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24.0 STATE OF CLIMATE CHANGE RESEARCH IN THE LAKE ERIE SOURCE PROTECTION REGION

Recent climate change studies focus on modeling a doubling of CO_2 in the atmosphere. Studies of the consequences of this climate change scenario specific to the Grand River watershed include Bellamy *et al.* (2002), de Loe and Berg (2006), de Loe *et al.* (2001) and Southam *et al.* (1999). As well, research on the broader Lake Erie basin give predictions on local scale impacts of climate change for the Grand River watershed, accounting for the meso-climatic influences of the Great Lakes.

Many recent studies have incorporated the changes already seen in the Great Lakes regional climate (such as Bruce *et al*., 2006; Chiotti and Lavender, 2008; Kunkel *et al*., 2009; Zhang *et al*., 2000). Research into climate change and water resources in the last decade are thought to be more reliable than previous studies (IPCC-TGICA, 2007). Recent studies have the advantage of analyzing observed changes as well as the availability of better modeling tools. Many recent studies agree that greater and more frequent extremes in temperature and precipitation are expected in the Lake Erie basin. More specifically, an annual average increase in both temperature and precipitation are the driving predictions for Ontario and the Lake Erie basin; both of which have the potential to dramatically impact water resources (Kling *et al*., 2003).

Annual average air temperature in the Lake Erie basin (including the Grand River watershed) is expected to increase only slightly; McBean and Motiee (2008) estimate 0.8^0C increase by 2050. The small increase, however, masks the intra-annual changes, as seasonal temperatures and diurnal temperatures are expected to fluctuate more dramatically (Cunderlik and Simonovic, 2004; Jyrkama and Sykes, 2007; Kunkel *et al.*, 2002). In particular, studies show much warmer winter temperatures will occur (Bruce *et al*., 2000; Cunderlik and Simonovic, 2004; Jyrkama and Sykes, 2007; Kunkel *et al*., 2002; Mortsch *et al*., 2000). Summer daily temperatures are projected to gradually increase towards 2030 and then a more rapid increase could have daily average summer temperatures 10^0C higher than the 1960-1990 average by 2100 (Kling *et al*., 2003).

For precipitation, the projected effects of a doubling of CO_2 are extensive. Annual total precipitation is predicted to increase over the next 50 years in the Great Lakes basin (McBean and Motiee, 2008); however net basin water supplies are projected to decrease due to greater evapotranspiration and runoff. The distribution of precipitation throughout the year will be altered, as Sharif and Burn (2006) estimate that only the months of January, March and October will have increased monthly precipitation. The other months may see a decrease in precipitation, including the months between April to September when water demand is the highest. The form of winter precipitation is expected to shift to rain instead of snowfall, as winter temperatures rise (Bruce *et al.*, 2000; Mortsch *et al.*, 2000). The extreme events for precipitation will be more intense and higher frequency (McBean and Motiee 2008), at the expense of the more gentle and persistent rainfall events (Mortsch *et al.*, 2000).

Warmer winter temperatures are predicted to be the most influential change for water resources in the Grand River watershed. Some of the changes predicted include more winter precipitation as rain, a smaller snowpack, higher evaporation from open water bodies that no longer freeze and an earlier and smaller spring freshet (Barnett *et al*., 2005; Bruce *et al*., 2000; Environment Canada, 2004; Jyrkama and Sykes, 2007; Mortsch *et al*., 2000). Soil moisture will start higher in the spring but drop lower in summer with anticipated higher evapotranspiration. This will lead to greater demand for water resources for irrigation and more frequent drought occurrence

(Brklacich, 1990; McBean and Motiee, 2008). Precipitation trends show more intense storms, causing a decrease in infiltration and groundwater recharge (de Loe and Berg, 2006; McLaren and Sudicky, 1993), higher sediment and nutrient loading in the creeks due to greater erosion (McBean and Motiee 2008) and fewer number of days with rain or longer dry periods (Mortsch *et al.*, 2000). Net basin supplies are projected to decrease, following decreases in runoff, infiltration, higher surface water temperatures and greater evapotranspiration (Lofgren *et al.*, 2002; Mortsch *et al.*, 2000) Overall, climate change is expected to shift the means in temperature, precipitation and evaporation which will lead to increased variability, more frequent and intense events (Francis and Hengeveld, 1998)) in de Loe *et al.*, 2001).

24.1 Potential Effects of Climate Change on Water Quantity and Quality

The predictions on climate change in the Grand River subwatersheds have implications to both water quality and quantity. In terms of water quality, the increased air temperature and greater occurrence of extreme precipitation events will lead to degraded water quality with lower dissolved oxygen rates and higher stream temperatures (Bruce *et al*., 2000; Chiotti and Lavender, 2008; Cunderlik and Simonovic, 2004). Higher sediment and nutrient loading are expected in the creeks due to greater erosion (McBean and Motiee, 2008), and coupled with increase in water temperature, will allow for an increase in nutrient concentrations and a rise in the number of cyanobacteria and algal blooms. The blooms will lead to more taste and odour problems in drinking water, a higher risk of water-borne diseases and increased treatment costs (Chiotti and Lavender, 2008; Hunter, 2003; de Loe and Berg, 2006). Decreases in runoff and baseflows from climate change are also important changes with respect to the dilution of sewage treatment effluent because less water will be available for waste assimilation (de Loe and Berg, 2006). The problem of reduced waste assimilation capacity is exacerbated by the projected increase in future populations in these areas and the ability of the system to meet wastewater discharge criteria (Bruce *et al*., 2000; Cunderlik and Simonovic, 2004).

