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19.0 CITY OF GUELPH AND TOWNSHIP OF GUELPH/ERAMOSA TIER 3 WATER BUDGET AND RISK ASSESSMENT

This section describes the Tier Three Water Budget and Risk Assessment completed for the municipal drinking water systems of the City of Guelph and the Township of Guelph / Eramosa (GGET Tier 3 Assessment; **Map 19-1**). This project was undertaken to evaluate the current and future sustainability of the water supply wells and surface water intake, and to identify potential threats to the drinking water supplies from a quantity perspective.

The GGET Tier 3 Assessment was initiated in 2008 for the City of Guelph as a pilot project as one of the first Tier 3 Assessments in the Province. The project included the:

- physical characterization of the groundwater and surface water systems,
- hydrogeologic field work, including drilling of deep bedrock monitoring wells, to address gaps in the conceptual understanding,
- the development and calibration of numerical modelling tools that are founded on the physical characterization, and
- the application of those tools to assess the risk to the municipal supply wells and intake.

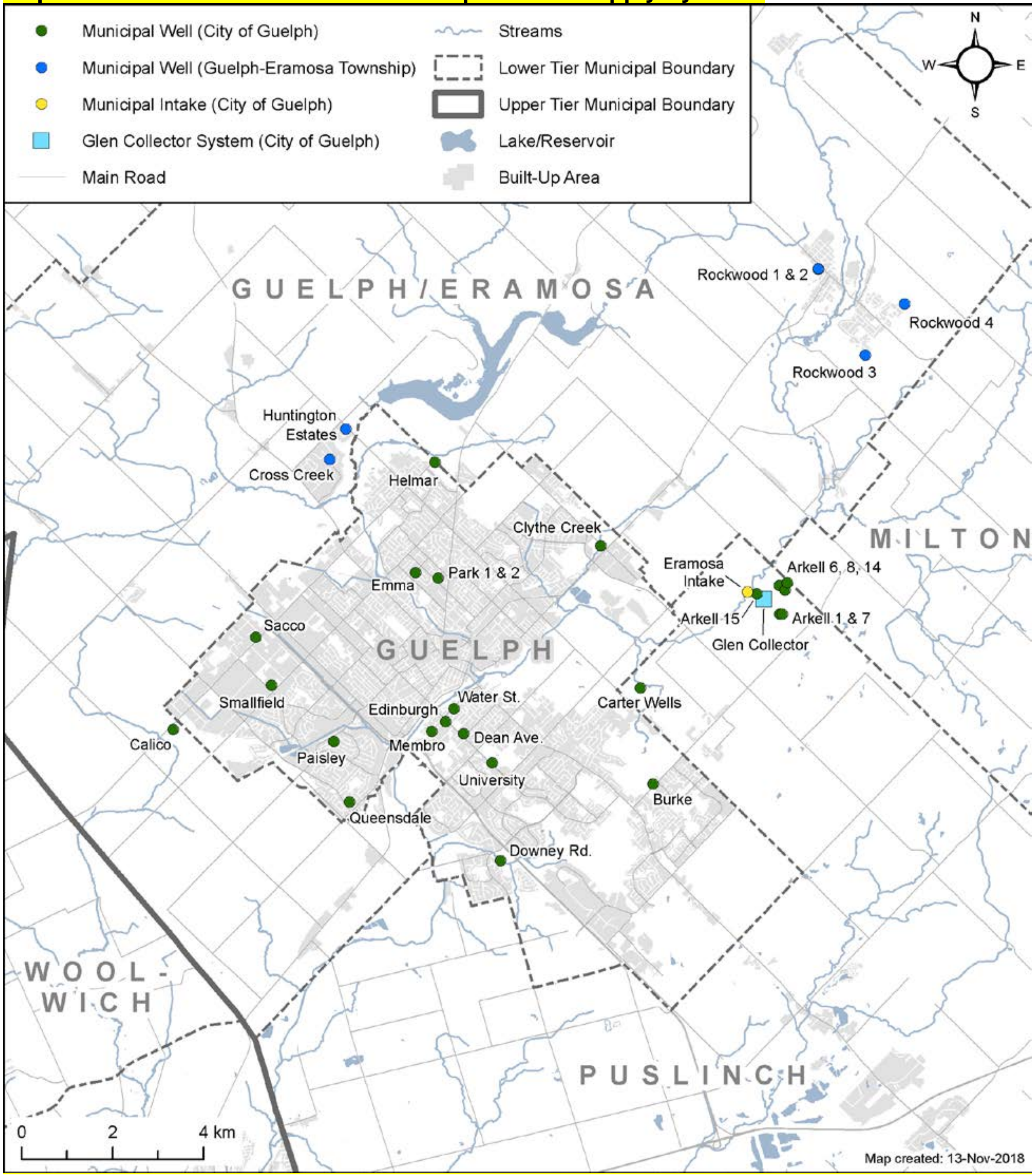
The GGET Tier 3 Assessment was finalized in 2017 and during the 9 year study period, the Tier 3 Assessment was expanded to include:

- the municipal supply wells of Rockwood and Hamilton Drive in the Township of Guelph/Eramosa, which included additional physical characterization, and refinement and calibration of the numerical groundwater flow model
- additional conceptual and numerical model updates in the areas of the Dolime Quarry and Aberfoyle to leverage the availability of additional data in these areas, and
- additional conceptual and numerical model updates to ensure consistency with the Tier 3 Assessment being simultaneously completed for the Regional Municipality of Waterloo and where there was overlap between numerical models and delineated vulnerable areas.

19.1 Background

The Ontario Ministry of Environment and Climate Change (MOECC) released a set of Technical Rules (MOECC, 2016) that require Tier 3 Assessments be completed in subwatersheds that have a *Moderate* or *Significant* water quantity stress in areas that supply municipal drinking water. A Tier Two Assessment was completed for the Grand River Watershed in 2009 (AquaResource 2009a, 2009b), which identified subwatersheds and groundwater assessment areas that contain municipal water supply systems that had an elevated (*Moderate* or *Significant*) potential for hydrologic stress from a surface water or groundwater perspective. This included the Upper Eramosa River Subwatershed and the Upper Speed River Assessment Area, which were classified in the Tier Two Assessment as having a *Moderate* stress level from a surface water and groundwater perspective, respectively. The municipal water supplies for the City of Guelph, as well as Rockwood and Hamilton Drive in the Township of Guelph/Eramosa (**Map 19-1**), were contained within these areas and were therefore required to undertake a Tier 3 Assessment.

Map 19-1: Tier 3 Assessment Municipal Water Supply Systems



19.2 Study Area

The Study Area (**Map 19-2**) was selected to encompass the entire hydrogeological system that influences the municipal water supply wells. The Study Area encompasses the City of Guelph, the Townships of Puslinch and Guelph/Eramosa, and also portions of Wellington County, Dufferin County, the regional municipalities of Waterloo and Halton, and the City of Hamilton. The Study Area is bounded to the west by the Grand River, a natural groundwater flow boundary condition, and to the east by the Niagara Escarpment.

19.3 Groundwater and Surface Water Characterization

The bulk of the Study Area (**Map 19-2**) lies within the west-central portion of the Grand River Watershed. Subwatersheds of the Credit River Watershed drain the land to the northeast along the eastern boundary of the Study Area, and subwatersheds of the Halton and Hamilton Conservation Authority jurisdictions lie to the southeast. Surface water features such as rivers, streams, lakes, and wetlands affect shallow groundwater flow and are an important part of understanding groundwater-surface water interactions.

19.3.1 Topography and Surface Water Features

Ground surface topography (**Map 19-3**) varies from a high of about 500 m above sea level (asl) on the crest of the Orangeville Moraine in the north, to a low of approximately 220 m asl in the southeast, south of the Niagara Escarpment. The topography is characterized by deep river valleys that have eroded into the landscape, and Quaternary landform features including the northeast to southwest trending Moraines (i.e., Orangeville, Breslau, Paris, Galt, and Moffat); the Eskers (i.e., Guelph, Ariss, and Eramosa); and northwest to southeast trending drumlins.

Immediately surrounding the Rockwood and Hamilton Drive areas of the Township of Guelph/Eramosa and the City of Guelph are the Speed River, Eramosa River, and Mill Creek subwatersheds. In addition to rivers and creeks, there are several large recreation and flood control reservoirs. These include Belwood Lake Reservoir located in the northwest portion of the Study Area, and Guelph Lake Reservoir within the Township of Guelph/Eramosa, north of Hamilton Drive and the City of Guelph. In the Region of Halton to the southeast, the Mountsberg Reservoir lies south of Highway 401, and in the southern part of the Study Area, the Valens Reservoir lies along the east side of the Grand River Watershed boundary. The only natural lake found in the Study Area is Puslinch Lake, a kettle lake found south of Highway 401 in the Cambridge area.

19.3.2 Geology and Hydrogeology

Bedrock Geology

The Paleozoic bedrock stratigraphy consists of sedimentary Silurian-aged dolostones, shales, limestones, and associated interbedded sedimentary bedrock formations that dip regionally to the southwest. The uppermost bedrock formations, as delineated in the conceptual model, are illustrated on **Map 19-4**. Bedrock outcrops at surface along the river valleys in Elora, Fergus, Rockwood, Eden Mills, and Guelph and in the eastern portion of the Study Area in Flamborough and Acton.

Table 19-1 lists the bedrock formations found in the Study Area from youngest (top) to oldest (bottom), as well as a brief description of the bedrock lithologies and the estimated thicknesses of the units. The naming of bedrock formations was revised over the course of the GGET Tier 3 Assessment (Brunton 2009); therefore, for clarity the bedrock stratigraphy for the past (Golder 2006) and revised names of bedrock units are both listed (**Table 19-1**).

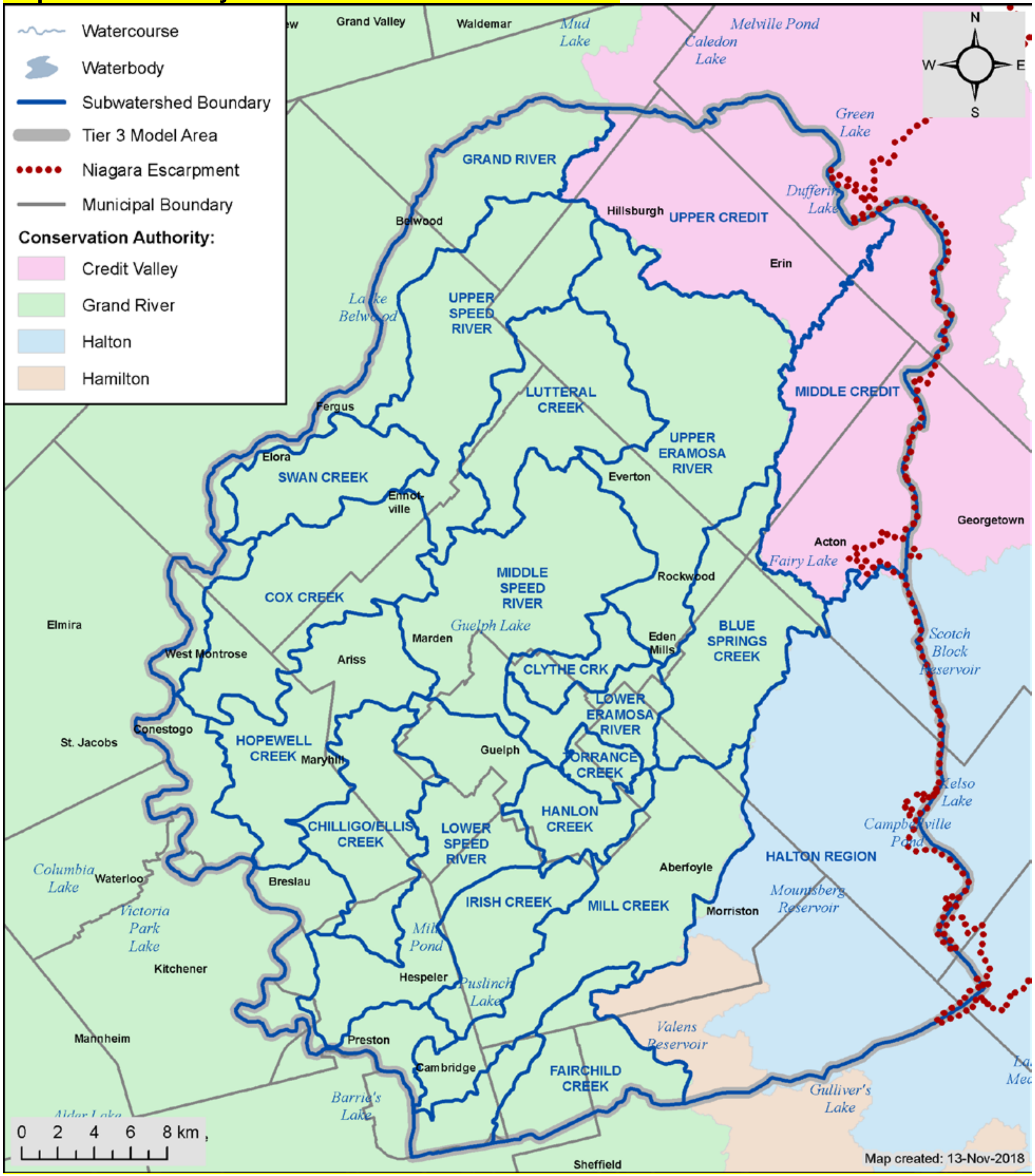
Table 19-1: Bedrock Formations in the Study Area

