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7.0 CITY OF GUELPH

7.1 Guelph Waterworks

The City of Guelph has 131,794 residents (Census, 2016) and it is one of the largest cities in Canada to rely almost exclusively on groundwater for its potable water supply. The population is projected to reach 191,000 by the year 2041. **Table 7-1** lists the system information for the City of Guelph drinking water supply system. The groundwater supply system comprises 25 groundwater wells distributed throughout the City, as listed in **Table 7-2** and **Table 7-3**. In 2008, 19 of the production wells were operated on a near continuous basis, four were out of service due to water quality or maintenance concerns and two were scheduled to be brought online in 2011. The majority of the wells draw water from deep confined bedrock formations, primarily the Gasport Formation (formerly the Amabel Formation) but to a lesser extent the Guelph, Eramosa and Goat Island Formations. The Vinemount Member, within the Eramosa Formation, is considered to be a regional aquitard and confines the Gasport Formation.

Table 7-1: Municipal Residential Drinking Water System Information for the Guelph Waterworks

DWS Number	DWS Name	Operating Authority	GW or SW	System Classification[1]	Number of Users Served
220000095	Guelph Waterworks	Guelph	GW and SW	Large Municipal Residential	135,000

[1] as defined by O. Reg. 170/03 (Drinking Water Systems) made under the *Safe Drinking Water Act, 2002.*

Table 7-2: Municipal Well Summary (m^3/day) for the Guelph Waterworks

City of Guelph Quadrant	Well / Collector Name	Depth (m)	Formation	Average Day Rate (2017)	Estimated Capacity[1]	WHPA Delineation Rate (80% of Capacity)
Northeast	Clythe Creek	58.9	Reformatory Quarry – Lower Gasport	N/O[3]	3,000[2]	2,400
Northeast	Emma	46.0	Upper - Middle Gasport	2,239	2,800	2,240
Northeast	Helmar	79.6	Upper - Middle Gasport	834	1,500	1,200
Northeast	Park #1 Park #2	57.0	Upper - Middle Gasport	2,498	8,000	6,400
Northwest	Calico	64.0	Upper Gasport	809	1,100	880
Northwest	Paisley	80.2	Upper - Middle Gasport	859	1,400	1,120
Northwest	Queensdale	74.4	Guelph – Upper Gasport	698	2,000	1,600
Northwest	Sacco	95.7	Guelph – Middle Gasport	N/O[3]	1,150[2]	920
Northwest	Smallfield	102.1	Guelph – Lower Gasport	N/O[3]	1,400[2]	1,120

Table 7-2: Municipal Well Summary (m^3/day) for the Guelph Waterworks

City of Guelph Quadrant	Well / Collector Name	Depth (m)	Formation	Average Day Rate (2017)	Estimated Capacity[1]	WHPA Delineation Rate (80% of Capacity)
Southeast	Arkell 1	20.1	Overburden – Contact Zone	27	2,000	1,600
Southeast	Arkell 14[6]	40.5	Upper - Middle Gasport	5,696	4,680[2]	3,744
Southeast	Arkell 15[6]	30.5	Upper – Lower Gasport	1,541	4,680[2]	3,744
Southeast	Arkell 6	41.2	Upper - Middle Gasport	3,947	6,500	5,200
Southeast	Arkell 7	43.3	Upper - Middle Gasport	4,413	6,500	5,200
Southeast	Arkell 8	30.5	Upper - Middle Gasport	1,770	6,500	5,200
Southeast	Arkell Glen Collector			10,377	6,900	6,900[4]
Southeast	Burke	79.6	Guelph – Middle Gasport	3,810	6,500	5,200
Southeast	Carter (In/Out)[7]	20.7	Guelph	2,574	5,500	4,400
Southwest	Dean Ave	57.2	Upper - Middle Gasport	685	1,500	1,200
Southwest	Downey Road	73.8	Upper - Middle Gasport	4,550	5,100	4,080
Southwest	Edinburgh[5]	69.5	Upper - Middle Gasport	N/O[3]	0	0
Southwest	Membro	73.2	Upper - Middle Gasport	2,522	6,000	4,800
Southwest	University	64.3	Upper Gasport	968	2,500	2,000
Southwest	Water Street	60.0	Upper - Middle Gasport	336	2,700	2,160
	Total			**51,153**	**89,910**	**73,308**

Notes: [1] Estimated Sustainable Rates from Water Supply Master Plan (Earth Tech et al., 2006)
[2] Sustainable Rate estimated by City of Guelph Water Services Division
[3] N/O = Not Operational; Wells not pumped during 2017 due to water quality or maintenance concerns
[4] 100% of the estimated pumping capacity is used for the Arkell Glen Collector in the WHPA delineation.
[5] No current plans to use the Edinburgh Well
[6] Arkell Wells 14 and 15 were brought online in 2011.
[7] Two wells located at Carter.

Table 7-3: Annual and Monthly Average Pumping Rates for the Guelph Waterworks[1] (m^3/day)

Well or Intake	Annual Avg.	Jan Avg.	Feb Avg.	Mar Avg.	Apr Avg.	May Avg.	Jun Avg.	Jul Avg.	Aug Avg.	Sep Avg.	Oct Avg.	Nov Avg.	Dec Avg.
Arkell #1	27	20	14	53	11	44	26	17	21	29	26	43	14
Arkell #6	3,947	4,783	4,218	5,201	4,937	2,780	4,930	5,580	3,225	730	53	5,700	5,221
Arkell #7	4,413	4,335	4,818	3,605	2,493	2,488	6,197	2,145	6,152	4,740	3,945	6,460	5,573
Arkell #8	1,770	972	1,369	732	1,646	169	375	738	820	2,038	5,500	3,578	3,304
Arkell #14	5,696	6,936	5,270	4,950	7,272	6,500	4,958	3,140	5,518	5,153	6,406	5,774	6,474
Arkell #15	1,541	1,876	3,535	3,710	666	1,080	1,706	1,281	1,491	495	909	1,154	585
Arkell Recharge Pump	2,948	0	0	0	22	5,948	8,145	7,899	7647	5,488	228	0	0
Arkell Glen Collector System	10,377	4,578	4,704	5,778	7,238	11,745	18,168	16,842	17,831	14,631	8,889	7,704	6,421
Burke	3,810	3,448	3,588	3,192	2,937	2,856	3,438	3,880	4,858	4646	4,489	4,415	3,976
Calico	809	874	907	763	790	861	786	783	718	772	824	825	802
Carter (In/Out)	2,574	0	0	562	3,093	3,717	2,956	3278	4,955	4,887	6,088	1,348	0
Clythe	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]
Dean	685	0	96	1,448	1,146	523	0	0	0	865	1,233	1,435	1,472
Downey	4,550	4,741	4,497	4,587	4,781	4,600	4,556	4,688	4,520	4,639	4,366	4,333	4,295
Edinburgh	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]
Emma	2,239	2,232	2,364	2,457	2,246	2,491	928	2,142	2,490	2,400	2,467	2,289	2,366
Helmar	834	850	769	949	909	917	908	968	945	529	947	650	668
Membro	2,522	2,985	2,993	2,993	2,988	2,923	2,187	2,390	1,666	2,845	2,619	2,516	1,161
Paisley	859	915	922	875	796	857	867	879	870	848	859	799	817
Park #1 Park #2	2,498	2,430	2,730	2,102	3,662	2,246	1,638	1,633	1,844	2,909	2,032	4,575	2,172
Queensdale	698	1,150	1,137	1,090	1,074	938	864	982	860	282	0	0	0
Sacco	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]
Smallfield	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]	N/O[2]
University	968	702	1,400	1,484	1,423	964	474	198	967	1,509	739	814	944
Water Street	336	613	555	408	658	993	807	0	0	0	0	0	0

1 Source: Ontario Drinking Regulation 170/03; 2017 Annual Summary Report (Guelph Waterworks Divison, 2018)
2 N/O = Not Operational; Wells not pumped during 2017 due to water quality or maintenance concerns

In addition to the groundwater supply wells, the City obtains water from the Arkell Spring Grounds collector system, also referred to as the Glen Collector. The system collects shallow groundwater from the overburden through a series of small diameter perforated pipes; this water is conveyed to the F. M. Woods Water Treatment plant for disinfection and distribution. In addition, the City has a water supply intake on the Eramosa River at the Arkell Spring Grounds that is used in association with the Arkell Recharge System. From April to November annually, water is pumped from the Eramosa River into a recharge pit and infiltration trench where it recharges the overburden aquifer supplying the Glen Collector System. This artificial groundwater recharge system is maintained by the City to augment groundwater flow and provide seasonal increases in water supply to the City.

The average daily water demand for 2017 is approximately 50,000 m^3/day including residential and ICI (industrial, commercial, and institutional) water consumption. Guelph's 2017 population was approximately 135,000. The City recently finalized its Water Conservation and Efficiency Strategy Update or WC&ES (Resource Management Strategies Inc., 2009) updating the City's long-term water demand estimates. The WC&ES estimated average-day water demand for the year 2031 to be 71,595 m^3/day for the residential population growth (169,000, which corresponds to an Ontario provincial "Places to Grow" population of 175,000) and ICI water demand

assumptions within the WC&ES (Note that maximum-day water demands may be higher by 30 percent or more). This projected average demand can be met using 80% of the estimated capacity for the City's wells and 100% of the capacity for the Arkell Glen Collector, as shown in **Table 7-2**.

7.2 Vulnerability Analysis

The following sections describe the delineation of vulnerable areas associated with the City's drinking water supplies. Areas within these vulnerable areas are assigned vulnerability scores which are a relative indicator of the ease with which contaminants could migrate into the water source. Details regarding the vulnerability assessment are provided in the technical report *City of Guelph Source Protection Project - FINAL Groundwater and Surface Water Vulnerability Report* (Vulnerability Report, AquaResource, 2010).

Modelling Approach for Guelph Waterworks

The City has used a three-dimensional, computer-based, groundwater flow model to define capture zones for the City's municipal wells. The groundwater flow model, developed in support of the City's Tier Three Local Area Risk Assessment, is the fourth generation model for the City with previous versions developed in 1999 (Resource Evaluation Study), 2003 (Arkell Spring Grounds Groundwater Supply Investigations) and 2006 (City of Guelph and Puslinch Township Groundwater Management Study). The most recent version of the model is the Tier 3 as described in Matrix (2017). This version of the groundwater flow model incorporates the results from a number of recent (2017) hydrogeological investigations conducted in and around the City and represents the best available information on the geology and hydrogeology of the area. The regional groundwater flow model, developed for the City of Guelph and surrounding area, was calibrated to observed hydraulic heads and surface water baseflows. The model is considered to be well calibrated because it represents the key elements of the groundwater flow system within a regional context, the parameter values used in the model are within physically realistic ranges, and the model provides an acceptable match to observed data on both regional and local scales.

The groundwater flow model was used to simulate the movement of groundwater through soil and bedrock and was developed to represent the actual groundwater flow system. On the basis that the model adequately represents the groundwater flow system, it was used to delineate the capture zones for each well using a particle-tracking technique (i.e. tracking particles of water for given time periods using the computer model). Particle-tracking techniques were used to estimate the directions and paths that groundwater is likely to travel and thus can be used to estimate the land areas within which groundwater may migrate towards a well. Additional details on the approach and methodology are provided in the full Vulnerability Report (AquaResource, 2010).

Wellhead Protection Areas were delineated for the City's municipal wells following a three-stage process. The first stage involved the delineation of capture zones which represent the specific areas of land where underlying groundwater migrates to a municipal well. The second stage involved assessing variations in the boundaries of the delineated capture zones to account for uncertainties in the conceptual and numerical models. The third stage results in delineating the final wellhead protection areas (WHPAs) based on all of the results of the uncertainty analyses.

Capture Zones

The development of capture zones is dependent on a number of factors including the geological and hydrogeological conceptual model, the numerical formulation of a computer-based groundwater flow model and its input parameters (e.g., effective porosity and hydraulic conductivity), and on the number and location of the municipal wells and the pumping rates applied to the wells.

In 2008, the average daily pumping rate of all of the City's wells was about 50,000 m^3/day, but the wells are capable of producing at higher sustainable rates. In addition, the City has several wells that are currently out of service or awaiting approvals. For the purposes of defining the WHPAs, an average daily pumping rate of 80% of the estimated sustainable capacity of the existing and future wells was used in the model. This higher average daily rate (approximately 73,300 m^3/day) is consistent with the water demand forecast for 2031 made in the recent update of the City's Water Conservation and Efficiency Strategy. However, for the model approach, the pumping rates were spread over the available municipal wells as compared to normal operation, wherein the supply is derived from main wells with additional supply derived from peaking wells during high demand periods.

Capture zones were delineated using a computer model (FEFLOW) based on the conceptual model, the model boundary conditions, the applied model parameters and using a combination of backward and forward particle-tracking. The capture zones are delineated under a scenario with the Dolime quarry no longer pumping water from the Guelph and Gasport Formations. Under this scenario, groundwater that is currently captured by the quarry's dewatering system is captured by the City's municipal wells in the vicinity of the quarry.

For backward particle-tracking, particles were released at multiple levels within all screened layers along the well, and also in the layers above and below the well interval. At each level approximately 100 particles were released in three circles around each well at distances from the well determined by the size of the surrounding finite-elements in the model. The distances ranged from 15 m to 270 m with the average being 90 m around the municipal wells. Particle tracks were calculated to steady state with time markers at 2-year, 5-year, and 25-year periods. There is a practical limit to the number of particles that can be released from each well and e tracked in the model due to computational constraints. This limitation allows only a finite number of particle pathlines to be calculated. Capture zones are delineated by encompassing all model-computed pathlines within an area, but there will be apparent gaps between pathlines that increase in magnitude as the particles move further away from the well (greater time-of-travel). As the particle-tracking method is an approximation of the true flow paths, the resultant capture zones will have inherent uncertainty in both direction and extent.

Forward particles were also released at ground surface and at the top of the Gasport aquifer layer to identify any potentially captured areas not included within the area delineated using backwards particle-tracking. Forward particles were also released at the end points of some of the backward particle-tracking paths to confirm that the forward and backward paths were the same.

Effective porosity is a key input parameter required for the delineation of capture zones and is required to calculate the linear groundwater velocities from the groundwater flow computations made by a groundwater flow model. To estimate the linear groundwater velocity, representing the speed at which a particle of water might travel, the Darcy flux is divided by the effective porosity of the porous media.

The effective porosities initially assigned to the model are summarized as follows:

- Bedrock (Except productive Gasport Formation) – 1%
- Productive Gasport Formation – 3%
- Overburden/Bedrock Contact Zone – 3%
- Overburden – 20%

This initial parameter set was used to define the base case capture zones that were previously published in the 2010 Vulnerability Report (AquaResource, 2010).

Capture Zone Uncertainty Scenarios

The City of Guelph has used three-dimensional groundwater flow models and particle tracking techniques to provide estimates of the capture zones for the 2-year, 5-year and 25-year time of travel. Out of necessity, the groundwater flow models are based on conceptual geologic and hydrogeologic models and are simplifications of the natural system. Under the assigned boundary conditions, the models are calibrated to the best-fit model parameters and supplemented with sensitivity analyses of the parameters. The key parameters in which there may be uncertainty include groundwater recharge and discharge and the three-dimensional distribution of the hydraulic conductivity and porosity of the geological media in the flow field. In addition, the Guelph model is based on one set of well pumping rates and variations in the pumping distribution for multiple well systems add additional uncertainty. The model solutions are not unique and different boundary conditions, well pumping rates and model parameters could give similar predictions of head.

Since the modelling approach has a number of inherent uncertainties, a scenario approach was used to assess uncertainties in the capture zones. In the scenario approach, as described in the MOE, 2006 draft Guidance Module 3 – Groundwater Vulnerability Analysis, the uncertainty of the capture zone is evaluated by completing a number of model simulations (scenarios) using a range of model parameter sets that lie within a reasonable and realistic range for the parameters of interest. The intent is to derive a series of capture zones that, when combined, assist in defining a more certain wellhead protection area.

The City of Guelph's assessment of the capture zones using the scenario approach considered the following:

Conceptual Model

The conceptual geological and hydrogeological model for the City of Guelph has evolved over the last two decades as more information is collected for the City and surrounding areas. Past groundwater flow models have shown variations in groundwater flow directions and velocities which have resulted in capture zones with variable size, shape and orientation. The current hydrogeological model for the City is considered to be relatively complex consisting of two bedrock aquifers (Guelph Formation and Gasport Formation, formerly referred to as the Amabel Formation) separated by a confining layer (Vinemount Member of the Eramosa Formation) with some uncertainty on the extent, thickness and hydraulic properties of the aquifer and aquitard units. Recent investigations have shown variability in aquitard thickness and the presence of permeable reefal structures in the Gasport aquifer that are not well defined and may not be adequately represented in the model. There is also less reliable information outside of the City on the extent and hydraulic properties for these formations. These uncertainties in the conceptual model will result in uncertainties in the capture zones which must be considered in the delineation of the WHPAs.

Hydraulic Properties of Aquifers and Aquitards

Sensitivity analyses have shown that the groundwater flow model is relatively sensitive to variations in the hydraulic properties of the Vinemount Aquitard and the Gasport Aquifer. A slightly lower hydraulic conductivity of the aquitard results in a larger capture zone. The hydraulic properties of the aquitard are difficult to measure and local variations are expected to exist. Similarly, a slightly lower hydraulic conductivity of the Gasport Formation will also result in a larger

capture zone. Furthermore, based on the results of pumping tests and wellfield shutdown tests, the Gasport aquifer is known to be heterogeneous, with greater local variation in hydraulic properties than the small variations used in the sensitivity analyses. The presence of karst features in the Gasport Formation adds an additional level of complexity to the interpretation of the hydraulic properties of the main water supply aquifer.

Wellfield Effects

The City's water supply is primarily derived from the Gasport Aquifer below the Vinemount Aquitard. With 18 active wells currently pumping large volumes (50,000 to 73,000 m^3/day) from the same confined bedrock aquifer in a relatively small area, there are mutual interference effects between wells and wellfields. Water level monitoring during pumping tests and wellfield shutdown tests have shown that the drawdown/recovery effects of the tests are transmitted up to 5 kilometers or more in some cases, particularly in the central portions of the City. These observations indicate that the entire system responds as a single wellfield.

Bedrock Aquifer Effective Porosity

Groundwater flow models require an effective porosity to calculate the groundwater velocity which in turn is used to estimate the travel times. The effective porosity of a fractured rock aquifer is a parameter that is difficult to determine on a regional scale. Regional studies of bedrock aquifers in Guelph and Cambridge have used porosity estimates in the range of 0.07 to 11 percent. Recent studies by the University of Guelph (K. Belan, M.Sc. Thesis, 2010, J. Munn, M.Sc. Thesis 2012, and others) determined effective fracture porosities for the bedrock formations in Guelph of 0.04 to 0.09 percent. As compared to the porosities used in the baseline case for the Guelph model (i.e. 1 to 3 percent), these low fracture porosities represent considerable uncertainty on the appropriate range of effective porosities to represent the capture zones for the Guelph bedrock aquifer. The use of low effective fracture porosities would result in considerably larger capture zones and WHPAs.

Equivalent Porous Media Assumption

The Guelph water supply aquifers are recognized as fractured bedrock aquifers with karst features. However, the modeling approach assumes that the scale of the regional model represents a large enough volume of the bedrock such that the bedrock will behave as an equivalent porous medium (EPM). This approach allows for the use of EPM models such as FEFLOW, which was used for the Guelph model. However, the assumptions inherent in using the EPM approach may not apply everywhere in the model area, and the fractured bedrock aquifer is known to have very permeable and productive fractures, karst features and low hydraulic conductivity layers. The assumption of the EPM approach introduces additional uncertainty into the conceptual model in that model hydraulic parameters may vary by several orders of magnitude in local areas as compared to the hydraulic parameters assumed for the regional area representative of the EPM. This uncertainty with respect to the EPM assumption needs to be taken into consideration in defining capture zones. In areas where fracture flow dominates over porous media flow, the model may overestimate the travel times and travel times may be much shorter than predicted by the EPM model.

Municipal Pumping Rates

As noted above, the municipal pumping rates shown in Table 7-2 were used as the base case for the model. In reality, the City's water supply is derived from a smaller number of main production wells to meet average daily demands and is supplemented to meet high demands using other wells as peaking wells. Pumping in municipal wells can vary significantly year to year, seasonally

due to demand, or due to system upgrade, maintenance and repair requirements. Furthermore, most of the City's wells draw water primarily from the same bedrock aquifer (Gasport Formation) and the wells have a marked mutual interference effect. Further, the cycling of wells on or off and shifting of the pumping centers in the City's wellfield will result in changes to the groundwater divides between wells and affect the capture zones. The effect of changes in pumping rates and the resulting effects on the capture zones has been considered when developing WHPAs.

Membro Capture Zone

The Membro Well represents a good example of the uncertainties associated with delineating capture zones in the City of Guelph. The Membro Well is a main producing well located in the middle of the City. Since the Membro Well is surrounded by other production wells in the City, its water supply is derived from many areas and its capture zone wraps around and between the capture zones of other wells. The particle tracks show a few single or multiple particle "stringers" that appear to extend between wells, the reliability of which are uncertain. The extent of the capture zone is sensitive to the Membro pumping rate and the pumping rate for other adjacent wells and dewatering pumping associated with the Dolime Quarry. Its water supply is also known to be derived from discrete fracture zones in a 10 m interval, the extent of which is only defined at the well. Given the uncertainties of fracture flow, the variability of potential pumping rates and the mutual interference effects of adjacent wells, the prediction of a capture zone for the Membro Well is uncertain. Similarly, the interpretation of the Issues Contributing Area (ICA) for the Membro Well (see below), from the particle tracks, is complex and the ICA has been simplified based on professional judgement to provide a more confident interpretation of the area that may contribute to issues at the Membro Well.

To evaluate these uncertainties and to assess the impacts on capture zones, a number of modeling scenarios were conducted. The scenarios considered the effects, in isolation and in combination, of variations in bedrock porosity and formation hydraulic conductivity (i.e. Gasport Formation and Vinemount Member) and municipal well pumping rates. EPM versus fractured media assumptions were evaluated based on comparisons between the base case porosities representative of porous media, and low effective fracture porosities representative of fractured media. The effects of variations of the conceptual models were completed by comparisons of earlier and current models.

Delineation of Wellhead Protection Areas for the Guelph Waterworks

The results of the numerous model scenarios were used to assess the extent of potential capture zones. The resulting capture zones from the model scenarios were overlaid and compared to evaluate the effects of uncertainty. On the basis of the potential capture zones and in recognition of the uncertainties discussed, the Wellhead Protection Areas shown in **Map 7-1** were delineated.

The City reassessed the capture zones and Wellhead Protection Areas in comparison to the areas delineated in AquaResource (2010) versus the updated Tier Three model (Matrix, 2017). The areas delineated in AquaResource (2010) included detailed sensitivity analyses to assess variable factors within the model such as aquifer and aquitard hydraulic conductivity, porosity and pumping rates as described above. The updated Tier Three model produces similar results for capture zones and Wellhead Protection Areas given the range of areas defined in the sensitivity analyses. As a result, no changes for the Wellhead Protection Areas were proposed due to the updates to the Tier Three model in 2017.

In general, the potential capture zones provide for a consistent interpretation of the necessary WHPAs. It is noted that the areas between wells/wellfields likely have the greatest uncertainty

resulting from well interference effects, variations in pumping rates and effective porosity effects. For the potential capture zones, the fracture porosity scenarios were found to result in the largest capture zones for the 2-year and 5-year time of travel. For the areas between wells/wellfields, where the gradients resulting from well drawdown are likely to be the greatest, fracture flow is likely to be a dominant factor. Outside of the areas between wells/wellfields, in upgradient areas where gradients are lower, the fracture flow capture zones likely underestimate the travel times. As a result, the scenario approach and the delineation of the WHPAs has been weighted to accept the more certain areas of the potential capture zones and to exclude the more extreme areas of the potential capture zones for the 2-year and 5-year time of travel.

Vulnerability Scoring in Guelph Waterworks Wellhead Protection Areas

As part of the Guelph-Puslinch Groundwater Protection Study (Golder, 2006b), aquifer vulnerability mapping was completed using a modified version of the MOE's Groundwater Intrinsic Susceptibility (GwISI) method (see MOE, 2001). As part of this Study, Golder (2006b) produced unadjusted and adjusted intrinsic vulnerability maps **(Map 7-2 and Map 7-3**) for individual aquifers that have classes of high, medium or low vulnerability. In the City of Guelph, this included shallow overburden aquifers (generally high vulnerability), intermediate to deep overburden aquifers, the Guelph Formation aquifer, and the Amabel Formation aquifer (also known as the Gasport Formation aquifer in more recent studies) (generally low vulnerability). Additional information regarding the initial vulnerability mapping can be found in the Guelph-Puslinch Groundwater Protection Study (Golder, 2006b).

Additional studies of the vulnerability of the Guelph water supply system were conducted as part of the 2006 Guelph Source Protection Project (AquaResource, 2007b) and the Final Groundwater and Surface Water Vulnerability Report (AquaResource, 2010). These studies evaluated the vulnerability of the bedrock aquifers using the Surface to Well Advection Time (SWAT) and the modified Groundwater Intrinsic Susceptibility Index (GwISI). The SWAT study concluded that the particle-tracking used in the SWAT method was very sensitive to both the configuration and hydraulic conductivity of the bedrock aquifers and the Eramosa/Vinemount aquitard which have a relatively high uncertainty. In addition, the travel times computed are much different for wells that are drawing water from shallower rock. Finally, the method was judged professionally to provide uncertain results in areas of potential surface water discharge or areas with strong downward vertical gradients in the bedrock as exist across large portions of the City. Based on the results of this study, it was concluded that while the technical approach provides insight into the groundwater flow system in the vicinity of a particular pumping well, the SWAT method would not be a reliable and defensible method for delineating the City's vulnerable areas.

Based on the occurrences of organic contaminants, and sodium and chloride concentrations in the City's municipal wells, the 2006 Guelph Source Protection Project (AquaResource, 2007b) determined that the Amabel/Gasport aquifer should not be assigned a low vulnerability score, as it was mapped in the Guelph-Puslinch Groundwater Protection Study. Rather, as described in AquaResource, 2010, the City chose to use vulnerability mapping for the shallowest bedrock formation when calculating the vulnerability scores. This approach recognized that a number of the City's municipal wells were cased into the bedrock with long intervals open to the shallow bedrock (Guelph Formation) and the deeper Amabel/Gasport Formation. Wells with long open hole intervals (i.e., Burke Well, Calico Well, Downey Well, Emma Well, Helmar Well, Sacco Well, Smallfield Well, Water Street Well) draw water from the deeper bedrock formations but a percentage of the water from each well is derived from the shallower formations (see also **Table 7-2**). It is also assumed that the aquitard is a confining layer but may be of variable extent or semi-confining in some areas. Using the shallowest bedrock aquifer as the basis for the vulnerability mapping is conservative, however, it recognizes that once contamination reaches the top of

bedrock in the City, there is always a potential that it could migrate directly to municipal wells open to the shallow bedrock or to the deeper aquifer through bedrock fractures or other preferential pathways.

The groundwater intrinsic susceptibility index (GwISI) is an indexing approach that takes advantage of an existing database of water well records and boreholes to produce an index or numerical score for each well in the database. The index considers the overburden soil type and thickness above the aquifer, and the static water level in the well. The GwISI is calculated by summing the product of the thickness of each geological unit overlying the aquifer with its corresponding K-Factor. The K-Factor is a dimensionless number that is loosely related to the exponent of the vertical hydraulic conductivity of the geological material (in m/s). In effect, the objective in assigning the K-Factor is to relate the degree of protection offered by each respective geological material that overlies the aquifer. Suggested K-Factors for this classification system are provided in the MOE's guidance document for groundwater vulnerability (MOE, 2006a).

For the GwISI method, index values < 30 would be categorized as "High"; index values ranging from 30 to 80 would be categorized as "Medium"; and index values > 80 would be categorized as "Low". The index value is then interpolated between the well locations to produce a complete spatial assessment (map) of the intrinsic vulnerability of the aquifer(s). When calculating the GwISI with respect to the top of bedrock, areas having thick overburden tend to have lower vulnerability, as with the Galt/Paris Moraine Area; and areas having thin overburden tend to have higher vulnerability, as with many areas along the Eramosa River where bedrock is close to surface.

For this current assessment, the GwISI method was modified to use an overburden thickness map created using existing information. The modifications include:

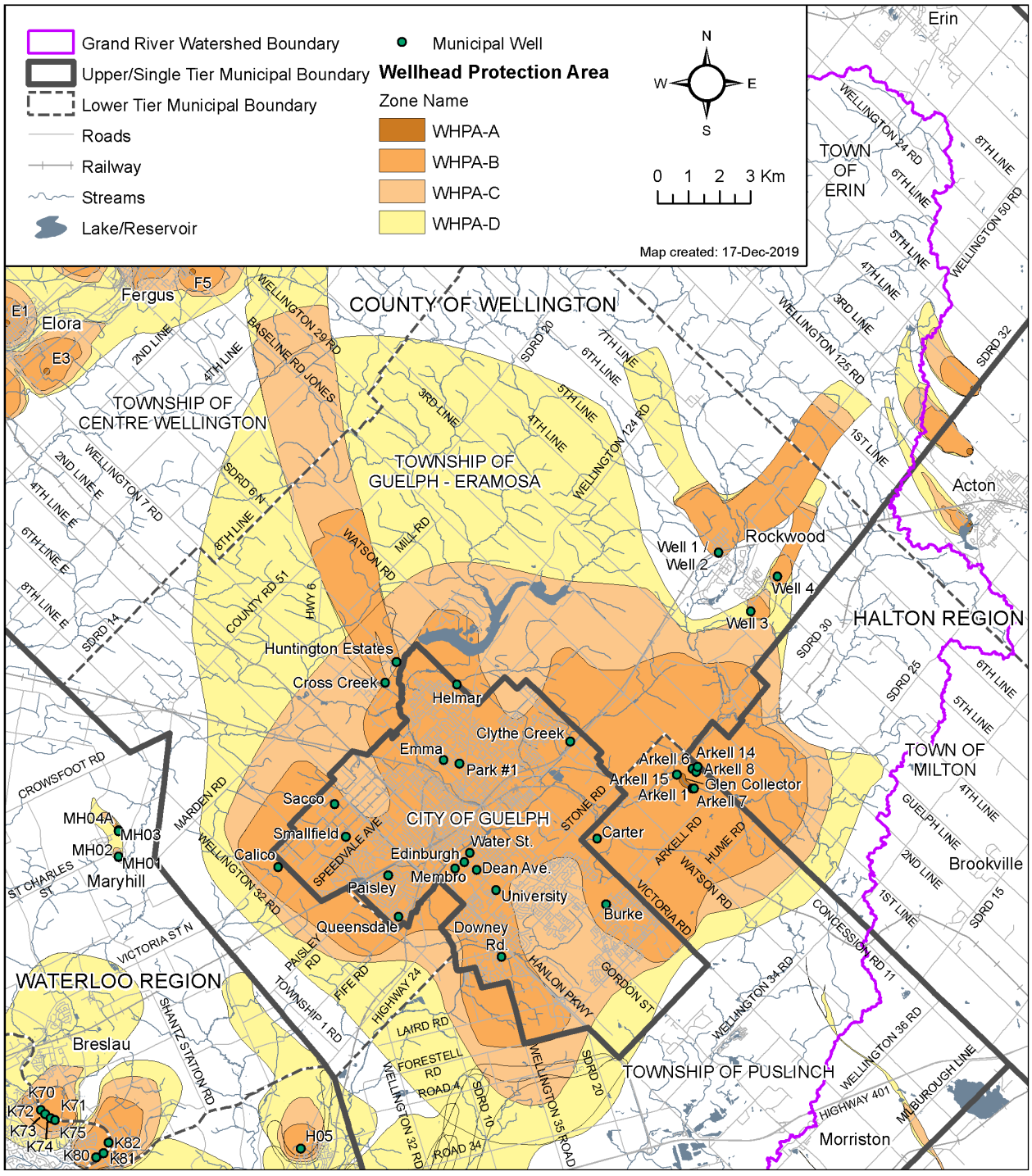
1. An overburden thickness map is generated for the study area using a Digital Elevation Model (DEM) and a top of bedrock elevation surface.

2. GwISI is estimated for water well records and boreholes using the regular GwISI technique and published K-Factors. The GwISI index value is then divided by the overburden thickness at the location of each water well record and borehole to calculate an Effective K-Factor.