In terms of water quantity, climate change is expected to shift the timing of seasonal events, including an earlier and lower spring freshet and changing levels in Lake Erie to rise and fall one month earlier on an annual basis, due to increased lake surface temperatures (Lenters, 2001; Lofgren *et al*., 2002; Millerd, 2006). The longer frost-free periods lead to increased potential evapotranspiration and an increase in drought occurrence (Environment Canada, 2004; McBean and Motiee, 2008), meaning that longer, drier and warmer growing seasons will lower soil moisture (more deficit) and increase the demand for irrigation (Brklacich, 1990; McBean and Motiee, 2008). Rainfall is expected to fall with more intensity but on fewer days, leaving longer dry spells that may exacerbate seasonal water shortages during low flow periods (Mortsch *et al*., 2000). Projected reductions in groundwater recharge to drawdowns of 2-7m will require wells to be drilled deeper, increasing costs to land owners and municipalities and could lead to rural domestic and urban water use conflicts (de Loe and Berg, 2006; McLaren and Sudicky, 1993). The reliability of water resources is compromised and unpredictability of the hydrologic cycle will demand more planning and adaptation by water managers (de Loe and Berg, 2006).

24.2 Potential Impacts of Climate Change on Lake Erie and Reservoir Levels

Impacts to Lake Erie will have important consequences with the changing climate. Anticipated changes in Lake levels are a function of the altered water balance of the basin including higher precipitation, a decrease in runoff, higher evapotranspiration and an increase in lake surface temperature (Jones *et al*., 2006; Lofgren, 2006; Millerd, 2006). Increasing water temperature in both summer and winter are projected for Lake Erie, causing large increases in evaporation especially in winter months as ice cover would minimize these losses. Net basin water supplies will be diminished (Mortsch, 2006), as any increases in precipitation are not expected to overcome the decreases in water due to evapotranspiration (Millerd, 2006). The reduction in winter ice formation on Lake Erie is expected to be considerable and perhaps non-existent in some years (Lofgren *et al*., 2002). Typically, Lake Erie would nearly freeze over in the months of January and February and limit the lake's influence on snowfall (Kunkel *et al*., 2009). As a consequence of open water in winter months, the lake-effect storm season off Lake Erie will be longer (Mortsch *et al*., 2000), however more of this precipitation will fall as rain due to a decrease in the frequency of air temperatures between optimal ranges for snow (-10^{0}C to 0^{0}C, (Kunkel *et al*., 2002). The seasonal variation in Lake Erie levels is also projected to increase, with low levels occurring more frequently, being most pronounced in the shallower western portion of Lake Erie (Lofgren *et al*., 2002; Mortsch *et al*., 2000; de Loe and Kreutzwiser, 2000). The decline in annual Lake Erie levels could as much as between 0.60m-1.36m from the International Great Lakes Datum of 1985 of 174.18m, according to the results of 3 Canadian GCM scenarios (Millerd, 2006; Mortsch *et al*., 2000). Jones *et al.* (2006) concluded that Lake Erie is possibly the most vulnerable of the Great Lakes to the effects of climate change, as they are the most southerly, shallowest and lowest volume and thus more susceptible to changes in thermal regime and lake levels. The consequences of Lake Erie level declines to the Lake Erie drinking water intakes would be costly if dredging or pipe extensions were required and, with less depth over the intake, raw water quality could be degraded.

Reservoirs in the Grand River watershed will be affected by climate change similar to the Great Lakes, just at a smaller scale. Winter ice cover is expected to be reduced, with some years without any cover at all, and consequently an increase in evaporation off the reservoirs and decrease in levels (de Loe and Berg, 2006; Lofgren et al., 2002). The operation of reservoirs will need to be modified, as flood risks will be less predictable in all seasons (Cunderlik and Simonovic, 2005). More frequent thaws in winter will cause snow-melt induced maximum flows to decrease while high-river flows may be more frequent (Cunderlik and Simonovic, 2005). The greater flood risk in winter months will be at the expense of an earlier and lower spring freshet, which will also alter reservoir operations for low flow augmentation in summer months (Bruce et al., 2000; Mortsch et al., 2000). The decrease in ice cover may have an effect on the amount of erosion from the banks of the reservoirs and the amount of sediment build-up behind the dam structure.

24.3 Effect of Projected Climate Changes on Assessment Report Conclusions

Projected climate changes may affect the assessment report conclusions with respect to the groundwater and surface-sourced drinking water supplies in the Grand River watershed. There is uncertainty regarding the net quantitative and temporal impacts to the Grand River water budget as precipitation, evapotranspiration, runoff, recharge and water use rates change. A Tier Two Assessment was completed for the Grand River Watershed in 2009 (AquaResource 2009a, 2009b), which identified subwatersheds and groundwater assessment areas that contain municipal water supply systems that had an elevated (*Moderate* or *Significant*) potential for hydrologic stress from a surface water or groundwater perspective. The water quantity stress analysis ~~(Section 3)~~ indicates that eleven municipal water systems are in areas with moderate or significant potential for stress: Elora/Fergus in the Township of Wellington Centre; Rockwood and Hamilton Drive in the Township of Guelph/Eramosa; the City of Guelph system including the Eramosa intake; Elmira, West Montrose, Conestogo Plains, and the Integrated Urban System in the Regional Municipality of Waterloo; Lynden in the City of Hamilton; and Bright in the County of Oxford. The Ontario Ministry of Environment and Climate Change (MOECC) released a set of updated Technical Rules (MOECC, 2017), which included the previous requirement of Tier Three Assessments to be completed in subwatersheds that have a *Moderate* or *Significant* water quantity stress in areas that supply municipal drinking water. Tier Three Water Budget and Risk Assessments were completed for the following municipal drinking water system study areas; the City of Guelph and the Township of Guelph / Eramosa, the Region of Waterloo, Whitemans Creek Tier 3, and Centre Wellington Scoped Tier 3 (ongoing). The purpose of the Tier Three Assessments is to provide a measured assessment of current and future sustainability of municipal drinking water systems in light of municipal growth and development and climate change. Specific climate change scenarios have been included in the City of Guelph and the Township of Guelph / Eramosa Tier 3 and will also be included in the Centre Wellington Scoped Tier 3. ~~The Tier 3 Water Quantity Stress Assessments for these eleven systems will look into the effects of drought, including the increased frequency of drought expected with climate change.~~