Previous Conceptualization[1]		Revised Conceptualization[2]		Lithology Description	Approximate Thickness (m)
Formation	**Member**	**Formation**	**Member**		
Guelph Formation		Guelph	Hanlon	Cream-coloured, medium to thick bedded, fossiliferous grainstones, wackestones, and reefal complexes	Up to 62
			Wellington		
Amabel	Eramosa	Eramosa	Stone Road	Cream-coloured, coarsely crystalline dolostone	
			Reformatory Quarry	Light brown-cream, pseudo-nodular, thick bedded, coarsely crystalline dolostone	5 to 50
			Vinemount	Grey-black, thinly bedded, fine crystalline dolostone with shaley beds	2 to 10
	Wiarton / Colpoy / Lions Head	Goat Island	Ancaster / Niagara Falls	Ancaster-Grey, cherty, fine crystalline dolostone; Niagara Falls-Fine crystalline, cross-laminated crinoidal grainstone with small reef mounds	5 to 40
		Gasport	Gothic Hill	Cross-bedded crinoidal grainstone-packstone with reef mounds and shell beds	25 to 70
		Rochester / Irondequoit / Rockway / Merritton Formation		Rochester- Calcareous shale with carbonate interbeds; Irondequoit- Thick-medium bedded crinoidal limestone; Rockway- Fine crystalline argillaceous dolostone with shaley partings; Merritton- Fine crystalline dolostone with shaley partings	3 to 5
Cabot Head / Reynales Formation		Cabot Head Formation		Non-calcareous shale interbedded with sandstone and limestone	10 to 39

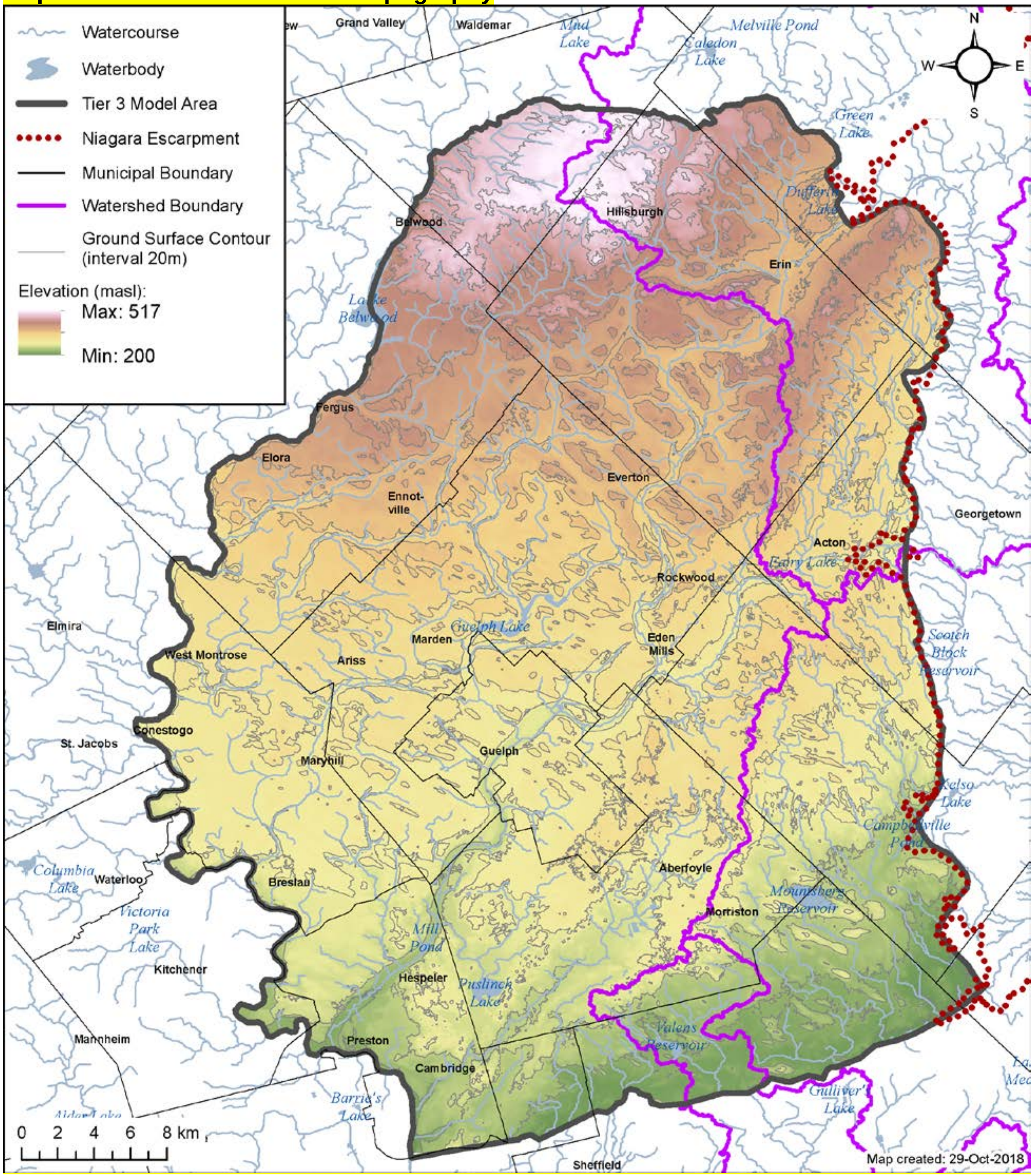
Sources:
[1] Golder (2006)
[2] After Brunton (2009)

Overall, the bedrock formations described above form a thick (40 m to 100 m) and extensive groundwater aquifer system. The cities of Guelph and Cambridge, Rockwood, and the communities within the Township of Centre Wellington rely on the Gasport and Guelph Formation units for the majority of their potable drinking water supplies. The Gasport Formation represents the most common aquifer used for groundwater supply within the Study Area due to the transmissive nature of the limestone unit. The Eramosa Formation overlies the Gasport Formation, and the Vinemount Member in particular consists of mud-rich dolostone beds that act as an aquitard limiting the lateral and vertical flow of water through the unit. The Vinemount Member is extensive and acts as an important aquitard throughout the Study Area although it was interpreted to have been removed by erosion in some areas (e.g., an area near Rockwood, between Blue Springs Creek and the Eramosa River).

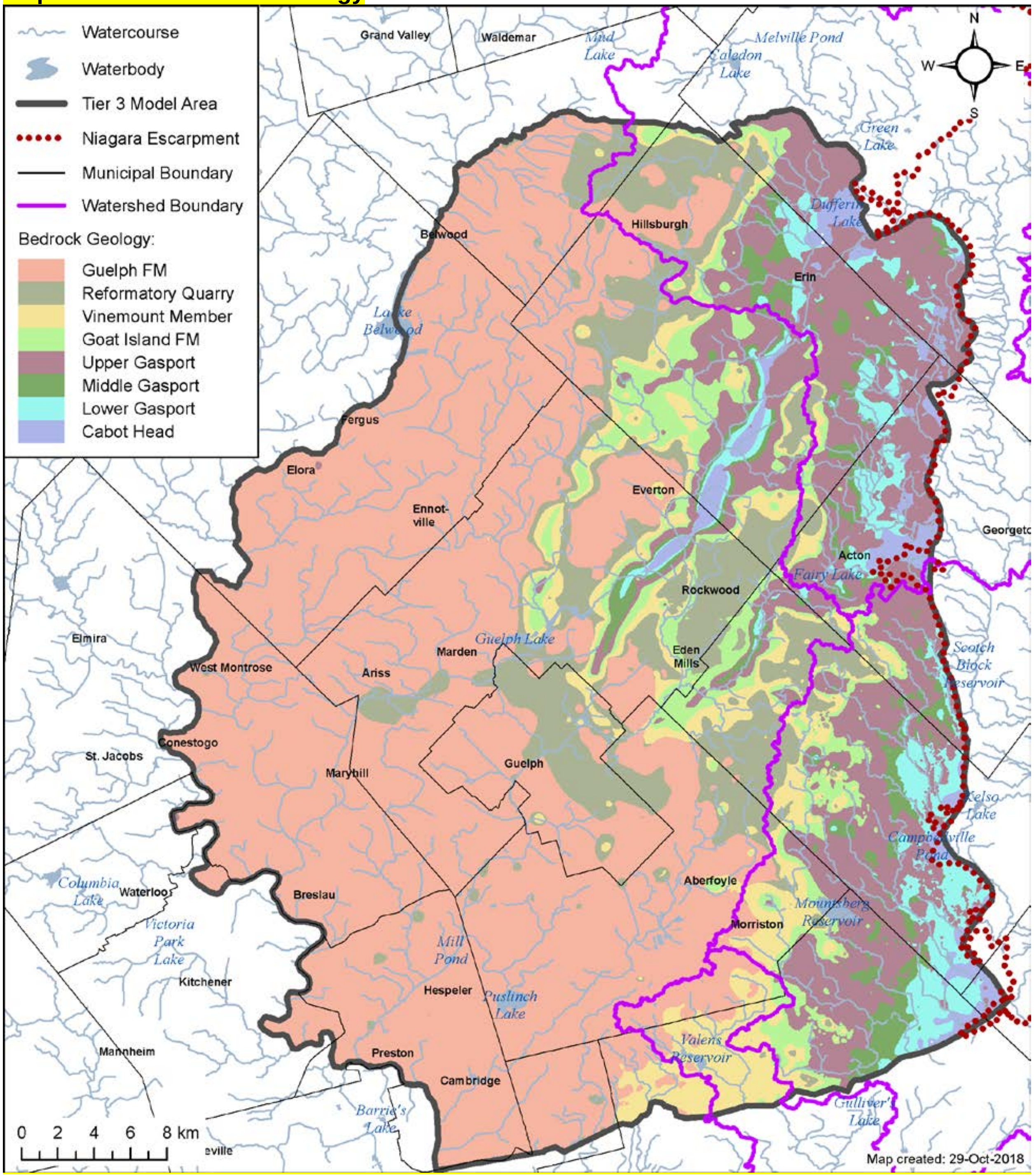
Map 19-2: Study Area and Surface Water Features



Map 19-3: Ground Surface Topography



Map 19-4: Bedrock Geology



Physiography and Quaternary Geology

The major physiographic regions of the Study Area (**Map 19-5**) include the following:

- **Guelph Drumlin Field**. Located in the west and central area, the Guelph Drumlin Field is characterized by till drumlins fringed by gravel terraces and separated by swampy valleys (Chapman and Putnam 1984; Appendix A).
- **Horseshoes Moraines**. This region covers the central eastern portion of the Study Area, east of the Guelph Drumlin Field and is characterized by moraines (e.g., Galt and Paris moraines) and old spillways with broad gravel and sand terraces and swampy floors (Chapman and Putnam 1984).
- **Flamborough Plain**. The Flamborough Plain encompasses a small area in the southeast. It consists of limestone bedrock with little or no overburden cover and a few drumlins (Chapman and Putnam 1984). The area is poorly drained and large swampy areas are common.
- **Waterloo Sandhills (Waterloo Moraine)**. The Waterloo Sandhills encompass a small area in the southwest. The surface is composed of well-drained sandy hills, some of them being ridges of sandy till while others are kames or kame moraines, with outwash sands occupying the intervening hollows (Chapman and Putnam 1984).
- **Hillsburgh Sandhills / Orangeville Moraine**. The most elevated region is the Orangeville Moraine, (Hillsburgh Sandhills; Chapman and Putnam 1984). This region encompasses the northern portion of the Study Area and is characterized as having rough topography primarily with sandy materials.

The surficial geology (**Map 19-5**) was mapped by various individuals including Karrow (1987, 1968) and compiled by the Ontario Geological Survey (2003). Surficial deposits are predominantly a combination of sand and gravel glaciofluvial and ice-contact stratified deposits, and silty to sandy tills that were laid down during glacial advance from the Lake Ontario basin. Overburden thickness ranges from 0 m, where bedrock outcrops in incised river valleys and along the eastern Study Area boundary, to approximately 80 m in buried bedrock valleys and on the Orangeville Moraine.

In addition to till units, other landform features such as moraines, eskers, drumlins, and kames are present. The Paris, Galt, Moffat, and Orangeville Moraines have been mapped and are composed primarily of till, but also contain associated ice-contact stratified drift, outwash deposits, or a mixture of the three on the flanks of the moraine. Eskers and kames mapped within the area are composed of sand and gravel, and drumlins of the Guelph Drumlin Field are generally composed of tills or a mixture of till and stratified sediment (Barnett 1992). Glaciofluvial deposits such as the Aberfoyle outwash channel along Mill Creek are composed of sand and gravel and are generally found in low-lying areas on the surfaces of the till plain or bedrock.

