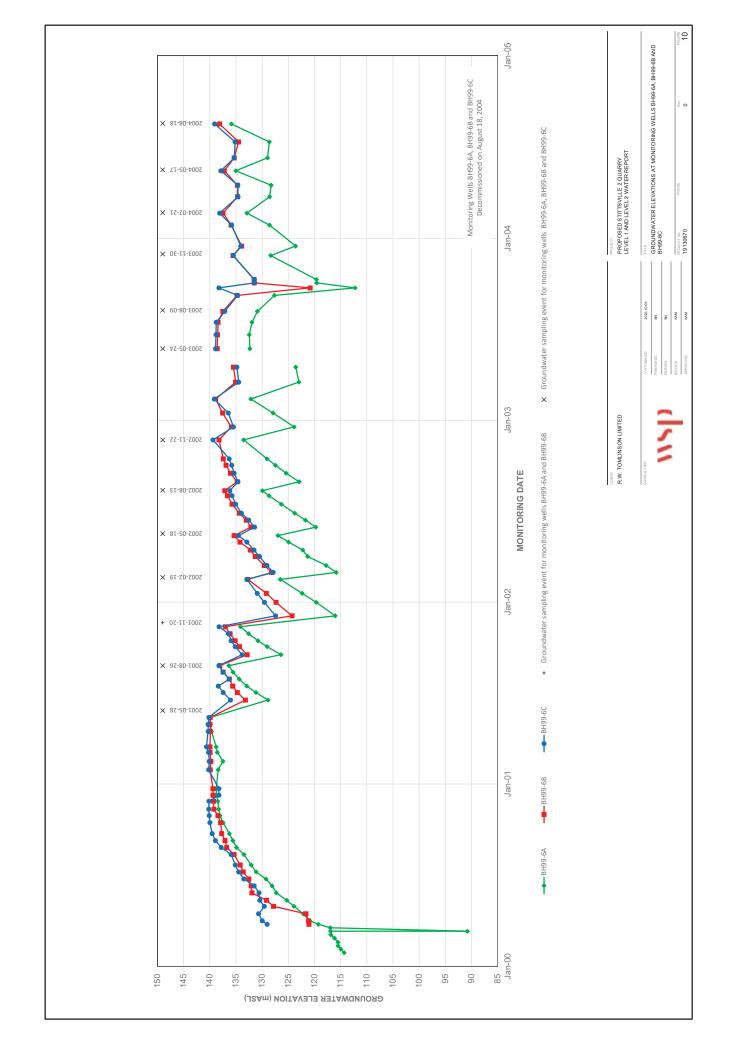


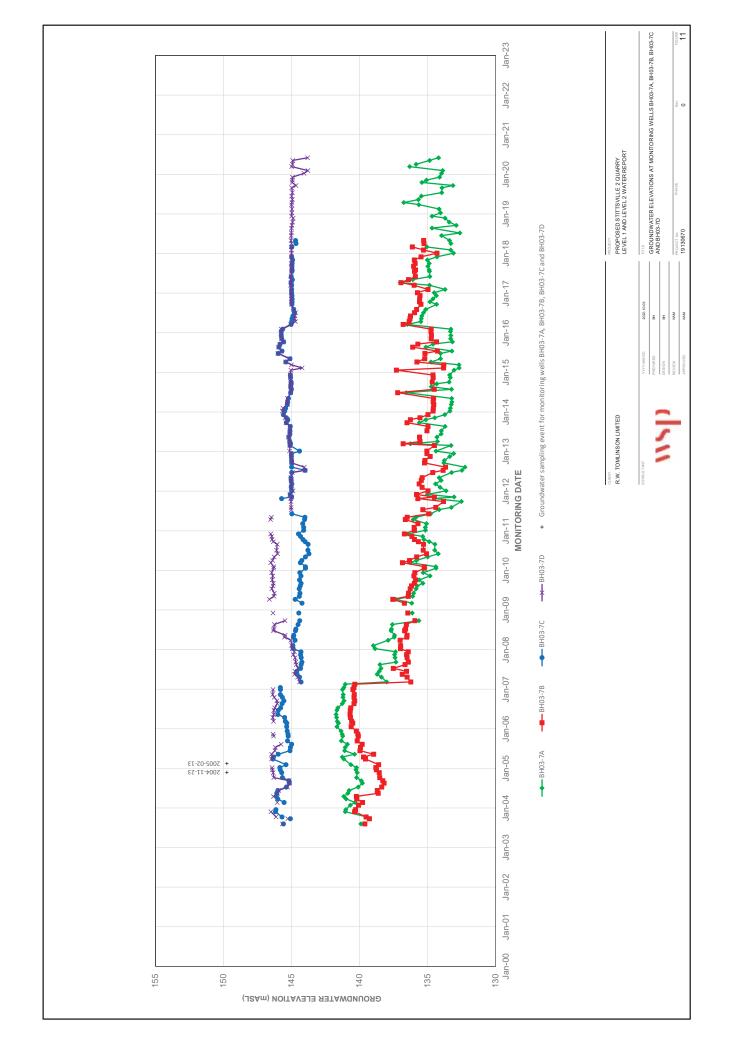


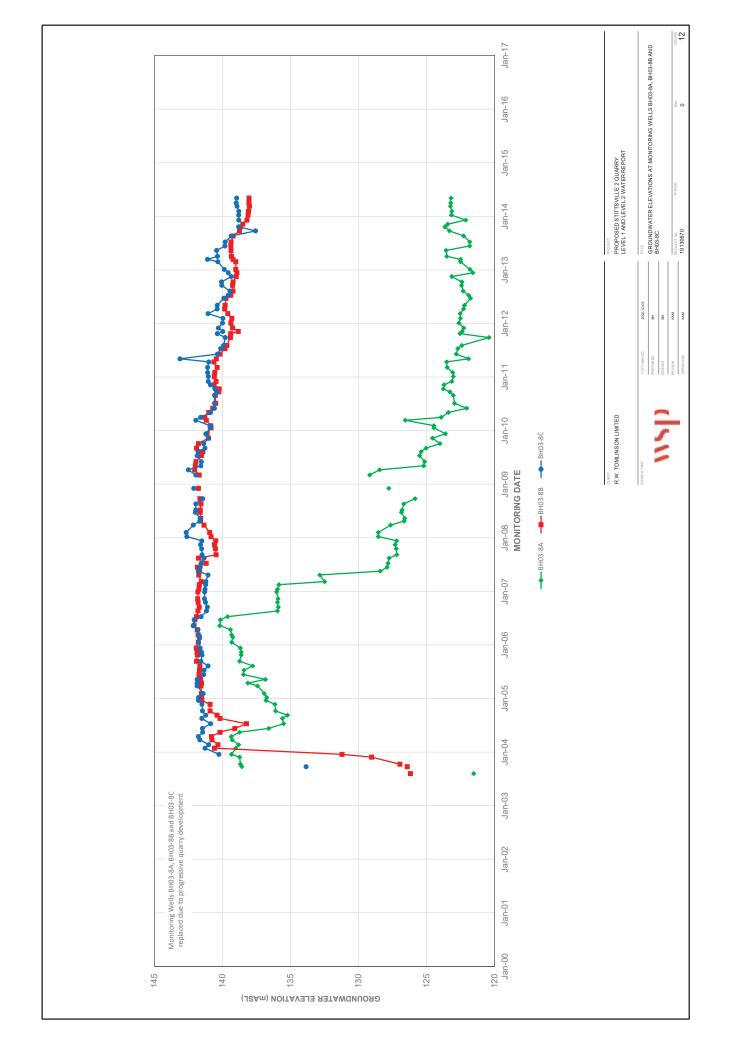


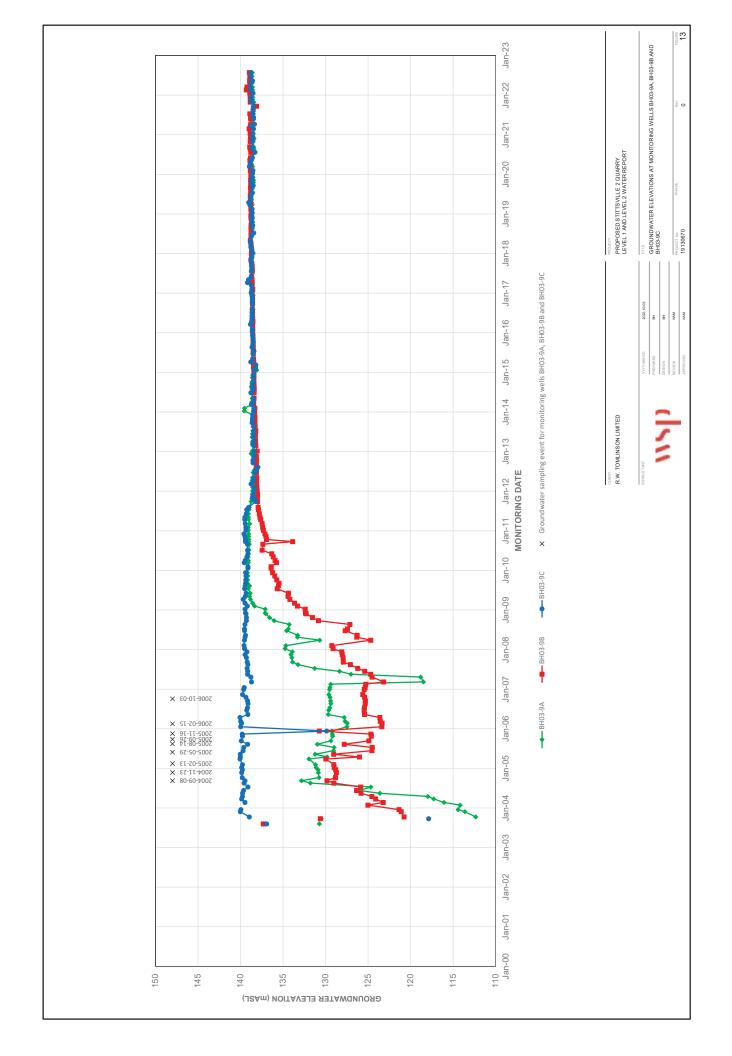


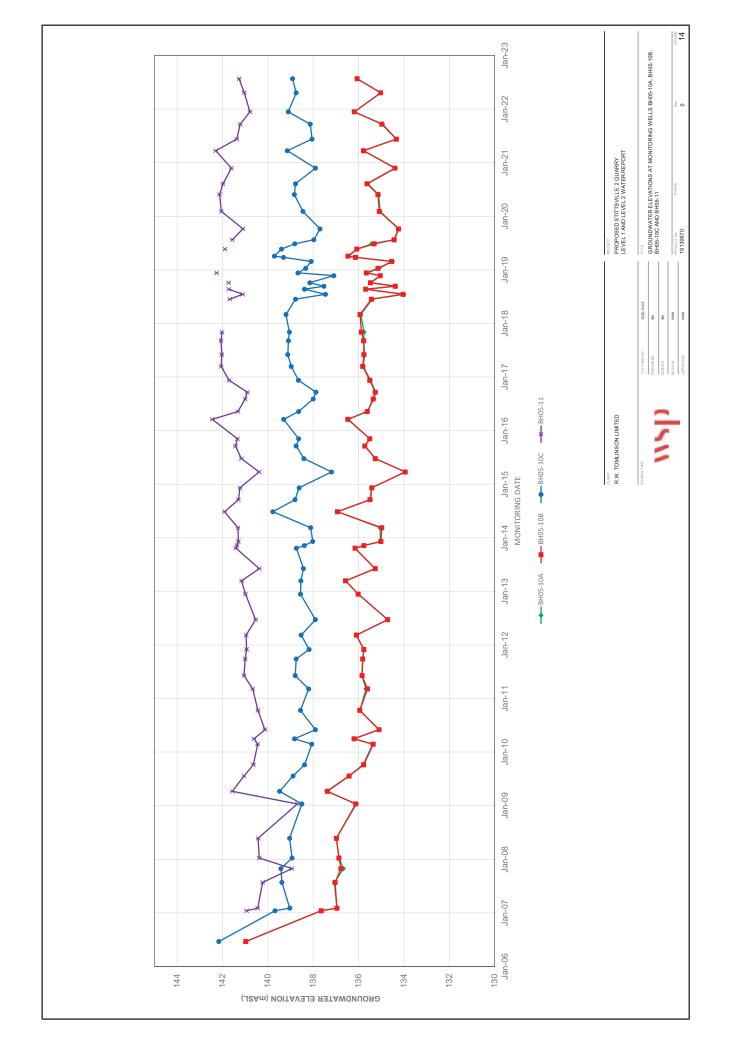


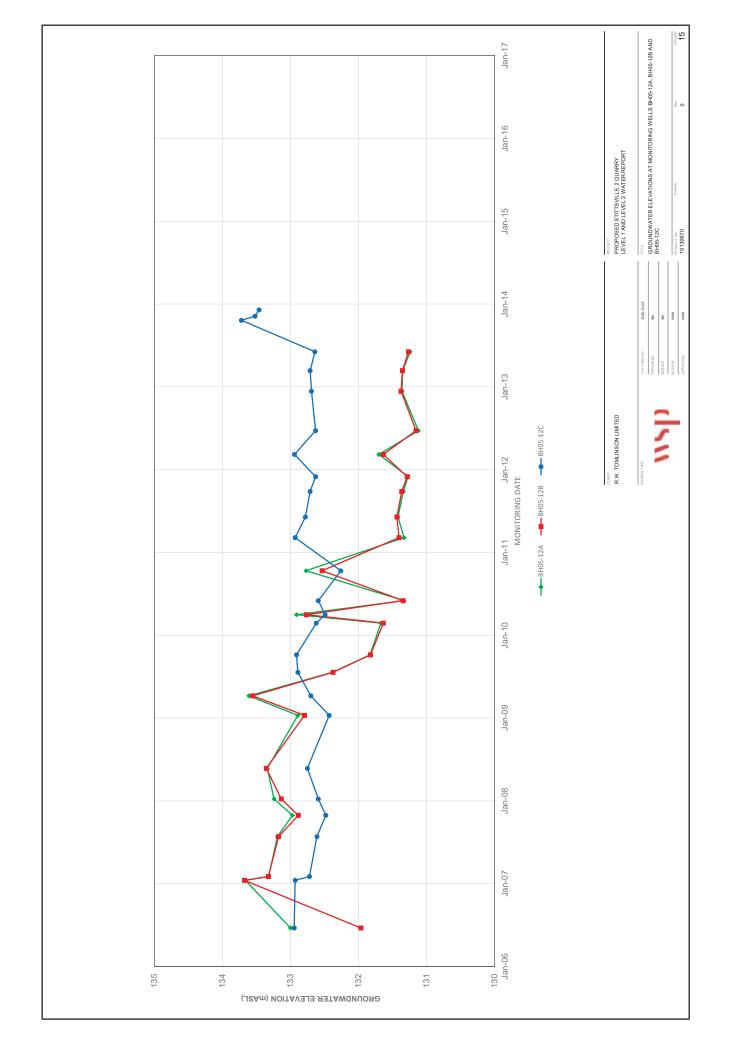


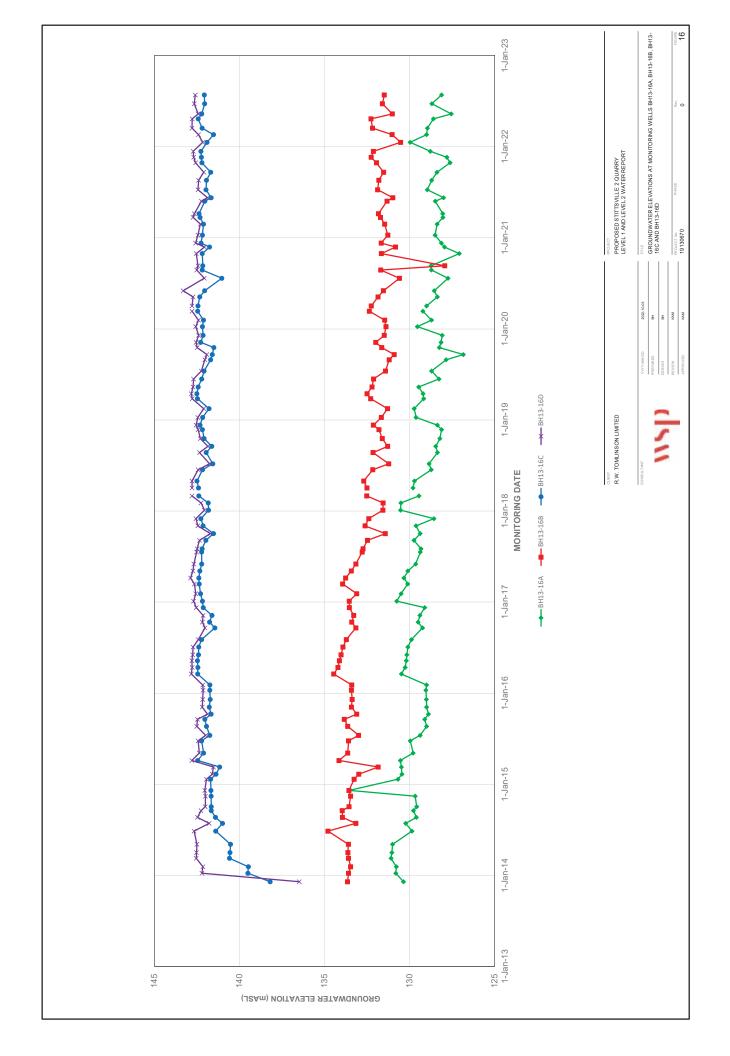