Changes in precipitation and flow regimes may also require revisions to reservoir operations to address water quality impacts upstream and downstream of these structures. The large reservoirs in the upper portions of the watershed are operated to augment downstream flows for water taking and wastewater assimilative capacity needs as well as flood management. Increasing nutrient loads and water temperatures have the potential to increase the occurrence of taste and odour problems in the riverine surface water intakes for the Guelph, Waterloo Region, Brantford and Ohsweken municipal water supplies. In addition to the potential for surface water quality problems, the Lake Erie intake for Dunnville, at a depth of 2.7 metres, is somewhat vulnerable to declining Lake Erie water levels.

25.0 CONSIDERATION OF GREAT LAKES AGREEMENTS

Under the Clean Water Act, the following Great Lakes agreements must be considered in the work undertaken in Assessment Reports:

- Canada-United States Great Lakes Water Quality Agreement (GLWQA)
- Canada – Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA)
- Great Lakes Charter
- Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement

The Great Lakes Water Quality Agreement and the Canada – Ontario Agreement generally deal with water quality concerns, while the Great Lakes Charter, the Great Lakes Charter Annex, and the Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement provide principles for joint water resources management and water quantity and quality concerns in the Great Lakes Basin.

25.1 Grand River Watershed and Great Lakes Agreements

The Grand River watershed drains directly into Lake Erie and has the potential to contribute pollutants to the lake. These pollutants, including sediments and nutrients, as well as organic and inorganic contaminants, contribute to the overall water quality of the nearshore of Lake Erie, including, but not limited to the IPZ-1 and 2 of the Dunnville drinking water intake.

In order to achieve water quality goals and objectives set under the Great Lakes Water Quality Agreement, Canadian and U.S. federal governments are addressing Areas of Concern (AOC) through Remedial Action Plans (RAP). No AOCs were identified in the Grand River watershed area in the GLWQA, and thus no remedial action plans are in place.

Additionally, the federal governments of Canada and the US have developed Lake-wide Management Plans (LaMP) in conjunction with the Province of Ontario and the States within the Great Lake watersheds. Lakewide Management Plans are broad plans to restore and protect water quality in the each Great Lake (Environment Canada, 2005). The Lake Erie LaMP, introduced in 2000, established an ecosystem vision for Lake Erie based on sustainable development and recognition of the multiple benefits of a healthy lake to society (United States Environmental Protection Agency, 2006). Since 2000, the Lake Erie LaMP has focused research and projects on nutrient management, biodiversity and habitat, emerging issues, and monitoring.

A bi-national nutrient management strategy is currently being developed by the Lake Erie LaMP that will "define the goals, objectives, targets, indicators, priority watersheds, monitoring and research needed to limit further eutrophication and improve current conditions in Lake Erie" (United States Environmental Protection Agency, 2010). This strategy will be an important foundation for future Great lakes targets under the Clean Water Act. In particular, the Grand River contributes approximately 40% of the total Phosphorus loading to the Eastern Basin of Lake Erie (Dolan and McGunagle, 2005). Reducing the load from the Grand River will be an important focus of long-term water quality objectives for Lake Erie.

As part of the Southern Grand River Rehabilitation Initiative under the Lake Erie Lake-wide Management Plan, targeted research and monitoring was undertaken in the lower Grand River to help identify areas of concern with respect to water quality and aquatic habitat. Intensive water quality monitoring in the summer and fall of 2003 and spring of 2004 at 15 sampling sites helped to characterize nutrient, dissolved oxygen and suspended sediment throughout the lower Grand River and tributaries. Important conclusions from this assessment show that the southern Grand River is nutrient-rich with high levels of phosphorus and nitrogen. Most of the samples analyzed for total phosphorus and nitrate do not meet the provincial or federal objectives. Preliminary trend analysis indicates that phosphorus concentrations are decreasing over the past 20 years while nitrate concentrations are increasing. Overall, the high nutrient and suspended sediment levels of the southern Grand River likely reflect the cumulative inputs from the watershed above Brantford.

The work undertaken and described in this Assessment Report contributes to the achievement of Goal 6 under Annex 3: Lake and Basin Sustainability under the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (Environment Canada, 2004). The report addresses two key results identified under Goal 6 of Annex 3 by identifying and assessing the risks to drinking water sources in Lake Erie (Result 6.1), and developing knowledge and understanding of water quality and water quantity issues of concern to Lake Erie (Result 6.2).

The Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement is a good faith agreement between the 8 U.S. Great Lakes States and the Provinces of Ontario and Quebec intended to implement the Great Lakes Charter and the 2001 Great Lakes Charter Annex. The Agreement sets out objectives for the signatories related to collaborative water resources management and the prevention of significant impacts related to diversions, withdrawals and loses of water from the Great Lakes basin (Ontario Ministry of Natural Resources, 2005). The agreement sets out conditions under which transfers of water from one Great Lake watershed into another (intra-basin transfer) can occur. The surface water intake in Grand River watershed are not considered to be intra-basin transfers since wastewater is discharged back into the Lake Erie watershed.