Hydrogeological Conceptual Model

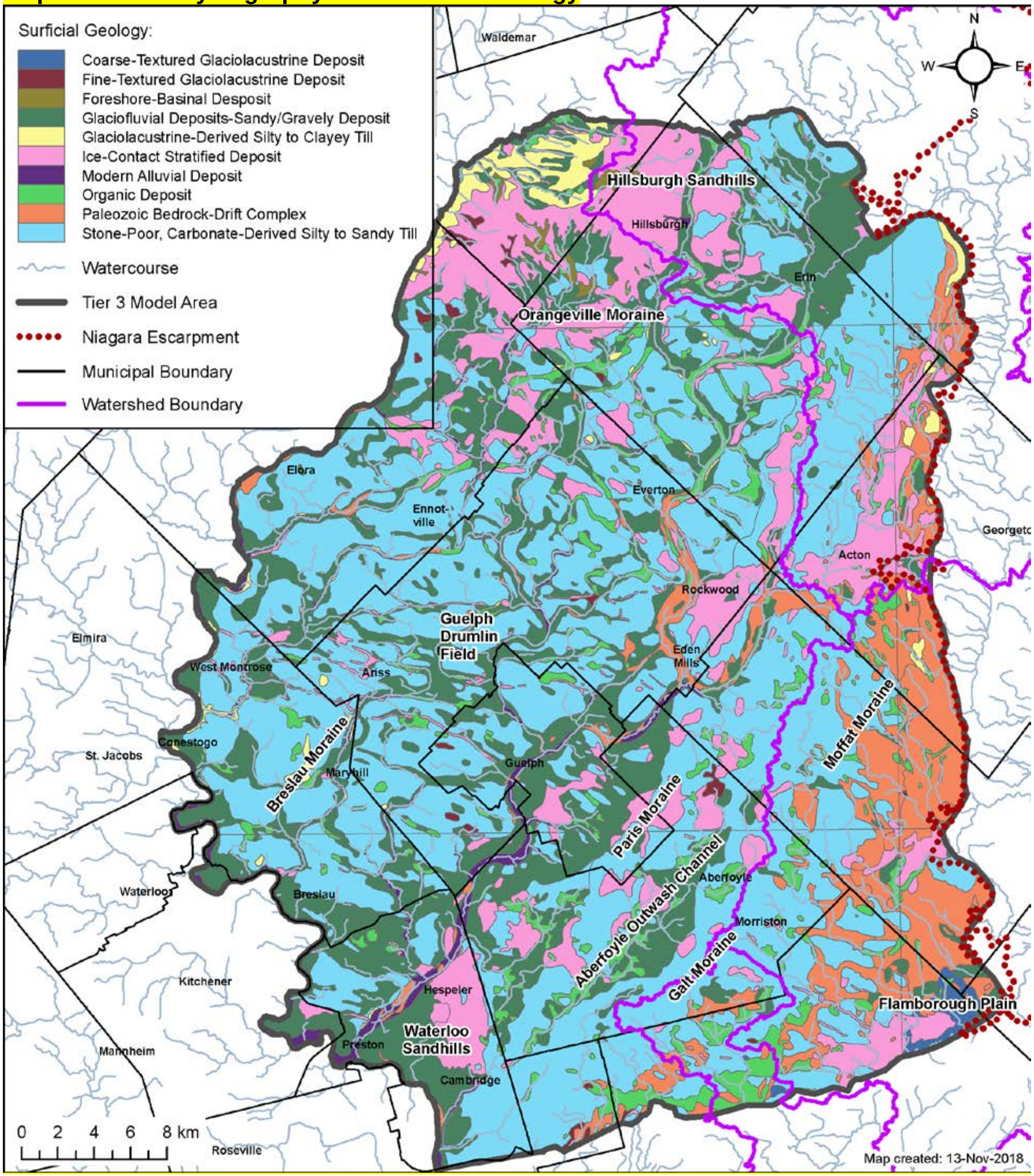
Hydrostratigraphy refers to the structure of geologic units in relation to the flow of groundwater through those units. Hydrostratigraphic units are derived from stratigraphic units based on their general hydrogeologic properties and are the fundamental "building blocks" of conceptual and numerical groundwater flow models. The delineation of hydrostratigraphic units based on geologic descriptions from cored borehole logs can be a relatively rough approximation; however, the available information is used in conjunction with regional and local scale interpretations of the spatial distribution of geologic units. Units composed primarily of coarse-grained overburden materials (e.g., sands and gravels) or highly transmissive bedrock units are referred to as aquifers and units composed of lower permeability overburden (e.g., clay or fine tills) or poorly transmissive bedrock units are referred to as aquitards.

Table 19-2 lists and describes the 11 hydrostratigraphic units identified within the Study Area: 2 overburden units, 8 bedrock units, and 1 overburden/bedrock unit. The GGET Tier 3 Assessment groundwater flow model was developed to reflect these hydrostratigraphic units. While not listed in **Table 19-1** or **Table 19-2**, the Salina Formation (an interbedded dolostone unit with interbeds of shale, gypsum, and anhydrite) is present in the Study Area in the westernmost areas of Cambridge, and inferred to be present in the Breslau area (Golder 2009). This formation is younger than the Guelph Formation but is not explicitly represented in the conceptual or numerical models due to its limited spatial extent. The Salina Formation was grouped together with the Guelph Formation, as the two units are interpreted to have similar hydrogeologic properties where the unit is present.

Table 19-2: Hydrostratigraphic Units in the Study Area

Hydrostratigraphic Unit	Geological Description	Specific Geologic Units
Upper Sand and Gravel Aquifer (Overburden A)	Outwash sand and gravel deposits and glacial tills	Coarse sand and gravel, Wentworth Till, Port Stanley Till, Fine-grained Sediments
Lower Till Aquitard (Overburden B)	Glacial tills (dense, sandy, silty) occasionally interbedded with discontinuous lenses of coarse sands/gravels	Wentworth Till, Port Stanley Till, Catfish Creek Till
Contact Zone Aquifer	Fractured bedrock and overlying basal unconsolidated deposits	Coarse, granular deposits overlying weathered bedrock
Bedrock Aquifer	Medium to thick bedded fossiliferous dolostone	Guelph Formation (incl. Eramosa Formation - Stone Road Member)
Bedrock Aquifer/Aquitard	Thickly bedded, coarsely crystalline dolostone	Eramosa Formation - Reformatory Quarry Member
Bedrock Aquitard	Thinly, shaley bedded, fine crystalline dolostone	Eramosa Formation - Vinemount Member
Bedrock Aquifer/Aquitard	Chert-rich, fine crystalline dolostone and cross-laminated crinoidal grainstone	Goat Island Formation
Bedrock Aquifer	Cross-bedded grainstone-packstone with sequences of reef mound and coquina lithofacies	Upper Gasport Formation
Bedrock Aquifer (High Permeability)	Cross-bedded grainstone-packstone with sequences of reef mound and coquina lithofacies; Highly transmissive with secondary porosity (cavities, vugs, fractures)	Middle Gasport Formation
Bedrock Aquifer	Cross-bedded grainstone-packstone with sequences of reef mound and coquina lithofacies	Lower Gasport Formation (incl. Roch./Iron./Rock./Merri. Fms.)
Bedrock Aquitard	Shale interbedded with sandstone and limestone	Cabot Head Formation

Map 19-5: Physiography and Surficial Geology



19.3.3 Groundwater and Surface Water Interactions

Interaction(s) between surface waters and groundwater are generalized as follows:

- Precipitation infiltrates through shallow unsaturated soil, recharging the underlying aquifers.
- Surface water bodies and wetlands gain water from the discharging of shallow and deep groundwater.
- Surface water bodies and wetlands loose water to the underlying groundwater flow system by outflow.

The following sections describe the hydrological and ecological system characterization completed to support the assessment of groundwater and surface water interactions.

Groundwater Recharge

Groundwater recharge is a hydrologic process where water moves downward from the ground surface to the underlying groundwater flow system. This process usually occurs in the unsaturated zone below plant roots and is often expressed as a flux to the water table surface. Recharge is the residual portion of precipitation left over after the subtraction of water returned to the atmosphere by evapotranspiration or transferred to stream channels by overland flow and interflow (above the groundwater system). The amount of groundwater recharge is influenced by the permeability of the ground surface; land use or vegetation; the depth, hydraulic conductivity and soil water storage characteristics of surficial overburden layers; and slope of the topography (if extremely steep).

Calibrated surface water or streamflow-generation models are used to generate recharge estimates for the groundwater flow model. Recharge estimates for the Study Area were estimated using three surface water models for the three watershed areas present within the Study Area (i.e., Grand River Watershed, Credit River Watershed, and the watersheds under the jurisdiction of the Halton and Hamilton Region Conservation Authorities, respectively). Estimated recharge rates ranged from a low of 0 mm/year where groundwater discharges to some wetlands, to a high of 533 mm/year on hummocky regions associated with the Paris and Galt moraines that are underlain by sand and gravel.

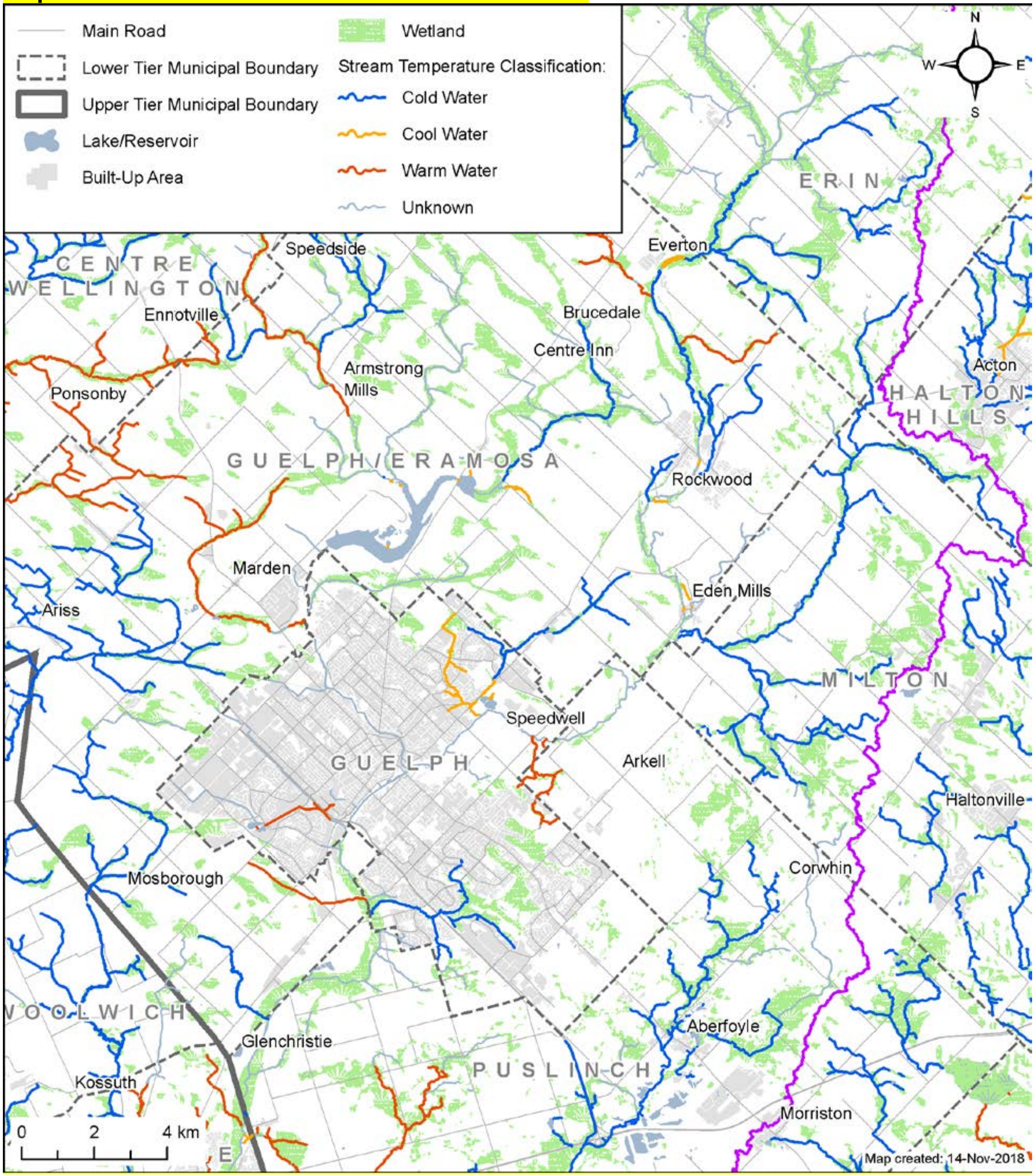
Groundwater Discharge and Ecological Resources

Groundwater discharge is important to sustaining cold water and cool water fisheries as the upwelling areas are critical for fisheries spawning and also for maintaining a moderate temperature and flow in creeks and streams. Cold water fisheries have been mapped by the province (MNR 2013) and Grand River Conservation Authority (GRCA; GRCA 2013) in several stream reaches within the Study Area, particularly in the headwaters of the Grand River (**Map 19-6**). Cold-water fish communities are mapped in all of or parts of the Eramosa River, Blue Springs Creek, Clythe Creek, Hanlon Creek, Speed River, Ellis Creek, Mill Creek, and Hopewell Creek. Due to the presence of online ponds, some of the stream designations have changed from cold-water streams, to cool or warm-water designations.