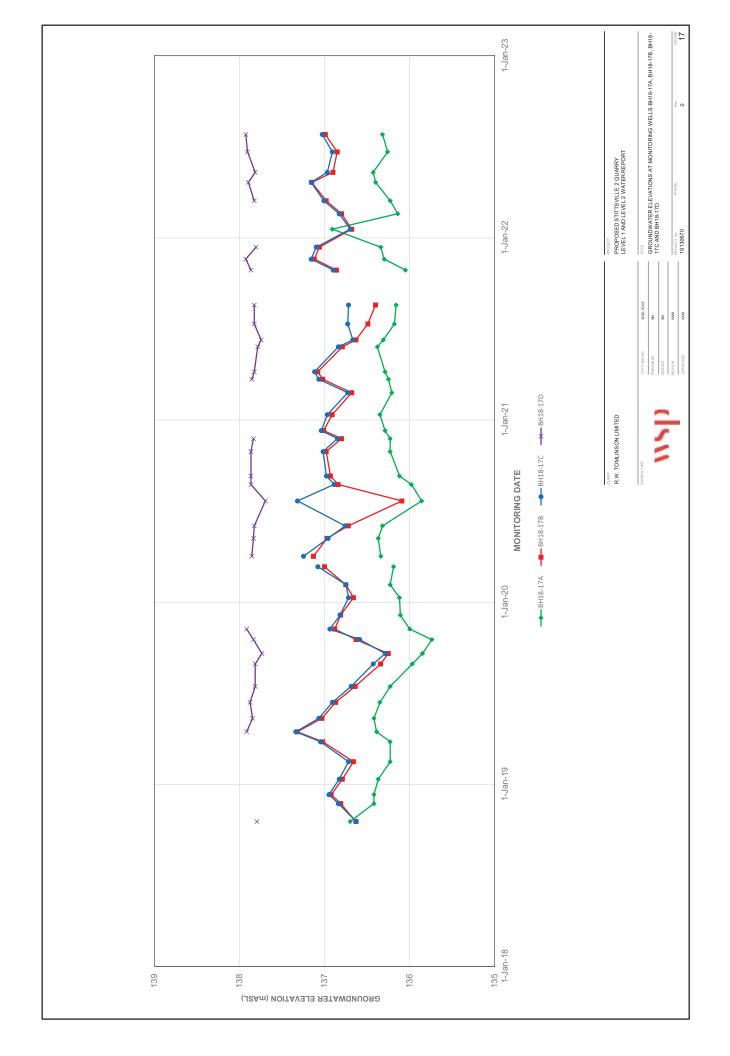


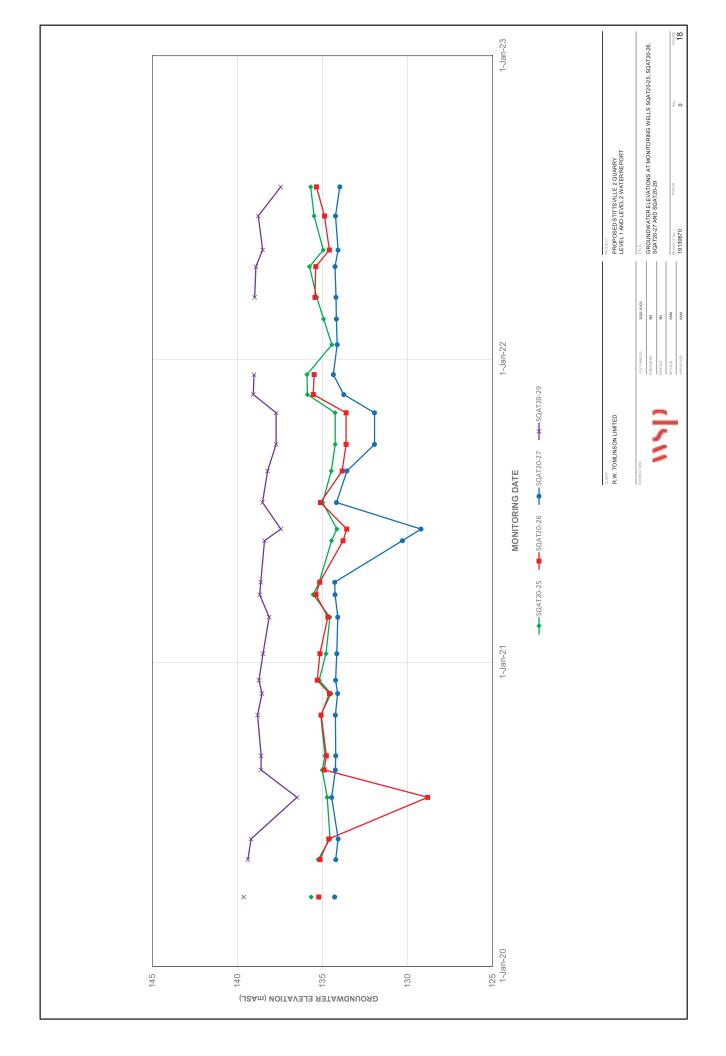


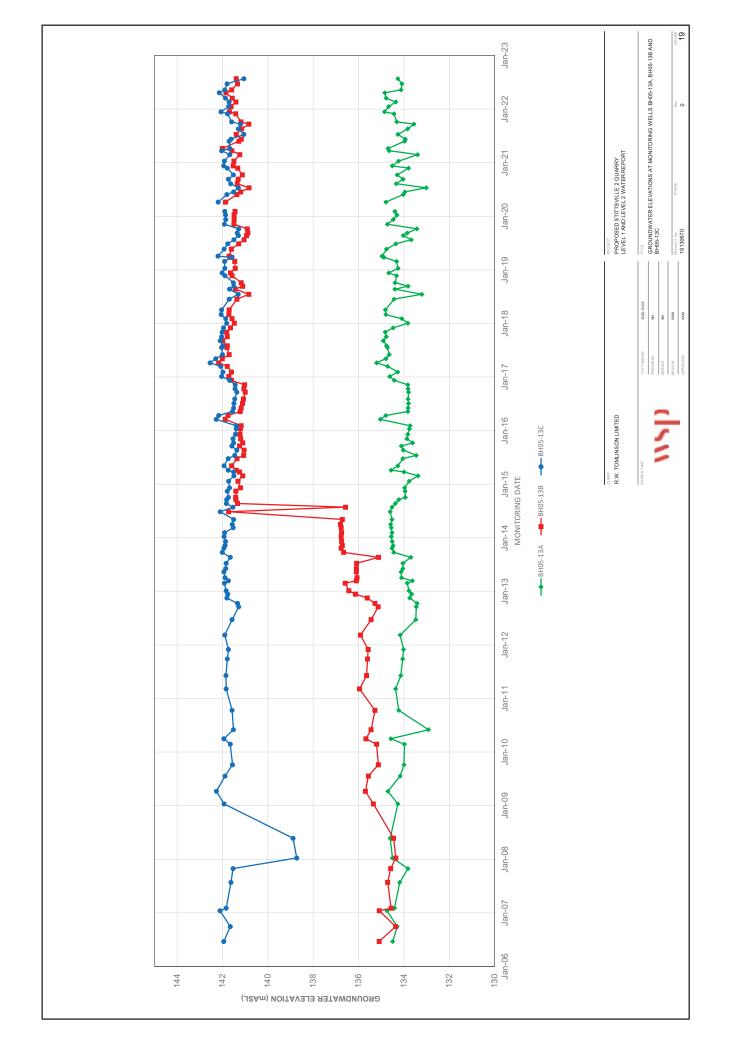


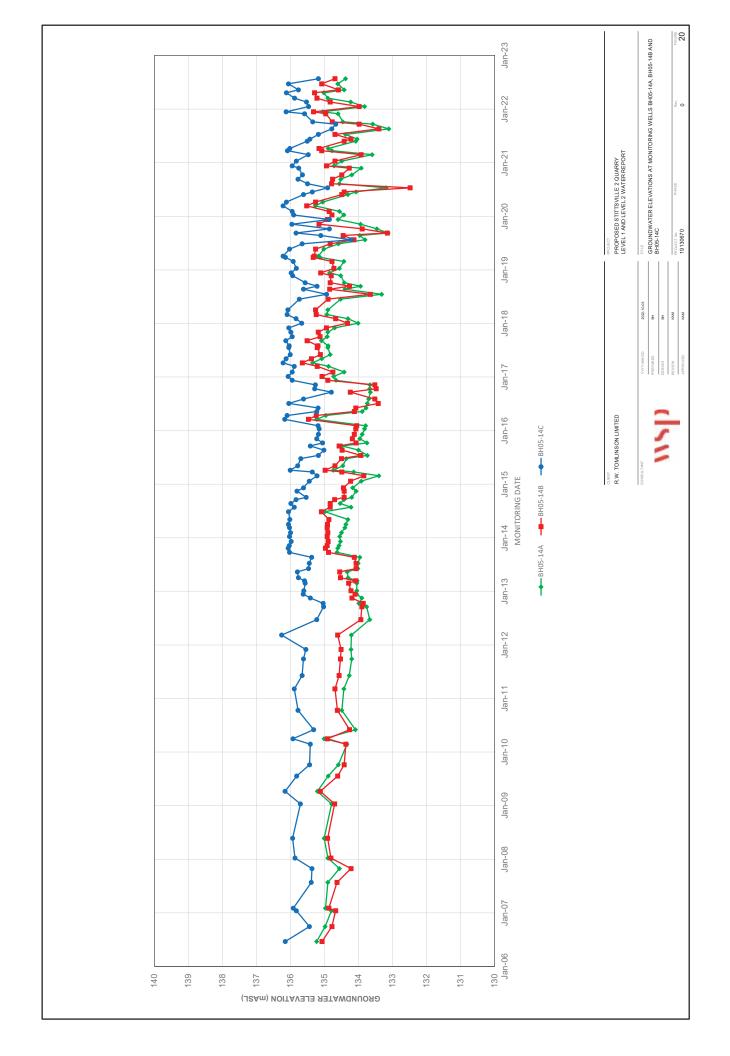


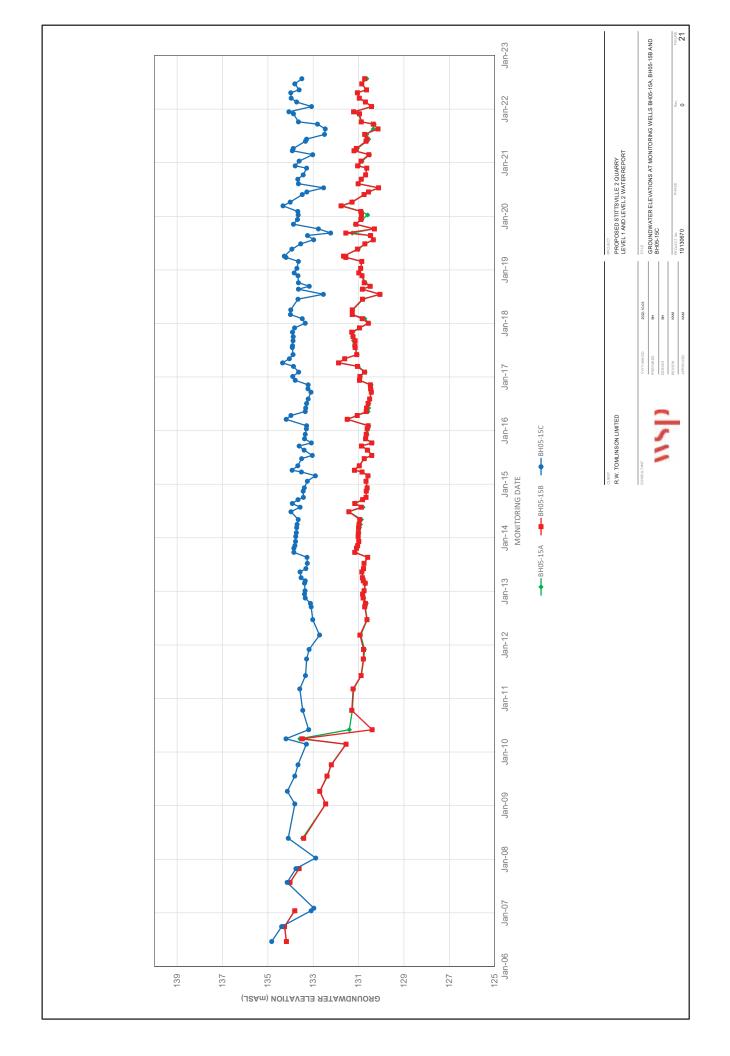


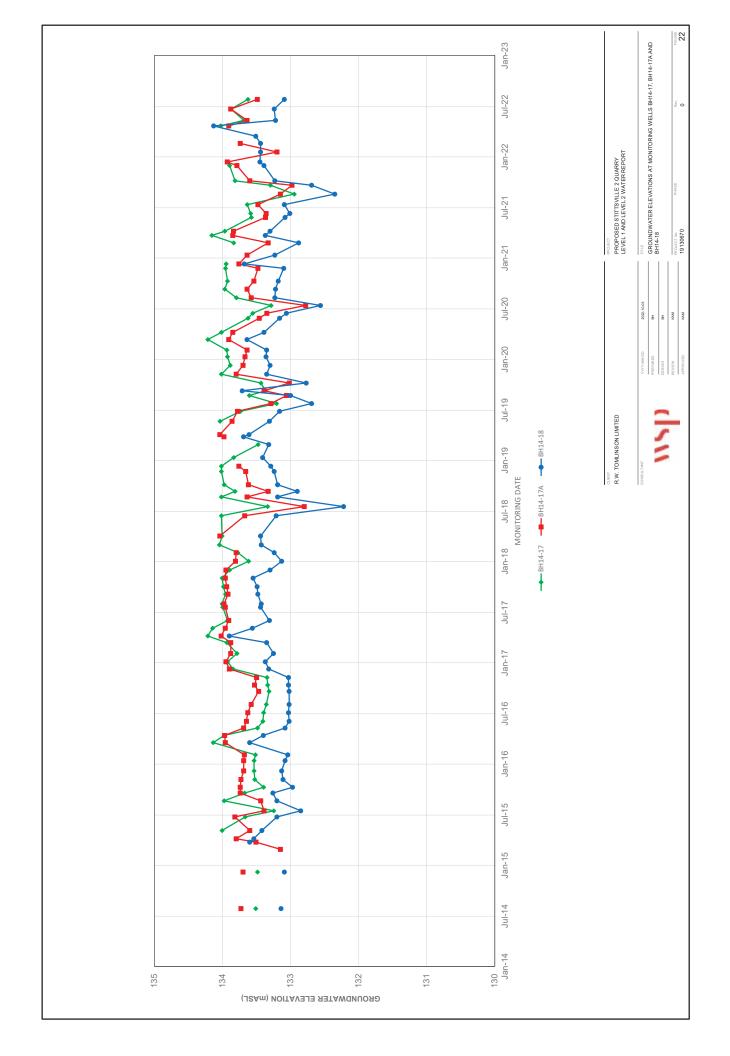


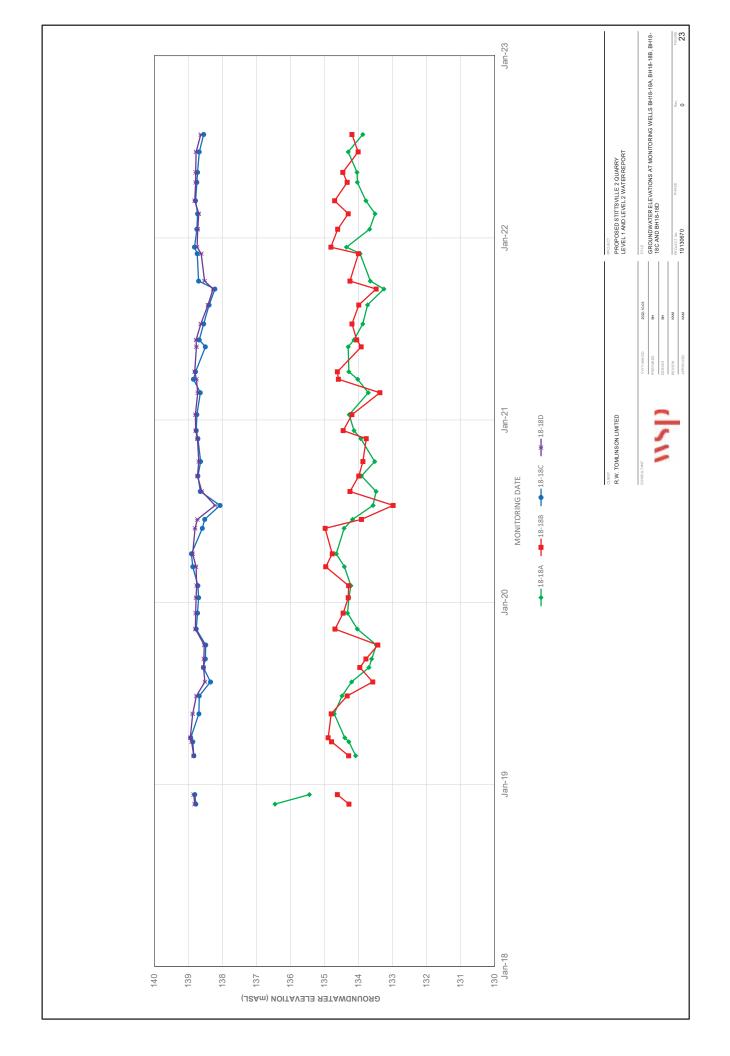