26.0 CONCLUSION

The Grand River Source Protection Area Assessment Report provides a summary of the results of technical studies undertaken to identify the threats to municipal drinking water sources in the Grand River watershed. Assessment Report findings have been used to develop policies for a Source Protection Plan to protect the sources of drinking water for the Southgate, Grand Valley, Amaranth, East Garafraxa, Shelburne, Wellington North, Mapleton, Centre Wellington, Guelph-Eramosa, City of Guelph, Waterloo Region, Perth East, Halton Hills, Oxford County, Brant County, City of Brantford, City of Hamilton, Six Nations and Haldimand County water supply drinking water systems in the Grand River watershed.

Watershed Characterization

The Grand River Source Protection Area is located in southwest Ontario and covers an area of approximately 6,800 km^2 draining to Lake Erie. Much of the land of the watershed is used for agriculture. The main urban areas are the Cities of Guelph, Waterloo, Kitchener, Cambridge and Brantford. There are two First Nations bands: Six Nations of the Grand River and Mississaugas of the New Credit.

Residents in the Grand River watershed receive drinking water supplies from both private and municipal supplies. 50 municipal systems and one First Nation system that provide water to 865,538 residents in the watershed.

In:	The communities of:	With:
Grey County	Dundalk	Groundwater wells
Dufferin County	Waldemar, Grand Valley and Marsville, Shelburne	Groundwater wells
Wellington County	Arthur, Moorefield, Drayton, Fergus, Elora, Hamilton Drive, Rockwood	Groundwater wells
City of Guelph	Guelph	Groundwater wells and Eramosa River surface water intake
Perth County	Milverton	Groundwater wells
Region of Waterloo	Waterloo, Kitchener, Cambridge, ~~Elmira,~~ St. Jacobs (Integrated Urban System), Hidden Valley, Wilmot Centre	Groundwater wells and Grand River surface water intake
	Ayr, Branchton Meadows, Roseville, Linwood, St. Clements, Wellesley, Foxboro Green, New Dundee~~ Baden~~, New Hamburg, ~~Conestogo,~~ Heidelberg, Maryhill, ~~West Montrose. ~~Elmira	Groundwater wells
Oxford County	Bright, Drumbo, Plattsville	Groundwater wells
Brant County	Paris, Brantford Airport, St. George and Mount Pleasant	Groundwater wells
City of Hamilton	Lynden	Groundwater wells
City of Brantford	Brantford, Cainsville	Grand River surface water intake
Haldimand County	Dunnville	Lake Erie surface water intake and Emergency

In:	The communities of:	With:
		Grand River Intake
Haldimand County	Caledonia and Cayuga	City of Hamilton Lake Ontario surface water intake in Halton-Hamilton SP Region
Haldimand County	Hagersville	Nanticoke Lake Erie surface water intake in Long Point Region SPA

First Nation	The communities of:	With:
Six Nations of the Grand River	Ohsweken and parts of the Reserve	Grand River surface water intake
Mississaugas of the New Credit	Parts of the Reserve	Nanticoke Lake Erie intake in Long Point Region SPA

The physiography of the Grand River watershed is dominated in the north and west by the Dundalk and Stratford Till Plains, in the centre and east by the Hillsburg and Waterloo Hills and the Horseshoe Moraines, and in the south by the Haldimand Clay Plain.

The Stratford Till Plain, which dominates in the northwest, is characterized by silty, clay-rich soils which are generally level and often poorly drained. Artificial drainage has made this a rich and productive agricultural region and, as a consequence, only a small portion of the land remains in woodlot, marsh or rough pasture.

The Horseshoe Moraine region consists of a series of moraines surrounding much of southwestern Ontario. The eastern leg of the horseshoe runs along the eastern boundary and through the central part of the Grand River watershed from the Town of Erin in the north, past Guelph and Cambridge to Paris and Brantford in the south. Some of this region is very hilly, often with steep irregular slopes and small enclosed basins. This region has large sand and gravel deposits with many extraction operations in southern Wellington County, southern Waterloo Region, and northern Brant County. This dynamic region provides extensive habitat including 5,000 hectares of wetlands. Approximately 30% of the moraine region is forested and fencerow vegetation is often well developed. The region hosts a number of cold-water watercourses that receive groundwater discharge including the Eramosa River and Mill Creek. Groundwater discharge also feeds the Grand River itself, between Cambridge and Brantford, providing a significant portion of the river's flow during summer months. The Waterloo Hills region, located in the centre of the watershed, is characterized by sand hills, gravel terraces and many swampy valleys. The soils of the hilly areas are rich and well drained.

The Haldimand Clay Plain south of the City of Brantford is characterized by heavy clay soils; much of the land is poorly drained and is used predominantly as livestock pasture and for soybean, corn and hay production. In this area, groundwater is generally obtained from the bedrock because sufficient quantities of water cannot be obtained from the overburden. Groundwater drawn from the bedrock aquifers in this area is often poor in quality as a result of naturally elevated concentrations of sulphur, salts and minerals in the water. For this reason, municipal and First Nations drinking water supplies have tended to be sourced from the Grand River or Lake Erie.

The geology of the Grand River watershed varies widely across the region. The entire watershed is underlain by carbonate bedrock formations which form north to south trending bands. Unconsolidated sediments, or overburden, deposited in relation to the movement of glaciers across the landscape over time overlay the bedrock formations. The overburden sediments are classified into three common groupings within the north, central and southern portions of the watershed. Overburden within the northern part of the watershed, are commonly tills and till-related materials. The central portion of the watershed contains a series of complex moraine systems, ice-contact, and outwash deposits, whereas the southern portion of the watershed is comprised of fine-grained glaciolacustrine, or clay-rich, sediment.

