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Regional Municipality of Waterloo Cambridge East Water Supply Class Environmental Assessment

Project File Report Appendix A Hydrogeology and Natural Environmental Report

Submitted to:

The Regional Municipality of Waterloo
Transportation and Environmental Services
Department
Water Services Division
150 Frederick St., 7th Floor
Kitchener, ON N2G 4J3

REPORT



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Table of Contents

1.0 Introduction	1
1.1 Class EA Objectives and Problem Statement	1
1.2 Scope of Work	2
1.3 Region Water Supply Strategies and Relevant Studies	3
1.3.1 Well Field Optimization Investigations at Existing Well Sites (2007 to 2016)	4
1.3.2 The Tier 3 Assessment (2008 to 2017).....	4
1.3.3 Water Supply Master Planning (2011 to 2015)	5
1.4 Report Outline	5
2.0 Overview of Study Area.....	6
2.1 Site Setting and Surrounding Land Use	6
2.2 Physiography and Topography	7
2.3 Surface Water Features	7
2.3.1 Speed River Subwatershed	7
2.3.1.1 Irish Creek Subwatershed and Puslinch Lake	8
2.3.1.2 Lower Speed River Subwatershed	8
2.3.2 Mill Creek Subwatershed.....	9
2.3.3 Middle Grand River Subwatershed	10
2.4 Terrestrial and Aquatic Habitat.....	10
2.4.1 Wetlands.....	10
2.4.2 Areas of Natural and Scientific Interest (ANSI)	11
2.4.3 Streams	11
2.4.4 Species at Risk.....	12
2.5 Geology	13
2.5.1 Overburden Geology	13
3.0 Hydrogeological Characterization	19



3.1	Well Field Descriptions and Summary of Optimization Investigations at Existing Well Sites	19
3.1.1	Pinebush Well Field	19
3.1.2	Clemens Mill Well Field	25
3.1.3	Shades Mill Well Field	28
3.1.4	Identified Additional Capacity to Supply WTPs from Existing Well Sites ..	31
3.2	Summary of Class EA Field Investigations and Groundwater Supply Exploration at New Sites	32
3.2.1	Class EA Field Investigations	32
3.2.2	Identified Additional Capacity to Supply WTPs from New Well Sites.....	33
3.3	Municipal Groundwater Use.....	35
3.3.1	Municipal Monitoring Network.....	35
3.3.2	Historical Pumping and Water Levels	35
3.4	Non-Municipal Groundwater Use	38
3.4.1	Non-Municipal Permitted Water Use.....	38
3.4.2	Private Domestic Wells	42
3.5	Groundwater Flow System Characterization.....	42
3.5.1	Hydrostratigraphy	42
3.5.2	Groundwater Flow Directions	43
3.5.3	Well Water Source Zones.....	44
3.5.4	Vertical Hydraulic Connections.....	47
3.5.5	Groundwater/Surface Water Interactions.....	50
3.5.5.1	Wetlands and Lakes	50
3.5.5.2	Streams	56
3.5.6	Groundwater Quality.....	56
3.5.6.1	Organic Groundwater Chemistry	57
3.5.6.2	Groundwater Chemistry at Additional Test Wells.....	58
4.0	Evaluation of Groundwater Pumping Strategies.....	59
4.1	Planning for Future Water Supply Requirements.....	59



4.2	Alternative Solutions	62
4.2.1	Pinebush Well Field Alternative Solutions	62
4.2.2	Clemens Mill Well Field Alternative Solutions	63
4.2.3	Shades Mill Well Field Alternative Solutions	64
4.3	Groundwater Pumping Model Scenarios	65
4.3.1	Long-Term (Steady-State) Simulations.....	65
4.3.1.1	Steady-State Simulated Groundwater Level Drawdown Results	67
4.3.1.2	Steady-State Simulated Effects on Surface Water: Water Balance Assessment.....	69
4.3.1.3	Steady-State Simulated Effects on Surface Water: Individual Streams and Puslinch Lake	71
4.3.2	Short Term Shutdown Contingency (Transient) Simulations	72
4.4	Assessment of Potential Effects.....	75
4.4.1	Potential Well Interference.....	75
4.4.2	Potential Effects on Terrestrial and Aquatic Features.....	76
4.5	Source Water Protection Assessment	77
5.0	Conclusions And Recommendations.....	78
5.1	Conclusions - Water Supply Potential.....	78
5.2	Conclusions - Impact Assessment.....	79
5.3	Recommendations	80
5.3.1	Operational Testing and Adaptive Management.....	80
5.3.2	Monitoring Program	81
6.0	REFERENCES	83

TABLES

Table 1: Conceptual Overburden Hydrogeological Model For Waterloo Region.....	15
Table 2: Revised Bedrock Stratigraphic Framework	17
Table 3: Pinebush Well Field – Tests, Rehabilitations and Modifications at Existing Well Sites	20



Table 4: Pinebush Well Details and Permits to Take Water.....	23
Table 5: Clemens Mill Well Field – Tests, Rehabilitations and Modifications at Existing Well Sites	25
Table 6: Clemens Mill Well Details and Permits to Take Water	27
Table 7: Shades Mill Well Field – Tests, Rehabilitations and Modifications at Existing Well Sites	28
Table 8: Municipal Permits to Take Water	30
Table 9: Well Capacities of New Test Production Wells at Existing Sites	31
Table 10: Summary of IUS Test Well Locations and Groundwater Supply Potential	33
Table 11: Non Municipal Permits to Take Water.....	39
Table 12: Estimated Depths of Well Water Source Zones	45
Table 13: Puslinch Lake Water Balance (from Harden, 1999)	55
Table 14: Pumping Rates and Water Treatment Plant Capacity (L/s)	61
Table 15: Pinebush (PB) Well Field Alternative Solutions.....	63
Table 16: Clemens Mill (CM) Well Field Alternative Solutions	63
Table 17: Shades Mill (SM) Well Field Alternative Solutions	64
Table 18: Summary of Alternative Water Supply Solutions and Steady-State Model Scenarios	67
Table 19: Summary of Horizontal and Vertical Groundwater Connections – Steady-State Model Scenarios	68
Table 20: Steady-State Model Water Balance Calculations - Source of Additional Future Water Supply (L/s)	70
Table 21: Steady-State Simulated Percent Reductions in Stream Baseflow and Groundwater Balance for Puslinch Lake	71
Table 22: Summary of Alternative Water Supply Solutions and Transient Model Scenarios	74
Table 23: Summary of Horizontal and Vertical Groundwater Connections – Transient Model Scenarios	74
Table 24: Recommended Monitoring Locations.....	81



FIGURES

- Figure 1 Cambridge East Study Area
- Figure 2 Location of Integrated Urban System and Supporting Well Fields
- Figure 3 Land Use
- Figure 4 Topography and Drainage
- Figure 5 Surface Water Catchments
- Figure 6 Environmentally Sensitive Features
- Figure 7 Quaternary Geology
- Figure 8 Conceptual Overburden Geological Model
- Figure 9 Bedrock Stratigraphy and Hydrogeological Model
- Figure 10 IUS Project Test Well and Monitoring Well Installation Locations
- Figure 11 Monitoring Locations during Testing
- Figure 12 Current Long-Term Monitoring Locations
- Figure 13 Annual Average Municipal Pumping Rates - Cambridge East Well Fields (1985-2015)
- Figure 14 Annual Average Municipal Pumping Rates by Well Field
- Figure 15a Historical Groundwater Elevation Monitoring
- Figure 15b Historical Groundwater Elevation Monitoring – Pinebush Well Field
- Figure 15c Historical Groundwater Elevation Monitoring – Clemens Mill Well Field
- Figure 16 Non-Municipal Groundwater Users
- Figure 17 Conceptual Model of Groundwater Flow within the Study Area
- Figure 18 Cross-Section Locations
- Figure 19 A-A' Cross-Section
- Figure 20 B-B' Cross-Section
- Figure 21 C-C' Cross-Section
- Figure 22 Interpreted Thickness of the Gasport Formation
- Figure 23 Interpreted Thickness of the Vinemount Formation
- Figure 24 Groundwater Flow in the Deep Bedrock - Gasport Formation
- Figure 25 Groundwater Flow in the Upper Bedrock - Guelph Formation
- Figure 26 Vertical Hydraulic Gradients in the Bedrock Aquifer
- Figure 27 28 Day Pumping Test – Observed Drawdown At The End of Test
- Figure 28 28 Day Pumping Test – Observed Drawdown After 7 Days of Pumping CMPW2-06 (Cedarbrook Well)
- Figure 29 Pinebush 15 Day Pumping Test – Observed Drawdown
- Figure 30a Hydraulic Head Profiles McCormick Point Wetland A-A'
- Figure 30b Interpreted Shallow Groundwater Flow Directions Around Puslinch Lake
- Figure 30c Conceptual Groundwater Flow in the Vicinity of Puslinch Lake
- Figure 31 Water Quality Results – Piper Diagram by Well Field
- Figure 32 Cambridge East WTPs – Long-Term Water Supply Requirements
- Figure 33 Cambridge East WTPs – Alternative Solutions and Simulated Water Supply Scenarios
- Figure 34 Steady-state Simulations – Extent of Drawdown
- Figure 35 Delineation of Subwatersheds for Model Water Balance Calculations



Figure 36 Cambridge East WTPs – Alternative Solutions and Simulated Water Supply
Scenarios – Short-Term Shutdown Contingency (Transient Scenarios)

Figure 37 Transient Simulations – Extent of Drawdown

Figure 38 Source Water Protection Areas

APPENDICES

Appendix A

Field Investigations

Appendix B

Natural Environment Inventory

Appendix C

On-going Region Monitoring Program

Appendix D

Groundwater Modelling



1.0 Introduction

The Regional Municipality of Waterloo (the Region) is undertaking a municipal Class Environmental Assessment (EA) to identify the preferred alternative for optimizing municipal groundwater supply taking in Cambridge East. This Class EA is a component of a larger project; the Integrated Urban System Groundwater Supply Optimization and Expansion Project (IUS Project) that was initiated in 2005 and directed to develop additional supplies in select areas across the Region. The Cambridge East Class EA Study Area, as shown on Figure 1, includes the Pinebush, Clemens Mill and Shades Mill well fields. It is approximately bounded on the west by Franklin Boulevard and extends east of Townline Road to include portions of the Townships of Puslinch and North Dumfries. It is approximately bounded on the north by Highway 401 and extends to Clyde Road in the south.

The Class EA is focused on assessing options for optimizing the Region's municipal well supplies to meet existing treatment capacity at the Pinebush, Turnbull (Clemens Mill) and Shades Mill Water Treatment Plants (WTPs). Golder Associates Ltd. (Golder), in association with Triton Engineering Ltd. (Triton), were retained by the Region to carry out the Class EA. S.S. Papadopoulos & Associates Inc. (SSPA) and Matrix Solutions Inc. (Matrix) were retained by the Region to complete groundwater modelling to support the hydrogeological assessment for the EA.

1.1 Class EA Objectives and Problem Statement

The EA objective is to assess options for optimizing groundwater supply capacity to the Pinebush, Turnbull (Clemens Mill) and Shades Mill Water Treatment Plants (WTPs) located in Cambridge East.

As shown on Figure 1, existing municipal wells supplying the WTPs include wells P10, P11 and P17 (Pinebush WTP), wells G16, G17 and G18 (Turnbull WTP) and wells G7, G8, G38, G39 and G40 (Shades Mill WTP). System wells that do not supply the treatment plants include wells G5/G5A, P9 and P15/P15A (Pinebush well field) and well G6 (Clemens Mill well field). Wells G40 and P15A are permitted but not yet connected to the system. Well P15A is a replacement well for P15, which will be decommissioned once well P15A is online.

The wells that pump to the WTPs have aesthetic water quality issues due to the presence of iron and/or manganese and therefore require treatment beyond disinfection. The wells that do not pump to the WTPs do not have these water quality issues and as a result, they pump directly to the distribution system following disinfection.

In April 2005, as part of the project initiation, the following problem statement was developed for the Cambridge East Water Supply Schedule B Class EA:

The Regional Municipality of Waterloo is currently re-evaluating existing groundwater supplies throughout the Region's Integrated Urban System (IUS) including the Pinebush, Clemens Mill and Shades Mill well fields in the area of Cambridge East. The Region has confirmed that these well fields are currently producing 272 L/s which is significantly below the extraction



rates permitted by the Ministry of Environment permits to take water of 516 L/s and the existing infrastructure treatment capacity of 390 L/s.

The purpose of this study is to undertake an investigation to assess the overall aquifer capacity, restore the capacity of existing well fields and optimize groundwater extraction in the Cambridge East area, recognizing that the Strategic Plan Option in the Region's Long-term Water Strategy/Master Plan includes maximizing the use of water treatment facilities in Cambridge East.

1.2 Scope of Work

This Hydrogeological and Natural Environment Report presents a characterization of existing environmental conditions, interpretation of the field study results and an evaluation of potential effects from optimized pumping scenarios in the Cambridge East Study Area to meet future water demands.

The main activities of the hydrogeological program included:

- A review of available background information including: geological, hydrogeological and hydrological information such as previous study reports, borehole water level and regional climate data, groundwater pumping records and the Region's groundwater monitoring program results;
- A review of available information and testing data for the existing Cambridge East municipal wells including: well construction, pumping tests, operational history, water quality and well rehabilitation activities;
- An extensive test drilling program to assess hydrogeological conditions to the base of the bedrock aquifer including:
 - Drilling, installing and step testing twelve (12) 152 mm (6-inch) diameter test wells;
 - Drilling, installing and step testing five 305 mm (12-inch) diameter test production wells at the five most favourable test well sites; and
 - Monitoring well drilling and installation at 20 sites, including multi-level monitoring wells (72 piezometers) completed in the bedrock and overburden at locations up to about 1 km from the test wells.
- Geophysical logging and flow profiling of boreholes that were completed as test wells and monitoring wells;
- The development of comprehensive monitoring programs in support of a long-term pumping test including: shallow water table piezometers located in environmentally sensitive areas and cold water streams, private wells, multi-level monitoring well nests, staff gauges in lakes and ponds, stream flow measuring stations and ecological monitoring transects;



- A 28-day long-term pumping test with a staggered start of pumping from three test production wells;
- Three additional constant rate pumping tests, ranging from 3 to 6 days in duration, at other test wells and test production wells;
- Sampling for water quality;
- Communication with the public and public meetings focused on the field testing program; and
- Comprehensive analysis of all test data and groundwater modelling completed by SSPA and Matrix (Appendix D) to assess long-term aquifer yields and potential effects on nearby sensitive environmental features and groundwater users.

1.3 Region Water Supply Strategies and Relevant Studies

In 1991, the Region initiated the Long-Term Water Strategy (LTWS), which included development of a Water Supply Master Plan (WSMP) to ensure adequate future supply of water to the Region. In May of 2000, the Region approved this WSMP, which provided a strategy for the long-term water supply to the Region until 2041. A key component of the WSMP is meeting the water demand requirements for the Integrated Urban System (IUS), a distributed network of production wells, a surface water intake, reservoirs, pumping stations and trunk water mains servicing the urban areas of the Region (i.e., municipalities of Waterloo, Kitchener and Cambridge as well as the communities of Elmira and St. Jacobs). This network controls how water is distributed throughout the broader IUS and into the specific pressure zones established within it. Figure 2 shows the location of the IUS supply sources in the vicinity of the Cambridge East Class EA Study Area and other nearby water supply well fields.

The Region initiated the IUS Project in 2005 with the initial objective of developing an additional 265 L/s of groundwater supply from new wells and underutilized wells within the Region's existing well fields, and a further 265 L/s from new areas. Task B of the IUS Project consisted of the Cambridge East Water Supply Class EA to investigate alternatives to supply the underutilized capacity of the Pinebush, Clemens Mill and Shades Mill WTPs in the area of Cambridge East. Golder conducted field investigations between 2005 and 2009, including test well drilling and long-term pumping tests, and identified options to optimize supply capacity to the treatment plants from new well sites.

The May 2000 WSMP was updated in 2007 and concluded that the 2000 plan was still valid. Following the completion of this assessment, the Region determined that water demands in the Region's IUS system had declined since the middle 2000s, due in part to water conservation and efficiency efforts, intensification and economic factors. As a result, this Class EA project timeline was extended to allow the Region to update water supply strategies and demand projections and conduct additional investigations/studies comprising the following:



- Well Field Optimization Investigations at Existing Well Sites (2007 to 2016);
- The Tier 3 Water Budget and Local Area Risk Assessment (2008 to 2017); and
- Master planning including: the Water Supply Master Plan (WSMP), Water Supply and Distribution Operations Master Plan (WSDOMP) and the Water Efficiency Master Plan (2011 to 2015).

1.3.1 Well Field Optimization Investigations at Existing Well Sites (2007 to 2016)

The IUS project Class EA field program focused on the investigation of areas located more than 500 m from existing supply wells, as earlier efforts at rehabilitating wells to restore capacity had not proven successful. In 2007, the Region initiated and implemented a multi-year supply-well upgrade program within the IUS which included a further evaluation of opportunities to restore well capacities and optimize takings at existing well sites in the Pinebush, Clemens Mill and Shades Mill well fields. Typically, the work entailed drilling replacement or new deeper wells located either on the existing well sites, or on adjacent Region owned lands, with the expectation that these wells could be readily permitted under existing Permits to take Water (PTTWs). At well sites supplying the WTPs, these investigations included:

- The deepening and installation of a steel well casing liner in production well G16 at the Clemens Mill well field (Lotowater, 2011);
- The construction and testing of new test production wells P10A, P10B, PBTW1-10, the installation of a steel well casing liner in existing production well P17, and the re-drilling and re-construction of existing production well P11, at the Pinebush well field (Burnside 2010b, 2011; Stantec, 2013a); and
- The construction and testing of a new test production well SMPW1-11 (later to be renamed G40) at the Shades Mill well field (Stantec, 2013b).

The results of these investigations, which are considered as part of this Class EA, are described in more detail in Appendix A of this report. Elsewhere in these well fields, additional investigations and supply well upgrades have also been completed, including construction and testing of new test production wells G5A (Burnside, 2010) and P15A (Stantec, 2015c), and installation of steel well casing liners in wells G6 (Lotowater, 2014a) and P9 (Lotowater, 2014b).

1.3.2 The Tier 3 Assessment (2008 to 2017)

The Region completed a Tier 3 Water Budget and Local Area Risk Assessment (Tier 3 Assessment) of the Region's groundwater supplies in the IUS and selected rural areas, as part of the source water protection process under the Clean Water Act (Matrix and SSPA, 2014). The Tier 3 Assessment included a characterization of existing municipal well fields, development of a numerical groundwater flow model and an assessment of sustainable municipal well pumping strategies to meet future water demands for the IUS. The results from



the Tier 3 Assessment were used to determine the sustainable long-term average day pumping rates from existing municipal wells for the WSMP update.

1.3.3 Water Supply Master Planning (2011 to 2015)

The updated WSMP was finalized in 2015 (Stantec, 2015a) and included optimizing supply capacity at the Cambridge East WTPs as part of the plan. The primary objective of the plan was to optimize the existing and planned water supply sources within the IUS for the medium-term planning horizon (20-year or 2031 based on initiation of the study in 2011) and to determine the water supply required for the long-term planning horizon (40 years or 2051) in order to meet demands, while maintaining a factor of safety in supply capacity. The results of the Tier 3 Assessment and several other studies including the WSDOMP (Stantec, 2015b) and the Water Efficiency Master Plan (Lura and Econics, 2014) were incorporated into the WSMP. The WSDOMP was completed to optimize the operating efficiency of the IUS. The solution of utilizing available capacity of the Cambridge East WTP facilities was selected as one of the preferred solutions of the WSDOMP to: 1) reduce reliance on the Middleton WTP; 2) help the Cambridge East pressure zone become more self-sufficient in terms of water supply sources; 3) provide more operational flexibility; and 4) reduce costs by optimizing use of existing facilities that are currently under capacity rather than building new treatment facilities. The WSDOMP also included planned improvements to more efficiently store and distribute water in these areas.

The water supply requirements of the various sources under consideration for the Cambridge East Class EA, as discussed in Section 4.1, were developed from both the updated WSMP and the WSDOMP.

1.4 Report Outline

This report is organized as follows:

- Section 1: Provides the background to the project, as well as the scope and objectives of the hydrogeological and natural environment studies supporting the Class EA.
- Section 2: Provides an overview of the regional setting and existing natural environment in the Cambridge East Class EA Study Area.
- Section 3: Presents a summary of groundwater use in the Study Area, a summary of the field investigations completed and provides a detailed hydrogeological characterization of the Cambridge East Class EA Study Area.
- Section 4: Provides a summary of the water supply requirements, a summary of the numerical groundwater flow modelling completed and an evaluation of groundwater pumping strategies and potential effects. It also provides a summary of the implications of the evaluated groundwater pumping strategies for source water protection.
- Section 5: Lists conclusions and recommendations developed on the basis of the hydrogeological and natural environment studies.



This hydrogeological and natural environment report is also supported by the following technical appendices:

Appendix A: Field Investigations

Appendix B: Natural Environment Inventory

Appendix C: Region's Ongoing Groundwater Monitoring Program

Appendix D: Groundwater Modelling (SSPA and Matrix, 2016; SSPA, 2017)

2.0 Overview of Study Area

2.1 Site Setting and Surrounding Land Use

The City of Cambridge, Ontario comprises the southern urban centre of the Tri-Cities of the Region of Waterloo, the largest municipality in Canada reliant on groundwater for the bulk of its water supplies. The City of Cambridge is an amalgamation of the former municipalities of Hespeler, Preston and Galt that each developed a water supply system based on groundwater pumping primarily from the bedrock aquifer. The treatment plants that are the focus of this Class EA are shown on Figure 1 and include the Pinebush, Turnbull (Clemens Mill) and Shades Mill plants. The Pinebush treatment plant is supplied by wells P10, P11 and P17, the Clemens Mill (Turnbull) treatment plant is supplied by wells G16, G17 and G18 and the Shades Mill treatment plant is supplied by wells G7, G8, G38, G39 and G40 (note G40 is yet to be commissioned). In addition, wells G5/G5A, P9 and P15/P15A are part of the Pinebush well field and well G6 is part of the Clemens Mill well field but these wells do not supply the treatment plants. Groundwater from the Pinebush and Clemens Mill well fields is obtained from the bedrock aquifer and groundwater from the Shades Mill well field is pumped from both the overburden and bedrock deposits. Figure 1 presents the locations of existing municipal wells.

Much of the Study Area has been developed in the last 25 years, with a mix of residential subdivisions and industrial/commercial development. Prior to this recent development, some older industrial and commercial sites were present along Franklin Boulevard and Pinebush Road, while rural residential development on private services was distributed along some sections of Avenue and Townline Roads in the southeast and east portions of this area. Some of these residences are still on private services while the remainder of the area is now municipally serviced. In the adjacent rural lands in Puslinch, east of Townline Road as well as to the southeast along Avenue Road, land use is primarily agricultural and rural residential. These residences are not serviced and rely on private wells for domestic water supplies. The main natural areas of undeveloped lands in Cambridge East include the Portuguese Swamp, an extensive wetland located in the east central portion of the area, and the Shades Mill Reservoir and Conservation Area, located in the south (Figure 3).



2.2 Physiography and Topography

The topography and drainage in the vicinity of the Study Area are shown on Figure 4. Elevations range from a high of about 320 metres above sea level (masl) in the area of the Pinebush well field, declining to lows of about 270 masl in the Grand River valley to the southwest and lows of 305 masl to the east in the vicinity of Puslinch Lake and to the southeast near Cedarbrook Creek. There are other ridges of high elevation to the east of Puslinch Lake and to the southeast of the Shades Mill well field, declining to about 295 masl toward Mill Creek.

Quaternary deposits, consisting primarily of glacial tills, kames and outwash sands, overlie the bedrock in most of the Cambridge East area. The most prominent topographic features in the area, the Paris and Galt moraines, are marked by broad northeast-southwest trending topographic ridges throughout most of the study area with irregular, hummocky topography and numerous closed depressions and small kettle lakes including Puslinch Lake. The Speed River and Mill Creek, which flow in a southwesterly direction through the Study Area to the Grand River, receive much of their baseflow from these moraines. Poorly drained soils occur in the north central portion of the Study Area at the Portuguese Swamp, with smaller areas generally to the south and east along Townline Road.

2.3 Surface Water Features

Surface water catchments are shown on Figure 5. Surface water drainage in Cambridge East is generally toward the Speed River in the north, the Grand River in the west and Mill Creek in the south. Cedarbrook Creek, in the Clemens Mill area, conveys drainage south to Mill Creek and into the Shade's Mills Reservoir. Locally within the Pinebush well field, surface drainage is toward Portuguese Swamp and easterly toward Puslinch Lake. Natural surface drainage in the area has been largely modified by land development and constructed stormwater management facilities.

The basic hydrologic and ecologic characteristics of the main subwatersheds are summarized and presented in the sections below.

2.3.1 Speed River Subwatershed

The Speed River is a major tributary to the Grand River and includes the Irish Creek Subwatershed and the Lower Speed River Subwatershed in the north of the Study Area. The (intermittent) surface water outflow from Puslinch Lake flows north into Irish Creek; this outflow in turn flows north and discharges into the Speed River. This subwatershed is bounded by the Mill Creek Subwatershed to the south.

The headwaters of the Speed River are located near the Orangeville Moraine to the north east of the City of Guelph. The river generally flows south through Guelph where it is joined by the Eramosa River. The river then flows in a southwesterly direction through the north portion of the Study Area and discharges to the Grand River in the Preston area of Cambridge.



2.3.1.1 Irish Creek Subwatershed and Puslinch Lake

The Irish Creek Subwatershed is summarized below.

- The highest land elevations are around the northeastern boundaries of the subwatershed, with an elevation of about 340 masl. The topography of the area is characterized by gently sloping land, with a low elevation of about 300 masl where the creek discharges to the Speed River. This creek drains an area of 43.1 km² that includes Puslinch Lake.
- Well-drained soils in the area are mostly stony, sandy loam till to the east and south, and gravel and medium sand around the northern and western areas. Some isolated wetlands are located throughout the drainage basin, with poorly drained soils of organic matter and till.
- Land use is primarily agricultural, with some isolated patches of forest cover and rural residential development around Puslinch Lake and along the east side of Townline Road. There is also some aggregate extraction to the north of Highway 401.
- Flow data has not been developed for Irish Creek, aside from three rounds of spot flow measurements collected at two temporary locations by Golder for the Tier 3 Assessment. These two locations are shown on Figure 5 with observed flows of 8, 23 and 31 L/s (691, 1,987 and 2,678 m³/day) at Station IC_10 and 62, 107 and 108 L/s (5,357, 9,245 and 9,331 m³/day) at IC_20 (Golder, 2011).

Puslinch Lake

Puslinch Lake, the largest kettle basin in southern Ontario, is essentially a closed shallow basin with intermittent seasonal outflow during high water conditions to Puslinch Lake Creek and Irish Creek via a swampy area on the north side. The kettle depressions were formed during deglaciation and resulted from melting of ice blocks from retreating glaciers. Kettle lakes gradually develop into bogs and fens when organic matter accumulates in oxygen depleted waters. Average depths over most of the basin during low-water phases in midsummer are less than two metres (Harden, 1999).

Puslinch Lake was characterized by Harden (1999) as part of a study to assess potential rehabilitation options to improve the lake's deteriorating conditions from eutrophication and the resulting infilling. This characterization included the assessment of a basic water balance for the lake and the collection of 40 cores through the lake bottom to characterize the depth of the water, the underlying lake bed organic sediment thickness, composition and chemistry. The catchment area of the Lake is 9.73 km² (Harden, 1999).

Puslinch Lake hydrology and groundwater surface water interactions are described further in Section 3.5.5.1.

2.3.1.2 Lower Speed River Subwatershed

The characteristics of the Lower Speed River Subwatershed are summarized below.



- The northern boundary of the Lower Speed River Subwatershed lies within the City of Guelph limits and the subwatershed extends southwest toward Cambridge, with a range of elevations from approximately 320 masl at its highest point in the north to 270 masl at its southern boundary, marked by its confluence with the Grand River.
- Much of the upstream section of the subwatershed, particularly along the Speed River bed, is comprised of well-drained gravelly soils, surrounded by loam, with medium sand in the southern reaches and some poorly drained areas.
- The Eramosa River drains into the Speed River within the City of Guelph and other major tributaries include Hanlon Creek, Irish Creek and Ellis Creek. The drainage area of the Lower Speed River is 91.3 km².
- Much of the land in the subwatershed is built-up to the north and south where the Speed River flows through Guelph and Cambridge, while the other dominant land use is open agricultural land with some forest bordering the river itself.

2.3.2 Mill Creek Subwatershed

The Mill Creek Subwatershed is summarized below and is described in detail in the Mill Creek Subwatershed Plan (CH2M Gore and Storrie Ltd. et al., 1996).

- The Mill Creek Subwatershed is long and narrow with the headwaters located southeast of the City of Guelph. The creek flows in a southwest direction for approximately 30 km, passing through the Shade's Mill Reservoir near its discharge to the Grand River at the south end of Cambridge. The Mill Creek Subwatershed is approximately 104 km² in area and is adjacent to the Lower Speed River Subwatershed to the north, and by the Fairchild Creek and Moffat Creek subwatersheds to the south.
- Soils in the area are mostly stony, sandy loam till and loam till with good drainage, as well as some well-drained gravel in the center of the drainage basin, south of Victoria Road. The lands in the valley surrounding Mill Creek, as well as to the south in the Cambridge area, are comprised of poorly drained till with organic matter found principally in the wetland areas.
- The highest land elevation in this subwatershed is located along the Paris Moraine in the north, with an elevation of about 360 masl, with lower elevations of about 300 masl adjacent to the creek. The topography is hummocky with some steep slopes and many natural closed depressions, some of which contain ponds and wetlands.
- This subwatershed encompasses a variety of land uses, including residential and commercial developments in the south around the City of Cambridge, several relatively large areas of dense forest and extensive open agricultural land. Numerous aggregate extraction sites are present in the central and upper sections of this creek.
- Mill Creek is a groundwater-fed stream resulting in cool to cold water over most of its length, with the exception of warming influences of ponds such as Mill Pond, Shade's Mills Reservoir and Aberfoyle Pond (CH2M Gore and Storrie Ltd. et al., 1996).



- The catchment area of the Mill Creek stream gauge at Sideroad 10, GRCA Station #8797042 (former WSC station 2GAC19), is approximately 82 km². Based on data collected at GRCA Station #8797042, the mean annual flow for this catchment area of Mill Creek is approximately 877 L/s (75,573 m³/day) (Golder, 2011b). Three rounds of spot flow measurements were collected by Golder in 2008 at a temporary location MC_20, further upstream in Mill Creek for the Guelph Tier 3 Assessment. The observed flows were 384, 383 and 408 L/s (33,178, 33,091 and 35,251 m³/day) at MC_20 (Golder, 2011b). The locations of MC_20 and GRCA Station #8797042 are shown on Figure 5.

2.3.3 Middle Grand River Subwatershed

The Middle Grand River Subwatershed is summarized below.

- The Middle Grand River Subwatershed, from the confluence of the Conestogo River to the Nith River, is the most urbanized part of the subwatershed. It contains parts of the cities of Waterloo, Kitchener and Cambridge. The natural river channel has been altered in places and increased areas of impervious surfaces in urban areas have led to some localized flooding (Lake Erie Region Source Protection Committee, 2015).
- Flow through the Middle Grand is regulated through upstream reservoirs. Spring flows are reduced by the reservoirs which capture the spring snow melt, and flows during the summer are augmented by the reservoirs (Lake Erie Region Source Protection Committee, 2015).
- The catchment area of the Middle Grand River Subwatershed at the WSC Station downstream of the discharge of Mill Creek (shown on Figure 5 as Station 02GA003) is approximately 3,515 km².

2.4 Terrestrial and Aquatic Habitat

This section summarizes existing terrestrial and aquatic habitat conditions in the Cambridge East Study Area. A technical memorandum describing the environmental inventory completed to support the Cambridge East Class EA is included in Appendix B. The features in the Study Area that have provincial or federal designations based on their ecological importance and sensitivity are described in this section. These include four provincially significant wetlands (PSW) and three regionally significant Areas of Natural Scientific Interest (ANSI) as shown on Figure 6. These features are based on Land Information Ontario (LIO) mapping from the Ontario Ministry of Natural Resources and Forestry (MNRF) (LIO, 2016).

2.4.1 Wetlands

The PSWs in the Study Area include the following.

- **Puslinch Lake – Irish Creek Complex** - This PSW of about 3.7 km² in area is located to the east of Townline Road and south of Highway 401, with Puslinch Lake, a large kettle basin, within the centre of the wetland complex. Surrounding wetland is composed of four wetland types (2% bog, 2% fen, 47% swamp and 49% marsh), including the McCormick Point Wetland, a peatland bog that has been studied extensively by the University of



Waterloo (Currie, 1995; Warner, 2010). Ecological functions of the Puslinch Lake-Irish Creek Complex include an active feeding area of nesting water birds, winter cover for wildlife with local significance for deer and regional significance for waterfowl staging.

- **Mill Creek Wetland Complex** – This PSW partially overlaps with the Galt Creek and Forest ANSI described below, totalling 5.4 km² in area.
- **Portuguese Swamp** – This PSW is located immediately south of municipal supply wells P11 and P17 and is also classified as an Environmentally Sensitive Policy Area (ESPA) by the Region. It is approximately 0.6 km² in area and consists of two wetland types (95% swamp and 5% marsh). Its ecological functions include an active feeding area for nesting waterbirds and winter cover for wildlife.
- **Moffat Creek Swamp** is a PSW located in the southern portion of the Study Area that is approximately 1.5 km² in area.

2.4.2 Areas of Natural and Scientific Interest (ANSI)

The areas designated as having Natural and Scientific Interest (ANSI) in the Study Area include:

- **Puslinch Lake Bog and Wetlands** – This is a regionally significant life science ANSI that largely corresponds with the Puslinch Lake – Irish Creek Complex PSW. It is noted that much of this area is designated as Core Greenlands in the Wellington County Official Plan (2015).
- **Galt (Mill) Creek and Forest** is a regionally significant life science ANSI located to the east of Townline Road and to the north of Concession 1. It is comprised of lowland mixed and coniferous swamp forest with some upland forest.
- **Puslinch Tract (Paris Moraine)** is designated as an earth science ANSI and is located to the northeast of Puslinch Lake and south of Highway 401.

2.4.3 Streams

The named watercourses in the Study Area and their thermal designations are as follows (LIO, 2016):

- Cedarbrook Creek (Cold water) - a small tributary to Mill Creek;
- Mill Creek (Cold water);
- Moffat Creek (Cold water); and
- Irish Creek (Warm water).

Warm water aquatic features are generally considered to be more robust and tolerant to external effects. Fish species occupying warm water are likewise considered to be more tolerant to changes in groundwater discharge. In contrast, cold water systems are supported



by significant groundwater inputs and are considered to be capable of supporting cold water fish species, which may be sensitive to reductions in groundwater discharge.

Fish species reported in watercourses within the Study Area include a range of cold to warm water species. There are approximately 83 native and non-native fish species present in waterbodies of the Study Area. Coldwater species such as brook trout (*Salvelinus fontinalis*) and mottled sculpin (*Cottus bairdii*) and top predator warm water species such as largemouth bass (*Micropterus salmoides*), northern pike (*Esox Lucius*) and walleye (*Stizostedion vitreum vitreum*) are resident in many areas, but the more dominant and common fish groups are represented by baitfish (i.e. minnows) (Wright and Imhof, 2001).

A fish inventory of Cedarbrook Creek was conducted by Golder in 2006 prior to the 28-day aquifer test. Based on the results of the inventory, 108 fish were caught consisting of 16 species. One adult brook trout was observed, and Cedarbrook Creek was assessed to provide potential spawning habitat for this species. Although two brown trout (*Salmo trutta*) were observed, habitat characteristics of the creek indicated it was not suitable spawning habitat for brown trout. Other common species observed included creek chub (*Semotilus atromaculatus*), blacknose dace (*Rhinichthys atratulus*), fathead minnow (*Pimephales promelas*), and bluntnose minnow (*Pimephales notatus*).

Sixteen species of fish are known to occur in Puslinch Lake, including northern pike (*Esox lucius*), white sucker (*Catostomus commersoni*), brown bullhead (*Ameiurus nebulosus*), yellow perch (*Perca flavescens*), smallmouth bass (*Micropterus dolomieu*) and largemouth bass. In addition, walleye have been stocked historically in the lake (Bonter et al. 2000) but their current status and success of the stocking efforts are not well documented.

2.4.4 Species at Risk

Based on the desktop assessment, 30 species designated as special concern, threatened or endangered under the Endangered Species Act (ESA) or the Species at Risk Act (SARA) were assessed to have moderate or high potential to occur within the Study Area (Appendix B). Of these, 18 have been designated as threatened or endangered under the ESA and receive individual and habitat protection. The other species with moderate or high potential, as indicated in Attachment 1 of Appendix B, do not have regulatory protection. However, habitat for these species must still be considered under the Significant Wildlife Habitat criteria of the Provincial Policy Statement (PPS) in the impact assessment for the EA:

- Six (6) birds (bank swallow, barn swallow, bobolink, chimney swift, eastern meadowlark, whip-poor-will);
- Four (4) mammals (small-footed myotis, little brown myotis, northern myotis, and tri-colored bat);
- Two (2) fish (redside dace and silver shiner);
- One (1) mollusc (wavy-rayed lampmussel);
- One (1) reptile (Blanding's turtle); and



- Four (4) vascular plants (American columbo, butternut, eastern flowering dogwood, and false hop sedge).

The majority of potential suitable habitat for these Species at Risk (SAR) is concentrated in the woodlands, wetlands and lakes in the Study Area (Figure 6). Some species, such as chimney swift, may also use anthropogenic structures for habitat. Based on the results of surveys conducted for another project that overlapped the southern end of the EA Study Area, three bird SAR have been recently observed (Savanta, 2015). These include barn swallow (*Hirundo rustica*), bobolink (*Dolichonyx oryzivorus*), and eastern meadowlark (*Sturnella magna*). Surveys completed in the Puslinch Tract Conservation Area have also identified several SAR, including little brown myotis, barn swallow, and eastern meadowlark (GRCA, 2004).

2.5 Geology

Municipal groundwater supplies in Cambridge East are derived primarily from the Paleozoic bedrock formations, which comprise a regionally extensive bedrock aquifer system. The Quaternary overburden sediments in the Shades Mill well field of Cambridge also provide some municipal supply although these deposits are localized in extent and generally less productive than the regional bedrock aquifer system.

2.5.1 Overburden Geology

In 1987, Karrow mapped and described the surficial Quaternary geology of Cambridge East (Karrow, 1987). The Ontario Geological Survey (OGS) surficial geology mapping for the Study Area is shown on Figure 7 (OGS, 2010). The surficial geology in the Study Area consists largely of sand and gravel outwash deposits (unit 7a and 7b) to the east of the Grand River and south of the Speed River. The Paris and Galt moraines are situated throughout most of the study area, extending in a northeast to southwest direction. Wentworth Till (unit 5b) overlies the Paris and Galt moraines. There are some organic deposits (unit 20) along the Mill Creek valley and the Puslinch Lake-Irish Creek Complex. There are some alluvial deposits (unit 19) in the vicinity of the Shade's Mills reservoir and along Mill Creek downstream from the Shade's Mills reservoir.

The thickness of the overburden deposits in the Study Area generally ranges from about 15 to 40 m. Bajc and Shirota (2007) developed a conceptual geological and hydrostratigraphic model for the Region that consists of an aquifer/aquitard sequence with 18 overburden units. Delineation of some of these OGS hydrostratigraphic units is difficult in parts of Cambridge due to similar lithologies of some of the tills and sand and gravel deposits present in this area. In Cambridge, only six of the 18 OGS model units are interpreted as regionally significant. This conceptual Quaternary geological model for the Region of Waterloo is presented schematically on Figure 8.

The key OGS model units present in Waterloo Region and the Study Area are highlighted below in Table 1 and shown on Figure 8. The OGS nomenclature uses "AT" for less permeable stratigraphic units that act as aquitards and "AF" for more permeable stratigraphic



units that represent aquifers. These hydrostratigraphic units are lettered sequentially from A to G, from youngest to oldest and are described below.

- **Wentworth Till (*Aquitard ATA2*)** is a stony, sandy silt to sand-textured till. This till was deposited by the last glacier to advance in the area and is mapped as the surficial deposit in the eastern part of Cambridge and into Puslinch and North Dumfries Townships (Unit 5b on Figure 7). In the Study Area, this till is generally less than 10 m thick and is often interbedded with sand and gravel. This till is coarse-grained with an open structure; precipitation falling on this till generally readily recharges the underlying soils. This till can be difficult to distinguish from other coarse tills and sand and gravel deposits.
- **Outwash Deposits (*Aquifer AFA2*)** is a unit of outwash sand and gravel in the Grand River Valley and vicinity (Unit 7a on Figure 7). Sand and gravel deposits are the primary Quaternary deposit in the area, with thicknesses generally between 10 and 30 m, and in some cases up to 40 m. These deposits are interpreted as the main production aquifer for the Shades Mill municipal wells. Bajc and Shirota (2007) note a coarsening upward sequence with silts and fine sands at depth in this outwash that are represented as aquitard unit ATA3. There is not an adequate data distribution to map ATA3 regionally, although it has been included in the conceptual model for the Cambridge Landfill area, located on the north flank of the Galt Moraine (Golder, 2008), where local scale high quality data are available to distinguish this unit.
- **Port Stanley Till (*Aquitard – ATB1*)** consists of fine-grained sandy silt to silty sand deposits which are sometimes stony. The Port Stanley Till was deposited by ice advancing from the Erie-Ontario ice lobe. These deposits are discontinuous across the Study Area and where present, are generally less than 10 m thick, although they have been mapped as being up to 30 m thick in isolated areas. This unit is finer grained than the Wentworth Till and behaves as an aquitard.
- **Waterloo Moraine Stratified Sediments (*Aquifer – AFB1*)** is a fine sand with some gravel. It corresponds with the mapped surficial ice contact sands and gravels in the Study Area (Unit 6 on Figure 7) and is present to the west of Puslinch Lake. Where the Waterloo Moraine Stratified Sediments are not present, the Port Stanley Till may directly overlie the underlying Catfish Creek Till.
- **Catfish Creek Till (*Aquitard ATC1*)** is a dense stony sandy silt to silty sand till that was deposited by a major glacial advance from the north to northeast that covered all of southern Ontario. It is generally less than 5 m thick in the Study Area and is discontinuous. In some locations in the Study Area, the Catfish Creek Till is found immediately overlying bedrock beneath clayey sediments. The Catfish Creek Till is difficult to distinguish from the other coarse tills and sand and gravel deposits in the Study Area since it has a low clay content and is often interbedded with sand and gravel. Hydrogeologically, properties of the Catfish Creek Till range from good aquitard to poor aquifer depending on local lithology and the amount of compaction and/or cementation.



- **Pre-Catfish Creek Sand and Gravel (Aquifer AFD1)** is a coarse grained sand and gravel deposit. This unit is discontinuous, rests on the weathered bedrock surface and is hydraulically connected with the upper weathered portion of the bedrock aquifer in the Study Area.

Table 1: Conceptual Overburden Hydrogeological Model For Waterloo Region

OGS Layer Name¹	OGS Hydrostratigraphic Unit Description	Predominant Materials
ATA1	Whittlesey clay	Silt and clay
AFA1	Whittlesey sand	Very fine to coarse sand
ATA2	Wentworth Till – may contain stratified drift	Stony, sandy till
AFA2	Outwash deposits – mainly Grand River outwash	Coarse sand and gravel
ATA3 ²	Fine-grained deposits (confined to Grand River valley)	Sandy silt and silt
ATB1	Upper Maryhill Till	Silty to clayey till
	Port Stanley Till	
AFB1	Upper Waterloo Moraine stratified sediments and equivalents	Mainly fine sand, some gravel
ATB2	Middle Maryhill Till and equivalents	Silty to clayey till, silt, clay
AFB2	Middle Waterloo Moraine stratified sediments and equivalents	Mainly fine sand, some gravel
ATB3	Lower Maryhill Till	Silty to clayey till
AFB3	Lower Waterloo Moraine stratified sediments or Catfish Creek outwash	Layered gravel, sand or silt; (Historical- sand, gravel)
ATC1	Upper/Main Catfish Creek Till	Stony, silty to sandy till
AFC1	Catfish stratified deposits	Sand and gravel
ATC2	Lower Catfish Creek Till	Stony, silty to sandy till
AFD1	Pre-Catfish Creek sand and gravel	Sand and gravel
ATE1	Canning Drift (pre-Catfish Creek Till)	Silty to clayey till, silt, clay
ATG1	Pre-Canning coarse-textured till	Stony, silty to sandy till
Bedrock	Guelph, Salina, Bass Islands, Bois Blanc Fm	Limestone, Dolostone, Shale

NOTES:

¹⁾ OGS units defined by the work completed by Bajc and Shirota (2007).



- 2) Unit ATB3 has been delineated in isolated areas in the Cambridge Landfill Area (Golder, 2008).

 Key overburden hydrostratigraphic units present in the Cambridge East Area.

2.5.2 Bedrock Geology

Bedrock formations in Cambridge East consist of limestone, dolostone and shale sequences that form an active groundwater flow system that is generally about 100 m in thickness. The bedrock formations dip gently (about 4 degrees) to the southwest (Karrow, 1987). These Paleozoic bedrock formations comprise one of the most extensive bedrock aquifers in Ontario that is the principal source of drinking water supplies for a number of municipalities, including the City of Guelph, located about 20 km to the northeast of Cambridge. Numerous domestic water wells within and to the east of Cambridge derive water supplies from this bedrock aquifer.

Figure 9 and Table 2 schematically illustrate the main Paleozoic bedrock formations present within the Study Area. The Ontario Geological Survey (OGS) has revised the nomenclature of Silurian dolostones in Southern Ontario during the course of the EA. The revised bedrock nomenclature for the Guelph and Cambridge areas was developed based on historical and recent detailed test borehole drilling and geologic logging undertaken by the OGS, the City of Guelph and the Region of Waterloo.