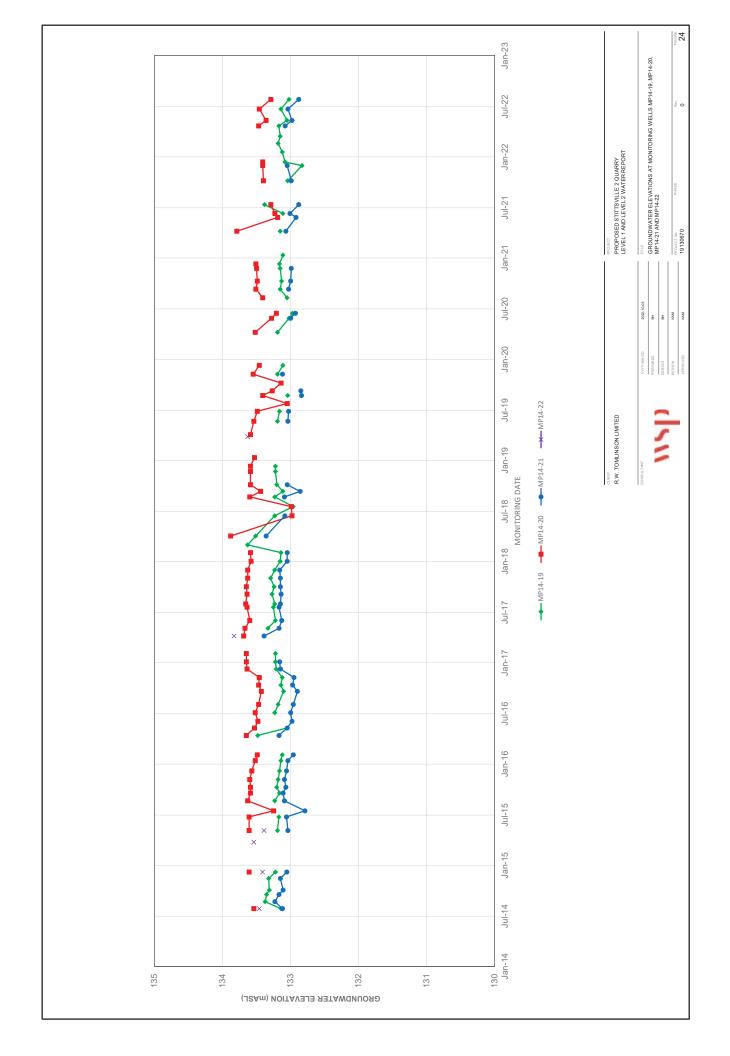


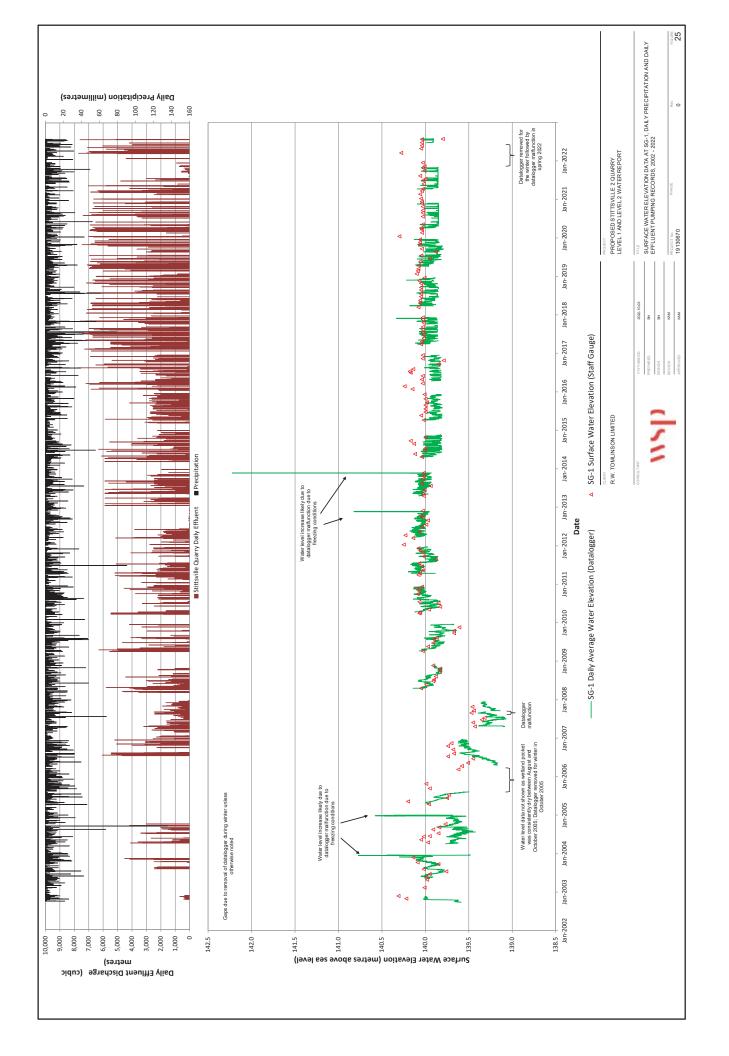


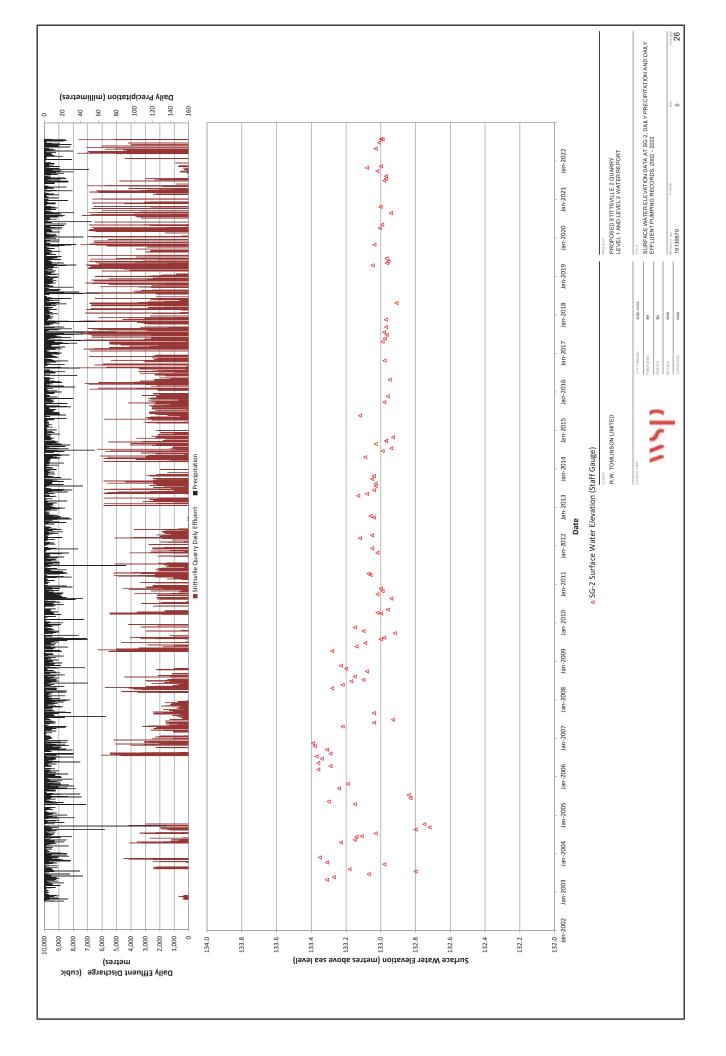


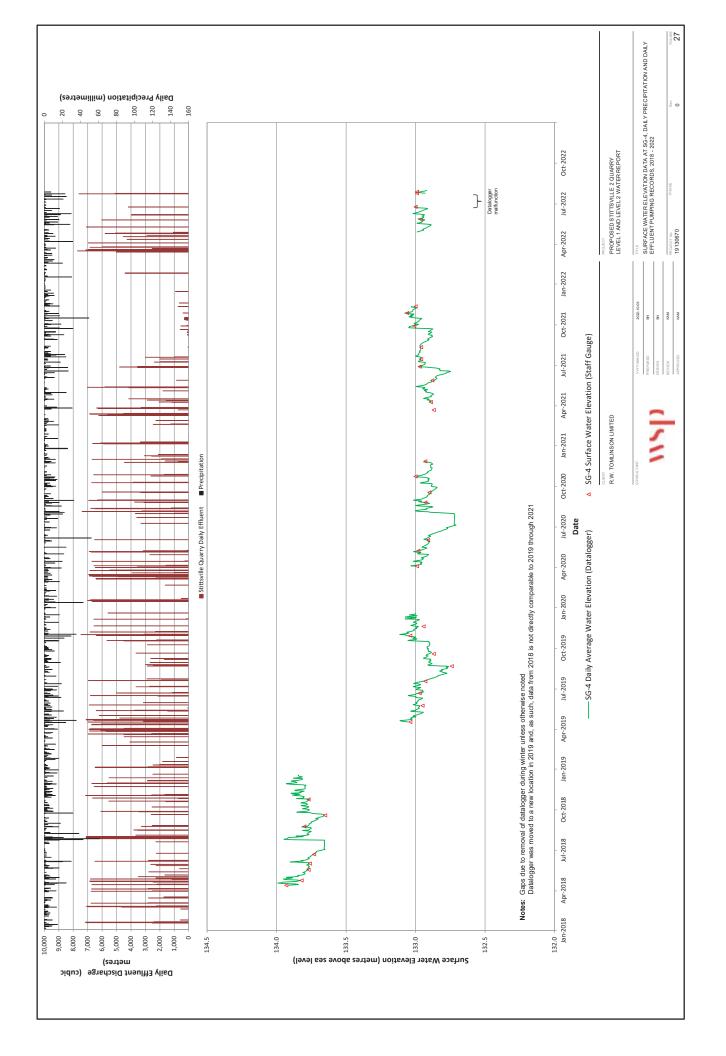


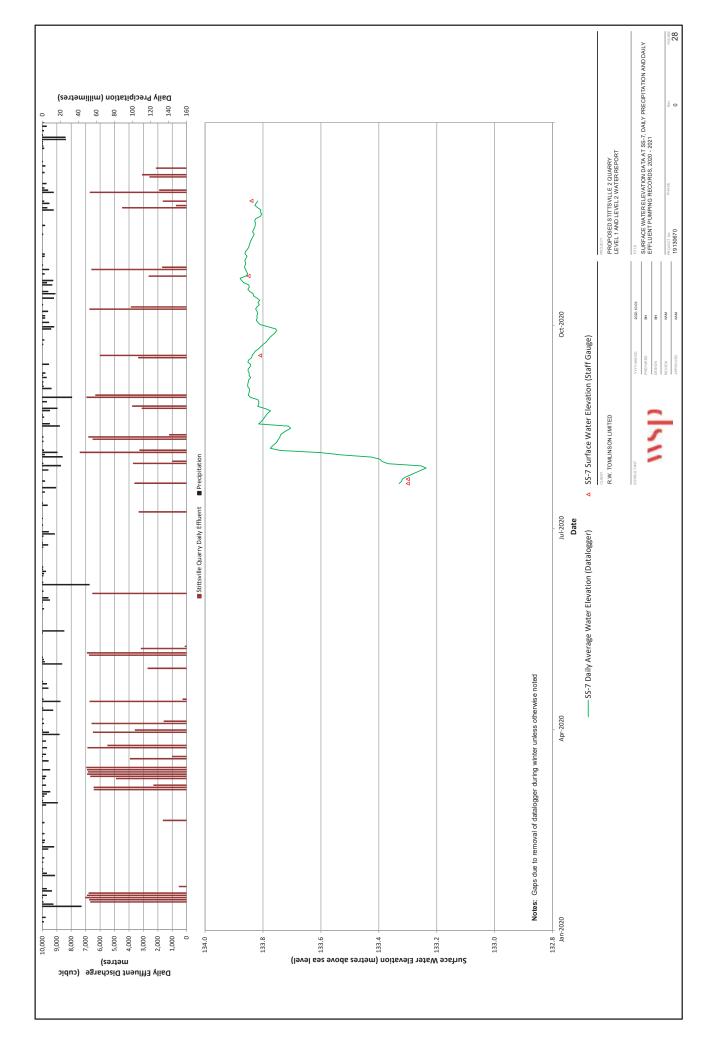


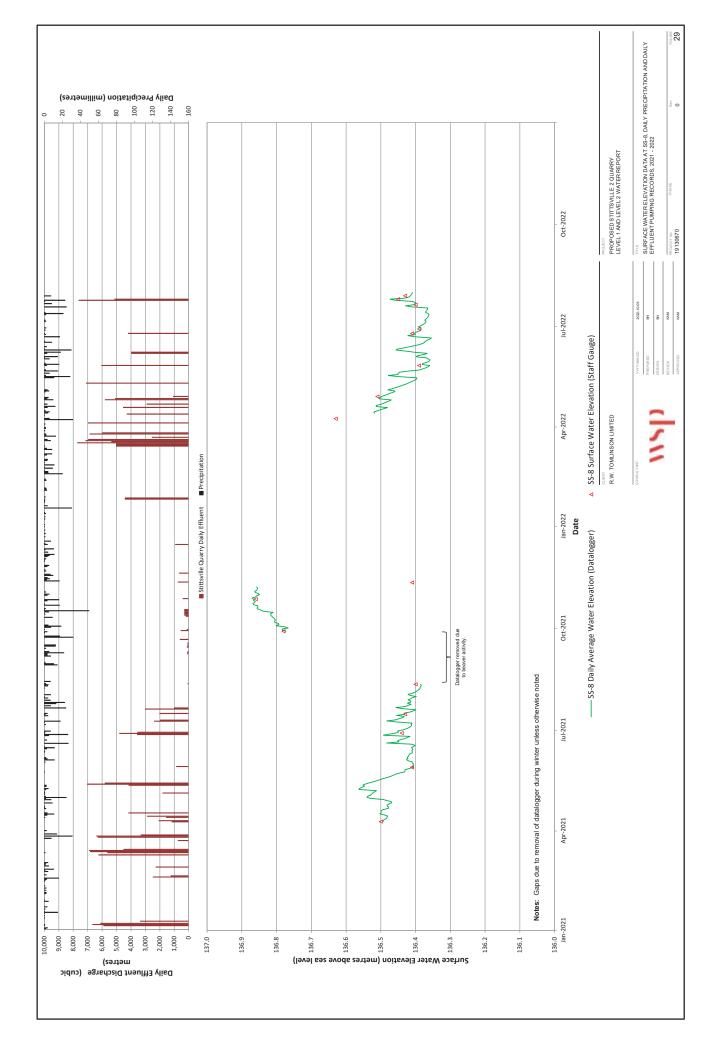


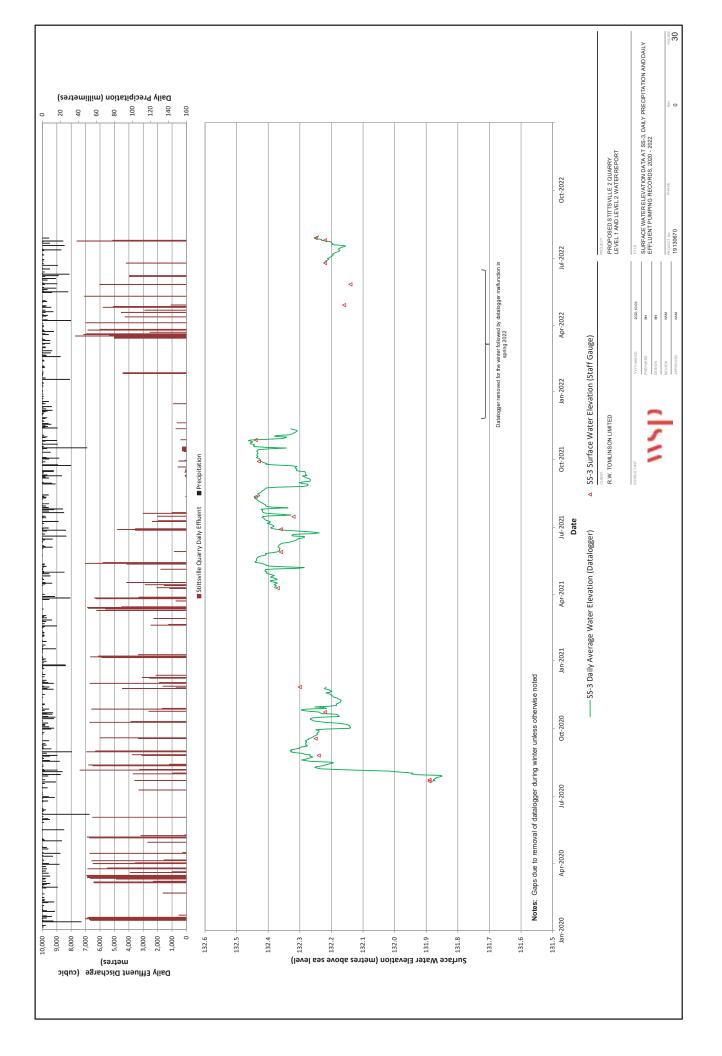