Provincially Significant Wetlands (PSWs) are identified by the province and mapped by a science-based ranking system. PSWs within the City of Guelph include Hanlon Creek Swamp, Torrance Creek Swamp, Clythe Creek Wetland, and Guelph-Northeast Complex. The latter is east of Hamilton Drive and extends into the Township of Guelph/Eramosa. PSWs within the Eramosa River subwatershed include the Eramosa/Blue Springs Creek Wetland (lying mostly in the Township of Guelph/Eramosa near and south of Rockwood), Knatchbull Wetland, Arkell-Corwhin Wetland, Torrance Creek/Hamilton Corners Wetland and Clythe Creek Wetland.

PSWs within the Speed River subwatershed include Hanlon Creek Swamp and Halls Pond Wetland. PSWs within the Mill Creek subwatershed include Mill Creek Wetland and Arkell-Corwhin Bog.

Map 19-6: Stream Classifications and Wetlands



19.3.4 Tier 3 Field Programs

Climate and Surface Water Monitoring

Climate and surface water monitoring is conducted at numerous locations within the Study Area. The Meteorological Service of Canada and the GRCA maintain climate stations, while the Water Survey of Canada (WSC) and the GRCA record streamflow at surface water flow monitoring stations.

A baseflow monitoring program was completed as part of the GGET Tier 3 Assessment (Matrix 2017) to supplement streamflow data collected by the WSC and GRCA. Baseflow is defined as the portion of streamflow that is derived from a combination of groundwater discharge and delayed flow from natural and artificial storage at surface. The purpose of the baseflow monitoring program was to provide estimates of groundwater discharge to enhance the understanding of the groundwater and surface water interaction, and support the calibration of the groundwater flow model. Surface water flow measurements were collected at 32 locations along various streams/rivers. Flow measurements were scheduled following a minimum of four consecutive days without observed precipitation to minimize the proportion of runoff in streamflow. Baseflow was estimated using the “velocity-area” method utilizing an impeller or electromagnetic flow meter and measuring cross-sectional stream areas, and “timed volume flow method” utilizing a bucket and stopwatch. Concurrent with the baseflow measurements, surface water quality measurements such as pH, conductivity, and temperature were collected to provide a snapshot of water quality conditions.

Hydrogeologic Field Program

In addition to the City of Guelph’s ongoing groundwater monitoring program, an advanced hydrogeologic drilling and monitoring program was carried out as part of the GGET Tier 3 Assessment. The purpose of the subsurface monitoring program was to obtain high-quality geologic and hydrogeologic information and to establish a network of deep monitoring wells outside the Guelph city limits. Eleven deep boreholes were drilled, logged, and investigated using geophysical methods to provide a complete stratigraphic profile from ground surface to the Cabot Head Formation. Hydraulic testing of the boreholes was completed utilizing packer tests, short term pumping tests, and a new technique known as FLUTe hydraulic conductivity profiling. Once borehole testing was completed, multi-level monitoring wells were installed at 11 sites utilizing a mix of traditional equipment and custom multi-level technology supplied by Westbay® Instruments, Solinst®, and FLUTe.

Water levels were monitored in all wells using a combination of automated data logging pressure transducers and manual measurements.

Water quality samples were collected in the field from four of the multi-level wells and analyzed for dissolved metals, nutrients, anions, and dissolved organic carbon.

In addition to ongoing monitoring and the Tier 3 Assessment monitoring program, aquifer response tests were carried out as part of hydrogeological investigations to support the ongoing management of municipal groundwater resources.

19.3.5 Land Use and Land Use Change

The Technical Rules (MOECC 2016) identify reductions in groundwater recharge as potential Water Quantity Threats. The GGET Tier 3 Assessment considered the impact of existing and future land development (as defined in the Official Plans) on groundwater recharge and municipal water sources. The assessment of the impact arising from land use development reflected changes in imperviousness but did not include an assessment of low impact development or other measures that may act to enhance groundwater recharge.

Existing land use representative of conditions in 2008 was determined using land use mapping provided by the Township of Guelph/Eramosa, the City of Guelph within the city, the Region of Waterloo for the Cambridge area, and by various municipalities for the surrounding rural areas. Satellite imagery from 2007 and 2008 was examined to confirm that planned development lands were not already developed in 2008.

Future land use was mapped to reflect the current Official Plans for County of Wellington, the City of Guelph, and the adjacent municipalities.

Future recharge reductions were identified by highlighting land areas where land use is forecasted to change from those designated in the current land use and those designated on the Official Plans. The change in imperviousness from the current to the future land use type was estimated based on typical impervious values for land use classifications.

19.3.6 Water Demand

With some exceptions such as firefighting and livestock watering, any persons or organizations withdrawing water at a rate greater than 50,000 L/day must apply for, and be granted, a Permit to Take Water (PTTW) from the Ministry of Environment, Conservation and Parks. This includes water takings permitted for municipal supply purposes, such as water obtained by GGET to meet their municipal water supply needs. A total of 31 municipal wells, a surface water intake that feeds water to an artificial recharge system, and a shallow groundwater collector are permitted as part of the PTTW program.

Municipal Water Supply Systems

City of Guelph

The City of Guelph relies mainly on groundwater for its municipal supply demands; it obtains its water from 23 municipal wells and the Glen Collector, a shallow infiltration gallery (**Table 19-3** and **Map 19-1**). Not all of the wells are currently in use where there is a lack of demand or due to water quality concerns. All of these wells, with the exception of the Edinburgh well which is currently not in operation, were used in the Tier 3 Assessment to meet future demands.

Table 19-3 City of Guelph Water Supply Wells

Quadrant	Well Name	Easting (NAD83)	Northing (NAD83)	Depth (m)	Formation Screened	Permitted Rate[1] (m^3/day)
Southeast	Glen Collector	Not applicable	Not applicable	Not applicable	Overburden	25,000
	Arkell 1	567944	4822434	20.1	Overburden/ Contact Zone	3,273
	Arkell 14	568096	4823126	40.5	Upper to Middle Gasport	9,504[3]
	Arkell 15	567440	4822878	30.5	Upper to Lower Gasport	9,504[3]
	Arkell 6	567934	4823061	41.2	Upper to Middle	9,504[3]

					Gasport	
	Arkell 7	567993	4822436	43.3	Upper to Middle Gasport	9,504[3]
	Arkell 8	568055	4822971	42.1	Upper to Middle Gasport	9,504[3]
	Burke	565157	4818701	79.6	Guelph to Middle Gasport	6,546
	Carter Wells	564870	4820808	20.7	Guelph	6,547
Southwest	Dean Ave.	560997	4819805	57.2	Upper to Middle Gasport	2,300
	Downey Rd.	561798	4817015	73.8	Upper to Middle Gasport	5,237
	Edinburgh[2]	560594	4820066	69.5	Upper to Middle Gasport	3,000
	Membro	560293	4819861	73.2	Upper to Middle Gasport	6,050
	University	561613	4819168	64.3	Upper Gasport	3,300
	Water Street	560773	4820356	60.0	Upper to Middle Gasport	3,400
Northeast	Clythe Creek[2]	564031	4823927	58.9	Reformatory Quarry to Lower Gasport	5,237
	Emma	559931	4823351	46.0	Upper to Middle Gasport	3,100
	Helmar	560357	4825777	79.6	Upper to Middle Gasport	3,273
	Park 1 and 2	560430	4823231	57.0	Upper to Middle Gasport	10,300
Northwest	Paisley	558126	4819636	80.2	Upper to Middle Gasport	3,200
	Calico	554602	4819900	64.0	Upper Gasport	5,237
	Queensdale	558482	4818297	74.4	Guelph to Upper Gasport	5,237
	Sacco[2]	556416	4821929	95.7	Guelph to Middle Gasport	1,640
	Smallfield[2]	556748	4820866	102.1	Guelph to Lower Gasport	1,964

Notes:
[1]Effective as of 2013
[2]Not currently operating
[3]Each well is individually permitted up to 9,504 m^3/day; however, the combined permitted rate is 28,800 m^3/day

The City of Guelph also sources a portion of its water supply from the Eramosa River intake, where surface water is pumped and then directed into an artificial recharge system that provides shallow groundwater to the Glen Collector. The Eramosa River intake is allowed to operate between April 15 and November 15 of each year according to the conditions of its PTTW.

Township of Guelph/Eramosa

The residents of Rockwood and Hamilton Drive rely entirely on the groundwater wells listed in **Table 19-4** for their potable water supplies (**Map 19-1**). In Rockwood, this water is pumped from three existing bedrock wells. A fourth bedrock well was recently constructed by the Township of

Guelph/Eramosa and now has a PTTW. The township expects to add this well to the Rockwood water supply system in the near future. In Hamilton Drive, municipal water is pumped from two bedrock wells completed in the same bedrock aquifer as Rockwood and the City of Guelph. These wells are located just north of the City's municipal boundary.

Table 19-4: Rockwood and Hamilton Drive Water Supply Wells

Location	Well Name	Easting (NAD83)	Northing (NAD83)	Formation Screened	Permitted Rate (m^3/day)
Rockwood	Rockwood Wells 1 & 2	568785	4830026	Middle Gasport	1,965
	Rockwood Well 3	569833	4828156	Middle Gasport	1,310
	Rockwood Well 4	570671	4829240	Upper to Middle Gasport	1,310
Hamilton Drive	Cross Creek	558038	4825840	Upper to Middle Gasport	812
	Huntington	558405	4826512	Upper to Middle Gasport	916

Other Municipalities

The study area includes additional municipal water supply wells not directly evaluated in the GGET Tier 3 Assessment (**Map 19-7**). Adjacent municipalities that use groundwater for supply include Maryhill, Fergus/Elora, Acton, and Cambridge. In addition, there are a number of communal water supplies in the area including Mini-Lakes, Irish Creek Estates, McClintock's Trailer Park, and Mill Creek Camping and Country Club.

The Region of Halton operates municipal wells within the Credit River Watershed, and these wells were studied within the Halton Hills Tier 3 Assessment (AECOM and AquaResource 2014). The Region of Waterloo operates municipal drinking water wells within the City of Cambridge, and these wells were studied as part of the Region of Waterloo Tier 3 Assessment (Matrix and SSPA 2014).

Municipal Water Demand

As part of the Tier 3 Assessment, the Allocated and Planned quantities of water need to be estimated for each existing and planned groundwater well or intake. The Allocated rates are estimated based on the Existing and Committed municipal water demands. The Planned quantity of water is the amount of water that meets the criteria of a planned system (MOE 2013).

As outlined in the Technical Rules (MOECC 2016) and Technical Guidance Memorandum (MOE 2013), the Existing, Committed, and Planned demand for this assessment needed to be established. The definitions of these terms, as outlined in the revised Technical Guidance Memorandum, are below.

- Existing demand refers to the amount of water currently taken from each well/intake during the Study Period. For this Tier 3 Assessment, the Existing demand was estimated as the average annual pumping during 2008 for the City of Guelph and 2009 to 2010 for Rockwood and Hamilton Drive.
- Committed demand is an amount greater than the Existing demand that is necessary to meet the needs of the approved Settlement Area within the Official Plan. The portion of this amount that is within the Current Lawful PTTW Taking is part of the Allocated rates.

Any amount greater than the Current Lawful PTTW Taking is considered part of the Planned quantity of water.

- Planned demand from an Existing well/intake is a specific additional amount of water required to meet the projected growth identified within a Master Plan or Class Environmental Assessment (EA), but is not already linked to growth within an Official Plan.
- Planned demand from a new Planned Well/Intake is a specific amount of water required to meet the projected growth identified within a Master Plan or Class EA but is not already linked to growth within an Official Plan.

For the municipal supply systems in the City of Guelph, Rockwood, and Hamilton Drive, none of the demands associated with these wells are considered to be Planned demand; thus, there was no Planned quantity of water to consider.

Existing Water Demand – City of Guelph

The Existing water demand for the City of Guelph in this Tier 3 Assessment was represented as the average annual pumping rates from the 2008 calendar year, approximately 47,700 m^3/day (**Table 19-5**). This compares to a maximum total permitted amount of approximately 132,600 m^3/day. The sustainable capacity of the system, as evaluated by the Water Supply Master Plan (Earth Tech et al. 2006) and the City of Guelph Water Services Division, is approximately 89,900 m^3/day (**Table 19-5**). Maximum daily demands can be much higher than average daily demands due to outdoor water use, industrial use, or other municipal water uses. The estimated sustainable capacity may be affected by climatic conditions (i.e., drought), well interference, and well efficiency such that the total capacity may not be always available.