The majority of the population of the Grand River watershed relies on groundwater as a clean, safe, drinking water supply. In addition to providing a safe source of drinking water, groundwater is used in agriculture, commercial, and industrial applications. Groundwater also plays a pivotal role in sustaining sensitive natural features and aquatic habitats such as streams and wetlands. It has long been recognized that groundwater has a vital role in the hydrologic function of the watershed. Groundwater provides critical baseflow to many parts of the watershed, thereby supporting aquatic and wetland ecosystems.

The northern portion of the watershed contains primarily till deposits, which do not to contain extensive or significant aquifer units. Communities such as Dundalk, Grand Valley, Waldemar, Marsville, Fergus, Elora, Guelph-Eramosa, and the City of Guelph rely on groundwater obtained from the Guelph, Goat Island, and Gasport Formations for municipal supply. Communities in Wellington North, such as Arthur, Moorefield, and Drayton obtain municipal water from aquifer units located in the overburden.

The Waterloo Moraine is one of the largest moraines within the Grand River watershed. A number of aquifers situated within the moraine are used by the Region of Waterloo for drinking water supply. The moraine is situated within the west-central part of Waterloo Region in the central portion of the watershed.

Located in the southwest portion of the watershed, the Norfolk Sand Plain is a significant source of groundwater within the overburden sediments. Groundwater from the aquifers located within the sand plain is used as a drinking water resource, and also relied heavily upon for crop irrigation and to meet agricultural water needs. Groundwater from these shallow aquifers also provides critical baseflow to Whitemans Creek which supports cold-water fisheries. The chemical characteristics of groundwater within the Grand River watershed are derived from two sources: (1) the ambient chemistry, where the composition of the groundwater reflects its relative residence time in the aquifer and the nature of the substrate through which it flows, and (2) anthropogenic impacts to the quality of the groundwater through various land use activities such as road salting, fertilizer and manure applications to agricultural fields, and industrial chemical use. In the Grand River watershed, three distinctive land use activities have impacted groundwater quality: road salting, the application of manures/fertilizer, and the use of industrial chemicals.

Surface water quality in the Grand River is influenced by the geology and current land use. Surface water quality parameters of interest within the Grand River include: chloride, sodium and nitrates. Chloride concentrations reflect the influence of urban point and non-point sources but levels in the Grand River do not exceed the aesthetics guideline for drinking water supplies of 250 mg/L. Levels do, however, approach the guideline for the protection of aquatic life (150 mg/L) albeit occasionally, usually during the spring freshet. Nitrate levels above 10 mg/L, the drinking water quality guideline for treated water, may cause concern for municipal supplies.

Research in the watershed indicated that shallow tile drainage may have an important role in the elevated nitrate concentrations seen in the upper central Grand River area. Progress to address data gaps identified in the Grand River watershed characterization report have been made and include; detailed Tier 3 water budget studies which contain updated local geologic and groundwater flow data determined through detailed field investigations and modeling.

Water Quantity Risk Assessment

Municipal water supply accounts for just over 57% of the consumptive water use in the Grand River watershed. Industrial and agricultural uses account for about 5% and 9% of the consumptive water use.

The surface water subwatershed stress assessment classifies three subwatersheds as having a moderate potential for stress under existing conditions (Eramosa River Above Guelph, Whitemans Creek and McKenzie Creek).

The groundwater stress assessment classifies three assessment areas as having a moderate potential for stress under existing conditions (Canagagigue Creek, Upper Speed, and Mill Creek), one additional assessment area as having a moderate potential for stress under future conditions (Irvine River), one assessment area as having a moderate potential for stress under drought conditions (Whiteman's Creek), and one assessment area as having a significant potential for stress under existing conditions (Central Grand).

Tier 3 local water quantity risk assessments are required for ten municipal systems:

Assessment Area	Municipality	Water Supply System
Canagagigue	Waterloo Region	Elmira
		West Montrose
		Conestogo Plains
Upper Speed/Eramosa	City of Guelph	City of Guelph wells and Eramosa River intake
	Guelph-Eramosa	Rockwood wells
		Hamilton Drive wells
Central Grand	Waterloo Region	Integrated Urban System wells
Irvine River	Centre Wellington	Fergus-Elora Integrated System wells
Whiteman's Creek	Oxford County	Bright wells

Tier 3 Water Budget and Risk Assessments

Tier 3 Assessments aim to determine if a municipality is able to meet their current and future water demands. Specifically, Tier 3 Assessments estimate the likelihood that a municipal drinking water aquifer or surface water feature (i.e., river or lake) can sustain pumping at their future pumping rates, while accounting for the needs of other water uses such as cold water streams, or other permitted water takers in the area. Tier 3 Assessments consider current and future municipal water demand, future land development plans, drought conditions, and other water uses as part of the evaluation.

Within the Grand River watershed, Tier 3 studies have been completed for municipal drinking water systems within the City of Guelph, Guelph/Eramosa Township, the Region of Waterloo, the Bethel Wellfield in the County of Brant, and the Bright Wellfield in Oxford County. Further information on these studies is found in Chapters 19 (City of Guelph and Guelph/Eramosa Township), 20 (Region of Waterloo), and 21 (Whitemans Creek). The Centre Wellington Scoped Tier 3 Assessment is currently underway, with an update to the assessment report once the study is complete.

Tier 3 Assessments were completed for the Town of Halton Hills and the Town of Orangeville. Although the Town of Halton Hills and the Town of Orangeville do not have wells located within the Grand River Watershed, the Wellhead Protection Area for Quantity extends into the Grand River Source Protection Area.