Table 2 shows the revised stratigraphic framework described by the OGS (Brunton, 2008, 2009; Brunton and Brintnell, 2011), compared to the stratigraphic framework that was previously used for the Cambridge area. The stratigraphy described in this report is consistent with this revised stratigraphic framework. However, it is noted that most of the borehole logs for this project were completed prior to the adoption of the revised stratigraphic framework and therefore refer to the previous geological nomenclature.



Table 2: Revised Bedrock Stratigraphic Framework

Revised Stratigraphic Framework		Previous Stratigraphic Framework	
Overburden		Overburden	
Guelph Formation	Hanlon Member	Guelph Formation	
	Wellington Member		
Eramosa Formation	Stone Road Member	Amabel Formation	Eramosa Member
	Reformatory Quarry Member		
	Vinemount Member		
Goat Island Formation	Ancaster / Niagara Falls Members		Warton / Colpoy / Lions Head Members
Gasport Formation	Gothic Hill Member		
Rochester / Irondequoit / Rockway / Merritton Formations			
Cabot Head Formation		Cabot Head / Reynales Formation	

SOURCE: Brunton, 2008, 2009; Brunton and Brintnell, 2011

The underlying bedrock geology generally comprises the following sequence in the Cambridge East area (from youngest to oldest):

- **Guelph Formation** consists of medium to thickly bedded crinoidal grainstones, wackestones and reefal complexes (Brunton, 2009). It is cream-coloured fossiliferous dolostone that is an important aquifer in Cambridge East, where it is most often the uppermost bedrock unit. It is typically 20 to 40 m thick in the Study Area.
- **Eramosa Formation – Reformatory Quarry Member** is a light brown to cream-coloured, pseudonodular, coarsely crystalline dolostone which is thickly bedded (Brunton, 2008). The Reformatory Quarry Member is a poor aquifer or a poor aquitard. Due to its uniform fine dolomite crystallinity, this unit is susceptible to karstification (Brunton, 2009). This unit also often contains mud-rich and microbial mat-bearing lithofacies that may act as a local aquitard, reducing the vertical permeability across this unit. In previous studies, this unit was logged as either the Guelph Formation or the Eramosa Member.
- **Eramosa Formation – Vinemount Member** is a dark grey to black dolostone unit. It consists of thinly bedded, finely-crystalline dolostone with shaley beds which give off a distinctive petroliferous odour when broken (Brunton, 2009). The Vinemount Member is absent over much of the City of Cambridge and is typically less than 10 m thick where present in the Study Area. This unit represents an aquitard where it is present.
- **Goat Island Formation** consists of two members: the upper Ancaster Member and lower Niagara Falls Member. The Ancaster Member is a grey, chert rich, finely crystalline dolostone. The Niagara Falls Member is a finely crystalline and cross laminated crinoidal grainstone with small reef mounds (Brunton, 2009). The finely crystalline nature of this



formation results in a lower hydraulic conductivity and transmissivity compared to the underlying Gasport Formation.

- **Gasport Formation** is a cross-bedded crinoidal grainstone-packstone with sequences of reef mound and coquina (shell bed) lithofacies (Brunton, 2009). In previous studies, this unit was referred to as the Amabel Formation. In Cambridge East, the formation generally varies in thickness from about 25 m to greater than 100 m. In the upper sections of the reef mounds, this formation is highly transmissive. This formation has been divided into upper, middle and lower hydrostratigraphic units to allow for general representation of the vertical distribution of the more transmissive reef mound and coquina shell bed lithofacies. Generally in Cambridge East, the lower 10 to 20 m of this formation has a much lower permeability than the upper and middle portions of the formation.

The following four bedrock units generally comprise a total cumulative thickness of about 4 to 5 m underlying the Gasport Formation. These are not often identified in borehole records as they are not readily distinguished from the Gasport Formation and thus are typically described as lower or undifferentiated Gasport Formation. They exhibit similar low permeability properties.

- **Rochester Formation** is a calcareous shale with carbonate interbeds (Brunton, 2009). It is a thin unit which is 1 to 2 m thick.
- **Irondequoit Formation** is a medium to thickly-bedded crinoidal grainstone (Brunton, 2009) with a thickness of approximately 3 m in Cambridge East.
- **Rockway Formation** is a greenish-grey, finely-crystalline argillaceous dolostone with shaley partings (Brunton, 2009). It ranges in thickness from about 1 to 2 m.
- **Merriton Formation** consists of a pinkish-brown, finely-crystalline dolostone with shaley partings (Brunton, 2009). Where present, it is usually less than 1 m thick.
- **Cabot Head Formation** is grey-green non-calcareous shale that is interbedded with sandstone and limestone. It ranges in thickness from 10 to 39 m (Johnson *et al.*, 1992). The Cabot Head shale acts as a regional aquitard forming the lower boundary of the active groundwater flow system in Cambridge East.



3.0 Hydrogeological Characterization

3.1 Well Field Descriptions and Summary of Optimization Investigations at Existing Well Sites

A number of groundwater supply studies in support of the development of municipal groundwater supplies have been conducted in this area beginning with an Ontario Water Resources Commission (OWRC) study dating from 1963 and a follow up study completed in 1965. It is noted that some of the first wells in Cambridge East were drilled prior to these studies. These and more recent water supply studies and well performance tests have been documented in reports for the Cambridge East area, including those completed by Golder (1991), Lotowater (1997), Burnside (2010a,b, 2011), Golder (2011a) and Stantec (2013a,b, 2015a). This section provides a description of the well fields including recent testing, rehabilitation and well modification/replacement work that has been done at existing well sites.

Within the Cambridge East Class EA well fields, the Region of Waterloo now operates the following existing municipal wells at the locations shown on Figure 1:

- Pinebush Well Field - Three bedrock wells that supply the Pinebush WTP (P10, P11, and P17) and five additional bedrock wells (G5, G5A, P9, P15 and P15A) that do not supply the WTP. Well P15A is a replacement well for P15 that has been drilled but is not yet connected to the system. P15 will be decommissioned when P15A comes online. Well P10 was constructed prior to the Ontario Water Resources Act and therefore does not require a PTTW;
- Clemens Mill Well Field - Three bedrock wells (G16, G17 and G18) that supply the Turnbull WTP and one bedrock well (G6) that does not supply the WTP; and
- Shades Mill Well Field - Five overburden wells (G7, G8, G38, G39 and G40) that supply the Shades Mill WTP. Well G40 was recently constructed to help supply the Shades Mill WTP; it is permitted but not yet connected.

Further descriptions of the wells in these well fields are provided below.

3.1.1 Pinebush Well Field

The Pinebush well field is located to the south of Highway 401 in the northern portion of the Cambridge East Study Area. Production wells in the Pinebush well field were constructed in the late 1950s, except for P17, which was constructed in 1994. Wells G5 and G5A pump directly to the distribution system following UV treatment, while P9 and P15/P15A can either be pumped directly to the distribution system or to the Rahman's Reservoir and Pumping Station located next to P9 and P15/P15A, following chlorination. Wells P10, P11 and P17 are pumped to the Pinebush WTP, where water is treated for iron and manganese and chlorinated, prior to being discharged to the distribution system.

Details regarding well performance assessments, rehabilitation programs and well replacements for wells in the Pinebush well field are summarized in Table 3.



Table 3: Pinebush Well Field – Tests, Rehabilitations and Modifications at Existing Well Sites

Well	Activity	Date	Comments
Pinebush Well Field			
P11 / P17	Variable Rate Step Testing and Flow	February 2004	Wells linked along a deep and very productive fracture so cannot pump both wells at the same time.
P10	Well and Pump Maintenance	June 2004	Sonar Jetting and airlift development resulted in performance restored to 1982 levels.
G5A	New Production Well	April 2009	New production well G5A drilled beside G5, cased through the upper bedrock (Reformatory Quarry Fm) and open in deeper water producing zones (Goat Island and Gasport Fms).
G5	Liner Installation	June 2009	A 225 mm diameter steel liner installed and cemented into place to a depth of 22.3 m below ground surface.
G5A	Variable Rate Step Testing pre and post Acid Injection	June 2009 and December 2009	Initial capacity of the well was less than 15 L/s. After enlarging water producing intervals by acid injection, airlift pumping and surging, a specific capacity of 0.7 L/s/m was measured while pumping at 21 L/s.
P10	Well Reconstruction	January 2010	Sealed low water producing zone at bottom of the well (33.5 to 64 m bgs) with bentonite and capped with cement.
P10A	New Production Well and Variable Rate Step Testing	April to May 2010	New production well P10A drilled beside P10, cased through the upper bedrock (Guelph Fm) and open in deeper water producing zones (Gasport Fm). During step testing, a specific capacity of 1.9 L/s/m was measured while pumping at 75 L/s.
PBTW1-10	New Test Production Well and Variable Rate Step Testing	July to September 2010	New test production well PBTW1-10 drilled beside the Pinebush WTP to the north of P10, cased 5 m into top of bedrock and open from 49 m to 146 m. The bottom of the hole was later sealed to a depth of 107 m. Most water in well is produced from the Gasport Fm. Initial testing indicated a potential capacity of 40 L/s.



Well	Activity	Date	Comments
P11	Performance Testing in test Well PB-TW2-11 Adjacent to P11	March to May 2011	Testing in the deep overburden/shallow bedrock indicated that overburden deposits/shallow bedrock do not provide a significant source of water. Production of sand during testing was problematic. A replacement well for P11 was not feasible within the Contact Aquifer at this location. Alternatively, well P11 was overdrilled and a new 254 mm well casing installed deeper into the bedrock to a depth of 44.0 mbgs to prevent sand production.
P10B	New Production Well and Variable Rate Step Testing	May 2011	Installation of new gravel pack well straddling bedrock/overburden interface, with screen from 26.5 to 33.5 m bgs. During step testing, a specific capacity of 3.6 L/s/m was measured while pumping at 40 L/s.
P17	Liner Installation	June 2011	A 225 mm diameter steel liner installed and cemented into place to a depth of 48.2 m below ground surface. The liner was installed to reduce sand and turbidity in P17.
P10A, P10B, PBTW1-10 and P17	Performance Testing at P10A, P10B and PBTW1-10	October 2011	A 15-day pumping test at Test Wells P10A, P10B, PBTW1-10 and P17 was conducted to evaluate sustainable aquifer yield, potential well interference and well field optimization. The long-term sustainable yield for these wells was estimated at 126 L/s with P10B at 30 L/s, P17 at 26 L/s and P10B and PBTW1-10 at a combined rate of 70 L/s. It is expected that P10 will be abandoned once P10A and P10B are brought online.
P15A	New Production well (PBTW2-13) Adjacent to P9 and P15 and Variable Rate Step Testing.	May 2014	A variable rate step test was performed on P15A to assess the well capacity. The well specific capacity at the end of testing was 8.4 L/s/m while pumping at a rate of 35 L/s
P9	Liner Installation	May 2014	A 200 mm diameter stainless steel liner was installed to a depth of 54.3 m below ground surface. The liner was installed to address concerns of cascading water from shallow bedrock water producing features.



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

Well	Activity	Date	Comments
P9 / P15A	Constant Rate Testing at P9 and P15A	May to June 2014	Performance and constant rate testing at P9 and P15A to confirm capacity and optimum pumping configuration of these two wells. P15A is expected to replace P15 when brought online.

The current permitted details and capacities for wells in the Pinebush well field are shown in Table 4.



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

Table 4: Pinebush Well Details and Permits to Take Water

Well Name	Date Constructed	Top Screen / Open Hole (mbgs)	Bottom Screen / Open Hole (mbgs)	Status	Permit Number	Maximum Permitted Water Taking (L/s)	Drinking Water License Rates (L/s)	WSMP Average Daily Rate (L/s)	WSMP Maximum Daily Rate (L/s)
Pinebush Well Field - Treatment Plant Wells									
P10	24-Feb-59	31.1 (casing depth)	64.3	Active	Permit Not Required	Note 1	120	36	40
P10A	13-Apr-10	58.0 (casing depth)	121.0	Test Well	Not permitted	NA		Note 2	Note 2
P10B	25-May-11	26.2 (casing depth)	33.5	Test Well	Not permitted	NA		Note 2	Note 2
P11	29-Oct-58	44.0 (casing depth)	83.8	Active	7343-9FFJBX	60		20	26
P17	19-Apr-94	48.2 (liner depth)	110.6	Active		60			
Pinebush Well Field - Wells That Do Not Supply Treatment Plants									
G5	29-Sep-58	22.3 (liner depth)	24.5	Active	4220-8HZHZQ	50	50	15	25
G5A	09-Apr-09	49.7 (casing depth)	126.5	Active					



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

Well Name	Date Constructed	Top Screen / Open Hole (mbgs)	Bottom Screen / Open Hole (mbgs)	Status	Permit Number	Maximum Permitted Water Taking (L/s)	Drinking Water License Rates (L/s)	WSMP Average Daily Rate (L/s)	WSMP Maximum Daily Rate (L/s)
P9	08-Apr-59	54.0 (liner depth)	80.2	Active	7600-A27NB5	49	30	15	15
P15	27-Jan-59	32.8 (casing depth)	74.1	Active			19	15	15
P15A	23-May-13	49.0 (casing depth)	135.0	Not Connected			Note 3	Note 2	Note 2

NOTES:

- 1) Well is grandfathered - permit is not required.
- 2) Recommended Daily Rate not provided in WSMP.
- 3) P15A not included in the Drinking Water License dated May 5, 2016 (MOECC, 2016).



For the Pinebush well field, permits include 7600-A27NB5 (for P9, P15 and P15A), 4220-8HZHZQ (for G5 and G5A) and 7343-9FFJBX (for P11 and P17). In addition, well P10 was constructed prior to the Ontario Water Resources Act and therefore does not require a PTTW.

Wells P10A and P10B do not currently have a PTTW and are intended as replacements for Well P10, which would be decommissioned once these new wells are permitted and brought online.

The 2015 WSMP recommended average and maximum daily total pumping rates for the Pinebush well field existing wells are 101 L/s (8,726 m³/day) and 120 L/s (10,368 m³/day), respectively. For the existing wells providing water to the Pinebush WTP, the 2015 WSMP recommended an average daily pumping rate of 56 L/s (4,834 m³/day) and a maximum daily pumping rate of 65 L/s (5,616 m³/day), which is less than the WTP capacity of 120 L/s (10,368 m³/day).

3.1.2 Clemens Mill Well Field

The Clemens Mill well field, located in the central part of the Cambridge East Study Area, consists of four bedrock wells (G6, G16, G17 and G18). Well G6 was constructed in 1959 and the other wells were constructed in the early 1990s. Water from well G6 is chlorinated and then pumped directly into the distribution system. Water from wells G16, G17 and G18 is pumped to the Turnbull WTP, and is chlorinated and treated to remove iron and manganese.

Details regarding well performance assessments, rehabilitation programs and well modifications are presented in Table 5.

Table 5: Clemens Mill Well Field – Tests, Rehabilitations and Modifications at Existing Well Sites

Well	Activity	Date	Comments
Clemens Mill Well Field			
G6	Pump Maintenance	February 2004	Pumping water levels have declined about 1 m; however, sufficient drawdown is available.
G18	Well and Pump Maintenance	September 2004	Rehabilitation including Sonar Jetting and Airlift development restored well performance to 1991 levels. A downhole video inspection showed a leak in a welded joint at about 13.4 m bgs. The casing was subsequently lined with PVC casing to seal the leak.
G17	Variable Rate Step Testing	November 2004	Well has lost approximately 50% of capacity.
G16	Well and Pump Performance Testing	February 2005	Test noted significant loss of capacity.



Well	Activity	Date	Comments
G18	Well Inspection and Testing	August 2010	Two lengths of black steel pipe replaced with galvanized pipe. Variable rate pumping test indicated well performing at close to as constructed capacity. Flow profile shows cascading source at 40.8 m b toc and major flow at 75-80 m btoc with cavern at 79 m btoc.
G16	Well Reconstruction and Liner Installation	March to April 2011	Well was deepened to a depth of 126.5 m bgs and a liner was installed to a depth of 58 m bgs. Lowering of the pump in the well resulted in an increased well specific capacity to 4.4 L/s/m. The well is able to meet its permitted rate of 38 L/s, with the potential of 75 L/s.
G17	Well Rehabilitation and Performance Testing	2013 / 2014	Rehabilitation of G17 only returned 15% of the well's specific capacity of about 5 L/s/m.
G6	Liner Installation	August 2014	A liner was installed to a depth of 44.3 m to increase the available drawdown in this well. The well was rehabilitated following liner installation. The specific capacity of the well remained at about 8.5 L/s/m following liner installation.



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

The well details are shown in Table 6 including the current permitted details and capacities.

Table 6: Clemens Mill Well Details and Permits to Take Water

Well Name	Date Constructed	Top Screen / Open Hole (mbgs)	Bottom Screen / Open Hole (mbgs)	Status	Permit Number	Maximum Permitted Water Taking (L/s)	Drinking Water License Rates (L/s)	WSMP Average Daily Rate (L/s)	WSMP Maximum Daily Rate (L/s)
Clemens Mill Well Field - Water Treatment Plant Wells									
G16	18-Aug-92	57.9 (liner depth)	126.5	Active	8842-9FDJUC	38	120	34	38
G17	25-Mar-94	61.7 (casing depth)	120.7	Active		50		25	35
G18	25-Jul-91	37.9 (casing depth)	92.7	Active		37.8		15	25
Clemens Mill Well Field - Wells That Do Not Supply Treatment Plants									
G6	08-Oct-59	44.3 (liner depth)	82.6	Active	8842-9FDJUC	25	22	10	15



All four production wells in the Clemens Mill well field are governed by a single permit, number 8842-9FDJUC. Only G6 does not supply the WTP.

It should be noted that well G18 is located on the Clemens Mill Public School property, not Region owned land, and this site may not continue to be suitable/accessible in the long term.

The 2015 WSMP recommended average and maximum daily pumping rates for the Clemens Mill well field of 84 L/s (7,258 m³/day) and 113 L/s (9,763 m³/day), respectively. For the wells providing water to the Turnbull WTP, the 2015 WSMP recommended an average daily pumping rate of 74 L/s (6,394 m³/day) and a maximum daily pumping rate of 98 L/s (8,467 m³/day), which is less than the WTP capacity of 120 L/s (10,368 m³/day).

3.1.3 Shades Mill Well Field

The Shades Mill well field, located in the southern part of the Cambridge East Study area along Franklin Boulevard and Clyde Road, consists of five overburden wells (G7, G8, G38, G39 and G40). Water from these production wells feeds the Shades Mill WTP where it is treated with UV, chlorinated and iron and manganese are removed prior to release into the distribution system (Stantec, 2015a). Wells G7 and G8 are shallow overburden wells, installed in 1958 and 1967, to depths of less than 18 m. These wells require frequent rehabilitation and have specific capacities of about 15 L/s/m and 10 L/s/m, respectively. The water level at G8 sometimes declines below the top of the screen, thus limiting the well yield (Stantec, 2015a). Well G38 was installed in 1994 and well G39 was installed in 1995 and both have shown a trend of decreasing specific capacities over time.

As part of the Region's program to optimize yields at existing well sites the following activities were conducted on well sites in the Shades Mill well field:

Table 7: Shades Mill Well Field – Tests, Rehabilitations and Modifications at Existing Well Sites

Well	Activity	Date	Comments
Shades Mill Well Field			
G38	Well Reconstruction and Interactions	May 2004	Liner placed in upper 5 m of screen in G38 to prevent sand inflow resulted in 60% reduction in specific capacity with yield reduced to 35 L/s
G38	Well Rehabilitation and Well Performance Testing	January 2012	Well air lifted with a rotating jetting tool on a drill rig and two treatments of sodium dithionite. A temporary increase in capacity at G38 which was not maintained during a pumping test later in 2012.
G39	Well Rehabilitation and Well	January 2012	Well rehabilitated with a drill rig using air lifting with a rotating jet tool, followed by two treatments of hydrochloric acid and one treatment of sodium dithionite. 15 -



Well	Activity	Date	Comments
	Performance Testing		20% increase in well yield with specific capacities ranging from 5.4 L/s/m to 4.3 L/s/m.
G40	New Production well (SM-PW1-11 later G40) Adjacent to G38 and G39 and Variable Rate Step Testing	August 2011	Test production well was step tested at rates of 15 L/s and 30 L/s with specific capacities ranging from 5.4 L/s/m and 5.3 L/s/m at the end of the 30-minute long steps.
G38, G39 and G40	Constant Rate Testing at G38, G39 and G40	January - February 2012	Evaluation of the 6-Day Pumping Test indicated an aquifer transmissivity of 780 m ² /day with the following optimized pumping scenario: G38 at 25 L/s, G39 at 50 L/s and G40 at 20 L/s.



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

The well details are shown in Table 8 including the current permitted details and capacities.

Table 8: Municipal Permits to Take Water

Well Name	Date Constructed	Top Screen / Open Hole (mbgs)	Bottom Screen / Open Hole (mbgs)	Status	Permit Number	Maximum Permitted Water Taking (L/s)	Drinking Water License Rates (L/s)	WSMP Average Daily Rate (L/s)	WSMP Maximum Daily Rate (L/s)
Shades Mill Well Field Water Treatment Plant									
G7	03-Sep-58	14.6	17.7	Active	3004-A9GHYU	174.5 ¹	150	20	27
G8	01-Jan-65	14.5	17.5	Active				10	15
G38	20-Dec-94	36.2	39.2	Active				15	25
G39	13-Jan-95	36.9	43.3	Active				30	50
G40	29-Jul-11	33.6	40.5	Not Yet Connected			Note 2	Note 3	Note 3

NOTES:

- 1) The maximum permitted daily rate for the Shades Mill well field is 174.5 L/s, but the annual daily average shall not exceed 150 L/s.
- 2) G40 not included in the Drinking Water License dated May 18, 2016.
- 3) Recommended Daily Rate not provided in WSMP.



In Shades Mill, wells G7, G8, G38, G39 and new well G40 are governed by permit number 3004-A9GHYU. Based on the Tier 3 Assessment and the 2015 WSMP, recommended average and maximum daily total pumping rates for the Shades Mill well field are 75 L/s (6,480 m³/day) and 117 L/s (10,109 m³/day), respectively. The current permitted rate from the Shades Mill well field is 175 L/s (15,080 m³/day). The permit indicates that the annual daily average taking in this well field shall not exceed 150 L/s (12,690 m³/day). It is noted that while permitted, well G40 has not yet been used to supply the system.

3.1.4 Identified Additional Capacity to Supply WTPs from Existing Well Sites

The identified well capacities of the additional Test Production wells drilled and tested at the P10 well site are summarized in Table 9.

Table 9: Well Capacities of New Test Production Wells at Existing Sites

Well Name	Well Field	Well Yield
PBTW1-10	Pinebush	70 L/s (with a maximum of 20 L/s from PBTW1-10)
P10A	Pinebush	
P10B (replacement for P10)	Pinebush	30 L/s

SOURCE: Stantec (2013a)

The capacity of existing well P10, which would decommissioned and replaced, is 40 L/s. Therefore an additional capacity of 60 L/s has been identified to supply the Pinebush WTP from existing well sites (PBTW1-10 and P10A capacity (70 L/s) plus P10B capacity (30 L/s) minus P10 capacity (40 L/s)).

As introduced in Section 3.1.1, a 15-day constant rate pumping test at P10A, P10B, PBTW1-10 and P17 was conducted in 2011 to evaluate sustainable aquifer yield, potential well interference and well field optimization (Stantec, 2013a). The 15-day test included a staggered start to allow for effects to be assessed at each pumping location. During the testing period, P17 was pumped to the system and operated on demand at 27 to 32 L/s, PBTW1-10 was initially pumped at 40 L/s, but was reduced to 20 L/s by the end of the test, P10B was pumped at 40 L/s and P10A at 70 L/s. The total combined pumping rate was as high as about 156 L/s. Pumping rates at nearby production wells in the Pinebush, Clemens Mill and Hespeler well fields were maintained at constant rates during testing. The combined sustainable well yield from these wells was determined to be 126 L/s with 30 L/s from P10B, 26 L/s from P17, and a total of 70 L/s from PBTW1-10 and P10A (with a maximum of 20 L/s from PBTW1-10). This optimized pumping scenario included a slightly reduced pumping rate from shallower well P10B (replacement for P10) and increased pumping from deeper wells P10A and PBTW1-10.

In addition to the identified new wells at the P10 well site, additional capacity of 20 L/s was identified from well G40 (Stantec, 2015a).



3.2 Summary of Class EA Field Investigations and Groundwater Supply Exploration at New Sites

3.2.1 Class EA Field Investigations

In support of the Cambridge East Class EA, a series of comprehensive hydrogeological field studies were undertaken between 2005 and 2009. Detailed discussions of the methodology and results of these field studies are provided in Appendix A following this report.

The locations of new wells installed as part of the investigations are shown on Figure 10 and the monitoring locations are shown on Figure 11. These field studies were subdivided into three phases, as further described below.

Phase I (2005/2006) – Pinebush, Clemens Mill and Shades Mill IUS Project Testing

The initial program for the Cambridge East investigations was focused in the Pinebush, Clemens Mill and Shade's Mills well fields. The program included installation and step testing of six test wells (two for Pinebush, three for Clemens Mill and one for Shades Mill), followed by drilling and step testing of three test production wells (CMPW2-06, PBPW1-06 and CMPW1-06), installation of 10 monitoring well nests, conversion of two test wells into bedrock monitoring well nests and a 28-day pumping test of the three test production wells. The 28-day pumping test was completed with a staged start of pumping from the three test production wells (CMPW2-06, PBPW1-06 and CMPW1-06) at rates of 37.5 L/s, 39.1 L/s and 37.5 L/s, respectively.

Due to the insufficient yield and poor water quality results obtained at the Shades Mill test well (SMTW1-05), additional testing in Shades Mill was proposed for Phase II to further investigate groundwater supply potential in that area. Also, investigations further west of Puslinch Lake were explored to expand options for the Pinebush well field.

Phase II (2007/2008) – Additional Pinebush and Shades Mill IUS Project Testing

Based on the results of the Phase I testing, the second phase of the Cambridge East investigations was initiated in 2007. During this phase, additional testing was undertaken in the Pinebush and Shades Mill well fields. In total, three test wells were drilled and step-tested in Shades Mill. Two of these test wells were converted into bedrock monitoring well nests (SMTW2-07 and SMTW3-07). The Shades Mill bedrock monitoring nests were sampled for water quality and an analysis was done to investigate groundwater sulphate concentrations. An overburden monitoring well nest was installed and a 3-day pumping test was conducted at the third Phase II Shades Mill test well (SMTW4-08). Subsequently the third test well was converted to a bedrock monitoring well nest. In Pinebush, a third test well (PBTW3-07) was installed and step-tested. Following this test, a test production well (PBPW2-08) was drilled, step tested and then a 3-day constant rate pumping test was conducted.

Phase II did not identify any suitable sources in the Shades Mill well field, so additional testing further east in the Town of Clyde was proposed for Phase III investigations.



Phase III (2008/2009) – North Dumfries IUS Project Testing

In 2008, a third phase of investigations was initiated in the vicinity of Clyde in the Township of North Dumfries. Initially two test wells (NDTW1-08 and NDTW2-08) were drilled and step-tested. Following these tests, a test production well (NDPW1-08) was drilled at the most favourable location and the remaining test well was converted into a monitoring well nest. At two additional sites, monitoring well nests (including piezometers in the bedrock and overburden) were installed and three additional shallow overburden monitoring well nests were installed. In 2009, two constant rate pumping tests were conducted at the test production well. The first was a 2-day test and the second was a 7-day test.

3.2.2 Identified Additional Capacity to Supply WTPs from New Well Sites

Table 10 summarizes test well locations and the groundwater supply potential at each of these locations.

Table 10: Summary of IUS Test Well Locations and Groundwater Supply Potential

Test Well (6")	Test Production Well (12")	Comments - Groundwater Supply Potential	Estimated Production Well Yields
Pinebush Well Field			
PBTW1-05	N/A	Specific capacity of 13 L/s/m at end of variable rate step testing; Location not carried forward for large diameter well testing due to proximity to Puslinch Lake. Slightly elevated concentration of iron.	N/A
PBTW2-06	PBPW1-06 (Witmer Park)	Specific capacity of 12.6 L/s/m at end of variable rate step testing at PBPW1-06; good water quality.	75 L/s
PBTW3-07	PBPW2-08 (Can-Amara Pkwy)	Specific capacity of 4.2 L/s/m at end of variable rate step testing at PBPW2-08.	38 L/s
Clemens Mill Well Field			
CMTW1-05	CMPW1-06 (Portuguese Club)	Specific capacity of 3.4 L/s/m at end of variable rate step testing at CMPW1-06.	50 L/s
CMTW2-05	CMPW2-06 (Cedarbrook)	Specific capacity of 12.2 L/s/m at end of variable rate step testing at CMPW2-06.	75 L/s
CMTW3-05	N/A	Specific capacity of 2.7 L/s/m at end of variable rate step testing; test well converted into a bedrock monitoring nest due to relatively low yield.	N/A



Test Well (6")	Test Production Well (12")	Comments - Groundwater Supply Potential	Estimated Production Well Yields
Shades Mill Well Field			
SMTW1-05	N/A	Low specific capacity at end of variable rate step testing of 1.6 L/s/m; poor water quality (high concentrations of hardness and sulphate); test well converted into a bedrock monitoring well nest.	N/A
SMTW2-07	N/A	Low specific capacity of 1.4 L/s/m at end of variable rate step testing; poor water quality (high concentrations of hardness and sulphate); test well converted into a bedrock monitoring well nest.	N/A
SMTW3-07	N/A	Low specific capacity of 2.6 L/s/m at end of variable rate step testing; poor water quality (high concentrations of hardness and sulphate); test well converted into a bedrock monitoring well nest.	N/A
SMTW4-08	N/A	Specific capacity of 4.0 L/s/m at end of constant rate testing; poor water quality (high hardness and sulphate concentrations).	N/A
Clyde Park Wells			
NDTW1-08	N/A	Specific capacity of 4.5 L/s/m at end of variable rate step testing; test well converted into a bedrock monitoring well nest.	N/A
NDTW2-08	NDPW1-08 (Clyde Park)	Specific capacity of 9.5 L/s/m at end of variable rate step testing at NDPW1-08 with well open over the Guelph to Gasport Fms. Specific capacity of 6.4 L/s/m, at end of the variable rate step testing at NDPW1-08 with well packer in place and open over the Gasport Fm.	50 L/s

As described in section 3.2.1, a 28-day pumping test was completed in 2006 with a staged start of pumping from the three test production wells (CMPW2-06, PBPW1-06 and CMPW1-06) at rates of 37.5 L/s, 39.1 L/s and 37.5 L/s, respectively. This represents a total tested increase of 114 L/s from these wells in the Pinebush and Clemens Mill well field areas. There was no measurable effect to Puslinch Lake, area wetlands or nearby creeks, during the test.



The detailed results of this pumping test are presented in Appendix A and are further discussed in Section 3.5.

3.3 Municipal Groundwater Use

3.3.1 Municipal Monitoring Network

The Region's long-term Groundwater Monitoring Program (GMP) includes a network of 102 monitoring wells (at 34 locations) in Cambridge East. This includes a mixture of monthly manual water level measurements and hourly measurements collected by electronic dataloggers in some of the wells. The GMP also includes monthly manual surface water level measurements, when ice free, at one location on Puslinch Lake. Figure 12 shows the locations monitored as part of the ongoing GMP monitoring program. It is noted that the conditions for the current PTTWs in Cambridge East require monitoring of only 41 of the 102 wells currently being monitored by the Region. Details on the ongoing GMP monitoring locations are provided in Table C1 in Appendix C.

The Township of Puslinch also collects ongoing monitoring data at three monitoring well locations within the Study Area (TW9-78, TW10-78 and MW09-T3-01), which are also shown on Figure 12.

3.3.2 Historical Pumping and Water Levels

Figure 13 presents the cumulative annual pumping rates between 1986 and 2015 for the three Cambridge East well fields. Note that these pumping rates include historical wells G10 and G11 (Shades Mill well field), which were decommissioned due to low well yield. The increase in rates during the mid-1990s reflects bringing new wells (G16, G17, G18 and P17) on line.

Between 2007 and 2015, the annual pumping rate at the Cambridge East Class EA well fields has totalled approximately 187 L/s (16,157 m³/day), which represents about 47% of the combined capacity of 390 L/s (33,696 m³/day) of the three WTPs. Between 2007 and 2015, the annual pumping rate of the Cambridge East Class EA wells supplying the WTPs was 127 L/s (10,923 m³/day).

Pumping rates at these well fields have not met the design capacity of the three WTPs. This is in part due to the decline in performance of some wells and to overly optimistic estimates of the well yields at the time of construction. In addition to wells providing water to the three WTPs, water from wells G6 (Clemens Mill) and G5/G5A, P9 and P15 (Pinebush) do not go through the WTPs and are pumped directly into the distribution system.

Figure 14 illustrates the annual municipal pumping volumes from each well field showing the individual pumping volume of each well. This figure illustrates the following:

Pinebush Well Field

- Since 1991, non-WTP wells (G5, P9 and P15) have been pumped at fairly stable rates with an average production total of 48 L/s.



- In 1994, added production totals from new well P17 were offset by decreases at well P11. From 1993 to 1996, production totals of the WTP wells were about 38 L/s.
- In 1997, pumping rates of the WTP wells began increasing, stabilizing and averaging about 56 L/s between 2004 and 2008. This increase was largely due to the increase in pumping at well P10.
- In 2009, pumping rates of the WTP wells declined, stabilizing at about 17 L/s in 2010 and 2011, followed by an increase in 2012 and peaking in 2013 at 43 L/s, as the pumping rate at well P10 increased. In 2015, production totals from the WTP wells were at 31 L/s.

Clemens Mills Well Field

- Between 1986 and 1993, only well G6 was online in the Clemens Mill well field, pumping at an average rate of about 12 L/s.
- A large increase in pumping occurred in the Clemens Mills well field between 1994 and 1998 as wells G17, G18 and G16 came online. Between 1996 and 2009, rates ranged from 43 L/s to 64 L/s, with an average rate of 56 L/s.
- Production totals declined in 2010, with an average pumping rate of 40 L/s between 2010 and 2015.

Shades Mill Well Field

- Between 1986 and 1992, production totals in the Shades Mill well field declined from about 90 L/s to about 42 L/s, largely due to declines in pumping from wells G10 and G11.
- In 1992 and 1993, wells G7 and G8 were largely offline, with well G7 coming back online in 1994 and well G8 coming back online in 1995. In 1994 and 1995, a decrease in pumping at wells G10 and G11 was largely offset by an increase in pumping at wells G7 and G8. Well G11 was taken offline in 1996 and well G10 was taken offline in 1997. Both of these wells have been decommissioned.
- Wells G38 and G39 were brought into full production in the Shades Mill well field in 1999. At this time, total pumping in Shades Mill increased from about 36 L/s in 1998 to 103 L/s in 1999.
- The average production total between 2000 and 2006 for the whole well field was 78 L/s. The average pumped volumes between 2007 and 2015 were lower at about 44 L/s.
- Since coming into production, well G38 has periodically been offline, including in 2000, 2003 and 2007 through 2009. Well G39 was also offline in 2007, 2009, 2014 and 2015.

In summary, from the early 1990s to the late 1990s, pumping rates increased from about 112 L/s in 1990 to 249 L/s in 1999, as new municipal wells were brought online in Cambridge East; including well P17 in 1994, wells G16, G17 and G18 in 1995 and wells G38 and G39 in the late 1990s. A review of long-term groundwater levels in the Cambridge East area shows



that during this period, groundwater levels declined locally in response to this increased pumping (Figure 15a).

Between 1999 and 2007 groundwater levels were generally stable, when annual pumping rates of about 223 to 264 L/s were reported.

At CMOW5B-94 (shown on Figure 15a), a bedrock piezometer located at the traffic circle on Townline Road, groundwater levels rose to a seasonal high of about 304.5 masl each spring during 1994 and 1995, but gradually declined until 2000 with seasonal highs of about 303.3 masl. Between 2000 and 2003, groundwater levels remained essentially stable at CMOW5B-94, rising slightly in 2004 and stabilizing at a slightly higher level with seasonal highs of about 303.5 masl.

In 2008 there was a rise in groundwater levels observed at CMOW5B-94, which likely corresponds with decreased pumping from about 245 L/s in 2006 to an average of about 195 L/s in 2008. Between 2010 and 2015 groundwater levels appeared to stabilize, with seasonal highs of about 304.2 masl. A similar pattern of groundwater level fluctuations was recorded in the overburden at OW4C-92 (also shown on Figure 15a), located on the west side of Townline Road, and at CMOW5F-94 at the Townline Road traffic circle.

Figure 15a also shows groundwater levels at two bedrock piezometers which were installed in Puslinch in 1978 and have been monitored by the Township of Puslinch, TW9-78 and TW10-78. These records showed a slight decline from 1993 to 2000, likely in response to increased pumping in Cambridge East during this period. Groundwater levels at TW9-78 and TW10-78 were fairly stable between 2000 and 2007, and showed a rise in 2008. Between 2008 and 2015, water levels have remained fairly stable, with the exception of a temporary decrease during the relatively dry summer of 2012.

Groundwater levels in Puslinch Lake also showed seasonal highs, generally in the spring. There was a decline in lake levels in 1998 and 1999. It is noted that 1999 was a dry year. Water levels in the lake increased slightly in 2000, with a higher than average amount of precipitation, and remained stable until 2003. In 2004, there was another slight increase in lake levels that remained fairly stable until 2007. Lake levels rose again slightly in the spring of 2008 and have remained fairly stable until 2015, with notably lower water levels in the second half of 2012, corresponding to a period of below average precipitation.

Figure 15b shows monitoring data from the Pinebush well field in the vicinity of Puslinch Lake, with Puslinch Lake (LWL) levels as well as hydrographs from shallow overburden and bedrock monitoring wells. Figure 15c shows monitoring data from overburden and bedrock wells from the Clemens Mill well field. Bedrock monitoring wells in the Gasport Formation (PBOW1A-06, CMOW1A-06 and CMOW2A-06) showed an influence from municipal pumping, particularly since 2011. Deep bedrock monitoring wells, PBOW2A-06 and CMOW5B-94, showed a response to municipal pumping, but to a lesser degree than PBOW1A-06, CMOW1A-06 and CMOW2A-06. All monitoring wells showed seasonal highs; these seasonal highs were also observed in Puslinch Lake water levels.



3.4 Non-Municipal Groundwater Use

3.4.1 Non-Municipal Permitted Water Use

Permitted water use for non-Municipal water takings, based on the MOECC's Permits to Take Water (PTTW) database are shown on Figure 16. Table 11 lists these PTTWs, along with water uses, sources of the water and permitted rates for takings within about 3 km of the municipal production wells. In total, there are 10 non-municipal PTTWs in the Study Area, extracting water from both surface water and groundwater. The total maximum permitted water taking from groundwater from these sources is 84 L/s (7,252 m³/day). Water takings for golf course irrigation are limited to 6 or 7 months per year. Permitting for dredging at Puslinch Lake of 132 L/s (11,360 m³/day) is limited to the months of July and August. Permitting for surface water taking at the Shade's Mills Reservoir of 248 L/s (21,433 m³/day) is limited to the summer months. Other purposes for water takings include for water supply, geothermal use, recreation and remediation.



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

Table 11: Non Municipal Permits to Take Water

Purpose	Source Name	Easting	Northing	Permit Number	Maximum Permitted Water Taking (L/s)	Months of Water Taking per Year	Source Water Type
Pinebush Well Field							
Water Supply - Puslinch Beach & Marine	2 Wells (East Well, West Well)	559989	4808018	5167-A3JPZB	1	12	Ground
		559417	4808034				
Miscellaneous- Puslinch Beach & Marine	Geothermal Well	559719	4807922				
Puslinch Lake Conservation Association - Dredging	Puslinch Lake Dredging Site #1 and #2	559111	4806813	0331-7FCPV9	132	2	Surface
		559733	4806987				
Golf Course - Irrigation	Irrigation Well	558420	4808700	8475-8GTNQH	11	7	Ground
	Irrigation Pond	558358	4808933		12		Surface
Clemens Mill Well Field							
Golf Course - Irrigation	Well PW1/89	557026	4804586	4540-8PCQCL	10	5	Ground
	Irrigation Pond	557084	4804661		13	7	



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

Purpose	Source Name	Easting	Northing	Permit Number	Maximum Permitted Water Taking (L/s)	Months of Water Taking per Year	Source Water Type
Recreational - Wetlands	Wetlands	560900	4806143	6155-8KCLLQ	64	12	Surface and Ground
Shades Mill Well Field							
Miscellaneous - Dams and Reservoirs	Mill Creek (Shade's Mills Reservoir)	557511	4802727	2547-9RGR46	248	3	Surface
Remediation	3 Wells (PW1, PW2, PW3)	557476	4801412	5087-7JYPSR	3	12	Ground
		557425	4801474				
		557408	4801531				
Remediation	Cambridge Landfill Well CL-PW4	558815	4801785	7781-9S2N3Z	11	12	Ground
Remediation	Cambridge Landfill Well CL-PW3	558519	4802347	5678-96NMZ3	11	12	Ground



Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report

Purpose	Source Name	Easting	Northing	Permit Number	Maximum Permitted Water Taking (L/s)	Months of Water Taking per Year	Source Water Type
Golf Course - Irrigation and Water Supply	3 Wells	561060	4803785	8410-9KTR9P	24	12	Ground
		561196	4803854				
		561189	4803847				
	3 Ponds	561171	4803818		68	6	Surface
		561163	4803899				
		561175	4803972				

NOTES:

Includes Permitted Water Takings within a distance of approximately 3 km from municipal wells



3.4.2 Private Domestic Wells

Water well data were assembled from recent MOECC well records. Figure 16 shows the location of private domestic water wells, the large majority of which are currently in use for the provision of domestic water supplies. There are numerous private wells in the Cambridge East area and in the rural area extending east from Townline Road in the Township of Puslinch. Some of these wells are completed in overburden and some in bedrock, generally within the upper few metres of the rock.

There are several clusters of private wells in the Cambridge East Study Area. East of the Study Area, around Puslinch Lake, there are clusters of private domestic and a few communal domestic supply wells. In rural areas, along Townline Road, the eastern boundary of the Study Area, as well as along Avenue Road, between the Clemens Mill and Shades Mill well fields, there are private domestic and a few livestock wells. Detailed well inventories were conducted as part of the testing programs as described in Appendix A.

Additional water use in the Study Area includes domestic water supply, livestock watering, irrigation, commercial and other demands that extract less than 50,000 L/day and do not require a permit.

3.5 Groundwater Flow System Characterization

3.5.1 Hydrostratigraphy

The conceptual hydrogeology of the Study Area is summarized on Figure 17 and is described in this section. Three key cross-sections have been prepared of the area at the locations shown on Figure 18 and are presented on Figures 19, 20 and 21. The thicknesses of the main aquifer unit (Gasport) and main aquitard (Vinemount) are shown on Figures 22 and 23, respectively.

The following observations are provided with respect to the distribution of the bedrock hydrostratigraphic layers in the Study Area.

- **Bedrock Contact Aquifer** - The upper weathered/fractured bedrock and overlying coarse materials typically form a thin (assumed thickness of 4 m) aquifer that is able to support domestic water wells and some municipal wells. This unit includes the coarse granular materials overlying bedrock at the base of the Catfish Creek Till that are identified in many boreholes in the Study Area.
- **Salina Formation** - Although there have been some anecdotal accounts of the Salina present in the Hespeler area, there is no clear evidence that this formation extends into the Study Area.
- **Guelph Formation** - The thickness of the Guelph Formation generally ranges from 10 to 40 m in the Study Area.
- **Eramosa Formation - Reformatory Quarry Member** - The Reformatory Quarry Member is generally less than 10 m thick in the Study Area and is thinner or absent above the thick Gasport reef mounds, where they are present.



- **Eramosa Formation - Vinemount Member** - The interpreted thickness of the Vinemount Member is shown on Figure 23. The Vinemount Member is not present overlying and to the west of the thick Gasport reef mounds observed in the Pinebush area. The Vinemount Member is present only in the eastern and southern part of the Study Area as shown on Figure 23. The Vinemount, where present in the Study Area, is less than 10 m thick and has a strong influence on vertical hydraulic connections and vertical hydraulic gradients within the bedrock aquifer, as described further in Section 3.5.4.
- **Gasport Formation** - The thickness of the Gasport Formation influences the distribution of the overlying bedrock units and is shown on Figure 22. The Cambridge East well fields are interpreted to be within or adjacent to a belt of composite reef mounds in the Gasport Formation that extend from the Middleton well field on the west side of Cambridge, northeast to Guelph and further north to the Fergus area. In the Study Area well fields, the thickness of the Gasport Formation varies from about 35 m near well G5 to about 75 m in the central area of the Pinebush well field. The steep topography of the top of the thick Gasport composite reef mounds in the eastern Pinebush area is typical of such reef mound sequences and is similar to that seen in the Middleton well field area and at the Guelph Dolime Quarry (Golder, 2011b). As described further in Section 3.5.3 and in the numerical modelling report in Appendix D, the Gasport Formation has been conceptually represented by upper, middle and lower hydrostratigraphic layers to represent vertical variability in the hydraulic conductivity of the unit and particularly, to represent an extensive higher permeability flow producing zone in the middle of the unit identified through well testing (Golder, 2011a).
- **Goat Island Formation** - The Goat Island Formation is generally thin (<5 m) or absent in areas of thick Gasport reef mounds. Thick sequences of Goat Island (>30 m) are found further west in Cambridge where the Gasport Formation is thinner.
- **Merritton, Rockway, Irondequoit and Rochester Formations (Included with the Lower Gasport Hydrostratigraphic Unit)** - These Formations are generally 4 to 5 m thick in total in the Study Area.
- **Cabot Head Formation (Underlying Low Permeability Bedrock)** - This Formation forms the lower boundary of the active groundwater flow system in the Cambridge area and acts as a regional aquitard. The Cabot Head shale dips to the southwest at approximately 4 degrees across the Cambridge area.