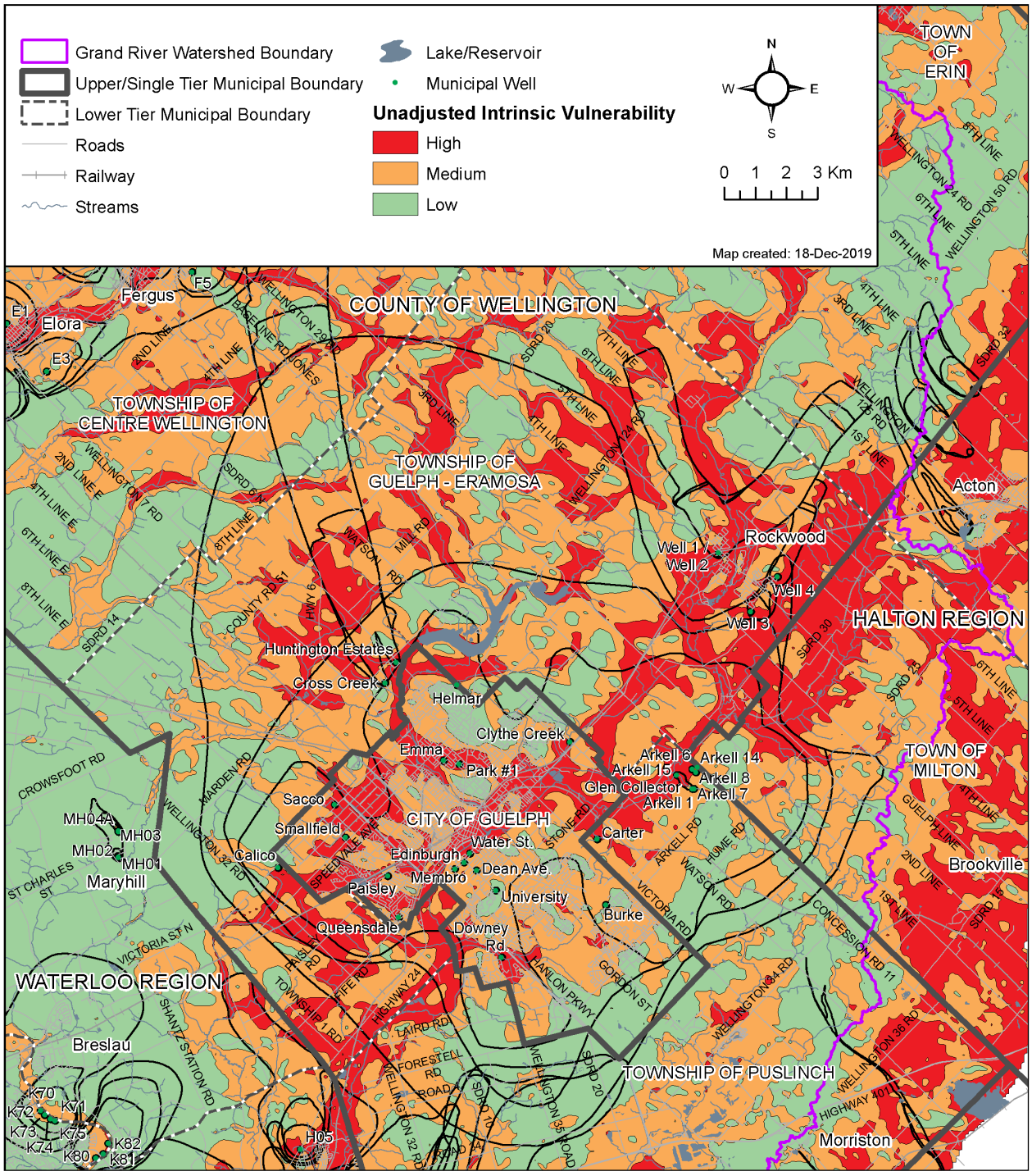
3. The Effective K-Factor is then interpolated across the land area. This map illustrates the general trends of higher and lower permeability soils as reported in the water well record database and higher quality boreholes.

4. For each grid cell, the interpolated Effective K-Factor is multiplied by the overburden thickness.

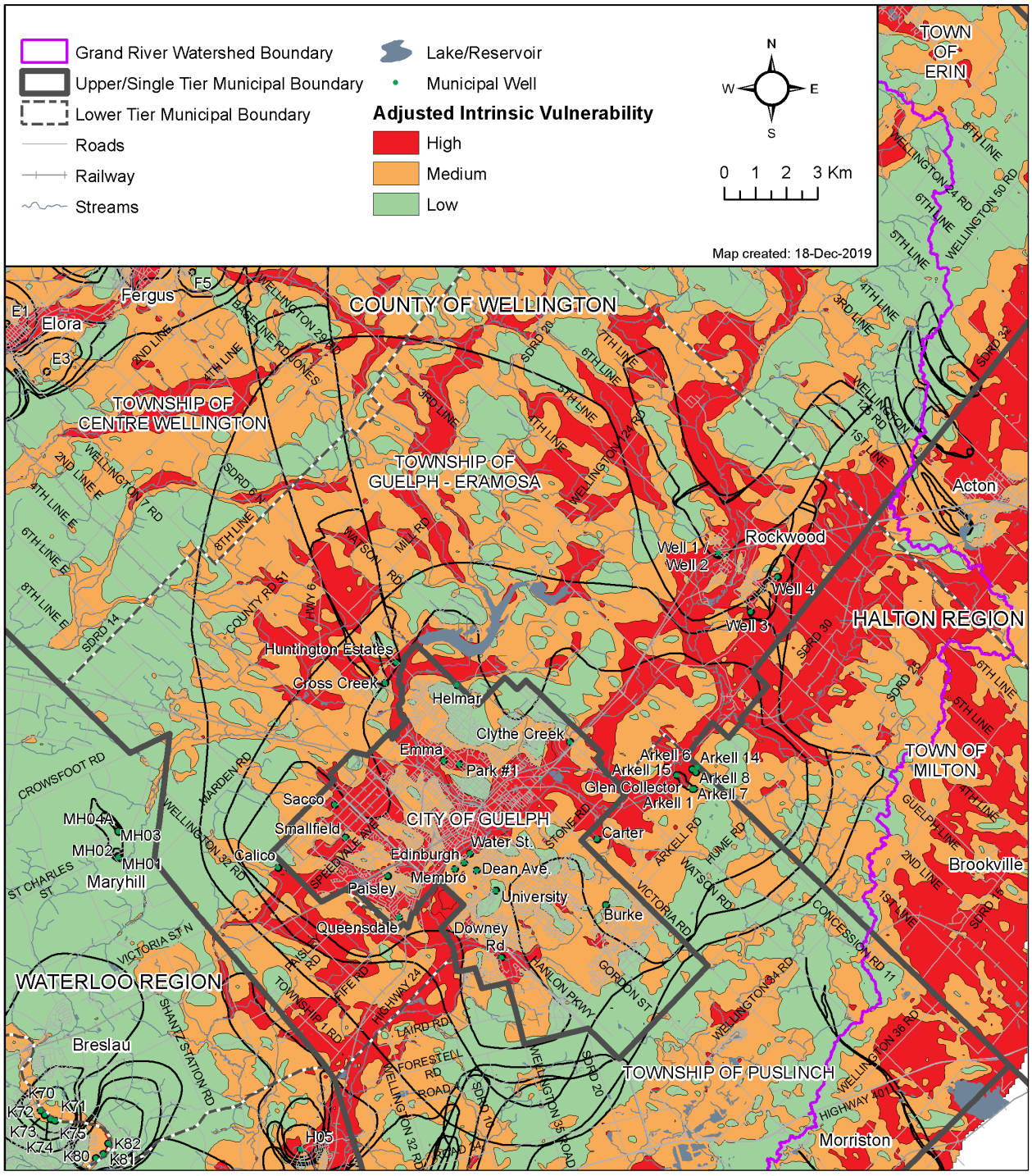
Map 7-1 Guelph Waterworks Wellhead Protection Area (overview)



Map 7-2 Guelph Waterworks Wellhead Protection Area Unadjusted Intrinsic Vulnerability



Map 7-3 Guelph Waterworks Wellhead Protection Area Adjusted Intrinsic Vulnerability



The modified GwISI map shows many of the same trends as the one prepared using the GwISI method; however, differences are seen along the Eramosa and Speed River Valleys where overburden is thin and shallow bedrock is more vulnerable to contamination originating from ground surface. The modified GwISI map also shows lower vulnerability trends along known thick overburden features, such as the Galt/Paris Moraine.

Identification of Transport Pathways within Wellhead Protection Areas

According to the Technical Rules (MOE, 2009b), the vulnerability scores are based on physical or natural protection above the municipal aquifers of interest. It is, however, recognized that anthropogenic activities such as large excavations, or pits and quarries, can compromise the natural protection of the overburden layers and increase the vulnerability of the aquifers to surficial contamination. Large diameter sewer mains or storm water management (SWM) ponds located within municipal capture zones are also interpreted by the MOE to increase the vulnerability of a municipal aquifer. Using professional judgment, vulnerability scores assigned to regions of a capture zone can be increased where transport pathways are noted.

The following anthropogenic activities were identified as having a potential effect on the vulnerability of the municipal aquifer:

1. Private wells that may be improperly constructed / poorly maintained;
2. Deep municipal sewers that intersect bedrock; and
3. Quarries and gravel pits.

Over 800 water well records are located within the City, however, details of the condition of the wells are largely unknown. Based on surveys of private wells within selective areas of the City conducted as part of the 2006 Source Protection Project (AquaResource, 2007b), AquaResource and the City decided that there was not sufficient information available to modify the vulnerability mapping to account for the potential for these wells to act as transport pathways to contaminate the aquifer.

The City provided a GIS layer of the municipal sewer infrastructure information including invert elevations of each manhole. The invert elevation data provided was compared to the bedrock elevation map to give an indication of where municipal sewers were likely to intersect bedrock. These areas may be more susceptible to the preferential movement of contaminants than shallower infrastructure installed above the bedrock.

Quarries and gravel pits represent a transport pathway of concern because the overlying protective layers of aquifer are removed, thereby, making the aquifer more vulnerable. One quarry and one gravel pit were identified in the vicinity of Guelph. The quarry is a particular concern for the City with respect to its potential to impact the drinking water supply due to the significant dewatering, depth of excavation (i.e. through the bedrock aquitard protecting the water supply aquifer) and its proximity to several municipal wells. Ongoing excavation of the aquitard as part of the quarry operations will increase the vulnerability of the area and upon closure of the quarry, act as a significant groundwater recharge area.

Transport pathways are intended to be accounted for in the refined vulnerability scoring of capture zones and may be used to increase the intrinsic vulnerability index (i.e., from low to moderate or moderate to high) to reflect the higher vulnerability caused by the pathway.

The updated assessment report will be revised to illustrate the transport pathways affecting the intrinsic vulnerability scores. Adjustments to the intrinsic vulnerability (e.g., high, medium, low)

were made in areas where the bedrock is intersected by sanitary or storm sewers, and in areas where pits and quarries were reported to exist. The intrinsic vulnerability was increased one step (e.g., from low to medium, and from medium to high) in areas where sewers were close to bedrock and in the vicinity of quarries and gravel pits. The vulnerability scores were not adjusted to account for the presence of improperly abandoned or poorly maintained boreholes.

Vulnerability Scoring in Wellhead Protection Areas

Vulnerability scoring is completed by overlaying the 2-year, the 5-year, and the 25-year time-of-travel capture zones with the intrinsic vulnerability map. Intersecting the classed vulnerability map with the capture zones creates a series of polygons that are assigned a vulnerability score based on the vulnerability and type of WHPA. The following table is provided in the Technical Rules (Table 2(a): Wellhead Protection Area Vulnerability Scores – ISI or AVI Location Within a Well Head Protection Area) (MOE, 2009b) and specifies the vulnerability score that is applied to areas within a WHPA based on the groundwater vulnerability in that area.

Table 7-4: Wellhead Protection Area Vulnerability Scores (From Technical Rules (MOE, 2009b)

Groundwater Vulnerability Category for the Area	WHPA-A (100 m)	WHPA-B (2-Year TOT)	WHPA-C (5-Year TOT)	WHPA-D (25-Year TOT)
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

Note: TOT represents time-of-travel.

Error! Reference source not found.**Map 7-4** through **Map 7-6** illustrates the transport pathways that were considered for vulnerability adjustment, the areas of influence as a result of the transport pathways and the final vulnerability for the urban area of the City of Guelph. **Map 7-7**Error! Reference source not found. through **Map 7-11** illustrates the final vulnerabilities for each of the urban insets for the City of Guelph. **Map 7-12**Error! Reference source not found. through **Map 7-14** illustrates the transport pathways that were considered for vulnerability adjustment, the areas of influence as a result of the transport pathways and the final vulnerability for the rural area around the City of Guelph. The Technical Rules stipulate that significant water quality threats can only be identified in areas where the vulnerability score is 8 or 10 under the regular threats assessment process.

As shown on these figures, vulnerability scores equal to 8 or 10 are located within large portions of the WHPA-A and WHPA-B (2 year time-of-travel) particularly along the Eramosa and Speed River Valleys where overburden is thin. Dissolved organic chemicals have been observed at a few of the City's pumping wells, particularly where the land areas with high vulnerability scores for those wells are associated with industrial or commercial land uses. These occurrences of contamination in the aquifer illustrate the potential that the deep water supply aquifer may be impacted by contamination originating at the ground surface. Historical occurrences of contamination also illustrate that there are areas within the City with high groundwater vulnerability and that the presence of an aquitard should not presume that the groundwater supply is not vulnerable to contamination issues.

Note that the Hamilton Drive production wells (Cross Creek and Huntington Estates) and the Rockwood production wells (well 1, well2, TW2/02, TW3/02), which are owned by the Township

of Guelph/Eramosa, overlap with the wellhead protection areas for the Guelph Waterworks, as seen on **Map 7-11.**

Uncertainty Factor – Groundwater Vulnerability Areas

The Technical Rules require that an analysis of uncertainty be carried out for the groundwater and surface water vulnerability study, and this analysis should assign an uncertainty factor of "high" or "low" to each of the vulnerable areas. The intent of the Technical Rules is to identify situations where a reasonable amount of additional work could significantly increase the certainty of the vulnerability assessment. While there are various sources of uncertainty as described in this report, the uncertainty factor for the groundwater vulnerable areas is "low" since the delineation of the vulnerable areas is based on a detailed scenario approach with the evaluation of a number of uncertainty factors. The results of this assessment are only likely to change with significantly more technical work which may only be achieved with significantly more regional characterization and more monitoring over large areas for many years. This conclusion is based on an assessment of several factors to be considered as required under the Technical Rules and discussed below:

- The groundwater and surface water vulnerability assessments both rely on a detailed characterization of a large amount of data collected over a long period of time.

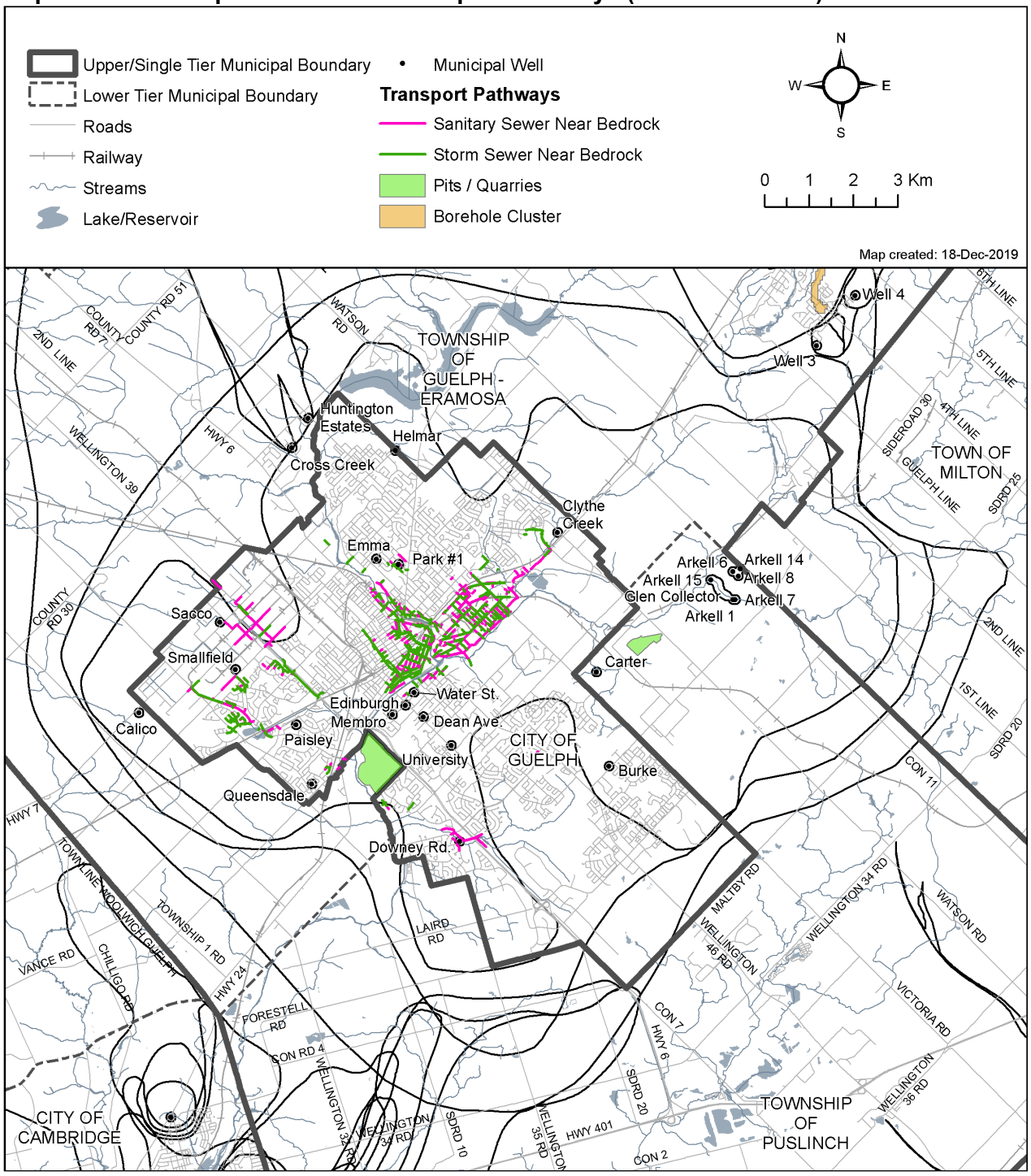
- The groundwater flow model has been shown to reflect groundwater flow processes both regionally and locally within the City by representing both water levels and flows to surface water under pumping conditions. The surface water model used to delineate the IPZ's simulated flow velocities similar to those measured using a dye tracer test.

- Each step of the model development process relied on data that had been collected and/or reviewed by professional engineers or geoscientists.

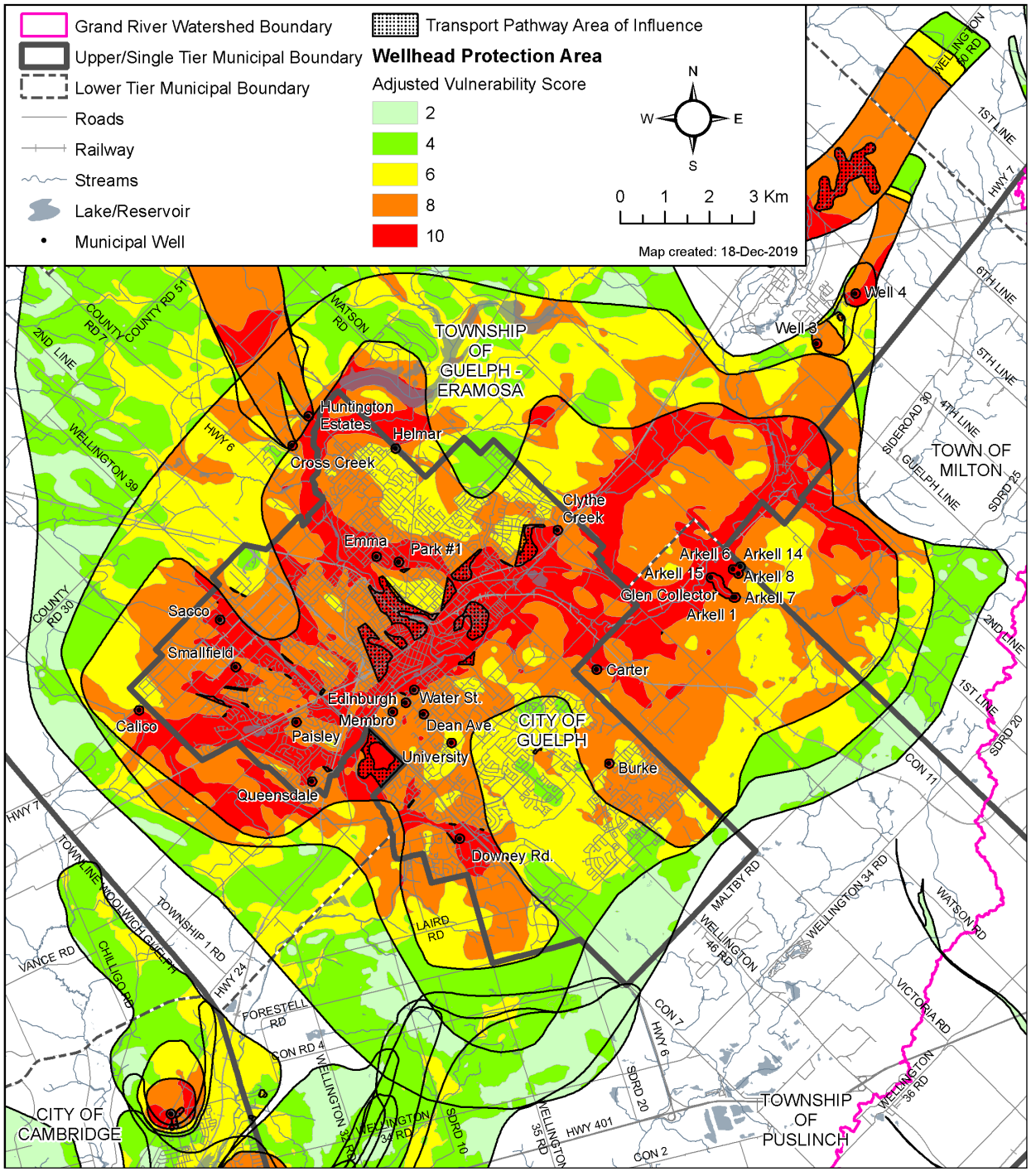
- The groundwater model calibration process included both steady-state and transient datasets and demonstrated that the final parameters derived are both consistent with field observations and those that would be expected based on the conceptual model. The capture zones delineated in this study are similar to those delineated using other models. The scenario approach was used to evaluate uncertainty in the potential capture zones. The vulnerable areas were based on the uncertainty analysis of the potential capture zones. The WHPAs reflect the combined areas of the potential capture zones based on the scenario approach and therefore there is a high level of certainty that the WHPAs define the appropriate vulnerable areas.

- The groundwater vulnerability categories (e.g., high, medium, and low) effectively assess the relative vulnerability of the underlying hydrogeological features. Many areas within the capture zones of the City's wells are identified as having a high vulnerability and this is consistent with occurrences of various contaminants which continue to be closely monitored by the City.

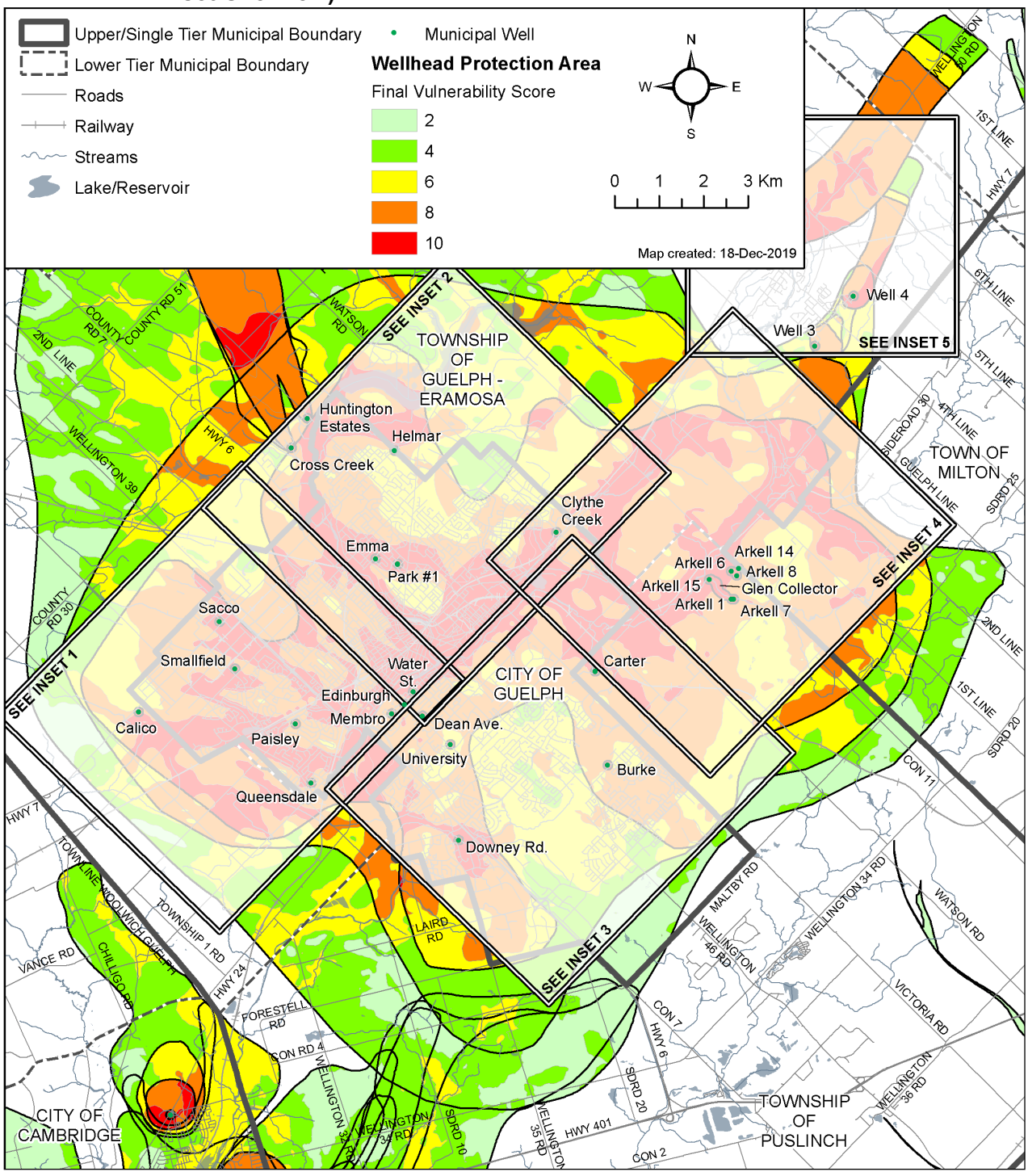
Map 7-4: Guelph Waterworks Transport Pathways (Urban Overview)



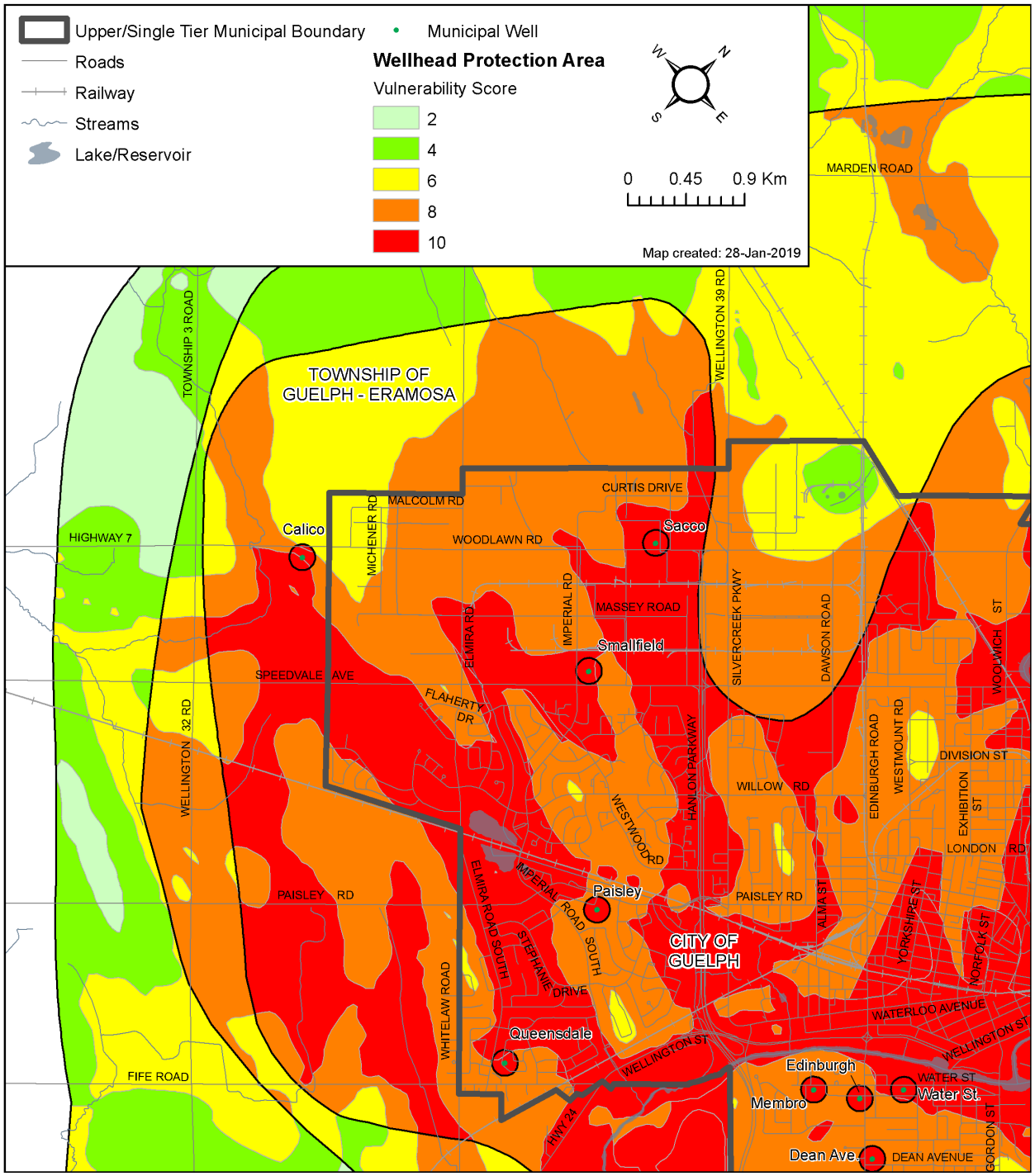
Map 7-5: Guelph Waterworks Wellhead Protection Area Transport Pathways Areas of Influence (Urban Overview)



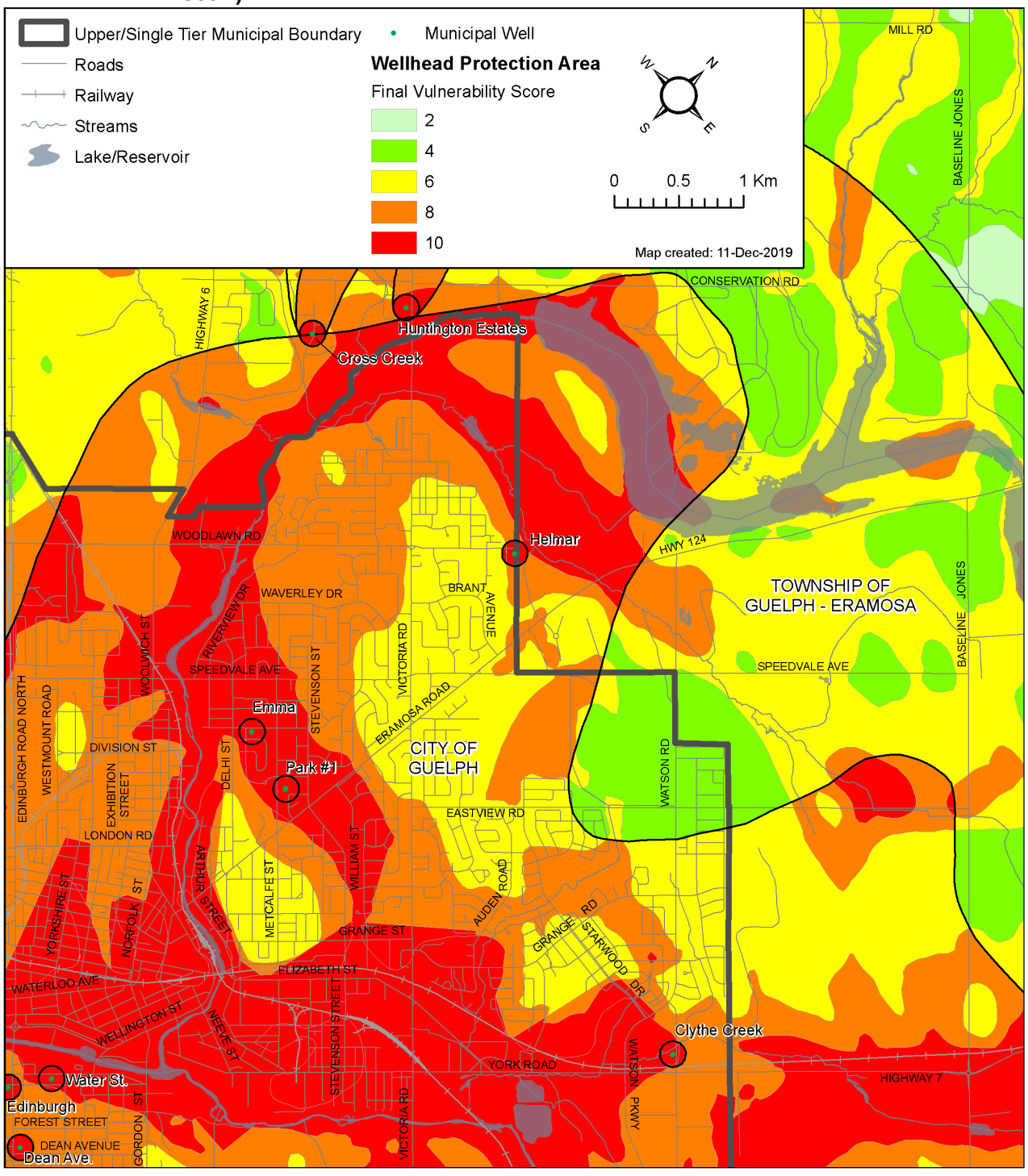
Map 7-6: Guelph Waterworks Wellhead Protection Area Final Vulnerability (Urban Inset Overview)