Guelph-Guelph/Eramosa Tier 3 Water Budget and Risk Assessment

The vulnerable areas in the GGET Tier 3 Assessment are represented by four WHPA-Qs (Groundwater Vulnerable Area) and an IPZ-Q (Surface Water Vulnerable Area). The largest WHPA-Q (WHPA-Q-A) is circular, with a diameter of approximately 20 km and extends around the City of Guelph and into the Township of Guelph/Eramosa. The extent of the WHPA-Q-A to the southwest toward the City of Cambridge was delineated based on the results of the GGET Tier 3 Assessment and the Region of Waterloo Tier 3 Assessment completed for the municipal wells in the City of Cambridge. Significant threats to drinking water quantity were identified as a result of assigning a *Significant* Risk Level to the WHPA-Q-A and IPZ-Q. These threats included 7,537 consumptive water takings (e.g., municipal and non-municipal takings) and 17.4 km^2 of recharge reduction areas.

Region of Waterloo Tier 3 Water Budget and Risk Assessment

The vulnerable areas in the Waterloo Tier 3 Assessment are represented by four WHPA-Qs. The WHPA-Q1-A underlies the western portions of Kitchener and Waterloo. The WHPA-Q1A area extends north to the town of Heidelberg, south to New Dundee, west to St. Agatha and east toward the Grand River. The WHPA-Q1B underlies the majority of the urban portion of Cambridge, and extends in a northwestward direction toward Guelph. The WHPA-Q1B extends into Guelph, as the northern model boundary condition for the Cambridge Model coincides with the pumped groundwater level elevations for the aquifers in Guelph. The WHPA-Q1C area is a small drawdown cone located around the Blair Road Wells (Wells G4 and G4A). The WHPA-Q1D area is represented by a 100 m buffer surrounding the Conestogo Plains Well Field (Wells C3 and C4). The consumptive water users and potential reductions to groundwater recharge within the WHPA-Q1s were not classified as Significant or Moderate water quantity threats, therefore no water quantity threats were identified within the WHPA-Q1s.

Whitemans Creek Tier 3 Water Budget and Risk Assessment

The Whitemans Creek Tier 3 Study evaluated the risk of water quantity impacts to the Bright Well Field in Oxford County and to the Bethel Well Field in the County of Brant, given planned growth (future land use and allocated water demand) and variable climate (average and drought conditions). The WHPA-Q for the Bright Well Field is a circle of 100 m radius around each production well, with a “low” risk level for water quantity impacts. Threats for the Bethel Well

Field WHPA-Q included 19 consumptive water takings (e.g., municipal and non-municipal takings) and 2.43 km^2 of recharge reduction areas.

Town of Orangeville Tier 3 Water Budget and Risk Assessment

A Tier 3 Assessment was completed for the Town of Orangeville. Although the Town of Orangeville in not located within the Grand River watershed, the WHPA-Q2 extends to portions of the Townships of Amaranth and East Garafraxa which are located within the Grand River watershed. Risk assessment scenarios resulted in a Significant Water Quantity Risk Level for WHPA-Q2. Threats for the Orangeville WHPA-Q2 within the Grand River watershed included 44 consumptive water takings.

Town of Halton Hills Tier 3 Water Budget and Risk Assessment

A Tier 3 Assessment was completed for the Town of Halton Hills. Although the Town of Halton Hills in not located within the Grand River watershed, the Acton Well Field WHPA-QA extends to a portion of the Town of Erin which is partially located within the Grand River watershed. Risk assessment scenarios resulted in a Significant Water Quantity Risk Level for WHPA-QA. Threats for the Halton Hills WHPA-QA within the Grand River watershed included 9 consumptive water takings.

Water Quality Risk Assessment

WHPAs are mapped for each municipal groundwater supply system based on a quantitative assessment of lateral groundwater flow in the vicinity of the municipal wellfield. A WHPA consists of four zones which are based on the time it takes for groundwater to travel from the water table surface to the municipal well. Using the calibrated groundwater flow models, capture zones in the Grand River watershed have been delineated through time of travel assessments using backward and forward particle tracking.

An aquifer vulnerability analysis is a physically-based evaluation of the geologic and hydrogeologic character of the sediments and bedrock overlying the municipal aquifer. The resulting calculations provide a rating of the intrinsic vulnerability for the aquifer of interest. Numerous approaches are available to estimate groundwater intrinsic vulnerability such as the Intrinsic Susceptibility Index (ISI), Aquifer Vulnerability Index (AVI), Surface to Well Advective Time (SWAT), Surface to Aquifer Advective Time (SAAT). To obtain the vulnerability score within a WHPA, a scoring matrix is applied which intersects the WHPA zones with the aquifer vulnerability classification. The presence of transport pathways are considered following the initial vulnerability assessment, and may result in a revision to the vulnerability assessment.

The Intake Protection Zone (IPZ) is the primary vulnerable area to be delineated to ensure the protection of the municipal surface water supply. For each drinking water system, an IPZ-1, IPZ-2 and IPZ-3 can be delineated. Surface water intakes are classified according to their location, with four different classifications (Types A, B, C, or D). Vulnerability scoring is based on the attributes of the intakes (e.g. length and depth), type of source water body, and the physical characteristics of the environment it is situated in.

In determining the potential impact of certain types of land use activities on municipal water quality, the percentage of managed lands and the livestock density in the surrounding area must be considered. Managed lands are those lands to which agricultural source material, commercial fertilizer, or non-agricultural source material are applied. Livestock density is a surrogate measure of the potential generation, storage, and application of agricultural source material within a given area, and is expressed in nutrient units generated per year, per acre. In addition, impervious surface area mapping is used in the scoring and assessment of threats related to road salt application.