3.5.2 Groundwater Flow Directions

Regional groundwater flow in the deep bedrock (Gasport Formation) and the uppermost bedrock (Guelph Formation) is shown on Figures 24 and 25, respectively. These maps were assembled using data specific to each of the bedrock units as obtained from monitoring well nests installed as part of this EA project and supported with data from the Region's water level monitoring program and WRAS+ database.



Groundwater flow in the Guelph (upper bedrock) and Gasport (deep bedrock) Formations in the area of Cambridge well fields is regionally to the southwest toward the Grand River. The pattern of groundwater flow in the bedrock aquifer is strongly influenced by municipal pumping and the interpretation of groundwater flow patterns is in part controlled by the available monitoring data. As such, groundwater flow within Cambridge is more complex than that shown on Figures 24 and 25. A more detailed pattern of groundwater flow in the bedrock was developed during this study from the numerical modelling (Appendix D) that incorporates municipal pumping.

The most noticeable feature on these figures is the locally steeper horizontal hydraulic gradient to the southwest of the Clemens Mill well field (extending downgradient from CMTW3-05) and the much lower gradient to the northeast from this monitoring location in both the Guelph and Gasport Formations. The lower horizontal hydraulic gradient extending northeast into the Township of Puslinch does not appear to be influenced by municipal pumping in Cambridge. Rather, this extensive area of low horizontal hydraulic gradient suggests the bedrock aquifer is more transmissive relative to the area southwest of the Clemens Mill well field. It should also be noted that the horizontal hydraulic gradient in the Gasport Formation is lower than in the overlying Guelph Formation in upgradient areas in the Township of Puslinch. This likely reflects the presence of the intervening low permeability layer and indicates the Gasport Formation is the more permeable of the two bedrock aquifer units. The Vinemount Member of the Eramosa Formation is absent over most of Cambridge East but present in the southern and eastern portions of the Study Area as shown on Figure 23.

The shallow groundwater elevations generally follow topographic variations. Contact Aquifer groundwater flow contours were developed during the numerical modelling completed for this study (Figure 12a in Appendix D). The highest groundwater elevations, above 315 masl, are simulated to be in the area of the Hespeler well field, with flow converging on the river valleys in the area; the Speed River to the north, the Grand River to the southwest and Mill Creek to the south. Locally an easterly component of Contact Aquifer groundwater flow is simulated into the Township of Puslinch, within the eastern area of the Pinebush and Clemens Mill well fields, with discharge toward Puslinch Lake or Mill Creek.

3.5.3 Well Water Source Zones

Dynamic flow profiling has been completed in over 20 open bedrock boreholes in the Study Area including production wells, test wells and monitoring wells. A summary of the flow producing intervals in the bedrock for each of the municipal wells and test wells in the area, for which dynamic flow profiling information was available, is presented in Golder (2011a) and is summarized here. The following table provides a summary of the identified flow producing intervals at the municipal wells and new test production wells.



Table 12: Estimated Depths of Well Water Source Zones

Well Name	Top Screen / Open Hole (mbgs)	Bottom Screen / Open Hole (mbgs)	Status	Identified Flow Producing Interval (mbgs)	Flow Producing Zone - Aquifer Unit
P10A	58.2 (casing depth)	121.0	Test Well	74-76; 106; 118	Gasport Formation
P10B	26.5	33.5	Test Well	31	Overburden and Guelph Formation
P10	31.1 (casing depth)	64.3	Active	No Flow Profile Available	N/A
PBTW1-10	49.2 (casing depth)	107	Test Well	60-67; 70-72; 80-94	Goat Island and Gasport Formations
P11	44.0 (casing depth)	83.8	Active	45-46	Gasport Formation
P17	48.2 (liner depth)	110.6	Active	55-60; 78-84	Gasport Formation
Witmer Park (PBPW1-06)	42.1 (casing depth)	138.7	Test Well	105-120	Gasport Formation
Can-Amera (PBPW2-08)	29.3 (casing depth)	128.0	Test Well	78-82; 90-105	Gasport Formation
G5	22.3 (liner depth)	24.5	Active	No Flow Profile Available	Guelph Formation
G5A	49.7 (casing depth)	126.5	Active	54-58; 95-100	Goat Island and Gasport Formations
P9	54.0 (liner depth)	80.2	Active	73-76	Gasport Formation
P15	32.8 (casing depth)	74.1	Active	52-53; 71-73	Goat Island Formation
P15A	49.0 (casing depth)	135.0	Test Well	53-58; 64-72	Goat Island Formation
G6	44.3 (liner depth)	82.6	Active	58	Guelph Formation
G16	57.9 (liner depth)	126.5	Active	61-88	Goat Island and Gasport Formations



Well Name	Top Screen / Open Hole (mbgs)	Bottom Screen / Open Hole (mbgs)	Status	Identified Flow Producing Interval (mbgs)	Flow Producing Zone - Aquifer Unit
G17	61.7 (casing depth)	120.7	Active	80-90; 104; 111	Goat Island and Gasport Formations
G18	37.9 (casing depth)	92.7	Active	72-76	Goat Island Formation
Portuguese Club Well (CMPW1-06)	32.3	121.9	Test Well	70-90; 90-105	Gasport Formation
Cedarbrook (CMPW2-06)	32.6	120.5	Test Well	98-112	Gasport Formation
G7	14.6	17.7	Active	14.6-17.7	AFA2 (Outwash Deposits)
G8	14.5	17.5	Active	14.5-17.5	AFA2 (Outwash Deposits)
G38	36.2	39.2	Active	36.2-39.2	AFA2 (Outwash Deposits)
G39	36.9	43.3	Active	36.9-43.3	AFA2 (Outwash Deposits)
G40	33.6	40.5	Test Well	33.6-40.5	AFA2 (Outwash Deposits)
Clyde Park (NDPW1-08)	24.7 (casing depth)	106.7	Test Well	86-94	Gasport Formation

NOTE:

N/A – not available

The following are the key observations regarding flow producing intervals observed at these well fields:

- Based on the results of the flow profiling completed, the majority of the flow into the test production wells likely originates from the middle Gasport Formation, for wells CMPW2-06, PBPW1-06, PBPW2-08 and NDPW1-08. At well CMPW1-06 the flow into the well is also likely from the middle Gasport Formation although there is a greater contribution to flow from the upper Gasport Formation. At well P10A, flow is predominantly from the upper and middle Gasport Formation and at PBTW1-10, flow is from the upper and middle Gasport Formation as well as from the Goat Island Formation. Flow to the wells predominantly from the Gasport Formation is consistent with observations of water bearing characteristics made during drilling and logging, and the observed water level



responses during testing, which was the greatest in the Gasport Formation. In most of the boreholes profiled in the Study Area, a major producing zone is present within the Gasport Formation, typically at depths of 90-110 mbgs. This zone in the middle Gasport unit coincides with the top of the first (oldest) phase of reef mounding and overlying coquina shell beds, where there is increased primary and/or secondary permeability. Additional producing zones in the Gasport are commonly found at the tops of second, and in some cases, third phases of reef mounding in the upper portion of the Gasport Formation. Correlation of these producing zones to the vertical sequence of reef mounding and coquina shell beds, as observed in cored boreholes, is part of ongoing research by the OGS (Frank Brunton - Ontario Geological Survey, personal communication).

- To the west of the thick reef mounds, in the area of P15 and at G5, the highly transmissive zone in the middle Gasport is not observed and a greater percentage of the flow is derived from flow producing zones within the Goat Island Formation.

3.5.4 Vertical Hydraulic Connections

In Cambridge East, the strongest hydraulic separation between upper and deep bedrock (i.e., groundwater level difference between piezometers installed in the Guelph and Gasport Formations at a monitoring well nest) occurs where the Vinemount Member of the Eramosa Formation is present. The strong upward gradients in the Shades Mill and North Dumfries areas occur across the Vinemount Member, with over 10 m of groundwater level separation in some places. In the City of Guelph, where municipal pumping has lowered groundwater levels in the underlying Gasport Formation, a groundwater level separation of 10 to 20 m is observed across the Vinemount Member. For the results developed in Guelph and Cambridge East, aquifer test interpretation and model calibration has shown that a low vertical hydraulic conductivity on the order of $1\text{E-}9$ m/s for the Vinemount Member is necessary to account for the groundwater level separation and limited hydraulic connections observed across this unit.

Groundwater elevations are lower in the deep bedrock (Gasport Formation) relative to the overlying Guelph Formation, indicating downward vertical hydraulic gradients over much of the Cambridge area (Figure 26) with the strongest downward gradients observed in the higher elevation upgradient areas to the northeast, extending into the Township of Puslinch. Upward hydraulic gradients occur in the lower elevation areas in the south of the Study Area in Shades Mill, and to the east in North Dumfries and the area surrounding Mill Creek in Puslinch. A multilevel piezometer in the Shades Mill area within the Gasport Formation (SMTW1A-05) was flowing (and is now shut in) with a groundwater level difference of more than 10 m relative to the Guelph Formation and similarly, flowing conditions were encountered in monitoring well nests in North Dumfries. Open bedrock holes located adjacent to Mill Creek (TW9-78 and TW10-78) in the Township of Puslinch have been periodically flowing, with water levels above ground or close to ground surface since their installation in 1978. The upward vertical gradients appear most pronounced where the low permeability Vinemount Member of the Eramosa Formation is interpreted to be present between the Gasport and Guelph Formations (Figure 23).



The observed drawdowns in the deep bedrock (Gasport Formation) and shallow bedrock/lower overburden (Contact Aquifer) are shown on Figure 27 for the 28-day pumping test completed in 2006 at wells CMPW1-06, CMPW2-06 and PBPW1-06, as described in detail in Appendix A. Figure 28 shows the observed drawdowns in the deep bedrock (Gasport Formation) and Contact Aquifer systems during this same test, but at the end of 7 days when only CMPW2-06 had been pumping. The drawdowns in the deep bedrock (Gasport Formation) and Contact Aquifer systems from the 15-day pumping test completed at the Pinebush well field are shown on Figure 29. These tests showed similar results regarding the vertical hydraulic connections between the deep bedrock aquifer, from which the pumping increases were focused, and the Contact Aquifer.

The following key points can be made regarding vertical hydraulic connections between the Gasport and Guelph Formations.

- Bedrock is generally vertically hydraulically connected throughout most of the central Pinebush and Clemens Mill well field areas. However, the lower portion of the Gasport Formation is generally poorly connected to the producing zones in the Middle Gasport throughout this area. The presence of vertical hydraulic connections in the bedrock of the Pinebush and Clemens Mill areas of Cambridge is supported by the results of the pumping tests. The absence of the Vinemount aquitard and the absence of strong vertical hydraulic gradients also support vertical connections across the bedrock in these areas.
- In the southern part of the Study Area near Mill Creek, strong upward vertical hydraulic gradients were observed between the Gasport and Guelph Formations under non-pumping conditions. The hydrograph for well nest CMOW2-06 near Mill Creek (Appendix A) illustrates the upward gradients between the Gasport (CMOW2A-06) and Guelph (CMOW2BC-06) Formations. The hydraulic conditions indicate the Vinemount Member of the Eramosa Formation at this location acts as a hydraulic barrier, limiting hydraulic connections between the Guelph and Gasport Formations. The Vinemount Member in this area is generally greater than 10 m thick and has been observed to contain little to no vugs/solution cavities/fractures and a high shale content; and hence a low permeability. Similar conditions were observed at SMTW1-05 when this borehole was instrumented with three bedrock piezometers. Two monitoring wells located in Puslinch in the vicinity of Mill Creek, TW9-78 and TW10-78 are flowing wells, again indicating the hydraulic influence of the low permeable Vinemount Member.
- In the central part of the Study Area in Puslinch, at well nest PBOW1-06, a strong downward hydraulic gradient was observed between the Guelph and Gasport Formations. This strong gradient is also consistent with the presence of a low permeability layer between these formations. The hydrograph for this well nest is shown on Figure A10 in Appendix A.
- A significantly different vertical hydraulic gradient was observed between the Gasport and Guelph Formations at well nest PBOW2-06 (Figure 26). At this location, there was a lower downward gradient evenly distributed across the upper Guelph interval



(PBOW2C-06), the lower Guelph interval (PBOW2B-06) and the Gasport interval (PBOW2A-06). The hydraulic responses observed at this location suggest that there may be a direct hydraulic connection between the Gasport and Guelph Formation in this area. The Vinemount Member pinches out between this monitoring well nest and the Witmer Park well located to the southwest. The vertical propagation of the hydraulic responses from the Gasport to Guelph Formation may be a result of the absence of the Vinemount Member in the Witmer Park area (and to the west of Witmer Park) or a generally higher permeability of the Vinemount Member in this area. This resulted in a greater amount of drawdown observed in the Guelph Formation in this area relative to locations further south.

The following key points can be made regarding vertical hydraulic connections between the bedrock and overburden.

- In the central and southern parts of the Study Area, hydraulic responses in the upper Guelph Formation and lower overburden were similar, with low to non-existent vertical gradients between these units. This suggests a relatively good hydraulic connection between the upper bedrock and lower overburden in this area.
- The bedrock is also well connected to the overburden in the Pinebush and Clemens Mill area where the Vinemount is absent, although thick (up to 30 m in some areas) sequences of fine-grained tills limit connection through to the shallow overburden.

To the northeast of the Witmer Park site at well PBOW2-06, relatively stronger downward hydraulic gradients between the lower overburden and upper bedrock were observed. This suggests the presence of relatively lower permeability strata which effectively limit the extent of vertical hydraulic connections between the upper bedrock and lower overburden. The thicker sequences of fine grained silts, clays and tills present in this area likely account for this stronger vertical gradient.

- The observed groundwater level responses suggest that the fine grained deposits in the overburden within the Study Area (Galt-Paris Moraine area) generally do not act as an effective or continuous aquitard isolating groundwater level changes in the bedrock from the overlying permeable lower overburden strata. There are some localized exceptions as noted above.

The following key points can be made regarding vertical hydraulic connections between the pumped overburden aquifer in the Shades Mill area (AFA2) and shallower aquifers and surface water.

- Wells G38 and G39 are hydraulically connected to the Shade's Mills Reservoir, from which they draw the majority of their water (Golder, 1995). This was confirmed in more recent testing of G38 and G40 in 2012 which showed a leaky confined aquifer, although a lower rate of leakage from the overlying reservoir was observed as compared to the 1994 testing (Stantec, 2013b).



- The sand and gravel aquifer in the vicinity of G38, G39 and G40 is also hydraulically connected to the shallow bedrock as observed during the G38 and G39 aquifer test in 1994 (Golder, 1995) and the G38 and G40 aquifer test in 2012 (Stantec, 2013b).

3.5.5 Groundwater/Surface Water Interactions

3.5.5.1 Wetlands and Lakes

The PSWs in the Study area include the Puslinch Lake and Irish Creek Complex, Portuguese Swamp, Mill Creek Wetland Complex and Moffat Creek Swamp as described in Section 2.4.1. As illustrated in the conceptual hydrogeological cross-section in Figure 17 and in the illustration of vertical gradients shown on Figure 26, Puslinch Lake and Portuguese Swamp are located in a regional groundwater recharge area, whereas Mill Creek Wetland Complex and Moffat Creek Swamp are in areas of regional groundwater discharge. However, locally shallow groundwater flow is influenced by local topographic variability. Groundwater recharge and discharge conditions and vertical hydraulic gradients also vary seasonally.

The McCormick Point Wetland in the Puslinch Lake Complex (Figure 6), is the most intensively studied wetland in the area. A review of 25 years of research of the McCormick Point Wetland led by Barrie Warner of the University of Waterloo is summarized in Warner (2010). This kettle wetland has many similar characteristics to other kettle wetlands in the area including Puslinch Lake and Little Lake (Figure 6). Similar to Puslinch Lake and Little Lake, this is a kettle wetland and has been infilled with sediments including detrital peat, limnic peat and gyttja and is underlain by the stony, sandy Wentworth till. Gyttja is a lacustrine mud formed by the partial decay of peat and is comprised of particulate organic debris and inorganic precipitates. At this site the gyttja was found to grade into a thin layer of clay and hardpan. The hydraulic conductivity of the organic sediments within each organic sediment layer was found to vary by several orders of magnitude due to different degrees of decomposition and compaction (Currie, 1995). Hydraulic tests of the gyttja layer showed a low horizontal hydraulic conductivity value ranging from 9×10^{-9} m/s to 1×10^{-8} m/s (Currie, 1995). The low permeability organic sediment layers limit the groundwater/surface water interactions at the wetland. Figure 30a shows a detailed transect of hydraulic head measured in multi-level wells installed and measured at the McCormick Point wetland by Currie (1995).

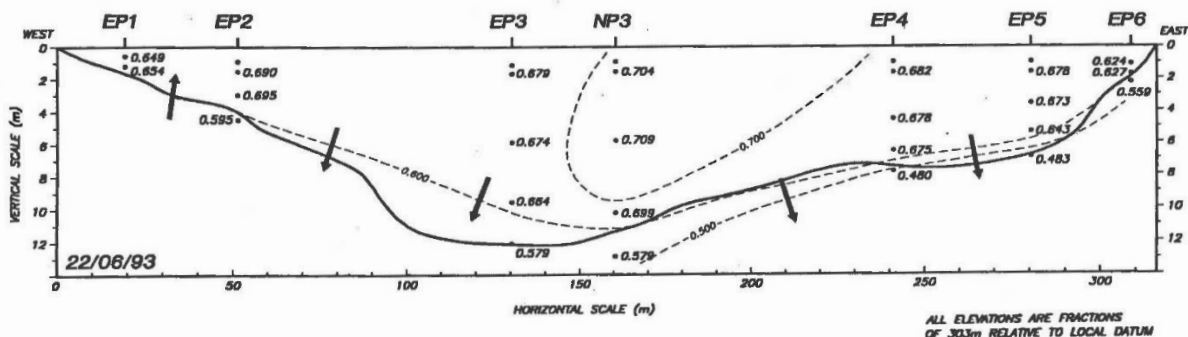


Figure 30a: Hydraulic Head Profiles McCormick Point Wetland A-A' (Currie, 1995)



Two important conclusions from the study of this wetland that are important to consider for other similar wetlands in the area are as follows:

- Hydraulic gradients in the wetland were found to change direction and magnitude seasonally, illustrating the short term variability of hydrological processes in the wetland. Groundwater flow directions were found to be generally out of the basin during October and June measurement periods and generally into the basin during the April period; and
- The low hydraulic conductivity layer of gyttja organic sediment results in a negligible flux of groundwater across the organic sediments and groundwater/surface water interactions in this wetland were found to occur only where this layer was thin or absent, which was at the perimeter of the wetland.

During the 2006 28-day pumping test completed for the EA, no responses to pumping were observed at the eight representative ecological monitoring wetland stations monitored in the Study Area (locations shown on Figure 11), including at the McCormick Point wetland. Vegetation and water level changes during the test reflected only seasonal variability.

Puslinch Lake and Irish Creek Complex

As described in Section 2.3.1.1, Puslinch Lake is a closed kettle basin with intermittent seasonal outflow/seepage during high water conditions to Puslinch Lake Creek and Irish Creek, via a swampy area on the north side of the lake and culverts under Lake Road. The lake receives input from precipitation primarily and also surface water runoff. Localized areas of groundwater discharge springs are reported to have been observed during lake dredging (personal communication David Taliano of the Puslinch Lake Conservation Association, Feb. 2017).

The characterization completed by Harden (1999) included the collection of 40 lake-bottom cores and depth measurements throughout the lake, as summarized below:

- The depth of the water (surface to the top of the organic sediments) was measured at 40 locations. A mean depth of 1.4 m was determined for the lake and a water volume of $2.27 \times 10^6 \text{ m}^3$ estimated. The depth of water was found to have two low points (as shown on Figure 13 and Figure 14 of Harden, 1999), northeast and southwest of Big Island, where the depth to the top of organic sediments was measured up to 6 m deep.
- The thickness of organic lake sediments was found to be variable with an undulated underlying till surface. The measured sediment thickness is illustrated on Figure 16 of Harden 1999. The two thickest sediment areas were found to the west and northeast of Big Island with thicknesses up to 12 m measured. Two areas were found where there were no lakebed sediments encountered including an area northwest of Big Island and southeast of Barber's beach.

A pilot program to dredge Puslinch Lake was initiated in 2000 by the Puslinch Lake Conservation Association (PLCA), in the vicinity of the McClintock's westerly water ski run. No dredging took place in the lake between 2001 until 2006; further dredging attempts using a



1000 foot discharge pipe between 2007 and 2009 were marginally successful. Beginning in 2013, the PLCA began to use a barge and tugboat to dredge the lake. In 2013 and 2014, dredging took place in the western part of the lake to the north of McCormick's Point and to the south of Sandy Shore Blvd. In 2015, dredging took place in the southern part of the lake to the east of McCormick's Point and in 2016 a channel was excavated to the south of Big Island in preparation for dredging the eastern portion of the lake. Continued dredging is planned in the eastern portion of the lake in 2017 (PLCA, 2017). As noted in Section 3.4.1, a PTTW (No 0331-7FCPV9) with a limit of 132 L/s (11,360 m³/day) is used by the PLCA for dredging operations from Puslinch Lake during the months of July and August.

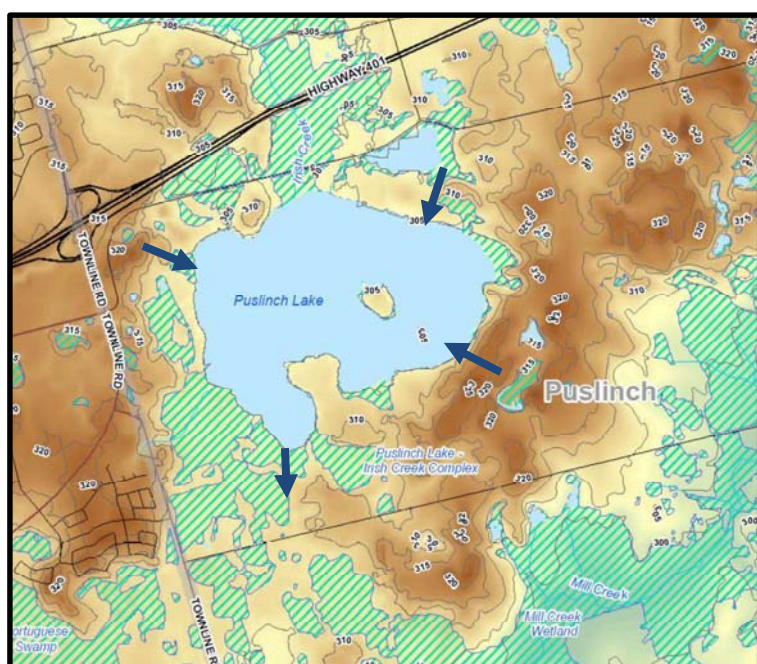


Figure 30b: Interpreted Shallow Groundwater Flow Directions around Puslinch

Figure 30b shows the general interpreted shallow groundwater flow directions around Puslinch Lake overlain on the topographic surface contours. The shallow groundwater flow generally flows from the topographic highs of the moraines from the northeast, southeast and northwest of Puslinch Lake, as also shown in the shallow groundwater elevation contour map on Figure 7 of Harden (1999). Groundwater flow has been found to flow south, with shallow groundwater levels measured below lake level in the southwestern shore of the Lake (Harden, 2010). In terms of shallow groundwater flow, the lake is conceptualized as a “flow through” lake with groundwater flowing in through shallow springs where lakebed sediments are thin in some shores and with groundwater flowing out to the southwest (Harden, 2010).

A conceptual cross-section illustration of the Puslinch Lake groundwater flow system is shown on Figure 30c.

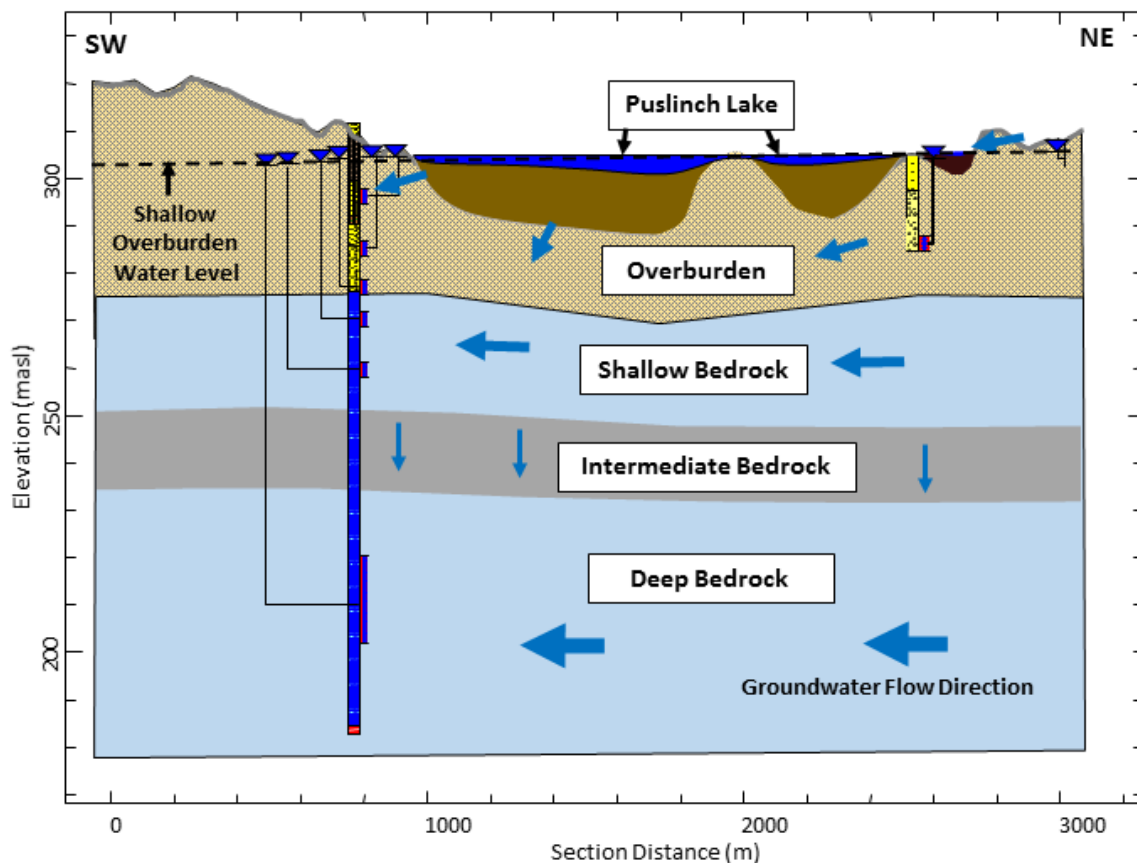


Figure 30c: Conceptual Groundwater Flow in the Vicinity of Puslinch Lake

This conceptual cross section oriented from northeast to southwest illustrates the groundwater flow direction is generally from the northeast to southwest. The groundwater interactions, similar to the McCormick Point wetland, are limited by the low permeability organic lakebed sediments and groundwater flux is negligible except where the lakebed sediments are thin or absent. As with the McCormick Point wetland, vertical hydraulic gradients change seasonally and shallow groundwater discharge is more likely to occur in the spring months when groundwater levels are at their highest. Regional groundwater flow in the deeper overburden is generally from the northeast to southwest and therefore, water levels are more likely to be higher with potential groundwater discharge in the northeast portion of the lake.

Figure 30C is a generalized illustration of shallow groundwater flow around the lake. The most detailed information on groundwater flow directions/gradients around the lake is from multi-level monitoring wells installed as part of the EA to the south and west of the lake, as further described below. Private wells monitored at the northeast shore of the lake had groundwater levels slightly below lake level. There are no monitoring well nests in the eastern portion of the lake to confirm if there are upward gradients present seasonally elsewhere in this portion of the lake.



Groundwater level data from shallow monitoring wells (PLOW1B-06 and PLOW2C-06) adjacent to Puslinch Lake (location shown on Figure 11) show that there are downward hydraulic gradients present between the lake level and the underlying overburden sand and gravel aquifer materials at these locations. As shown on Figure 15B, these downward gradients have been present since 2006 when these monitoring wells were installed. This is consistent with the assessment of shallow groundwater flow directions in this southwestern portion of Puslinch Lake completed by Harden (2010), which showed that groundwater flow is to the south in this area, with shallow groundwater levels below lake level. Monitoring well PTOW1, located to the northeast of Puslinch Lake with a depth of about 5.5 m, had a static groundwater level elevation of about 305 masl during testing in 2006, indicating a shallow groundwater gradient toward Puslinch Lake from the northeast.

The responses to pumping in the Puslinch Lake area during the 2006 28-day test, including lake levels and shallow monitoring wells less than 5 m deep (PLOW1B-06, PLOW2C-06 and PTOW1) are shown on Figures A6.10 and A6.11 in Attachment 6 of Appendix A. During this test, Puslinch Lake levels and the shallow water table rose in response to precipitation events, by about 0.07 m and 0.2 m, respectively. No responses to pumping were observed in the lake level or these shallow monitoring wells and downward hydraulic gradients were maintained during the pumping test.

Changes in overburden groundwater levels in monitoring wells installed to deeper depths to the south and west of Puslinch Lake were observed during the 28-day pumping test. As shown on Figure A17 (Appendix A), these wells had a static groundwater level elevation of about 303.5 masl prior to the 28-day pumping test, approximately 1.1 m lower than the static level of Puslinch Lake at 304.6 masl, indicating that these deeper overburden monitoring wells are less hydraulically connected to Puslinch Lake, with downward hydraulic gradients. At the end of the pumping test, the observations included a drawdown of 0.36 m at PLOW1A-06 (installed to a depth of 10.7 m), a drawdown of 0.45 m at PLOW1B-06 (installed to a depth of 12.0 m), a drawdown of 0.50 m at PBOW1F-06 (installed to a depth of 11.3 m), a drawdown of 0.88 m at PBOW2F-06 (installed to a depth of 17.1 m) and a drawdown of 0.40 m at private well C2 (installed to a depth of 27.4 m).

Harden (1999) presented a basic quantitative water balance for Puslinch Lake. This was a rough analysis and is re-presented here, including general comments on the uncertainties in the estimated components. The estimated values for precipitation, runoff, evaporation and lake outflow from Harden (1999) are presented in Table 13. The net recharge to groundwater from the Lake can then be derived by subtracting the outflows from the inflows and is 250,910 m³/year or 8 L/s. The rate reported by Harden of 225,000 m³/year (Harden, 1999; Table 3; reported as “Estimated Deep Aquifer Recharge”) is similar to the value re-calculated here using the same assumptions.



Table 13: Puslinch Lake Water Balance (from Harden, 1999)

Component		Rate (m/year)	Area	Rate (m ³ /year)	Rate (L/s)
Precipitation on Lake	Inflow	0.946	1,560,000	1,475,910	47
Runoff to Lake	Inflow	0.205	8,165,000	1,675,000	53
Evaporation from Lake	Outflow	0.652	1,560,000	1,000,000	32
Lake Outflow	Outflow			1,900,000	60
Net Recharge from Lake to Groundwater	Inflows Minus Outflows			250,910	8

It is important to note that there is a high degree of uncertainty in the water budget components assumed by Harden, such as the runoff to the lake and the lake outflow which are difficult to measure. The estimated groundwater recharge from the lake using this approach is not reliable due to uncertainty in the components. For example, 10% greater assumed values for outflows (evaporation and lake outflow), which is within the expected level of uncertainty, would result in an estimated net recharge from the lake to groundwater of zero.

Portuguese Swamp

There are two overburden monitoring well nests at the edges of the Portuguese Swamp, CMOW1-92 and CMOW2-92. Groundwater level data from these two monitoring nests showed that downward hydraulic gradients were present in the vicinity of the Portuguese swamp (Figure A6.5 in Attachment 6 of Appendix A). During the 28-day pumping test, the shallow water table levels at the shallowest monitors CMOW1C-92 (depth of 7.3-10.4 m), CMOW1D-92 (depth of 1.3-3.0 m), CMOW2C-92 (depth of 8.6-11.6 m) and CMOW2D-92 (depth of 1.3 to 3.0 m) increased during testing in response to rainfall events. Downward hydraulic gradients were maintained for the duration of the pumping test.

During the 15-day Pinebush pumping test in 2011, no responses to pumping were observed in the shallow drive point piezometers, DP3-11 and DP5-11 installed adjacent to the Portuguese swamp. There were small responses to pumping at CMOW1C-92 and PBOW1B-11 (depth of 6.1-7.6 m), with drawdowns of approximately 0.25 m and 0.30 m, respectively. Downward hydraulic gradients were maintained at all locations in the vicinity of the Portuguese swamp during this test.



3.5.5.2 Streams

Irish Creek

Irish Creek has been designated as a warm water creek by the Ministry of Natural Resources and Forestry (MNRF) (LIO, 2016). As described in Section 2.3.1.1, some information is available on groundwater discharge (baseflow) in Irish Creek from spot low flow measurements taken by Golder at stations IC_10 and IC_20 during the Guelph Tier 3 project field program (Golder, 2011b). Measurements were taken on days with a minimum of four consecutive prior days without observed precipitation in the area. These measurements showed that the creek was receiving some groundwater discharge, with low flow measurements ranging from 8 to 108 L/s. Irish Creek was not monitored during the 28-day pumping test, as it was outside the expected zone of influence of pumping. Continuous flow rate information is not available for Irish Creek.

Cedarbrook Creek

Cedarbrook Creek has been designated as a cold water creek by the MNRF (LIO, 2016) (Figure 6) that is groundwater supported. During the 28-day pumping test upward hydraulic gradients were observed, as measured at shallow piezometers and stream level stations installed in the creek (Figure A6.6 in Attachment 6 of Appendix A). Higher creek water levels resulted from the discharge of pumped water from CMPW1-06 and CMPW2-06 into Hilborn Pond and Cedarbrook Creek.

Mill Creek

Mill Creek has been designated as a cold water creek by the MNRF (LIO, 2016) (Figure 6) that is groundwater supported. Baseflow to Mill Creek, as observed during spot low flow measurements in 2008, ranged from 384 to 408 L/s (Golder, 2011b). For the 28-day pumping test, in the area adjacent to Avenue Road, the water level response hydrographs during testing are shown for the bedrock, overburden and shallow water table on Figures A14 and A15 of Appendix A. In this area, drawdown was limited to the lower Gasport Formation while water levels in the overlying Guelph Formation (SMTW1BC-05) did not respond to pumping. The shallow water table hydrograph (well 9203305), from a dug domestic well located at 855 Avenue Road, is representative of the background influence of the seasonal rains on the water table during the testing period, which was not influenced by the pumping test.

3.5.6 Groundwater Quality

Water quality results from the Cambridge East IUS testing are provided in Appendix A. The chemistry of major anions and cations in groundwater obtained from the test wells during pumping tests is summarized on the Piper plot shown on Figure 31. Water quality in the Cambridge East well fields ranges from calcium bicarbonate type to calcium sulphate type. Groundwater quality in the Pinebush well field tends to be dominated by the presence of calcium and bicarbonate ions consistent with this carbonate (dolomite) bedrock aquifer. Groundwater quality in the bedrock of the Shades Mill well field, including in North Dumfries, tends to be dominated by the presence of sulphate anions, which likely reflects a greater occurrence of gypsum and/or anhydrite (sulphate minerals) within the bedrock aquifer.



Groundwater from the Clemens Mill well field ranges from calcium bicarbonate type to calcium sulphate type.

There were no exceedances of health-related Ontario Drinking Water Standards (ODWS) (i.e., Maximum Acceptable Concentration (MAC)) for any tested inorganic parameter of groundwater from the Test Production Wells, PBPW1-06, PBPW2-08, CMPW1-06, CMPW2-06 and NDPW1-08. The only measured exceedances of the ODWS from all these test production wells was for hardness, a non-health related Operational Guideline (OG) of 80 to 100 mg/L. Hardness ranged from as low as 332 to 356 mg/L at CMPW1-06 and PBPW2-08 to as high as 523 to 558 mg/L at NDPW1-08. These hardness values were consistent with those historically observed at existing municipal supply wells in the Pinebush and Clemens Mill well fields. There was also an ODWS Aesthetic Objective (AO) exceedance for iron at NDPW1-08 (0.54 mg/L), exceeding the quality standard of 0.3 mg/L.

In the Pinebush and Clemens Mill well fields, inorganic water quality at the test production wells, PBPW1-06, PBPW2-08, CMPW1-06 and CMPW2-06 was generally characterized by concentrations of sodium (5 to 11 mg/L), chloride (5 to 25 mg/L), iron (0.04 to 0.28 mg/L) and manganese (0.005 to 0.008 mg/L) within the low end of the range of concentrations historically observed in the Pinebush and Clemens Mill production wells. It is noted that the Canadian Drinking Water Guidelines (CDWG) for manganese are currently being updated, including a new health based MAC of 0.1 mg/L and a new AO of 0.02 mg/L. In the current ODWS, there is no health based MAC objective; the new CDWG AO is lower than the current ODWS AO of 0.05 mg/L. Concentrations of manganese in these four Pinebush and Clemens Mill test production wells met these higher CDWG standards. Concentrations of sulphate at PBPW2-08 (58 to 63 mg/L) were on the higher end of the range of concentrations observed for the Pinebush production wells, while sulphate concentrations at PBPW1-06 (99 to 139 mg/L), CMPW1-06 (88 to 120 mg/L) and CMPW2-06 (207 to 288 mg/L) were slightly higher than the range typically observed in the Pinebush and Clemens Mill production wells, but less than the ODWS-AO of 500 mg/L.

3.5.6.1 Organic Groundwater Chemistry

Samples for organic water chemistry analyses were obtained during the pumping tests at PBPW1-06, CMPW1-06, CMPW2-06, PBPW2-08 and NDPW1-08. With the exception of total xylenes at PBPW1-06, CMPW1-06 and CMPW2-06, the results were all below the method detection limits (MDL) reported by the laboratories. All reported parameters were below the Maximum Acceptable Concentrations (MAC) and the Interim Maximum Acceptable Concentrations (IMAC) as outlined in the ODWS.

Low levels of xylene (total) were detected in PBPW1-06, CMPW1-06 and CMPW2-06, ranging from 0.005 to 0.022 mg/L. These concentrations were below the current ODWS AO of 0.3 mg/L for total xylenes. However, in 2014, Health Canada set a health-based CDWG for xylenes at 0.09 mg/L and an AO of 0.02 mg/L, which will be adopted into the ODWS in 2017. The concentration of 0.022 mg/L of total xylenes at CMPW1-06 will exceed the new ODWS AO. While the origin of this xylene is not known, it could be an artifact of well construction and this occurrence is not thought to reflect a local land use or water quality concern; however,



these wells should be re-sampled to establish that xylenes do not represent a concern for a future municipal groundwater supply.

The method detection limits (MDL) for two compounds, 2,4-Dichlorophenol and 2,3,4,6-Tetrachlorophenol in the PBPW1-06, CMPW1-06, CMPW2-06 and PBPW2-08 samples, as reported by the Region's Laboratory, were higher than the objectives set out in the ODWS. The Region reported an MDL for 2,4-Dichlorophenol of 0.005 mg/L, a value that exceeded the AO of 0.0003 mg/L for this parameter and for 2,3,4,6-Tetrachlorophenol, the reported MDL of 0.001 mg/L was equal to the AO value for this parameter. This does not indicate that these compounds are necessarily present in this water; however these parameters should be re-analyzed in future using appropriate method detection limits.

Some parameters included in the ODWS Table 2 were not reported by the Region's Laboratory; these included NDMA, NTA, antimony, bromate and arsenic. Prior to bringing any new wells online, these wells should be re-sampled and analyzed for the full ODWS suite, confirming the MDLs meet the ODWS. Based on discussions with the Region, it is also recommended that these wells be analyzed for 1,4 Dioxane, a compound that has been detected in municipal wells elsewhere in the Region.

3.5.6.2 Groundwater Chemistry at Additional Test Wells

During the 15-day pumping test at P10A, P10B, PBTW1-10 and P17, groundwater samples were taken from these wells and analyzed for microbiological, inorganic and organic parameters with respect to the ODWS Tables 1 to 4 (Stantec, 2013a). Total coliforms and *Escherichia coli* (*E. coli*) were not detected in any sample during the test. With respect to inorganic water quality, there were no ODWS MAC exceedances. Hardness exceeded the ODWS AO criteria, ranging in concentration from 270 to 290 mg/L at P10A and PBTW1-10 and from 400 to 460 mg/L at P10B. Iron concentrations at P10A (0.6 mg/L) and P10B (1.1 mg/L to 1.2 mg/L) exceeded the ODWS AO criteria of 0.3 mg/L. Manganese concentrations at P10B (0.09 to 0.13 mg/L) exceeded the current ODWS AO of 0.05 mg/L as well as the updated CDWG standard of 0.02 mg/L. Turbidity levels of 6 to 7 NTU in P10A and 9 to 13 NTU in P10B also exceed the ODWS AO of 5 NTU. It was interpreted that the elevated turbidity levels were related to the iron and manganese concentrations in P10A and P10B. The Pinebush WTP includes a filtration system for iron and manganese removal.

Water quality data from the deeper bedrock wells, including P10A and PBTW1-10, indicated low chloride and sodium concentrations. Water quality data from P10B, screened across the deep overburden and into the shallow bedrock, had higher sodium (41 to 74 mg/L) and chloride (100 to 160 mg/L) concentrations, likely indicating effects of nearby road salting practices. (Stantec, 2013a).

Groundwater samples from PBTW1-10 and P10B were also obtained during the 15-day pumping test for analysis of volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), pesticides, herbicides, PCBs, dioxins and furans. There were no exceedances of the ODWS MAC for any tested organic parameter and all organic compounds



measured were below the MDLs, including also the earlier tested parameters from P10A (R.J. Burnside, 2011).

4.0 Evaluation of Groundwater Pumping Strategies

4.1 Planning for Future Water Supply Requirements

As noted in section 1.3, both the WSMP (Stantec, 2015a) and the WSDOMP (Stantec, 2015b) recommended the optimization of groundwater supplies to the WTPs in Cambridge East to help meet medium-term (2031) and long-term (2051) projected IUS water demands. The Cambridge East WTP facilities are crucial in the WSDOMP, due to their central locations on the east side, which would allow water to be pumped north or south as needed to help meet IUS water demands and in the event of short-term supply shutdowns at other sources.

As noted in Section 1.3.2, the Region developed a regional scale 3-dimensional numerical model of the groundwater system that was used to assess water availability to meet projected 2031 demands for the Region's IUS. This included a portion of the increase in supply coming from the Cambridge East well systems and WTPs. The Tier 3 assessment used the average day municipal well pumping rates for year 2008 as the "existing conditions" on which to evaluate the sustainability of supply sources due to changes in future land uses, pumping rates and drought conditions. The 2008 rates were used for all the municipal wells in the IUS, with the exception of wells G38 and G39, for which the 2005/2006 average day pumping rates were assigned, as these wells were offline in 2007/2008. These same "existing condition" rates were used in this Class EA to compare other options for optimizing the supply of water to the three WTPs in Cambridge East. The specific options evaluated included:

- **Existing Pumping Conditions-** The 2008 pumping rates (2005/2006 for G38 and G39) used in the Tier 3 "existing condition" were used as the baseline to compare other options. This represented a total supply to Cambridge East WTPs of 187 L/s;
- **2031 Supply from Existing Wells Only-** This option used the pumping rates for the existing Cambridge East WTP wells that were used in the Tier 3 assessment to help meet the projected IUS 2031 demands. This represents an 18 L/s increase at WTP wells, over the existing pumping conditions, to a total of 205 L/s;
- **2031 Supply from Existing and New Wells-** This option included pumping from existing and new Cambridge East WTP wells, in different configurations, to help meet the projected IUS 2031 demands. This represents a 38 L/s increase at WTP wells, over the existing pumping conditions, to a total of 225 L/s.

Figure 32 illustrates the existing conditions and potential future supply rates for the Cambridge East WTP wells and the total capacity of the WTPs. While this figure shows the average day rates, actual daily pumping rates vary considerably and daily maximum rates can typically be about one-third higher than average-day rates. The engineered components of the water supply system, including the water treatment plants (WTPs), are typically sized to



accommodate daily maximum pumping rates, which is why the total licenced capacity of the WTPs is considerably greater than the average daily pumping rates presented on Figure 32. Average daily pumping rates are used herein as the basis for the Class EA evaluations.

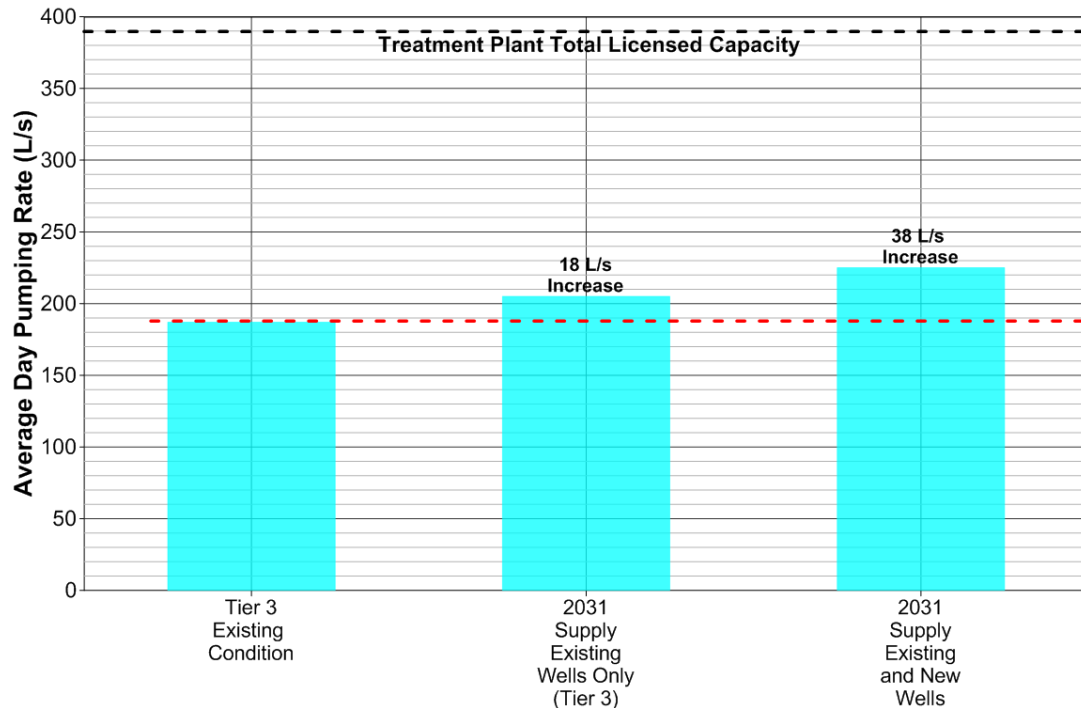


Figure 32: Cambridge East WTPs – Long-Term Water Supply Requirements

As noted previously, the Tier 3 modelling formed the basis for the numerical modelling conducted to support this EA. During the EA, the Tier 3 model was enhanced in the Cambridge East area. Additional transient model calibration was undertaken utilizing data collected during a 15-day pumping test of the Pinebush Well Field, which was conducted at a higher pumping rate (126 L/s) than the wells are typically pumped during normal operation.