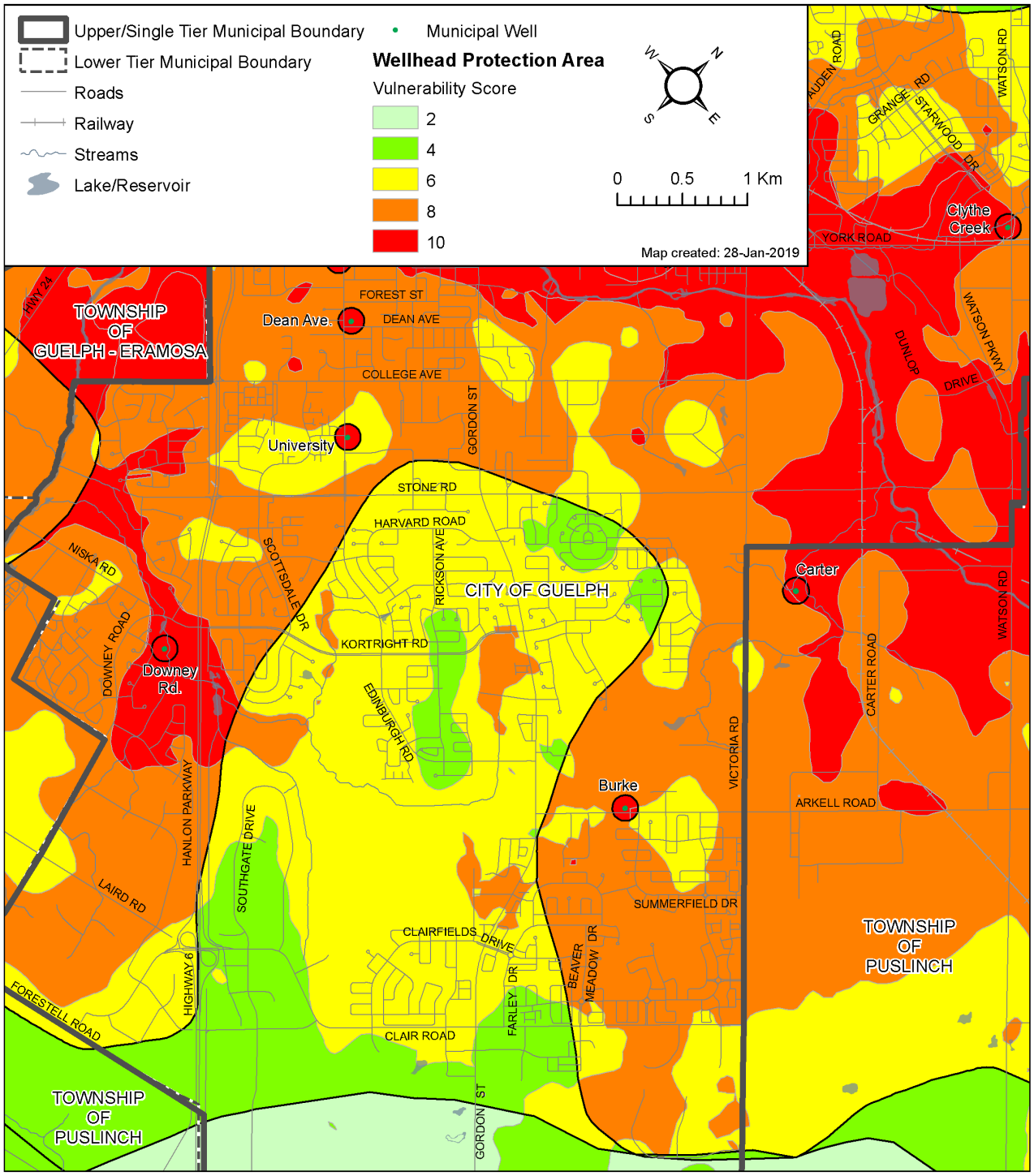
Map 7-7: Guelph Waterworks Wellhead Protection Area Final Vulnerability (Urban Inset 1)



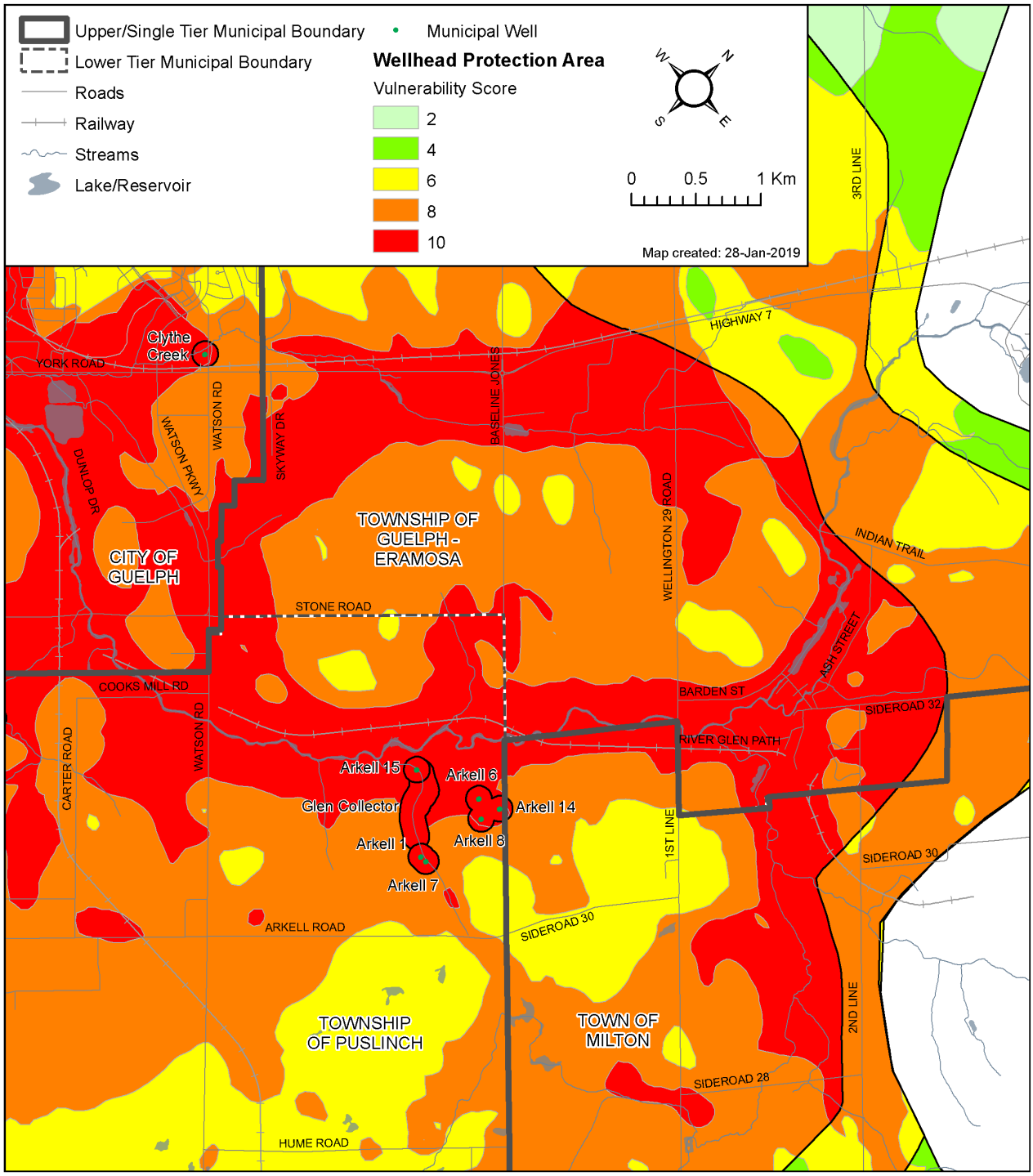
Map 7-8: Guelph Waterworks Wellhead Protection Area Final Vulnerability (Urban Inset 2)



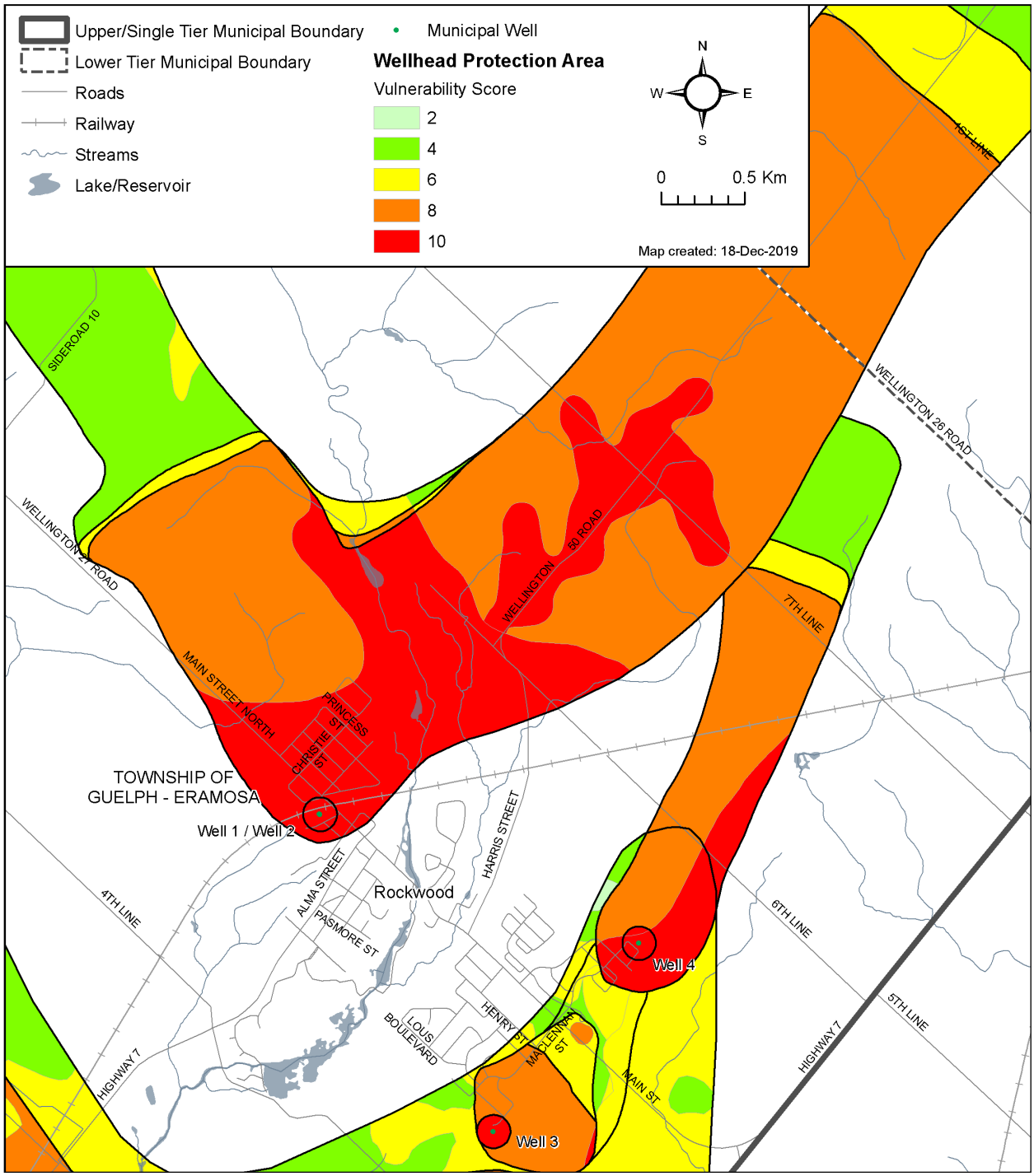
Map 7-9: Guelph Waterworks Wellhead Protection Area Final Vulnerability (Urban Inset 3)



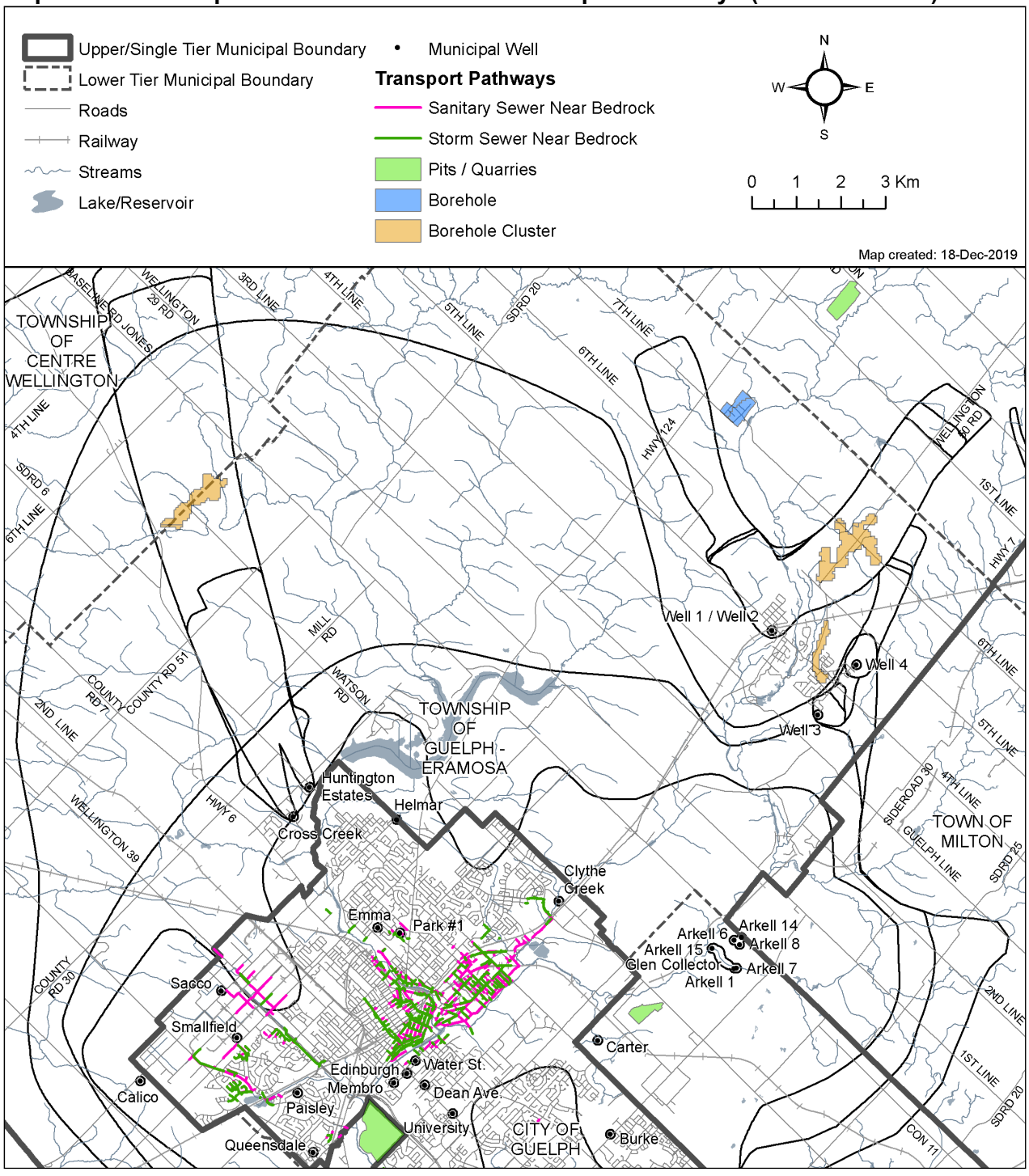
Map 7-10: Guelph Waterworks Wellhead Protection Area Final Vulerability (Urban Inset 4)



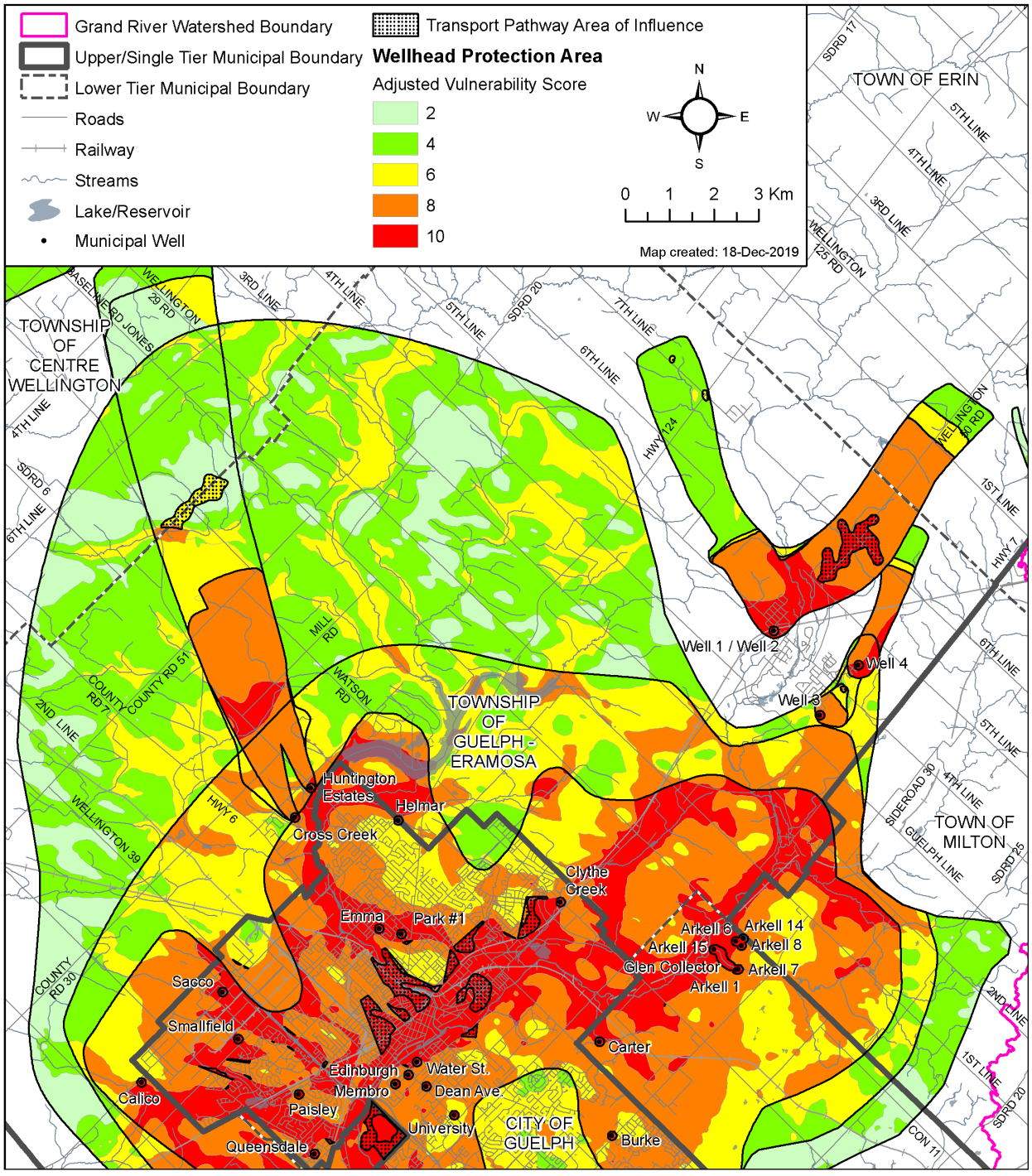
Map 7-11 Guelph Waterworks Wellhead Protection Area Final Vulnerability (Urban Inset 5) with Rockwood Wellhead Protection Area Overlay



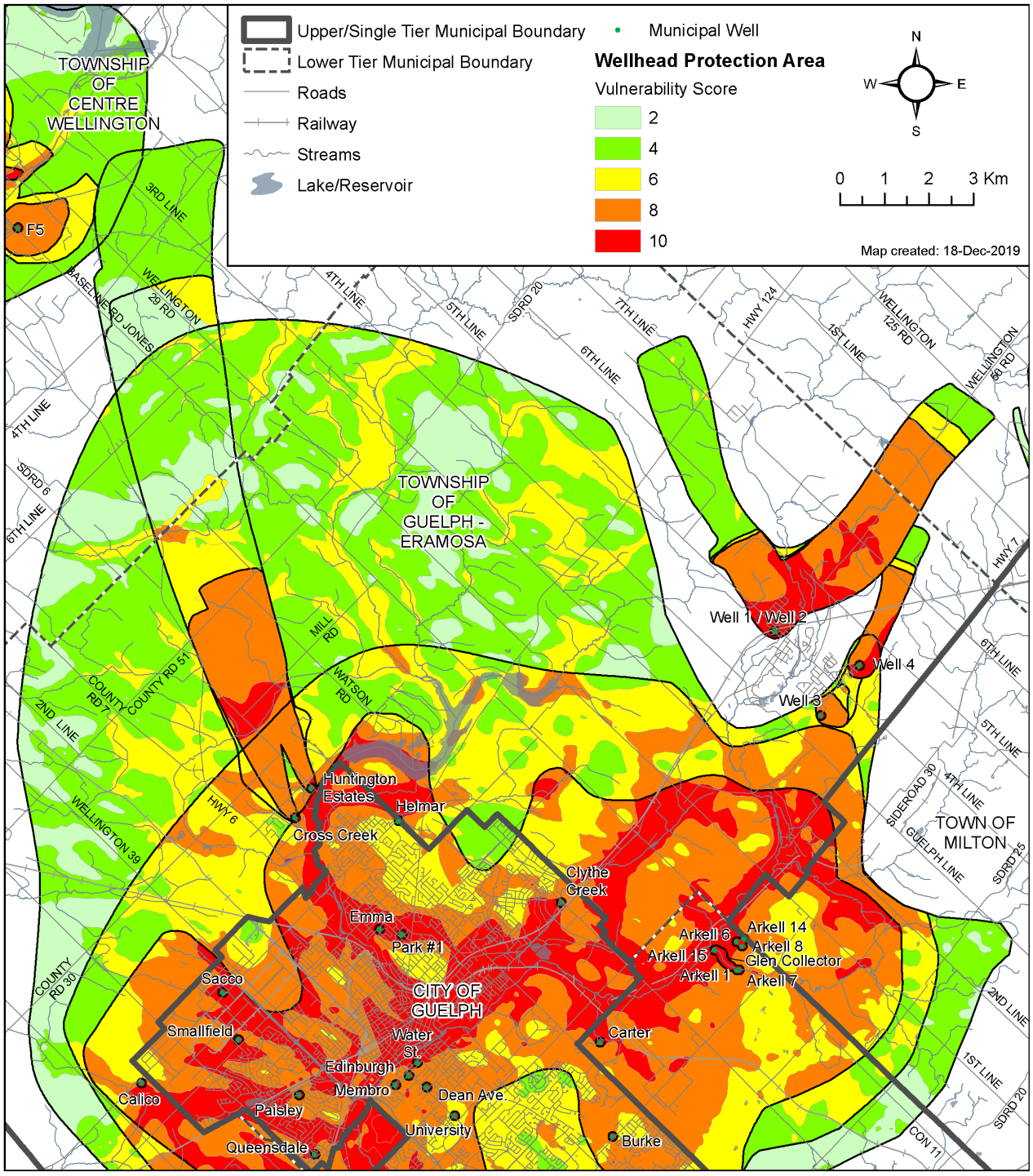
Map 7-12: Guelph Waterworks Rural Area Transport Pathways (Rural Overview)



Map 7-13: Guelph Waterworks Rural Area Wellhead Protection Areas Transport Pathways Areas of Influence (Rural Overview)



Map 7-14: Guelph Waterworks Wellhead Protection Area Final Vulnerability (Rural Overview)



Intake Protection Zones in the City of Guelph

Similarly to the Groundwater Vulnerability Assessment, which is required by the Clean Water Act for groundwater wells, a Surface Water Vulnerability Assessment is required for surface water intakes. The Surface Water Vulnerability Assessment utilizes standardized buffers around watercourses, and in-river time-of-travel calculations to identify the river and land areas (i.e., Intake Protection Zones, IPZs) where, should a spill occur, the quality of the raw intake water could be compromised.

The City of Guelph has a surface water intake on the Eramosa River located upstream of the Arkell Weir **(Map 7-15).** The intake pumps water from the river to the Arkell Recharge System. The water is infiltrated into the ground through a recharge pit and trench. The water is recovered in the Glen Collector System. The intake operates under a Permit to Take Water from April 15 to November 15 and is dependent on adequate flows in the river.

The Eramosa River intake consists of a pump attached to a concrete platform approximately 6 m from the southern river bank. A small run-of-the-river hydraulic structure or overflow weir is located approximately 85 m downstream of the intake, creating an impoundment in the vicinity of the intake structure approximately 2 m deep. The weir is constructed from rock and concrete but is very leaky. Neither the City nor the Grand River Conservation Authority imposes any operating hydraulic controls on the weir. The tracer test completed in support of the IPZ delineation study indicated that the ponded water upstream of the dam functions as a mixing zone; however, the river velocity is maintained in the downstream direction.

The weir does create a backwater area that serves to maintain a relatively constant head over the intake structure and pumps. Although the weir creates a backwater condition and therefore reduces the velocity of the stream in the vicinity of the weir, the change in velocity is small. The intake is considered a Type C river intake due to the fact that the area upstream of the weir maintains riverine characteristics. There is constant flow in the downstream direction, particularly during high flow conditions hence the direction of the flow does not change. As well, the change in velocity is small enough that it does not significantly influence the flow characteristics of the river and therefore does not warrant a change to a Type D intake. The weir is not large enough to create a significant impoundment or reservoir, which would behave more like a lake and justify a Type D classification. The Type D classification would create a much larger IPZ-1, which is not justified for this intake. For these reasons, a request was made under Technical Rule 55.1 to have this intake classified as Type C. **Appendix B** provides a copy of the written notice from the Director classifying the Eramosa River intake as Type C.

Following the methods outlined in Chapter 3 of this Assessment Report , the IPZ-1 was delineated based on a semi circle with a 200 m radius, centered on the intake, extending upstream. While the rules suggest extending the IPZ-1 10 m downstream of the intake, the IPZ-1 for the Eramosa intake was extended downstream of the intake to the face of the weir. This allows for an extra level of protection against a spill anywhere within the ponded water upstream of the weir. This modification to the IPZ-1 delineation method for a Type C intake was considered appropriate as opposed to classifying the intake as Type D which would require a significant amount of land area downstream of the weir to be included within the IPZ-1. Including the land areas downstream of the intake within the IPZ-1 would not be appropriate as it is impossible for a spill to migrate upstream above the weir. Where the delineated area abutted land, a setback of 120 m or the Regulation Limit, whichever was greater, was utilized. As the semi-circle abutted land on both sides of the Eramosa River, the IPZ-1 was laterally extended to include the full extent of the Regulation Limit.

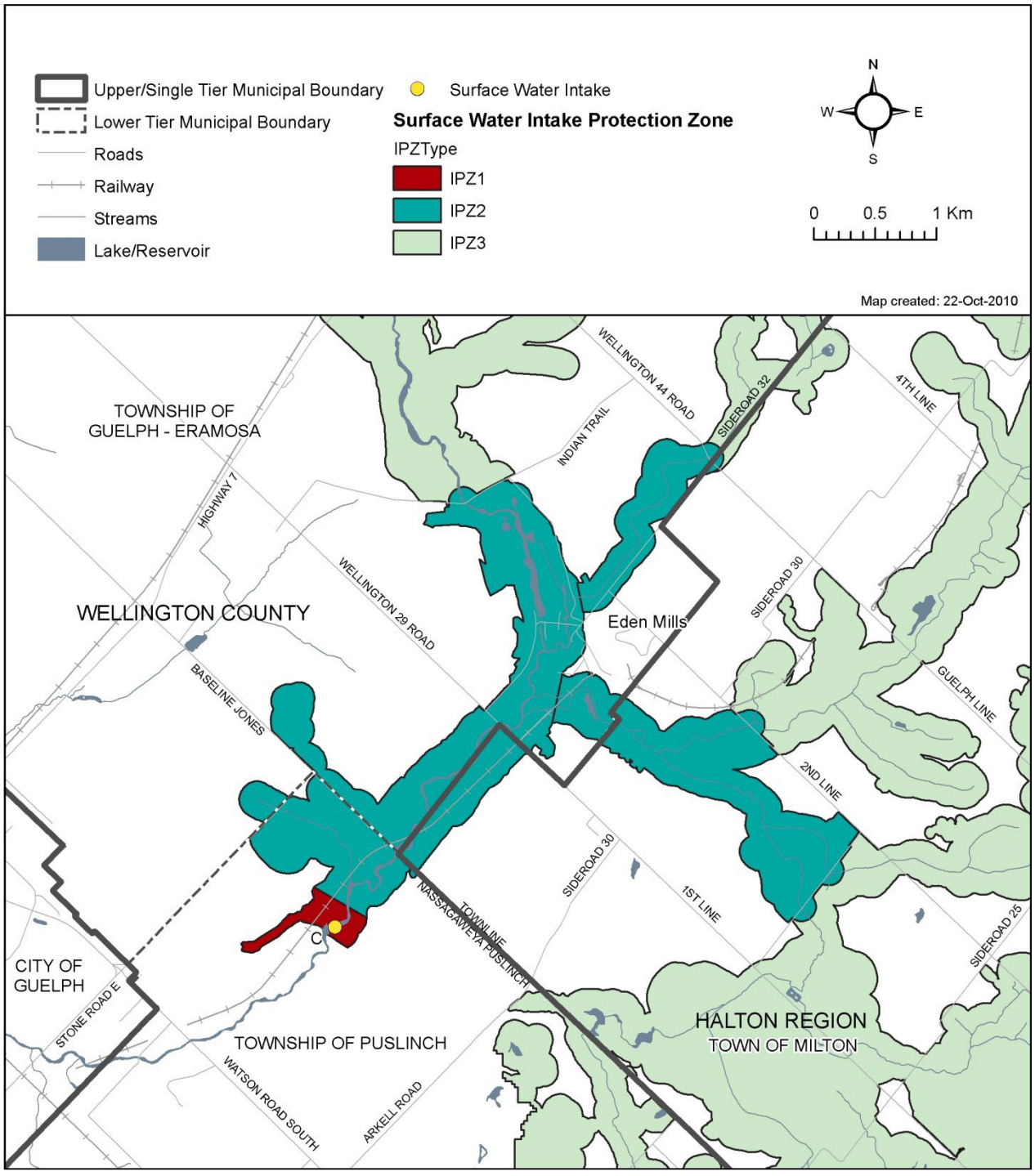
The IPZ-2 requires the determination of travel times in the river. The travel times were determined in the river using a series of dye tracer tests. Non-toxic fluorescent dye was added to the river at several locations and the time for the dye to flow to the intake was determined by monitoring downstream of the release location and at the intake. The travel times determined from the tracer tests were used to calibrate a low flow hydraulic model of the river and used to estimate time of travel under higher flow conditions. The model was developed using 26 detailed river cross sections and calibrated to observed water levels. Water levels simulated by the model were found to closely match observed levels. Time of travel characteristics from the dye tracer tests compared favourably to the time of travel characteristics predicted by the hydraulic model.

Based on this time of travel and in consultation with City of Guelph staff, the IPZ-2 was delineated to extend upstream of the Eden Mills Pond, at the Indian Road bridge crossing. Flow monitoring data indicates that a streamflow equal to 5.6 m^3/s is greater than 95% of all flow conditions that have historically been observed during the normal operation window of the Arkell Intake (April 15 – November 15). The hydraulic model output and the dye tracer tests indicates that the upstream extent of Eden Mills Pond approximately represents a six hour time-of-travel to the Eramosa River Intake at a streamflow condition of 5.6 m^3/s. This time-of-travel includes both the mixing time for water in the pond and the time for water to travel to the Intake at high flow conditions. A six hour time-of-travel was deemed appropriate in that it allows time for the City to be contacted in response to a reported event in the River and an operator to be dispatched to the site to manually shut down the Eramosa River Intake pump.