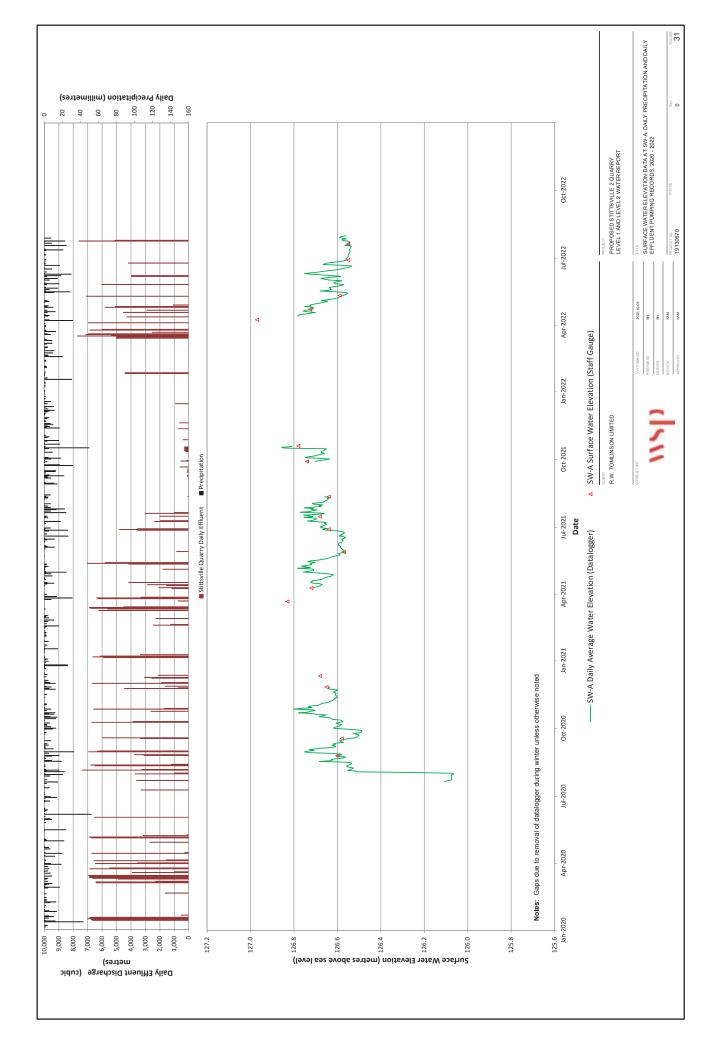


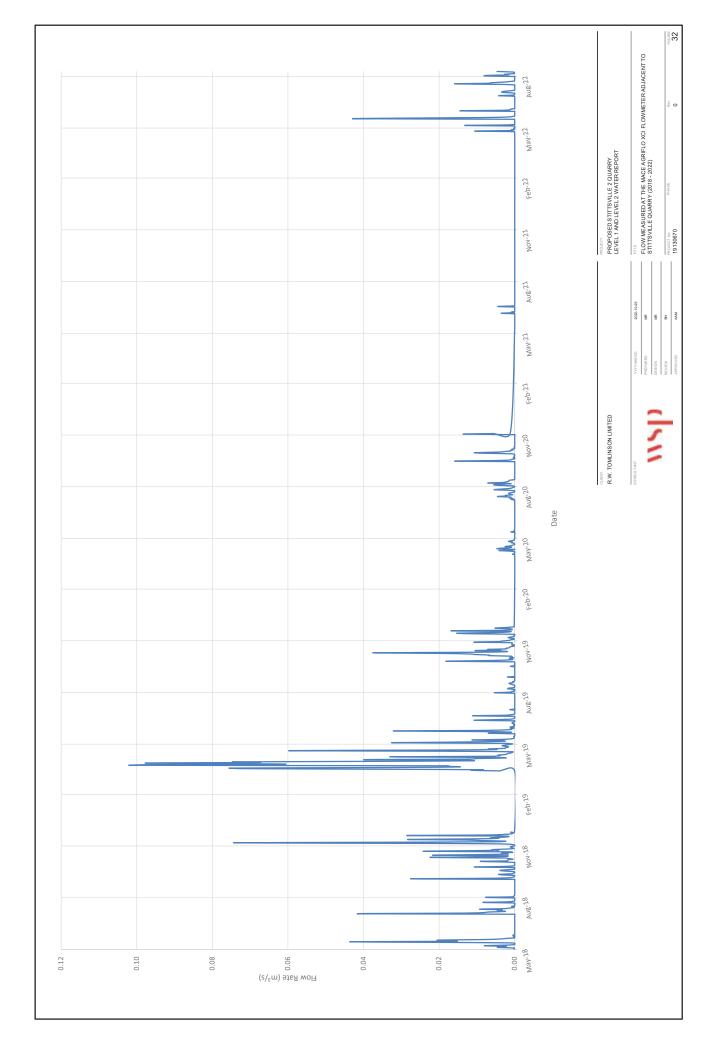


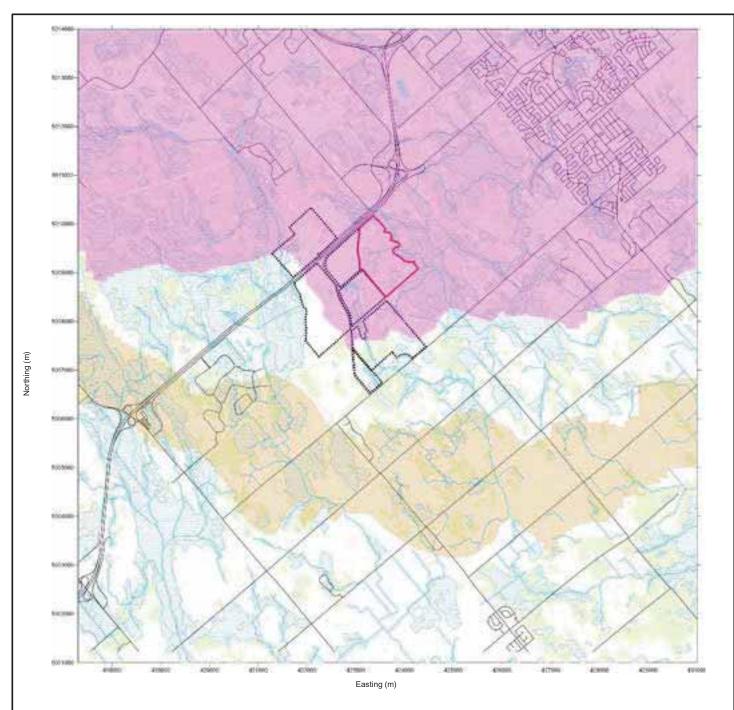












LEGEND

WOODED AREA

WETLAND AREA WATERBODY

WATERCOURSE

PROPOSED STITTSVILLE 2 QUARRY EXTRACTION LIMIT

LICENSED QUARRY BOUNDARIES

AREA UNDERLAIN BY TRANSMISSIVE ZONE (Contact between Bobcaygeon and Gull River)