Table 19-5: Allocated Rates - City of Guelph

Well Name	**Rates (m^3/day)**				
	Existing Demand (Average 2008)	**Maximum Permitted Pumping**	**Estimated Capacity[1]**	**Allocated (2031) Demand**	
				Average Annual Conditions	**Drought Conditions**
Arkell 1	730	3,273	2,000	1,400	1,400
Arkell 14	0	28,800[3]	28,800	3,300	4,400
Arkell 15	0			3,300	4,400
Arkell 6	3,774			4,900	5,300
Arkell 7	3,689			4,900	5,300
Arkell 8	3,694			4,900	4,900
Burke	5,385	6,546	6,500	6,000	6,300
Calico	748	5,237	1,100	1,100	1,100
Carter Wells	2,004	6,547	5,500	4,000	4,400
Clythe Creek	0	5,237	3,000[2]	2,200	2,200
Dean Ave.	1,215	2,300	1,500	1,500	1,500
Downey Rd.	3,940	5,237	5,100	5,100	5,200
Edinburgh[4]	0	3,000	0	0	0
Emma	2,273	3,100	2,800	2,100	2,400
Helmar	500	3,273	1,500	1,100	1,200
Membro	3,036	6,050	6,000	4,200	4,300
Paisley	762	3,200	1,400	800	1,000

Table 19-5: Allocated Rates - City of Guelph					
Well Name	**Rates (m^3/day)**				
	Existing Demand (Average 2008)	**Maximum Permitted Pumping**	**Estimated Capacity[1]**	**Allocated (2031) Demand**	
				Average Annual Conditions	**Drought Conditions**
Park 1 & 2	5,897	10,300	8,000	6,400	6,900
Queensdale	702	5,237	2,000	2,000	2,000
Sacco	0	1,640	1,150[2]	1,150	1,150
Smallfield	0	1,964	1,400[2]	1,400	1,400
University	1,648	3,300	2,500	2,500	2,500
Water Street	1,184	3,400	2,700	2,300	2,400
Total (Wells)	**41,181**	**107,641**	**82,950**	**66,550**	**71,550**
Glen Collector	6,500	25,000	6,900	6,900	1,892
Total	**47,681**	**132,641**	**89,850**	**73,450**	**73,442**

Notes:
[1] Estimated Sustainable Rates from Water Supply Master Plan (Earth Tech, et al. 2006), up to the maximum permitted rate
[2] Sustainable Rate estimated by City of Guelph Water Services Division
[3] Each well is individually permitted up to 9,504 m3/day; however, the combined permitted rate is 28,800 m^3/day.
[4] The City of Guelph is not planning on using Edinburgh due to water quality concerns.

Allocated Rates - City of Guelph

According to the Technical Guidance Memorandum (MOE 2013), the Committed demand represents the additional quantity of water over and above the Existing demand that is required to meet the future water demand in the City of Guelph. The Allocated rate represents the sum of the Existing and Committed demands.

The City of Guelph finalized its *Water Conservation and Efficiency Strategy Update* in 2009 (WC&ES; RMSi 2009), updating the City of Guelph's long-term water demand estimates. With a forecasted 2031 population of 175,000 residents, the WC&ES estimated an average-day water demand (without considering additional water conservation efforts) to be 71,595 m^3/day. This demand represents the target total Allocated demand for the City of Guelph's water supply system and a target Committed increase in demand of 23,914 m^3/day (50% increase) over Existing demand (47,681 m^3/day).

Two different sets of Allocated rates were developed for individual wells and the Glen Collector to accommodate the following:

1) Allocated rates under average annual conditions, and

2) Allocated rates under low water (drought) conditions.

Table 19-5 summarizes the Allocated rates under average annual and drought conditions for each well and the Glen Collector. The methods used to establish the rates for each well are described in detail in the Tier 3 Assessment report (Matrix 2017). Values of safe additional available drawdown were also calculated for each municipal well. Safe additional available drawdown is defined as the additional depth that water within a pumping well could fall relative to current pumping conditions and still maintain that well's Allocated rate. This calculation is also discussed in detail in Appendix F of Matrix (2017).

The sum of the Allocated rates for the City of Guelph's drinking water system is 73,450 m^3/day. This rate exceeds the target total Allocated rate provided by the WC&ES for the average-day water demand in 2031 by 1,855 m^3/day (compare to 71,595 m^3/day) and adds a level of conservatism to the final Allocated demand estimate under average conditions. This is a Committed increase in demand of 25,769 m^3/day (54% increase) over Existing demand (47,681 m^3/day).

The second set of Allocated rates under drought conditions were required to compensate for a decrease in discharge from the Glen Collector during low water periods. During drought conditions, the City may have to pump less from the Eramosa intake resulting in a lower yield from the Glen Collector. The total Allocated demand for the water supply system under drought conditions is 73,442 m^3/day and conservatively exceeds the 2031 target provided by WC&ES (compare to 71,595 m^3/day). This represents a Committed increase in demand by 25,761 m^3/day (54% increase) over Existing demand (47,681 m^3/day).

The estimates of Allocated demand under average and drought conditions (**Table 19-5**) represent the average-day demands and are less than the estimated capacity of the total system (89,850 m^3/day) and maximum permitted taking (132,641 m^3/day). Maximum-day water demands (due to increased outdoor water use, industrial use, or other municipal water uses) may be 34% higher (i.e., peaking factor of 1.34) than the estimated average-day water demand amount, according to projections in the WC&ES (RMSi 2009). It is important to consider these short-term extremes in pumping when assessing a well's ability to accommodate additional demand. To assess whether the water supply system can operate at maximum-day (peaking) requirements under target Allocated conditions, the following formula is used:

$$\textit{Maximum-Day Demand} = \textit{Target Allocated Rate} \times \textit{Peaking Factor}$$
$$\textit{Maximum-Day Demand} = 71{,}595\ m^3/day \times 1.34 = 95{,}937\ m^3/day$$

This maximum-day demand is less than the total permitted capacity (132,641 m^3/day) of the water supply system, but greater than the estimated capacity (89,850 m^3/day) of the system. It is anticipated that the deficit (6,087 m^3/day) between the estimated system capacity and maximum-day demand would be offset during these short periods by the volume of water available in storage. The City of Guelph's drinking water system has the capacity to store 59,200 m^3 of water using five underground storage reservoirs and three water towers (City of Guelph 2014), providing additional supplies for almost 10 days during these periods. Further, the rates that comprise the estimated system capacity represent the sustainable rates over the long term. Over a short-time frame, during periods of extreme water use, the wells would be able to accommodate an even greater demand close to their permitted rates.

Water Demand - Rockwood and Hamilton Drive

Existing municipal demand for the Rockwood and Hamilton Drive wells was calculated based on the average demand from 2009 and 2010 for each municipal well (except Rockwood Well 4, which has not yet started production) (**Table 19-6**). This period was selected to align with available municipal water level data and the reference data used to estimate population growth forecasts for the two communities. The use of a 2-year period avoids misrepresenting short-term trends in demand in these small systems that might occur over a single year but are not representative of average conditions (e.g., a well shutting down for maintenance).

Table 19-6: Municipal Water Demand - Rockwood and Hamilton Drive

Location	Municipal Well	Aquifer	Rates (m^3/day)		
			Maximum Permitted	**Existing Demand (Average 2009 to 2010)**	**Allocated Rate (Average and Drought)**
Rockwood	Rockwood Well 1	Middle Gasport	1,965	283	396
	Rockwood Well 2	Middle Gasport		262	367
	Rockwood Well 3	Upper to Middle Gasport	1,310	422	572
	Rockwood Well 4	Upper to Middle Gasport	1,310	n/a	572
Hamilton Drive	Cross Creek	Upper to Middle Gasport	812	87	90
	Huntington	Upper to Middle Gasport	916	92	95
Total			6,313	1,146	2,092
n/a - rate not available. Rockwood Well 4 is not yet in operation.					

None of the demands associated with these wells are considered to be Planned demand, therefore, the Allocated water supply needs of both communities was solely based on the increase in pumping related to the Committed demands. The Allocated rates estimated for Hamilton Drive were determined from a water use study completed for the Township of Guelph/Eramosa (Watson and Associates Economists Ltd. 2011). These estimates represent the Committed demand forecasted until the year 2020, which is an increase in demand relative to that observed in 2010. The Allocated rates estimated for Rockwood were determined using water use forecasts that would be required to reach the build-out of Rockwood in 2026 (Burnside 2013).

The increase in pumping from Existing to Allocated rate was estimated to be 6 m^3/day (an increase of 3%) for the Hamilton Drive water supply system, and 940 m^3/day (an increase of 97%) for the Rockwood water supply system.

Table 19-6 summarizes the final set of Allocated rates (Existing plus Committed demands) for each well in Rockwood and Hamilton Drive. These rates were used for both average and drought conditions in the Risk Assessment scenarios. In Rockwood, the total Allocated rate was estimated to be 1,907 m^3/day, whereas that for Hamilton Drive was estimated to be 185 m^3/day. For both systems, the total Allocated rate is less than the total permitted rate.

For the purposes of the Risk Assessment scenarios, the increase in pumping associated with the Committed increase was distributed equally amongst the two wells in Hamilton Drive (i.e., 3 m^3/day/well). For Rockwood, the total Allocated rate was distributed according to recommendations provided by Burnside (2015), with 40% distributed to Rockwood wells 1 and 2 combined, 30% to Rockwood Well 3, and 30% to Rockwood Well 4. Safe additional available drawdown was calculated for each well to define the additional depth that the water level can decline in each well and still maintain each well's Allocated rate. This calculation is discussed in detail in Appendix F of Matrix (2017).

Non-Municipal Water Demand

In addition to municipal water takers, there are also a number of large non-municipal permitted water takers within the Study Area (**Map 19-7**). Consumptive groundwater demands for permitted, non-municipal water users were estimated using either reported pumping rates or estimated pumping rates in the absence of reported actual rates. Pumping rates were estimated by combining the permitted rate with the months of expected active pumping and a consumptive factor. Monthly water use estimates were derived by identifying the months where water taking is expected to be active, based on the purpose of that taking, and combining this with the maximum permitted withdrawal and the maximum permitted days per year as specified in the PTTW database. Consumptive factors (Kinkead Consulting and AquaResource 2009) are subsequently applied to determine the proportion of pumped water that is not returned to the original source in a reasonable amount of time. Groundwater takings are typically 100% consumptive (i.e., consumptive factor of 1), since it is seldom returned to the groundwater system, but rather discharged to surface water systems. Other water uses, such as for irrigation, have a consumptive factor less than 1, where some water would percolate beneath the evaporative root zone and return to the groundwater system.

Table 19-7 summarizes the permitted rates and estimated consumptive demands by water use sector for the whole Study Area. The maximum permitted use totals 351,032 m^3/day while the estimated consumptive water demand for the Study Area is 63,092 m^3/day.

Table 19-7: Summary of Permitted Rates and Consumptive Demands by Water Use Sector for Study Area

Specific Purpose	Max Permitted Rate (m^3/day)	Percentage of Total Permitted Takings	Consumptive Demand (m^3/day)	Difference (Max Permitted - Consumptive) (m^3/day)
Pits and Quarries	191,710	52%	20,356	171,353
Aggregate Washing	82,716	22%	3,124	79,592
Aquaculture	16,564	5%	15,072	1,492
Golf Course Irrigation	17,913	5%	3,068	14,845
Communal	10,893	3%	5,512	5,381
Other - Industrial	10,246	3%	4,472	5,774
Other - Agricultural	5,894	2%	610	5,284
Field and Pasture Crops	5,475	1%	415	5,060
Bottled Water	5,057	1%	3,093	1,964
Sod Farm	4,696	1%	239	4,457
Groundwater	2,183	1%	1,853	330
Other - Water Supply	2,178	1%	267	1,911
Fish Ponds	1,962	<1%	2	1,960
Campgrounds	1,785	<1%	448	1,337
Food Processing	1,760	<1%	311	1,449
Other - Remediation	1,483	<1%	960	523
Mall / Business	1,316	<1%	1,316	0
Other - Dewatering	899	<1%	213	686
Heat Pumps	885	<1%	821	64
Nursery	328	<1%	46	282
Brewing and Soft Drinks	553	<1%	0	553