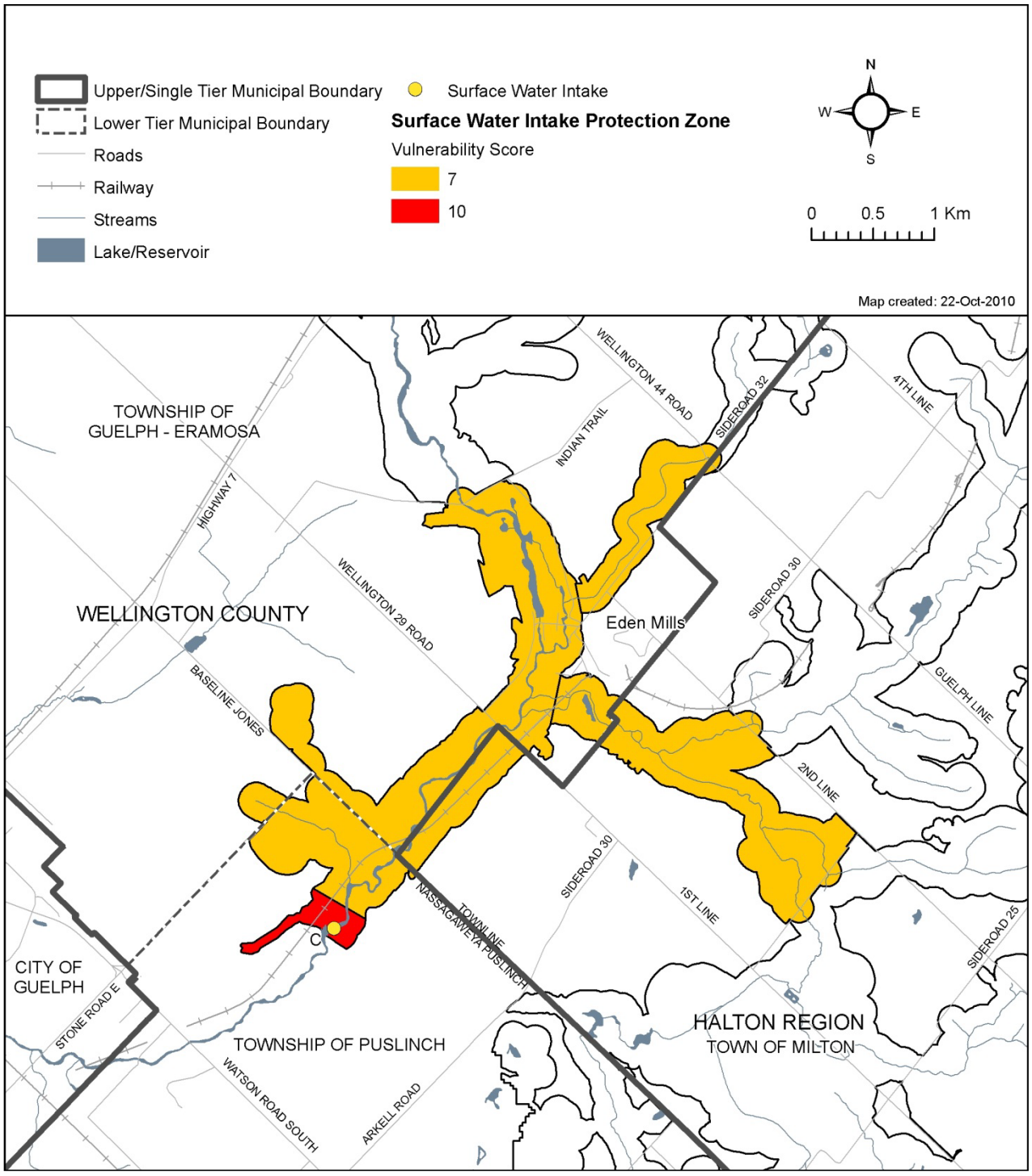
Transport pathways were considered in the delineation of IPZ-2 for the Eramosa Intake and consisted of Blue Springs Creek and an un-named tributary that flows through Eden Mills to the Eramosa River. Hydraulic modeling of these natural tributaries was not undertaken but IPZ-2 was extended up these creeks to include the first road crossing.

The lateral extent of the IPZ-2 is defined as an overland setback from those watercourses that are included within the longitudinal extent of the IPZ-2. As per the Technical Rules, a setback of 120 m, or the Regulation Limit, whichever was greater, was utilized.

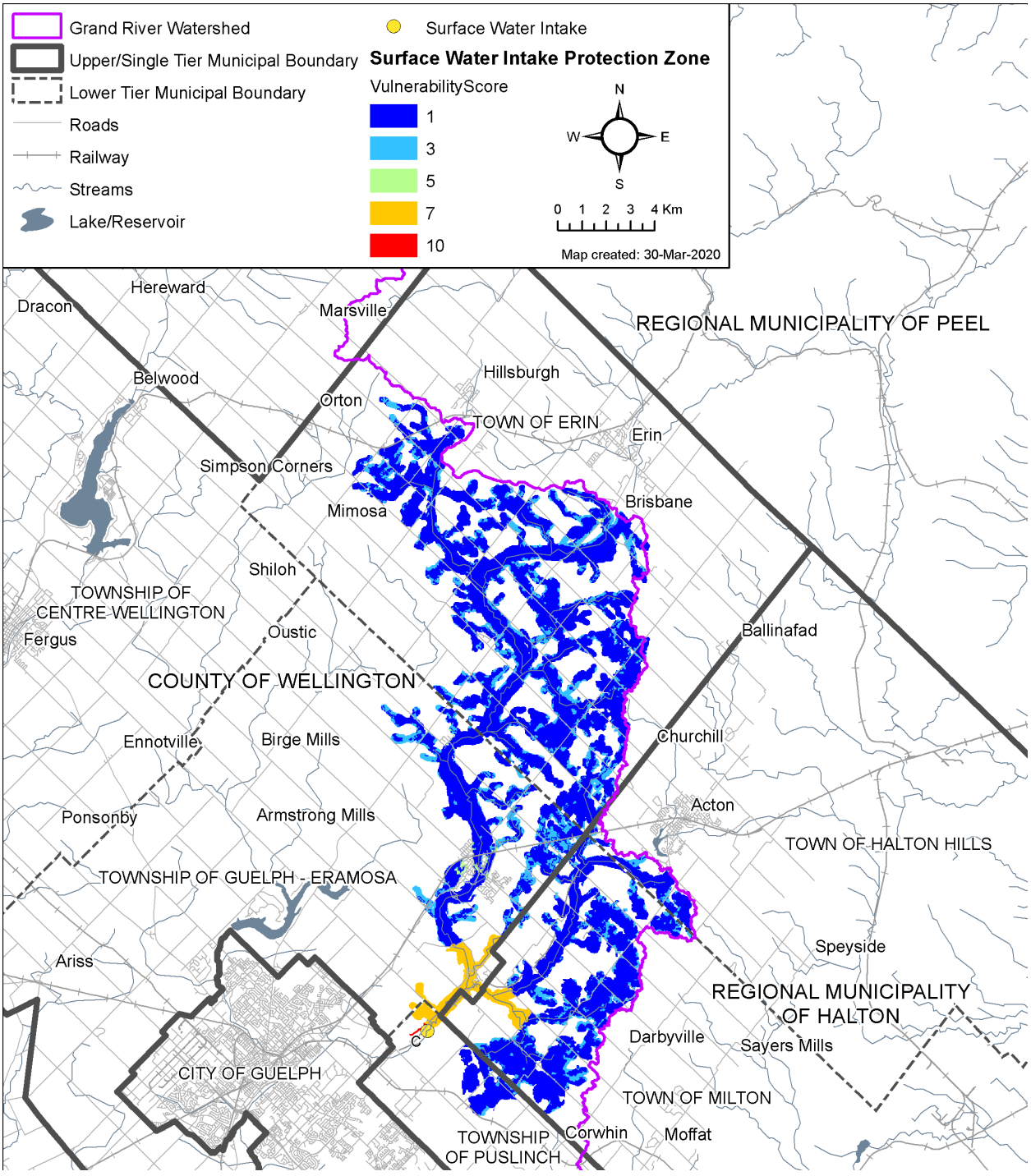
Map 7-15: Eramosa River Intake Protection Zones



Map 7-16: Eramosa River Intake Protection Zone Vulnerability



Map 7-17: Eramosa River Intake Protection Zone 3



IPZ-3 was delineated by identifying all watercourses/water bodies that supply water to the Arkell Intake. This includes any watercourse within the Eramosa River watershed, or its tributaries. A lateral setback from the included watercourses was applied, equal to 120 m or the Regulation Limit, whichever was greater.

Additional details on the process and method to determine the Eramosa River Intake Protection Zones are provided in the consultant's report.

The resulting intake protections zones are shown on **Map 7-15.**

Vulnerability Scores in Intake Protection Zones

Following the Technical Rules, the surface water vulnerability score is computed by multiplying two factors: the area vulnerability factor, which represents the vulnerability of the intake protection zone; and the source vulnerability factor, which represents the vulnerability of the intake.

The area vulnerability factor is an integer from 1 to 10, where 10 represents the highest vulnerability. As outlined in the Technical Rules, the area vulnerability factor is based on four local attributes as follows:

1) the percentage of land in the IPZ;
2) the land cover, soil type, permeability, and slope;
3) the consideration of transport pathways such as tile drainage, swales and sewer discharge pipes; and
4) for IPZ-3, the proximity of the IPZ-3 to the intake.

The source vulnerability factor for a Type C intake is a number expressed to a single decimal, ranging from 0.9 to 1, where 1 represents the highest vulnerability. As outlined in the Technical Rules, the source vulnerability factor is based on three features:

1) the depth of the intake;
2) the distance of the intake from land; and
3) the history of water quality concerns at the intake.

The area and source vulnerability factors and resulting vulnerability scores for the Eramosa River Intake are discussed in the following sections.

The Technical Rules state that the IPZ-1 is assigned an Area Vulnerability Factor of 10, as it is closest to the intake, has a higher vulnerability than the IPZ-2 or IPZ-3, and any water quality threats in this area would likely impact the drinking water intake. Therefore, the Eramosa River Intake IPZ-1 was assigned an Area Vulnerability Factor of 10.

According to the Technical Rules, an IPZ-2 for a Type C intake shall be assigned an area vulnerability factor that is not less than 7 and not more than 9 based on the vulnerability of the area where a higher factor corresponds to a higher vulnerability. The local features within the Eramosa River Intake IPZ-2 were taken into account to assign the Area Vulnerability Factor.

Land cover within the IPZ-2 consists of mainly natural areas (66%), including forests, wetlands and plantations. These natural areas have a high water-holding potential, promote infiltration and reduce direct runoff. A very small area of the IPZ-2 consists of built-up areas, specifically Eden Mills, which represents 3% of the IPZ-2 area. As a result, there is very little urban runoff within

the IPZ-2. The remaining area within the IPZ-2 consists of agricultural lands (26%). These areas are generally buffered from the Eramosa River by natural areas and there is a lower potential for the Eramosa River to receive direct runoff from farmers' fields. Overall, the land cover within the IPZ-2 would suggest that the area vulnerability factor should be at the low end of the prescribed range.

A final consideration was given to transport pathways within the IPZ-2. There are no sanitary sewers draining into the IPZ-2. Urban development is very limited in the subwatershed. A visual inspection of the Eramosa River was performed in June 2006. A very local storm sewer collection system is located within the Village of Eden Mills and appears to be entirely contained within the IPZ-2 boundaries. No tile drains were identified along the Eramosa River from the intake to Eden Mills. Vegetated drainage swales and ditches are located and were observed within the village of Eden Mills and along roads crossing the IPZ-2.

Based on the high percentage of land area, low urban drainage, and no transport pathways, the Eramosa River Intake IPZ-2 was assigned an area vulnerability factor of 7. This area vulnerability factor is at the low end of the prescribed range of 7 to 9 for the IPZ-2 and this is considered reasonable given the land cover, soils and permeability of the area as well as the very few transport pathways in the area. Based on the vulnerability assessment, the most significant transport pathways in the IPZ-2 would be roadside drainage ditches which cross the Eramosa River, Blue Springs Creek, and several small tributaries.

As stated in the Technical Rules, the IPZ-3 is assigned one or more area vulnerability factors ranging from 1 to 9, but not greater than the area vulnerability factor for the IPZ-2. Therefore, no areas within the IPZ-3 can be assigned an area vulnerability factor greater than 7.

The local attributes were used to assign the area vulnerability factors for the Eramosa River Intake IPZ-3. The IPZ-3 includes nearly all land area (95%) with generally consistent soils and hydrological conditions. As the area vulnerability factor can change within the IPZ-3, it is assigned to represent the relative impact of land cover on vulnerability with consideration given to transport pathways.

Land cover within the IPZ-3 consists primarily of natural areas (forests, wetlands, plantations), fringe agricultural areas, and very few built-up areas, namely in Rockwood, Everton, and Glenellen. Built-up areas would represent a higher vulnerability than agricultural and natural areas as they generate more direct runoff, contain possible drinking water threats, and are likely to include more transport pathways. However, ditches in Everton, and storm sewers and ditches in Rockwood, are used to convey stormwater to the river. These ditches and sewers could act as transport pathways for sediment and pollutants. The built-up areas within the IPZ-3 are a minimum of 8 km upstream of the intake, and therefore would not cause as great of a threat as those within the IPZ-2. As a result, all built-up areas within the IPZ-3 are assigned an Area Vulnerability Factor of 5. This recognizes that the built-up areas represents the most vulnerable land within the IPZ-3, but is less vulnerable than similar built-up areas within the IPZ-2.

Agricultural areas and golf courses promote more infiltration and generate less direct runoff than urban areas and therefore were assigned a lower area vulnerability factor than built-up areas. The agricultural areas are mainly within the contributing areas of smaller tributaries, and around the perimeter of the IPZ-3, but not directly connected to the major water courses. The major water courses are buffered from agricultural runoff by natural vegetated areas. However, these areas contain drinking water threats associated with livestock, fertilizers, and pesticides, and possibly

include transport pathways such as tile drains. As a result, the agricultural areas have a higher vulnerability than the natural areas and are assigned an area vulnerability factor of 3.

Natural areas make up the majority of the IPZ-3. These areas have high infiltration rates and very low runoff volumes, due to high permeability soils and bedrock, and hummocky and karst topography. Hummocky topography contains numerous surface depressions which collect and retain overland runoff, resulting in wetlands or kettle lakes that act as closed drainage systems. Karst topography forms sinkholes, caves and underground channels, and provides considerable infiltration capacity as well as potentially high travel times to the river. While they represent potential local transportation pathways, mapping of karst features with connection to surface water is not available and therefore the regional IPZ-3 mapping does not take into account this process. Although they are not mapped, there may be areas where karst features are transport pathways. As the natural areas in the IPZ-3 generally have very low overland runoff, no urban drainage and a low potential to contain drinking water threats, they are assigned the lowest area vulnerability factor of 1.

In summary, areas within the Eramosa Intake IPZ-3 are assigned an area vulnerability factor of 5 for urban areas, 3 for agricultural areas and golf courses and 1 for natural areas.

The Technical Rules specify that Type C surface water intakes are assigned a source vulnerability factor ranging from 0.9 to 1. While there is no history of water quality concerns with the Eramosa River Intake, it is a shallow intake (1.5 m) and it is within several meters of the shoreline. In addition, surface water from the intake is recharged directly into groundwater through the Arkell Springs Recharge System and as a result any contaminant introduced to the intake could be introduced into groundwater very quickly if not observed early enough to shut down the intake. In consideration of the nature of the intake and the potential for contamination to be introduced into the groundwater, the Eramosa River Intake is assigned a source vulnerability factor of 1.

The vulnerability scores for the IPZ-1, IPZ-2, and IPZ-3 are summarized in **Table 7-5**. The scores are calculated by multiplying the area vulnerability factors by the source vulnerability factors discussed in the previous sections.

Table 7-5: Summary of Vulnerability Scores for Eramosa Intake IPZs

Intake Protection Zone	Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score
IPZ-1	10	1	10
IPZ-2	7	1	7
IPZ-3 Built Up Areas	5	1	5
IPZ-3 Agricultural Areas	3	1	3
IPZ-3 Natural Areas	1	1	1

Map 7-16 illustrates the vulnerability scoring for the IPZ areas.

Uncertainty of Vulnerability Scores

The uncertainty level associated with the Arkell Intake system is low.

Delineation of intake protection zones was based on sufficient GIS data, historical flow records, field studies including geomorphology and dye tracers, hydraulic modeling, professional judgment and local knowledge to provide a reasonable level of confidence for the purposes of this report. IPZ-1 and IPZ-3 are relatively straight-forward GIS exercises based on readily available GIS data and therefore have a low uncertainty. IPZ-2 was based on comprehensive field investigations, and hydraulic modeling and are considered to have low uncertainty as well.

The various components of the source vulnerability factor (i.e. depth of intake, distance from land, and history of water quality concerns) are well known and therefore there is low uncertainty with respect to this factor.

The area vulnerability factor for IPZ-1 is prescribed in the Technical Rules (c.f. Rule 88), which means this factor has low uncertainty. Area vulnerability factors for IPZ-2 and IPZ-3 were based on the percentage of each vulnerable area composed of land, the runoff potential (e.g. land cover, soil type, slope, etc.) and the hydrology/hydrogeology of transport pathways as described above. These components of the area vulnerability factor are based on the best available data and are considered to be well characterized with reasonable confidence. The area vulnerability factor for IPZ-3 also takes into account proximity to the intake, which was estimated using GIS. Overall, it can be stated that the level of uncertainty of the area vulnerability factors for IPZ-2 and IPZ-3 is low.

To-date the City of Guelph has experienced minimal water quality issues with the Intake, and this can be partly attributed to a relatively low vulnerability of the system. While the delineation of the IPZ-2 zone and the assignment of the area vulnerability factors for each of the zones is based on a number of assumptions as described above, the system remains relatively well-protected due to natural conditions (e.g. wetlands and forests) and minimal land development.

Groundwater Vulnerability – GUDI Wells (Carter Wells)

The Technical Rules require the delineation of separate vulnerable areas for groundwater wells where the well obtains water from a raw water supply that is groundwater under the direct influence (GUDI) of surface water as determined in accordance with subsection 2 (2) of O. Reg. 170/03 (Drinking Water Systems) made under the Safe Drinking Water Act, 2002. These vulnerable areas are classified as WHPAs and described as follows:

1. Area WHPA-E, being the area delineated in accordance with the rules that apply to the delineation of an IPZ-2, as if an intake for the system were located in the surface water body influencing the well at the point closest in proximity to the well; and
2. Area WHPA-F, being the area delineated in accordance with the rules that apply to the delineation of an IPZ-3, as if an intake for the system were located in the surface water body influencing the well at the point closest in proximity to the well.

The City operates three systems that are considered to be GUDI systems: the Glen Collector system, Arkell 1 Well and the Carter Wells. The Glen Collector system and Arkell 1 wells are influenced by the Eramosa River, and therefore the IPZ-1, IPZ-2, and IPZ-3 areas delineated in the previous section are relevant for those systems.

The Carter wells are located adjacent to Torrance Creek, a small watercourse draining an area of the southeast quadrant of the City of Guelph (**Map 7-9**). The system consists of two bedrock

wells located at a distance of about 3 m apart. The wells obtain their water from the shallow bedrock which, at this location, consists of the Guelph Formation but the shallow bedrock is hydraulically connected to the water table and some of the well water is derived from Torrance Creek.

The WHPA-E and WHPA-F vulnerable areas were delineated for the Carter Wells which are considered GUDI Systems. These areas are analogous to the IPZ-2 and IPZ-3 vulnerable areas for a Type C intake and summarized below:

1. WHPA-E: It was estimated that the time of travel from the headwaters of the creek to the well is less than 2 hours, therefore the entire length of Torrance Creek was included within the WHPA-E for the Carter Wells. While the estimated water velocity is not based on hydraulic calculation the relatively short length of the Creek warrants having the entire length included within the WHPA-E area. Per Technical Rule 47(5)(b), WHPA-E was delineated from a point in the creek closest to the well. The WHPA-E is further delineated using the greater of a lateral setback of 120 m or the Regulation Limit as defined by the GRCA and as shown on **Map 7-18.**
2. WHPA-F: A WHPA-F was not delineated for the Carter Wells, as the WHPA-E includes all of Torrance Creek.

The area vulnerability score the Carter WHPA-E was given an intermediate value of 8 taking into consideration the following:

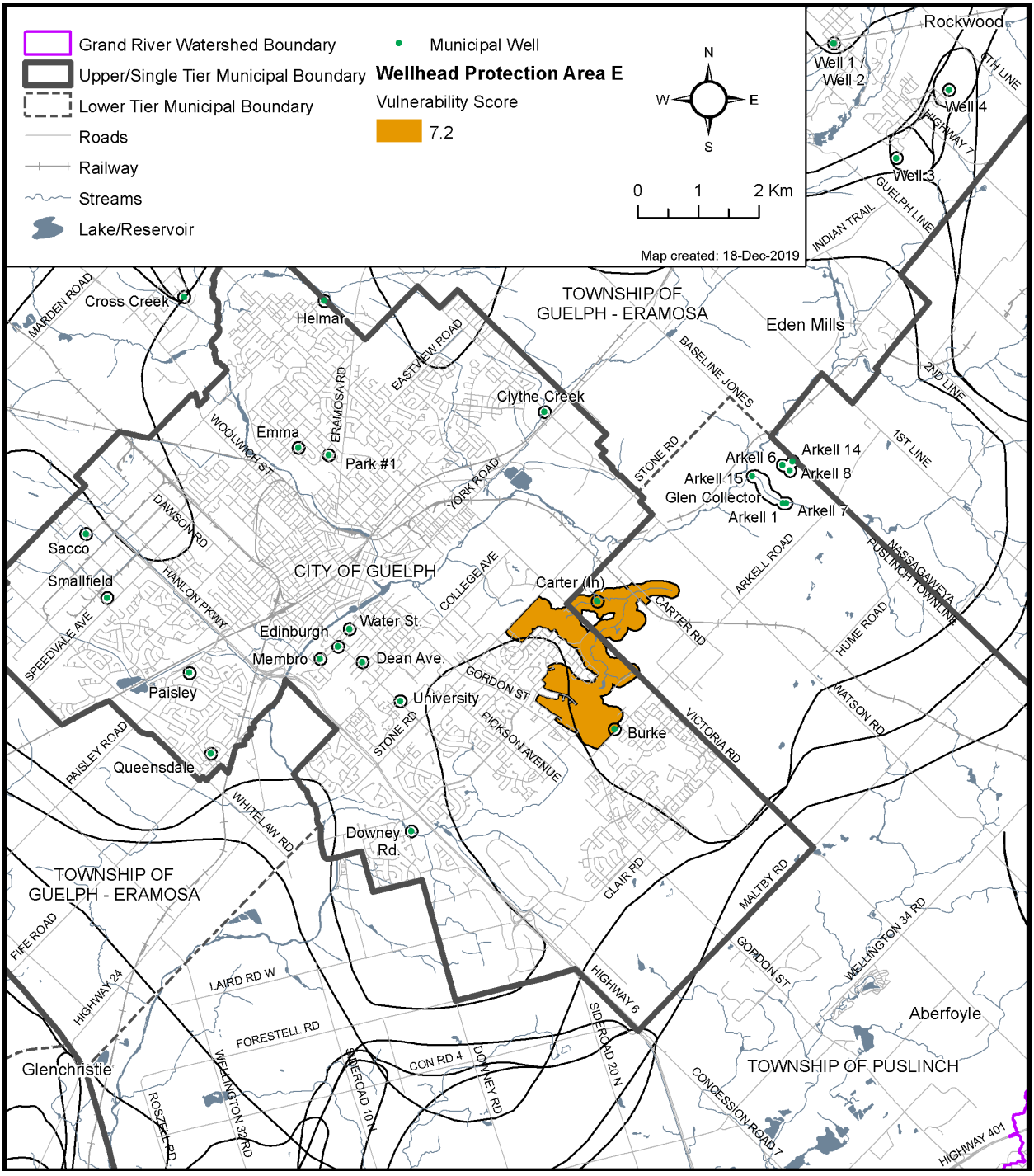
- The WHPA-E is primarily composed of land.
- Dominant land-uses include natural/vegetated areas (61%), and agricultural lands and golf courses (26%). Residential land-use makes up only 8% but there is proposed development in a portion of the WHPA-E that is expected to increase this percentage.
- There are several existing and proposed stormwater systems that discharge into Torrance Creek.

The source vulnerability score for the Carter WHPA-E was assigned based on the assumption that the GUDI well is equivalent to a Type C intake. The source vulnerability score was assigned a value of 0.9 (i.e., the lowest possible value for a Type C intake) to reflect the inherent protection provided by in situ filtration and dilution of surface water by groundwater within the capture zone of the well. Multiplying the source and area vulnerability factors together yields a vulnerable score of 7.2 for the WHPA-E for the Carter wells. **Table 7-6** provides a summary of the vulnerability score components.

Table 7-6: Vulnerability score summary for the Carter WHPA-E Zone

Location	Vulnerable Area	Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score
Carter Wellfield	WHPA-E	8	0.9	7.2

Map 7-18: Guelph Water Supply Wellhead Protection Area E Vulnerability



Peer Review of WHPAs and Vulnerability

The *City of Guelph Source Protection Project Groundwater and Surface Water Vulnerability Report* by AquaResource Inc. was submitted for external Peer Review by Christopher Neville of S.S. Papadopulos and Associates Incorporated. The comments on the Groundwater Vulnerability components were received on November 23, 2009 and were incorporated into the final report. The Peer Reviewer stated:

> *"In our opinion, the approaches adopted for the City of Guelph vulnerability assessment are consistent with the Clean Water Act Technical Rules (December 12, 2008) and the Ontario Ministry of the Environment Source Water Protection Guidance Documents. Although we have some detailed comments on the report, it is unlikely that we would reach conclusions regarding the vulnerability of the City of Guelph wells that are significantly different from those presented in the report."*

The Surface Water Vulnerability components were submitted to Dr. Hugh Whiteley for peer review. Dr. Whiteley approved of the technical work and provided comments that were also incorporated into the final report.

Data Sources Used, Limitations of Data and Methods

AquaResource (2010) provides a detailed description of the data sources used and the limitations of the data and methods. **Table 7-7** provides a summary of the data sources. For the groundwater vulnerability assessment, the vulnerable areas are delineating using a detailed three-dimensional groundwater flow model. While the development of the groundwater flow model has relied on a great amount of detailed geological and hydrogeological data, it remains a simplification of a very complex groundwater flow system. The vulnerability mapping methodology is based on a sound scientific concept that the vulnerability of the city's groundwater supplies is related to the thickness of overburden and the permeability of overburden materials. However, the accuracy of the vulnerability mapping is limited to the amount of high quality data available, and where this data is not available, vulnerability is interpolated from nearby areas.

Table 7-7: Data Sources for WHPA and IPZ Delineation and Vulnerability Scoring

Data Type	Source	Purpose
Quaternary geology, hummocky topography, landuse, watercourse mapping using Water Virtual Flow and Water Poly Segment GIS datasets	Ministry of Northern Development, Mines, Natural Resources and Forestry	Delineation and vulnerability scoring of Eramosa IPZ
Conservation Authority Regulation Limits GIS dataset	Grand River Conservation Authority	Delineation of Eramosa IPZ
Dye tracer study of Eramosa River and Blue Springs Creek	Collected as part of technical study for Assessment Report	Determine time of travel to Eramosa River intake
Geomorphology survey of Eramosa River	Collected as part of technical study for Assessment Report	Used to develop HEC-RAS hydraulic model to evaluate time of travel over a range of flows

Table 7-7: Data Sources for WHPA and IPZ Delineation and Vulnerability Scoring

Data Type	Source	Purpose
Daily average flow for Eramosa River (WSC Gauge ID 02GA029) and Blue Springs Creek (WSC Gauge ID 02GA031)	Water Survey of Canada	Establish design flow to determine time of travel at high flow conditions
Visual identification of tile drains, drainage ditches, stormwater outfalls, etc. along the Eramosa River during field studies	Collected as part of technical study for Assessment Report	Identification of transport pathways in IPZ
Water Well Information Systems (WWIS)	Providence of Ontario	Identify geological units and existing well information.
Available Hydrogeological Information (i.e., geological maps, cross-sections and water quality)	Various	To determine hydrogeological conditions to apply to modelling.

While there are limitations to the data and methods the model and modelling approach represents the current 'state of the art' with respect to the understanding of the City's groundwater flow system. This understanding will be enhanced in the future as additional data is collected and new methods are applied to map the vulnerability of the City's drinking water supplies.

Delineation of the surface water intake protection zone on the Eramosa River was based on dye tracer studies carried out under low flow conditions and a hydraulic model constructed using geomorphic survey data collected specifically for this purpose. Ideally, the dye tracer study should have been conducted under high flow, bankfull conditions but this was not possible due to logistical and scheduling constraints. This limitation was addressed by using a hydraulic model to estimate time of travel under high flow conditions. The primary limitation for the delineation of IPZ-2 was the lack of data for Blue Springs Creek and the unnamed tributary that were included as transport pathways. The IPZ-2 was conservatively extended up these pathways to the nearest upstream road crossing. In terms of the vulnerability scoring for the intake protection zones, there was sufficient data to establish the vulnerability score and no limitations were identified.

Uncertainty Assessment for the Vulnerability Analysis

The Technical Rules require that an analysis of uncertainty be carried out for the groundwater and surface water vulnerability study, and this analysis should assign an uncertainty factor of "high" or "low" to each of the vulnerable areas. The intent of the Technical Rules is to identify situations where a reasonable amount of additional work could significantly increase the certainty of the vulnerability assessment. While there are various sources of uncertainty as described in this report, the uncertainty factor for the groundwater and surface water vulnerable areas is "low'. The results of this assessment are only likely to change with significantly more technical work which may only be achieved with significantly more monitoring over large areas for many years. This conclusion is based on an assessment of several factors to be considered as required under the Technical Rules as listed in the following table.

Table 7-8: Uncertainty Analysis Factors (Part 1.4 Rule 14)

Uncertainty Assessment Factors	Description
14(1) The distribution, variability, quality and relevance of data used in the preparation of the assessment report.	The groundwater and surface water vulnerability assessments both rely on a detailed characterization of a large amount of data collected over a long period of time.
14(2) The ability of the methods and models used to accurately reflect the flow processes in the hydrological system.	The groundwater flow model has been shown to reflect groundwater flow processes both regionally and locally within the City by representing both water levels and flows to surface water under pumping conditions. The capture zones delineated in this study are similar to those delineated using other models. The scenario approach was used to evaluate uncertainty in the potential capture zones. The vulnerable areas were based on the uncertainty analysis of the potential capture zones. The WHPAs reflect the combined areas of the potential capture zones based on the scenario approach and therefore there is a high level of certainty that the WHPAs define the appropriate vulnerable areas. The surface water model used to delineate the IPZ's simulated flow velocities similar to those measured using a dye tracer test.
14(3) The quality assurance and quality control procedures applied,	Each step of the model development process relied on data that had been collected and/or reviewed by professional engineers or geoscientists.
14(4) The extent and level of calibration and validation achieved for models used or calculations or general assessments completed.	The groundwater model calibration process included both steady- state and transient datasets and demonstrated that the final parameters derived are both consistent with field observations and those that would be expected based on the conceptual model.
14(5) For the purpose of subrule 13(1), the accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.	The groundwater vulnerability categories (e.g., high, medium, and low) effectively assess the relative vulnerability of the underlying hydrogeological features. Many areas within the capture zones of the City's wells are identified as having a high vulnerability and this is consistent with occurrences of various contaminants which continue to be closely monitored by the City.
14(6) For the purpose of subrule 13(4), the accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features.	The surface water vulnerability categories effectively assess the relative vulnerability of the hydrological features. With respect to the City's Eramosa River intake, much of the IPZ-2 and IPZ-3 areas are contained within rural areas with naturally vegetated wetlands and forests buffering the river and its tributaries.

7.3 City of Guelph Drinking Water Quality Threats Assessment

Land Use Inventory Methodology

The water quality threats assessment relies on an accurate spatial inventory of landuse across the vulnerable areas. This inventory also includes databases and datasets which describe activities relating to business activities and the handling and storage of hazardous chemicals. **Table 7-9** lists the data sources used to develop the inventory.

Table 7-9: Data Sources For Threats Inventory

Data Source	*Data Provider*	*Date Acquired*
Provincial and Federal database search Environmental Registry (EBR) Regulation 347 Waste Generators Ontario PCB inventory Regulation 347 Waste Receivers National PCB inventory National Pollutant Release Inventory Anderson's Disposal Sites Chemical Register Fuel Storage Tanks Scott's Manufacturing Directory	Ecolog ERIS	October 2008
Operational and non-operational retail fuel sites, cancelled retail fuel sites, commercial fuel oil tanks	Technical Standards and Safety Authority (TSSA)	June 2009
Property Taxation Records and corresponding data	MPAC Municipal Connect™	May – November 2009
Parcel Mapping and Property Codes	City of Guelph Planning Department	September 2009
Storm Water Pond Inventory 2008	City of Guelph	September 2009
Storm Water Management Facilities Inventory 2010	City of Guelph	September 2010
Septic System Inventory	City of Guelph	October 2008
Limited Field Survey of agricultural properties	Stantec	May 2009
Roadside Survey of agricultural properties in the IPZ-1 and WHPA-E areas	Stantec	September 2010
Vulnerability Scoring	AquaResource and Stantec	December 2009

Development of the landuse inventory for the City of Guelph involved the following tasks:

1. Development of spatial reference data. This task included loading and cross-checking property (e.g., parcel maps) for the City of Guelph, Town of Milton and the County of Wellington.

2. Geo-referencing of Threats Data. The City's existing threats database (2007) was geo-referenced with the City of Guelph's parcel mapping.

3. Loading Activity and Land Use Data. The datasets listed in **Table 7-9** were loaded into the database and linked to tax roll data and parcel spatial data, where possible. Each property was then assigned a unique location identifier separate from the tax roll number. Data

checking included linking historical data to new datasets, removal of duplicate data, and elimination of businesses that were no longer in operation.

4. Field Verification. The field verification exercise was completed in July-August 2008 to confirm the locations of businesses that were identified as potential threats. Additional field verification was undertaken of significant threats without matching civic addresses or roll numbers in the fall of 2010.

5. Assigning Vulnerability Scores to Parcels. The vulnerability mapping was overlaid on the parcel mapping, and each property was linked to a vulnerability zone identifier. For the storm water management (SWM) ponds, the City of Guelph zoning information was overlaid to determine the land use of the drainage area for the SWM pond.

The final land use inventory information provided sufficient information to identify activities and circumstances at each parcel to identify water quality threats as described in the following section.

Managed Lands and Livestock Density

This section describes work completed to identify and classify managed lands, nutrient units, livestock operations and corresponding agricultural threats. Methods used to calculate managed lands and livestock density are further outlined in Chapter 3 of the Assessment Report.