In the Grand River watershed, drinking water threats within either WHPAs or IPZs of municipal drinking water systems were identified through the following:

- An activity prescribed by the Act as a Prescribed Drinking Water Threat;
- An activity identified by the Source Water Protection Committee as an activity that may be a threat and (in the opinion of the Director) a hazard assessment confirms that the activity is a threat;
- A condition that has resulted from past activities that could affect the quality of drinking water; or
- An activity associated with a drinking water Issue.

All significant threats must be addressed in the Source Protection Plan. The LESPR SPC may choose to develop policies to address low or moderate drinking water threats.

Municipal Drinking Water Systems

In all, there are 50 municipal systems and one First Nations drinking water system. Of these, there are 49 groundwater municipal systems, including two integrated groundwater/inland river systems, three inland river systems, one Lake Erie intake. In addition, one pipeline system from Lake Ontario provides water to residents in the Grand River watershed. Municipal systems are owned and operated by upper, lower, and single tier municipalities. Municipal water demand within the watershed is estimated at approximately 86 million m^3/yr, and this volume services approximately 865,538 residents.

Dundalk – Township of Southgate

The Dundalk municipal water supply system consists of three bedrock wells (Wells D3, D4 and D5) and services a population of approximately 1,700 people. Wellhead Protection Areas are delineated for each well: a 100 m proximity zone and three time-related (2-year, 5-year and 25-year) capture zones generated through a groundwater model. Final vulnerability scores include 10 in WHPA-A, 6 in WHPA-B, 2 in WHPA-C and 4 and 2 in WHPA-D. ~~The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells.~~

The water quality threats assessment shows that three activities on three properties may be significant threats within the WHPA-A or WHPA-B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Waldemar – Township of Amaranth

Three wells (PW1, PW2 and PW3) supply groundwater to the Waldemar Heights water supply system. The wells are completed in bedrock and draw water from the locally confined Guelph – Amabel aquifer. The municipal system supplies water to approximately 342 residents. Final vulnerability scores include 10 in WHPA-A, 10, 8 and 6 in WHPA-B, 2 in WHPA-C and 6 and 2 in WHPA-D. ~~The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells.~~ Adjustments were made to the vulnerability mapping to account for the transport pathway provided by the sand and gravel pit located on the eastern edge of WHPA-D.

The water quality threats assessment shows that 39 activities on 36 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Grand Valley – Town of Grand Valley

The Grand Valley water supply system includes four wells (PW1, PW2, PW3 and PW4) that are completed in the Guelph-Amabel bedrock formation and service a population of approximately 1,600 people.

Wells PW1 and PW2 are located east of the Grand River in the flood plain and obtain water from a leaky confined bedrock aquifer. Vulnerability scores are predominantly high to medium with high vulnerability mapped along bedrock outcrops along the Grand River valley and areas of thin overburden. Adjustments were made to the vulnerability mapping to account for potential transport pathways (concentrations of private wells and underground infrastructure within the village limits, aggregate operations). Wells PW3 and PW4 are west of the Grand River. The bedrock in the area of PW3 and PW4 is protected by over 24 m of fine-grained overburden.~~,~~ Final vulnerability scores include 10 in the WHPA-As, 10, 8 and 6 in the WHPA-Bs, 8, 6 and 2 in the WHPA-Cs and 6, 4 and 2 in WHPA-D. ~~which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells.~~ PW4 is~~d~~ permanently off-line and a capture zone was not delineated for this well.

The water quality threats assessment shows that 29 activities and 1 condition on 29 properties may be significant threats within WHPA-A, B and C. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Marsville – Township of East Garafraxa

The Marsville water supply system includes two wells which service approximately 80-90~~130~~ people. The wells, which tap the locally confined Guelph – Amabel aquifer, draw water from the upper weathered and competent middle portion of the bedrock aquifer. Because of the low pumping rate within a very productive aquifer, the pumped water is replenished to the aquifer within the 2-year capture zone and, therefore, no 5-year or 25-year zones have been delineated. Overburden in the vicinity of the Marsville well is approximately 62 m in thickness.~~;~~ Final vulnerability scores include 10 in WHPA-A and 6 in WHPA-B.~~the low vulnerability results in a medium vulnerability score in the 2-year wellhead protection zone and high vulnerability within the 100-metre zone around the well.~~

The water quality threats assessment shows that 10 activities on 8 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Shelburne – Township of Melancthon

The Shelburne water supply includes ~~one~~ two wells located within the Grand River watershed in the Township of Melancthon. The well contributed to the Shelburne water supply system which services approximately 6800 people. The well is drilled to a depth of 86.6 metres below ground surface. Final vulnerability scores include 10 in WHPA-A, 10, 8 and 6 in the WHPA-Bs, 8, 6 and 2 in the WHPA-Cs and 4 and 2 in the WHPA-Ds. ~~The area has low to medium vulnerability, therefore the resulting vulnerability scores are low to medium, except in the WHPA-A where it is high.~~

The water quality threats assessment shows that there are ~~7~~ 4 activities on ~~3~~ 2 properties that may be significant drinking water threats within the WHPA-A. An Issues-based threat analysis was also completed through a review of water quality data collected from the municipal well. No Issues-based threats were identified within the WHPA.

Orangeville Water Supply

The Town of Orangeville is located in the headwaters of the Credit Valley River and in the Credit Valley Source Protection Area. Orangeville has 12 water supply wells in nine well fields that supply the town of approximately 29,000 people. The wells obtain water from a combination of overburden and bedrock aquifers (Burnside, 2010). Portions of WHPA-B, C and D for the Orangeville wells, with the exception of Well 10, cross into the Grand River Source Protection Area.

An Issues evaluation was also completed by reviewing water quality data collected from the municipal wells. Sodium and Chloride were both identified as Issues under Technical Rule 114. An Issue Contributing Area has been delineated the well field of Well 2A, Well 5/5A and Well 9A/9B for the Issue of chloride. Both a chloride and sodium Issue Contributing Area has been delineated for the well field for Wells 6 and 11 and is the 25 year time-of-travel.