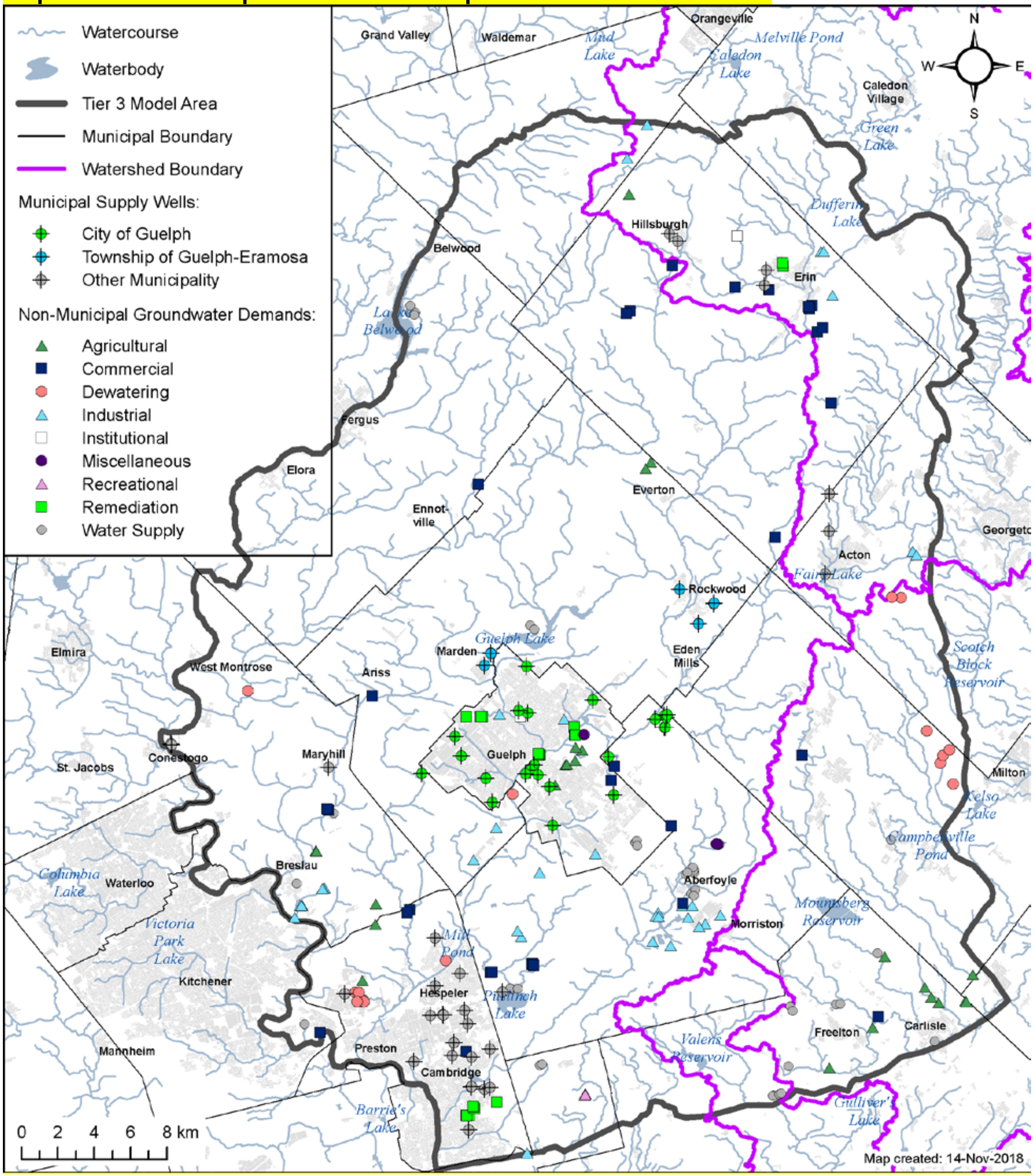
Table 19-7: Summary of Permitted Rates and Consumptive Demands by Water Use Sector for Study Area

Specific Purpose	Max Permitted Rate (m^3/day)	Percentage of Total Permitted Takings	Consumptive Demand (m^3/day)	Difference (Max Permitted - Consumptive) (m^3/day)
Manufacturing	529	<1%	529	0
Other - Institutional	137	<1%	137	0
Cooling Water	110	<1%	53	57
Construction	100	<1%	8	92
Schools	100	<1%	83	17
Other - Commercial	64	<1%	52	12
Irrigation	60	<1%	32	28
Total	351,032	100%	63,092	303,011

Note:
Permits were current as of the Study Period and obtained from the *Permit to Take Water Database* (MOE 2008)

Matrix (2017) provides additional details for each of the permits, as well as the methods used to represent the non-municipal water takings in the models.

Map 19-7: Municipal and Non-Municipal Groundwater Demands



19.4 Risk Assessment

19.4.1 Model Development

As part of the Tier 3 Assessment, surface water and groundwater modelling tools were developed to help assess the sustainability of the municipal water sources. The models were developed based on a detailed characterization of the groundwater and surface water systems, and they were refined around wells to a level supported by available data. The models were calibrated to represent typical operating conditions under average (steady-state) and variable (transient) pumping conditions.

Surface Water Flow Model

The Grand River Tier 3 surface water model has been developed and refined over the last few decades. The surface water model simulates runoff, recharge, evapotranspiration, and streamflow across the Grand River Watershed. The model was built using the GAWSER (Guelph All-Weather Sequential-Events Runoff) code and was originally developed for flood forecasting. More recently, the GAWSER model was adapted for continuous hydrological simulation and applied to estimate groundwater recharge rates across the Grand River Watershed. This continuous model was applied by the GRCA as part of the Grand River Tier Two Water Budget (AquaResource 2009a) and Subwatershed Stress Assessment (AquaResource 2009b).

The GAWSER model was refined within the GGET Tier 3 Assessment Study Area (Matrix, 2017) to better represent current land use and groundwater recharge rates, and to improve the simulated streamflow in the Eramosa River (supplying the City of Guelph's surface water intake). The GAWSER model refinements focused on improving the calibration of the Mill Creek Subwatershed, Upper Speed River Watershed, Eramosa River Watershed, and Blue Springs Creek Subwatershed. The land areas associated with these drainage areas represent a large proportion of the Study Area and are key groundwater recharge areas associated with the municipal drinking water supplies. The results suggested the average and transient groundwater recharge rates estimated by the GAWSER model are reasonable over the long-term and suitable for use in the Tier 3 Assessment.

Groundwater Flow Model

To assess the potential impacts of increased municipal groundwater demands on other water uses, a detailed conceptual model of the geologic, hydrogeologic, and hydrologic systems was developed with particular focus on the areas surrounding municipal well fields. A FEFLOW (Diersch 2006) groundwater model was constructed to represent the interaction between the groundwater system and the surface water system. This model updated and refined the previous approach followed in the Guelph-Puslinch groundwater flow model (Golder 2006), with several key advancements:

- The geographic coverage of the groundwater flow model was extended to include the Grand River to the west and the Niagara Escarpment to the east. Extending the model boundary westward to the Grand River provides a natural boundary condition for groundwater flow. The Niagara Escarpment represents the physical location where the Gasport Formation bedrock aquifer, the main aquifer supplying the municipal water supplies, pinches out.
- The conceptual model was based on detailed interpretation of geologic units at numerous high-quality boreholes located throughout the Study Area. This is in contrast to the bedrock conceptual model used in the Guelph-Puslinch groundwater flow model which was conceptually simplified by representing layers with constant thickness.

- Since the development of the Guelph-Puslinch model, the City of Guelph has installed several groundwater monitoring wells screened in discrete hydrogeologic units. These wells measure groundwater elevations and vertical gradients throughout the city on a continuous basis and provided an improved and enhanced understanding of the bedrock flow system.
- The Township of Guelph/Eramosa has conducted additional studies for the municipal systems in Rockwood that have improved the understanding of the bedrock system.
- The groundwater flow model was refined to include additional surface water features that were not previously represented in the Guelph-Puslinch Groundwater Flow Model.

Model calibration is a process whereby model parameters are adjusted within physically acceptable limits until the model simulations reflect actual measured conditions. The groundwater model was calibrated to long-term steady-state conditions and to transient conditions that included the simulation of a long-term pumping test (City of Guelph) and shorter-term tests (Rockwood and Aberfoyle). The groundwater flow model was calibrated to water level measurements from MOECC domestic water wells records, City of Guelph and Township of Guelph/Eramosa high-quality monitoring wells, and other high-quality wells that are part of other studies. The model was also calibrated to low streamflow targets estimated from baseflow observations and streamflow gauge data collected by the GRCA, WSC, and others at locations spread throughout the Study Area.

Calibration of the groundwater flow model relied on estimates of groundwater recharge across the landscape represented by the model. Groundwater recharge estimates used in the calibration of the model include the following:

- The Grand River Watershed GAWSER streamflow generation model (version 6.5, Schroeter & Associates 2004; AquaResource 2009a)
- The Credit River Watershed HSP-F model (AquaResource 2009c)
- Halton and Hamilton Region Conservation Authorities PRMS model (EarthFx 2009)

Additional information on the surface water and groundwater flow model development and calibration is provided in Matrix (2017).

19.4.2 Risk Assessment Results

The groundwater flow model was used to delineate the WHPA-Q (Groundwater Vulnerable Area) and IPZ-Q (Surface Water Vulnerable Area). These areas were delineated where the quantity of water available to municipal drinking water systems could be affected by other existing, new, or expanded water takings. Four WHPA-Qs were delineated surrounding the municipal wells for GGET (**Map 19-8**) and one IPZ-Q was delineated as the upstream contributing area for the Eramosa intake (**Map 19-9**).

A set of Risk Assessment scenarios was developed to represent the municipal Allocated rates and current and future land uses (as defined by the Official Plans). The calibrated groundwater flow model was used to estimate both the changes in water levels (drawdown) in the municipal supply aquifer and the impacts to groundwater discharge and baseflow under average and drought climate conditions.

The drawdown under each of the Risk Assessment scenarios was calculated and compared to the safe additional available drawdown at each municipal well. The drawdown at each well is calculated relative to the 2008 average pumped conditions (for the City of Guelph wells) and the interpreted low operating water levels (for the Hamilton Drive and Rockwood wells), and accounts for well losses at each municipal well. For the 10-year drought scenarios, the maximum drawdown over the entire drought simulation was examined. The model simulated drawdown was then compared to the safe additional available drawdown to identify municipal wells where there is a potential that the wells will be unable to pump at their Allocated rates.

The Queensdale Well was predicted to be unable to pump at its Allocated rate during average climate and drought conditions. As a result, the WHPA-Q that encompasses the Queensdale Well (WHPA-Q-A; **Map 19-8**) was assigned a *Significant* Risk Level. As the IPZ-Q and WHPA-Q-A are interconnected through the Glen Collector and the artificial recharge system that is supplied by the Eramosa River Intake, the IPZ-Q was also assigned a *Significant* Risk Level.

Simulated groundwater discharge reductions were examined for the average climate and increased demand scenario. There are six locations where baseflow is simulated to be reduced by 10% or more:

- Torrance Creek (41%)
- Chilligo/Ellis Creek at Wellington Road 32 (32%)
- Hanlon Creek South Tributary at Highway 6 (31%)
- Blue Springs Creek South Branch at 28th Side Road (27%)
- Hanlon Creek at Waterfowl Park (19%)
- Hanlon Creek at Highway 6 (11%)

As Chilligo/Ellis Creek, Blue Spring Creek, and Hanlon Creek are classified as cold-water streams and have simulated baseflow reductions of 10% or more, a Water Quantity Risk Level classification of *Moderate* should have been assigned to the WHPA-Q-A. However, due to the Queensdale Well's inability to pump at its Allocated rate, a Risk Level of *Significant* had already been assigned.

The Technical Rules state that an uncertainty assessment on the assignment of a Risk Level to the Groundwater (i.e., WHPA-Q) and Surface Water (i.e., IPZ-Q) Vulnerable Areas is required. If a Vulnerable Area is assigned a Risk Level of *Moderate* based on the scenarios assessed, the Risk Level should be assigned as *Significant* if an uncertainty analysis characterizes the uncertainty as *High* and a sensitivity analysis suggests that the Risk Level of the Vulnerable Area could be *Significant*. As WHPA-Q-A and the IPZ-Q were already assigned the highest possible Risk Level (i.e., *Significant*) based on predicted exceedance of the drawdown threshold at the Queensdale Well, an uncertainty analysis on predicted impacts to cold-water streams or PSWs could not increase the Risk Level any higher. However; an uncertainty analysis was still carried out to guide future efforts on increasing the certainty of model predictions.

The uncertainty with respect to the impacts on discharge to cold water streams and PSWs was found to be *High*; however, this uncertainty did not impact the Risk Level that was already designated as *Significant*.

There was a *High* level of uncertainty with respect to the predicted ability of Arkell Well 1 to pump at its Allocated rate under existing and future land uses during drought conditions. At the maximum predicted drawdown, it had limited available drawdown remaining in the well, about 0.1 m. Considering that Arkell Well 1 is screened within shallow overburden units and is highly influenced by recharge, which itself is a high source of uncertainty, it is concluded that this well may not be able to pump at the Allocated rate under drought conditions. If predicted drawdown at the Queensdale Well had not already triggered a *Significant* Risk Level, this *High* uncertainty in the predicted results at Arkell Well 1 would have triggered it.

The uncertainty with respect to the predicted drawdown at other municipal wells, including the Queensdale Well, is *Low*. This is due to the iterative refinements made to the hydrostratigraphic model of the groundwater flow system over a number of years and a numerical model that is well-calibrated to water levels measured at high-quality observation wells. The model results are also consistent with well capacity estimates based on traditional hydrogeology analytical techniques.