It is important to note that the proposed pumping increases in Cambridge East would be implemented gradually over the next 15 years as IUS water demands increase. This extended time period allows for monitoring and evaluating the effects of that increase over time.

The water supply rate options considered as part of the Cambridge East Class EA are further described below.

Existing Pumping Conditions

Table 14 presents the existing condition pumping rates for wells supplying the WTPs, along with pumping from other wells in Cambridge East. This table also identifies the individual wells supplying the respective WTP in each well field, the total permitted pumping limit as



provided on the PTTWs for these wells, along with the licenced limit of each of the WTPs in Cambridge East.

Table 14: Pumping Rates and Water Treatment Plant Capacity (L/s)

	Tier 3 existing conditions average day pumping rates (L/s)	PTTW permit total (L/s)	WTP Licenced Capacity (L/s)
Pinebush WTP (Wells P10, P11, P17)	56	120	120
Turnbull (Clemens Mill) WTP (Wells G16, G17, G18)	54	126	120
Shades Mill WTP (Wells G7, G8, G38, G39 and G40)	77	175	150
Total - Cambridge East WTP Wells	187	421	390
Other Wells in Cambridge East (Pinebush and Clemens Mill well fields)	63	94	-
Total – All Wells in Cambridge East	250	515	-

The existing condition average day pumping rates for wells supplying the three WTPs in Cambridge East totalled 187 L/s. Accounting for wells in Cambridge East that do not supply the WTPs, but pumped directly to the distribution system, total groundwater pumping for the entire Cambridge East area under the Tier 3 existing conditions was 250 L/s. Again these are the same rates used for existing pumping conditions in the Tier 3 Assessment.

2031 Supply From Existing Wells Only

As part of the Tier 3 Assessment, pumping rates were optimized for existing municipal supply wells to represent how the Region could meet the projected IUS 2031 water demands with existing supply wells. These rates represented only one possible set of rates that could be used across the IUS. For Cambridge East, this included an additional 18 L/s from existing wells supplying the Cambridge East WTPs. The remaining additional water (20 L/s for a total of 38 L/s) needed in Cambridge to help meet the 2031 demands, was supplied by wells located elsewhere in Cambridge. This resulted in a total average day supply of 205 L/s for the three Cambridge East WTPs. Although this scenario helped to meet the overall IUS 2031 supply requirements, it did not meet the objectives of the WSMP and WSDOMP, which recommended increased utilization of the Cambridge East WTPs existing capacity due to their optimal locations on the east side of Cambridge, as discussed previously.



2031 Supply From Existing and New Wells

As part of this Class EA, both existing and some of the new wells installed as part of this Class EA, or other related projects, were simulated to increase the average day water supply from the Cambridge East WTPs by 38 L/s. This rate represented all the water that was needed to meet 2031 demands in Cambridge, to be supplied from these wells, which is consistent with the overall objectives of the WSDOMP. This represented a total average day supply requirement of 225 L/s for the WTPs.

It should be noted that the proposed increase in pumping from the Cambridge East well fields is significantly less than what was originally considered at the start of the Class EA project (Ref Section 1.3). Accordingly, it is also about one third of the pumping rate used during the 28-day constant rate pumping test conducted on these wells in 2006. As previously discussed, no measurable effects were observed on Puslinch Lake, wetlands, or nearby creeks during this pumping test.

The options assessed for this Class EA reflect how the water supply system for the Cambridge East WTPs could be operated to help meet the average day projected IUS 2031 demands. The Region also undertook modelling evaluations to assess how the water supply to Cambridge could be maintained on a short-term basis during a period when a large water source was unavailable, to facilitate well replacement or equipment upgrades. This could require temporary increased pumping at other Cambridge wells to offset this short-term reduction in pumping at a specific facility. Groundwater pumping strategies to meet this hypothetical short term shutdown were also evaluated in this Class EA, as a contingency planning measure, and are presented in Section 4.3.2.

4.2 Alternative Solutions

Alternative solutions developed to help meet projected IUS 2031 supply requirements, from wells in Cambridge East, included increased pumping from existing wells, increased pumping from wells at existing sites that have been modified to provide for higher pumping rates, increased pumping from new wells at existing sites, and increased pumping from new well sites.

The following sections identify the production wells that could be utilized for each of the alternative water supply solutions to be evaluated as part of the Cambridge East Class EA. This analysis evaluated various well pumping configurations that could be used to help meet the projected IUS 2031 demands and to maximize the use of the Cambridge East WTPs, as recommended in the WSMP/ WSDOMP.

4.2.1 Pinebush Well Field Alternative Solutions

The alternative solutions under consideration for the Pinebush well field are summarized in Table 15.



Table 15: Pinebush (PB) Well Field Alternative Solutions

Alternative Solutions		Maximizes Use of Treatment Plant
PB-1	Do Nothing: Use existing wells: • P10, P11, P17	No
PB-2	Apply Alternative Solution PB-1 and construct new wells at existing sites: • P10A, P10B, PBTW1-10	Yes
PB-3A	Apply Alternatives PB-1 and PB-2 and use well at new site: • PBTW1-06 (Witmer Park)	Yes (Provides more water than is needed in 2031 so is not carried forward)
PB-3B	Apply Alternatives PB-1 and PB-2 and use well at new site: • PBTW2-08 (Can-Amera Parkway)	Yes (Provides more water than is needed in 2031 so is not carried forward)

For the Pinebush well field, the investigations have shown that through constructing new wells at existing sites, the use of the Pinebush WTP can be maximized (alternative PB-2). In order to minimize potential effects in new areas as well as operational complexity, this solution would be preferred compared to moving to new sites, so the new wells (Witmer Park – alternative PB-3A and Can-Amera Parkway- alternative PB-3B) were not carried forward for further evaluation in the Class EA.

4.2.2 Clemens Mill Well Field Alternative Solutions

The alternative solutions under consideration for the Clemens Mill well field are summarized in Table 16.

Table 16: Clemens Mill (CM) Well Field Alternative Solutions

Alternative Solutions		Maximizes Use of Treatment Plant
CM-1	Do Nothing: Use existing wells only: • G16, G17, G18	No
CM-2	Apply Alternative CM-1 and adapt and modify wells at existing sites: • Increase pumping from deepened G16	No
CM-3A	Apply Alternatives CM-1 and CM-2 and use well at new site: • CMPW2-06 (Cedarbrook)	Yes



Alternative Solutions		Maximizes Use of Treatment Plant
CM-3B	Apply Alternatives CM-1 and CM-2 and use well at new site: • CMPW1-06 (Portuguese Club)	Yes

As mentioned previously, existing well G18 is located on the Clemens Mill Public School property, not Region owned land, and this site may not continue to be suitable/accessible in the long term. This potential situation will be considered in the evaluation of alternative solutions.

4.2.3 Shades Mill Well Field Alternative Solutions

The alternative solutions under consideration for the Shade's Mills well field are summarized in Table 17.

Table 17: Shades Mill (SM) Well Field Alternative Solutions

Alternative Solutions		Maximizes Use of Treatment Plant
SM-1	Do Nothing: Use existing wells: • G7, G8, G38 and G39	No
SM-2	Apply Alternative SM-1 and construct new well at existing site: • G40	No
SM-3	Apply Alternatives SM-1 and SM-2 and use well at new site: • NDPW1-06 (Clyde Park)	Yes (As supplies can be more cost effectively provided at Pinebush and Clemens Mill, this alternative is not carried forward)

There are several combinations of alternative solutions at the three well fields that enable the Region to meet 2031 supply scenarios for the WTPs. As noted previously, while increased pumping at the Shades Mill well field can provide the required supply for the Shades Mill WTP (SM-3), the much greater distance between the new well at Clyde Park and the WTP make this alternative cost prohibitive compared to options for either the Pinebush and/or Clemens Mill well field(s) and WTPs. Therefore, this alternative solution (SM-3) was not carried forward in the Class EA and pumping at the Tier 3 existing condition rates for the Shades Mill wells was maintained for the evaluations.



4.3 Groundwater Pumping Model Scenarios

4.3.1 Long-Term (Steady-State) Simulations

Numerical modelling was completed to simulate potential changes in the groundwater environment, relative to the existing pumping conditions, for the alternative solutions considered to meet the projected IUS 2031 supply requirements of the Cambridge East WTPs. Details of model construction, calibration and the simulations are presented in Appendix D.

The steady-state modelling results were compared to existing conditions by comparison of groundwater levels and flows; specifically the following changes in the groundwater flow systems were assessed for each model simulation scenario:

- Groundwater levels in the lower bedrock system, the aquifer that provides the bulk of the groundwater pumped at municipal production wells;
- Groundwater levels in the contact aquifer system, the aquifer at the base of the overburden and including the upper fractured bedrock. Groundwater in this system supports the shallow water table that in turn supports groundwater dependant environmental features such as streams and wetlands, and also shallow domestic water wells;
- Changes in the water balance and vertical flow to the bedrock aquifer in different subwatersheds;
- Changes in the groundwater discharge (baseflow) to local streams; and
- Changes in the water balance for Puslinch Lake.

The steady-state scenarios provided simulations for the operation of various combinations of the supply wells to provide the projected 2031 IUS supply requirements from the Cambridge East WTPs. These simulations were completed for 'steady-state' conditions; for which the pumping rates were maintained at a constant rate on a continuous basis and the resultant effects on long-term average groundwater levels were analyzed (relative to the existing pumping conditions as used in the Tier 3 Assessment). The combinations of alternative solutions and steady-state model scenarios considered are illustrated on Figure 33.

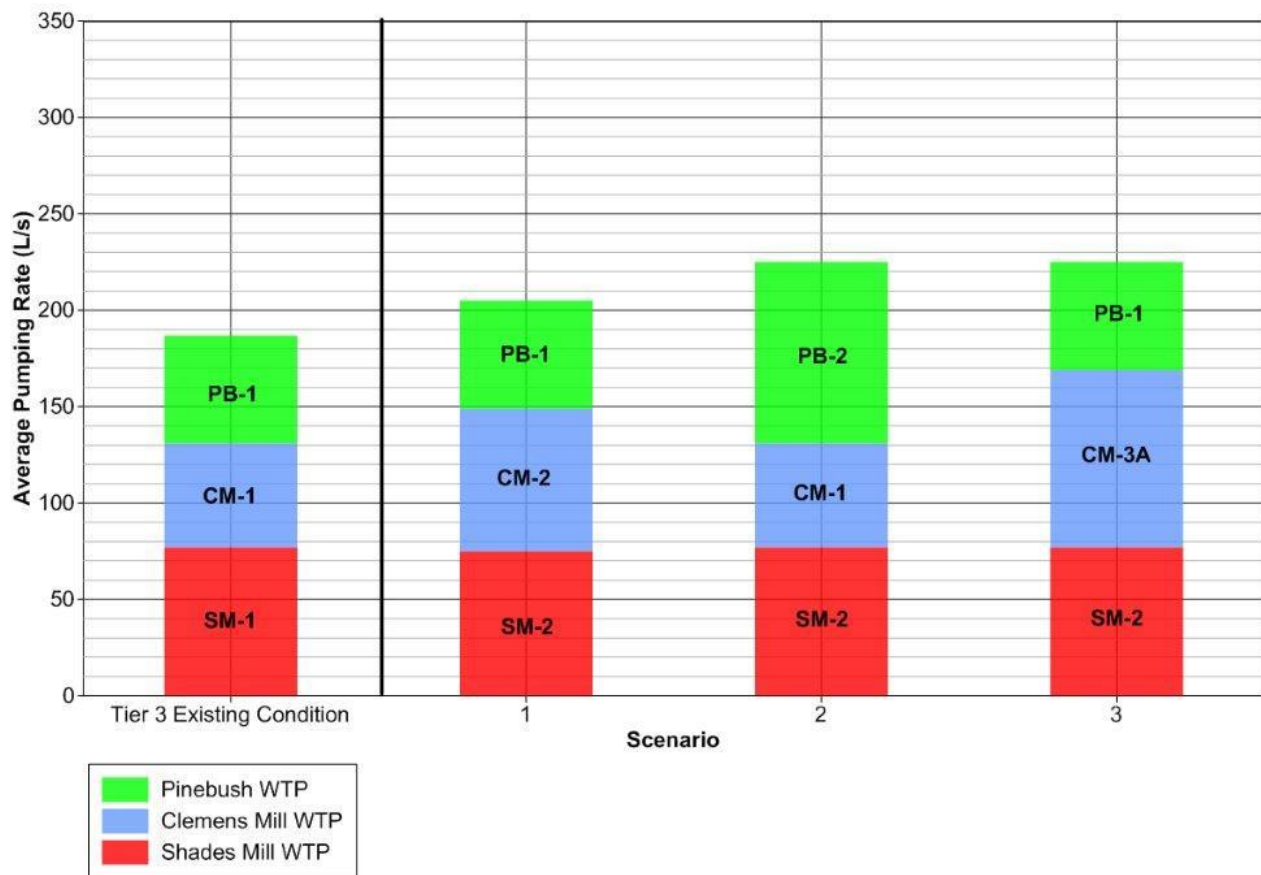


Figure 33: Cambridge East WTPs – Alternative Solutions and Simulated Water Supply Scenarios

The three steady-state water supply scenarios varied in the distribution of wells from which the additional water was obtained, specifically:

- **Scenario 1:** moderate increased pumping from Clemens Mill, with additional increases elsewhere from Cambridge existing municipal wells (alternative solutions PB-1, CM-2 and SM-2). This scenario is equivalent to the Tier 3 project 2031 scenario.
- **Scenario 2:** increased pumping from new wells located in the vicinity of well P10 at the Pinebush well field (wells P10A, P10B and PBTW1-10) (alternative solutions PB-2, CM-1 and SM-2). This scenario included reduced pumping from the Contact Aquifer well P10B (which replaced P10) and increased pumping from the deep aquifer at P10A and PBTW1-10. The rates of other wells remained the same as the existing conditions for this scenario; and



- **Scenario 3:** increased pumping from a new well (Cedarbrook), which is one of two possible new wells located in the Clemens Mill well field (alternative solutions PB-1, CM-3A and SM-2). The rates of other wells remained the same as the existing conditions for this scenario.

Table 18 summarises the steady-state model scenarios simulated along with the alternative solution that each simulation represents.

Table 18: Summary of Alternative Water Supply Solutions and Steady-State Model Scenarios

Model Scenario	Alternative Solutions	Change in pumping (L/s) at Cambridge EA WTPs	Focus of Increased Pumping	Comment
1	PB-1, CM-2 and SM-2	Pinebush 0 Clemens Mill +20 Shades Mill -2	Distributed in Clemens Mill existing wells as well as in other well fields elsewhere in Cambridge	Tier 3 project 2031 scenario. Provides minor additional water for Turnbull WTP.
2	PB-2, CM-1 and SM-2	Pinebush +38 Clemens Mill 0 Shades Mill 0	In Pinebush in the vicinity of well P10	Provides additional water for Pinebush WTP.
3	PB-1, CM-3A and SM-2	Pinebush 0 Clemens Mill +38 Shades Mill 0	In Clemens Mill, including Cedarbrook Well (CMPW2-06)	Provides additional water for Turnbull WTP.

Of the two new wells in the Clemens Mill well field, the Cedarbrook well was more productive than the Portuguese Club well, so the Portuguese Club well (alternative solution CM-3B), was not considered in the steady-state simulations. As discussed previously, the use of the new Clyde Park well to provide additional water supply for the Shades Mill WTP (alternative solution SM-3) was not considered because it would be cost-prohibitive to connect this well to the WTP, compared to connecting new wells in either of the Pinebush or Clemens Mill well fields to their respective WTPs.

4.3.1.1 Steady-State Simulated Groundwater Level Drawdown Results

The simulated extent of the area influenced by pumping the required additional 38 L/s for each of the steady-state scenarios is shown on Figure 34, for the Gasport and Contact aquifers, and is summarized in Table 19.



Table 19: Summary of Horizontal and Vertical Groundwater Connections – Steady-State Model Scenarios

Model Scenario	Lateral Extent of Effect in Gasport Aquifer	Lateral Extent of Effect in Contact Aquifer	Vertical Connection from pumped Gasport Aquifer to Overlying Contact Aquifer
1	Limited to within about 1 km from well G16 and extended slightly east of Townline Road	Insignificant	Very Limited to No Vertical Connection
2	Extending east of Townline Road and to Puslinch Lake	Similar to Gasport effect although diminished, extending to western edge of Puslinch Lake	Some Vertical Connection
3	More extensive to the east of Townline Road	Localized in the vicinity of Portuguese Swamp and only slightly extended east of Townline Road	Limited Vertical Connection

The limits of the area of influence of the additional pumping were delineated as the simulated contour of 2 m decline in groundwater levels (2 m drawdown) with respect to existing conditions. The 2 m contour represents the likely minimum change in groundwater levels that can be reasonably distinguished from observed background fluctuations in groundwater levels. It should be noted that the 2 m criterion was adopted for the water quantity well head protection area (WHPA-Q1) for the Region's Tier 3 Assessment (Matrix and SSPA, 2014). The simulated 1 m drawdown contours are also shown. The greatest lateral extent of simulated effect occurred in the Gasport Aquifer, the aquifer in which the pumping wells are completed, with less effect simulated in the overlying Contact Aquifer. This is consistent with the results observed during the pumping tests and was expected as the production wells are completed within main flow producing zones in the Gasport Aquifer.

The Tier 3 Assessment scenario (Scenario 1) included increased pumping primarily from the deepened well G16. Since this deepened well draws water from the Gasport Aquifer, the simulated drawdown was largely limited to within this deep aquifer, with localized drawdown simulated in the immediate vicinity of G16 in the Contact Aquifer (Figure 34).

For Scenario 2, with the pumping increases in the Pinebush area, there was some simulated vertical connection from the Gasport Aquifer to the Contact Aquifer in the Pinebush area, as shown by the similar extent of the simulated 1 m drawdown contours in the two aquifers. This is consistent with the absence of the low permeability Vinemount Aquitard in this area, although the other bedrock units do limit the vertical hydraulic connection to some degree. For Clemens Mill, the simulated area of influence in the Contact Aquifer was much smaller relative to that of the underlying Gasport Aquifer, indicating a weaker vertical hydraulic



connection compared to the Pinebush area. This is due to the presence of the Vinemount Aquitard overlying the pumped Gasport Aquifer zone in the vicinity of the Cedarbrook well.

4.3.1.2 Steady-State Simulated Effects on Surface Water: Water Balance Assessment

The groundwater model results also provide estimates of potential effects to the surface water environment. It is important to note that there is a relatively high degree of uncertainty in the model simulations of changes to surface water levels and flows, since no responses to actual pumping have been observed at surface water features to constrain the model, and as a regional scale model, it is very difficult to incorporate every surface water feature in the model.

To assess the general source areas of the additional pumped water, model water balance estimates were completed. Pumped groundwater ultimately represents a potential loss of water from surface water features within the various subwatersheds. Figure 35 provides the delineation of local subwatersheds within the simulated pumping zone of influence considered in this analysis (SSPA and Matrix 2016; Appendix D). For each of these subwatersheds, the simulated increase in the quantity of groundwater that flowed down across the top of the bedrock, in response to increased pumping, is summarized in Table 20. The remainder of the additional water was simulated as capture of regional bedrock groundwater flow from outside of the areas shown on Figure 35.

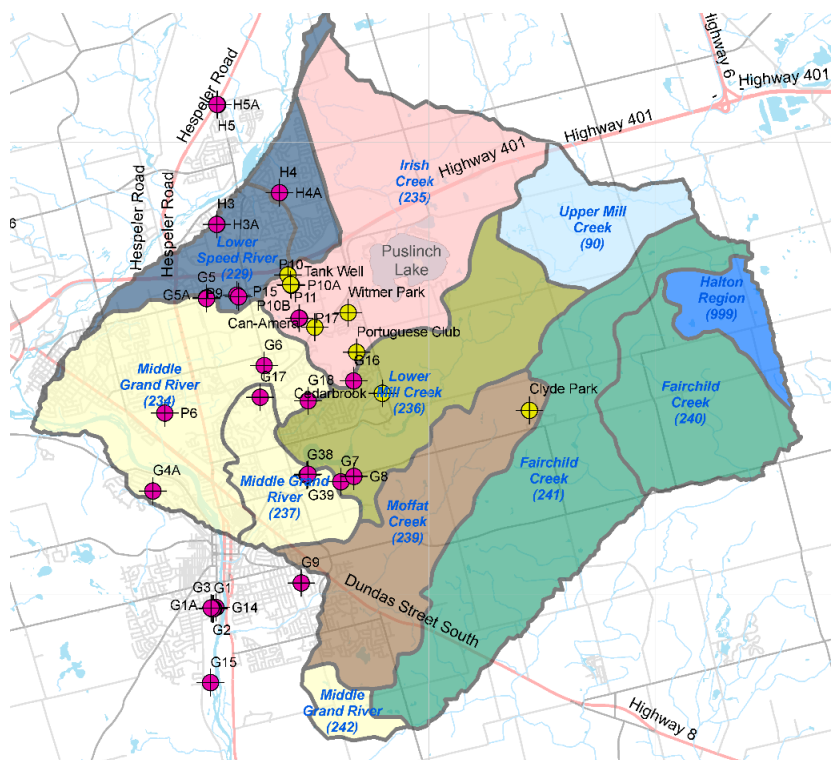


Figure 35: Delineation of Subwatersheds for Model Water Balance Calculations
Source: SSPA and Matrix, 2016 (Figure 46, Appendix D)



Table 20: Steady-State Model Water Balance Calculations - Source of Additional Future Water Supply (L/s)

Model Water Balance Component		Scenario 1	Scenario 2	Scenario 3
Additional Groundwater Pumped to Cambridge East WTPs (L/s)		18 (plus 20 elsewhere in Cambridge)	38	38
Source of Additional Pumped Groundwater (L/s)	Lower Speed River Subwatershed (84)	13	3	1
	Lower Speed River Subwatershed (229)	10	4	N/A
	Irish Creek Subwatershed (235)	10	16	14
	Lower Mill Creek Subwatershed (234)	4	3	8
	Middle Grand River Subwatershed (234)	1	2	1
	Other Subwatersheds per Figure 35	N/A	2	6
	Regional Bedrock Groundwater Flow Capture ¹	N/A	8	8
	Total	38	38	38

Note: 1) This remainder of the additional water was simulated as capture of regional bedrock groundwater flow from outside of the areas shown on Figure 35.

These simulations provide a general indication of which subwatersheds are the source of the additional pumped water for each scenario, as summarized below:

- The Existing Wells (Tier 3) steady-state Scenario 1 showed the majority of the additional pumped groundwater was sourced from the Lower Speed River and Irish Creek Subwatersheds.
- The Pinebush focused steady-state Scenario 2 showed the majority of additional pumped groundwater was sourced from the Irish Creek Subwatershed.
- The Clemens Mill focused steady-state Scenario 3 showed the majority of additional pumped groundwater was sourced from the Irish Creek and Lower Mill Creek Subwatersheds.



4.3.1.3 Steady-State Simulated Effects on Surface Water: Individual Streams and Puslinch Lake

Effects on surface water flows were also simulated, as represented by changes in groundwater discharges to individual streams, and compared to the simulated Tier 3 existing conditions baseflow. As mentioned previously, it is important to note that there is a relatively high degree of uncertainty in the model simulations of changes to surface water flows, since no responses to pumping have been observed at surface water features to constrain the model.

The potential effect on Puslinch Lake was also assessed, as represented by simulated quantities of groundwater inflows and outflows (water balance), and compared to the simulated Tier 3 existing conditions water balance. The results for the model scenarios are summarized below and presented in Table 21.

Table 21: Steady-State Simulated Percent Reductions in Stream Baseflow and Groundwater Balance for Puslinch Lake

Station	Steady-State Scenario		
	1	2	3
Aberfoyle Creek (3AQ131)	No Change	No Change	No Change
Mill Creek (2GAC19)	<1%	<1%	<1%
Irish Creek (IC-20)	11%	14%	14%
Ellis Creek (between EC_20 and CGC10)	2%	<1%	<1%
Puslinch Lake (increase in net groundwater outflow)	3%	6%	6%

Scenario 1: With the exception of Irish Creek, the simulated changes in groundwater discharge to streams with respect to existing conditions were negligible (generally less than 1%). For Irish Creek, it was simulated by the model that baseflows would be reduced by 11%. For Puslinch Lake, the simulated changes in groundwater water budget were in the order of 3%.

Scenario 2: The simulated groundwater discharge reductions to most streams were small and similar to the results for Scenario 1. For Irish Creek, a 14% reduction in baseflow was simulated. For Puslinch Lake, the simulated changes in the groundwater budget were in the order of 6%.

Scenario 3: The only appreciable reduction in groundwater discharge to surface water for Scenario 3 was simulated to occur at Irish Creek with a 14% reduction, which is the same as



in Scenario 2. The simulated changes to the water budget of Puslinch Lake were approximately the same as for Scenario 2, with an increase in net groundwater outflow of about 6%.

Relative to Scenario 1, there was a simulated 3% reduction in groundwater discharge to Irish Creek and a 3% simulated increase in net groundwater outflow from Puslinch Lake for both Scenario 2 and Scenario 3.

4.3.2 Short Term Shutdown Contingency (Transient) Simulations

The focus of the Class EA impact assessment was on the long-term (steady-state) potential effects; however, two transient simulations were completed to provide information on how the Region might operate the system as a planning contingency in the event of a large well shutdown. The potential effects from this shutdown would be temporary, not long-term; however, an assessment of the potential effects of the shutdown is provided for completeness.

To better understand the potential effects of increasing pumping in Cambridge East for a short duration, the model was used to evaluate the temporary shutdown of the largest supply well in Cambridge, while pumping to meet the projected 2031 supply requirements. For example, the temporary shutdown of Middleton Well G2 in 2031, could require supplying an additional average day rate of 98 L/s from the three Cambridge East WTPs, resulting in a total average day supply requirement of 285 L/s. The transient simulations are described in a separate modelling technical memorandum (SSPA, 2017; Appendix D).

A temporary increase in pumping from Pinebush and Clemens Mill for a period of three months was simulated, with the model running in transient mode, to assess the effects of the short-term shutdown contingency case, after which pumping would be returned to the previous 2031 rates (Figure 36). A period of three months was evaluated to represent an assumed period of time for the Region to reconfigure pumping from other existing Cambridge sources to accommodate the shutdown, until the source could be re-activated. It should be noted that for the transient simulations, shallow groundwater responses at distance from the pumping centres may have still been developing, before pumping conditions were returned to previous rates and groundwater levels recovered. Two transient scenarios were evaluated, as illustrated in Figure 36 and summarized below.

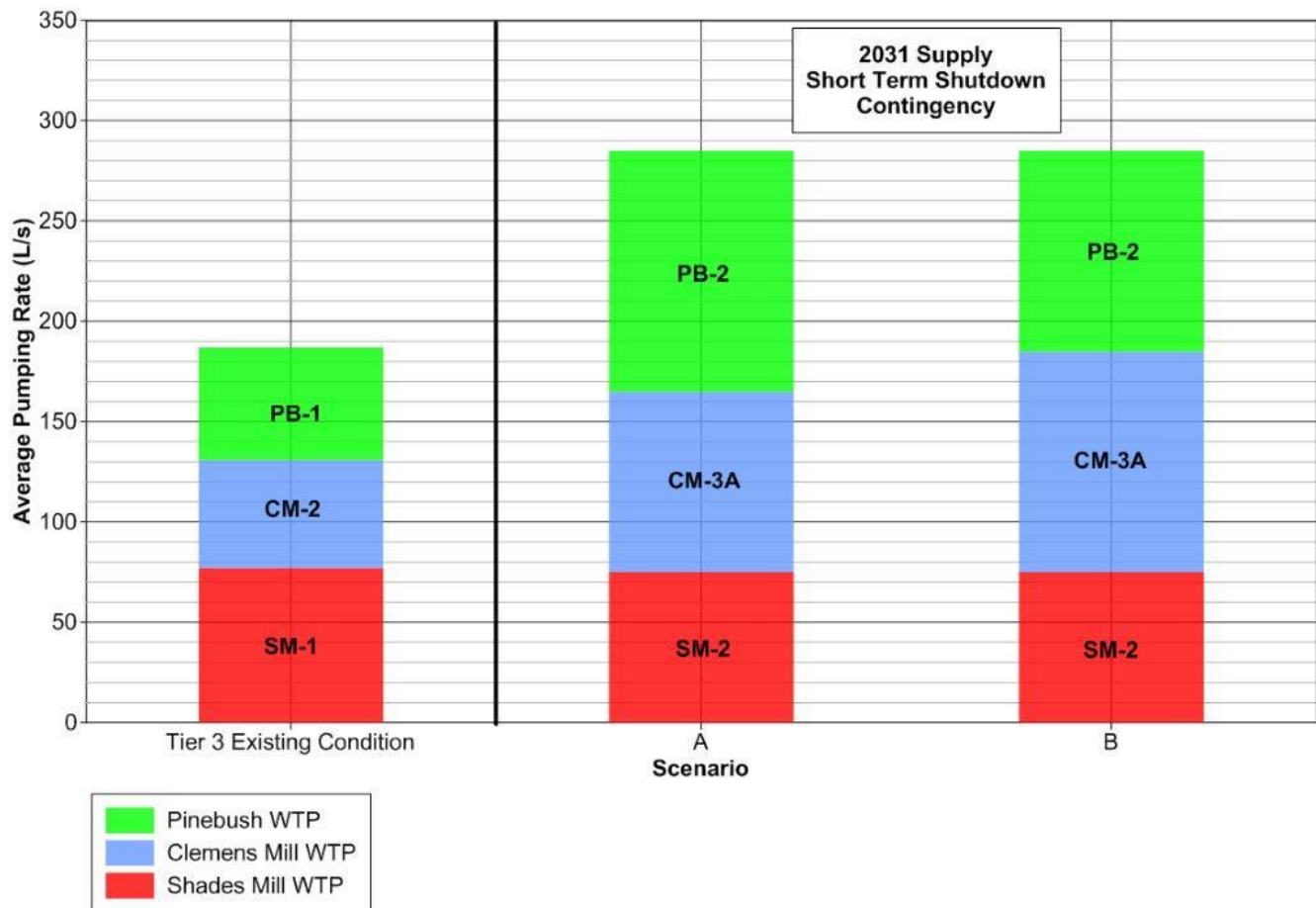


Figure 36: Cambridge East WTPs – Alternative Solutions and Simulated Water Supply Scenarios – Short Term Shutdown Contingency (Transient Scenarios)

The two transient scenarios varied in the distribution of wells from which the additional water was obtained, specifically:

- **Scenario A:** Maximize pumping in Pinebush with the remainder from Clemens Mill, including the new Cedarbrook well site (alternative solutions PB-2, CM-3A and SM-2); and
- **Scenario B:** Maximize pumping in Clemens Mill, including the new Cedarbrook well site, with the remaining increase at the Pinebush well field (alternative solutions PB-2, CM-3A and SM-2).

Table 22 summarizes the transient model scenarios along with the alternative scenario that each shutdown simulation represents. These scenarios involve pumping from the same wells and the same alternative solutions but using different pumping rates.



Table 22: Summary of Alternative Water Supply Solutions and Transient Model Scenarios

Transient Model Scenario	Alternative Solutions	Change in pumping (L/s) at Cambridge EA WTPs	Focus of Increased Pumping	Comment
A	PB-2, CM-3A and SM-2	Pinebush +64 Clemens Mill +36 Shades Mill -2	Maximized in Pinebush with remainder in Clemens Mill (including Cedarbrook well)	Maximizes WTP capacity at Pinebush and provides additional water for Turnbull WTP
B	PB-2, CM-3A and SM-2	Pinebush +44 Clemens Mill +56 Shades Mill -2	Maximized in Clemens Mill (including Cedarbrook well) with remainder in Pinebush (in vicinity of well P10)	Maximizes WTP capacity at Turnbull and provides additional water for Pinebush WTP

The extents of the simulated drawdowns for the transient simulated scenarios are shown on Figure 37 and are summarized in Table 23.

Table 23: Summary of Horizontal and Vertical Groundwater Connections – Transient Model Scenarios

Transient Model Scenario	Lateral Extent of Effect in Gasport Aquifer	Lateral Extent of Effect in Contact Aquifer	Vertical Connection from pumped Gasport Aquifer to Overlying Contact Aquifer
A	Extended approximately 4 km east of Townline Road	Extended east of Townline Road to western edge of Puslinch Lake	Moderate Vertical Connection in Pinebush area, less connected in the vicinity of Cedarbrook well
B	Extended approximately 4 km east of Townline Road	Extended east of Townline Road to western edge of Puslinch Lake	Moderate Vertical Connection in Pinebush area, less connected in the vicinity of Cedarbrook well

The greatest lateral extents of simulated effects occurred in the Gasport Aquifer, the aquifer in which the pumping wells are completed, with less effects simulated in the overlying Contact



Aquifer. This is consistent with the results observed during the pumping tests completed for this Class EA, and was expected as the production wells are completed in this deep aquifer. The extents of drawdowns in the Gasport Aquifer were slightly more extensive for the transient simulations than for the steady-state simulations and were slightly larger than the combined drawdowns in the Gasport from both Scenario 2 and Scenario 3. The eastern extents of drawdowns in the Contact Aquifer for Scenarios A and B were similar to the drawdown in the Contact Aquifer in Scenario 2, although slightly more extensive. The extent of drawdown in the Contact Aquifer is greater for Scenarios A and B relative to Scenario 3, due to the fact that Scenario 3 only included a pumping increase from the Cedarbrook well, which is less hydraulically connected to the Contact Aquifer.

Within the Contact Aquifer, the drawdown extents were similar for transient Scenarios A and B, with some subtle differences. The drawdown for Scenario B extended slightly further south, due to pumping from the Cedarbrook well. These scenario results indicated that increased pumping from the Cedarbrook well (Scenarios 3 and B) had little effect on the eastern extents of drawdowns in the Contact Aquifer. This is due to the fact that the Cedarbrook well pumping zone in the Gasport is well confined by the overlying Vinemount aquitard and therefore, there is little vertical connection to the Contact Aquifer from pumping at this well, as was supported by observations during the pumping tests.

Effects on surface water flows were also simulated by considering the changes in groundwater discharges to individual streams with respect to the Tier 3 existing pumping conditions. In addition, the potential effect on Puslinch Lake was assessed relative to the existing conditions quantity of groundwater inflows and outflows (water balance). The results for the transient model scenarios are summarized below.

Scenario A: For Irish Creek, the simulated reduction in baseflows was similar to the steady-state scenarios (approx. 14%). For Puslinch Lake, the simulated changes in groundwater budget at the end of the three month shutdown period were less than 1%.

Scenario B: For Irish Creek, the simulated reduction in baseflows was similar to the steady-state scenarios and scenario A (approx. 14%). For Puslinch Lake, the simulated changes in groundwater budget at the end of the three month shutdown period were less than 1%.

4.4 Assessment of Potential Effects

4.4.1 Potential Well Interference

The zones of influence of additional pumping for the steady-state scenarios are shown on Figure 34 for the deep bedrock Gasport Aquifer and the shallow bedrock Contact Aquifer, as described in Section 4.3.1.1. Although the simulated zones of influence were much larger in the Gasport Aquifer, wells completed in this zone would be very deep and likely have sufficient depth of water column, such that their operation would not be affected by the relatively small groundwater level declines simulated by the model.

Within the much smaller zones of influence in the Contact Aquifer, the majority of the wells completed in this aquifer are deep enough that they would not be impacted by the simulated



small declines in groundwater levels. However, shallow wells with a small amount of water available for drawdown, could be impacted by the additional pumping.

If pumping from the municipal wells negatively affect private wells, the Region is required, as per the Regional Council's approved well interference policy and as a condition of the Region's PTTWs, to respond to and address well interference complaints. Procedures could include provision of temporary water supply, investigation of well complaint, lowering of pump in a well to increase the amount of available water column, or installation of a replacement well (ROW, 2015).

It is noted that during the 28-day pumping test in 2006, while drawdowns in groundwater levels were measured in 10 private supply wells, this did not affect the use and functioning of the wells. Two private wells, one overburden and one bedrock, were monitored during the 15-day pumping test in 2011; no drawdown was observed in these wells during testing.

Based on the results from the steady-state modelling scenarios, simulated groundwater level changes in the Contact Aquifer for Scenario 1 would be limited to the immediate vicinity of well G16. With the increased pumping in the Pinebush well field for Scenario 2, it may have more widespread affects on groundwater levels in the Contact Aquifer, extending to the east of Townline Road and to the western edge of Puslinch Lake; however, effects will be negligible on the eastern side of the lake. For Scenario 3, with increased pumping from the Cedarbrook well, effects on groundwater levels in the Contact Aquifer were simulated to be localized in the vicinity of Portuguese Swamp, and extended only slightly east of Townline Road. The simulated scenarios indicated the potential for well interference would primarily be at the properties without municipal servicing in the Township of Puslinch, to the east of Townline Road and west of Puslinch Lake.

4.4.2 Potential Effects on Terrestrial and Aquatic Features

There were no measureable effects observed in the streams, wetlands and creeks that were monitored during the 28-day pumping test in 2006 or the 15-day pumping test in 2011. However, effects on springs and surface water may have been too small to measure or distinguish from natural seasonal variations.

Effects on surface water baseflow simulated by the steady-state model scenarios indicated that surface water effects would primarily occur in the Irish Creek Subwatershed, which includes the following sensitive features: Irish Creek (warm water creek), and the Puslinch Lake Wetland Complex and the Portuguese Swamp (provincially significant wetlands).

For Scenario 1, the model simulated that baseflows in Irish Creek would be reduced by approximately 11% and groundwater discharge to Puslinch Lake would be reduced by approximately 3%. For Scenarios 2 and 3, the model simulated that the effects on the Irish Creek Subwatershed would be similar, with a simulated reduction in baseflow to Irish Creek of approximately 14% and groundwater discharge to Puslinch Lake of approximately 6%. Similar reductions to groundwater discharge were simulated by the transient model simulations,



under the short-term higher pumping rates, in the event of a shutdown of Cambridge's largest well G2.

The simulated changes in groundwater discharge to Irish Creek are assigned a high level of uncertainty. Limited data are currently available to characterize conditions in Irish Creek. Data on the properties of the streambed of Irish Creek and continuous stream flow data are not available. Similarly, the modelled changes to the Puslinch Lake water balance also have a high degree of uncertainty, as further described in Appendix D.

These model results can be used to identify areas for enhanced future monitoring as further described in Section 5.3. Given the high uncertainty in the modelling and the fact that no changes to surface water levels and flows were observed during the pumping tests, longer term operational testing and enhanced monitoring are needed to confirm if any impacts to surface features would actually occur. Changes of less than 10% in discharge to surface water features are not expected to be measureable and distinguishable from background climatic variability, as also described in the Tier 3 Assessment. Irish Creek and Puslinch Lake are not considered coldwater aquatic habitat and therefore, similar to the approach used in the Tier 3 Assessment, the simulated changes in groundwater discharge may be too small to measure and are not expected to significantly affect aquatic habitat.

In addition to the above, there is a high degree of uncertainty regarding the role of groundwater in the Puslinch Lake water balance. No relation between pumping rates and lake water levels was observed during the testing and during the decades of lake level monitoring. As such, no impacts from pumping are expected on the lake water levels.

Based on the model simulation results, lake level and Irish Creek baseflow monitoring should continue under long-term operational testing with enhanced monitoring, as described in Section 5.3, to confirm that the pumping does not negatively affect surface water features.

4.5 Source Water Protection Assessment

Current Source Water Protection Policy Areas

The Region delineated a set of wellhead protection areas (WHPAs) in 2010 (AQR, 2009) for their existing water supply wells and these WHPAs were included in the Grand River Conservation Authority (GRCA) approved Assessment Report (Lake Erie Source Protection Committee, 2015). Updated WHPAs and vulnerability scoring for the Region's existing water supply wells were completed (Matrix, 2017a and 2017c) and will be included in the future amended Assessment Report and Source Protection Plan.

The implications for landowners located within source protection areas are related to the policy areas in the source protection plan that were developed based on the vulnerability scores for the respective areas. The updated vulnerability score areas, with applicable policies for these scenarios, have been delineated, including the following policy areas:

- Vulnerability of 10 (red on vulnerability scoring figures). These are areas where chemical handling including fuel, certain industrial chemicals and wastes policies will require spill



containment and implementation of response measures. Also, within these areas, salting of parking lots will be required to be conducted in accordance with right time / right place / right amount principles; and

- Vulnerability of 8 (orange on vulnerability scoring figures). These are areas where handling of certain industrial chemicals and wastes will require spill containment and implementation of response measures.

Effects of EA Alternatives on Source Water Protection Policy Areas

To assess the implications for source water protection of pumping from new wells in the Cambridge East EA area, a series of wellhead protection areas were delineated for the Class EA alternative solutions (Matrix, 2017b).

Figure 38 shows a comparison of the extent of these areas between the various scenarios. It is apparent that there is little difference in the source protection policy implications between Alternative Solutions 2B (Scenario 2) and 3A (Scenario 3), which include pumping from new wells, and the current protection areas. This is due to the fact that the areas are largely influenced by the intrinsic vulnerability of the aquifers, which doesn't change between the different pumping scenarios. Intrinsic aquifer vulnerability describes the degree of natural protection of groundwater from contamination due to the physical characteristics of the land and subsurface.

Prior to implementation of the Preferred Alternative Solution, final WHPAs and vulnerability scoring will need to be completed for inclusion in an updated Assessment Report and Source Protection Plan taking into account new wells and proposed pumping increases.

5.0 Conclusions And Recommendations

5.1 Conclusions - Water Supply Potential

The Class EA has concluded that with optimization of pumping strategies at existing and new well sites, the Cambridge East area is capable of supplying the Region's IUS with additional water. The results of the optimization investigations and groundwater exploration studies are summarized in the following sections.

Pinebush WTP

- A combined sustainable capacity of 126 L/s was identified from wells P10A, P10B and P11/P17 and new well PBTW1-10 to meet the capacity of the WTP from existing well sites (Stantec, 2013a). This optimized scenario included a slightly reduced pumping rate from shallower well P10B (replacement for P10) and increased pumping from deeper wells P10A and PBTW1-10.
- New wells at the Witmer Park and Can-Amara Parkway locations were identified with estimated capacities of 75 L/s and 38 L/s, respectively. The Witmer Park and Can-Amara Parkway wells were not carried forward in the Class EA since the WTP capacity can be



met by wells at existing sites and demands do not necessitate going beyond the WTP capacity at Pinebush.

Clemens Mill (Turnbull) WTP

- Additional capacity of 20 L/s was obtained through the deepening of well G16 as part of the optimization investigations; however, the full capacity of the WTP could not be supplied from existing well sites.
- New wells at the Cedarbrook and Portuguese Club locations were drilled, tested and identified as alternatives to meet the supply capacity for the WTP.
- The Cedarbrook well draws water from a deeper and more confined aquifer zone, is further from sensitive features (i.e. Puslinch Lake and Portuguese Bog) and has a greater capacity than the Portuguese Club well. Therefore, the Class EA impact assessment focused on long-term pumping increases from the Cedarbrook well to supply the Clemens Mill WTP. The Cedarbrook well was tested at a rate of 38 L/s and the testing and modelling showed that this rate was sustainable over the long term.

Shades Mill WTP

- As part of the Region's well optimization investigations, new well G40 was constructed at the WTP site.
- Poor water quality (high sulphate) and poor yield was found from test wells in the bedrock aquifer in the Shades Mill area.
- Further east in the village of Clyde, a bedrock well was drilled and tested with an estimated capacity of 50 L/s. The Clyde Park well was not carried forward in the Class EA assessment of alternatives since additional supply capacity can be found more readily, and more cost-effectively, in the Clemens Mill and Pinebush well fields and updated predicted demands do not necessitate maximizing capacity at all three WTPs.

5.2 Conclusions - Impact Assessment

The following are the key conclusions from the evaluation of groundwater pumping strategies and impact assessment:

Well Interference Potential

- The pumping tests completed from the new wells did not affect the use and functioning of existing private supply wells.
- The simulated zones of influence from the increased pumping scenarios were more extensive in the deeper (Gasport) Aquifer; however, wells completed in this zone likely have sufficient depth of water column, such that their operation would not be affected by small groundwater level declines.
- Within the much smaller simulated zones of influence in the Contact Aquifer, the majority of the wells completed in this aquifer are deep enough that they would not be impacted



by the simulated small declines in groundwater levels. However, shallow wells with a small amount of water available for drawdown within the simulated zone of influence in the Contact Aquifer, could be impacted by additional pumping.