AREA OF HIGHER TRANSMISSIVITY ROCKCLIFFE FORMATION

R.W. TOMLINSON LIMITED

PROPOSED STITTSVILLE 2 QUARRY LEVEL 1 AND LEVEL 2 WATER REPORT

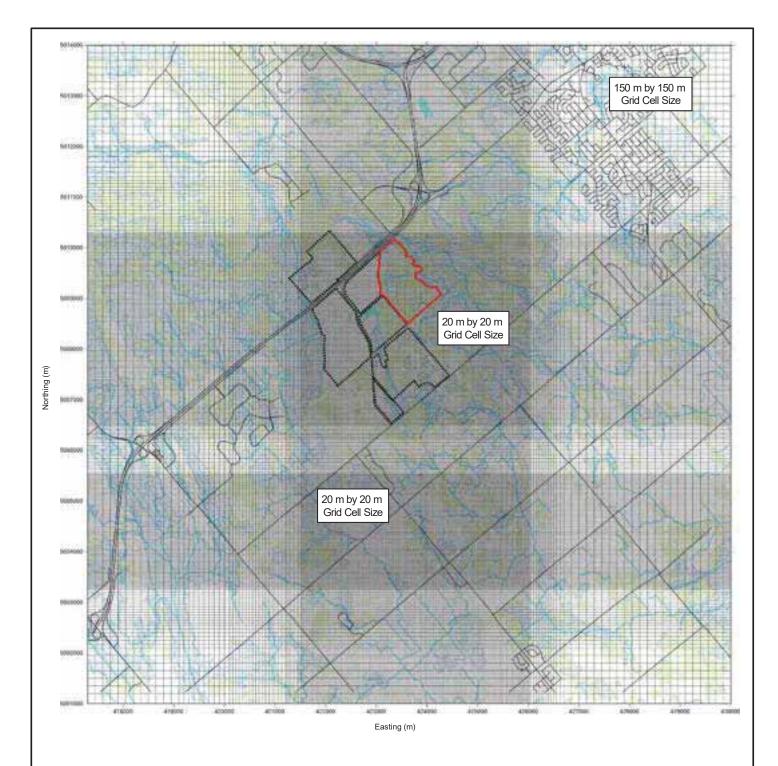
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DESIGN	SPS	
REVIEW	ВН	
APPROVED	BH	