19.4.3 Significant Water Quantity Threats

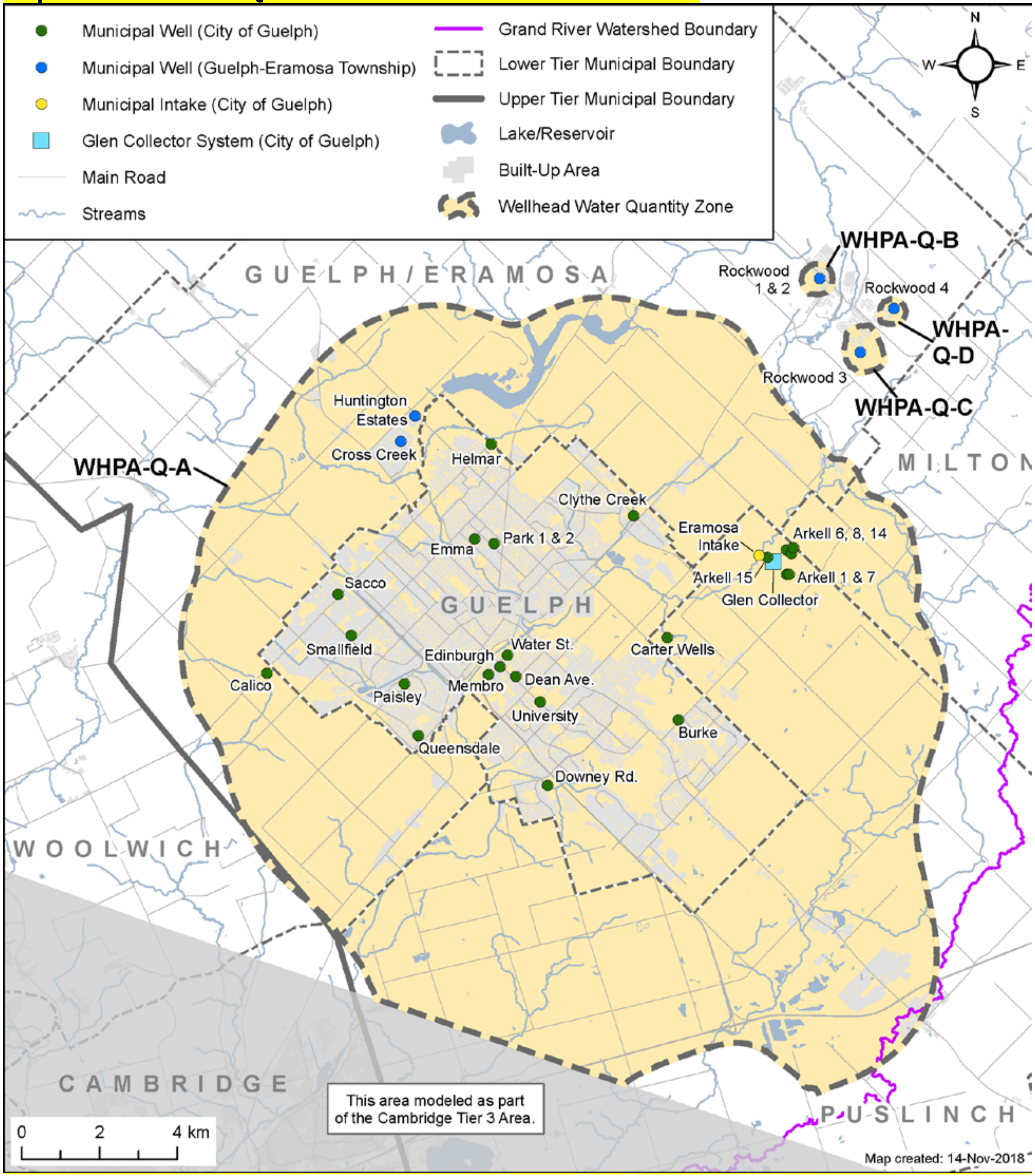
Under the source protection program, the Province identified 22 activities that are prescribed as drinking water threat activities. For water quantity vulnerable areas with a *Significant* Risk Level, all existing and new consumptive water takings located within the areas that draw water from within the WHPA-Q or the IPZ-Q or activities that reduce groundwater recharge are classified as Significant Threats. **Table 19-8** summarizes the Significant Threats identified within the WHPA-Q-A (**Map 19-10**) and IPZ-Q (**Map 19-11**). These consumptive takings and recharge reduction areas are classified as Significant Threats regardless of their location within the WHPA-Q. Municipal permitted water takings are classified as Significant Threats as increases in municipal pumping from a well may result in the water level in that same well to decline below its safe threshold. In total, there were 7,537 Significant consumptive taking threats and 17.4 km^2 of Significant recharge reduction threats identified within the WHPA-Q-A and IPZ-Q.

Table 19-8: Summary of Significant Water Quantity Threats

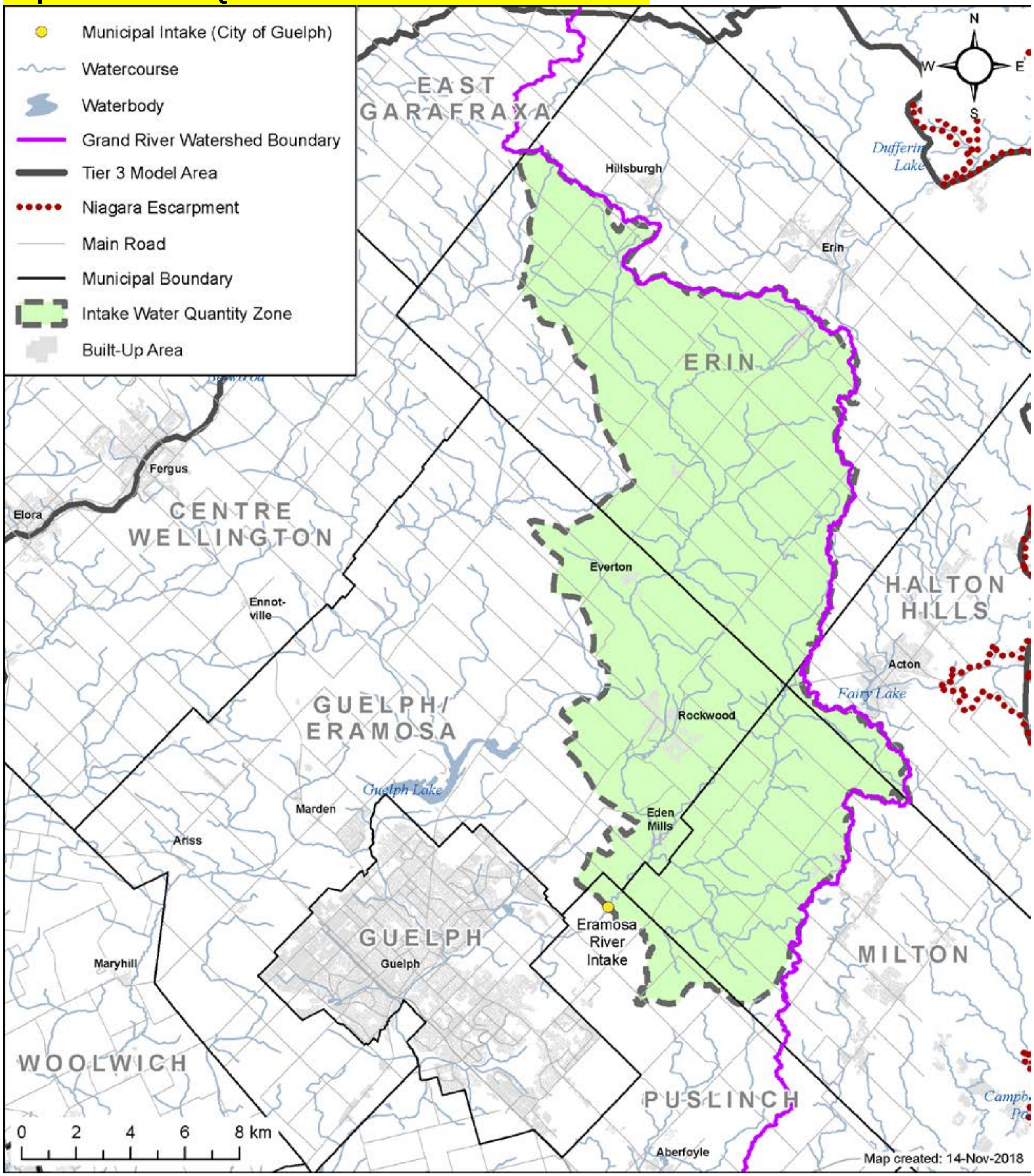
Threat Group	Vulnerable Area	
	WHPA-Q-A	IPZ-Q
Municipal	29	12
Non-municipal Permitted	71	13
Non-municipal, Non-permitted[1]	5,153	2,671
Total	5,253	2,696
Recharge Reduction[2]	16.3 km^2 (5.3% of Groundwater Vulnerable Area A)	1.0 km^2 (0.4% of Surface Water Vulnerable Area)
Total[3]	Total number of *Significant* threats identified within all Vulnerable Areas of the Water Quantity Risk Assessment	7,537[4]

Notes:
[1]Only domestic water wells recorded in the Water Well Information System database (MOE 2012) are included. These are exempt from permitting if they are taking less than 379,000 L/day.
[2]Recharge reduction threats are summarized by identifying the total area represented by Recharge Reduction Polygons and as a percentage of the total area of interest
[3]Total number of *Significant* threats does not include individual Recharge Reduction Polygons as those threats have been identified on a per-area basis.
[4]Total number of *Significant* threats identified within all Vulnerable Areas is not equal to the sum of *Significant* threats from each individual Vulnerable Area due to overlapping Vulnerable Areas where some threats lie within both the WHPA-Q-A and IPZ-Q.

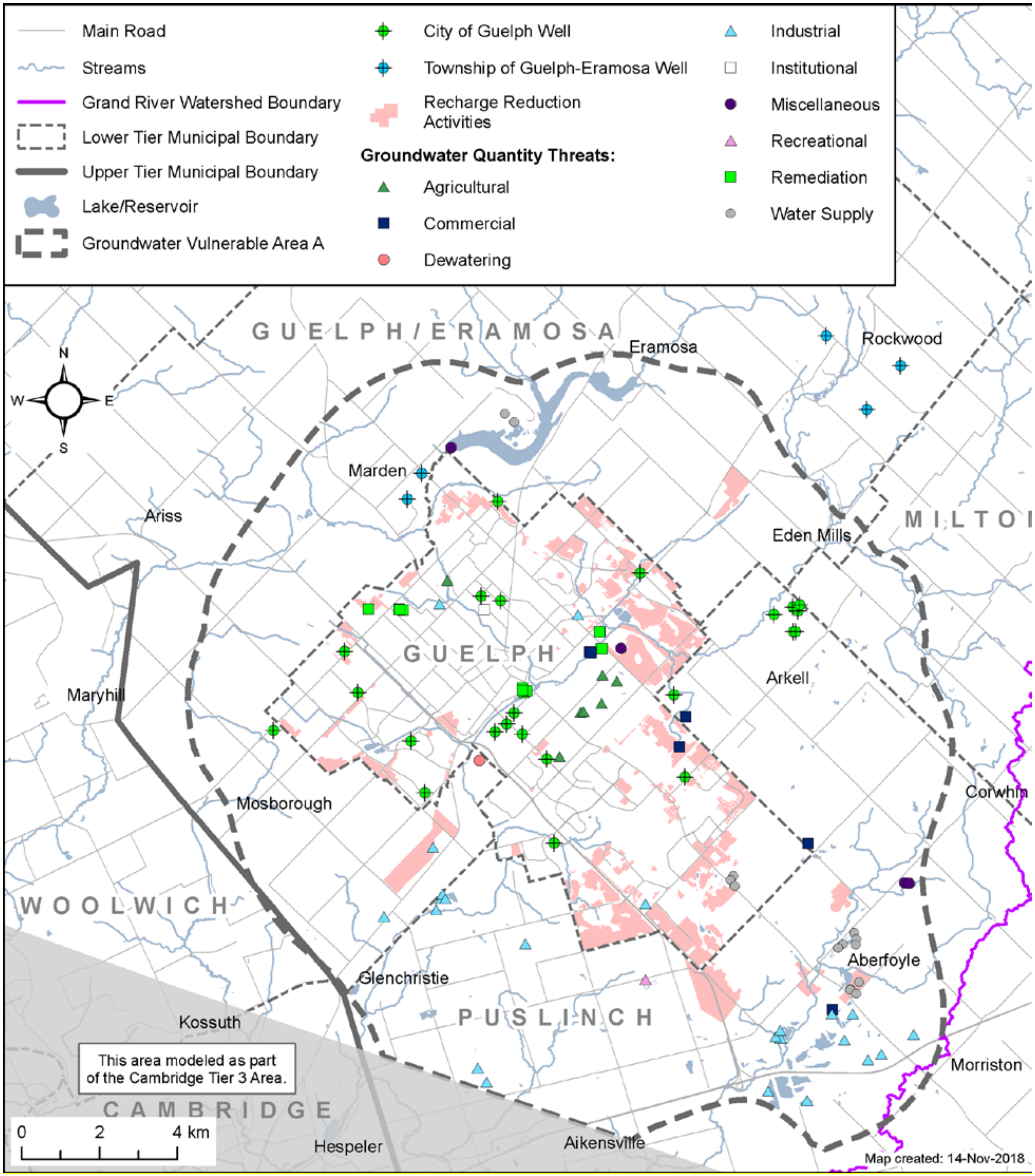
Map 19-8: WHPA-Qs Delineated in the Tier 3 Assessment