Five agricultural threats relating to application of fertilizer, agricultural source material, and non-agricultural source material are prescribed drinking water threats (MOE, 2009b) and require the calculation of percent managed lands and/or nutrient units/area. These threats include:

- The application of agricultural source material (ASM) or non-agricultural source material (NASM) (percent managed land and nutrient units per acre);
- The application of commercial fertilizer (percent managed land and nutrient units per acre);
- The use of land as an outdoor confinement area or a farm-animal yard (nutrient units per hectare);
- The use of the land as livestock grazing or pasture land (nutrient units per acre); and
- Storage of agricultural source material (nutrient units per acre).

Therefore, to determine if any of the five threats were significant in the WHPAs or IPZs for the City of Guelph, the following approach to the threat allocation was taken, using the Revised Technical Memorandum from GRCA, dated September 23, 2009 (GRCA, 2009a) by using the vulnerable area land segments:

1. Determination of percent managed lands for agricultural and non-agricultural lands within the WHPAs and IPZs for the City of Guelph;
2. Calculation of nutrient units (NU) based on barn size and livestock information available for farms identified in the WHPAs and IPZs for the City of Guelph; and,
3. Enumeration of the significant threats based on the new guidance and the results of items 1 and 2 above.

Percent managed lands range from 7% in IPZ-2 to 57% in WHPA-C (**Table 7-10**). These results are generally consistent with the land use observed in these vulnerability zones. **Map 7-19** and **Map 7-25** shows the results for the percent managed land for the WHPAs and IPZs, respectively.

Seventeen agricultural properties were identified in WHPA-B, WHPA-C, WHPA-D, WHPA-E and IPZ-2 areas with sufficient data to calculate nutrient units and/or limited information regarding livestock operations. **Map 7-20** illustrates livestock density as estimated in the City's WHPAs, and **Map 7-27** illustrates the livestock density as estimated for the City's IPZs.

Following the guidance provided by GRCA (2009a), WHPA-A areas within the urban area of the City of Guelph (where livestock would not be housed and where predominant land use was non-agricultural) were assigned a NU/acre of 0 (**Map 7-20**). The percent managed land for this area ranged from 0% for the Helmar wellfield to 43% for the Membro wellfield (AquaResource, 2010). The average percent managed land for WHPA-A was 23%. IPZ-1 is comprised entirely of Grand River Conservation Authority or City of Guelph lands and all forested with no livestock (**Table 7-10**, **Map 7-27**). Additionally, the WHPA-A areas for Arkell 1, 6, 7 and 8 wells and for the Carter wells are predominantly woodlot and greenspace (i.e., limited managed lands), and therefore, nutrient units are assumed to be zero for these areas (**Map 7-20**).

A summary table indicating the percent managed land and nutrient units calculated for each WHPA and IPZ is presented below:

Table 7-10: Summary of Calculated Percent Managed Land and Nutrient Units/Acre for WHPAs and IPZs

WHPA/IPZ	*Percent Managed Lands (%)*	*Nutrient Units/Acre*
WHPA-A	23	0
WHPA-B	17	0.5
WHPA-C	57	0.3
WHPA-D	52	0.05
WHPA-E	19	2.8
IPZ-1	15	0
IPZ-2	7	3.8

The minimum percent of managed lands required for the applicable chemical threats to be significant is between 40% and 80%, and the minimum NU/acre required is at least 0.5 NU/acre (or 120 NU/hectare for animal confinement and/or pasture and grazing). Therefore, based on the current dataset and given the largest calculated percent managed lands for the WHPAs and IPZs, the highest NU/acre calculated and the corresponding vulnerabilities, no significant chemical threats were identified for any of the above listed prescribed agricultural threats in the WHPAs or IPZs for the City of Guelph.

The nutrient units estimates generated for this assessment are preliminary due to the limited data sets available for the calculations and have not been updated to reflect the 2010 vulnerability mapping or scoring. Sufficient detailed data from agricultural properties was not available to ascertain if pathogen threats (such as manure storage, grazing, pasture or outdoor confinement) were present on parcels within the IPZs and WHPAs for the City of Guelph.

Although it is unlikely that any significant chemical threats with respect to the land application of nutrients will be identified in the vulnerable areas, an assessment of potential threats from pathogens could identify parcels in these vulnerable areas where these threats could be significant. As such, the uncertainty of this aspect of the study is high.

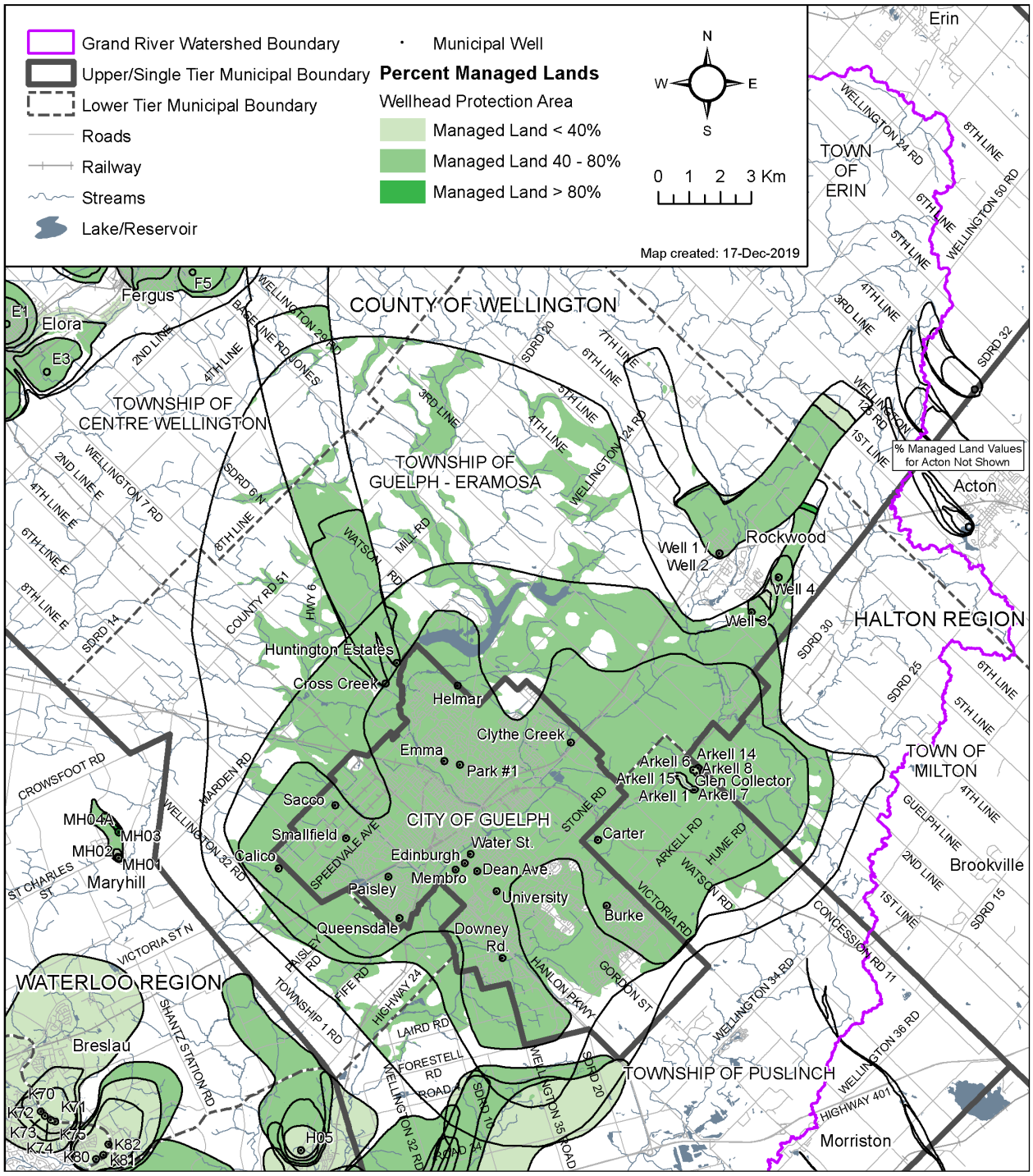
Percent Impervious Surface Area

As required by Technical Rule 16(11), an assessment of impervious surfaces was completed to identify potentially significant threats from road salt application. The calculations of percent impervious area were completed using the moving window average method for WHPA-A through WHPA-D and IPZ-3 (with vulnerability scores 9-10). The calculation of percent impervious area were comleted using the 1km x 1km method for the IPZ-1 and IPZ-2. Details on the moving window average and 1km x 1km methods are in Chapter 3 of the Assessment Report.

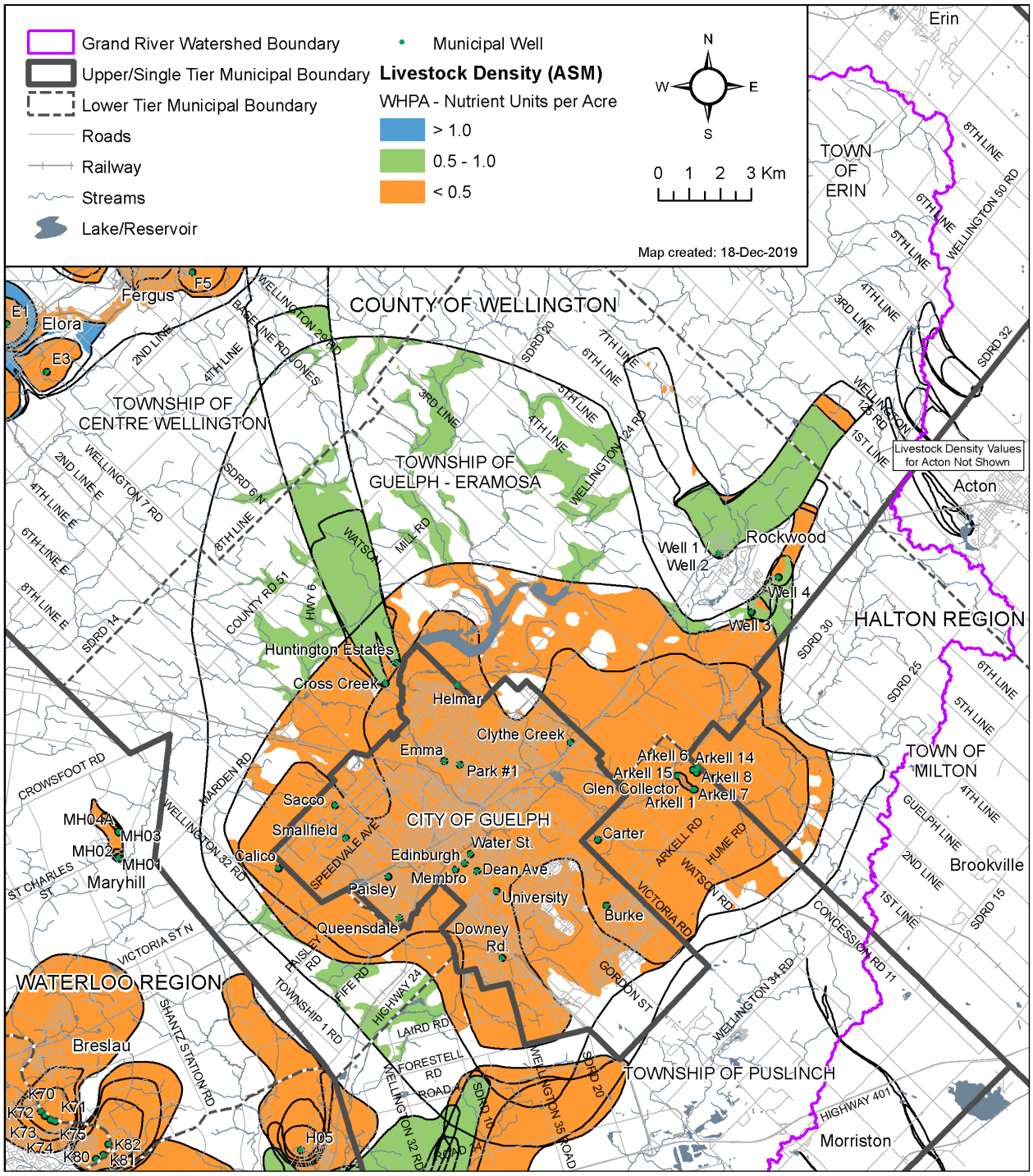
Map 7-21 illustrates the percent impervious area for each grid polygon in the WHPAs. **Map 7-29** illustrates the same for the IPZs. This assessment includes all roadways and highways, but does not include parking lots or pedestrian walkways.

The maximum percent impervious area was 17%. Therefore, given the circumstances for road salt application threats as presented in the TDWT and, given the vulnerability over WHPA-A, WHPA-B and IPZ-1 areas, as well as the small percent impervious areas calculated, no significant threats for road salt application were identified for the City of Guelph. While the analysis of impervious areas could be refined to include pedestrian walkways and parking lots, it is likely that this analysis will not increase the percent impervious area in the grid polygons to greater than 80%. As a result, significant threats for application of road salt will not be identified unless the area of the polygon is reduced substantially. The uncertainty of the analysis is therefore low based on the polygon size assumed.

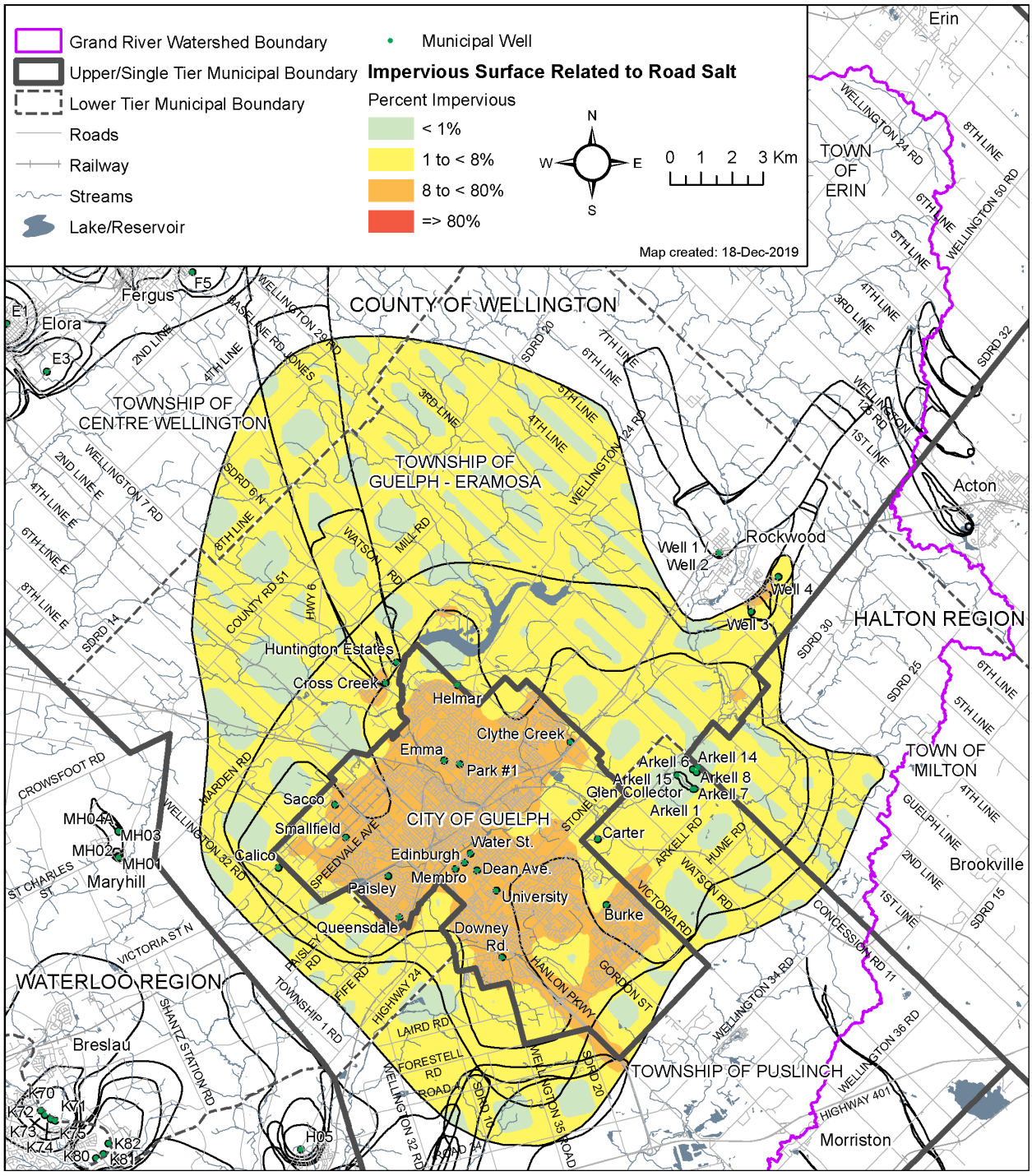
Map 7-19: Guelph Waterworks Percent Managed Lands (WHPAs)



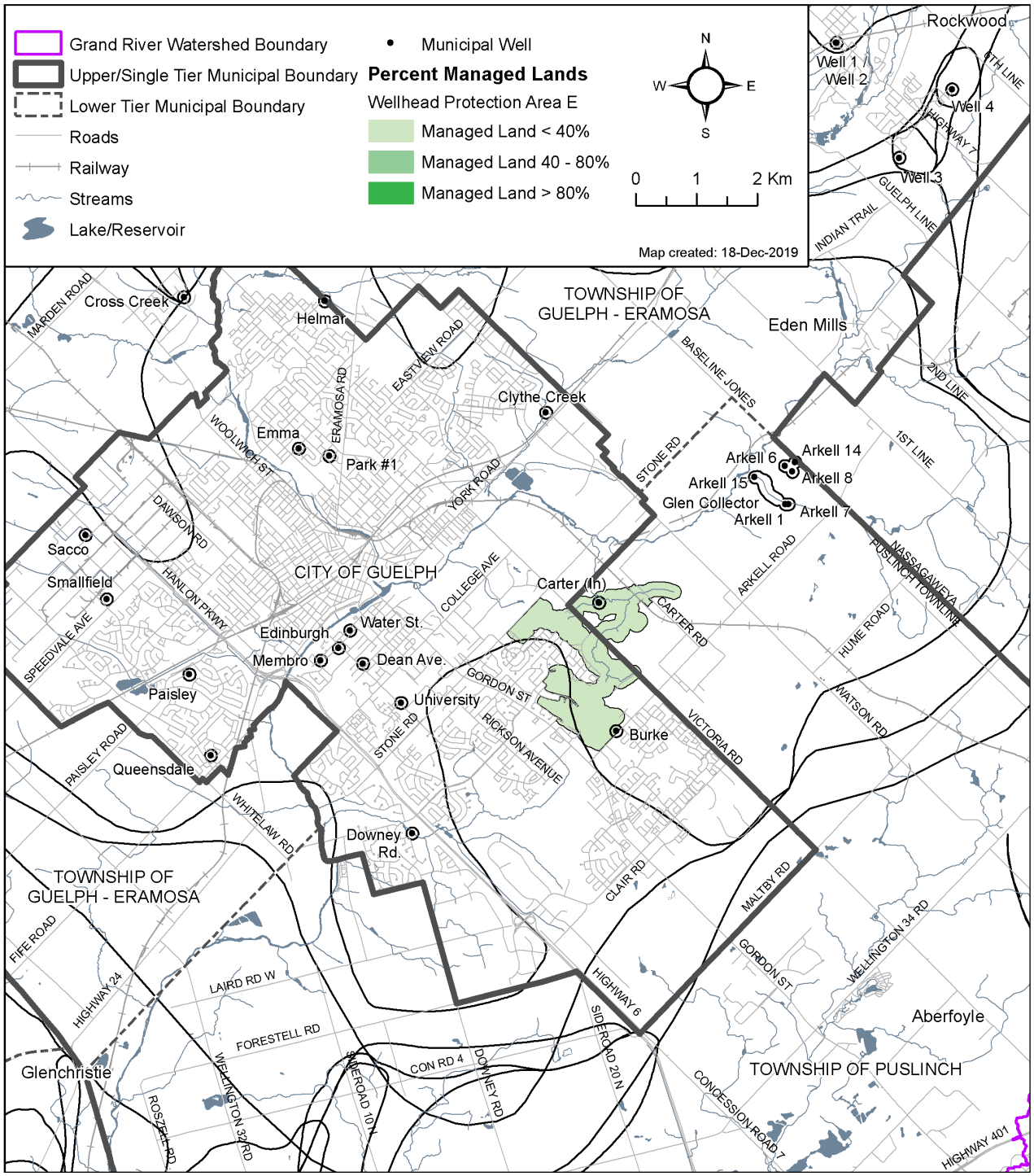
Map 7-20: Guelph Waterworks Livestock Density (WHPAs)



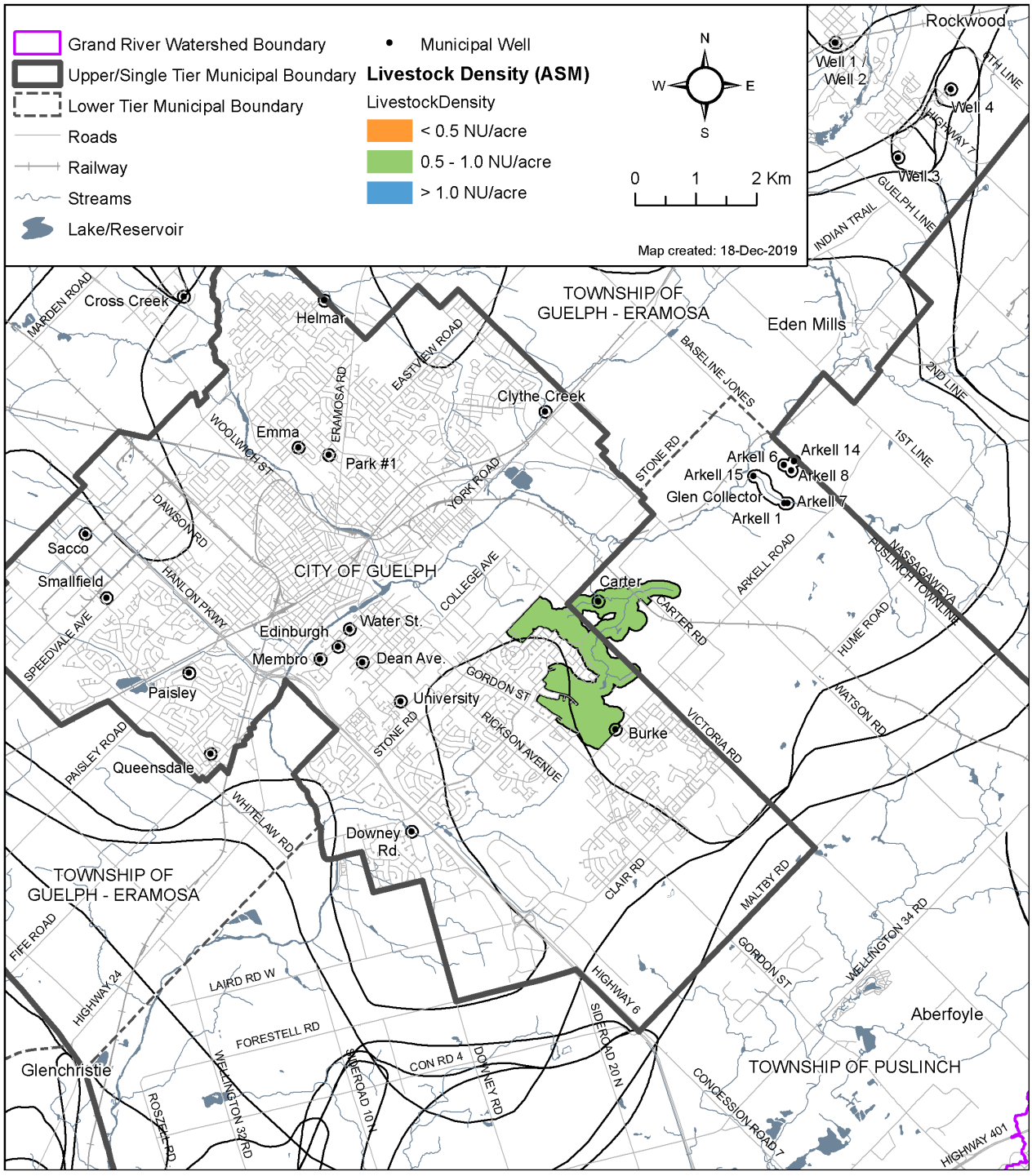
Map 7-21: Guelph Waterworks Percent Impervious Surfaces (WHPAs)



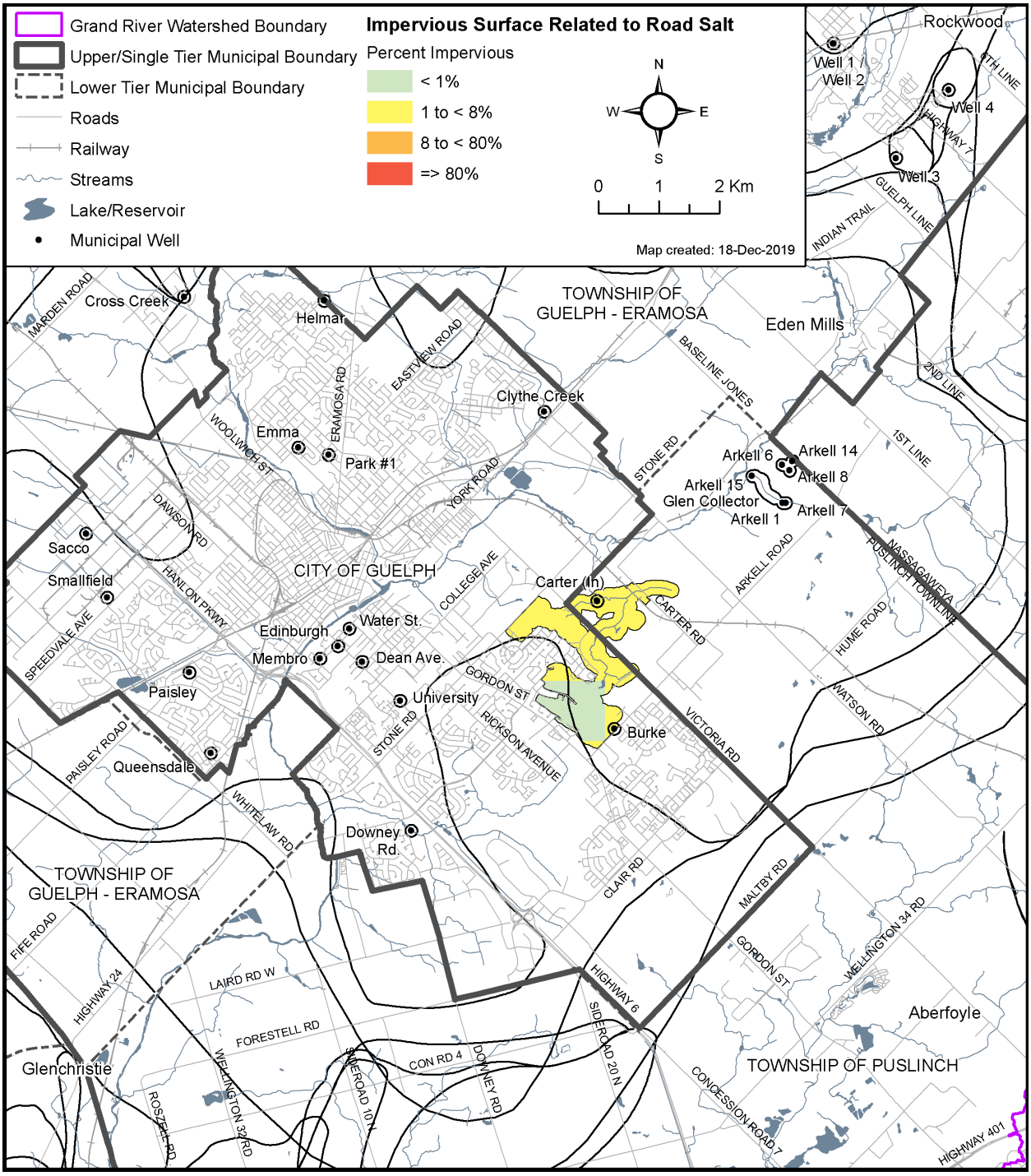
Map 7-22: Carter WHPA-E Percent Managed Lands



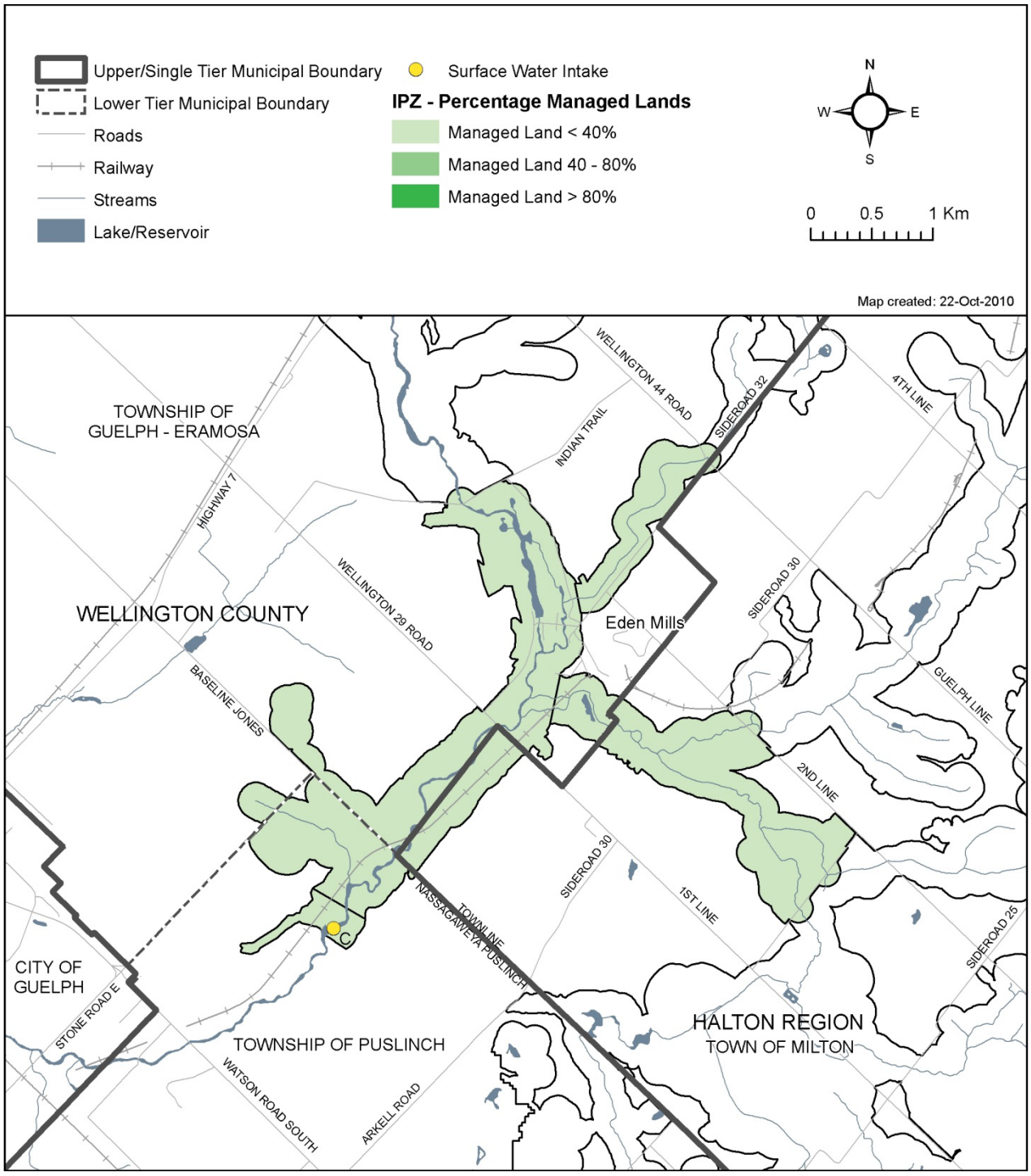
Map 7-23: Carter WHPA-E Livestock Density