- Based on the results from the simulated long-term water supply scenarios, the simulated zone of influence in the Contact Aquifer for Scenario 2, with increased pumping in the Pinebush well field, extended to the east of Townline Road and to the western edge of Puslinch Lake. The zone of influence in the Contact Aquifer for Scenario 3, with increased pumping from the Cedarbrook well, was localized in the vicinity of Portuguese Swamp and extended only slightly east of Townline Road.
- If pumping from the municipal wells negatively affects private wells the Region is required, as per Regional Council's approved well interference policy and as a condition of the Region's PTTWs, to respond to and address well interference complaints. Procedures could include provision of temporary water supply, investigation of well complaint, lowering of pump in a well to increase the amount of available water column, or installation of a replacement well (ROW, 2015).

Potential Effects on Environmentally Sensitive Features

- The majority of the additional water from the increased pumping was simulated to be sourced from the Irish Creek Subwatershed, including provincially significant wetlands of the Puslinch Lake Wetland Complex and Portuguese Swamp, and Irish Creek, which is classified as a warm water creek.
- No effects to surface water features due to pumping have been observed during the pumping tests and operational monitoring. The effects may be too small to measure or distinguish from natural seasonal variations.
- The long-term simulated effects on surface water features of increased pumping in the Pinebush area (Scenario 2) were similar to the effects of increased pumping in the Clemens Mill area (Scenario 3) and included a simulated reduction in baseflow to Irish Creek (14% reduction) and an increase in net outflow of groundwater from Puslinch Lake (6% increase). Relative to the 2031 pumping scenario completed in the Tier 3 Assessment (Scenario 1), that included pumping only from existing wells, this represents a 3% difference.

Simulation of long-term pumping increases did not identify significant effects on the Irish Creek baseflow and vertical groundwater gradients and groundwater balance around Puslinch Lake. However, the simulation of these features has a high degree of uncertainty. Irish Creek and Puslinch Lake are not considered coldwater aquatic habitat and therefore, similar to the findings of the Tier 3 Assessment, the minor simulated changes in groundwater discharge may be too small to measure and are not expected to significantly affect aquatic habitat. Long-term operational testing and enhanced monitoring are needed to confirm if effects on surface water features would actually occur with increased pumping.



5.3 Recommendations

5.3.1 Operational Testing and Adaptive Management

Long-term operational testing with enhanced monitoring is needed to confirm the results of the pumping tests and the model simulations. Prior to permitting of new wells carried forward in this Class EA (i.e. P10A, P10B, PBTW1-10 and Cedarbrook well), it is recommended that an operational testing and adaptive management plan be developed. The adaptive management plan should provide a framework for assessing the environmental effects of the well field operation and provide a mechanism for making adjustments based on the results of long-term operational testing and monitoring.

To ensure that the optimized pumping rates are sustainable, an operational testing program should be developed, which would include pumping over a longer period than the pumping tests completed to date, with the water supplied to the distribution system. The pumping period could be on the order of 3 to 5 years, during which existing and new wells would be pumped in configurations similar to the scenarios assessed in this Class EA. The operational testing program should include an enhanced monitoring program of groundwater and surface water, as described in the next section.

5.3.2 Monitoring Program

Earlier in the Class EA process, it was recommended that the Region incorporate the following IUS monitoring locations into their ongoing groundwater monitoring program (GMP): PBOW1-06, PBOW2-06, CMOW1-06, CMOW2-06 and PLOW1-06. These locations, as well as other monitoring wells, have since been added into the GMP, as listed in Table 24. This table shows the monitoring wells currently required to be monitored as part of the Region's PTTWs, as well as on-going monitoring at other nearby wells that are recommended to be included in a long-term monitoring program associated with the operational testing and adaptive management program.

Table 24: Recommended Monitoring Locations

Well Field	Monthly Water Level Currently Required by PTTW	Wells Currently being Monitored by Region. (Potential Additions to Long Term Monitoring Program)
Pinebush	OW1-92, OW3-95, PBOW1B-08, G5-TW2-08, PBOW1-11, PBOW1-13	PBOW1-06, PBOW2-06, PLOW1-06, P10-TW1-09, OW5-94, LWL (Puslinch Lake), P10, P11, P17
Clemens Mill	OW4-92, OW6-94, CMOW3-06, CMOW1-10, CMOW2-10	CMOW1-06, CMOW2-06, CMTW3-05, CMOW1-15
Shades Mill	SM1A-02, SM3-07, SMOW1-11, SMOW4A-14, SMOW5A-14	SMTW1-05, NDTW1-08, SMOW1-14, SMOW2-14, SMOW3-14



In addition to these wells, monitoring has been on-going at Puslinch Township wells TW9-78, TW10-78 and MW09-T3-01.

The following are general recommendations for enhancement of the long-term monitoring program:

- On-going groundwater level monitoring is limited to the area west of Puslinch Lake. Additional monitoring wells are recommended to the east of the lake to better define groundwater gradients and monitoring of groundwater level changes in this area, as follows:
 - A multi-level deep monitoring well nest should be installed near Irish Creek north of Puslinch Lake.
 - An additional multi-level deep monitoring well nest should be installed to the northeast/east of Puslinch Lake.
 - Additional shallow overburden monitoring wells and mini-piezometers should be installed in accessible locations in the vicinity of the Puslinch Lake shoreline.
 - A deep monitoring well nest is also recommended further east of PB-OW1-06 along Concession 1, in the vicinity of Mill Creek, to better define the eastern limits of the zone of influence of the pumping.
- Shallow overburden wells and a mini-piezometer are recommended east of CM-OW2-06 along Gore Road in the vicinity of Mill Creek.
- Water levels in Puslinch Lake should be monitored at a higher frequency (datalogger for continuous measurement during ice-free conditions).
- A stream gauging station is recommended on Irish Creek for continuous flow gauging, during ice-free conditions.
- Additional spot baseflow measurements are recommended for Irish Creek.
- Mini-piezometers are recommended to be installed adjacent to Irish Creek to assess shallow groundwater gradients.
- Monitoring of existing mini-piezometers at Cedarbrook Creek should be included in the program.

A detailed monitoring program considering the above recommendations should be developed prior to permitting new wells as part of an operational testing and adaptive management program.



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Report Signature Page

GOLDER ASSOCIATES LTD.

Jennifer Hancox, M.Sc., P.Geo.
Hydrogeologist

John Piersol, M.Sc., P.Geo.
Associate, Senior Hydrogeologist

JLH/JAP/III/mp

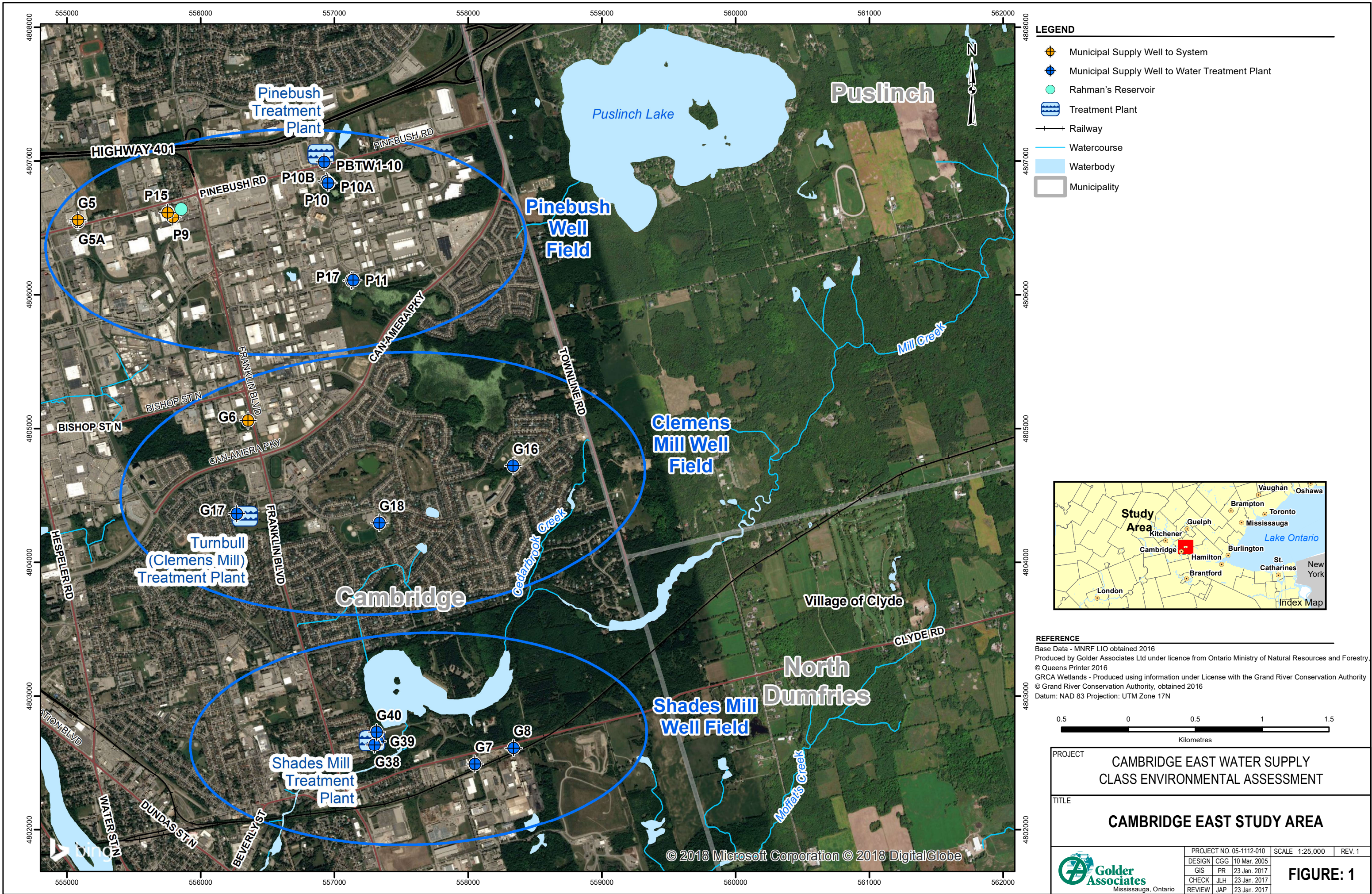
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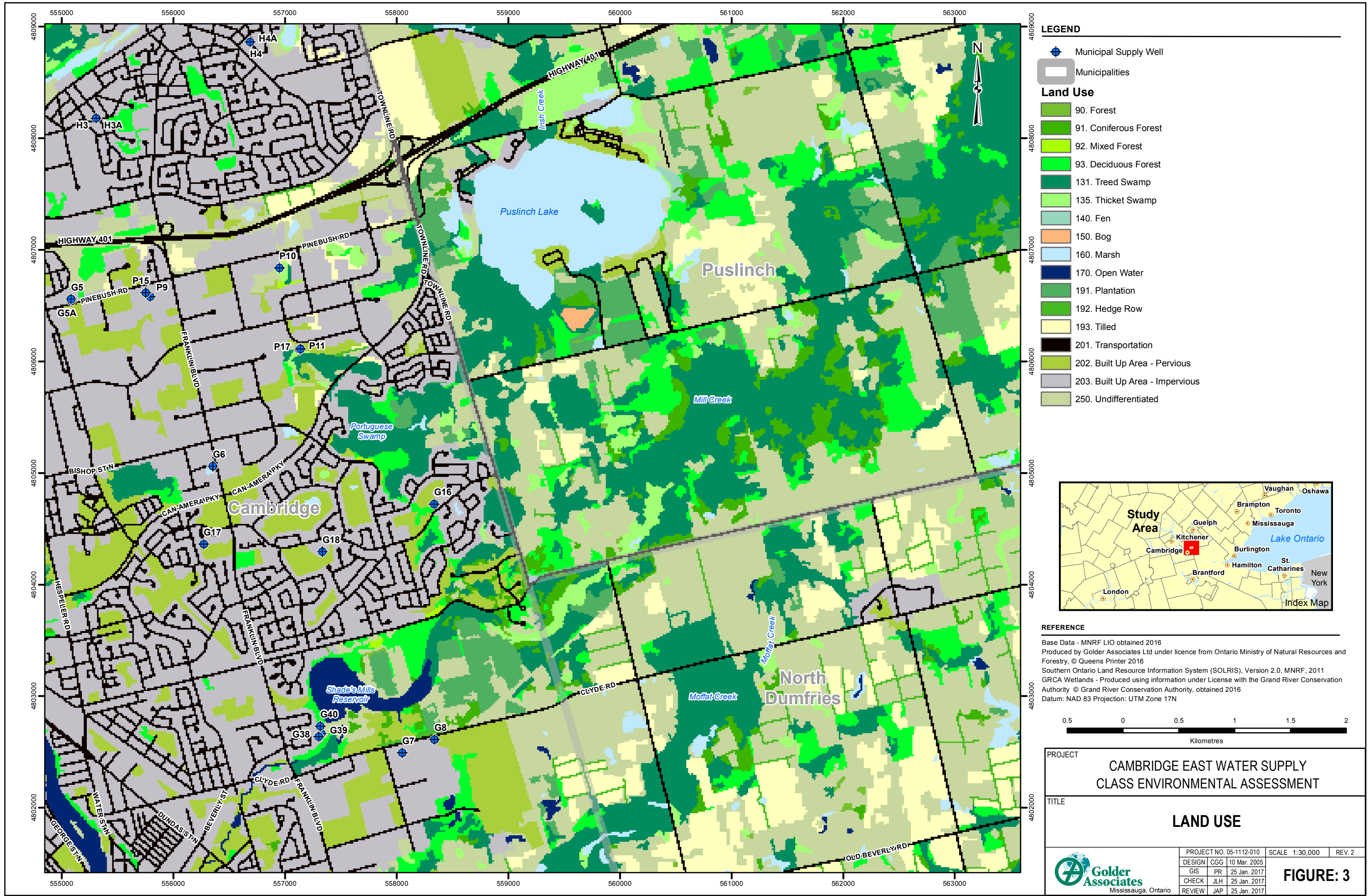


Figures

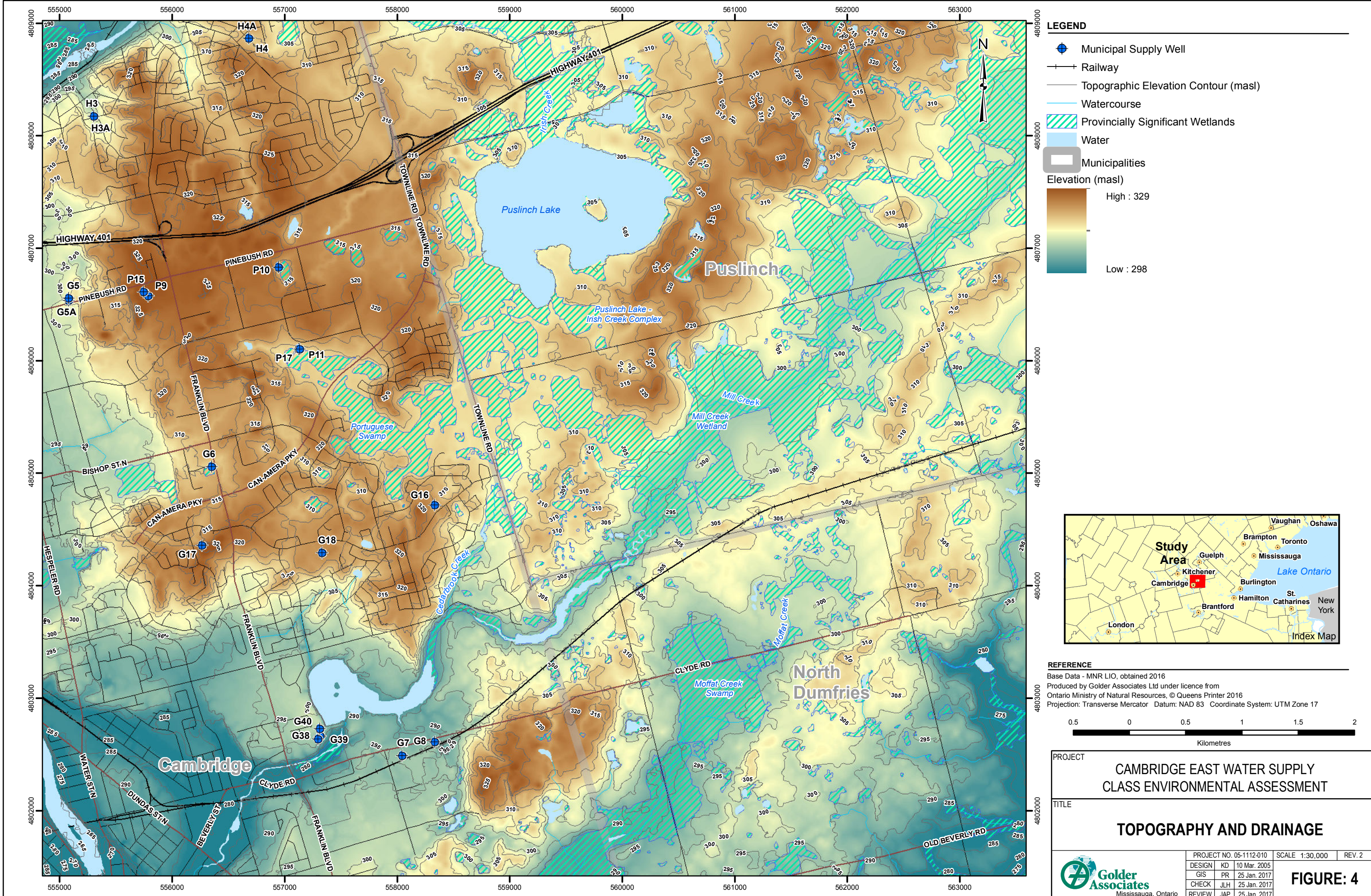
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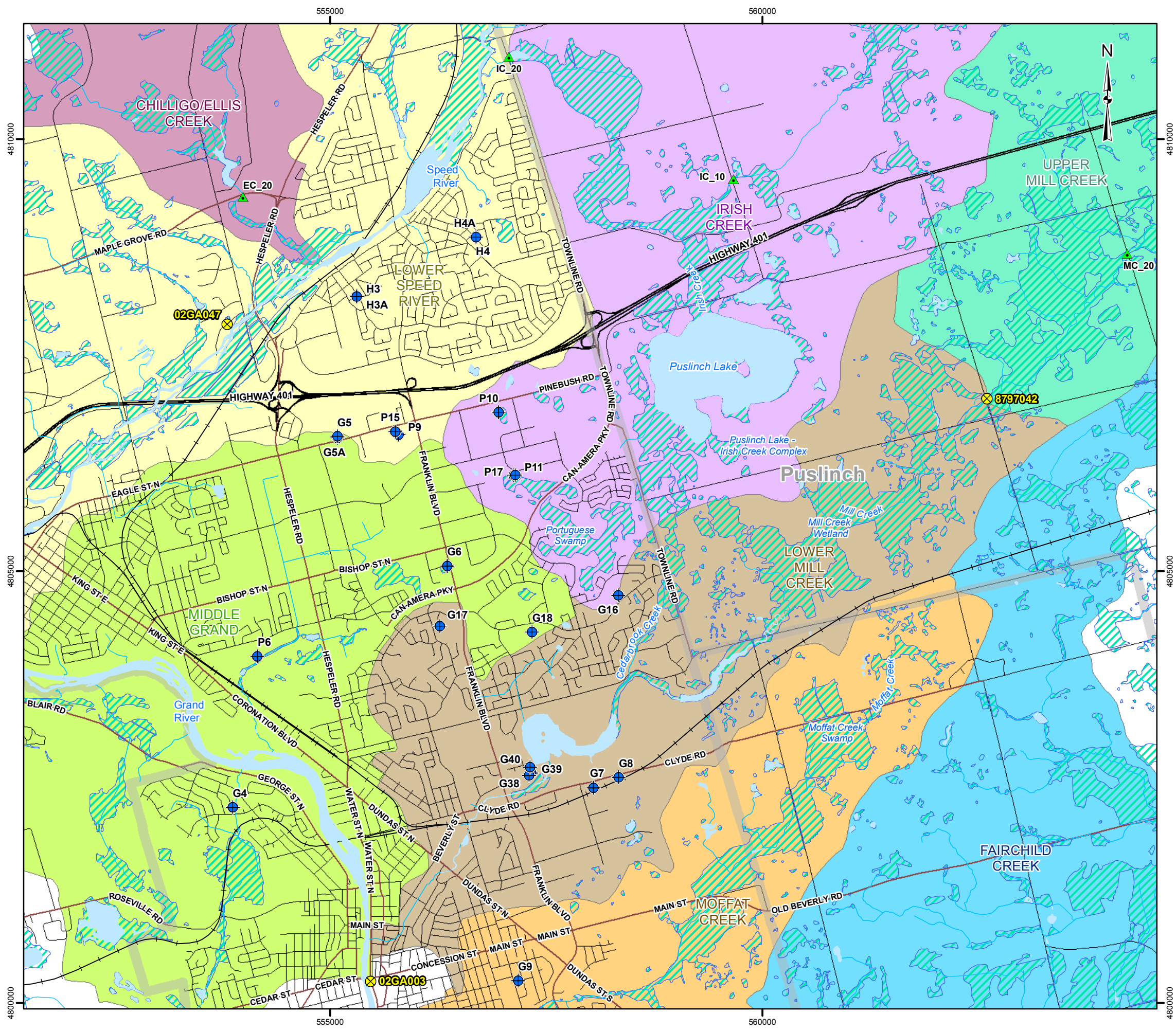
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LEGEND

- Municipal Supply Well
- Baseflow Monitoring Locations
- Water Survey of Canada Hydrometric Stations
- Railway
- Watercourse
- Water
- Provincially Significant Wetlands
- Municipalities

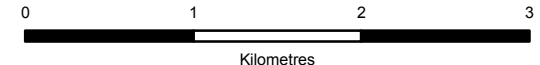
Subwatersheds

- Fairchild Creek Subwatershed
- Middle Grand Subwatershed
- Moffat Creek Subwatershed
- Lower Mill Creek Subwatershed
- Upper Mill Creek Subwatershed
- Irish Creek Subwatershed
- Lower Speed River Subwatershed
- Chilligo/Ellis Creek Subwatershed



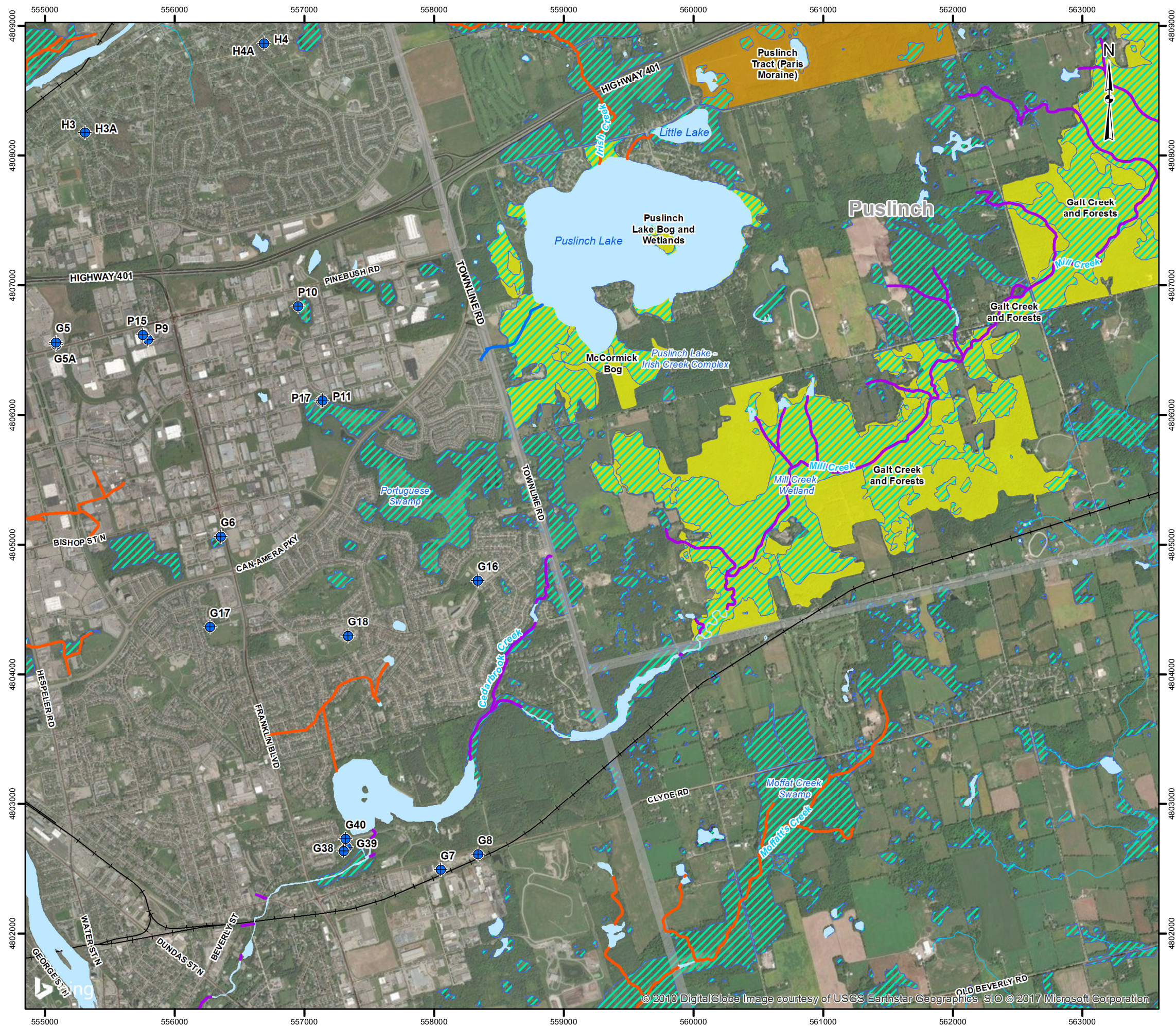
REFERENCE

Base Data - MNR LIO, obtained 2016
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2016
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 17

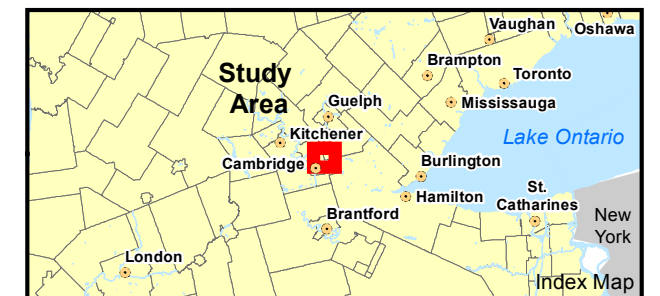


PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT			
	TITLE			
SURFACE WATER CATCHMENTS				
 Mississauga, Ontario	PROJECT NO.	05-1112-010	SCALE	1:45,000
	DESIGN	KD	10 Mar. 2005	REV. 2
	GIS	PR	25 Jan. 2017	
	CHECK	JLH	25 Jan. 2017	
	REVIEW	JAP	25 Jan. 2017	

FIGURE: 5



480 Municipalities



A scale bar labeled 'Kilometres' with markings at 0.5, 0, 0.5, 1, 1.5, and 2.

CAMBRIDGE EAST WATER SUPPLY
CLASS ENVIRONMENTAL ASSESSMENT

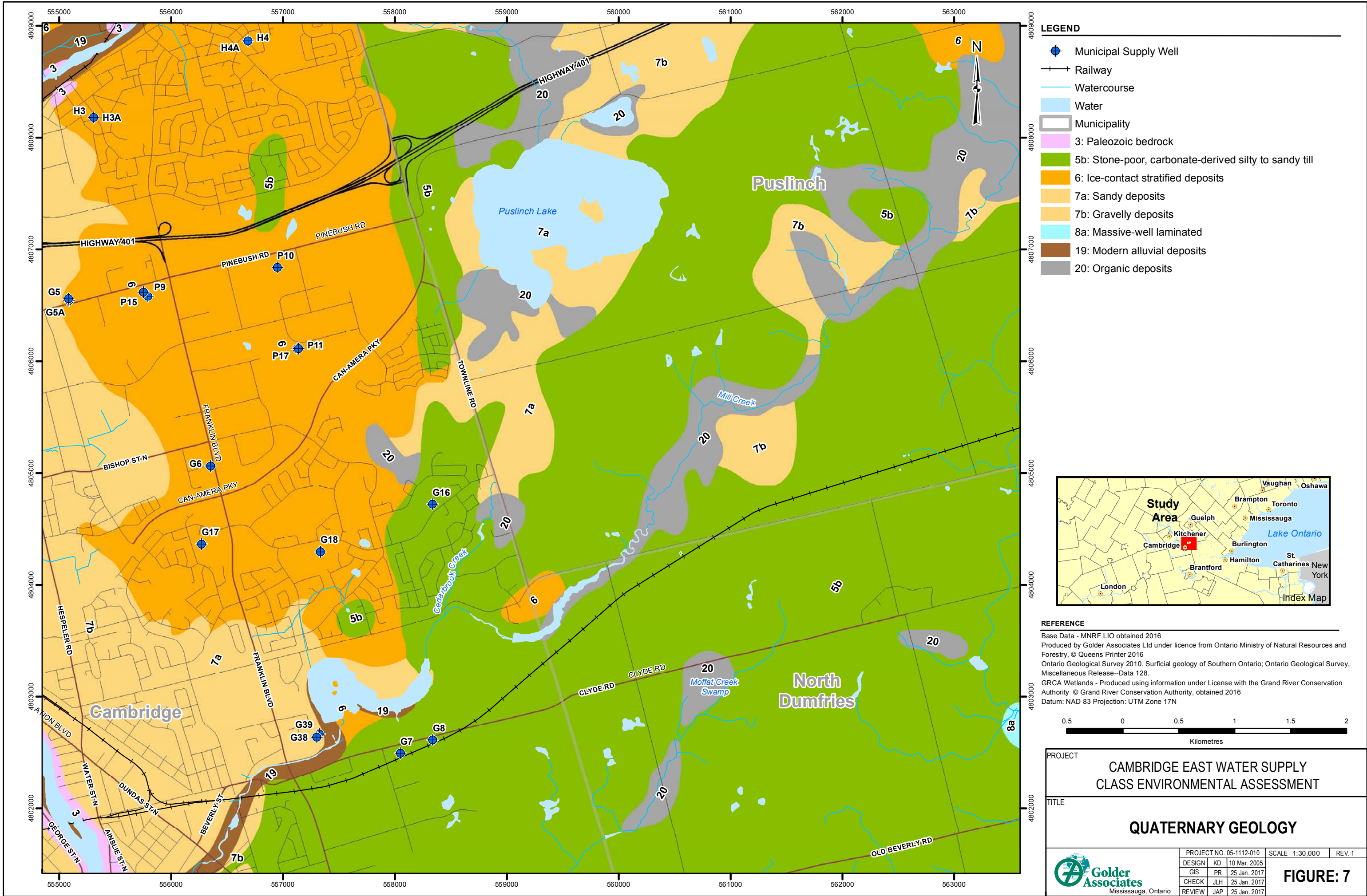
ENVIRONMENTALLY SENSITIVE AREAS



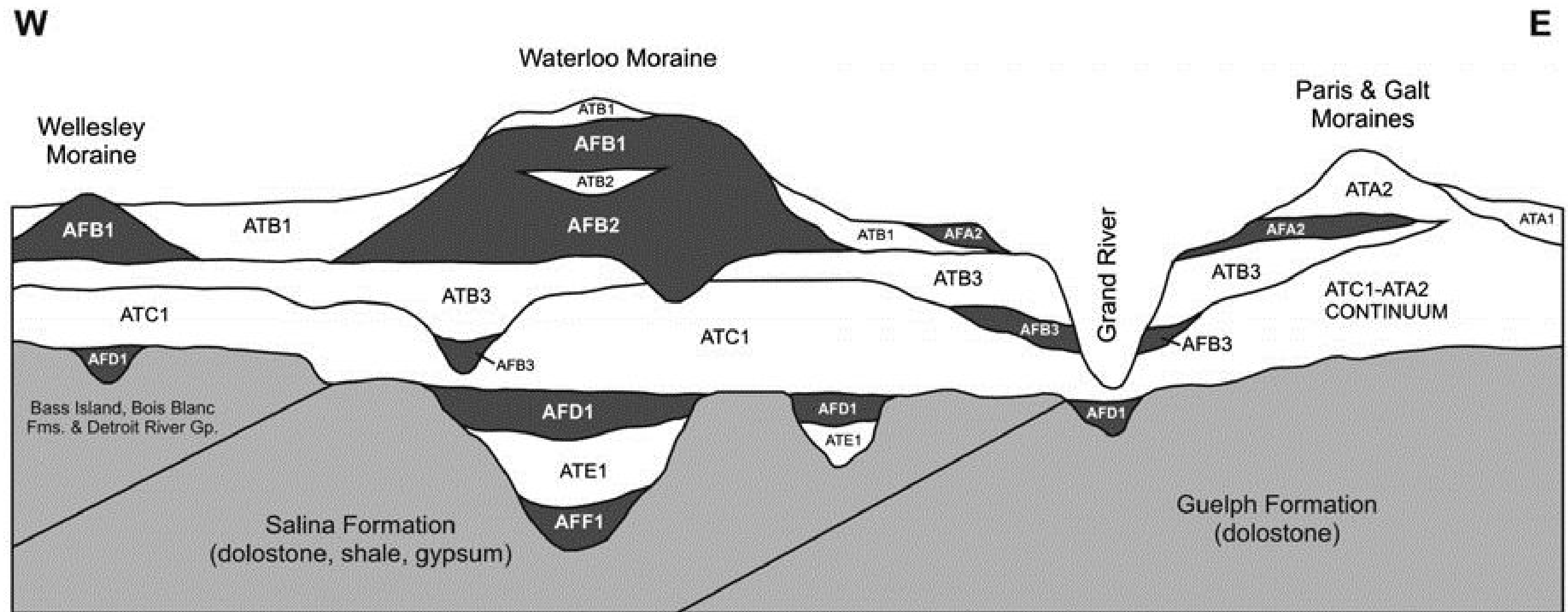
PROJECT No. 05-1112-010			SCALE 1:30,000	REV. 2
DESIGN	CGG	10 Mar. 2005	FIGURE: 6	
GIS	PR	25 Jan. 2017		
CHECK	JLH	25 Jan. 2017		
REVIEW	JAP	25 Jan. 2017		

FIGURE: 6

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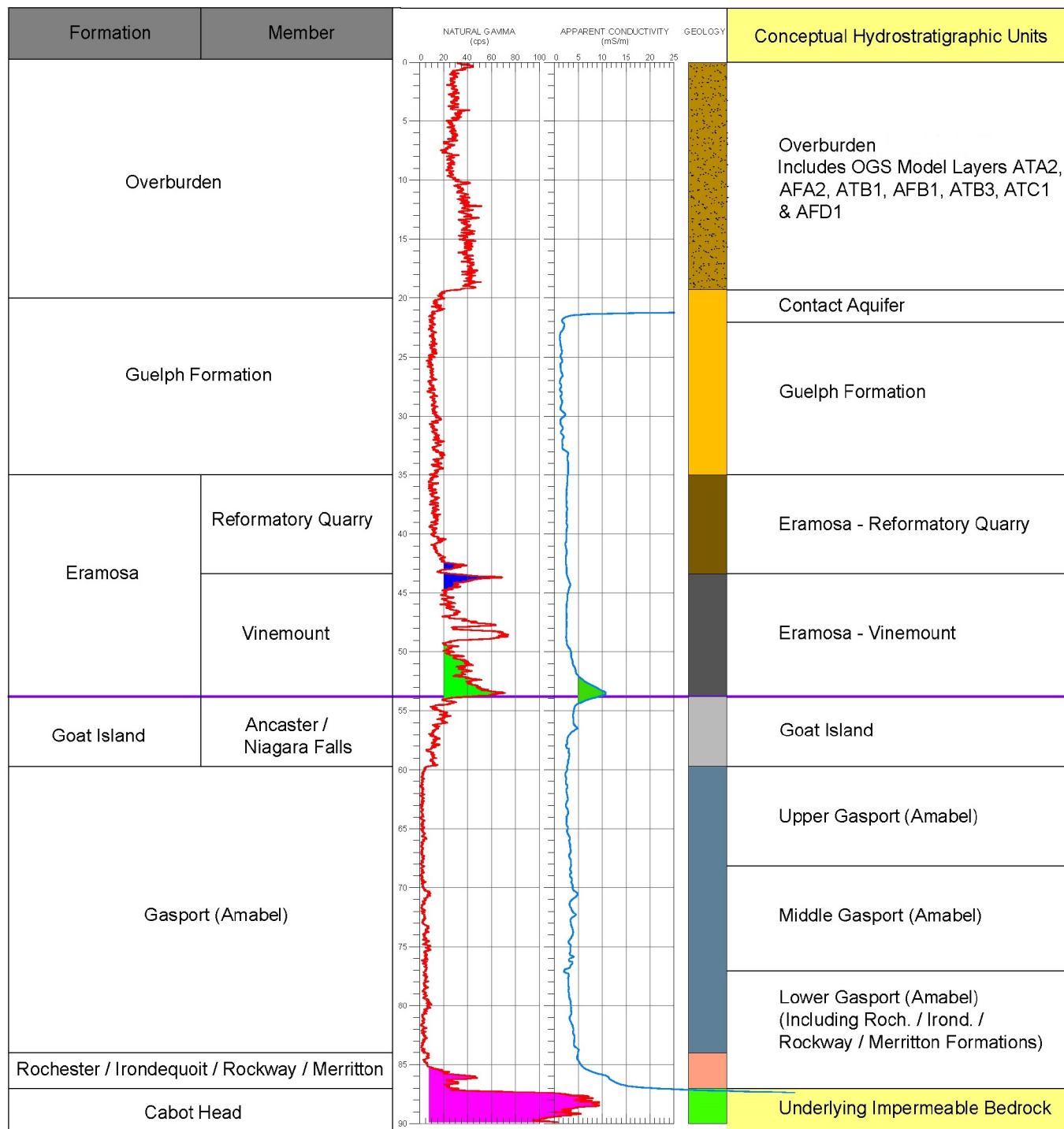
ATA1: Whittlesey-Warren Clay
ATA2: Wentworth Till
AFA2: Grand River Outwash Deposits
ATB1: Upper Till (Mornington, Tavistock, Upper Maryhill and Port Stanley)
AFB1, AFB2 and AFB3: Waterloo Moraine Aquifers and equivalents

ATB2 and ATB3: Waterloo Moraine aquitards and equivalents
ATC1: Catfish Creek Till
AFD1: Pre-Catfish Creek Till glaciofluvial deposits
ATE1: Canning Drift
AFF1: Pre-Canning glaciofluvial deposits
Bedrock: Silurian and Devonian

REFERENCE
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PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT		
TITLE		CONCEPTUAL OVERBURDEN GEOLOGICAL MODEL		
 Golder Associates Mississauga, Ontario	PROJECT NO. 05-1112-010		SCALE	REV. 1
	DESIGN	CGG	10 Mar. 2005	
	GIS	PR	8 Aug. 2016	
	CHECK	JLH	8 Aug. 2016	
	REVIEW	JAP	8 Aug. 2016	

FIGURE: 8

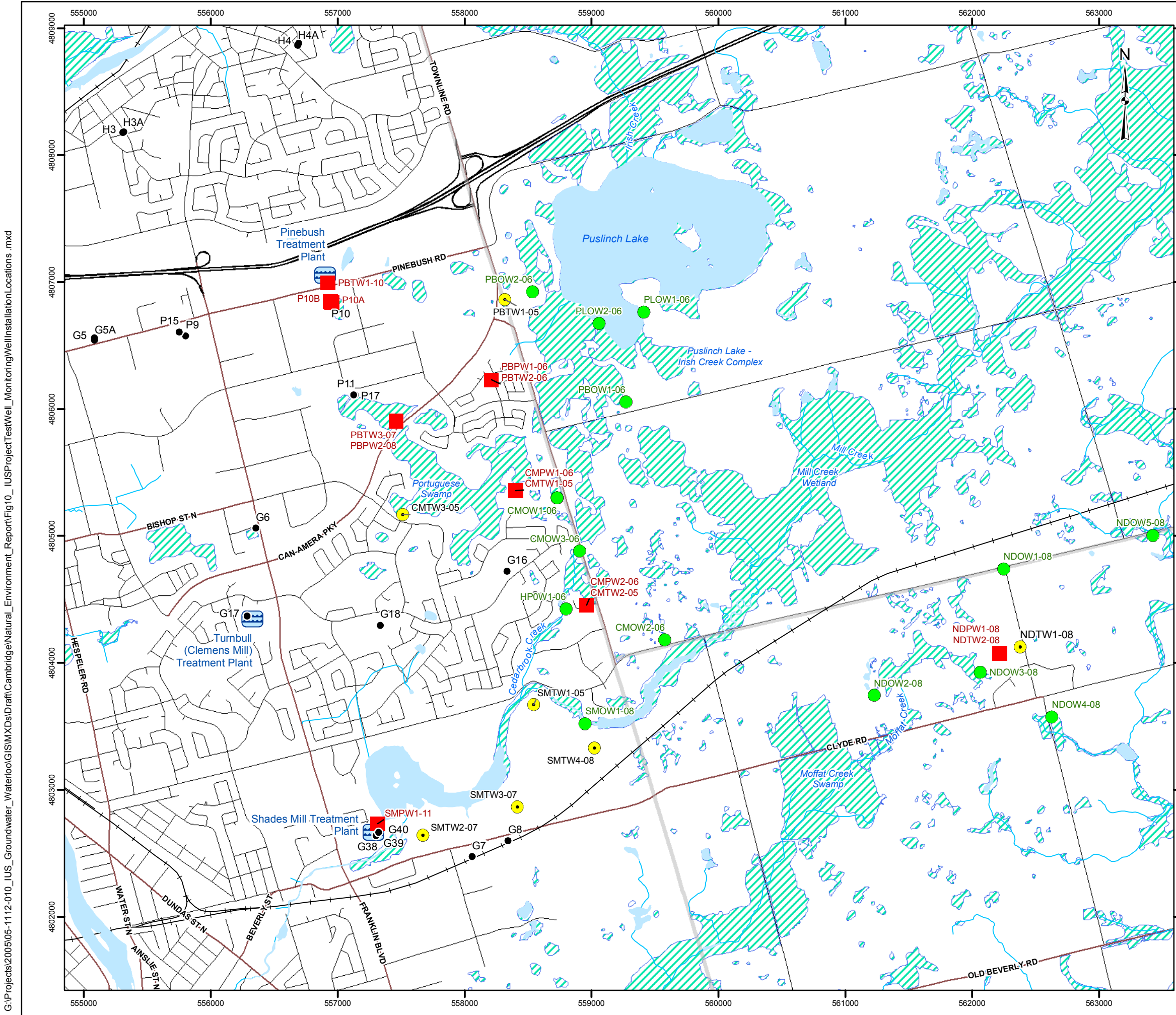
**NOTE:**

THE SALINA FORMATION (NOT SHOWN ABOVE) IS PRESENT AS THE UPPERMOST BEDROCK UNIT ONLY IN THE EXTREME WESTERN PORTION OF THE CAMBRIDGE AREA.