TRANSMISSIVE ZONE AND HIGHER TRANSMISSIVITY **ROCKCLIFFE ZONE**

PROJECT No.	PHASE	Rev.	FIGUAE
19130670		0	33



LEGEND

WETLAND AREA

WATERBODY

WATERCOURSE **ROADS**

PROPOSED STITTSVILLE 2 QUARRY EXTRACTION LIMIT LICENSED QUARRY BOUNDARIES

R.W. TOMLINSON LIMITED

CONSULTANT

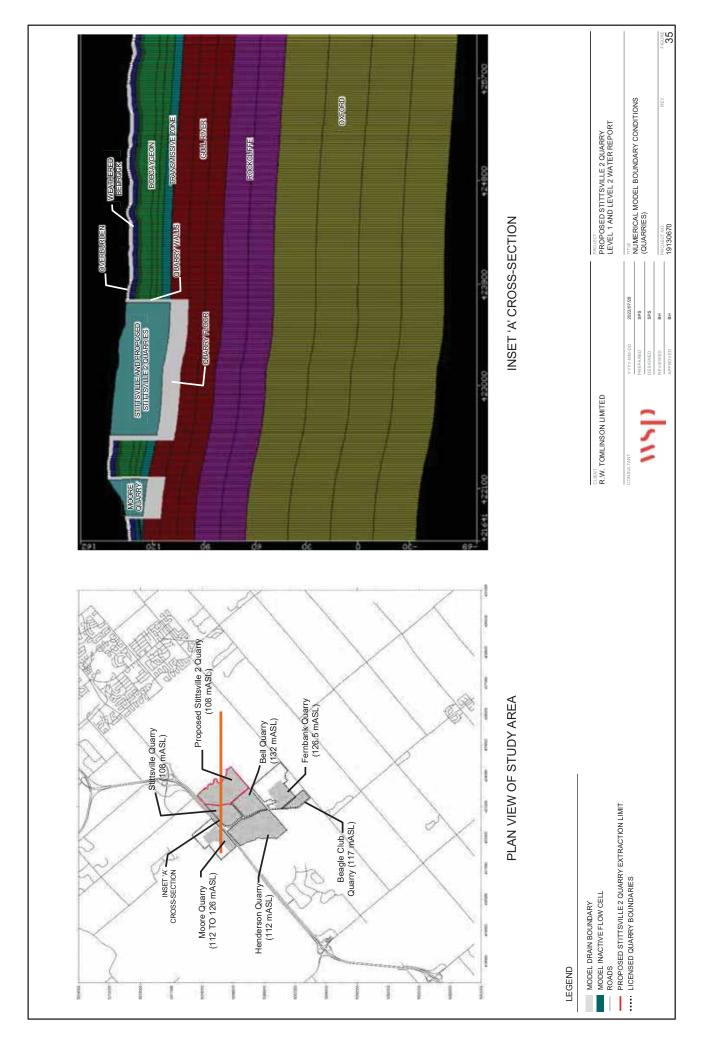


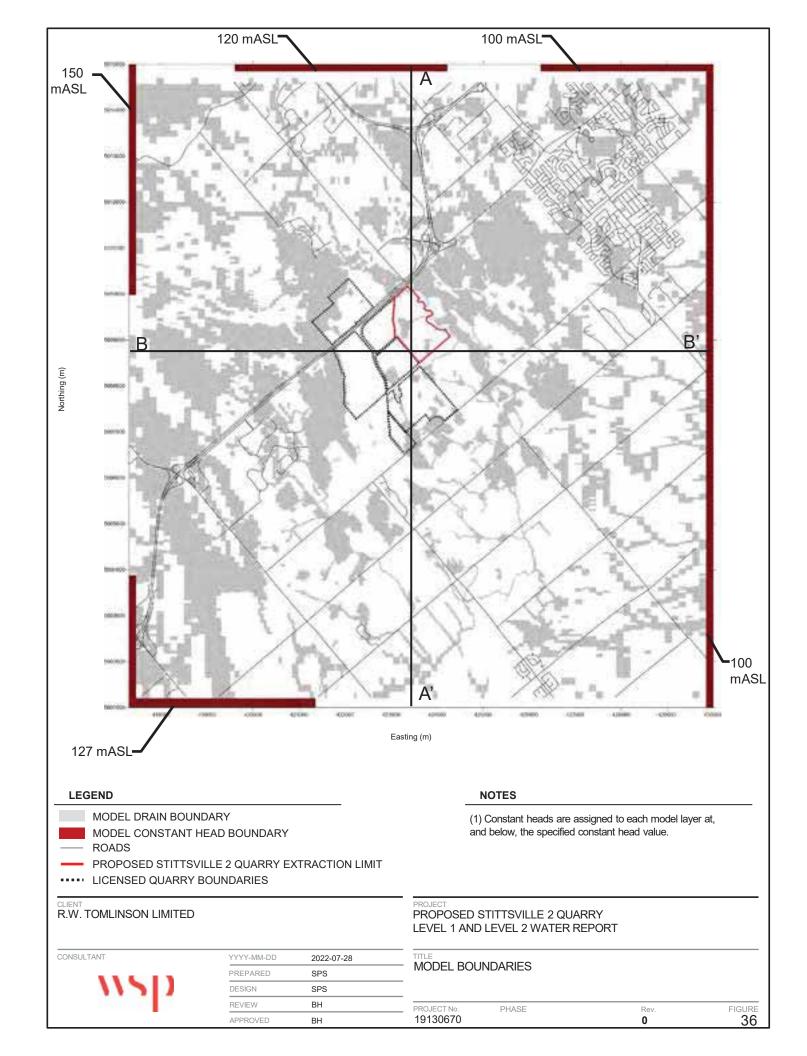
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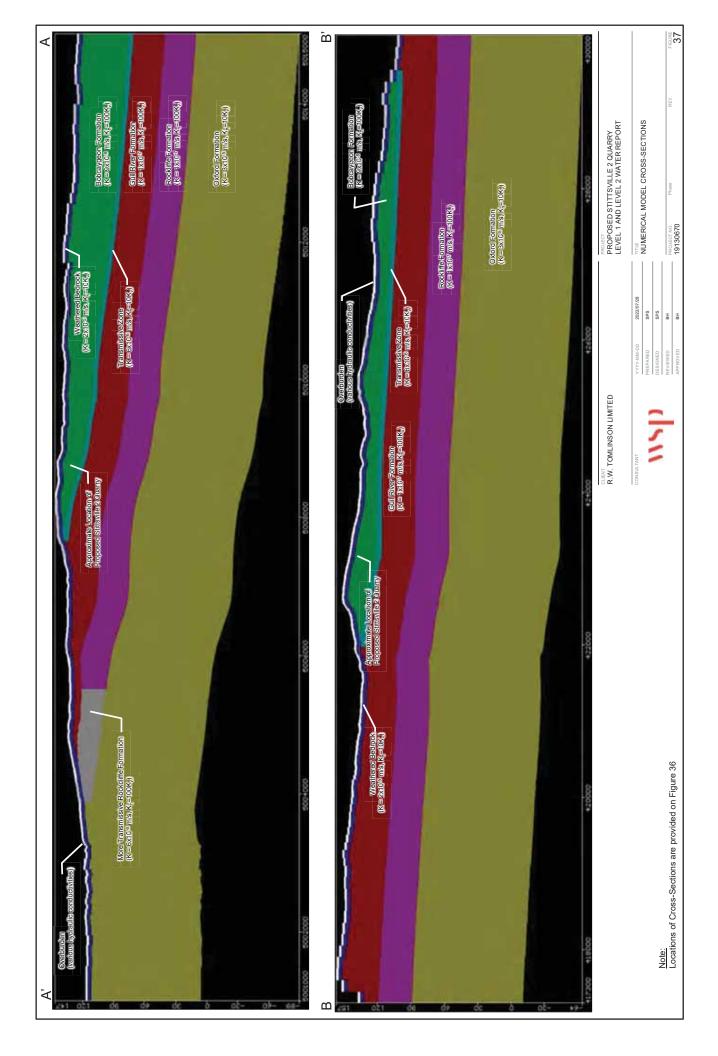
PROPOSED STITTSVILLE 2 QUARRY LEVEL 1 AND LEVEL 2 WATER REPORT

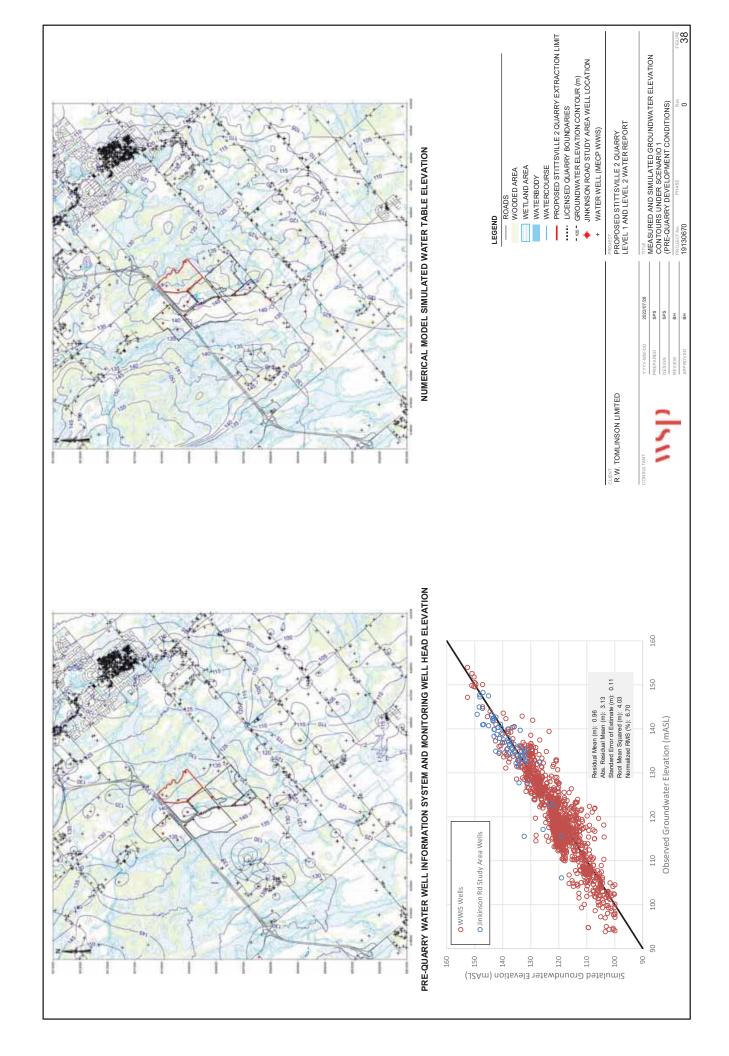
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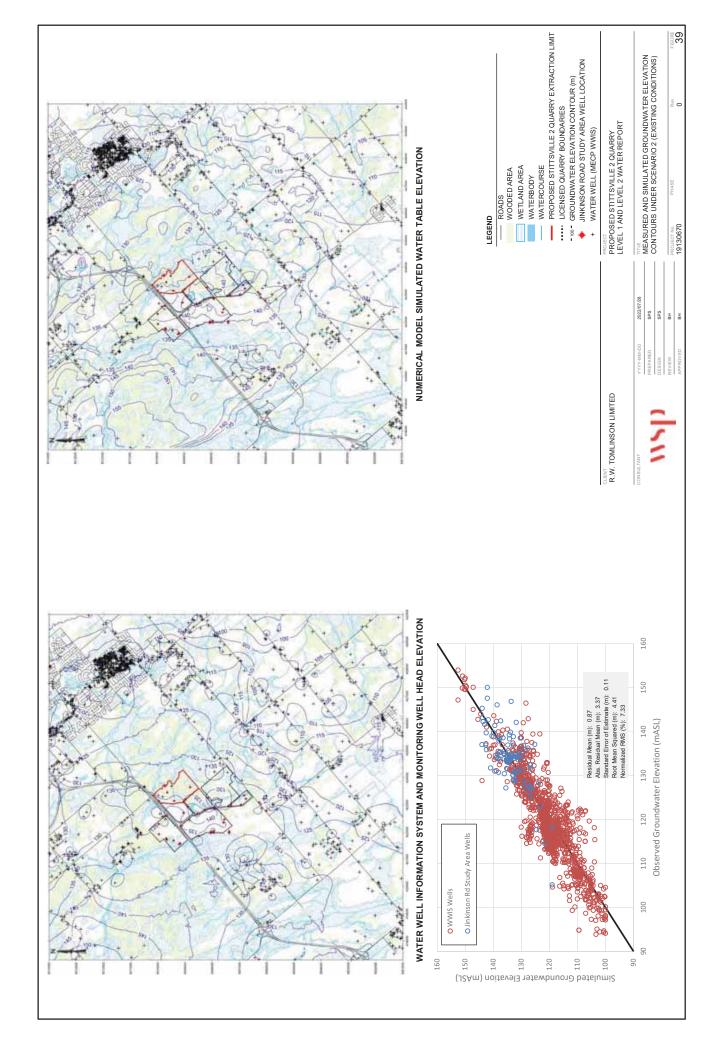
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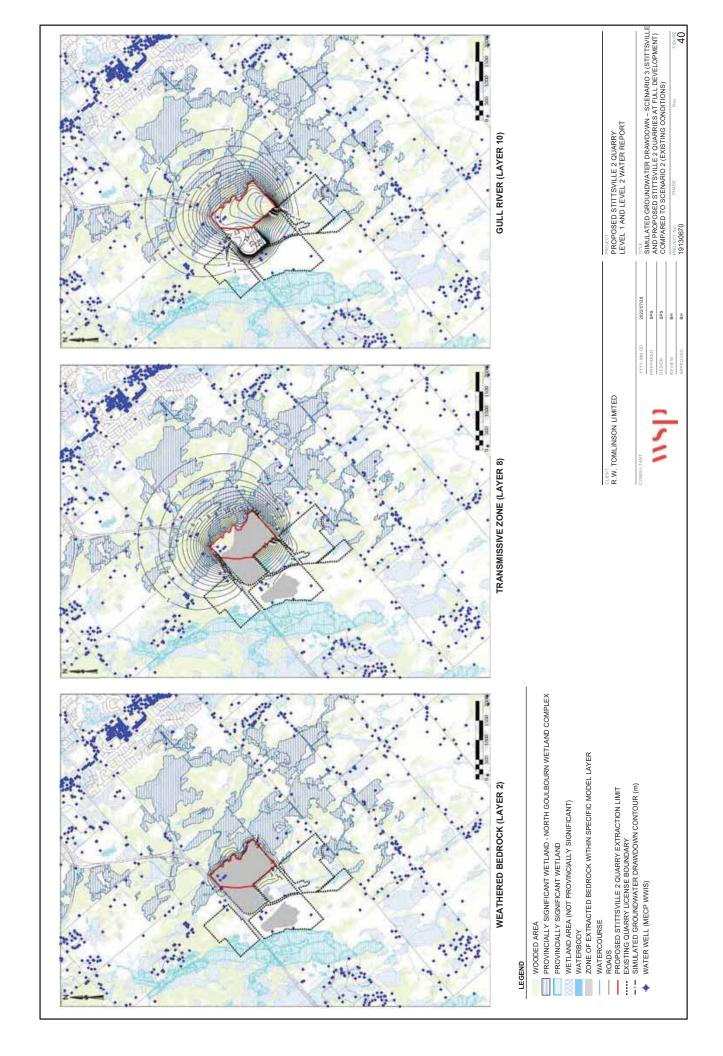