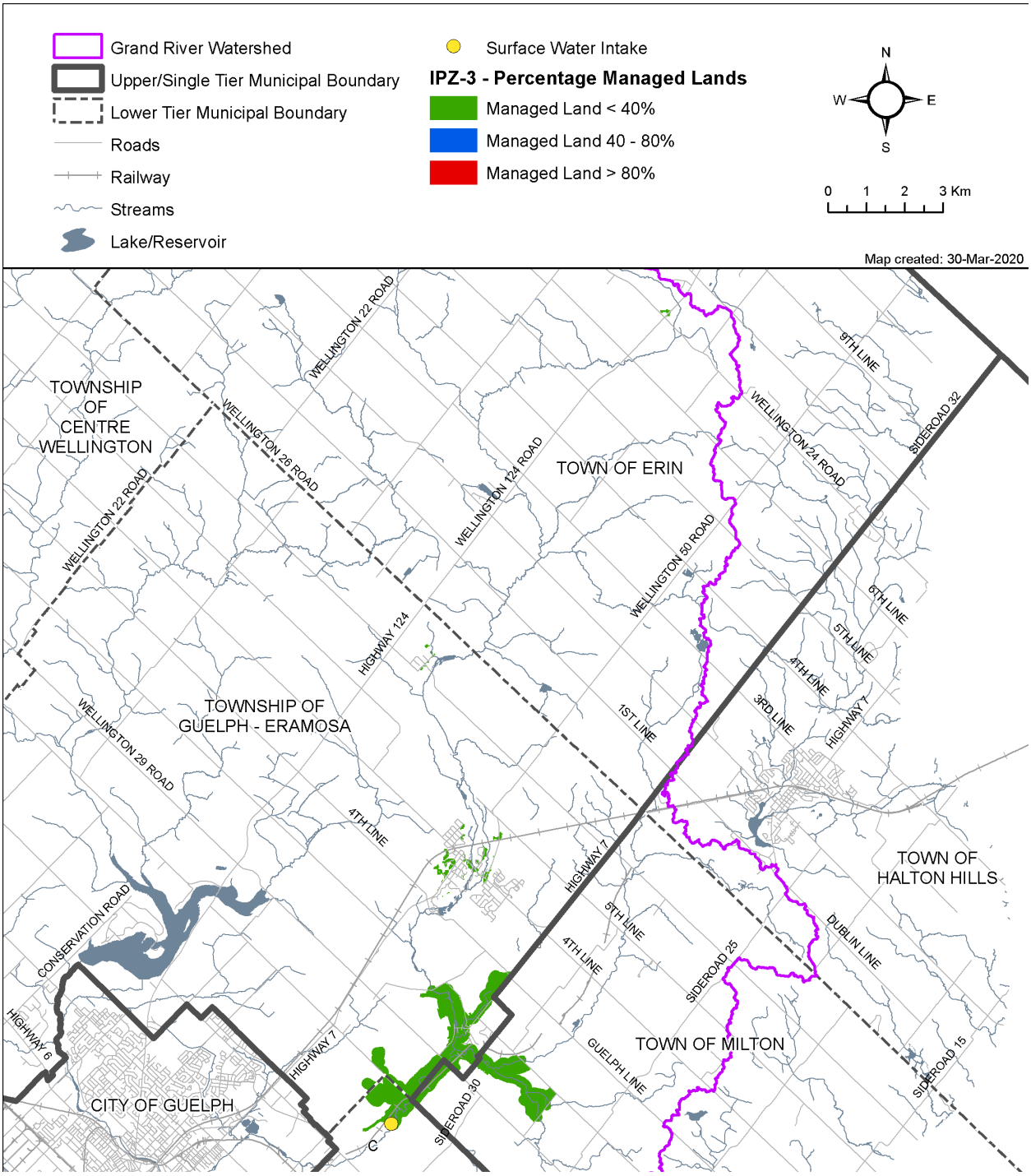
Map 7-24: Carter WHPA-E Percent Impervious Surfaces



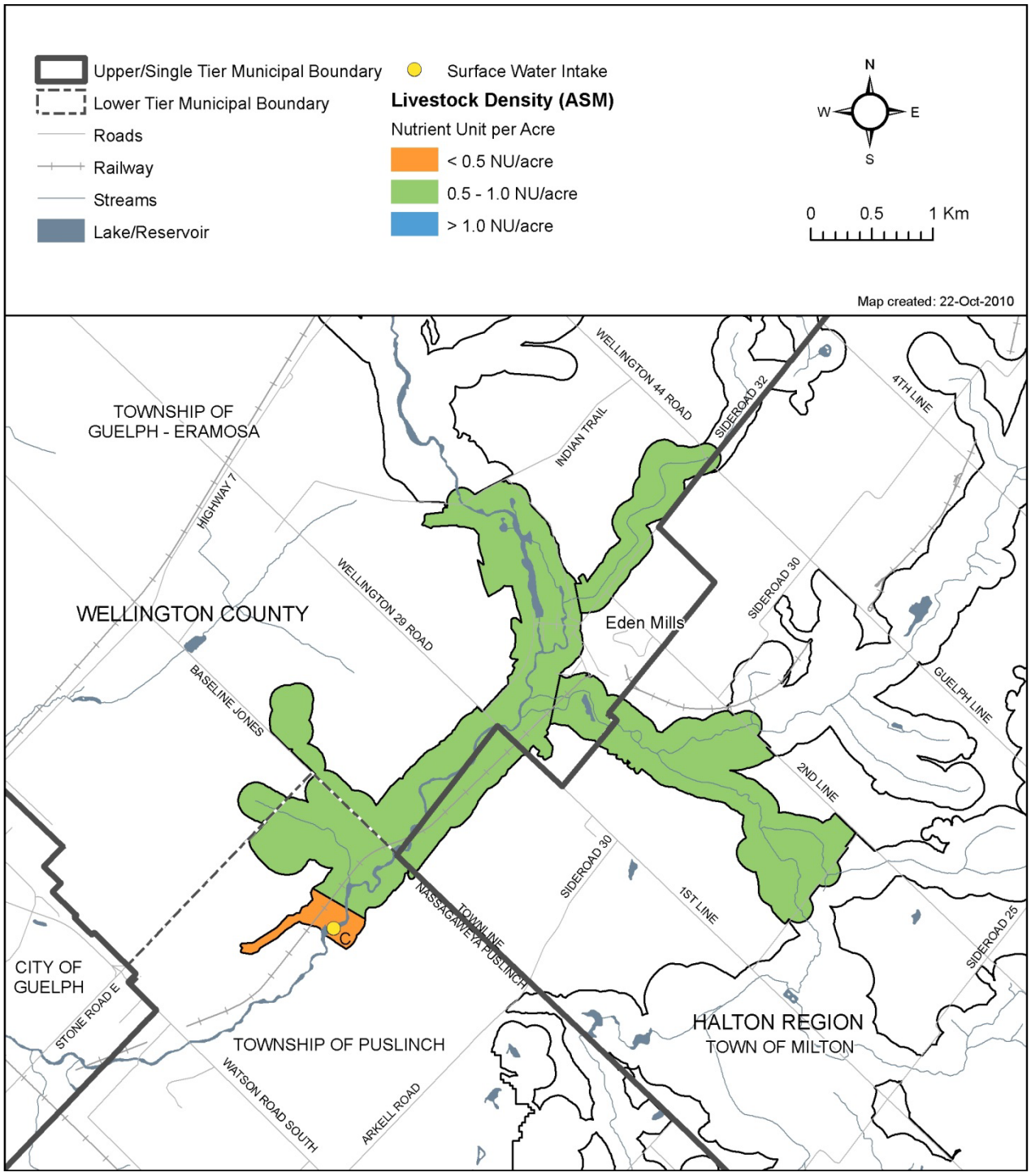
Map 7-25: Eramosa River Intake Percent Managed Lands (IPZs)



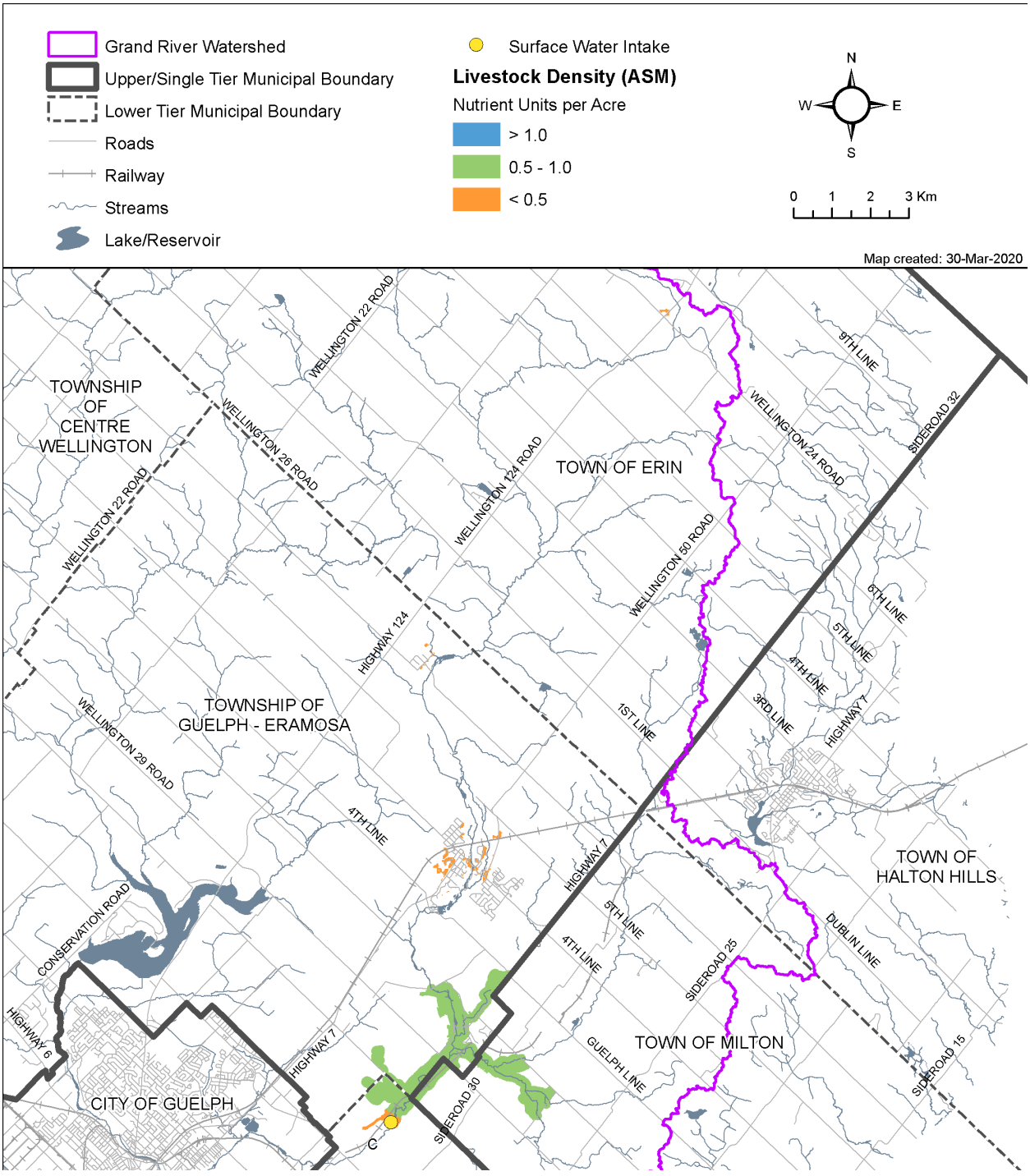
Map 7-26: Eramosa River Intake Protection Zone 3 Percent Managed Lands



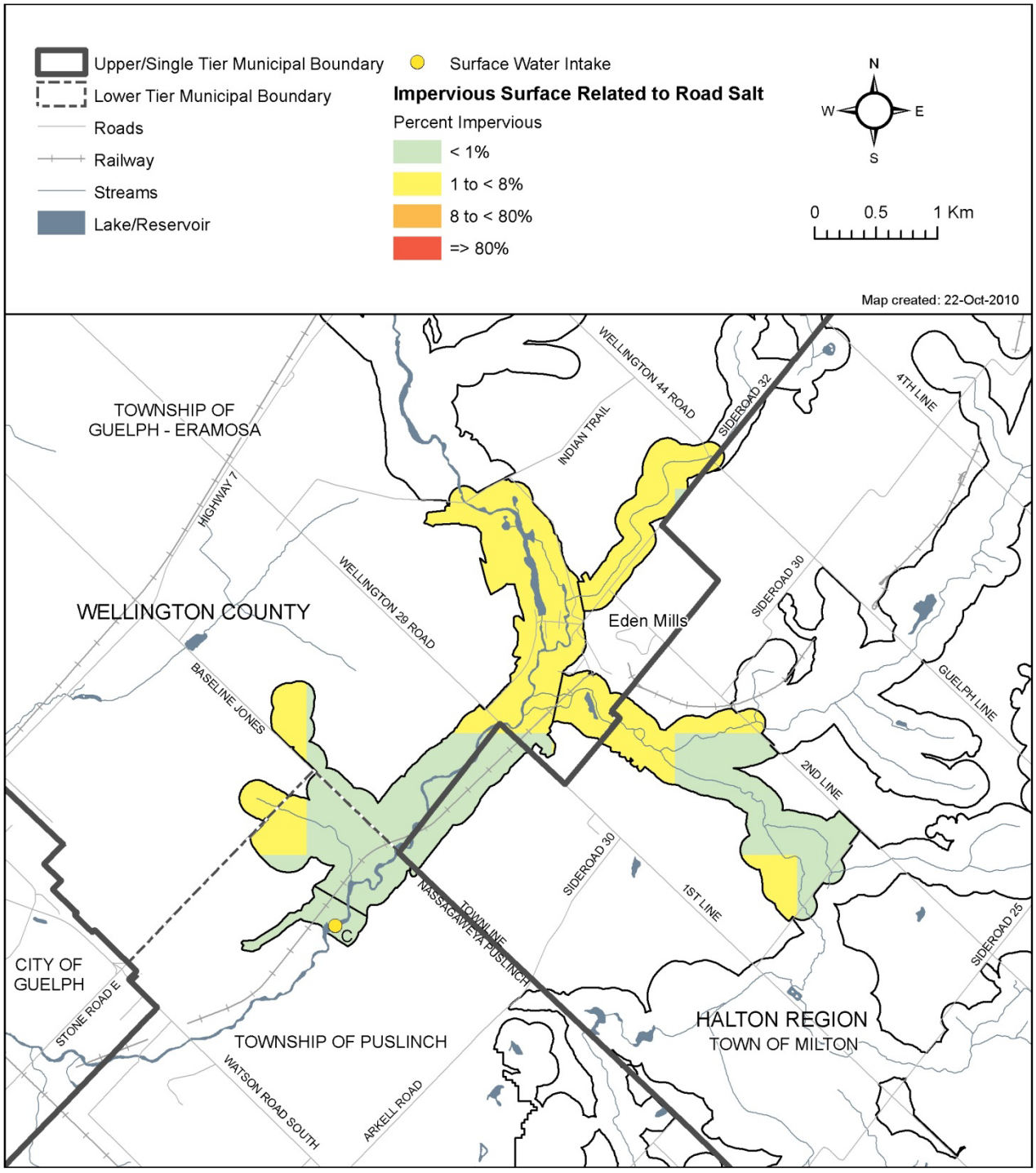
Map 7-27: Eramosa River Intake Livestock Density (IPZs)



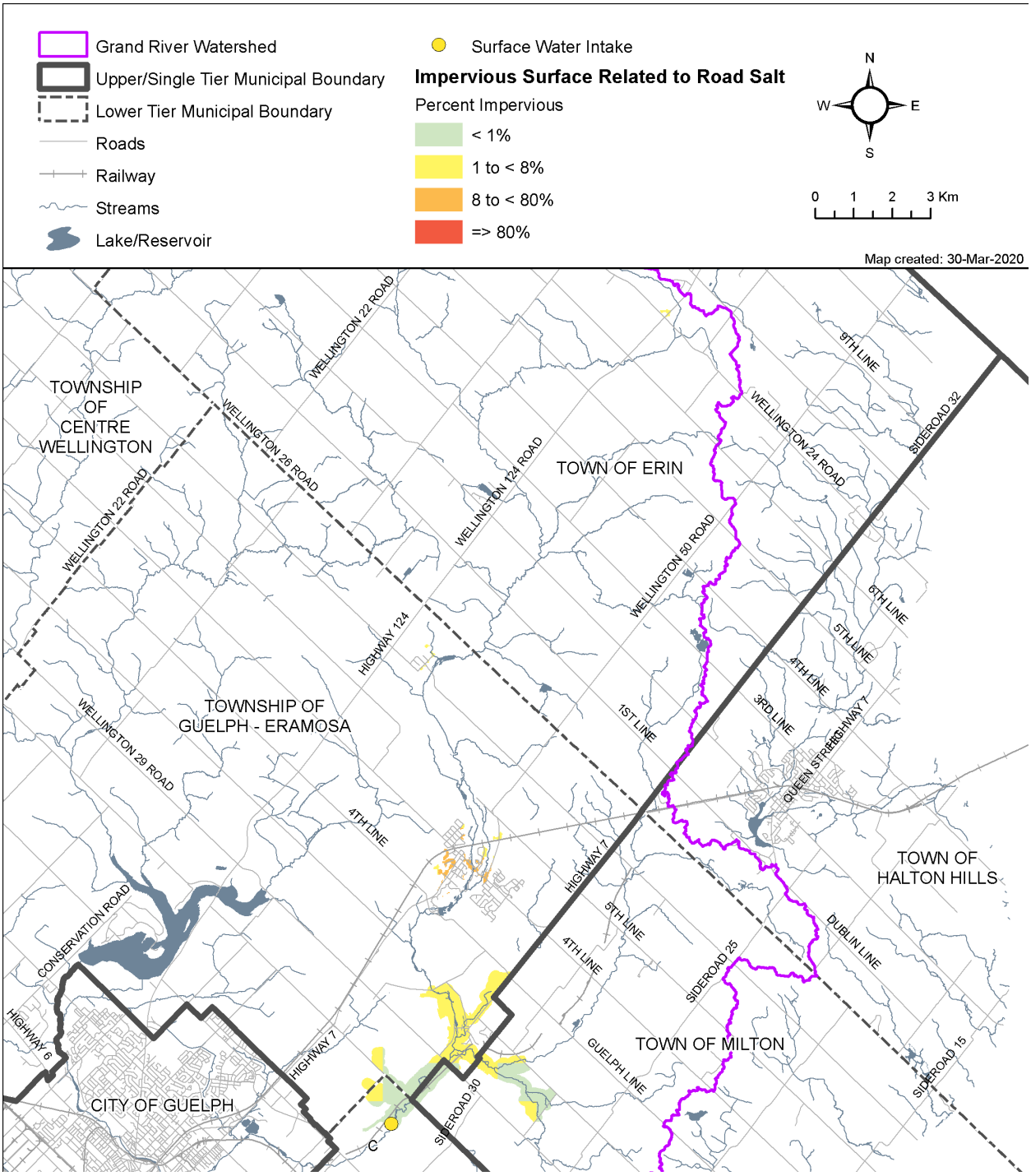
Map 7-28: Eramosa River Intake Protection Zone 3 Livestock Density



Map 7-29: Eramosa River Intake Percent Impervious Surfaces (IPZs)



Map 7-30: Eramosa River Intake Protection Zone 3 Percent Impervious Surfaces



7.4 Drinking Water Quality Threats Assessment

The Ontario Clean Water Act, 2006 defines a Drinking Water Threat as "an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat."

Identification of Significant, Moderate and Low Drinking Water Quality Threats for the Guelph Waterworks

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the Tables of Drinking Water Threats available through www.sourcewater.ca. Information on drinking water threats is also accessible through the Source Water Protection Threats Tool: http://swpip.ca. For local threats, the risk score is calculated as per the Director's Approval Letter, as shown in **Appendix C**. The information above can be used with the vulnerability scores shown in **Maps 7-6, 7-7, 7-8, 7-9, 7-10, 7-11, 7-14, 7-16, 7-17,** and **7-18** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 7-11 and **Table 7-12** provide a summary of the threat levels possible for the Guelph Waterworks, for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL), and Pathogens.A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not. The colours shown for each vulnerability score correspond to those shown in the maps.

Table 7-11: Identification of Drinking Water Quality Threats in the City of Guelph Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Threat Classification Level		
			Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	WHPA-A/B	10	✔	✔	✔
	WHPA-B/C	8	✔	✔	✔
	WHPA-B/C/D	6		✔	✔
	WHPA-C/D	2 & 4			
	WHPA-E	7.2		✔	✔
Handling / Storage of DNAPLs	WHPA-A/B/C	Any Score	✔		
	WHPA-D	6		✔	✔
	WHPA-D	2 & 4			
	WHPA-E	7.2		✔	✔
Pathogens	WHPA-A/B	10	✔	✔	
	WHPA-B	8		✔	✔
	WHPA-B	6			✔
	WHPA-C/D	Any Score			
	WHPA-E	7.2		✔	✔

Table 7-12: Identification of Drinking Water Quality Threats in the City of Guelph Intake Protection Zones

Threat Type	Vulnerable Area	Vulnerability Score	Threat Classification Level		
			Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	IPZ-1	10	✔	✔	✔
	IPZ-2	7		✔	✔
	IPZ-3	5			✔
	IPZ-3	1 & 3			
Handling / Storage of DNAPLs	IPZ-1	10	✔	✔	
	IPZ-2	7		✔	✔
	IPZ-3	5			✔
	IPZ-3	1 & 3			
Pathogens	IPZ-1	10	✔	✔	✔
	IPZ-2	7		✔	✔
	IPZ-3	5			✔
	IPZ-3	1 & 3			

Land-Use Inventory Methodology

Initial Assessment

The water quality risk assessment task involved a review of each parcel to identify the potential for any of the activities and circumstances published in the Ministry of the Environment's Table of Drinking Water Threats. Information reviewed for each parcel includes business information and chemical handling information prepared in the land use inventory. Where there is a potential for these activities and circumstances to exist on a property, the threats enumeration task was followed to identify the circumstances associated with an activity. Conservative assumptions were used for the threats enumeration. Significant water quality threats were then identified based on these assumptions and the Table of Drinking Water Threats. No site by site evaluation has been undertaken to confirm the activities and circumstances at each property.

For all circumstances other than the handling of Dense Non-Aqueous Phase Liquids (DNAPL), the Table of Drinking Water Threats (MOE, 2009d) requires that the vulnerability score be greater than or equal to 8 for a significant water quality threat to be present. The threat enumeration exercise initially focused only on those areas having a vulnerability score greater than or equal to 8 to identify potential significant threats. Additionally, circumstances relating to the handling and storage of DNAPLs can be significant in WHPA-A, WHPA-B and WHPA-C. Activities where these circumstances could occur were identified in this exercise as a priority for enumerating significant threats.

During the risk assessment, comments were added to businesses/properties in the database to support the classification of significant threats. Where only a business or property owner name was available and data was not found on the property use or activity, a comment was assigned to the parcel indicating that sufficient data was not available to identify threats for that parcel. In total, 77 properties/businesses were identified where sufficient data was not available to assign threats. Where at least one activity could be identified for a business/property and that activity

could not be a significant threat based on the vulnerability score, a comment was added indicating the activity was not a significant threat for the applicable vulnerability.

For each property, data from the 2009 Guelph database was queried to view data from the various sources for each property. Based on the data available for that property, a threat category and corresponding applicable circumstances were assigned to each property. This step relied on a worst-case assumption of the circumstances that may accompany that property.

Where limited data was available from the data sources and certainty in the data was not high, an assumption matrix was used to help assign threats. The assumption matrix was constructed for land use activities encountered in the data sets for the City of Guelph and was used to help identify potentially contaminating activities and the associated potential contaminants of concern. The following sources were used to develop the assumption matrix:

- Table 2 - Potentially Contaminating Activities from the MOE Proposal for Amending Ontario Regulation 153/04, Brownfield Record of Site Condition (EBR Registry Number 010-4642), October 2008;
- Canadian Water and Wastewater Association (CWWA) website in the 'Directory of Contaminants Database' (http://www.cwwa.ca/Contaminants/Search.asp), last updated September 24, 2004; and
- Threats and specified chemicals or pathogens listed in the Tables of Drinking Water Threats (MOE, 2009d).

The assumption matrix was constructed to compare a land use activity (e.g., dry cleaner) to a list of contaminants of concern (from the sources listed above), and linked the activity and potential contaminants of concern to an applicable threats category from the Tables of Drinking Water Threats. To assign the threat, assumptions on the land use activity were compiled (e.g. grade of handling, grade of storage, facility type, storage volume, etc.) and in the case where data was not available for the property, assumptions were made that would enumerate the threat as significant.

Several stages of quality control and quality assurance were completed during and after the threat enumeration process. The first involved cross checking properties that should be assigned threats based on vulnerability to confirm that they were assigned a threat (if applicable) or that a comment was added to the property to indicate insufficient data was available to allocate a threat. The second stage involved a check of approximately 20% of the properties by someone other than the database user to review the threat assignments and uncertainty assignments against the data available for each property and confirm an appropriate threat had been allocated. Any errors or discrepancies identified in this stage were resolved and re-checked during data follow up.

Based on the data analysed and the threat enumeration exercise, the following activities that could potentially become significant threats were identified in the vulnerability zones:

- Metal manufacturing (including tools and automotive parts);
- Meat packing plants and food processing;
- Septic systems;
- Vehicle repair and maintenance operations;
- Waste disposal sites;
- Photography, printing and/or duplicating centers;
- Retail fuel sites; and
- Dry cleaners and laundries.

Roadside Survey of Agricultural Properties in IPZ-1 and WHPA E

A roadside survey program was also undertaken of the agricultural properties located in the IPZ-1 near the Arkell Spring Grounds and the WHPA-E for the Carter Wells. The roadside survey involved reviewing land use on agricultural properties identified within these areas to assess if activities that could be significant threats such as confinement of livestock or storage/application of manure could be occurring in these areas. Parcels were enumerated as significant threats based on data collected during the survey.

Guelph Source Water Protection Survey of Significant Threats

In late 2010, the City of Guelph undertook a survey program of significant threats identified in the initial assessment. The survey was executed based on the model and documents produced by the Region of Waterloo, but were tailored to the City of Guelph's information requirements. The format of the survey was to deliver a hard copy of the survey documents to each significant threat, if possible.

An attempt was made to link all significant threats indentified in the initial assessment in the database to a parcel/tax roll or, at minimum, a civic address so a copy of the survey package could be delivered. This was completed by matching significant threat data on 2010 MPAC tax roll and parcel information provided by the City of Guelph as well as GRCA. Additional steps also included a limited field verification program to obtain civic address information for records that were not matched to tax roll information. This program was undertaken in the fall of 2010 and included obtaining GPS coordinates for properties where possible. Approximately 23 records from the City of Guelph database could not be matched to tax roll data or a civic address and as such, these significant threats did not receive a survey and have since still been considered as significant threats based on the initial assessment.

The duration of the survey period was approximately 6 weeks, and comprised of a mail-out of the survey to property owners with identified significant threats, as well as landowner contact visits to verify information and facilitate survey completion. A workshop was also held and phone calls were made to landowners, where possible, to facilitate survey completion.

The following counts were compiled from the survey program:

- In total, 914 survey packages were mailed out;
- Approximately 196 surveys were returned and marked as out of business; and
- Approximately 50 surveys were delivered as part of the personal visits list.

In total, 236 surveys were completed with the following breakdown:

- 5 agricultural surveys completed;
- 196 commercial/industrial sector surveys completed;
- 27 municipal/institutional sector surveys completed;
- 8 rural residential surveys completed; and
- 0 vacant property surveys completed.

Data obtained through the surveys was imported into the 2009 Guelph database and was linked to existing information for each parcel collected as part of the initial assessment. The data was then used to re-enumerate the properties to either validate the assumption/allocations made in the initial assessment or update the threats enumeration to reflect new information collected. Where a survey was not completed, the parcel has remained a significant threat through this

assessment. Where data indicated duplication of site location or information, screening was completed to eliminate duplication in order to obtain the most up to date location information per parcel. Re-enumerations were also quality checked at a frequency of 10% to assess if re-enumeration were appropriate.

7.5 Conditions Evaluation

Conditions are contamination that already exists and is a result of past activities that could affect the quality of drinking water. As described in the Technical Rules (MOE, 2009) the following conditions are considered drinking water threats to municipal sources if located within vulnerable areas:

1. The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or wellhead protection area;
2. The presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquids in surface water in a surface water intake protection zone;
3. The presence of a contaminant listed in Table 2 of the Soil, Groundwater and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table;
4. The presence of a contaminant in surface soil in a surface water intake protection zone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial / commercial / community property use set out for the contaminant in that Table; and
5. The presence of a contaminant in sediment, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceed the sediment standard set out for the contaminant in that Table.

Further, the Technical Rules describe the following situations where a condition would be classified as a significant threat as follows:

- An area within a vulnerable area is an area where a condition that results from a past activity listed in accordance with rule 126 is a significant drinking water threat if the risk score of the area in respect of the condition is equal or greater than 80.
- The condition is associated with a drinking water issue described in subrule 114(1) or (2);
- The condition is identified as a drinking water threat in accordance with subrule 115(4);
- The condition is located in an Issue Contributing Area identified in accordance with subrule 115(3); and
- There is evidence that the condition is or may be causing off-site contamination or the condition is on the property where the surface water intake, well or monitoring well identified in accordance with subrule 115(2) is located.

The following describes the methodology utilized to identify conditions within the City of Guelph, and if those conditions were identified as significant drinking water threats.

Conditions Database Development

The City of Guelph has compiled a detailed inventory of technical reports relating to sites with contaminated soil or groundwater. This inventory was developed based on the following sources:

- Technical documents maintained by the City. Sources included documents relating to known brownfield/contaminated sites, and
- Digital copies of documents provided by the Ministry of Environment. These documents were provided in response to a Freedom of Information request made by the City of Guelph.

As part of the conditions assessment, more than 220 documents were converted into a digital PDF format. Each document was categorized according to one of 91 unique properties within the city. The database recorded specific information regarding each property including the type of report (e.g., Environmental Site Assessments, Remediation Reports, Risk Assessment), contaminants presented in each report, and status of remediation activities.

The next step of the conditions assessment involved extracting specific groundwater and soil monitoring data for each property from the technical reports. In total, the assessment identified approximately 3,400 groundwater monitoring wells and soil samples presented in the technical reports. Groundwater and soil chemistry laboratory results were then extracted from reports and entered into an EQuIS (EarthSoft Inc.) relational database. In total, this database contains more than 7,500 samples and 130,000 unique laboratory results.

Revised Conditions Assessment

This analysis was completed to determine whether a condition exists as per the Technical Rules, and if that condition could then also be identified as a significant drinking water threat (SDWT). The initial conditions assessments completed in support of the Draft Assessment Report (AR) in 2010 and Updated Assessment Report (UAR) in 2011 were reviewed by the MOE and comments were provided to the City of Guelph in late 2011. The assessment methodology and results presented below were revised/updated to address the comments received, and discussion with MOE based on the conditions assessment presented in the Draft AR and the 2011 UAR.

The re-evaluation of the conditions focused on several key areas as described below:

1. Using available data and following the Technical Rules (MOE, 2009) to assess if a property is a condition;
2. Using available data and following the Technical Rules (MOE, 2009) to determine if an identified condition is also a SDWT;
3. Reviewing additional information provided by the MOE, and, where necessary, reviewing the reports available to the City to support the analysis in 1 and 2 above;
4. Re-evaluating properties previously considered inconclusive; and,
5. Re-evaluating available data to determine if properties with recent exceedances were appropriately listed as conditions.

Applicable Site Condition Standards

The standard used to evaluate groundwater exceedances was revised to comply with the Technical Rules and MOE guidance. As presented above, Technical Rule 126(3) and the definitions in Part I.1 specify that the Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the EPA dated March 9, 2004 should be used. However, as per additional guidance from the MOE, the amended site condition standards under O.Reg. 153/04 (April 15, 2011) can be used, if the assessment report can demonstrate that the standard being used is relevant to drinking water protection. The component of the MOE 2011 Table 2 relevant to drinking water is the GW1 component value (MOE, 2011).

Therefore, groundwater exceedances were considered to be concentrations which exceeded either the MOE 2004 Table 2 SCS, or the MOE 2011 GW1 component value.

The search query used to extract the most recent exceedances from the conditions database at a property was reviewed to determine if the database queries captured the exceedances of the applicable site condition standards at the reviewed sites. The database query was revised to obtain the most recent data from each sampling point at each property and compare the data to the applicable standards.

All parameter types were reviewed as part of the analysis completed for this assessment. However, the parameters listed below were those with persistent detections and/or exceedances above standards:

- Benzene, Toluene, Ethylbenzene and Xylenes (BTEX);
- Trichloroethylene (TCE);
- Perchloroethylene (PCE);
- Polycyclic Aromatic Hydrocarbons (PAHs); and,
- Volatile Organic Compounds (VOCs) (for parameters other than TCE and PCE).

To meet Technical Rules 140 and 141(3), the vulnerability score and location within an issues contributing area (ICA) were required. These parameters were added to the assessment based on the current mapping of ICAs and vulnerable areas/scores from the 2011 UAR, and data available for each property.

Reports Provided by the MOE

The conditions assessment was conducted based on data made available by the MOE in 2009 resulting from a Freedom of Information request. More than 200 documents were reviewed in conjunction with relevant City site-specific reports. To the extent possible, the information from these reports was incorporated into a database.

Unfortunately, the City was generally unable to obtain updated information from the MOE, so some aspects of the assessment were limited. The MOE was able to provide limited additional detail where updated information indicated a condition could be removed. As a result, it should be noted that the City is not necessarily in possession of all recent and relevant monitoring reports for all the properties reviewed in this assessment.

In the 2011 conditions assessment, the analysis of two properties as conditions was considered to be inconclusive based on the assessment approach utilized at the time. In this updated assessment, these properties were re-evaluated based on the revised approach.

Results of the Revised Conditions Assessment

Based on the above analysis, the list of sites identified as conditions and SDWTs, and the evaluation of each site in the context of the Technical Rules (MOE, 2009) is presented in **Table 7-13.**

Note that due to a lack of definitive, site-specific information, the City was unable to distinguish between a “source” site, where the contaminants in question were originally discharged to the environment due to a historical event that took place at the site and an ”impacted” site where contaminants that were introduced into the environment from a historical event that took place at another site have migrated onto the “impacted site”. As a result, some sites in **Table 7-13** may be

"source" sites and some sites may be "impacted" sites. This is an important point since it means that the Condition is not necessarily limited to the property where the past activity took place. In addition, it also means that there may be fewer contaminant plumes in the City than may be indicated by **Table 7-13**.

Township of Puslinch Conditions Assessment

The results of the condition site assessment presented in the Approved Grand River Assessment Report (August 2012) indicated that no potential or condition sites were identified within the Township of Puslinch. The condition site assessment presented in the 2015 Approved Grand River Assessment Report (November 25, 2015) identified one potential condition site within the Township of Puslinch within the municipal wellhead protection area for a well that is part of the City of Guelph Waterworks. At the time, there was uncertainty whether the site met the Technical Rules as a condition or significant drinking water threat condition site.