GEOPHYSICAL LOG LEGEND:

-  NATURAL GAMMA LOG
-  APPARENT CONDUCTIVITY LOG
-  LOG SIGNATURE REFERENCE LINE
(BASE OF ERAMOSA MEMBER)
-  GEOPHYSICAL MARKER BED 1
-  GEOPHYSICAL MARKER BED 2
-  GEOPHYSICAL MARKER BED 3

PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT		
TITLE		BEDROCK STRATIGRAPHY AND HYDROGEOLOGICAL MODEL		
PROJECT No. 05-1112-010		SCALE AS SHOWN	REV. 0.0	
DESIGN	KD	8 Apr. 2009	FIGURE: 9	
GIS	PR	30 Jan. 2017		
CHECK	JLH	30 Jan. 2017		
REVIEW	JAP	30 Jan. 2017		



LEGEND

IUS Project Monitoring Well

Municipal Supply Well

Test Well/Test Production Well

IUS Project Test Well

Treatment Plant

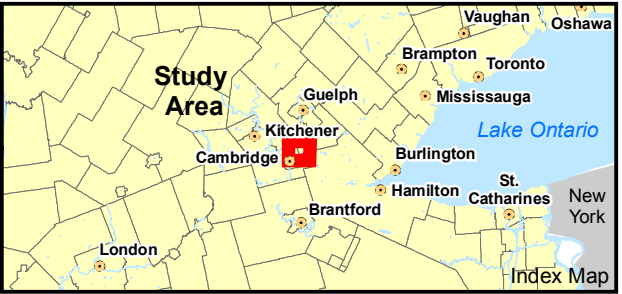
Railway

Watercourse

Waterbody

Provincially Significant Wetlands

Municipality



REFERENCE

Base Data - MNRF LIO obtained 2016
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Datum: NAD 83 Projection: UTM Zone 17N



PROJECT

CAMBRIDGE EAST WATER SUPPLY
CLASS ENVIRONMENTAL ASSESSMENT

TITLE

IUS PROJECT TEST WELL
AND MONITORING WELL INSTALLATION LOCATIONS



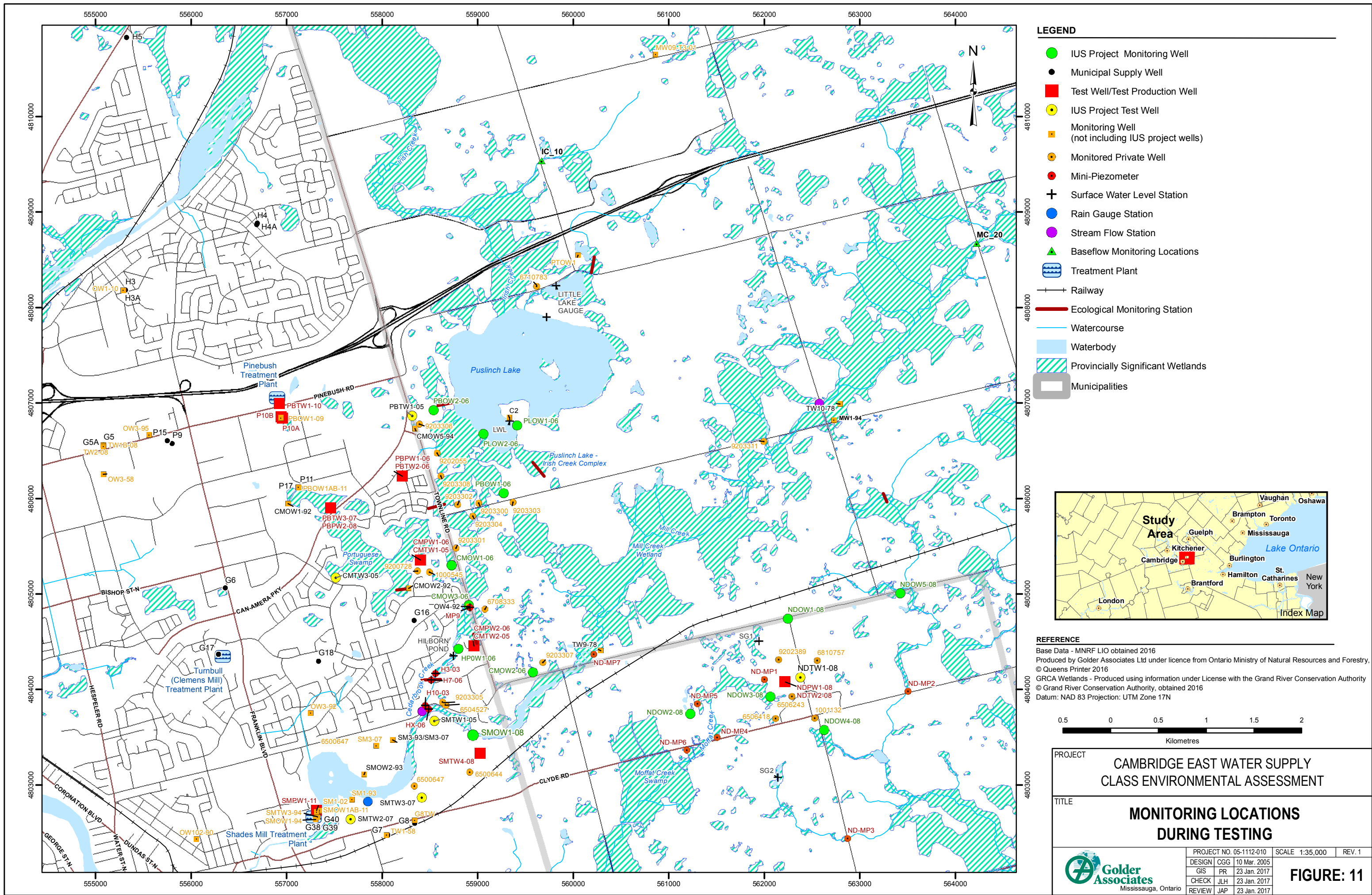
Golder
Associates

Mississauga, Ontario

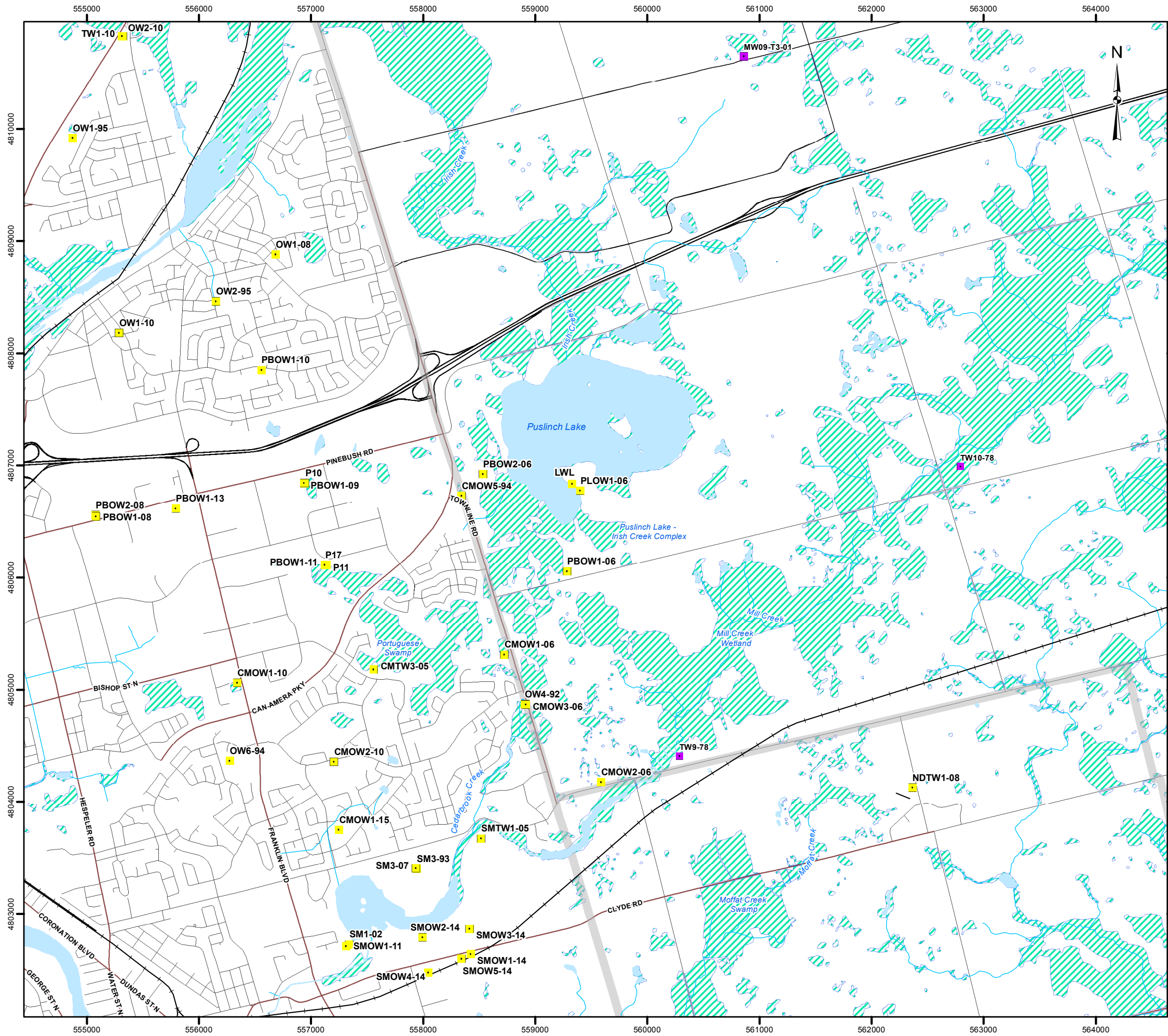
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DESIGN	CGG	10 Mar. 2005			
GIS	PR	25 Jan. 2017			
CHECK	JLH	25 Jan. 2017			
REVIEW	JAP	25 Jan. 2017			

FIGURE: 10

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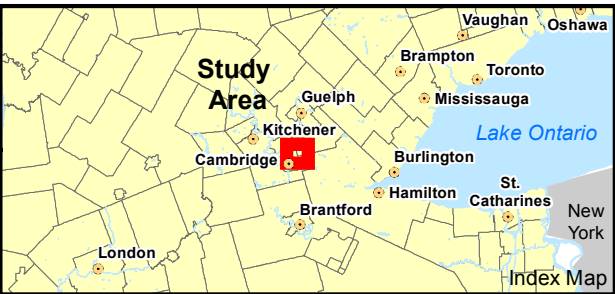


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LEGEND

- Ongoing Township of Puslinch Monitoring Locations
- Ongoing Region GMP Monitoring Location
- Railway
- Watercourse
- Waterbody
- Provincially Significant Wetlands
- Municipalities



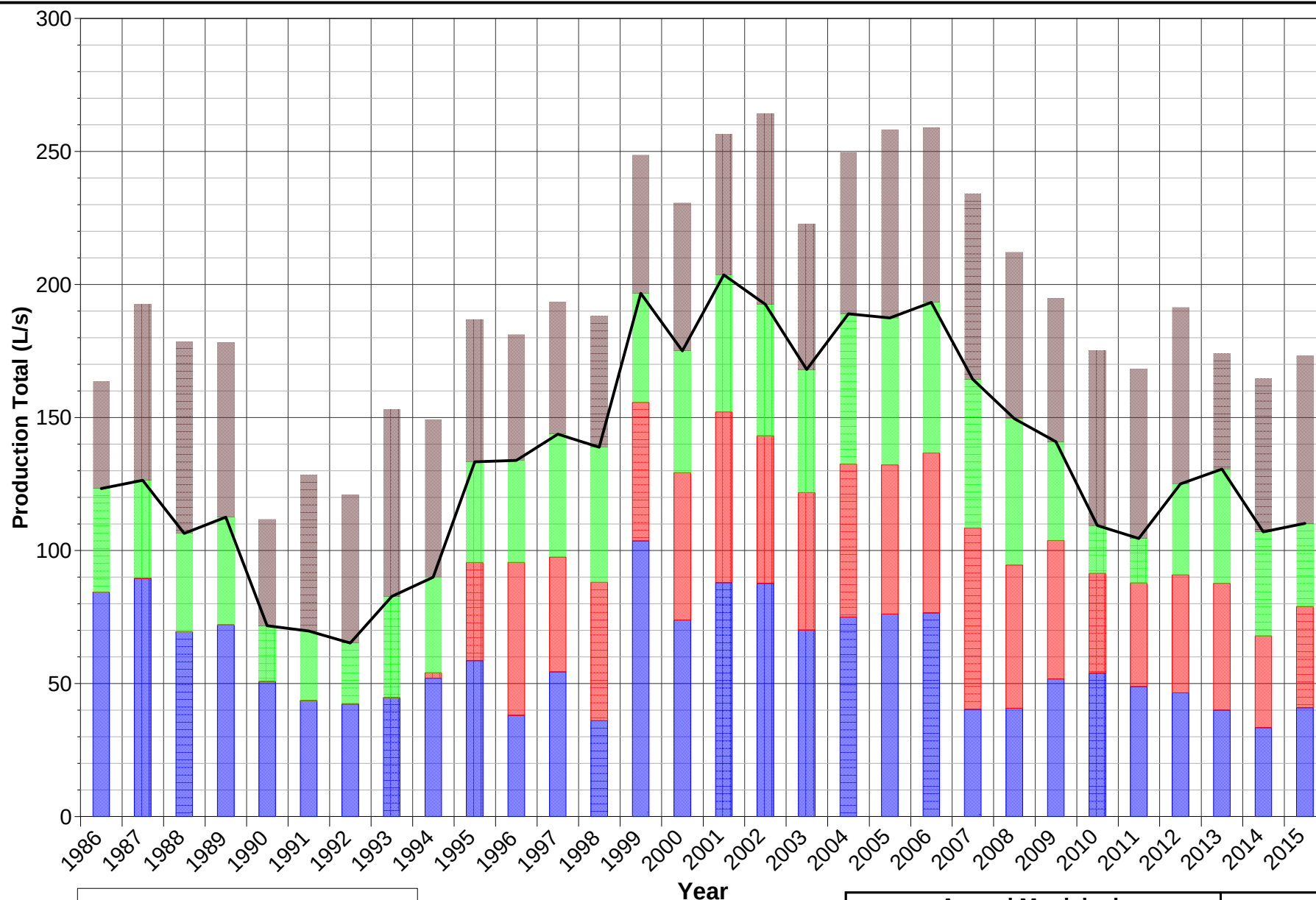
REFERENCE

Base Data - MNRF LIO obtained 2016
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Datum: NAD 83 Projection: UTM Zone 17N



PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT			
TITLE	CURRENT LONG-TERM MONITORING LOCATIONS			
 Mississauga, Ontario	PROJECT NO.	05-1112-010	SCALE	1:35,000
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	REVIEW	JAP	23 Jan. 2017	

FIGURE: 12



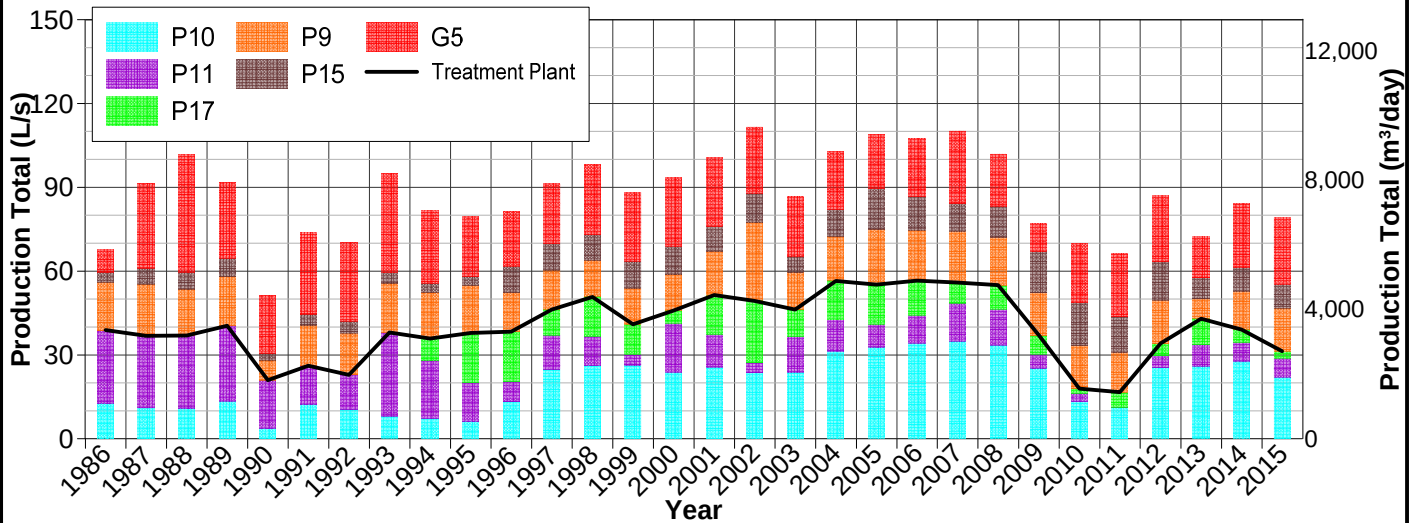
**Cambridge East
Water Supply
Class Environmental
Assessment**

**Annual Municipal
Pumping Rates
Cambridge East Well Fields
(1985-2015)**

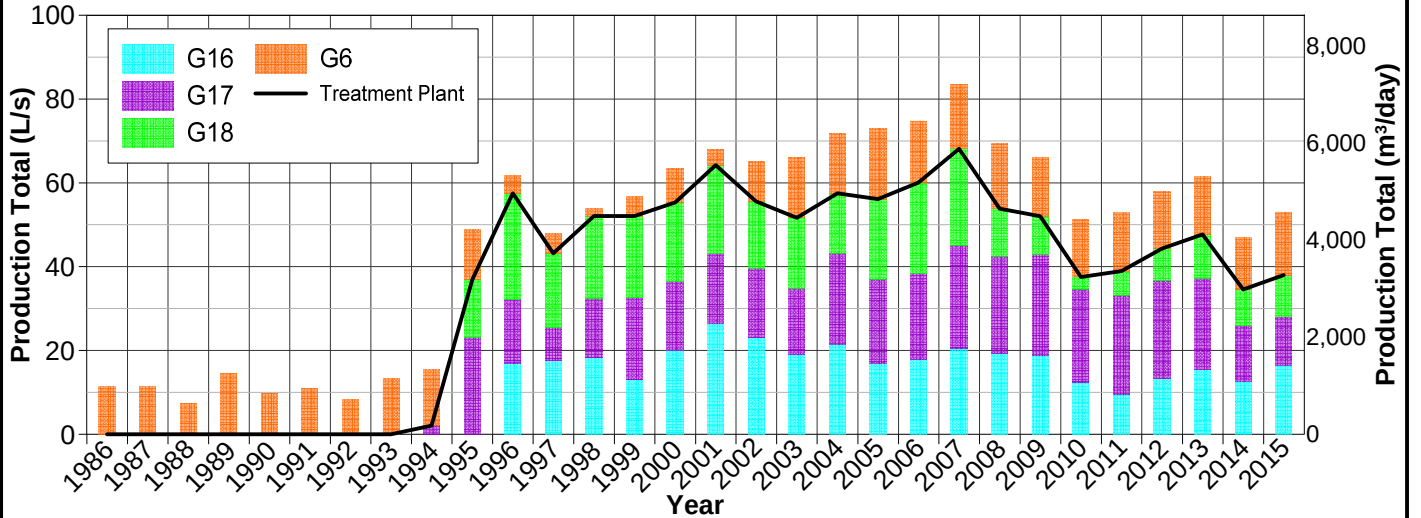


DRAWN: JLH	APPROVED: JAP	DATE: FEBRUARY 2017
PROJECT: 05-1112-010 (1500)	FIGURE: 13	

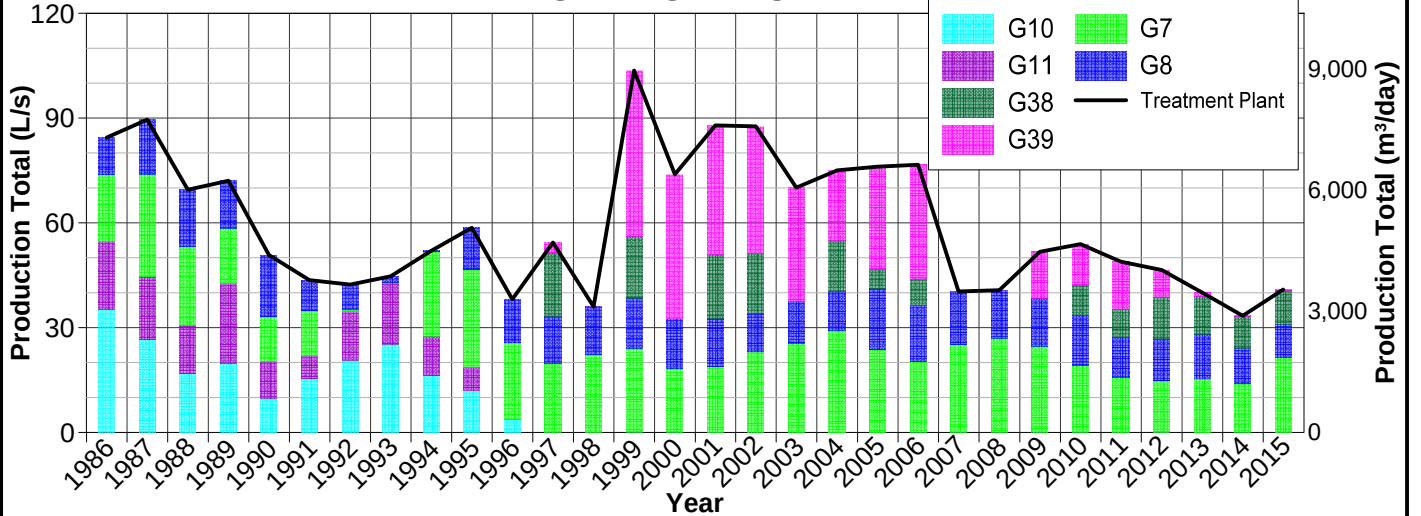
PINEBUSH WELL FIELD



CLEMENS MILL WELL FIELD



SHADES MILLS WELL FIELD

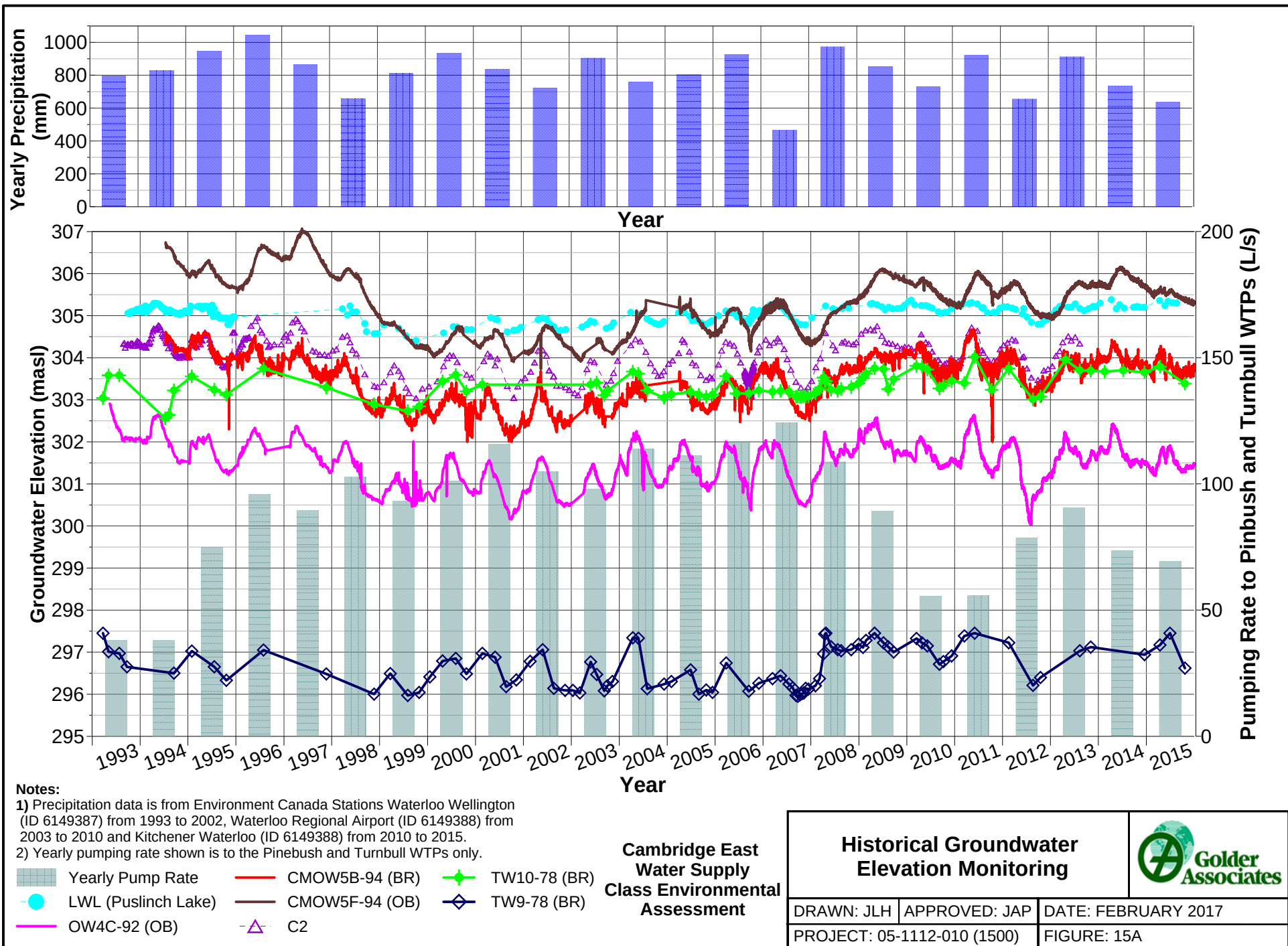


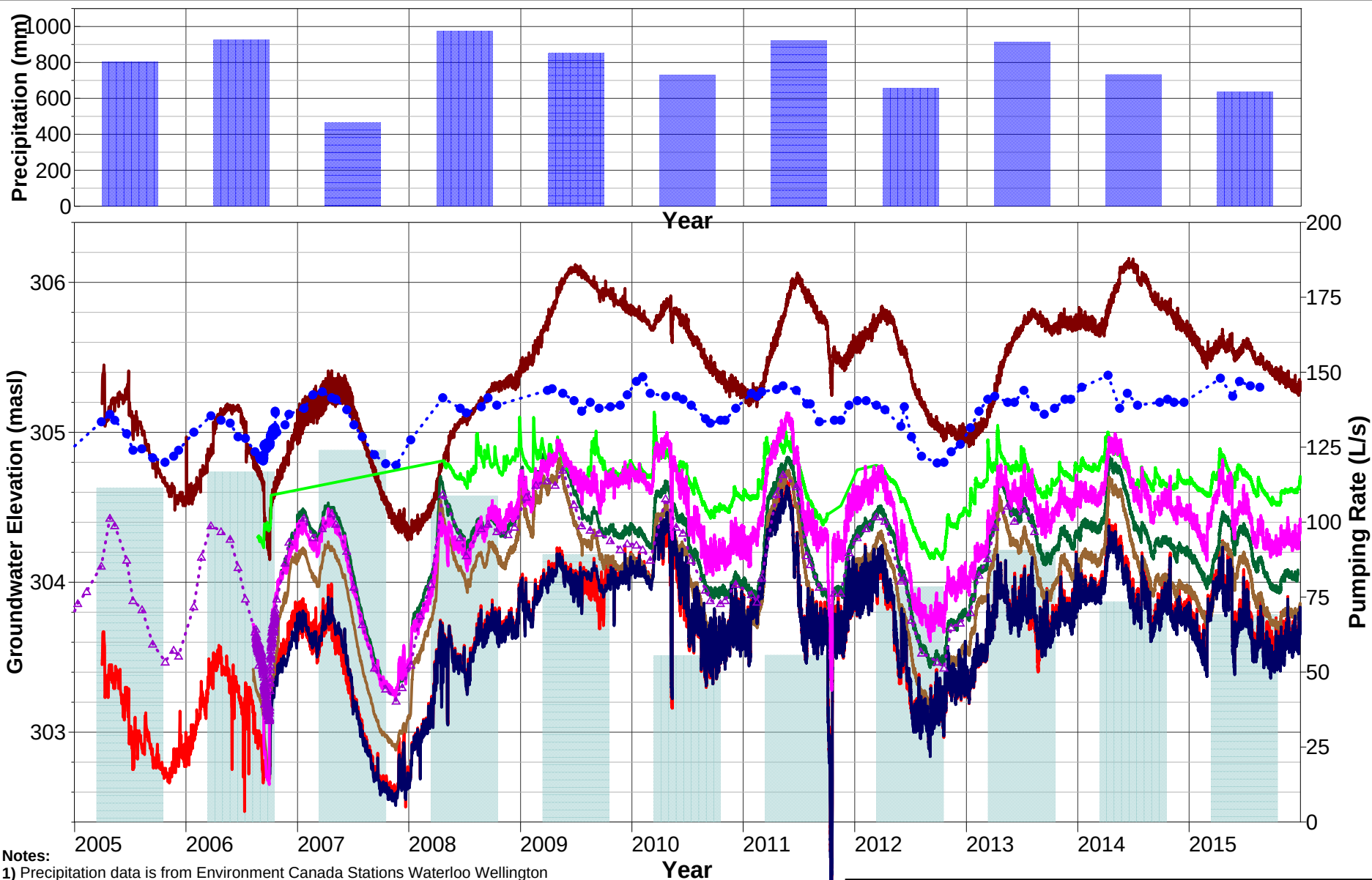
Cambridge East
Water Supply
Class Environmental
Assessment

Annual Municipal Pumping Rates by Well Field



DRAWN: JLH	APPROVED: JAP	DATE: FEBRUARY 2017
PROJECT: 05-1112-010 (1500)		FIGURE: 14

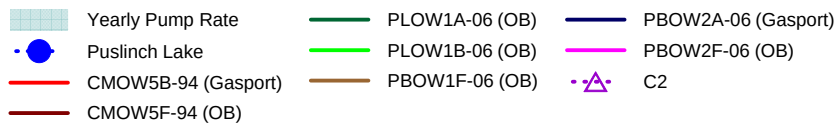




Notes:

1) Precipitation data is from Environment Canada Stations Waterloo Wellington (ID 6149387) from 1993 to 2002, Waterloo Regional Airport (ID 6149388) from 2003 to 2010 and Kitchener Waterloo (ID 6149388) from 2010 to 2015.

2) Yearly pumping rate shown is to the Pinebush and Turnbull WTPs only.

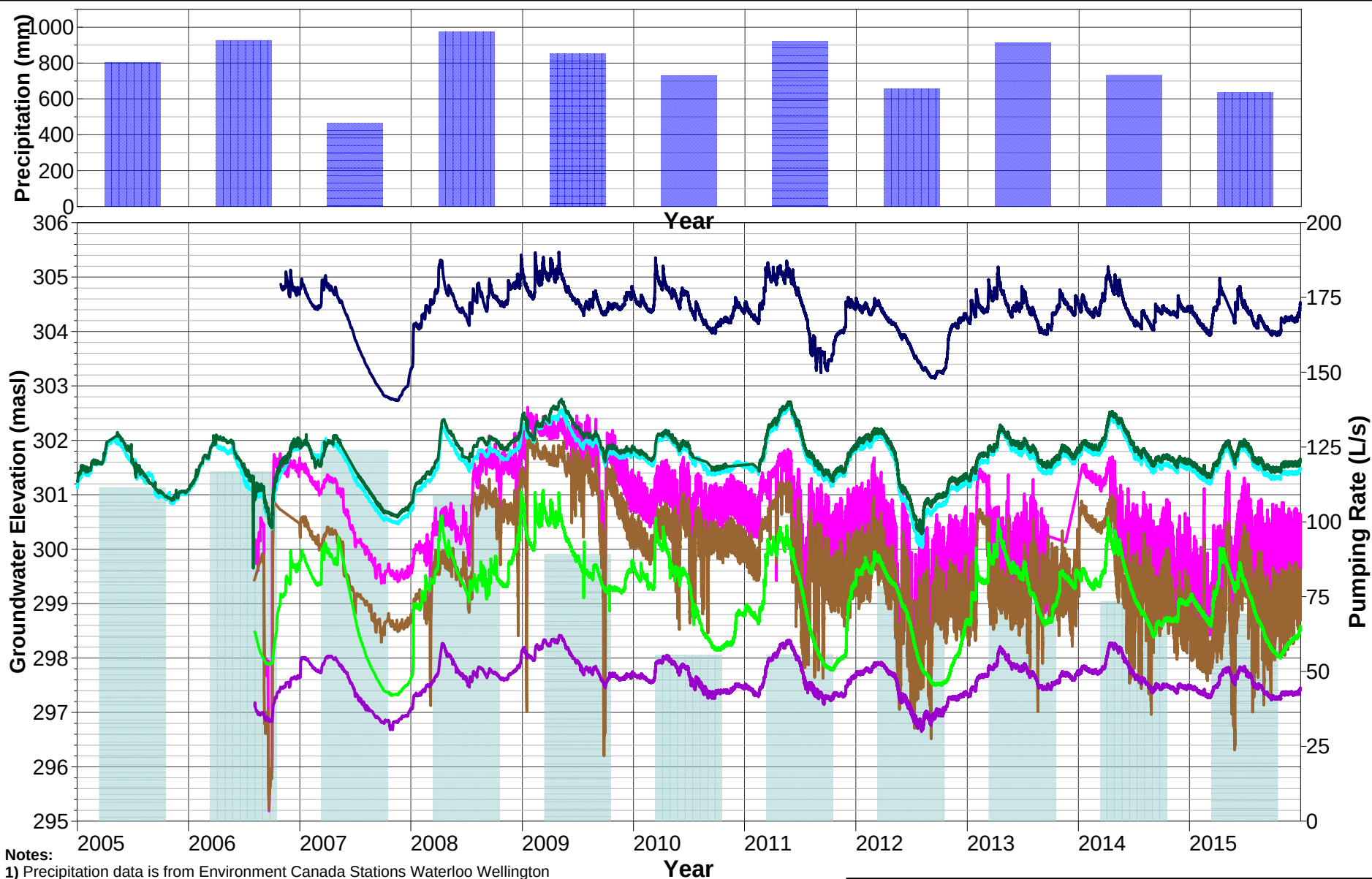


**Cambridge East
Water Supply
Class Environmental
Assessment**

**Historical Groundwater
Elevation Monitoring
Pinebush Well Field**



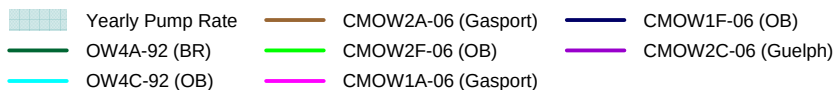
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PROJECT: 05-1112-010 (1500)		FIGURE: 15B



Notes:

1) Precipitation data is from Environment Canada Stations Waterloo Wellington (ID 6149387) from 1993 to 2002, Waterloo Regional Airport (ID 6149388) from 2003 to 2010 and Kitchener Waterloo (ID 6149388) from 2010 to 2015.

2) Yearly pumping rate shown is to the Pinebush and Turnbull WTPs only.



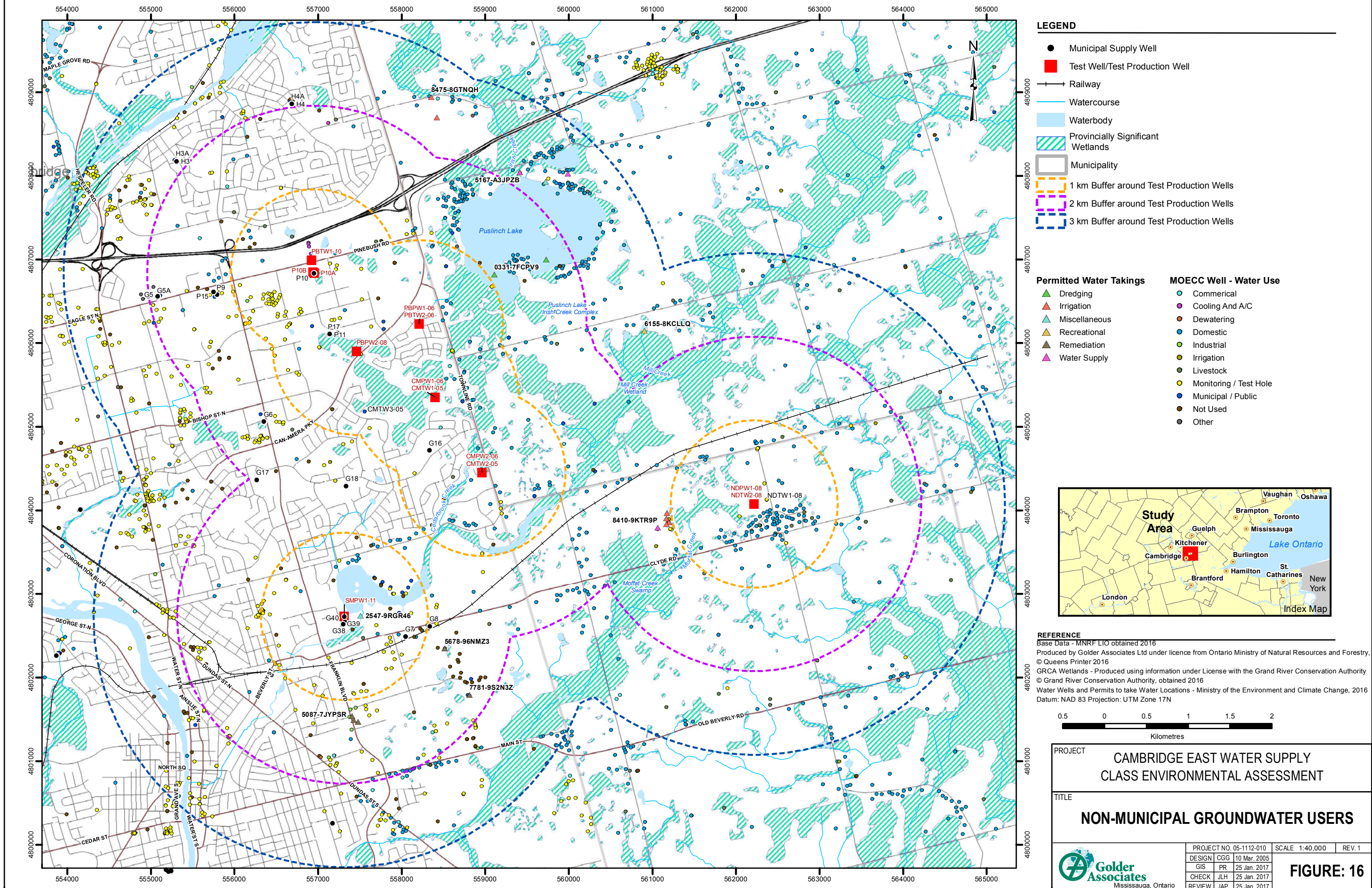
**Cambridge East
Water Supply
Class Environmental
Assessment**

**Historical Groundwater
Elevation Monitoring
Clemens Mill Well Field**

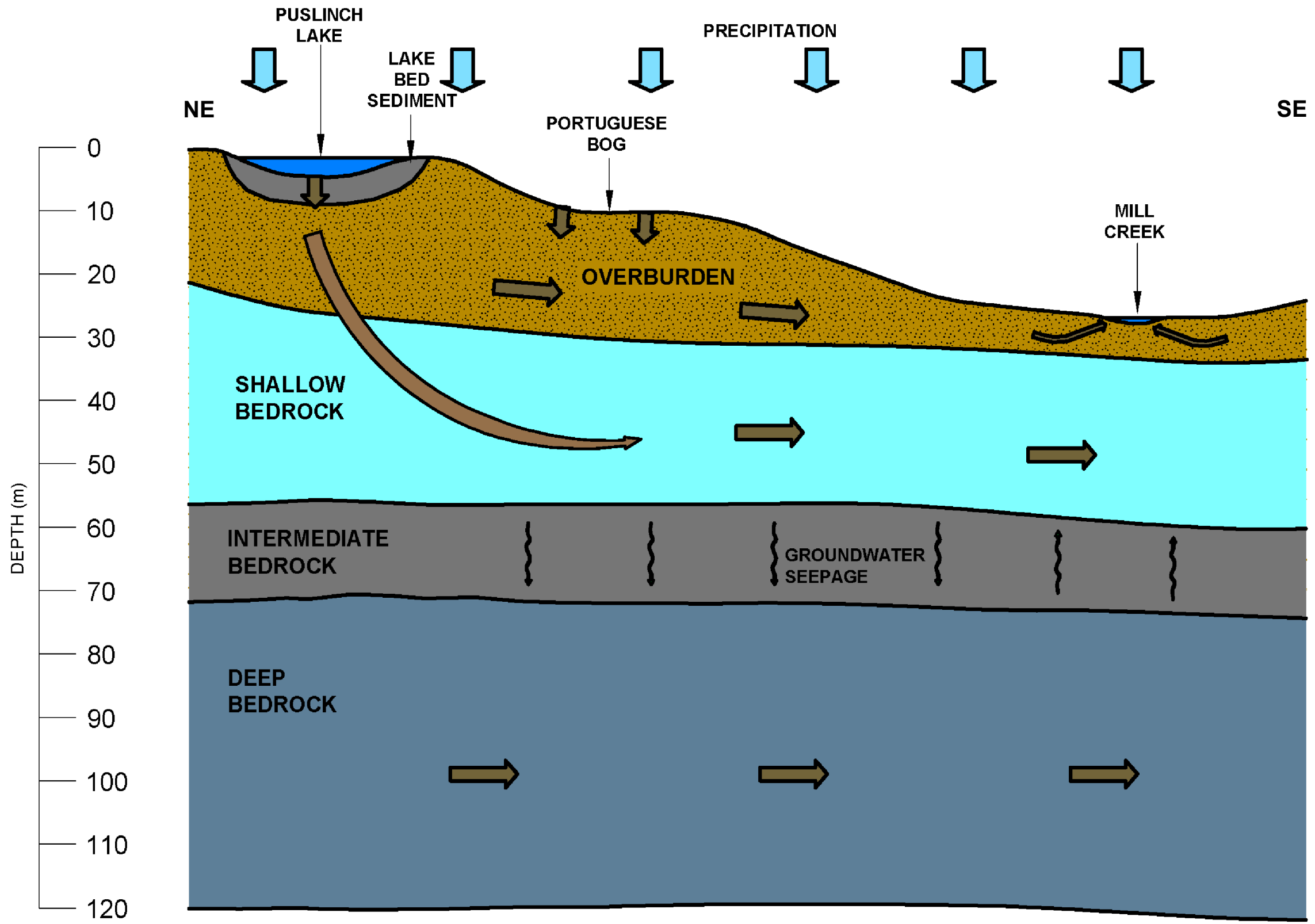


DRAWN: JLH	APPROVED: JAP	DATE: FEBRUARY 2017
PROJECT: 05-1112-010 (1500)		FIGURE: 15C

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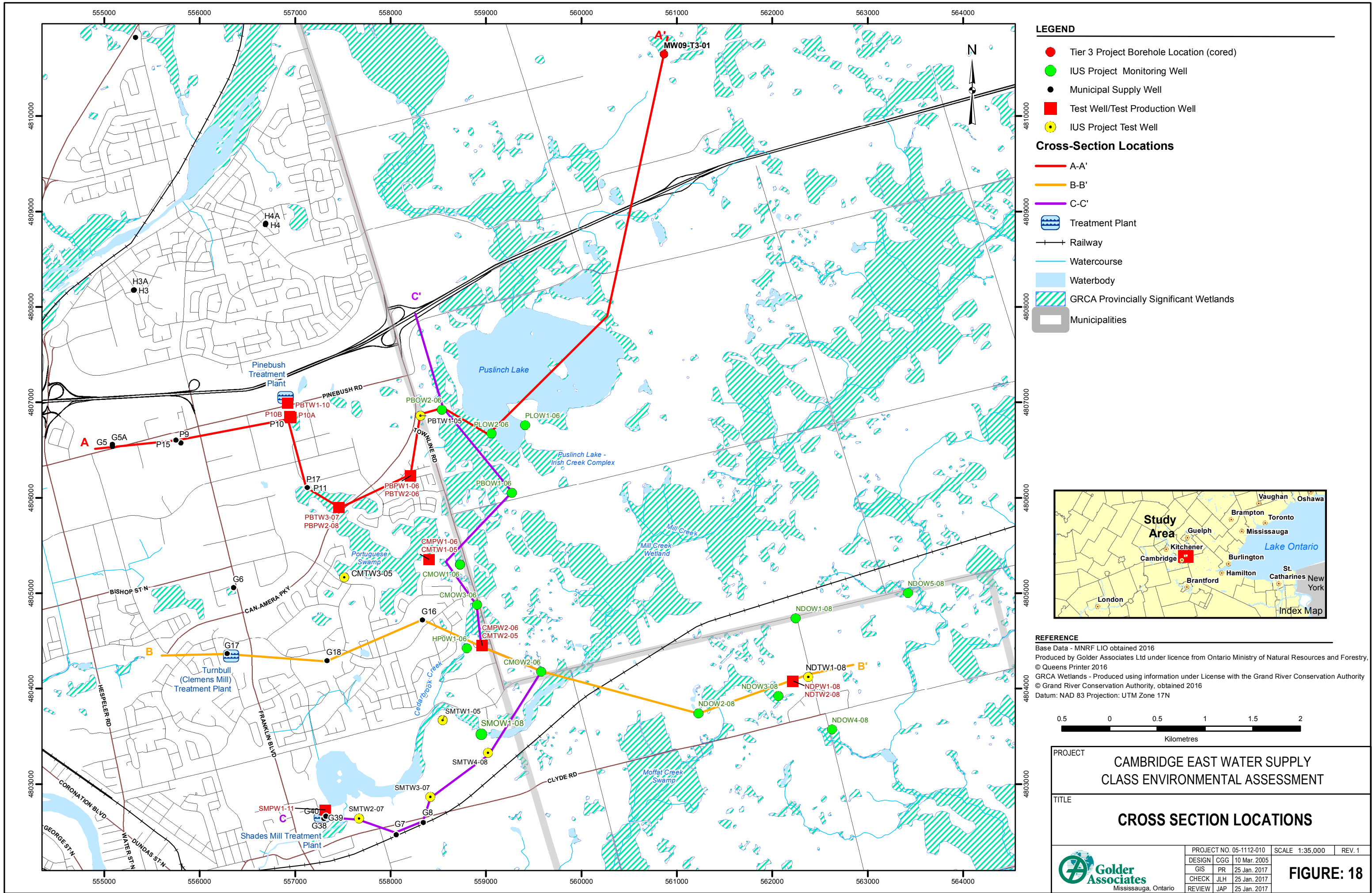


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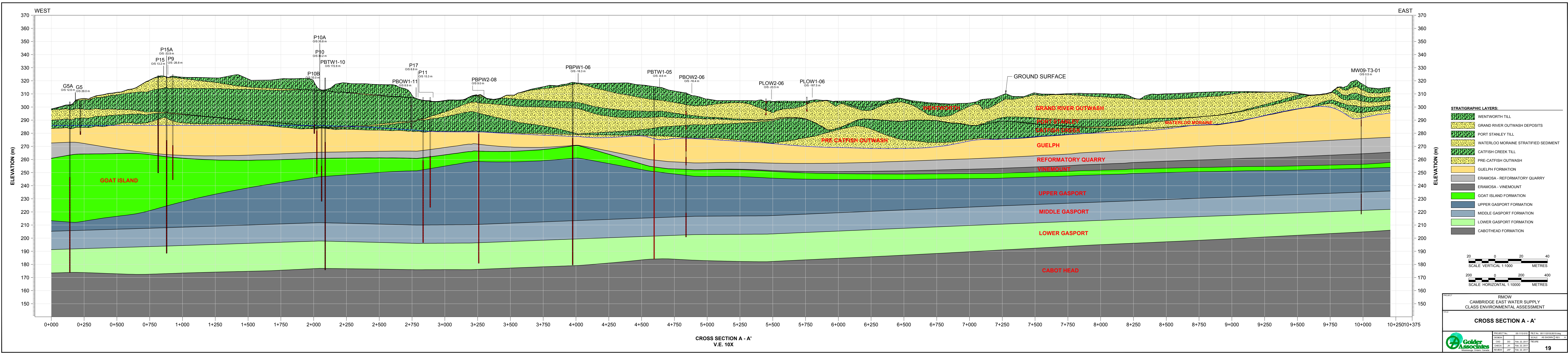


PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT	
TITLE		CONCEPTUAL MODEL OF GROUNDWATER FLOW WITHIN THE STUDY AREA	
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	GIS	PR	16 Feb. 2017
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	REVIEW	JAP	16 Feb. 2017
		REV. 1	

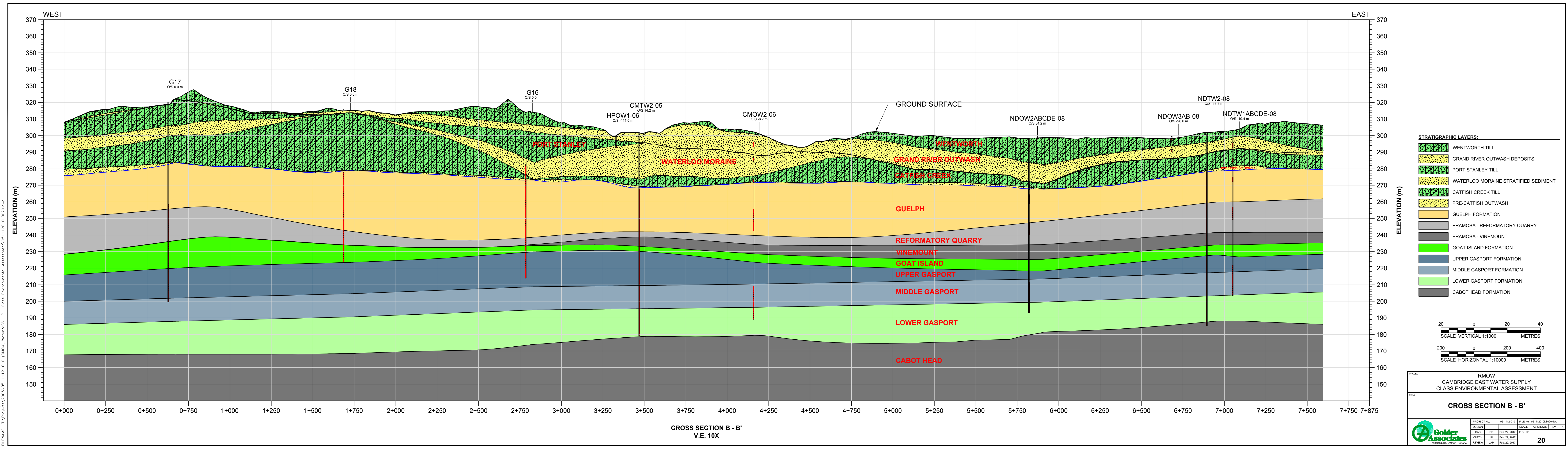
FIGURE: 17



PLOT DATE: February 22, 2017
FILENAME: T:\Projects\2005\05-1112-010 (RMOW, Waterloo)\LB- Class Environmental Assessment\05112010LB019.dwg

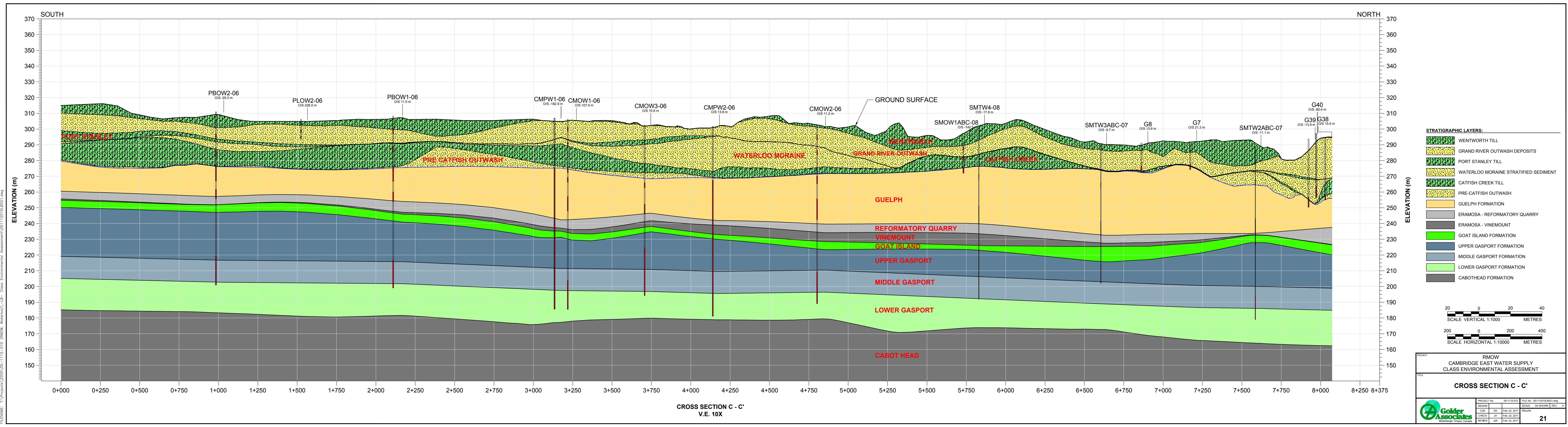


PLOT DATE: February 22, 2017
FILENAME: I:\Projects\2005\05-1112-010 (RMOW, Waterloo)\LB- Class Environmental Assessment\051112010LB020.dwg



PROJECT		RMOW CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT	
TITLE		CROSS SECTION B - B'	
 Mississauga, Ontario, Canada	PROJECT No.	05-1112-010	FILE No. 051112010LB020.dwg
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SCALE		AS SHOWN	REV. A
FIGURE		20	

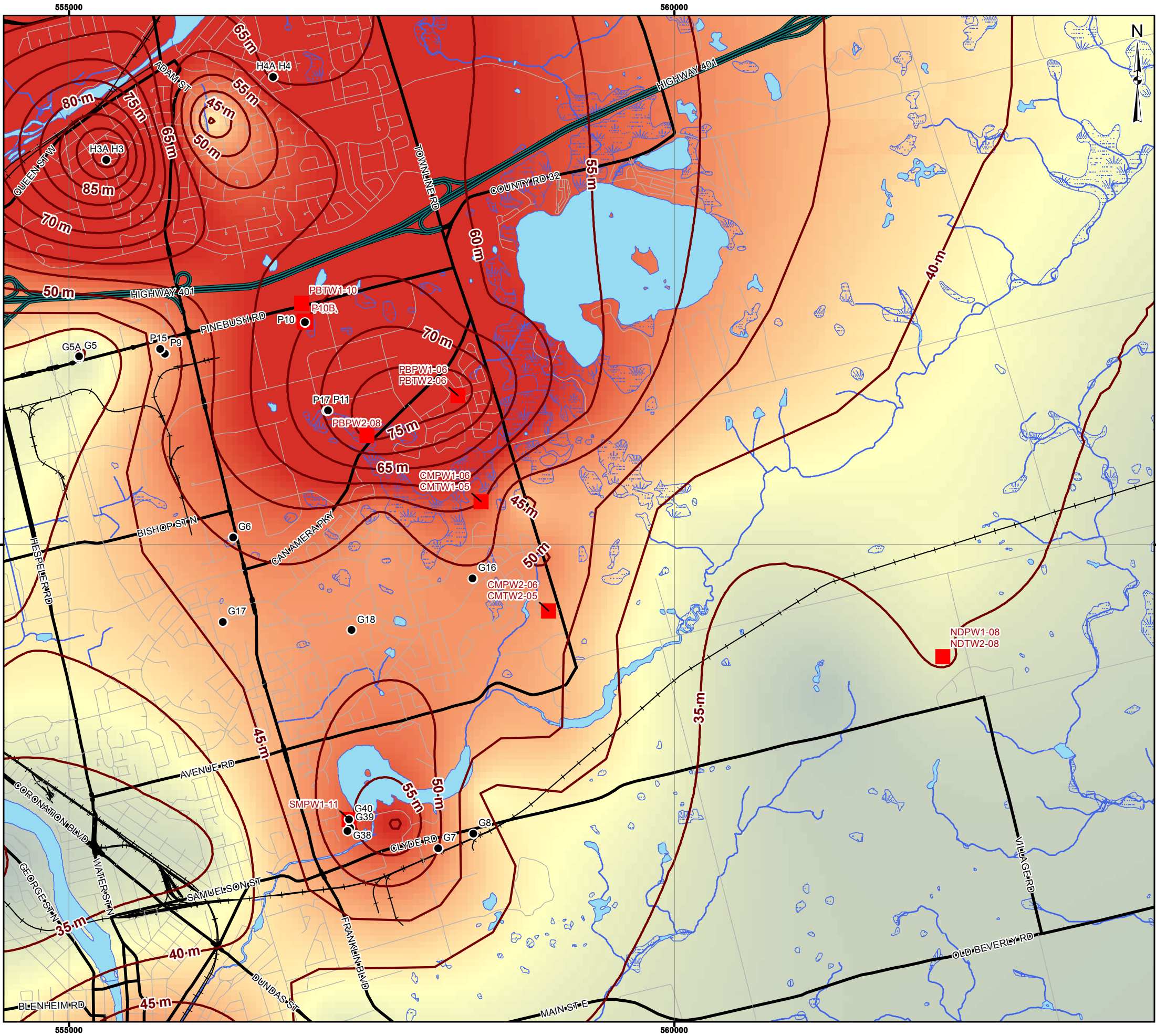
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TITLE		CROSS SECTION C - C'	
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DESIGN	DD	Feb. 22, 2017	SCALE AS SHOWN
CAD	DD	Feb. 22, 2017	FIGURE
CHECK	JH	Feb. 22, 2017	
REVIEW	JAP	Feb. 22, 2017	

21

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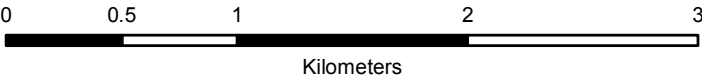
LEGEND

- Municipal Supply Well
 - Test Production Wells
 - Contour - Interpreted Thickness of Gasport Formation (m)
 - Expressway
 - Principal Highway
 - Major Road
 - Local road
 - Railways
 - Watercourse
 - Waterbody
 - Wetland
- Interpreted Thickness of Gasport Formation**
- 100
- 20



REFERENCE

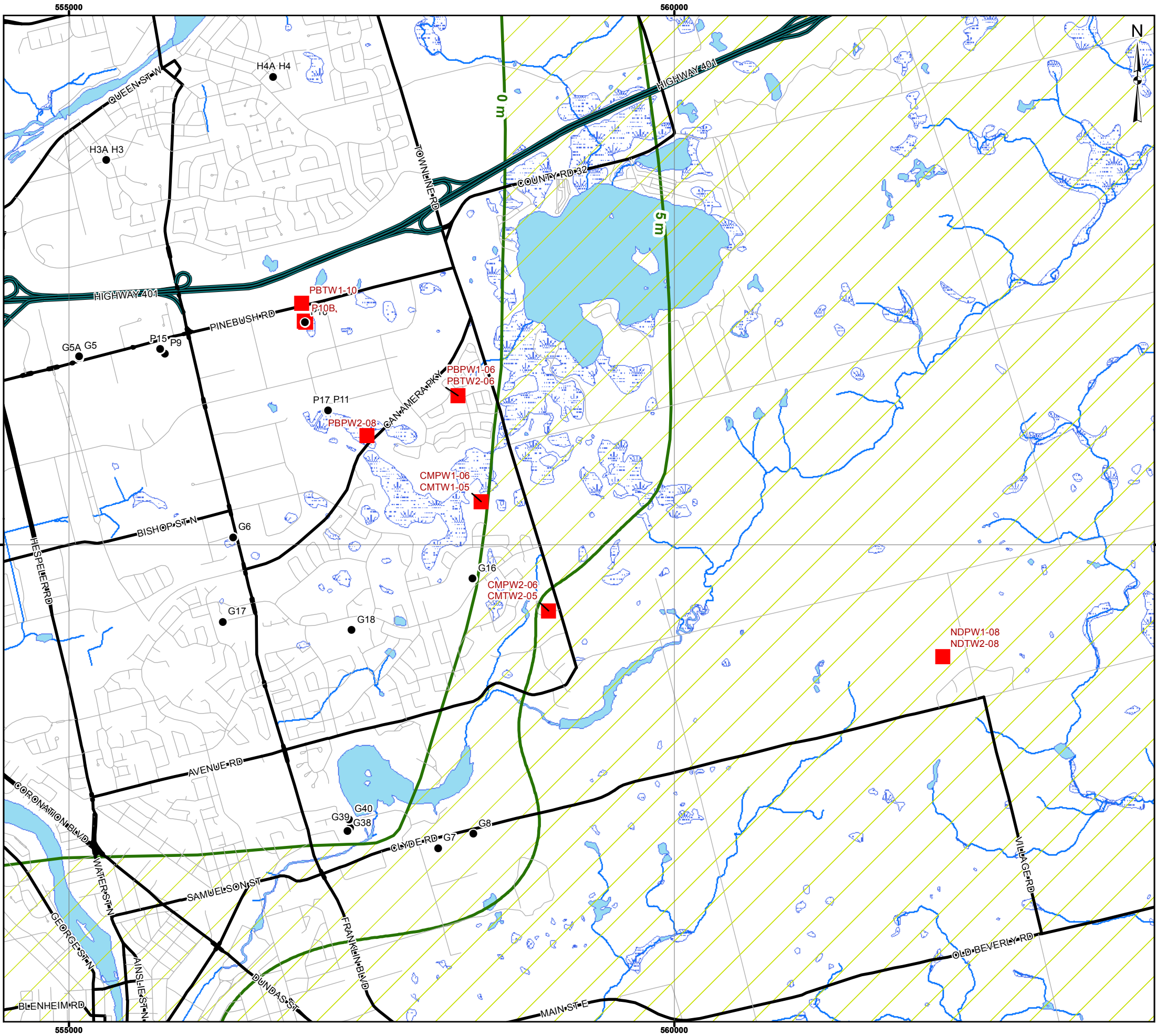
Base Data - MNR NRVIS, obtained 2004, CANMAP v2005.4
Produced by Golder Associates Ltd under licence from
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Datum: NAD 83 Projection: UTM Zone 17N



PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT		
TITLE	INTERPRETED THICKNESS OF GASPORT FORMATION		
 Mississauga, Ontario	PROJECT NO.	05-1112-010	SCALE 1:32,785
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	GIS	PR/JMC 10 Aug. 2016	
	CHECK	JLH 10 Aug. 2016	
	REVIEW	JAP 10 Aug. 2016	

FIGURE: 22

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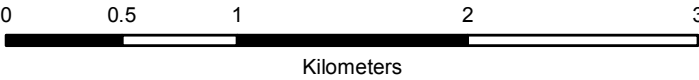
LEGEND

- Municipal Supply Well
- Test Production Wells
- Contour - Interpreted Thickness of Vinemount Member (m)
- Expressway
- Principal Highway
- Major Road
- Local road
- Watercourse
- Waterbody
- Wetland
- Vinemount Member Present



REFERENCE

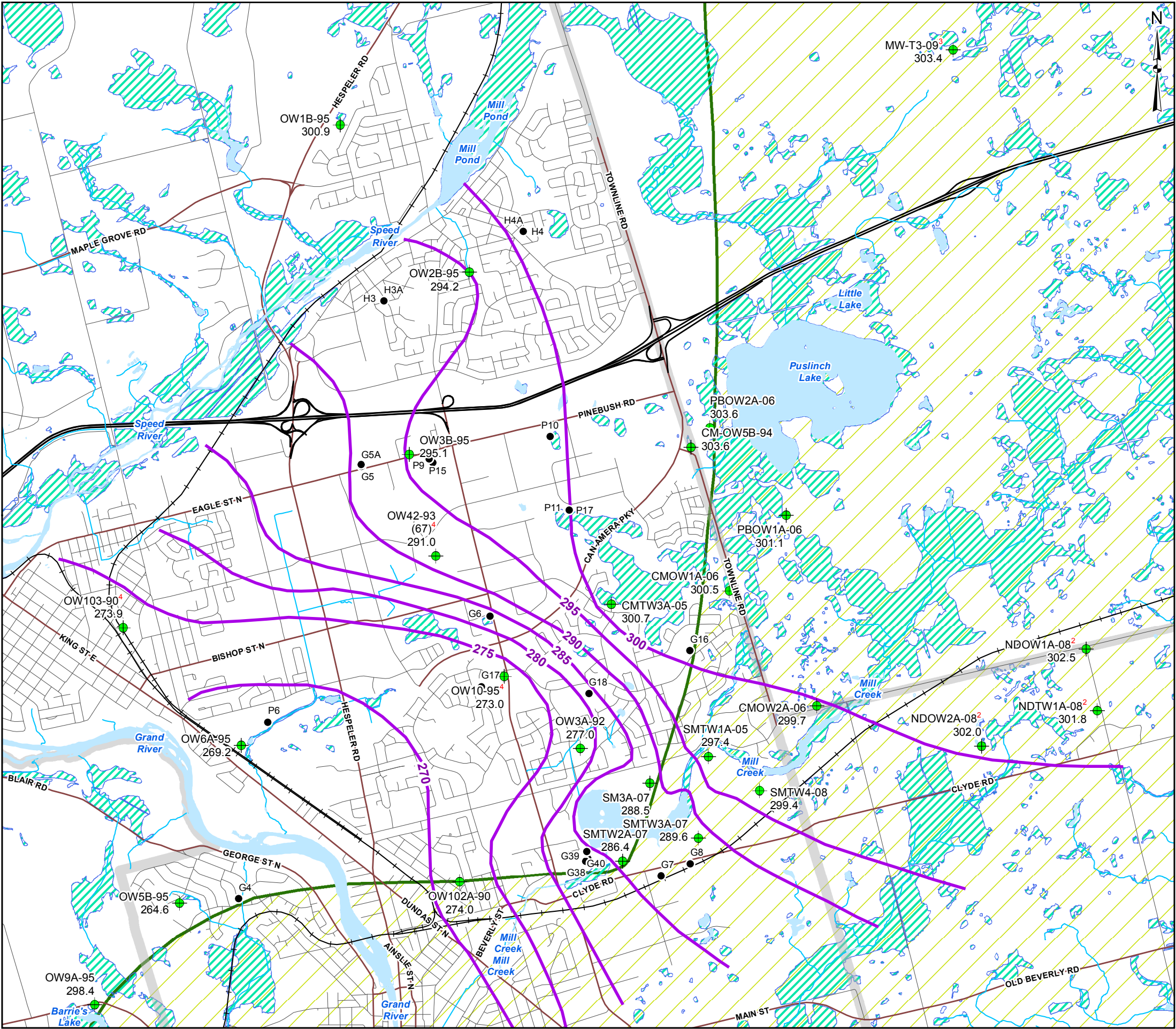
Base Data - MNR NRVIS, obtained 2004, CANMAP v2005.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2006
Datum: NAD 83 Projection: UTM Zone 17N



PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT		
TITLE	INTERPRETED THICKNESS OF ERAMOSA FORMATION – VINEMOUNT MEMBER		
 Mississauga, Ontario	PROJECT NO.	05-1112-010	SCALE 1:32,785
	DESIGN	KD 29 Nov. 2007	Ver. 1.0
	GIS	PR/JMC 10 Aug. 2016	
	CHECK	JLH 10 Aug. 2016	
	REVIEW	JAP 10 Aug. 2016	

FIGURE: 23

G:\Projects\2005\05-1112-010_IUS_Groundwater_Waterfoot\GIS\MXDs\Draft\Cambridge\Natural_Environment_Report\Fig24_GroundwaterFlowDeepBedrockGasportFormation.mxd



LEGEND

Monitoring Well

Municipal Supply Well

Groundwater Elevation Contour

Railway

Principal Highway

Major Roads

Local Roads

Watercourse

Waterbody

GRCA Provincially Significant Wetlands

Vinemount Member Present

Municipalities

NOTE

All water level data is based on measurements between 4/21/08 and 5/04/08 unless indicated by ¹⁻⁴

¹

- indicates water level reading taken from 8/21/06 or 9/01/06

²

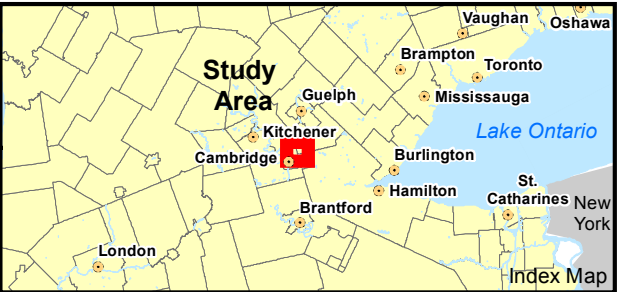
- indicates water level reading taken from January 2009

³

- indicates water level taken from 6/18/09 to 7/21/09

⁴

- indicates water level reading based on historical data



REFERENCE

Base Data - MNRF LIO obtained 2016

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Datum: NAD 83 Projection: UTM Zone 17N



PROJECT

CAMBRIDGE EAST WATER SUPPLY
CLASS ENVIRONMENTAL ASSESSMENT

TITLE

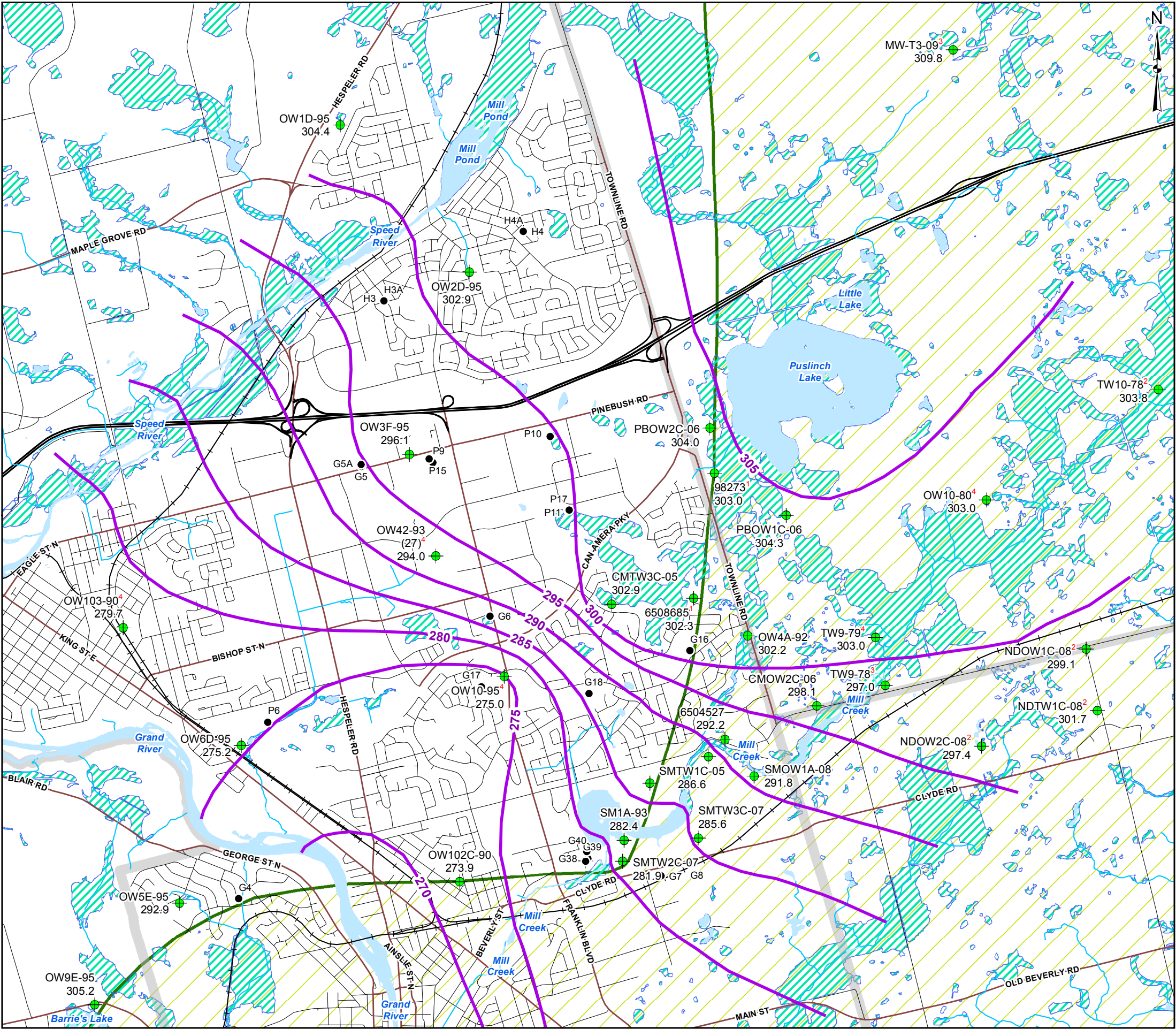
GROUNDWATER FLOW IN THE DEEP
BEDROCK – GASPORT FORMATION

Golder
Associates

Mississauga, Ontario

PROJECT NO.	05-1112-010	SCALE	1:40,000	REV.	1
DESIGN	CGG	10 Mar. 2005			
GIS	PR	8 Aug. 2016			
CHECK	JLH	8 Aug. 2016			
REVIEW	JAP	8 Aug. 2016			

FIGURE: 24



LEGEND

Monitoring Well

Municipal Supply Well

Groundwater Elevation Contour

Railway

Principal Highway

Major Roads

Local Roads

Watercourse

Waterbody

GRCA Provincially Significant Wetlands

Vinemount Member Present

Municipalities

NOTE

All water level data is based on measurements between 4/21/08 and 5/04/08 unless indicated by ¹⁻⁴

¹

- indicates water level reading taken from 8/21/06 or 9/01/06

²

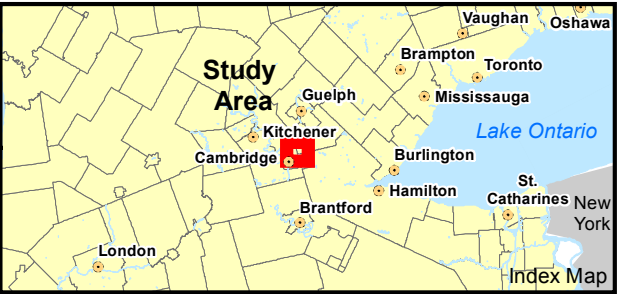
- indicates water level reading taken from January 2009

³

- indicates water level taken from 6/18/09 to 7/21/09

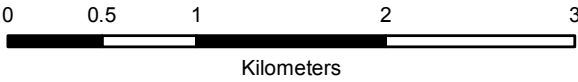
⁴

- indicates water level reading based on historical data



REFERENCE

Base Data - MNRF LIO obtained 2016
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Datum: NAD 83 Projection: UTM Zone 17N



PROJECT

CAMBRIDGE EAST WATER SUPPLY
CLASS ENVIRONMENTAL ASSESSMENT

TITLE

GROUNDWATER FLOW IN THE UPPER
BEDROCK – GUELPH FORMATION

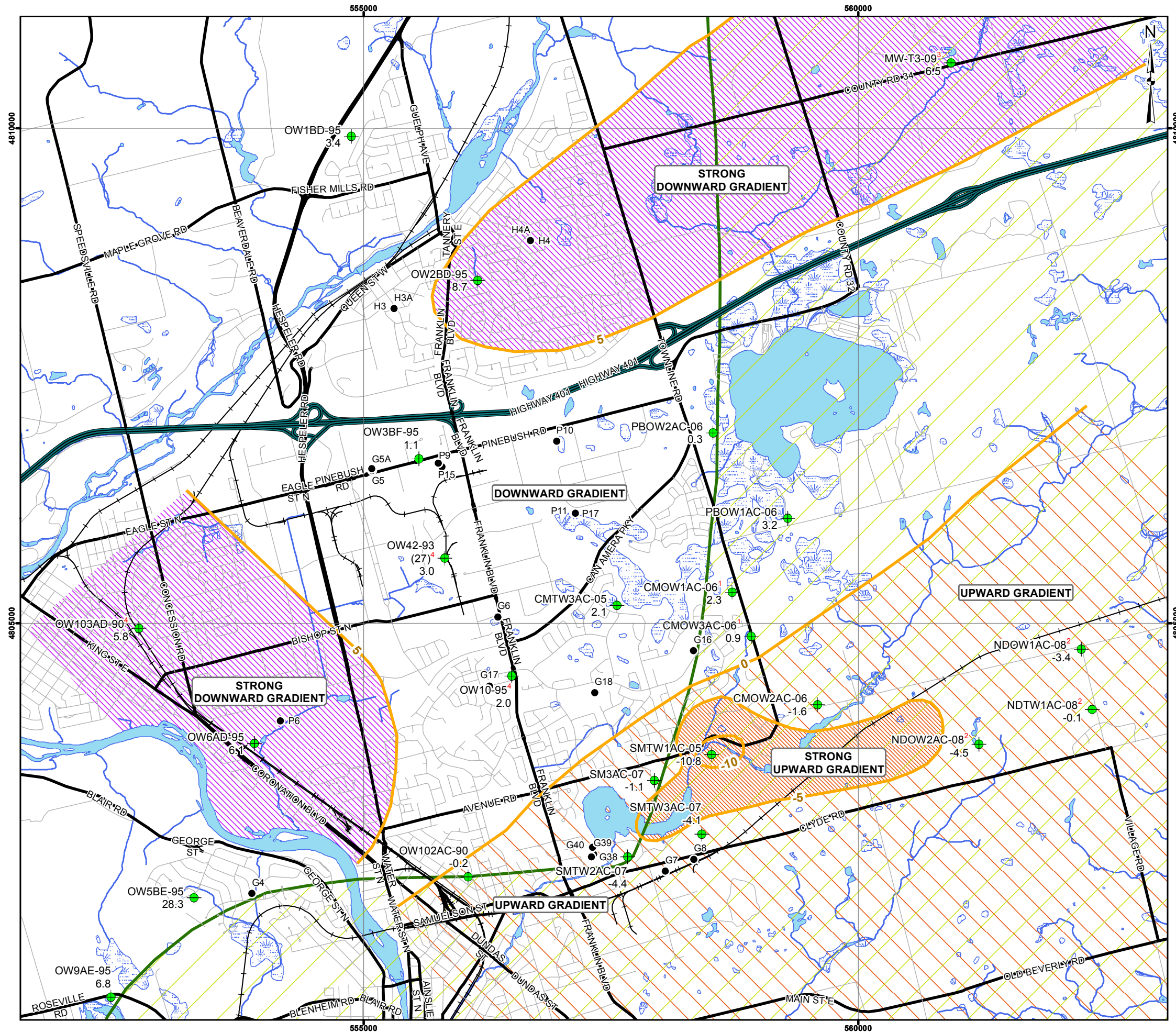
Golder
Associates

Mississauga, Ontario

PROJECT NO.	05-1112-010	SCALE	1:40,000	REV.	1
DESIGN	CGG	10 Mar. 2005			
GIS	PR	8 Aug. 2016			
CHECK	JLH	8 Aug. 2016			
REVIEW	JAP	8 Aug. 2016			

FIGURE: 25

G:\Projects\2005\05-1112-010_IUS_Groundwater_Waterloo\GIS\MXDs\Draft\Cambridge\Natural_Environment_Report\Fig26_Bedrock_Vertical_Hydraulic_Head.mxd



LEGEND

- Municipal Supply Well
- Monitoring Well
- Head Difference Contour
- Watercourse
- Waterbody
- Wetland
- Upward Gradient
- Strong Upward Gradient
- Strong Downward Gradient
- Vinemount Member Present

NOTE

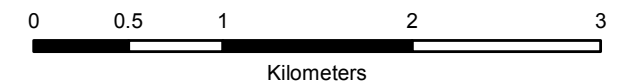
All water level data is based on measurements between 4/21/08 and 5/04/08 unless indicated by ¹⁻⁴

- ¹ - indicates water level reading taken from 8/21/06 or 9/01/06
- ² - indicates water level reading taken from January 2009
- ³ - indicates water level taken from 6/18/09 to 7/21/09
- ⁴ - indicates water level reading based on historical data
- ^{3,4} - Head Difference Value
(Shallow Minus Deep Bedrock Hydraulic Head (m))
+ = Downward Gradient
- = Upward Gradient



REFERENCE

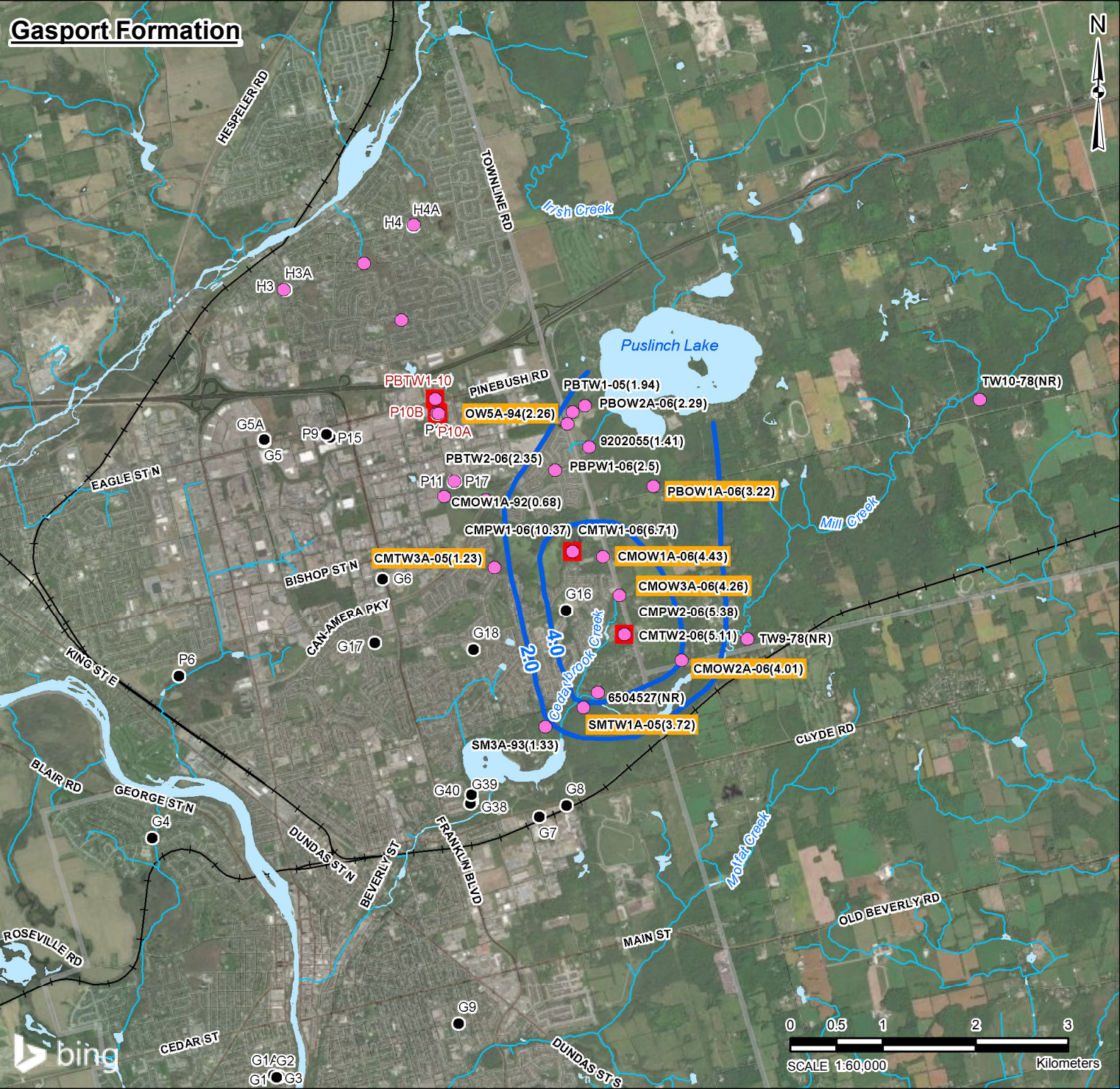
Base Data - MNR NRVIS, obtained 2004, CANMAP v2005.4
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2006
Datum: NAD 83 Projection: UTM Zone 17N



PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT		
TITLE	VERTICAL HYDRAULIC GRADIENTS IN BEDROCK AQUIFER		
 Golder Associates Mississauga, Ontario	PROJECT NO.	05-1112-010	SCALE 1:40,000
	DESIGN	KD 29 Nov. 2007	Ver. 1.0
	GIS	PR/JMC 10 Aug. 2016	
	CHECK	JLH 10 Aug. 2016	
	REVIEW	JAP 10 Aug. 2016	

FIGURE: 26

G:\Projects\200505-1112-010_IUS_Groundwater_Waterloo\GIS\MXDs\Draft\Cambridge\Presentation\Client_Presentation_20170322\Fig27_28DayPumpingTest_ObservedDrawdownEndofTest.mxd

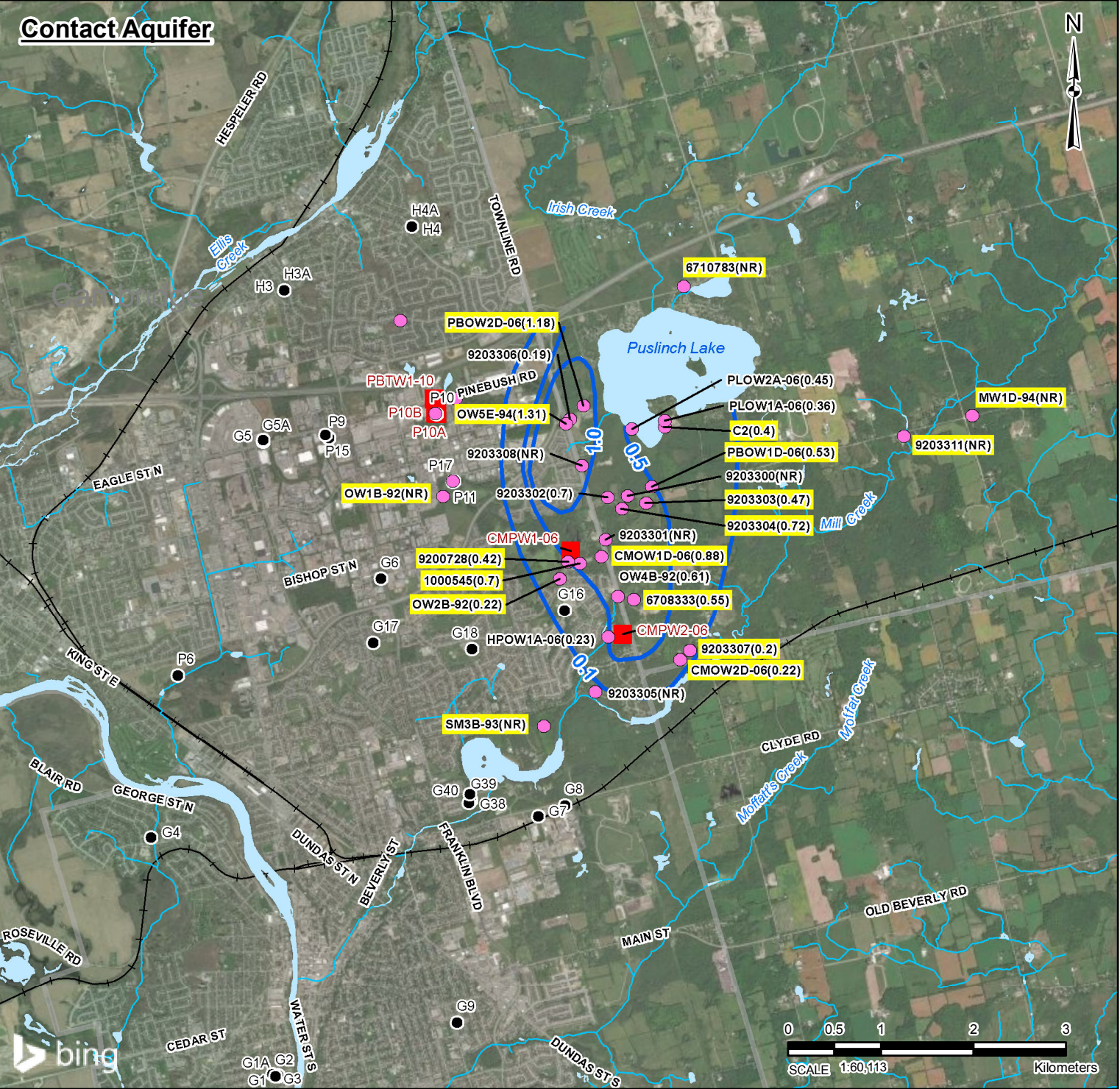


LEGEND

- Monitored Well
- Municipal Supply Well
- Test Production Wells
- Observed Drawdown Contour (28 Day Pumping Test)
- Gasport Monitored Interval
- Lower Overburden Monitored Interval
- NR No Response

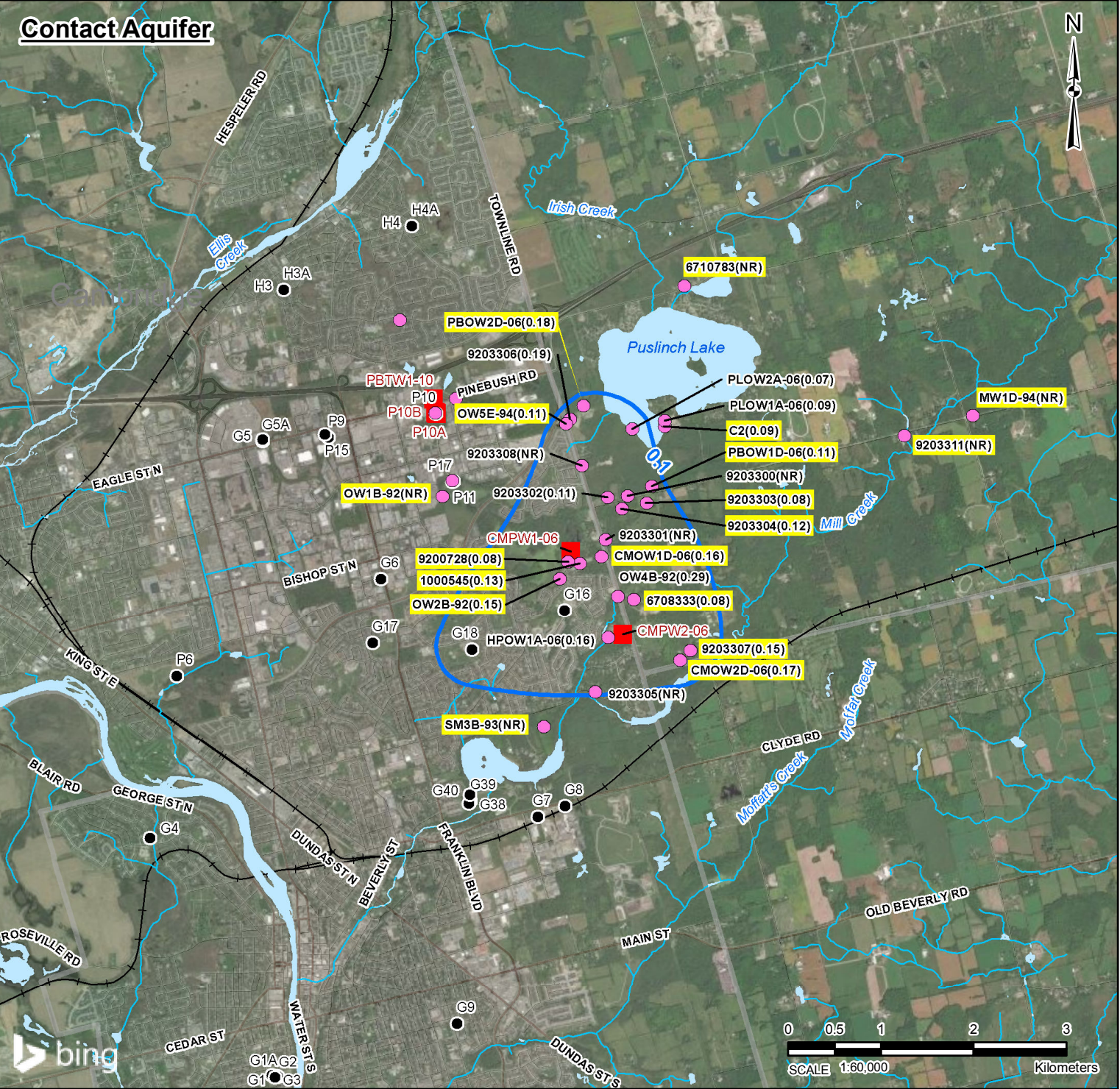
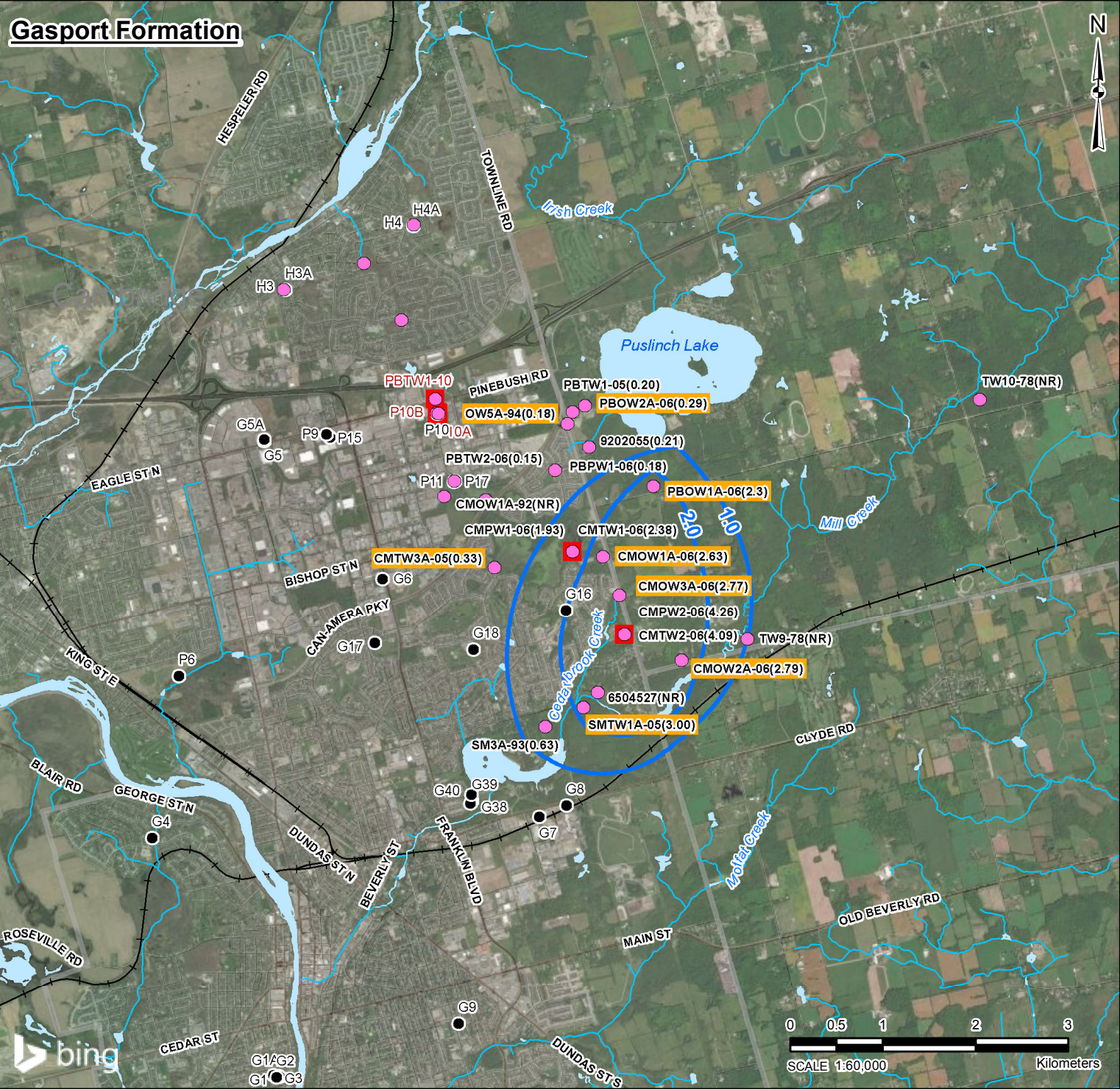
REFERENCE