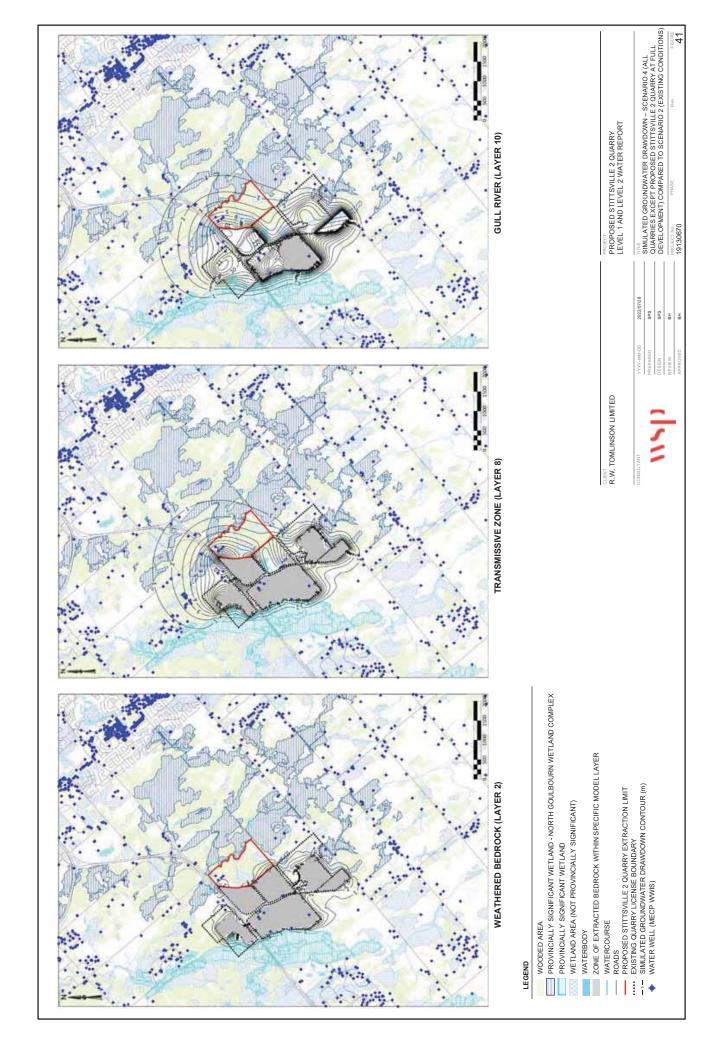


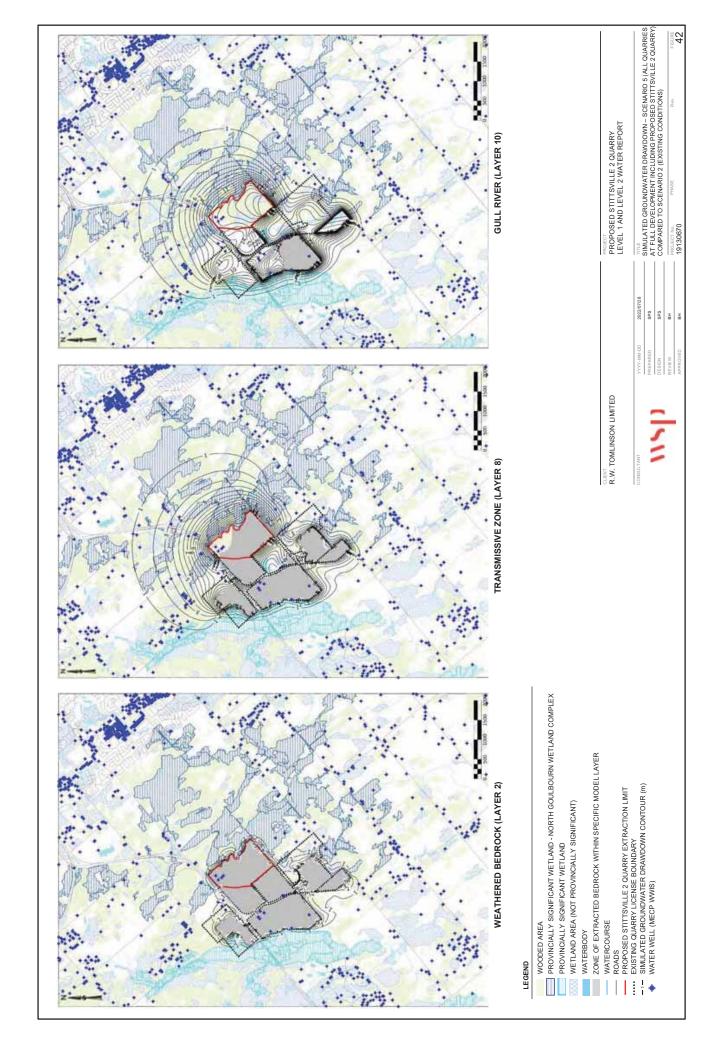


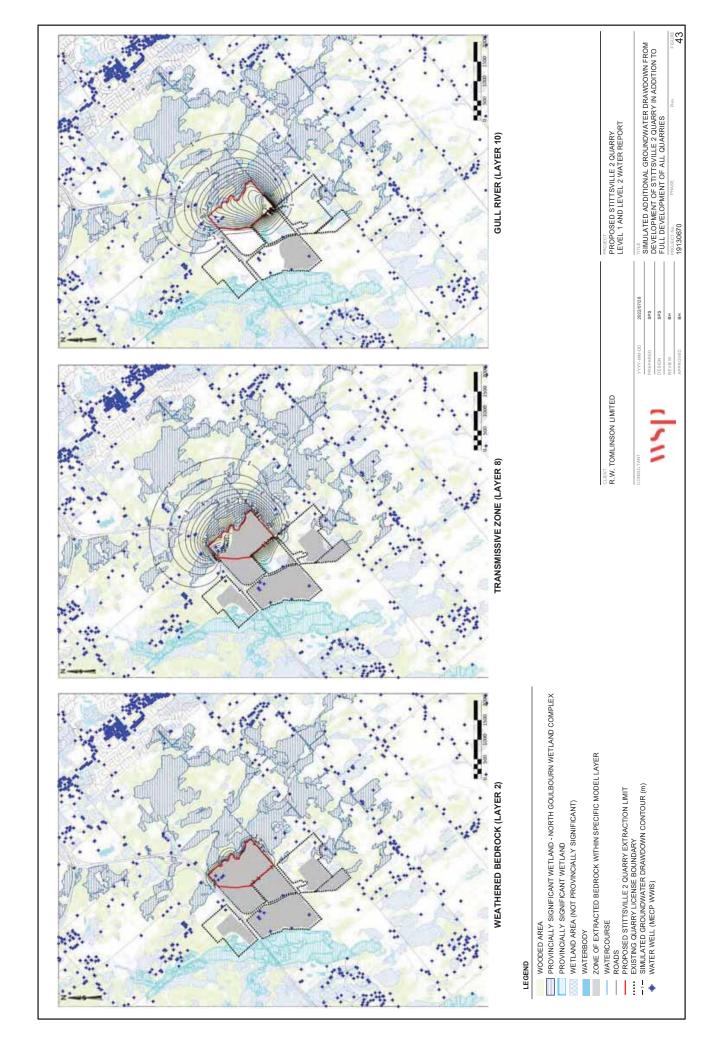


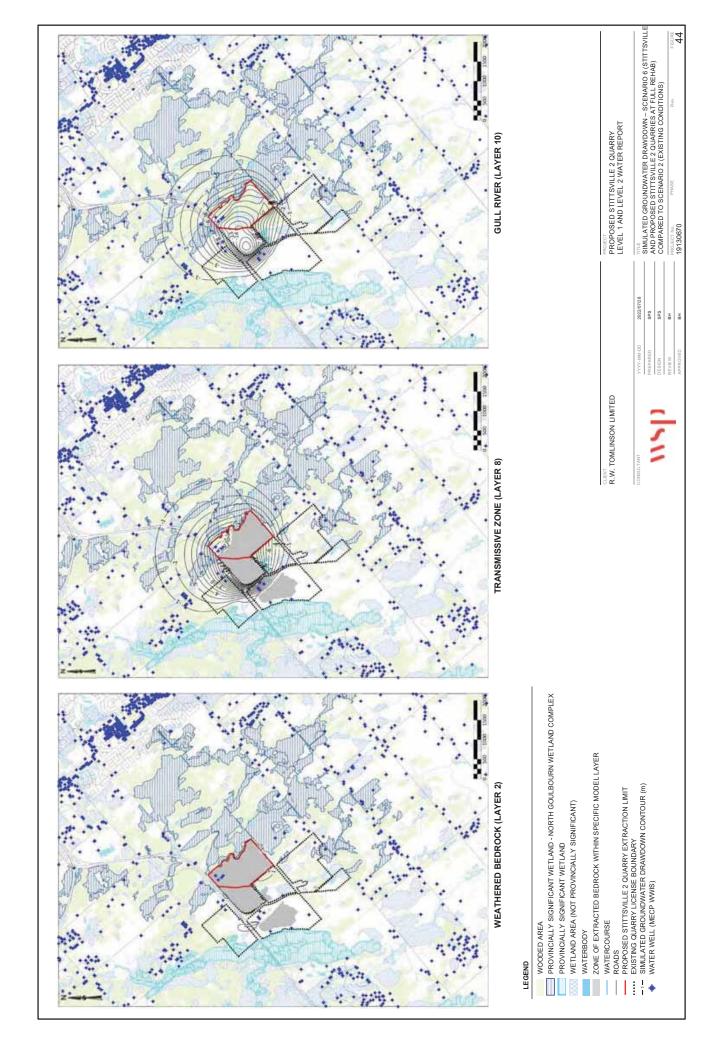


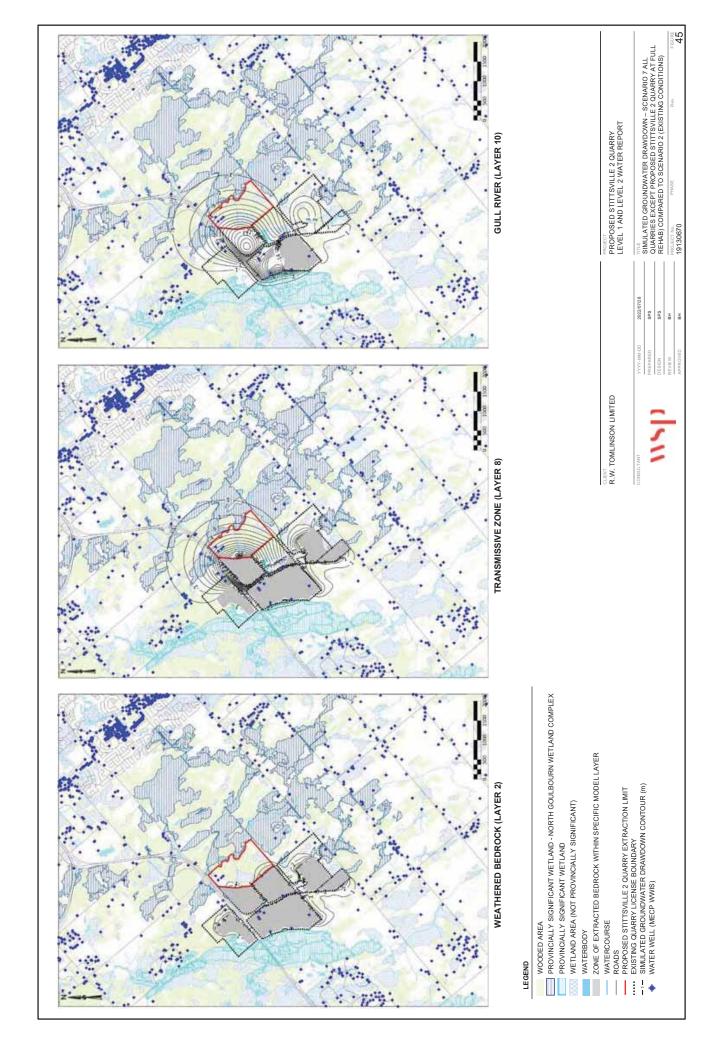


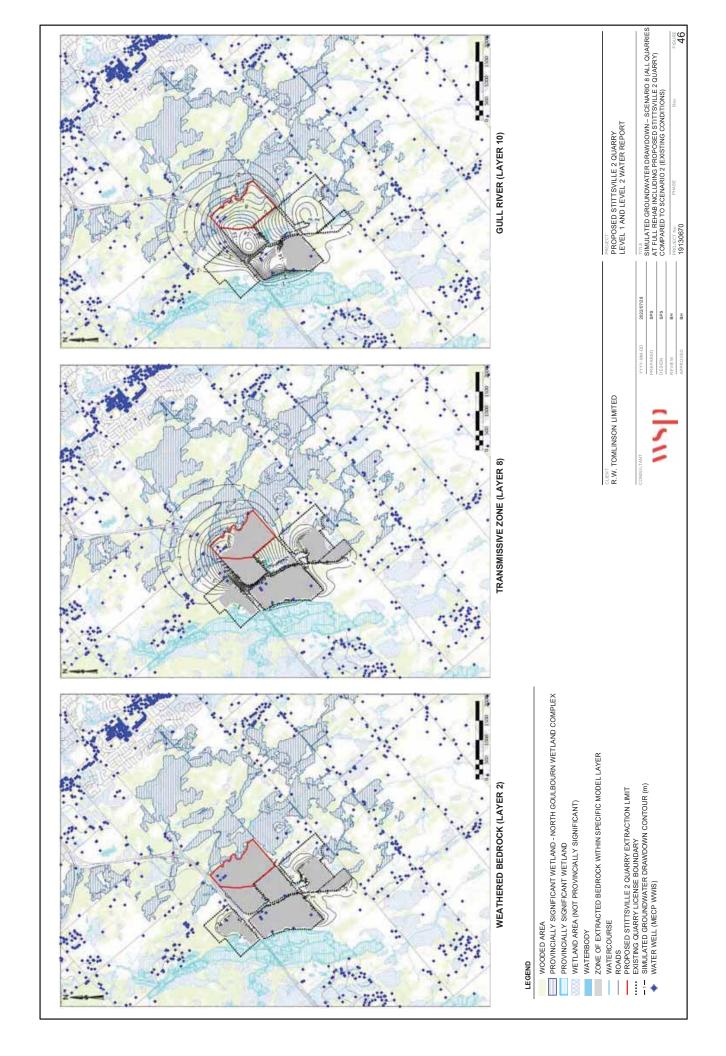


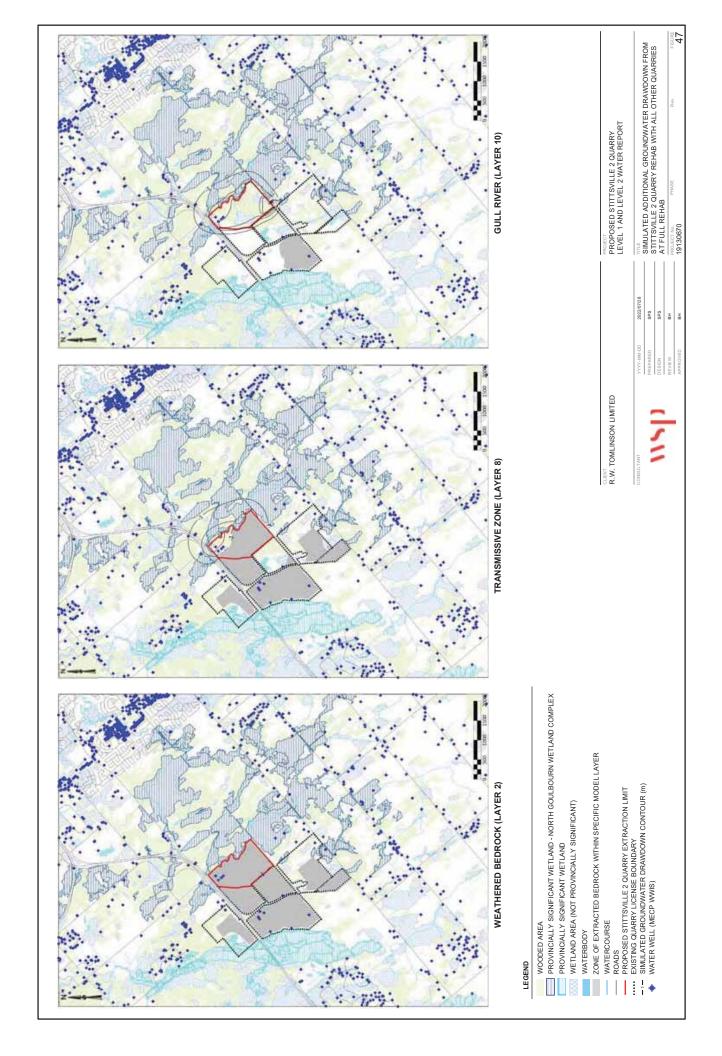


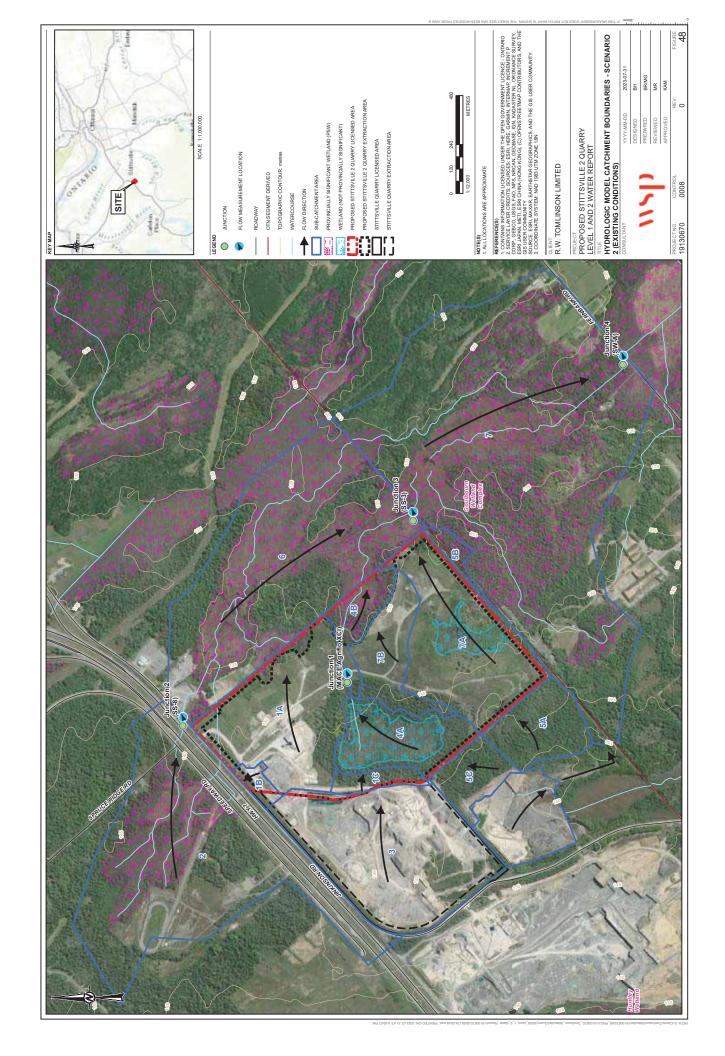


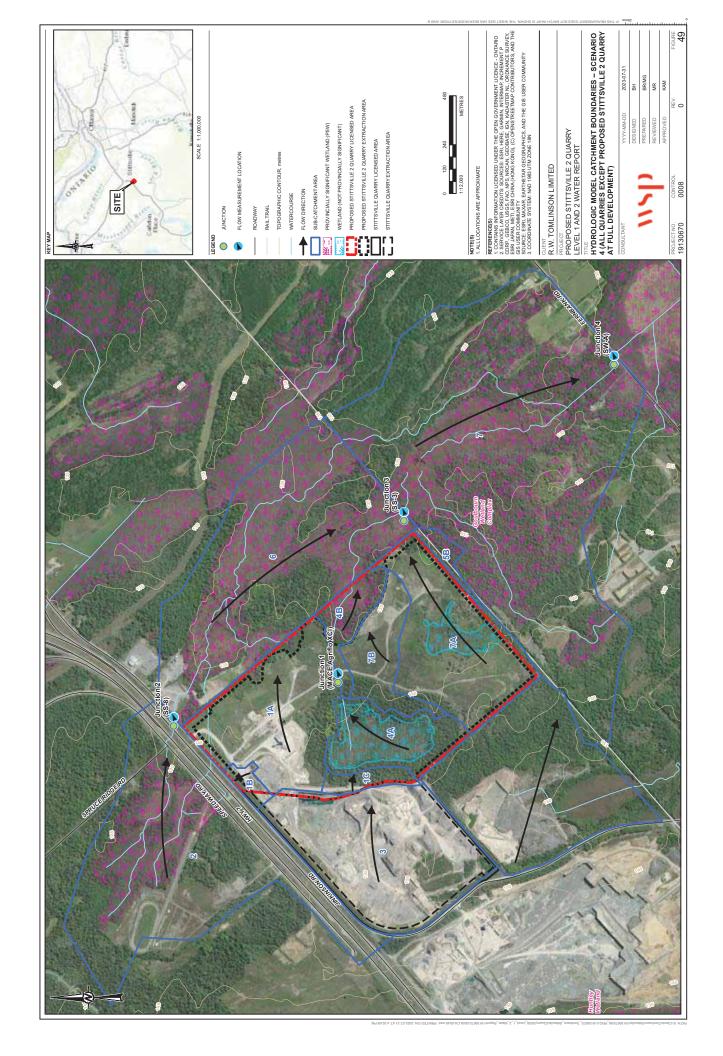


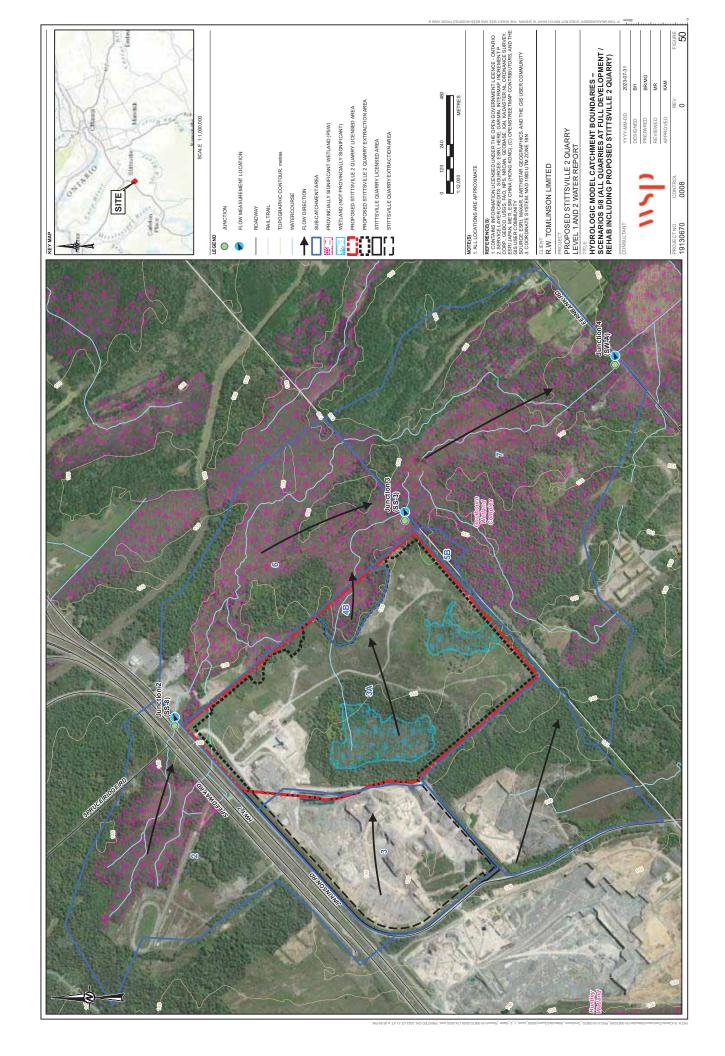


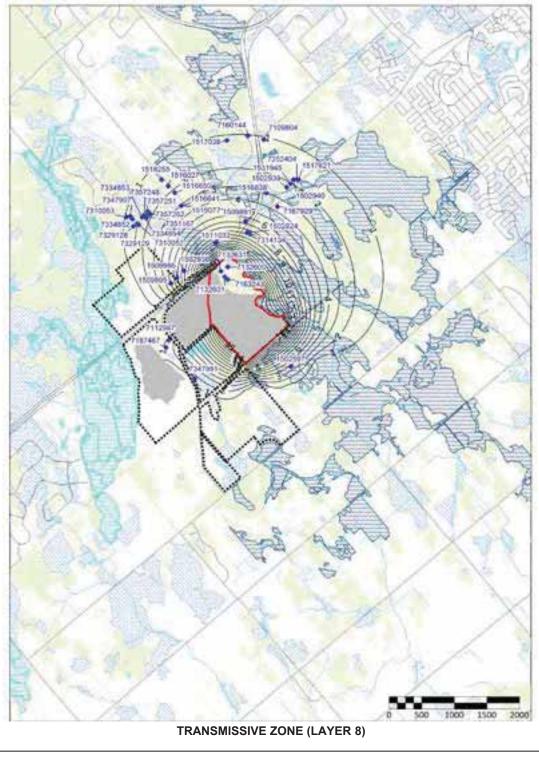












WOODED AREA PROVINCIALLY SIGNIFICANT WETLAND - NORTH GOULBOURN WETLAND COMPLEX PROVINCIALLY SIGNIFICANT WETLAND PROPOSED STITTSVILLE 2 QUARRY EXTRACTION LIMIT WETLAND AREA (NOT PROVINCIALLY SIGNIFICANT) WATERBODY ZONE OF EXTRACTED BEDROCK WITHIN SPECIFIC MODEL LAYER WATER WELL (MECP WWIS)

R.W. TOMLINSON LIMITED

CONSULTANT

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PREPARED	SPS	
DESIGN	SPS	
REVIEW	ВН	
APPROVED	BH	

PROPOSED STITTSVILLE 2 QUARRY LEVEL 1 AND LEVEL 2 WATER REPORT

WWIS WATER WELLS LOCATED WITHIN THE PREDICTED ONE METRE DRAWDOWN CONTOUR IN THE TRANSMISSIVE ZONE

 PROJECT No.
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