At this time there still remains uncertainty whether the site meets the Technical Rules as a condition or significant drinking water threat condition site. In this Assessment Report the site is therefore still identified as a potential condition site for impacting groundwater quality pending further analysis. Once completed, the results of this assessment would be included in a future Assessment Report.

Table 7-13 Properties Classified as Signficant Water Quality Threats through the Conditions Evaluation

Site	Parameter	Meets Rule 126 as a Condition	Evaluation of Technical Rule 140, 140.1					Evaluation of Technical Rule 141				WHPA (Well Name)	Significant Drinking Water Threat
			Vulnerability Score	Contamination Off-Site (regardless of source)	Hazard Rating	Risk Score	Meets Technical Rule 140 as a SWDT Condition	Meets 141 (1) (TCE exceedance)	Meets 141 (3) (Located in an ICA)	Meets 141 (4) (TCE Contamination Off-site)	Meets Technical Rule 141 as a SWDT Condition		
1	PCE	Yes	8	Yes	10	80	Yes	No	NA	NA	No	C (Membro)	Yes
2	VOCs, PCBs	Yes	8	Yes	10	80	Yes	No	NA	NA	No	C (Membro)	Yes
3	TCE, VOCs	Yes	10	Yes	10	100	Yes	Yes	Membro	Yes	Yes	B (Membro/ Smallfield)	Yes
4	TCE, VOCs, BTEX/PHC, PCE	Yes	10	Yes	10	100	Yes	Yes	Membro	Yes	Yes	B (Membro/ Smallfield)	Yes
5	TCE	Yes	10	Yes	10	100	Yes	Yes	Smallfield	Yes	Yes	B (Smallfield)	Yes
6	TCE	Yes	10	Yes	10	100	Yes	Yes	Smallfield / Membro	Yes	Yes	A (Smallfield), B (Membro)	Yes
7	TCE	Yes	10	Yes	10	100	Yes	Yes	Membro / Emma	Yes	Yes	B (Emma), C (Membro)	Yes
8	VOCs, BTEX/PHCs, PCE	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Emma)	Yes
9	TCE	Yes	10	Yes	10	100	Yes	Yes	Membro/ Smallfield	Yes	Yes	B (Membro/ Smallfield)	Yes
10	TCE, BTEX/PHC	Yes	10	Yes	10	100	Yes	Yes	Membro	Yes	Yes	B (Membro)	Yes
11	TCE, VOCs	Yes	8	Yes	10	80	Yes	Yes	Membro / Smallfield	Yes	Yes	B (Membro/ Smallfield)	Yes
12	TCE, BTEX/PHC, VOCs	Yes	10	Yes	10	100	Yes	Yes	No	NA	No	B (Water)	Yes

Table 7-13 Properties Classified as Signficant Water Quality Threats through the Conditions Evaluation

Site	Parameter	Meets Rule 126 as a Condition	Evaluation of Technical Rule 140, 140.1					Evaluation of Technical Rule 141				WHPA (Well Name)	Significant Drinking Water Threat
			Vulnerability Score	Contamination Off-Site (regardless of source)	Hazard Rating	Risk Score	Meets Technical Rule 140 as a SWDT Condition	Meets 141 (1) (TCE exceedance)	Meets 141 (3) (Located in an ICA)	Meets 141 (4) (TCE Contamination Off-site)	Meets Technical Rule 141 as a SWDT Condition		
13	BTEX/PHC	Yes	8	Yes	10	80	Yes	No	NA	NA	No	B (Membro)	Yes
14	BTEX/PHC	Yes	8	Yes	10	80	Yes	No	NA	NA	No	C (Membro)	Yes
15	TCE< VOCs, BTEX/PHC PAHs	Yes	10	Yes	10	100	Yes	Yes	No	NA	No	B (Water)	Yes
16	BTEX/PHC, VOCs, PAHs	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Water)	Yes
17	PAHs	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Water)	Yes
18	BTEX/PHC	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Membro)	Yes
19	TCE, PCE, VOCs	Yes	10	Yes	10	100	Yes	Yes	No	NA	No	B (Water)	Yes
20	BTEX	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Membro)	Yes
21	BTEX/PHC, VOCs	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Water)	Yes
22	BTEX	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Water)	Yes
23	BTEX/PHC	Yes	10	Yes	10	100	Yes	No	NA	NA	No	B (Water)	Yes
24	TCE, PCE, BTEX/PHC	Yes	10	Yes	10	100	Yes	Yes	No	NA	No	B (Water)	Yes

7.5.1 Conditions Evaluation Summary for the Guelph Waterworks

Based on the data collected, there are ~~35~~ 36 properties within the City's WHPAs where a contaminant has been detected exceeding the potable groundwater standard. Twenty~~-four~~ of these properties were also identified as significant water quality threats. Parameters reviewed in this analysis and found to be at concentrations in exceedance of the MOE Table 2 of the Soil, Groundwater and Sediments Standards dated March 9, 2004, or the drinking water component value (GW1) for Table 2 (MOE, 2011) were:

- Nitrates (NO_3);
- Benzene, Toluene, Ethylbenzene and Xylenes (BTEX);
- Trichloroethylene (TCE);
- Perchloroethylene (PCE);
- Polycyclic Aromatic Hydrocarbons (PAHs); and,
- Volatile Organic Compounds (VOCs) (for parameters other than TCE and PCE).

Properties that have concentrations of chloride and/or sodium have not been included in this analysis, as it is difficult to differentiate an on-site source of these contaminants from off-site sources such as road de-icing activities on adjacent roadways. Additionally, properties with metals parameters have not been included in the off-site analysis as they are considered to be less mobile than organic contaminants (such as TCE, BTEX, or PCE); therefore, the likelihood of them migrating to an off-site location is considered to be low.

A summary of the number of properties evaluated and categorized in the conditions assessment is presented in **Table 7-14** below.

Table 7-14 Summary of Conditions Assessment

Category	Number of Properties
Total Number of Properties Evaluated	81
Site Identified as Conditions	36
Conditions that are also SDWTs	24
Conditions, but not SDWTs	9
Conditions, but inconclusive if SDWTs	2
No longer identified as Condition based on Revised Assessment	3

7.6 Drinking Water Quality Issues Evaluation

The objective of the Issues evaluation is to identify drinking water issues where the existing or trending concentration of a parameter or pathogen at an intake, well or monitoring well would result in the deterioration of the quality of water for use as a source of drinking water. The parameter or pathogen must be listed in Schedule 1, 2 or 3 of the Ontario Drinking Water Quality Standards (ODWQS) or Table 4 of the Technical Support Document for Ontario Drinking Water Quality Standards, Objectives and Guidelines (Technical Rules XI.1 (114-117)).

Once a drinking water Issue is identified, the objective is to identify all sources and threats that may contribute to the Issue within an Issue Contributing Area (ICA) and manage these threats appropriately. If at this time the ICA can not be identified or the Issue can not be linked to threats, then a work plan must be provided.

If an Issue is identified for an intake, well or monitoring well, then all threats related to a particular Issue within the Issue Contributing Areas are identified as significant drinking water threats, regardless of the vulnerability.

Data Sources, Methodology, and Results

For this updated assessment of drinking water quality Issues under Technical Rule 114, the City of Guelph's drinking water quality monitoring results for the period of 2008 to 2018 were compared against provincial drinking water quality standards. The initial Drinking Water Issues Assessment was documented in the City's Water Quality Threats Assessment Report (AquaResource, 2010). **Table 7-15** identifies the water quality parameters and their related standards, which were either exceeded at the City of Guelph's wells or where there is an upwards trend with the possibility of exceedance at the City of Guelph's wells. The review identified two water quality parameters associated with an Issue including Trichloroethylene (TCE) and nitrate.

While not classified as Issues under Technical Rule 114, sodium and chloride concentration are increasing at several wells within the city and they must continue to be watched closely within the City to identify and manage impacts associated with road salting activities. Two such wells are highlighted herein and will continue to be closely monitored and possibly added to a new ICA in a future Assessment Report update.

In addition, there have been other chemicals such as cis-1,2-DCE (a breakdown product of TCE) observed at the City's wells and while these detections do not present themselves as Issues at the present time, the City will remain diligent in evaluating monitoring well data to identify trends and potential future water quality Issues.

Table 7-15: Provincial Standards for Water Quality (Ontario Drinking-Water Quality Standards Regulation O. Reg. 169/03)

Parameter	Source	Criteria
Sodium[1]	Aesthetic Objective	200 mg/L
Chloride	Aesthetic Objective	250 mg/L
Trichloroethylene (TCE)	Ontario Drinking Water Quality Standard, MAC	0.005 mg/L
Nitrate	Ontario Drinking Water Quality Standard, MAC	10 mg/L

Notes: [1]The Medical Advisory Level for Sodium is 20 mg/L, but water may continue to be distributed and consumed at these concentrations.

Based on the available data, four wells, including Carter, Emma, Membro, and Smallfield, either exceeded the drinking water objectives or appear to be trending toward exceeding the drinking water objectives. **Table 7-16** summarizes the water quality standards for each of the four municipal wells. Details on the Drinking Water Issues Assessment for each well are provided below.

Table 7-16 Identified Issues under Technical Rule 114

Municipal Well	Issue
Carter Wells	• Historical Nitrate concentrations above drinking water standard[1], however water quality has been improving
Emma Well	• TCE concentrations are decreasing from elevated concentrations previously identified; • Cis-1,2 Dichloroethylene concentrations trend increasing
Membro Well	• TCE concentrations are decreasing from elevated concentrations previously identified; • Cis-1,2 Dichloroethylene concentrations trend increasing
Smallfield Well	• TCE concentrations above drinking water standard

Notes: [1] Water from the Carter Wells are combined with other waters from the Arkell Spring Grounds to lower the nitrate concentrations to a level that is less than the drinking water standard.

Carter Wells

The Carter Wells consist of two wells at the same well house location which are separated by approximately 3 m. The wells are classified as groundwater under the direct influence of surface water (GUDI) with effective in-situ filtration and draw water from the shallow groundwater system. The Carter Wells contain Nitrate at concentrations that historically exceeded the Ontario Drinking Water Quality Standard (ODWQS) of 10 mg/L for Nitrate (as Nitrogen). The initially assessed water quality data for the Carter Wells was provided in the Water Quality Threats Assessment Report (AquaResource, 2010). The water from the wells is blended with water from the Arkell Spring Grounds in the distribution system to reduce the Nitrate concentrations to below the ODWQS. The City has a Standard Operating Procedure that prevents the well from being pumping without the dilution provided by the water from the Arkell Spring Grounds.

The groundwater in the area is known to contain Nitrates. A number of domestic water wells at residential homes in the area have also been identified with Nitrate concentrations that exceed the ODWQS. The source of Nitrate was believed to be derived from agricultural land use in the local area and the area has undergone several land use changes associated with urban development and changes to rural land uses. Ongoing studies by the City's contracted consultant suggest that surface ponding along Torrance Creek in the area may have contributed to the

historically degraded water quality. However, the Carter Wells have not been pumped consistently for a long duration in recent years in order to confirm a reliable trend to the Nitrate concentrations. At the time this updated assessment was prepared (January 2019), conclusions had not yet been provided for the ongoing studies at the Carter Wells to adequately confirm the concentrations trends for Nitrates and further updates to the ICA will be reviewed in the next update to the Assessment Report.

Current trends in Nitrate concentrations (

Figure 7-1) are promising as they show a decreasing trend, however, as discussed, current studies on the Nitrate concentration trends are ongoing have yet to be confirmed by the City.

On the basis of historical exceedances of the ODWQS and that the groundwater from these wells cannot be used in the municipal system without dilution, the City continues to identify the Nitrates in the Carter Wells as a Drinking Water Issue.

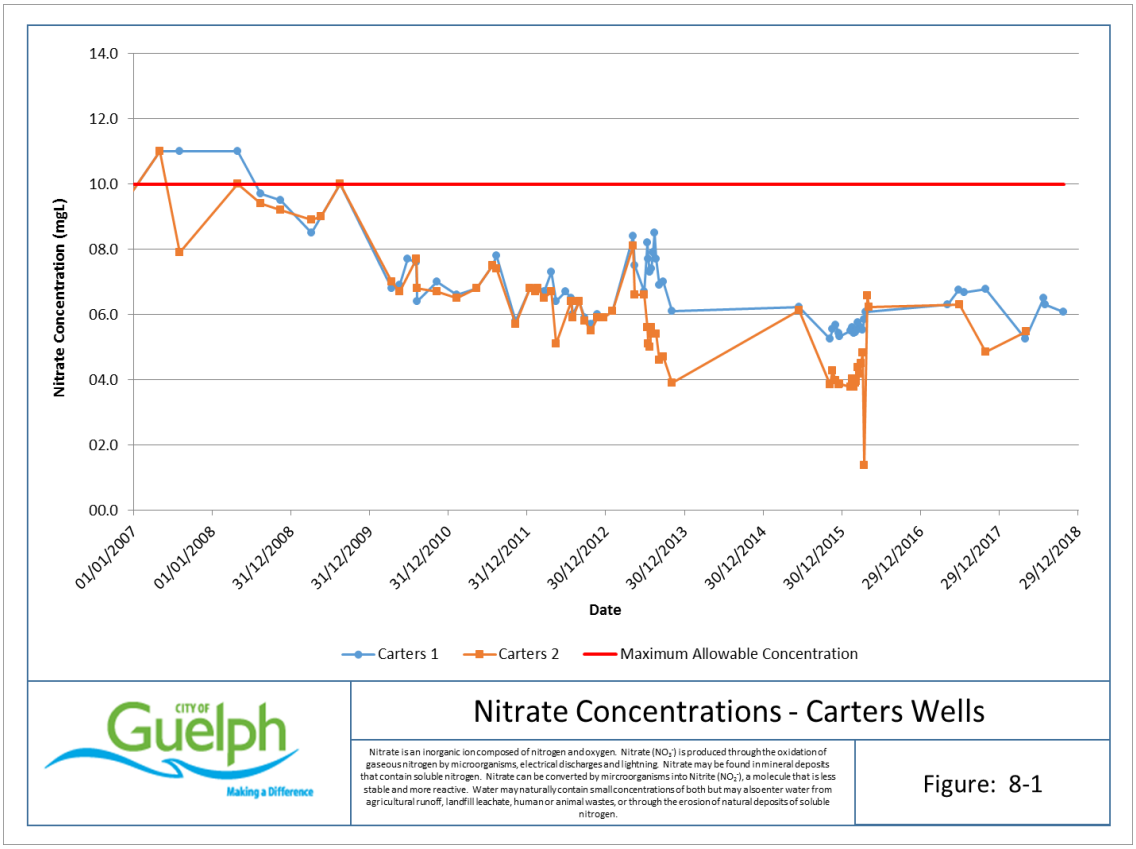


Figure 7-1 Nitrate Concentrations and Trend in the Carter Wells

Emma Well

The Emma Well is located on Emma Street between Metcalfe Street and Delhi Street at the street address of 93 Emma Street. The well was installed in 1931.

The water quality for the Emma Well had shown an increasing trend for TCE between 1997 and 2007. The initially assessed water quality data for the Emma Well was provided in the Water Quality Threats Assessment Report (AquaResource, 2010).

Recent water quality data (i.e. post 2008) have shown a downward trend in TCE concentrations since the original water quality assessment (**Figure 7-2**) but an increasing trend of a TCE breakdown product (cis-1,2 Dichloroethylene). This trend could potentially be a result of infrequent pumping of the well, or improved water quality. Through a joint study with the University of Guelph, the Issues related to TCE around the Emma Well are currently being examined in depth. Conclusions have not yet been provided for the ongoing work at Emma and further updates to the ICA will be reviewed in the next update to the Assessment Report.

The City continues to monitor TCE concentrations and TCE breakdown products in the Emma Well and will review the water quality data to evaluate if the TCE concentrations support a continued classification of having a TCE ICA, as defined under the *Clean Water Act, 2006.*

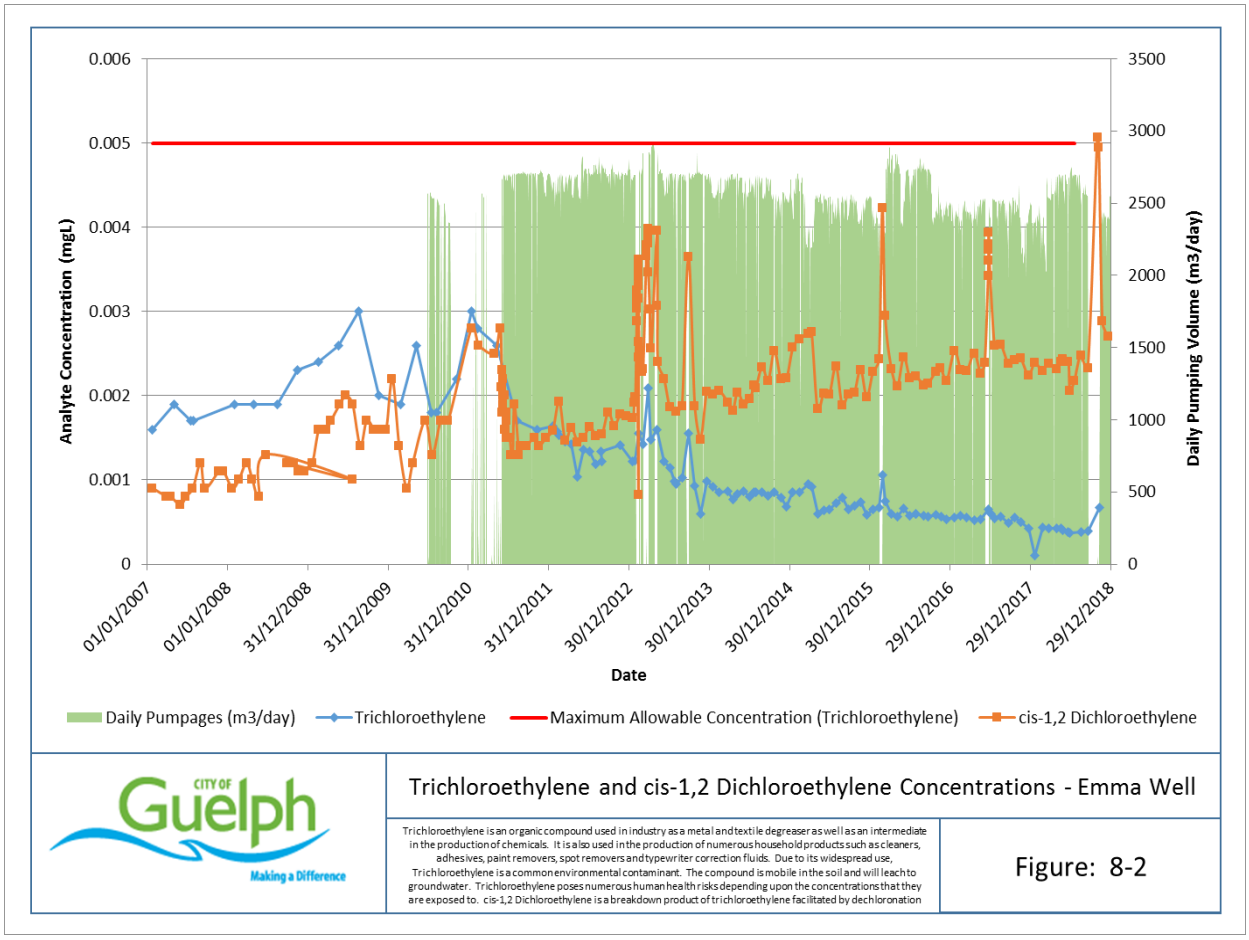


Figure 7-2 Trichloroethylene Concentrations and Trend in the Emma Well

Membro Well

The Membro Well was brought into service in 1994 and production from the well increased when the Edinburgh Well was removed from service. Initially, TCE concentrations in the well were low, on the order of less than 1 µg/L. TCE, as well as cis-1,2-DCE gradually began to increase after 1994 and TCE concentration peaked at 3.9 µg/L. The initially assessed water quality data for the Membro Well is provided in the Water Quality Threats Assessment Report (AquaResource, 2010). The most recent Membro water quality data indicates a decreasing trend in TCE concentrations (**Figure 7-3**).

Since 2002, the City has taken steps to slow the increasing TCE concentration trend in the well. In 2004, the City installed a liner in the well to limit the production for the well to depths of about 40 m below ground surface. In addition, through operational experience, the City has shown that the TCE concentration increases with increased pumping rates and therefore the City has slowed the increasing trend by reducing the pumping rate of the well. In order to limit the inflow of TCE to the well, the City has cut the typical pumping rates at the well to less than half.

Given the historical TCE concentrations in the well and the fact that the well cannot be operated at its full capacity in order to control the increasing concentration of TCE, the City has identified the TCE in the Membro Well as a Drinking Water Issue.

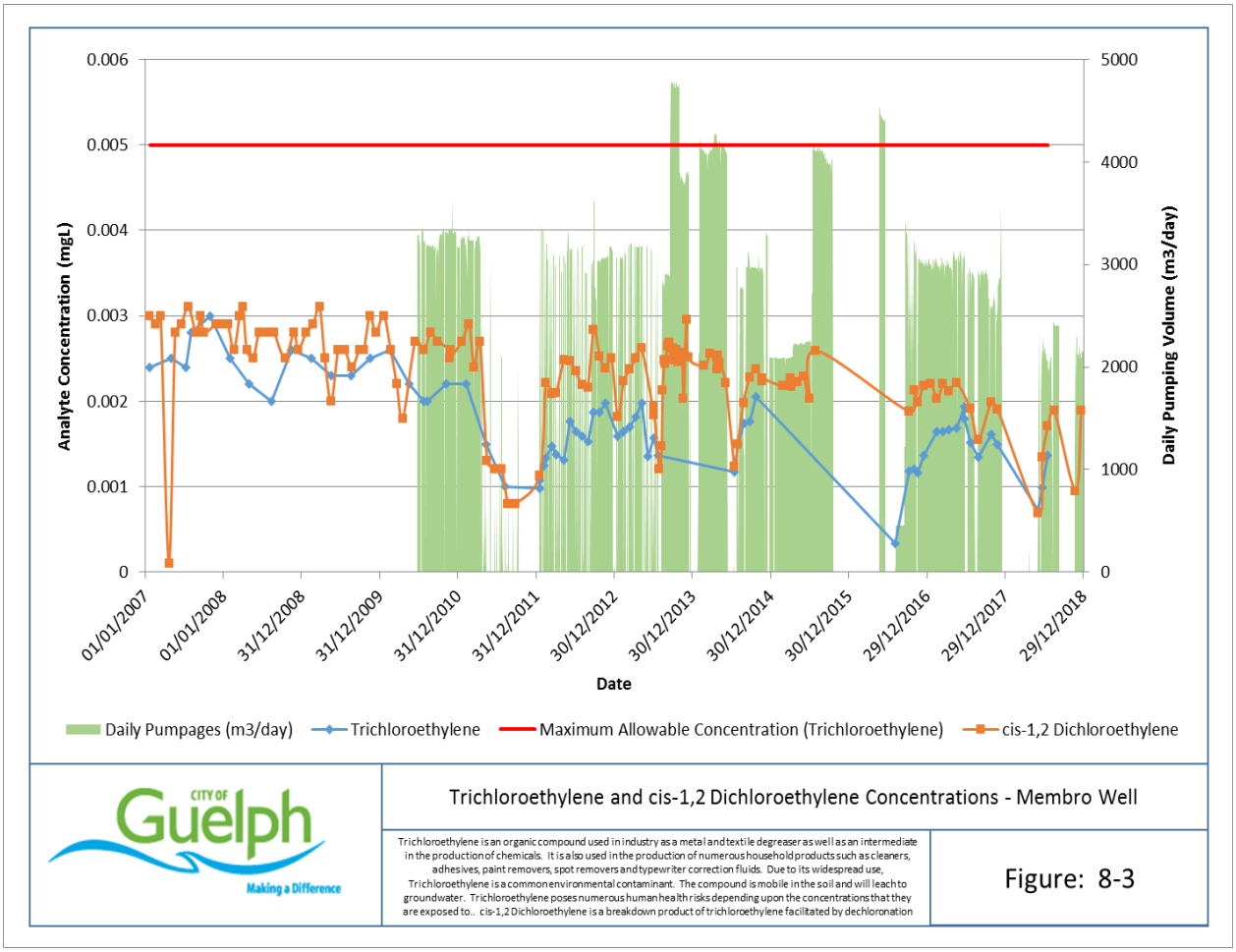


Figure 7-3 Trichloroethylene Concentrations and Trend in the Membro Well

Smallfield Well

As noted in the initial Water Quality Threats Assessment Report (AquaResource, 2010), the Smallfield well was removed from service in 1994 when the TCE concentration increased to just less than the ODWQS. TCE concentrations were reportedly as high as 45 µg/L as compared to the ODWQS of 50 µg/L at the time (**Figure 7-4**). The ODWQS Maximum Acceptable Concentration (MAC) for TCE is now 5 µg/L. Like most communities in Ontario, Guelph would not allow the water quality to deteriorate to the point where it exceeds the ODWQS and the well was removed from service in 1994. Historical water quality results for the Smallfield Well are found in the Water Quality Threat Assessment Report.

In 2008, the City initiated a project to determine the feasibility of returning the Smallfield Well to service. Pumping tests and water quality sampling were conducted on the well. The well was pumped (in conjunction with the Sacco Well) for a period of 13 days from December 9 to December 22, 2008. TCE concentrations in the well, while they declined during the pumping test from a high of 106 µg/L to about 20 µg/L, still exceeded the ODWQS of 5 µg/L at the end of the test (**Figure 7-5**). In addition, high TCE concentrations in groundwater (i.e. as high as 50,000 µg/L) have been found on adjacent properties within 500 m of the Smallfield Well.

Since the 2008 assessment of the well, no work has been completed in the area as the City has relied upon the MECP to address the offsite historical contamination. Given that there are a number of contaminated sites with known TCE in groundwater in the capture zone of the Smallfield Well, the water quality issues with the well are expected to be unchanged from previous reporting.

On the basis of the historical water quality results and the results from the pumping tests, it is the City's opinion that the water quality in the Smallfield Well contains TCE above the ODWQS such that it is unfit for use as a drinking water source without treatment. Therefore, this well meets the test of Technical Rule 114 and on this basis, the City continues to include the Smallfield Well as a Drinking Water Issue.

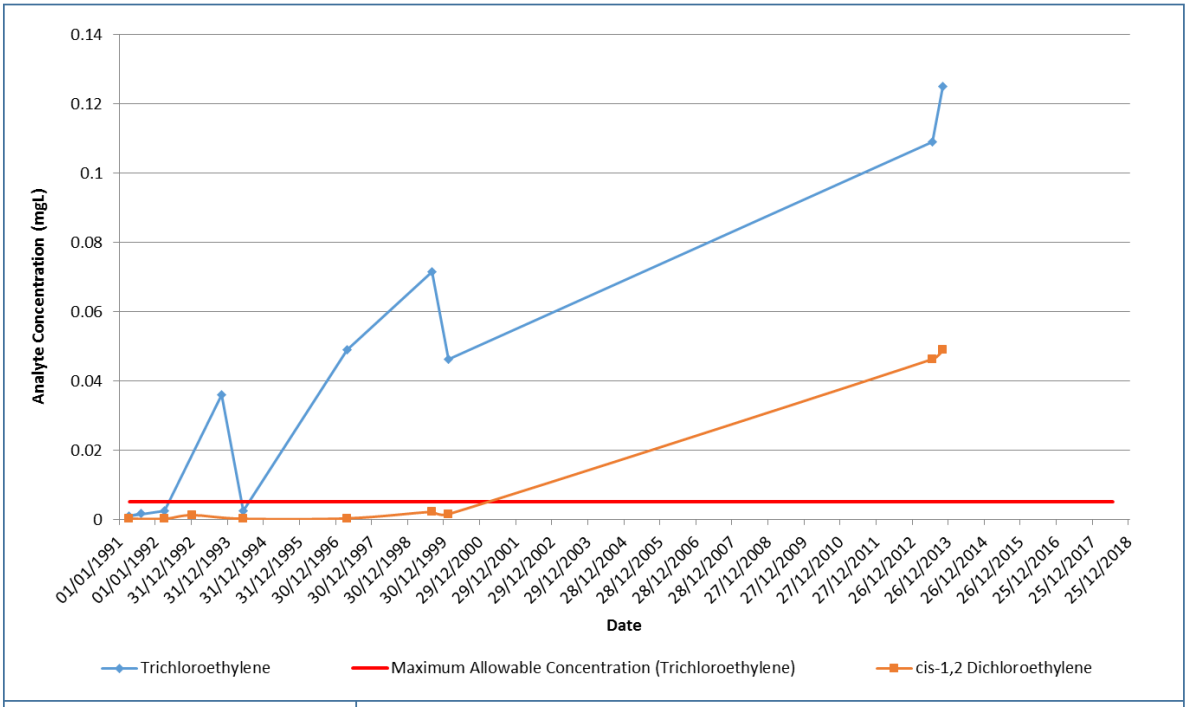


Figure 7-4 Historical Trichlorothylene Concentrations in the Smallfield Well

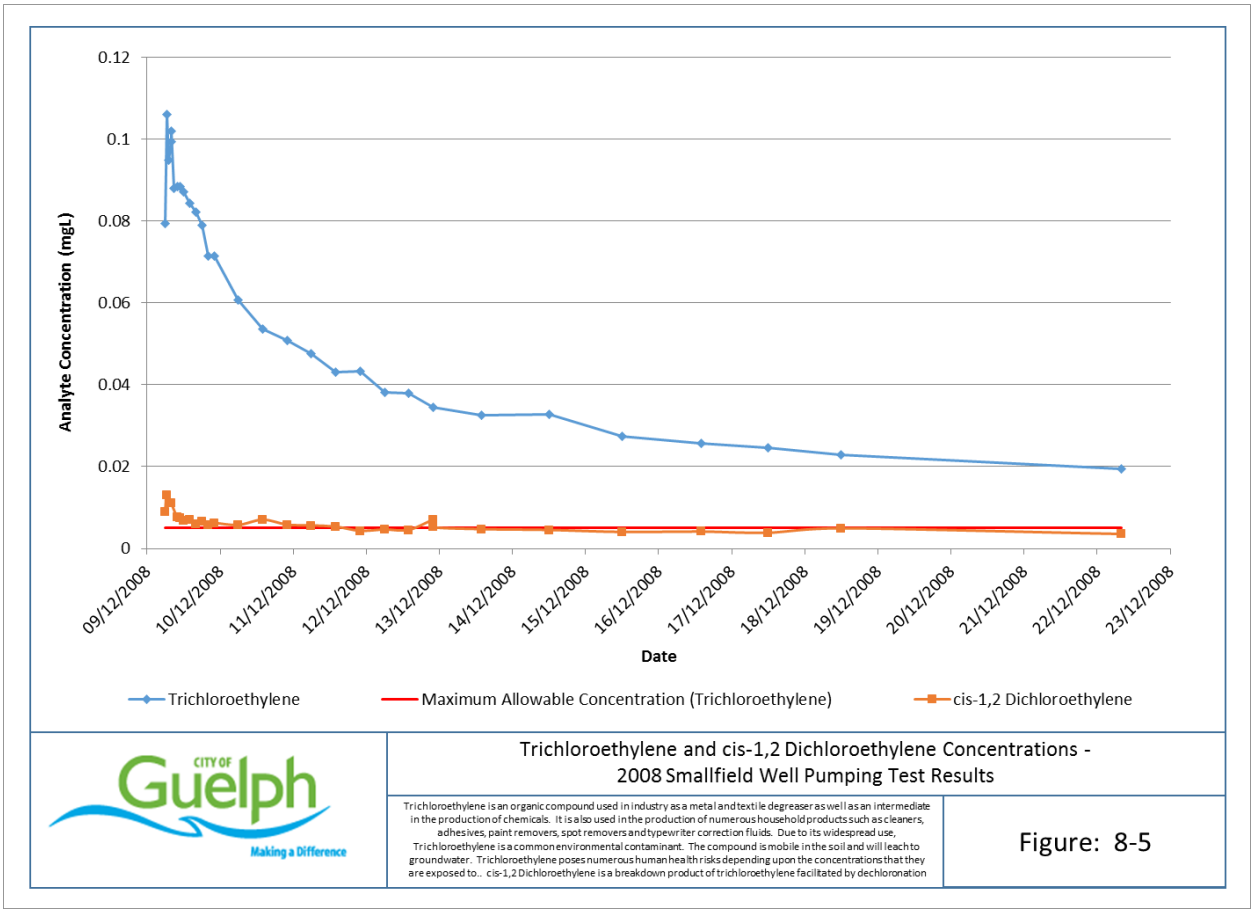


Figure 7-5 Trichloroethylene Concentrations for Smallfield Well (2008 Pump Test Results)

In addition to detections at the above wells, Trichloroethylene (TCE) and other VOCs (e.g., cis-1,2-DCE) have been detected at very low concentrations at a number of additional wells. Sodium concentrations were either at or above the Medical Advisory Level (20 mg/L) but below the Aesthetic Objective (200 mg/L) at a number of other wells. Although these wells are well below the Aesthetic Objective, the province requires that the local Medical Officer of Health be notified when the sodium concentration exceeds 20 mg/L so the City should continue to monitor concentrations at those wells accordingly. There are increasing sodium and chloride concentrations at a number of wells indicating road salting impacts.

Contributing Areas to Issues and Issue-Based Threats

The 25-year capture zone for each well where an Issue has been identified is being identified as the Issue Contributing Area. As such, properties within the Issues Contributing Areas with activities that would be contributing to an Issue at a corresponding well were also reviewed and quantified as part of this threat assessment.