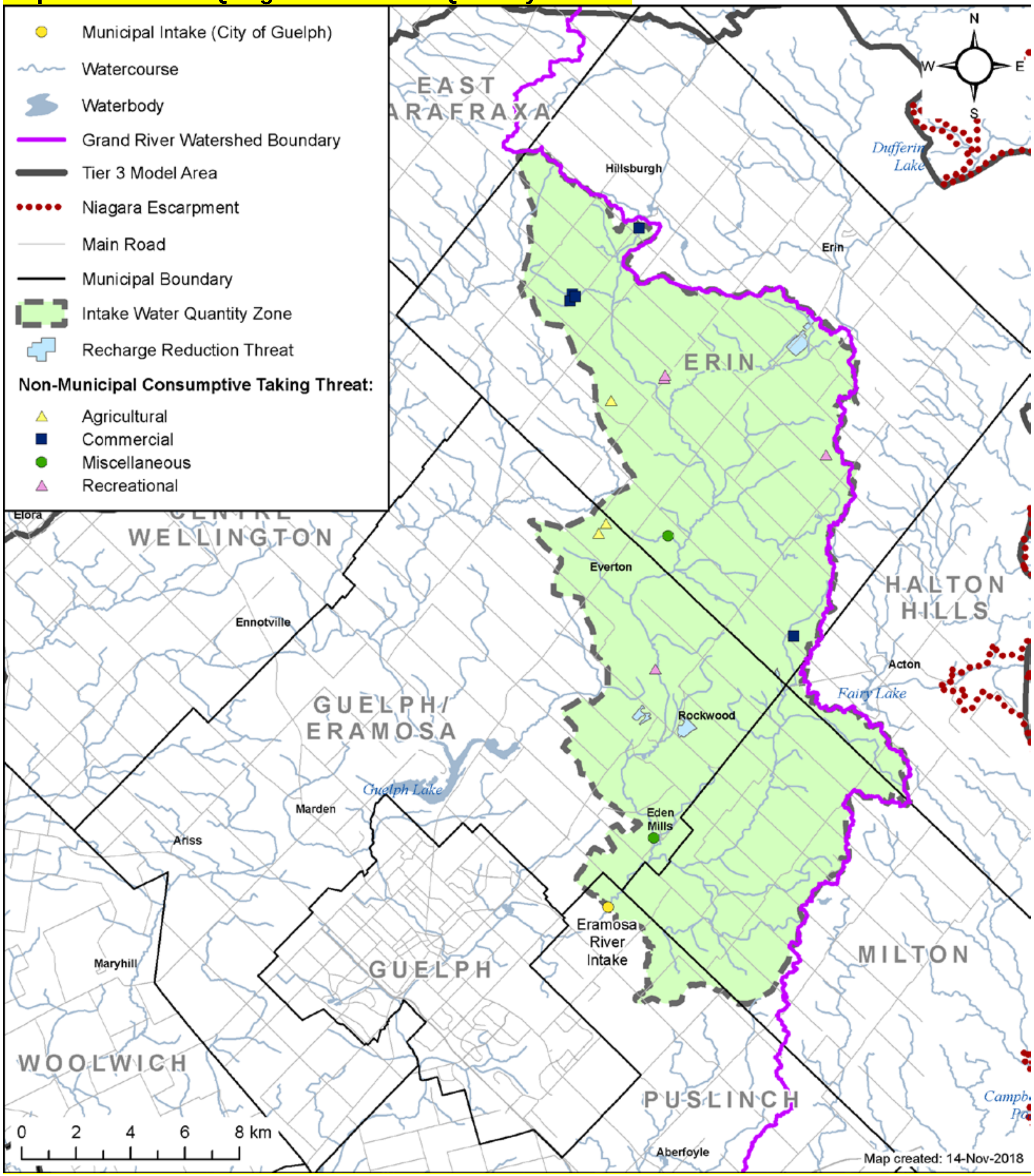
Map 19-9: IPZ-Q Delineated in the Tier 3 Assessment



Map 19-10: WHPA-Q Significant Water Quantity Threats



Map 19-11: IPZ-Q Significant Water Quantity Threats



19.5 Section Summary

The vulnerable areas in the GGET Tier 3 Assessment are represented by four WHPA-Qs (Groundwater Vulnerable Area) and an IPZ-Q (Surface Water Vulnerable Area). The largest WHPA-Q (WHPA-Q-A) is circular, with a diameter of approximately 20 km and extends around the City of Guelph and into the Township of Guelph/Eramosa. The extent of the WHPA-Q-A to the southwest toward the City of Cambridge was delineated based on the results of the GGET Tier 3 Assessment and the Region of Waterloo Tier 3 Assessment completed for the municipal wells in the City of Cambridge (Matrix and SSPA 2014).

The Tier 3 Assessment scenarios demonstrated that the City of Guelph's Queensdale Well is unable to pump at the Allocated rates under both average and drought conditions. All other municipal wells of the City of Guelph and the Township of Guelph/Eramosa in Rockwood and Hamilton Drive are likely to be able to pump at their current and Allocated rates under all conditions, but there is a *High* level of uncertainty with the results for the City of Guelph's Arkell Well 1. The scenario results are supported by historical operating experience in the City of Guelph where many of the wells have pumped at rates equivalent to their Allocated rates over prolonged periods of time. The primary municipal water supply aquifer is protected in most areas by the Vinemount Member aquitard, which reduces the vulnerability of the supply to drought. While all Tier 3 municipal wells except the Queensdale Well are expected to meet their Allocated rates, water levels at Arkell Well 1, Arkell Well 8, Arkell Well 14, Arkell Well 15, Burke Well, Carter Well, Emma Well, and Rockwood Well 3 may be more susceptible to drought conditions. This result demonstrates the Water Quantity Risks to the City of Guelph's water supply and, although only Queensdale Well exceeded the safe water level in the drought scenario, redistributing pumping to other wells might not mitigate the *Significant* Risk Level without other Risk Management Measures.

Even with the recent permitting of all Arkell Spring Ground wells, the City of Guelph's water supplies may not have the capacity to meet the 2031 estimated water demand due to the predicted impacts at the Queensdale Well. Furthermore, the City of Guelph will require all wells to be pumped at their Allocated rates, leaving little redundancy in the system. Redundancy is required to allow for the rehabilitation and maintenance of one or more wells, loss of one or more wells due to contamination, or long term interference from other water users.

There is a potential that pumping may decrease groundwater discharge to wetlands and cold-water streams. Results from the steady-state model indicated decreases of 10% or more in groundwater discharge to cold-water streams, such as the South Branch of Blue Springs Creek, Chilligo/Ellis Creek, and Hanlon Creek. There are also predicted reductions of shallow groundwater levels greater than 1 m around PSWs in the northwest, northeast, and southeast areas of the City of Guelph. As a result, WHPA-Q-A and the IPZ-Q would be assigned a *Moderate* Risk Level even if the drawdown threshold had not been exceeded at the Queensdale Well (resulting in a *Significant* Risk Level). In addition, there is a *High* level of uncertainty with respect to the predicted impacts to cold-water streams and wetlands.

Significant threats to drinking water quantity were identified as a result of assigning a *Significant* Risk Level to the WHPA-Q-A and IPZ-Q. These threats included 7,537 consumptive water takings (e.g., municipal and non-municipal takings) and 17.4 km^2 of recharge reduction areas.

19.6 References

AECOM and AquaResource, Division of Matrix Solution Inc. (AECOM and AquaResource). 2014. Halton Hills Tier Three Water Budget and Local Area Risk Assessment Final Risk Assessment Report. Report prepared for the Regional Municipality of Halton. Guelph, Ontario. October 2014.

AquaResource Inc. (AquaResource). 2009a. Integrated Water Budget Report, Grand River Watershed. Report prepared for Grand River Conservation Authority. Breslau, Ontario. June 2009.

AquaResource Inc. (AquaResource). 2009b. Tier 2 Water Quantity Stress Assessment Report, Grand River Watershed. Report prepared for the Grand River Conservation Authority. Breslau, Ontario. December 2009.

AquaResource Inc. (AquaResource). 2009c. Integrated Water Budget Report – Tier 2, Credit Valley Source Protection Area. Report prepared for Credit Valley Conservation Authority. Breslau, Ontario. April 2009. http://www.ctcswp.ca/files/CVC_Integrated_Water_Budget_Report.pdf

Barnett P.J. 1992. "Chapter 21: Quaternary Geology of Ontario." In: Geology of Ontario. Ontario Geological Survey, Special Volume 4, Part 2. Thurston P.C. et al. (Eds.). Toronto, Ontario. Pages 1,011-1,090.

Brunton F.R. 2009. "Update of Revisions to the Early Silurian Stratigraphy of the Niagara Escarpment: Integration of Sequence Stratigraphy, Sedimentology and Hydrogeology to Delineate Hydrogeologic Units." In: Summary of Field Work and Other Activities 2009. Ontario Geological Survey. Open File Report 6240. pp. 25-1 to 25-20.

R.J. Burnside and Associates Ltd. (Burnside). 2015. Comments on the Draft City of Guelph Tier 3 Water Quantity Report, Project No.: 300036495.0000. Memorandum prepared for the County of Wellington. Guelph, Ontario. June 16 2015.

R.J. Burnside and Associates Limited (Burnside). 2013. Technical Memorandum No. 1 Water/Wastewater Infrastructure Phasing, Project No.: MSA143810.0006. Memorandum prepared for Township of Guelph/Eramosa. Guelph, Ontario. October 24, 2013.

Chapman L.J. and D.F. Putnam. 1984. The Physiography of Southern Ontario. Third Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources. Toronto, Ontario. July 9, 1984.

City of Guelph. 2014. Annual & Summary Report for the Period of Jan. 1, 2013 – Dec. 31, 2013 for: Guelph Drinking Water System [Corporation of the City of Guelph] and Gazer Mooney Subdivision Distribution System [Township of Guelph/Eramosa]. Water Services Planning, Building, Engineering and Environment. Revision Date February 24, 2014. http://guelph.ca/wpcontent/uploads/Annual-Summary-Water-Services-Report-2013.pdf

Diersch H.-J.G. 2006. FEFLOW 5.4 – Finite Element Subsurface Flow and Transport Simulation System, User's Manual. WASY GmbH. Berlin, Germany.

EarthFX Incorporated (EarthFX). 2009. Final Report, Simulation of Groundwater Flow in the Vicinity of the Cedarvale Wellfield, Georgetown, Ontario: Model Development and Calibration Report. Report prepared for Regional Municipality of Halton.

Earth Tech Canada Inc., Lura Consulting, Lotowater Geoscience Consultants Inc., C.N. Watson and Associates Ltd. 2006. City of Guelph Water Supply Master Plan. Draft Final Report prepared for the City of Guelph. September 2006.

Golder Associates Ltd. (Golder). 2009. Final Report on IUS Groundwater Supply Optimization and Expansion Project: Task D3 – Hydrogeological Assessment of Potential New Well Sites In the Breslau Area. Report prepared for the Region of Waterloo Water Services Division. Kitchener, Ontario. June 2009.

Golder Associates Ltd. (Golder). 2006. Guelph-Puslinch Groundwater Protection Study. Report prepared for the Grand River Conservation Authority. Cambridge, Ontario. May 2006.

Grand River Conservation Authority (GRCA). 2013. Thermal Classification of Municipal Drains.

Karrow P. F. 1987. Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario. Ontario Geological Survey Report 255.

Karrow P.F. 1968. Pleistocene Geology of the Guelph Area, Southern Ontario. Geological Report 61. Ontario Department of Mines, Toronto.

Kinkead Consulting and AquaResource Inc. 2009. Methodology for Identifying Large Consumptive Water Users: Great Lakes - St. Lawrence River Basin Sustainable Water Resource Agreement. Report prepared for the Ontario Ministry of Natural Resources. Waterloo, Ontario.

Matrix Solutions Inc. (Matrix). 2017. City of Guelph and Township of Guelph/Eramosa Tier Three Water Budget and Local Area Risk Assessment. March 2017.

Matrix Solutions Inc. (Matrix) and S.S. Papadopulos and Associates Inc. (SSPA). 2014. Region of Waterloo Tier Three Water Budget and Local Area Risk Assessment. Report prepared for the Region of Waterloo. Waterloo, Ontario. September 2014.

Ontario Geological Survey (OGS). 2003. Surficial Geology of Southern Ontario. Ontario Geological Survey. Miscellaneous Release Data 128 – Revised.

Ontario Ministry of the Environment. (MOE). 2013. Memorandum: Assignment of Water Quantity Risk based on the Evaluation of Impacts to Other Water Users. Memorandum prepared for Source Protection Regions. Toronto, Ontario. December 2, 2013.

Ontario Ministry of the Environment. (MOE). 2012. Water Well Information System. Contains information licensed under the Open Government License – Ontario.

Ontario Ministry of the Environment. (MOE). 2008. Permit to Take Water Database. Contains information licensed under the Open Government License – Ontario. Accessed in March 2008. https://www.ontario.ca/data/permit-take-water

Ontario Ministry of the Environment and Climate Change. (MOECC). 2016. Technical Rules: Assessment Report, Clean Water Act, 2006. November 20, 2008. Amended on December 12, 2008 (administrative amendments), November 16, 2009 (EBR Posting Number EBRO10-7573), and December 2, 2013 (Technical Bulletin). Updated on May 19, 2016. https://www.ontario.ca/page/technical-rules-assessment-report

Ontario Ministry of Natural Resources (MNR). 2013. Provincial stream thermal classification mapping.

Resource Management Strategies Inc. (RMSi). 2009. Water Conservation and Efficiency Strategy Update (WC&ES). Final Report. Report prepared for the City of Guelph. Guelph, Ontario. May 2009.

Schroeter & Associates. 2004. GAWSER: Guelph All-Weather Sequential-Events Runoff Model, Version 6.5, Training Guide and Reference Manual. Submitted to the Ontario Ministry of Natural Resources and the Grand River Conservation Authority.

Watson and Associates Economists Ltd. 2011. Township of Guelph/Eramosa Water and Wastewater Rate Study. October 25, 2011.