Base Data - MNR LIO obtained 2016
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources and Forestry, © Queens Printer 2016
Datum: NAD 83 Projection: UTM Zone 17N



PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT			
TITLE	28 DAY PUMPING TEST – OBSERVED DRAWDOWN AT THE END OF THE TEST			
 Golder Associates Mississauga, Ontario	PROJECT No. 05-1112-010	SCALE AS SHOWN	REV. 0.0	FIGURE: 27
	DESIGN PR 2 Feb. 2017			
	GIS PR 22 Mar. 2017			
	CHECK JLH 22 Mar. 2017			
	REVIEW JAP 22 Mar. 2017			

G:\Projects\200505-1112-010_IUS_Groundwater_Waterloo\GIS\MXDs\Draft\Cambridge\Presentation\Client_Presentation_20170322\Fig28_28DayPumpingTest_ObservedDrawdown.mxd



LEGEND

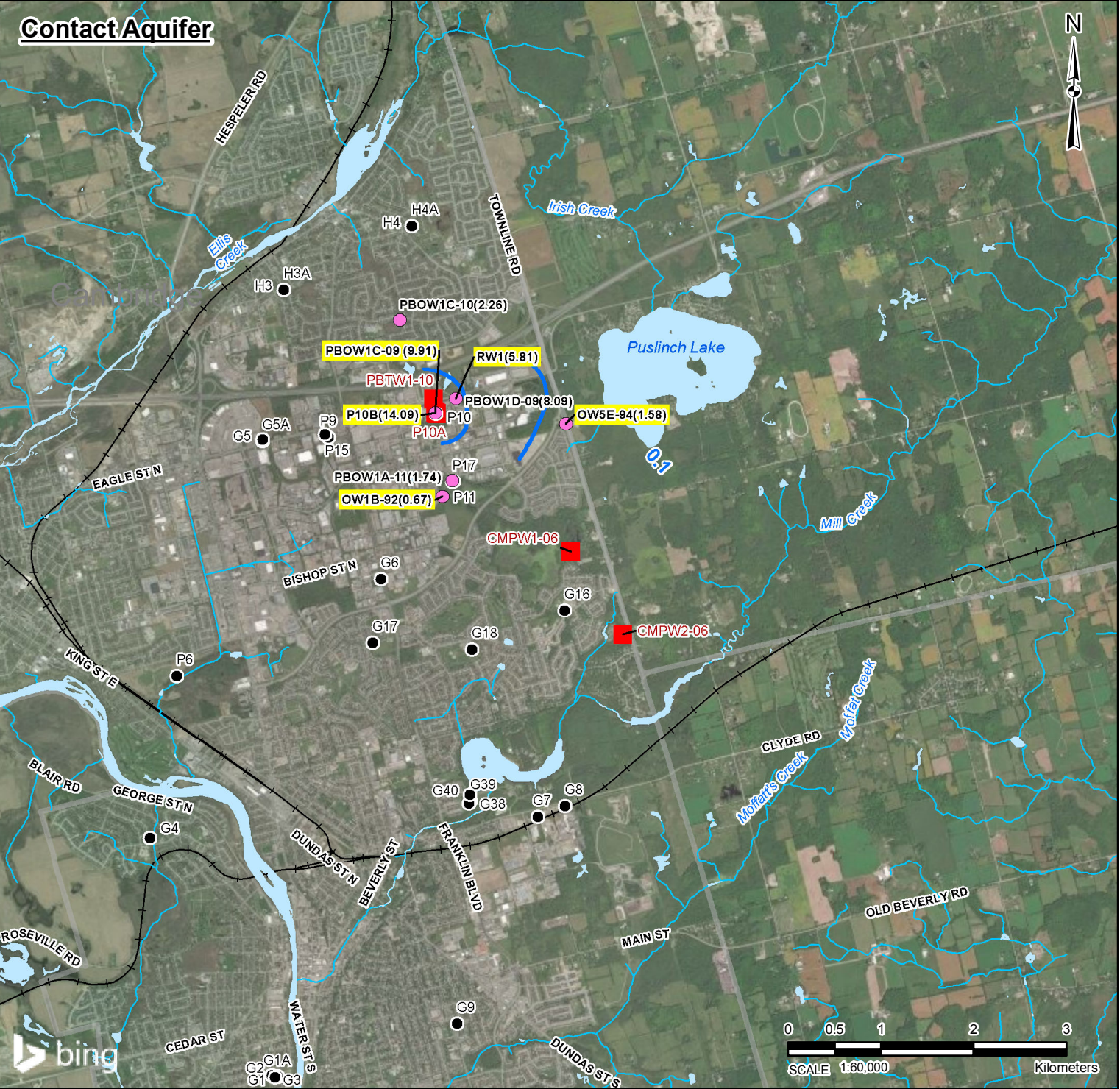
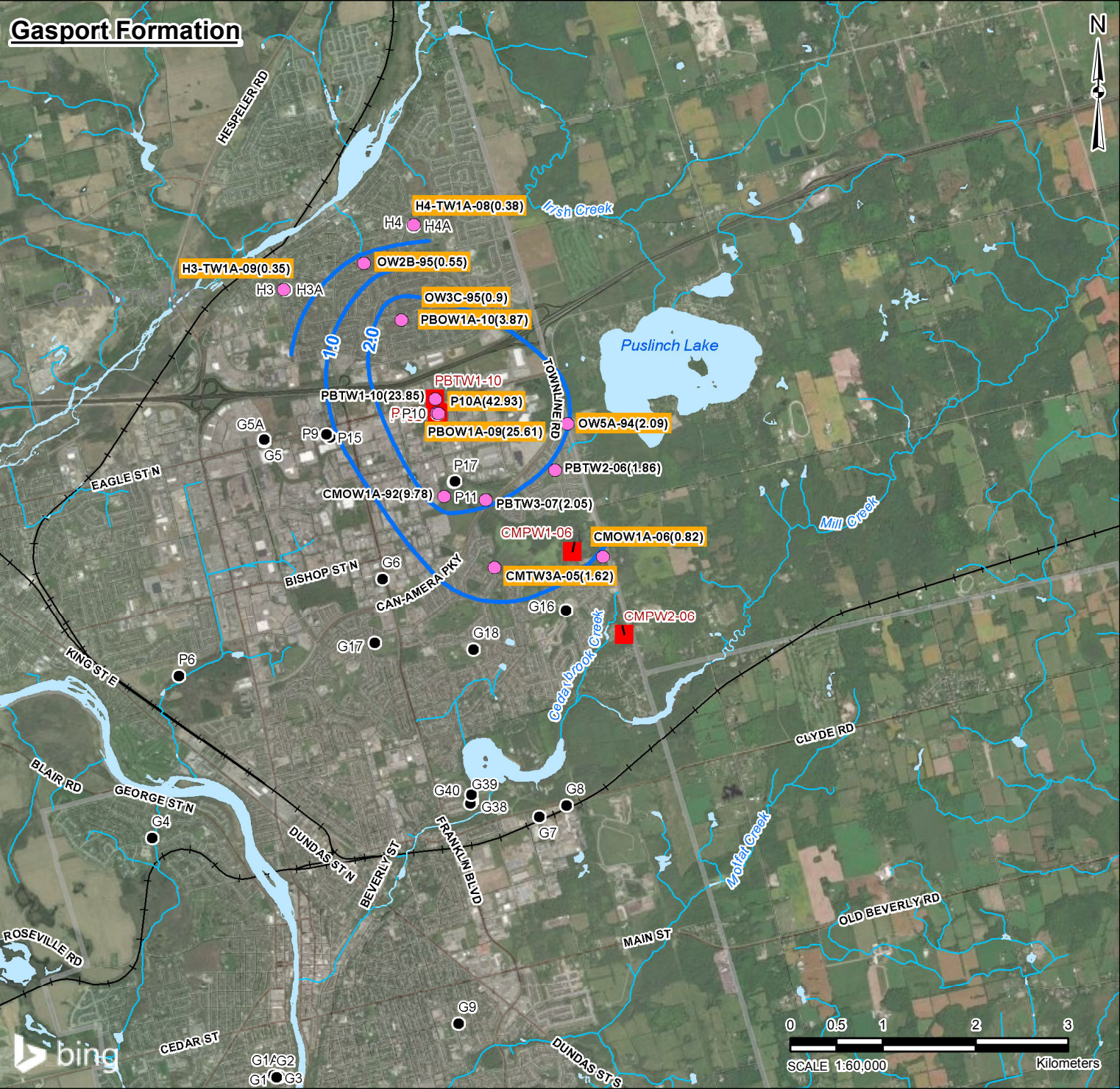
- Monitored Well
- Municipal Supply Well
- Test Production Wells
- Observed Drawdown Contour (After 7 Days of Pumping at CMPW2-06).
- Gasport Monitored Interval
- Lower Overburden Monitored Interval
- NR No Response

REFERENCE

Base Data - MNR LIO obtained 2016
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Datum: NAD 83 Projection: UTM Zone 17N

PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT			
TITLE		28 DAY PUMPING TEST – OBSERVED DRAWDOWN AFTER 7 DAYS OF PUMPING CMPW2-06 (CEDARBROOK WELL)			
 Golder Associates Mississauga, Ontario	PROJECT No.	05-1112-010	SCALE AS SHOWN	REV. 0.0	
	DESIGN	PR	2 Feb. 2017	FIGURE: 28	
	GIS	PR	22 Mar. 2017		
	CHECK	JLH	22 Mar. 2017		
REVIEW		JAP	22 Mar. 2017		

G:\Projects\200505-1112-010_IUS_Groundwater_Waterloo\GIS\MXDs\Draft\Cambridge\Presentation\Client_Presentation_20170322\Fig29_Pinebush_15daypumpingTest_mxd



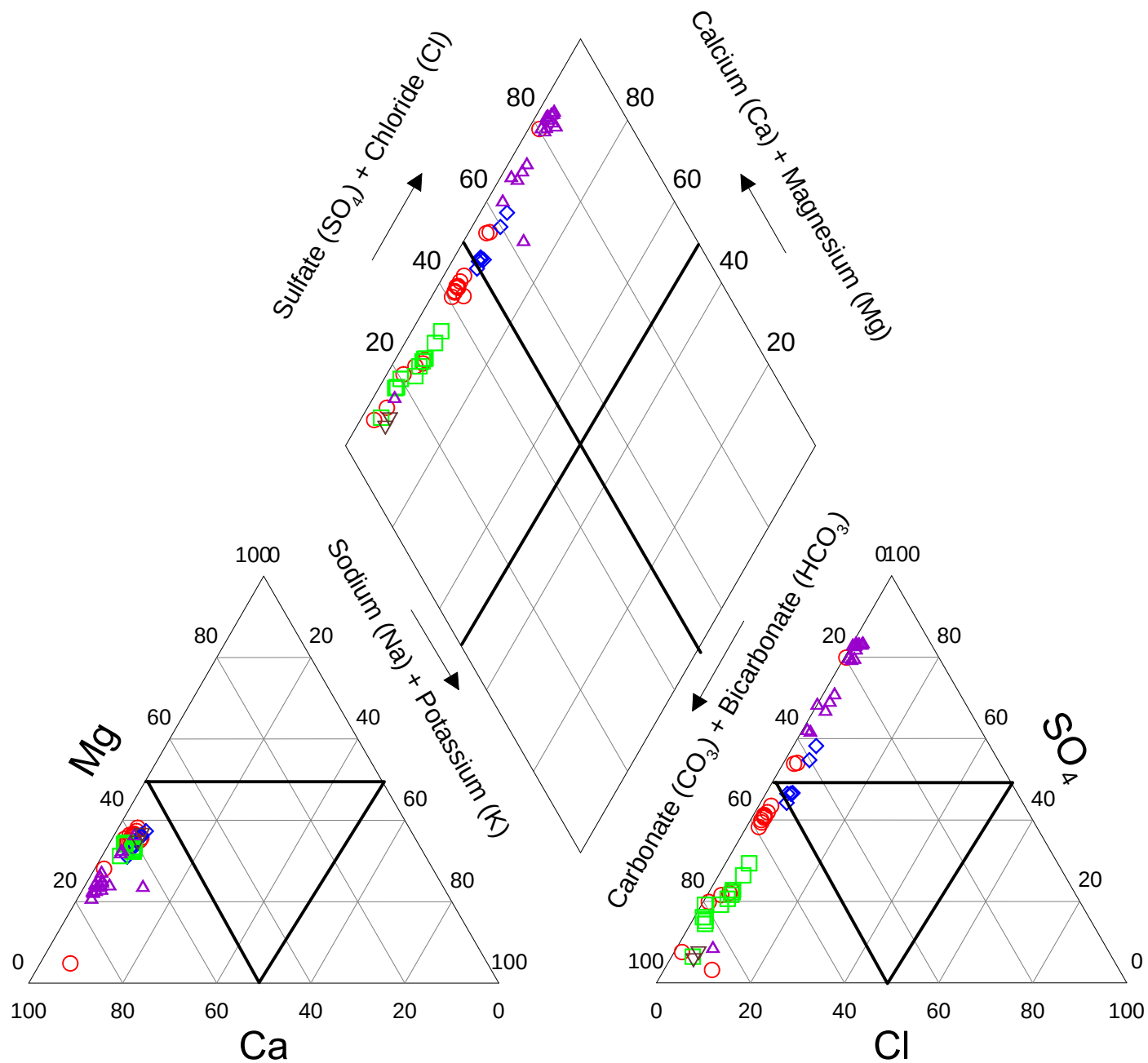
LEGEND

- Monitored Well
- Municipal Supply Well
- Test Production Wells
- Observed Drawdown Contour (Pinebush 15 Day Pumping Test)
- Gasport Monitored Interval
- Lower Overburden / Upper Guelph Formation Monitored Interval
- NR No Response

REFERENCE

Base Data - MNRF LIO obtained 2016
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Datum: NAD 83 Projection: UTM Zone 17N

PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT				
TITLE		PINEBUSH 15 DAY PUMPING TEST OBSERVED DRAWDOWN				
 Golder Associates Mississauga, Ontario	PROJECT No. 05-1112-010		SCALE AS SHOWN	REV. 0.0		
	DESIGN	PR	2 Feb. 2017	FIGURE: 29		
	GIS	PR	22 Mar. 2017			
	CHECK	JLH	22 Mar. 2017			
	REVIEW	JAP	22 Mar. 2017			



- Clemens Mill
- ◇ North Dumfries
- Pinebush
- △ Shades Mill
- ▽ Puslinch

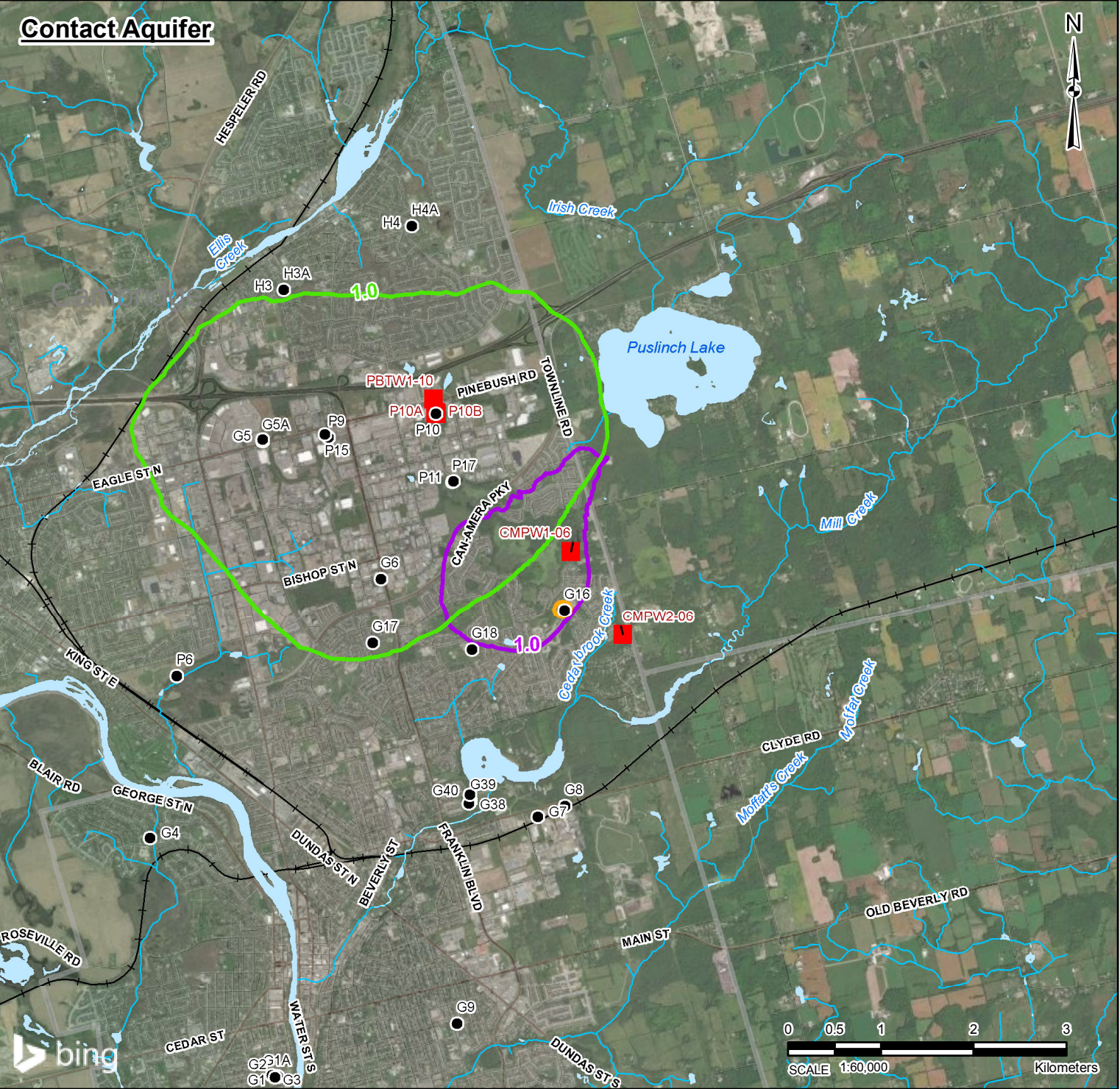
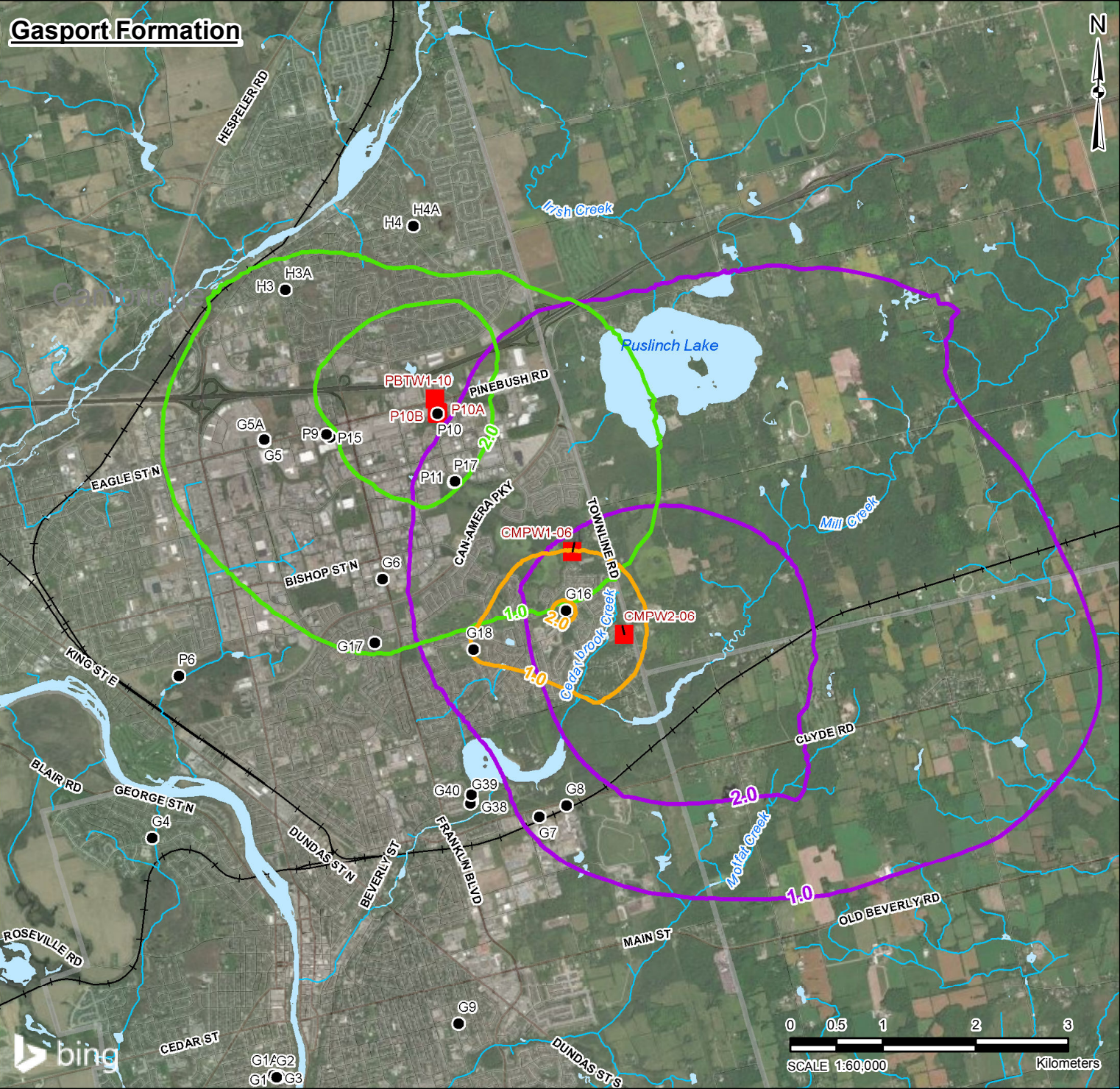
**Cambridge East
Water Supply Class
Environmental
Assessment**

**Water Quality Results
Piper Diagram by Well Field**



DRAWN: JLH	APPROVED: JAP	DATE: AUGUST 2016
PROJECT: 05-1112-010 (1500)		FIGURE: 31

G:\Projects\200505-1112-010_IUS_Groundwater_Waterloo\GIS\MXDs\Draft\Cambridge\Natural_Environment_Report\Fig34_SteadyStateSimulations.mxd



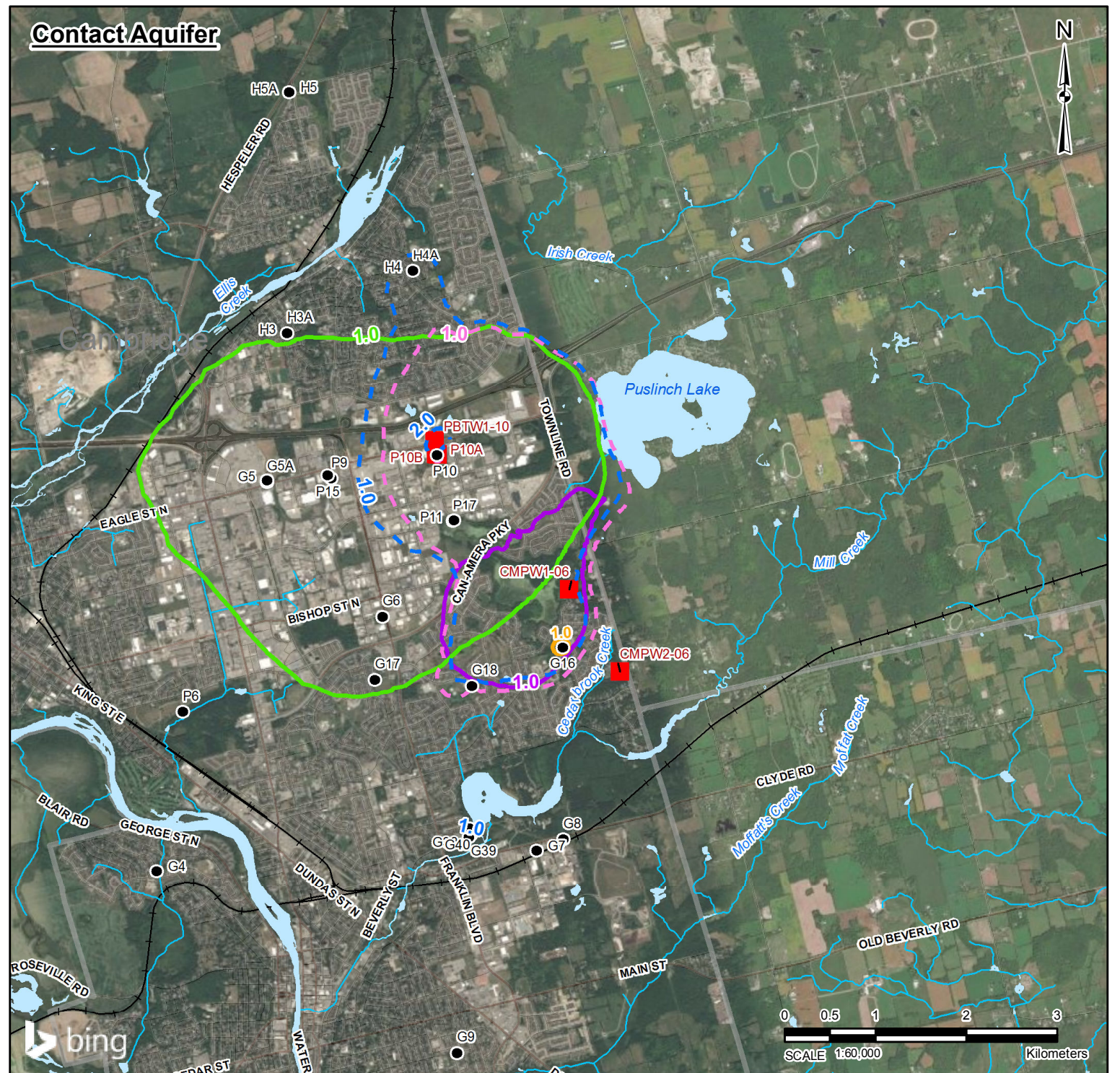
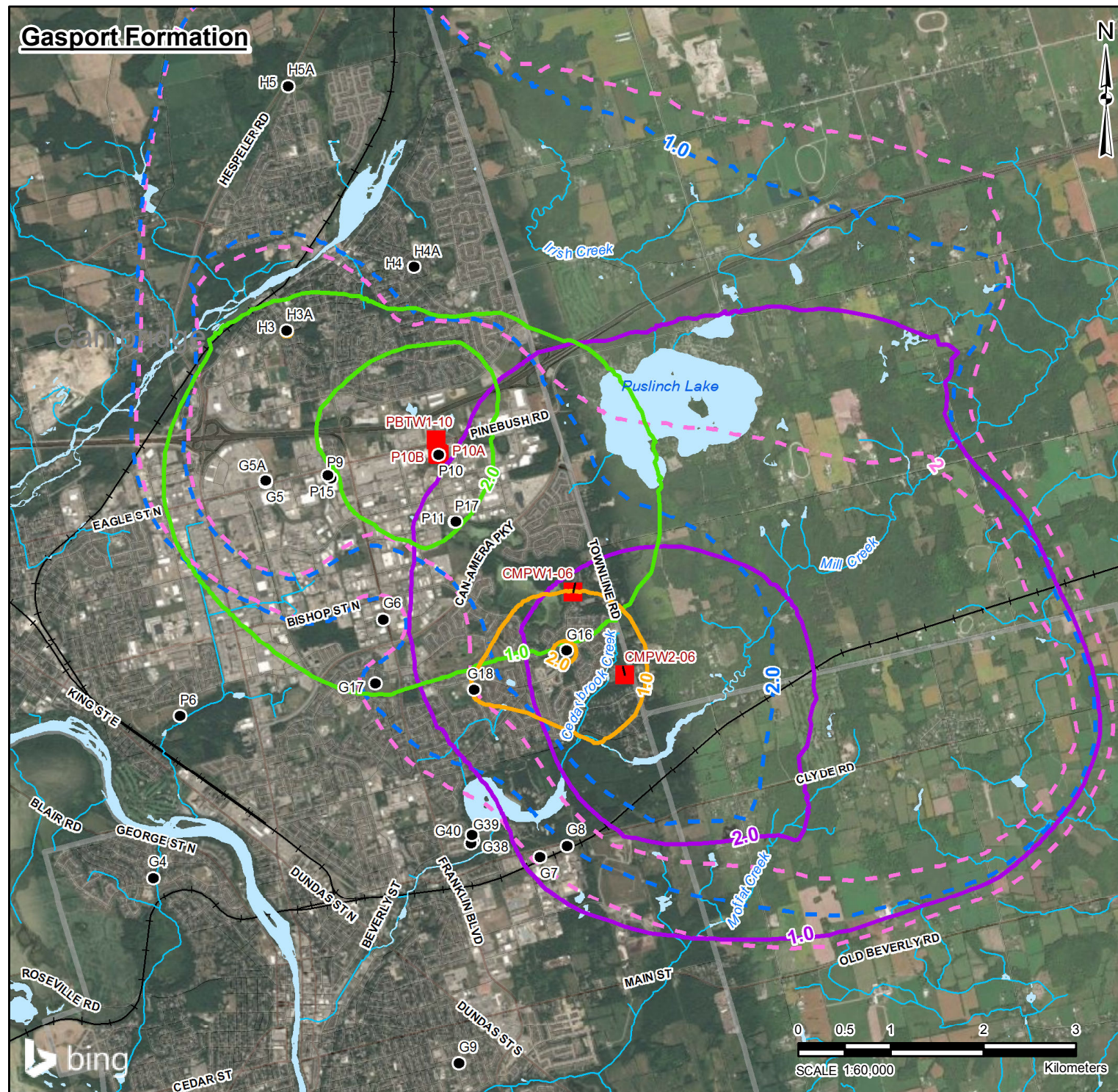
LEGEND

- Municipal Supply Well
- Scenario 1
- Scenario 2
- Scenario 3
- Test Production Wells
- Waterbody
- Watercourse
- +— Railway

REFERENCE

Base Data - MNR LIO obtained 2016
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources and Forestry, © Queens Printer 2016
Datum: NAD 83 Projection: UTM Zone 17N

PROJECT	CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT			
TITLE	STEADY STATE SIMULATIONS - EXTENT OF DRAWDOWN			
 Golder Associates Mississauga, Ontario	PROJECT No. 05-1112-010		SCALE AS SHOWN	REV. 0.0
	DESIGN	PR	2 Feb. 2017	FIGURE: 34
	GIS	PR	2 Feb. 2017	
	CHECK	JLH	2 Feb. 2017	
	REVIEW	JAP	2 Feb. 2017	



LEGEND

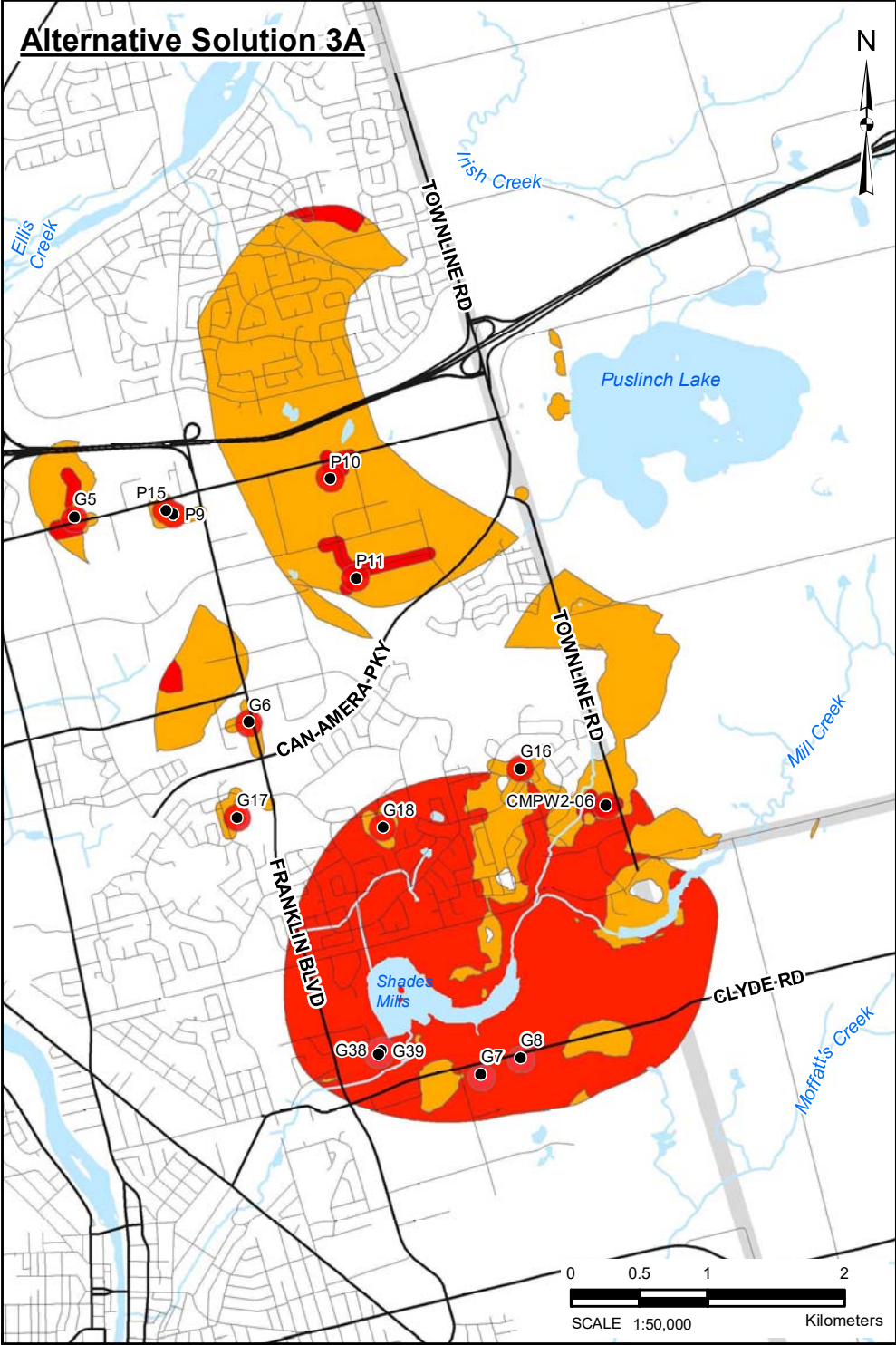
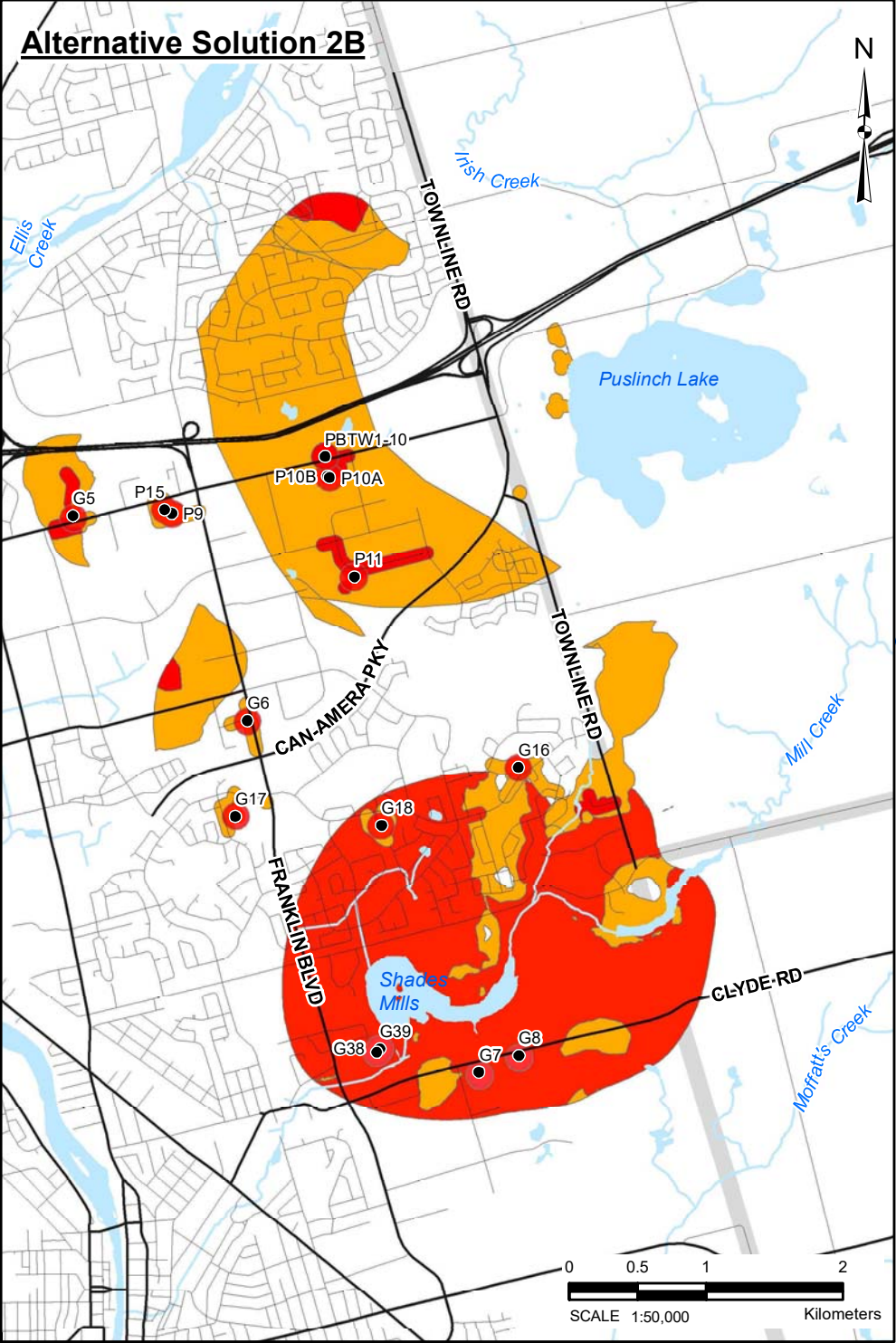
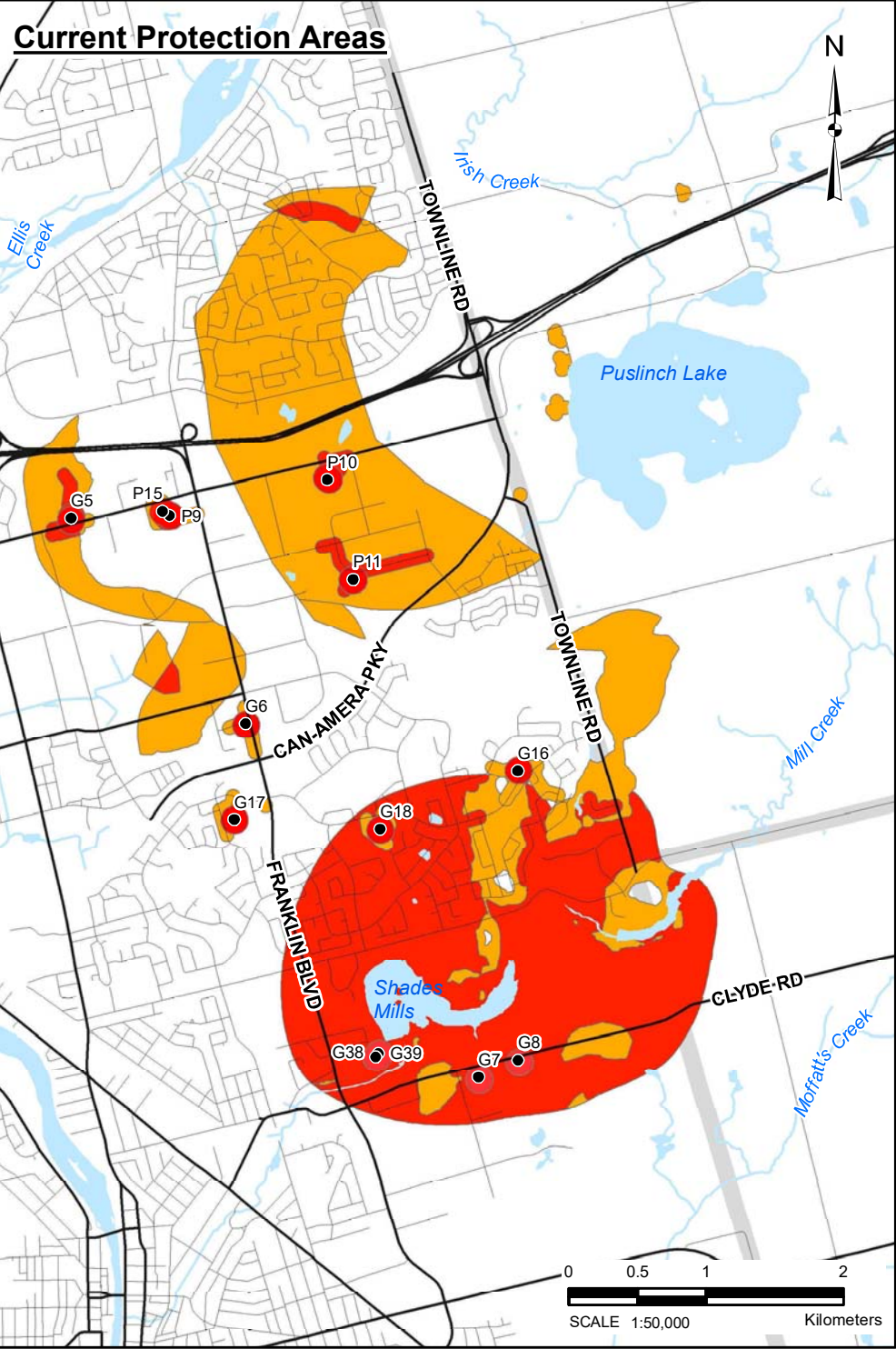
- Municipal Supply Well
 ■ Test Production Wells
 — Scenario 1
 — Scenario 2
 — Scenario 3
 - - Scenario A
 - - Scenario B
 Waterbody
 Watercourse
 Railway

REFERENCE

Base Data - MNRF LIO obtained 2016
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Datum: NAD 83 Projection: UTM Zone 17N

PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT	
TITLE		TRANSIENT SIMULATIONS – EXTENT OF DRAWDOWN	
 Golder Associates Mississauga, Ontario	PROJECT No. 05-1112-010		SCALE AS SHOWN
	DESIGN	PR	2 Feb. 2017
	GIS	PR	18 Apr. 2017
	CHECK	JLH	18 Apr. 2017
	REVIEW	JAP	18 Apr. 2017
			FIGURE: 37

G:\Projects\200505-1112-010_IUS_Groundwater_Waterloo\GISMX\Drafts\Cambridge\Natural_Environment_Report\Fig38_SourceWaterProtectionAreas.mxd



LEGEND

- Municipal Supply Well
- Watercourse
- Waterbody

Areas Where:
- Chemical handling including fuel, certain industrial chemicals and waste will require spill containment and response.

- Salting of parking lots will be required in accordance with right time/right place/right amount principles.

Areas Where:
- Handling of certain industrial chemicals and wastes will require spill containment and response.

REFERENCE

Base Data - MNRF LIO obtained 2016, ROW 2017
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Datum: NAD 83 Projection: UTM Zone 17N

PROJECT		CAMBRIDGE EAST WATER SUPPLY CLASS ENVIRONMENTAL ASSESSMENT			
TITLE		SOURCE WATER PROTECTION AREAS			
 Golder Associates Mississauga, Ontario		PROJECT No. 05-1112-010		SCALE AS SHOWN	REV. 0.0
		DESIGN	PR	2 Feb. 2017	
		GIS	PR	21 Aug. 2018	
		CHECK	JLH	21 Aug. 2018	
		REVIEW	JAP	21 Aug. 2018	

FIGURE: 38

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Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444