Nitrate was identified as an Issue for the Carter Wells and an Issue Contributing Area was identified. New information that has yet to become available may warrant an update to the extent of the ICA for the Carter Wells. Once completed, the results of the current studies would be included in a future Assessment Report update.

The following **Table 7-17** lists all activities based on the provincial Tables of Drinking Water Threats that are associated with nitrate and that would be identified as a significant drinking water threat if they exist within the Issue Contributing Area.

Table 7-17: Activities that Contribute to Nitrate Issues within an Issue Contributing Area

Prescribed Drinking Water Threat	Threat Subcategory	Chemical of Concern
The application of agricultural source material to land.	Application Of Agricultural Source Material (ASM) To Land	Nitrogen
The application of commercial fertilizer to land.	Application Of Commercial Fertilizer To Land	Nitrogen
The application of non-agricultural source material to land.	Application Of Non-Agricultural Source Material (NASM) To Land (Including Treated Septage)	Nitrogen
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Application Of Untreated Septage To Land	Nitrogen
The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Grazing and pasturing)	Nitrogen
	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Yards or confinement)	Nitrogen
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage System Or Sewage Works - Combined Sewer discharge from a stormwater outlet to surface water	Nitrogen
	Sewage System Or Sewage Works - Discharge Of Untreated Stormwater From A Stormwater Retention Pond[1]	Nitrogen
	Sewage System Or Sewage Works - Industrial Effluent Discharges	Nitrogen
	Sewage System Or Sewage Works - Sanitary Sewers and related pipes	Nitrogen
	Sewage System Or Sewage Works - Septic System	Nitrogen
	Sewage System Or Sewage Works - Septic System Holding Tank	Nitrogen
	Sewage System Or Sewage Works - Sewage treatment plant bypass discharge to surface water	Nitrogen
	Sewage System Or Sewage Works - Sewage Treatment Plant Effluent Discharges (Includes Lagoons)	Nitrogen
	Sewage System Or Sewage Works - Storage Of Sewage (E.G. Treatment Plant Tanks)	Nitrogen
The storage of agricultural source material.	Storage Of Agricultural Source Material (ASM)	Nitrogen

Table 7-17: Activities that Contribute to Nitrate Issues within an Issue Contributing Area

Prescribed Drinking Water Threat	Threat Subcategory	Chemical of Concern
The handling and storage of commercial fertilizer.	Storage Of Commercial Fertilizer	Nitrogen
The handling and storage of non-agricultural source material.	Storage of Non-Agricultural Source Material (NASM)	Nitrogen
The storage of snow.	Storage Of Snow	Nitrogen
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Storage, Treatment And Discharge Of Tailings From Mines	Nitrogen
	Waste Disposal Site - Landfilling (Municipal Waste)	Nitrogen
	Waste Disposal Site - Landfilling (Solid Non Hazardous Industrial or Commercial)	Nitrogen

[1] *The City of Guelph does not consider storm sewer piping to be part of a storm water management facility.*

No existing significant threats were identified within the Issue Contributing Area of the Carter wells. However, Golder (2006c) indicated that there was manure storage at a hobby farm and a horse operation within the WHPA-E and the contributing area of the Carter wells. Additionally, Golder (2006c) indicated manure spreading also in an area that appears to be within the WHPA-E and the contributing area for the Carter wells. These may also be sources of the nitrate Issues at the Carter wells; however a full assessment of manure storage and spreading was not possible for this assessment report. A roadside survey of the properties within the WHPA-E for the Carter well was undertaken. Based on the roadside survey results and the vulnerability score in this area, none of the properties were identified as significant threats. Therefore, additional work may be required to further assess the sources of nitrate in the Carter wells, including personal visits to agricultural properties in the area.

Trichloroethylene (TCE) was identified as an Issue for the Membro Well. The Issues Contributing Area for the Membro Well is shown in **Map 7-32.** The Issues Contributing Area for the Membro Well was generated using the City's groundwater flow model. **Map 7-32** illustrates the ICA for the Membro Well only and no other wells were used to generate the map. The shape of the Membro ICA is unusual. The particle tracks for the Membro Well wrap around some of the other wells due to the close proximity of the Membro Well to other wells within the various wellfields for the City of Guelph. The Membro Well also has a higher pumping rate than adjacent wells, such as the Dean Well and the University Well, and the Edinburgh Well was not operating in the simulation. In addition, the City's water supply is contained within a multiple aquifer system consisting of a deep bedrock aquifer (Gasport Formation) and a shallow bedrock aquifer (Guelph Formation) separated by a confining aquitard (Eramosa Formation). Some of the particles tracks move upward from the Gasport Formation through the aquitard to the Guelph Formation and then move upgradient in the shallower formations. As noted previously, the interpretation of the ICA for the Membro Well, from the particle tracks, is complex and the ICA has been simplified, based on professional judgement, to provide a more confident interpretation of the area that may contribute to issues at the Membro Well.

The following **Table 7-18** lists all activities that are associated with TCE and that would be identified as a significant drinking water threat if they exist within the Issue Contributing Area (**Map 7-32)**.

Table 7-18 Activities that Contribute to Trichloroethylene (TCE) Issues within an Issue Contributing Area

Prescribed Drinking Water Threat	Threat Subcategory	Chemical of Concern
The handling and storage of a dense non-aqueous phase liquid.	Handling Of A Dense Non Aqueous Phase Liquid (DNAPL)	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
	Storage Of A Dense Non Aqueous Phase Liquid (DNAPL)	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Land Disposal of Municipal Waste	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
	Land Disposal of Commercial or Industrial Waste	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
	Land Disposal of Liquid Industrial Waste	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Combined sewer that may discharge to sanitary	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
	Industrial sewage	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
	Wastewater Treatment Facility	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene
	Treatment Tank/Storage Tank	Trichloroethylene or another DNAPL that could degrade to Trichloroethylene

The following existing chemical threats were identified within the Issue Contributing Area of the Membro well field that could be sources of the Issues at this well:

- Operation of a waste disposal site (1 property) and;
- Handling and storage of DNAPLs (285 properties).

TCE was identified as an Issue for the Smallfield Well **(Map 7-33).** The following chemical threats were identified within contributing area of the Smallfield Well that could be sources of the Issues at this well:

- Handling and storage of DNAPLs (75 properties); and
- Handling and storage of organic solvents (17 properties).

TCE was identified as an Issue for the Emma Well **(Map 7-33).** The chemical threat of handling and storage of DNALPs (24 properties) was identified within the contributing area of the Emma well field and could be sources of the Issues at this well.

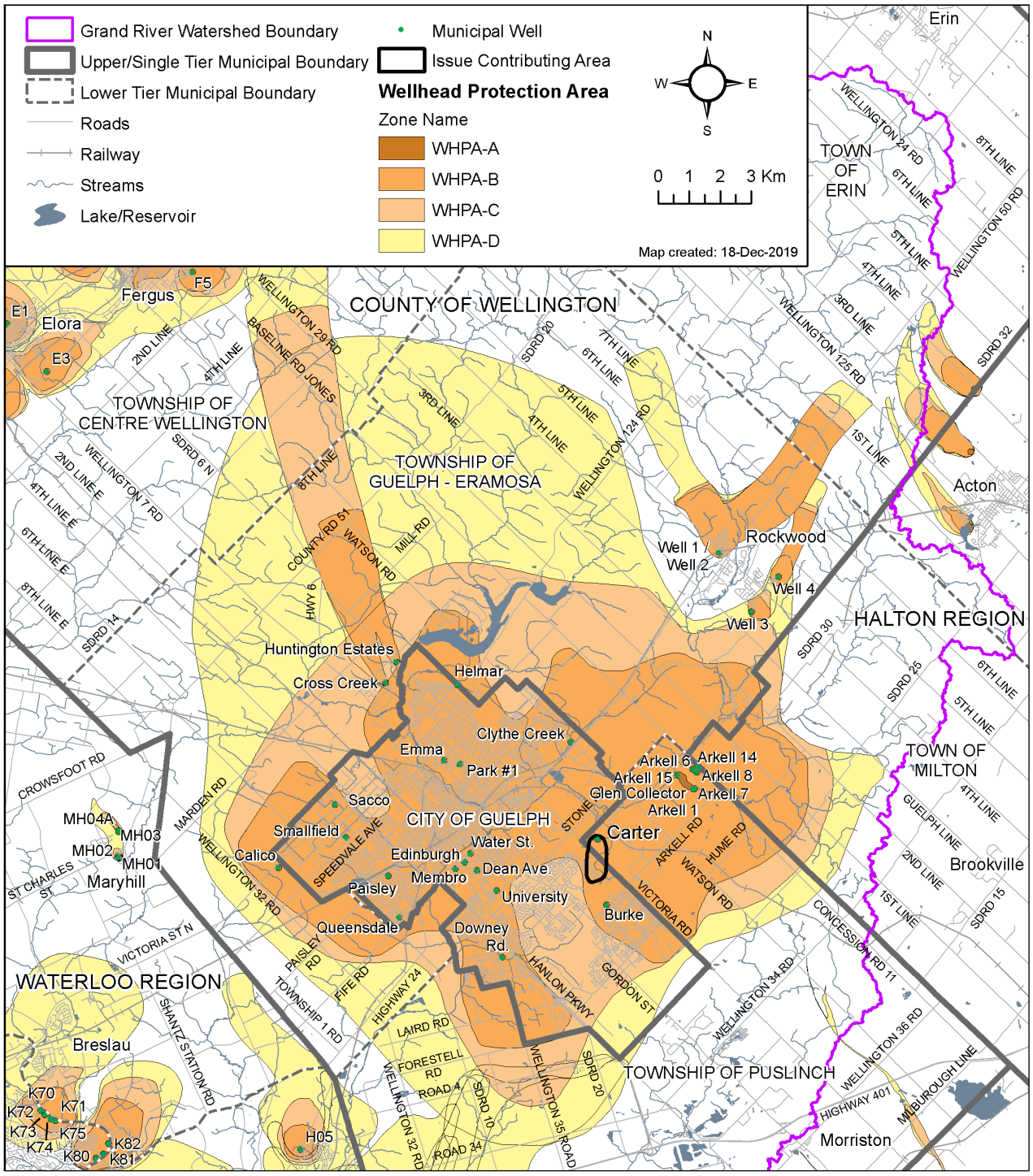
Summary of Identified Issues

The review identified two water quality parameters that may be associated with an Issue including Trichloroethylene (TCE) and nitrate. Nitrate was identified as an Issue under Technical Rule 114 at the City of Guelph's Carter Wells, which TCE was identified as an Issue at the Membro, Smallfield, and Emma wells. While not currently classified as Issues, sodium and chloride concentrations are increasing at several wells within the City and they must continue to be watched closely within the City to identify and manage impacts associated with road salting activities.

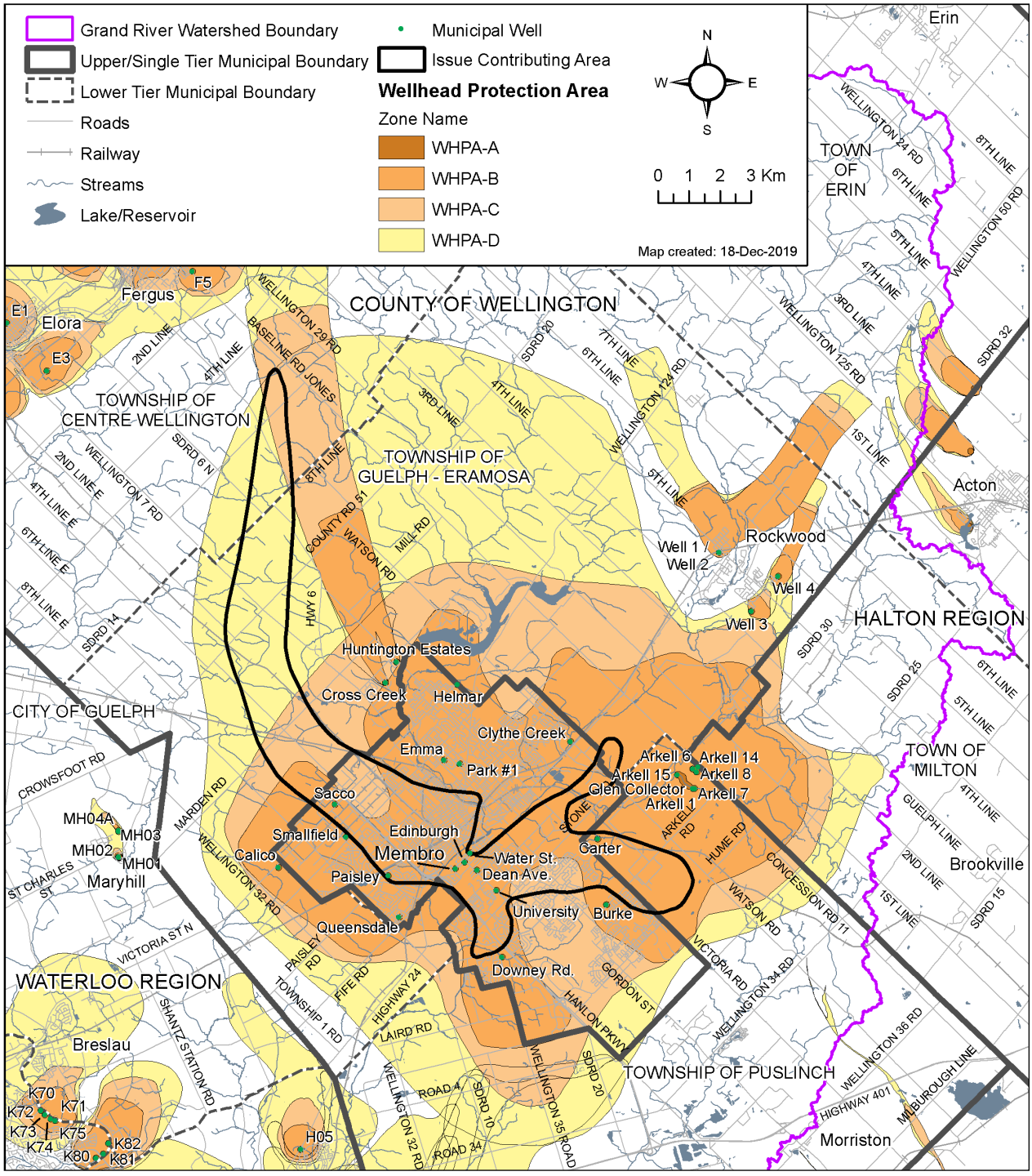
There are no significant gaps with respect to the identification of drinking water quality Issues. The City of Guelph maintains a comprehensive drinking water quality monitoring program to identify any current or potentially future water quality parameters that might exceed drinking water standards or show a trend of exceeding those standards in the future.

The uncertainty with respect to the classification of drinking water Issues in the City of Guelph is low as the conclusions are supported by the consistent water quality monitoring trends. The Issues identified have been of concern by the City over a relatively long period of time.

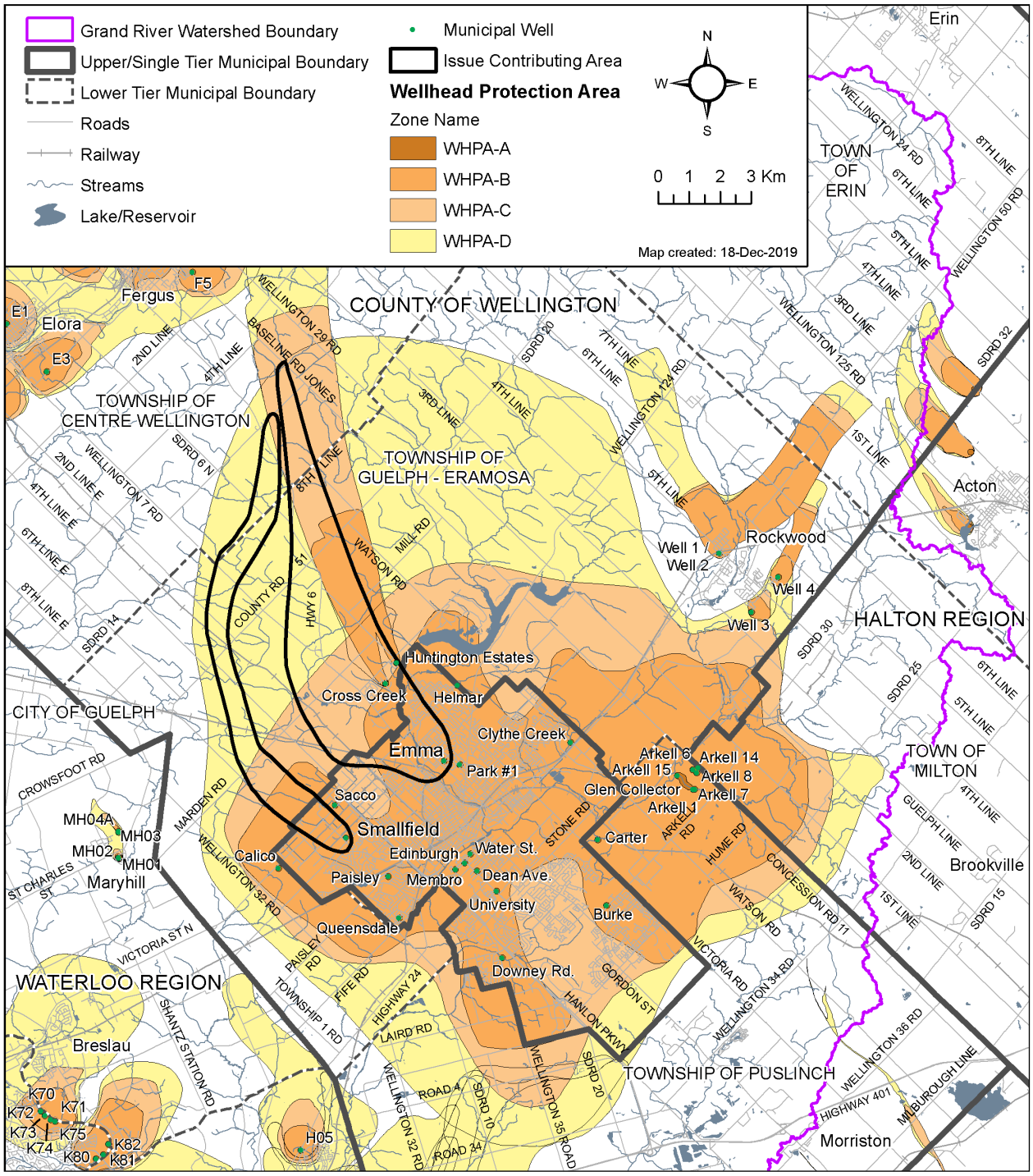
Map 7-31 Carter Well Nitrate Issue Contributing Area



Map 7-32 Membro Well Trichloroethylene Issue Contributing Area



Map 7-33: Emma and Smallfield Wells Trichloroethylene Issue Contributing Area



7.7 Enumeration of Significant Drinking Water Quality Threats

Table 7-19 summarizes the number and type of potential significant threats and applicable circumstances by WHPA. No activities were identified in the WHPA-E, IPZ-1 or IPZ-2 areas that could be significant threats. It is noted that these areas are generally comprised of wooded areas (greenspace) and some agricultural lands.

Table 7-19: Significant Drinking Water Quality Threats for the Guelph Waterworks

PDWT[1] #	Threat Subcategory[2]	Number of Activities	Vulnerable Area
1	Waste Disposal Site- Storage of Hazardous Waste at Disposal Sites	42	WHPA-B
	Waste Disposal Site- Storage of wastes described in clauses (p), (q), (r), (s), (t) or (u) of the definition of hazardous waste	18	WHPA B
2	Sewage System or Sewage Works- Septic System	456	WHPA A WHPA B
	Sewage System or Sewage Works- Storage of Sewage (e.g., treatment plant tanks)	1	WHPA-B
	Sewage System or Sewage Works- Discharge of Untreated Stormwater from a Stormwater Retention Pond	14	WHPA-B
3	Application of Agricultural Source Material to Land	68	WHPA-A WHPA-B ICA
4	Handling and Storage of Agricultural Source Material	19	WHPA B
7	Handling and Storage of Non-Agricultural Source Material	4	WHPA A WHPA B
8	Application of Commercial Fertilizer	2	ICA
9	Handling and Storage of Commercial Fertilizer	27	WHPA B
10	Application of Pesticides to Land	67	WHPA-A WHPA-B
11	Handling and Storage of Pesticides	38	WHPA B
14	Storage of Snow	2	WHPA-B
15	Handling and Storage of Fuel	284	WHPA A WHPA B
16	Handling and Storage of Dense Non-Aqueous Phase Liquids	608	WHPA A WHPA- B WHPA-C ICA
17	Handling and Storage of Organic Solvents	160	WHPA A WHPA B
21	Management or handling of Agricultural Source Material- Agricultural Source Material (ASM) Generation (Grazing and pasturing)	20	WHPA-B
Total Number of Properties		**1119**	
Total Number of Activities		**1830**	
Total Number of Conditions		**24**	

Table 7-19: Significant Drinking Water Quality Threats for the Guelph Waterworks

PDWT[1] #	Threat Subcategory[2]	Number of Activities	Vulnerable Area

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in O.Reg 287/07 s.1.1.(1)

2: Where applicable, waste, sewage, and livestock threat numbers are reported by sub-threat; fuel and DNAPL by Prescribed Drinking Water Threat category.

Note: The City of Guelph does not consider storm sewer piping to be part of a storm water management facility.

The 1830 significant threats correspond to approximately 1119 locations. Several parcels include multiple threats.

The non-agricultural significant threats were generally located within the City of Guelph boundaries. Outside of the City of Guelph, significant threats were located in the Township of Puslinch and the Township of Guelph-Eramosa. There were no significant threats enumerated in the Township of Milton. The highest concentrations of non-agricultural significant threats were located in proximity to the Sacco and Smallfield well fields in the western portion of the City of Guelph, and between the Membro/Water Street well fields and Emma/Park well fields, near the central portion of the City of Guelph. Several significant non-agricultural type threats were also located south of the Clythe Creek well.

Data Gaps for the Enumeration of Significant Drinking Water Quality Threats for the Guelph Waterworks

Based on the results of the threats enumeration exercise the database was used to identify data gaps and uncertainties for all relevant data records. Data gaps were classified as the following:

- Spatial Data Gaps – identified when there was no spatial data or incorrect spatial data available for a record;
- Spatial/Tabular Data Gap – identified when the tax roll/parcel data was inconsistent with other data sources for a specific property;
- Lack of data – identified where key data was not available for a property (e.g. no civic address available); and
- Non-matches – where records could not be matched to tax roll or parcel fabric for properties based on incomplete information or poor quality data sources.

Spatial data and spatial/tabular data gaps were addressed by linking properties to the best available data source for spatial matching. Typically the best data source was the tax roll data set. Where this could be accomplished, these records were also tied to the corresponding parcel fabric.

Data gaps were not addressed as part of this assessment. The lack of data pertained to the limited amount of data available from all data sources collected to date for determining livestock type on several of the agricultural properties in the 2009 Guelph Database.

Non-matched records were addressed in several ways. Firstly, records that should not be matched to tax roll information were separated out, (i.e., storm water pipe and sanitary sewer

networks) and were stored in the database without tax roll numbers or linked parcel fabric. Individual properties/businesses that could not be matched to tax roll data were assigned a unique value in the tax roll number field (based on a sequential numerical system) so they could be maintained, assigned threats and queried. Where possible, non-matched records identified in the initial assessment were field verified in the fall of 2010.

Remaining properties that could not be matched or lacked data were tabulated and were stored as 'null' records in the database. The breakdown of the data management and data gaps are as follows:

- 9,699 records were stored in the database for the threats assessment;
- 2,138 of the records were linked to tax roll (or unique value as described above) and/or parcel fabric;
- 7,561 of the records were points or lineaments for sanitary sewer pipe, storm water pipe and road networks, therefore they did not have tax roll numbers or parcel fabric linked to the record; and
- The remaining 25 records were non-matches.

7.8 Guelph Waterworks Section Summary

The scope of this assessment included the compilation of existing data relating to water quality monitoring data, as well as land use activities and environmental reports to identify Issues, threats, and conditions. As described in the report, there are potentially more than a thousand significant water quality threats and numerous potential conditions, and further work will be required to refine the list of conditions and threats to a higher level of certainty.

Groundwater Vulnerability

WHPAs for the City of Guelph's current and planned wells were delineated using a particle-tracking technique and the groundwater flow model currently being developed in support of the City's Tier Three Local Area Risk Assessment. These WHPAs include the WHPA-A, WHPA-B, WHPA-C and WHPA-D areas as required under the Technical Rules (MOE, 2009). The WHPAs are estimated based on the City's projected water demand for 2031.

A large portion of the City of Guelph's land area was found to be contained within the 2-year WHPA (WHPA-B) and most of the land area is contained within the 5-year WHPA (WHPA-C).

The final delineation of the WHPAs was based on an uncertainty analysis using the scenario approach as described in the draft Guidance Module 3 – Groundwater Vulnerability Analysis. The scenarios considered the effects, in isolation and in combination, of variations in bedrock porosity and formation hydraulic conductivity (i.e. Gasport Formation and Vinemount Member) and municipal well pumping rates. The final WHPAs were based on a weighted assessment of the combined areas of the capture zones. While these areas are delineated using the best information and interpretation available, the time-of-travel associated with potential contaminants cannot be estimated exactly. The development of groundwater protection policies that can be applied over the broader landscape is prudent to address this uncertainty; these policies should be focused on land areas that have a reasonable likelihood to be contained within the capture zone for a municipal supply well as defined by the WHPAs.

Groundwater vulnerability maps are created to identify areas where the groundwater supply aquifer has a high, medium or low vulnerability to contamination from ground surface. For this

study a modified version of the Groundwater Intrinsic Susceptibility Index (GwISI) was developed which takes into account a map of overburden thickness in addition to the estimated GwISI value at wells (e.g., water well records, municipal wells). The modified version of the GwISI method is implemented to better represent the influence of areas having low or high overburden thickness where there are few estimates of the ISI value from which to interpolate.

This study creates a GwISI map for the top of bedrock. Although the City of Guelph's main water supply aquifer is within the Gasport Formation, which is located underneath the Vinemount/Eramosa aquitard, the City does have several wells that are open across the shallower Guelph Formation, or open across both the Guelph and Gasport Formations. Establishing the vulnerability at the top of bedrock is justified from both the precautionary perspective, as well as from field evidence that suggests that where contamination is present at the top of bedrock there is a potential for this contamination to migrate to the water supply aquifer through fractures in bedrock. The presence of sand and gravel pits, bedrock quarries and sanitary or storm sewers near or beneath the top of bedrock surface are also considered when assigning the relative groundwater vulnerability. Where these transport pathways exist, the groundwater vulnerability is increased from low to moderate, or from moderate to high.

This study follows the MOE's vulnerability scoring methodology as written in the Technical Rules to assign scores to vulnerable areas within the City's WHPAs. The results identify large areas of the City having high vulnerability scores equal to 8 or 10. These areas with high vulnerability are typically located within the WHPA-A (e.g., 100 m) or WHPA-B (e.g., 2-year time-of-travel) areas and have relatively thin overburden. These results are intuitive in that where the bedrock is close to ground surface it is more vulnerable to contamination.

Surface Water Vulnerability

The City operates a surface water intake on the Eramosa River. Water is pumped from this intake on a seasonal basis and introduced into groundwater through an artificial groundwater recharge system at the Arkell Spring Grounds. Similar to the Groundwater Vulnerability Assessment, a Surface Water Vulnerability Assessment is required under the Technical Rules for surface water intakes to delineate both the vulnerable areas for a surface water intake and to assign vulnerability scores for those areas.

Following the MOE's Guidance and the Technical Rules (MOE, 2009b) the following vulnerable areas are delineated for the Eramosa River intake:

1) Intake Protection Zone 1 (IPZ-1) - This vulnerable area is based on a semi-circle of 200 m radius, extending upstream of the intake. The IPZ-1 intake is also extended downstream to the Arkell weir/impoundment below the intake. A setback of 120 m or the extent of the Conservation Authority Regulation Limit is applied.
2) Intake Protection Zone 2 (IPZ-2) - The IPZ-2 vulnerable area is delineated beginning at the IPZ-1 and extending upstream of Eden Mills to the Indian Road Bridge across the Eramosa River. During high flow conditions, the time-of-travel from this location to the intake is estimated to be approximately 6 hours. Delineation of the IPZ-2 was based on the results of a dye-tracer test scaled up to a higher flow using a hydraulic model. While the Technical Rules require a minimum two-hour time-of-travel criteria, the City of Guelph prefers that the longer time period be used to represent the IPZ-2 reflecting the amount of time that might be needed for the municipality to respond to an upstream spill.
3) Intake Protection Zone 3 (IPZ-3) - The IPZ-3 vulnerable area is delineated to include all watercourses providing water to the intake, buffered to either 120 metres or the

Conservation Authority Regulation Limit, whichever is greater. These watercourses include the Eramosa River, Blue Springs Creek, and their tributaries.

The vulnerability scores assigned as part of this study are as follows:

- IPZ-1. All of the IPZ-1 was assigned a vulnerability score equal to 10;
- IPZ-2. All of the IPZ-2 was assigned a vulnerability score equal to 7;
- IPZ-3. The IPZ-3 was assigned vulnerability scores equal to 5, 3 and 1, depending on the landuse within the area.

GUDI Well Vulnerability

The Technical Rules require the delineation of separate vulnerable areas for groundwater wells where the well obtains water from a raw water supply that is groundwater under the direct influence (GUDI) of surface water as determined accordance with subsection 2 (2) of O. Reg. 170/03 (Drinking Water Systems) made under the Safe Drinking Water Act, 2002.

The City's Carter Wells are considered to be GUDI systems and are located adjacent to Torrance Creek, a small watercourse draining an area of the southeast quadrant of the City of Guelph. The system consists of two bedrock wells located at a distance of about 3 m apart. The wells obtain their water from the shallow bedrock which, at this location, consists of the Guelph Formation.

The Technical Rules require that the WHPA-E and WHPA-F vulnerable areas be delineated for GUDI systems. These areas are analogous to the IPZ-2 and IPZ-3 vulnerable areas and are summarized below:

1) WHPA-E: Based on a rough time-of-travel estimate, it was recommended that the entire length of Torrance Creek be considered within the WHPA-E for the Carter Wells. It is noted here that while the estimated water velocity is not based on hydraulic calculation the relatively short length of the Creek warrants having the entire length included within the WHPA-E area. The WHPA-E is further delineated using the greater of a lateral setback of 120 m or the Regulation Limit as defined by the GRCA.

2) WHPA-F: A WHPA-F was not delineated for the Carter Wells, as the WHPA-E includes all of Torrance Creek.

A vulnerable score of 7.2 was assigned to the WHPA-E for the Carter Wells.

Water Quality Threats Assessment

Issues

The City of Guelph identified two water quality parameters (Trichloroethylene (TCE) and nitrate) as a drinking water quality Issue under Technical Rule 114. Based on the available data, four wells, including Carter, Emma, Membro and Smallfield, either exceeded the drinking water objectives or appear to be trending toward exceeding the drinking water objectives. In addition to the above wells, chlorinated organic compounds including TCE, Dichloroethylene (DCE) and Tetrachloroethylene (PCE) have been detected at low concentrations at several additional wells which further emphasizes the need to manage drinking water threats within the City.

While not classified as Issues in this report, trends in sodium and chloride concentrations in groundwater are a concern. There are increasing sodium and chloride concentrations at a number

of wells indicating road salting impacts. Sodium concentrations were either at or above the Medical Advisory Level (20 mg/L) but below the Aesthetic Objective (200 mg/L) at a number of other wells. Although the concentrations in these wells are well below the Aesthetic Objective, the ODWQS require the local Medical Officer of Health be notified when the sodium concentration exceeds 20 mg/L so the City should continue to monitor concentrations at those wells accordingly. Consideration should also be given to how the City of Guelph will handle sodium and chloride levels that exceed the Medical Advisory Level.

Threats

The City of Guelph's work relating to the water quality risk assessment included the following components:

- Development of Water Quality Threats Database;
- Assessment of Managed Lands and Agricultural Based Threats;
- Assessment of Impervious Areas; and,
- Enumeration of Water Quality Threats;
- Completion of a survey of significant threats identified during the initial assessment; and
- Re-enumeration of significant threats.

No significant water quality threats were found relating to managed lands and impervious areas.

The significant threat enumeration approach identified a total of 1,830 activities being identified that would result in the classification of a significant drinking water quality threat based on the assumptions made relating to the circumstances for each of those activities. The 1,830 significant threats correspond to 1119 locations in the City and County of Wellington. Several properties indicated multiple threats, as well as both chemical and pathogen threats.

Conditions

A revised conditions assessment was completed based on the MOE's review of the 2010 and 2011 conditions assessments submitted in support of the Draft AR and the UAR, respectively. The revised conditions assessment was completed through an evaluation of the sites in the conditions database, additional information obtained from the MOE for select sites, and a comparison of properties to the Technical Rules (MOE, 2009) to determine if sites were conditions and/or SDWTs. In total, 80 sites were evaluated in the assessment, with 35 properties identified as conditions, 24 of those also identified as SDWTs. Further, two sites were found to be conditions, but there was insufficient or appropriate information available in the conditions database of MOE files to determine if they were also SDWTs. Finally, three sites which were identified as conditions in the 2011 assessment were re-evaluated and determined to no longer be conditions in the revised assessment. It should be noted that this conditions evaluation was done with data available at the time of reporting. The City of Guelph is not necessarily in possession of all recent and relevant monitoring reports for these properties.

In accordance with Source Protection Plan Policy CG-NB-1.19, the City of Guelph meets with MECP semi annualy to review and exchange information related to condition sites.