The water quality threats assessment shows that ~~84~~ 32 activities on ~~68~~ 11 properties may be significant threats within WHPA-B, C and D or ICA. ~~In addition, 44 water quantity threats on 44 properties may be significant threats within WHPA-Q2.~~

Arthur – Township of Wellington North

Within the Township of Wellington North, the community of Arthur's municipal water supply system consists of 3 overburden wells (Wells 7B and 8A/8B). The municipal system supplies water to approximately 2,500 people within the community. All three wells are completed in the deep overburden aquifer at approximately 46 m below ground surface. The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells. Adjustments were made to the vulnerability mapping to account for the transport pathways (buried infrastructure within the WHPA-B).

The water quality threats assessment shows that 14 activities on 6 properties may be significant threats within WHPA-A and C. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Drayton – Township of Mapleton

Two municipal wells, completed in the Salina bedrock formation, supply approximately 1,550 people in the community of Drayton. Both wells are completed as open hole in the upper portion of the dolostone bedrock aquifer which is overlain by about 58m of fine-grained overburden. Because of the low vulnerability in the area, vulnerability scores are low to medium in most of the wellhead protection areas and high within the 100-metre area around the wells.

The water quality threats assessment shows that 18 activities on 7 properties may be significant threats within WHPA-A and B. An issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats were identified within the municipal groundwater system.

Moorefield – Township of Mapleton

The Moorefield Water Supply has two pumping wells and supplies approximately 550 people. Water in the wells comes from an extremely permeable portion of the dolomite bedrock aquifer at a depth of 82m. The aquifer is described as a confined aquifer with little to no leakage. The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells.

The water quality threats assessment shows that 9 activities on 3 properties may be significant threats within WHPA-A. An issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats were identified within the municipal groundwater system.

Township of Centre Wellington (Fergus-Elora)

Within the Township of Centre Wellington, the communities of Fergus and Elora are supplied by an integrated municipal groundwater system. Together, the water systems are referred to as the Centre Wellington Supply System which serves 12,893 residents in Fergus and 5,202 residents in Elora. The water supply system for Elora consists of three bedrock wells referred to as E1, E3 and E4. The water supply system for Fergus consists of six bedrock wells referred to as F1, F2, F4, F5, F6 and F7. All of the wells are made in the Gasport (formerly Amabel) bedrock formation and are protected by the Eramosa Member which functions as an aquitard in this area. Vulnerability in the wellhead protection areas, assessed using the Surface to Aquifer Advection Time (SAAT) methodology, is moderate across much of the area; vulnerability scoring is generally high in the WHPA-A immediately along the Grand River, high-moderate in the WHPA-B and moderate in the WHPA-C.

Since Well F2 is identified as groundwater under the direct influence of surface water (GUDI), a WHPA-E was delineated in addition to the WHPA-A to D. The WHPA-E has a vulnerability score of 6.3.

The water quality threats assessment shows that 48 activities on 34 properties may be significant threats within WHPA-A, B and C for the Elora wells. 161 activities on 108 properties may be significant threats within the WHPA-A, B and C for the Fergus wells. An issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats were identified within the municipal groundwater system.

Rockwood – Township of Guelph/Eramosa

The water supply system for Rockwood includes two well fields, the Station Street Well Field (Well 1 and 2) and the Bernardic Well Field (TW3/02, Well 3) serving a population of 3,970 people. A fourth well (Well 4) is located northeast of Hwy7 and is not currently online but has been identified as a future municipal supply. Wells 1 and 2 are approximately 60 m deep and completed in bedrock. The bedrock is part of the heterogeneous, layered and fractured Gasport aquifer and is overlain by approximately 6 m of stony gravel overburden. Well 3 is located southeast of the Eramosa River and is completed in bedrock. Water is drawn from depths of approximately 45 to 49m. The wellhead protection areas are located in areas dominantly classified as medium to high vulnerability with only the WHPA-D of Rockwood Wells 3 and 4 classified as low. Areas of high vulnerability are located in areas of bedrock outcrop and thin overburden, which tend to be located along the Eramosa River. The vulnerability scoring is high in the WHPA-A, high to moderately high in the WHPA-B and moderate to moderately high in the WHPA-C for each of the wells. Adjustments were made to the vulnerability mapping to account for the transport pathways along Main street and Harris Street and in the hamlet of Everton due to the high density of private wells, and in the area of an aggregate operation on Wellington Road 125 within WHPA-D for Rockwood Wells 1 and 2.

Although the Rockwood Wells 1 and 2 are identified as groundwater under the direct influence of surface water (GUDI), there is no evidence of a connection or interaction with a surface water body that would decrease the time of travel of water to the well; therefore, no WHPA-E was delineated for these wells.

The water quality threats assessment shows that 151 activities on 52 properties may be significant threats within WHPA-A, B and C. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Hamilton Drive – Township of Guelph/Eramosa

The community of Hamilton Drive has a serviced population of approximately 653 people and is supplied by two bedrock wells (Cross Creek and Huntington wells) that draw groundwater from the Guelph bedrock formation. The Cross Creek Well is completed with an open bedrock hole with the bedrock overlain by 21 m of clay overburden. The Huntington Well is also completed with an open bedrock interval and is overlain by 3 m of till. The wellhead protection areas are located in areas classified dominantly as medium vulnerability with some low vulnerability areas within the far northern parts of the WHPA-D zones. Some areas of high vulnerability are mapped where bedrock outcrops along the drainage courses such as the Speed River, Marden Creek and Cox Creek. The vulnerability scoring is high in the WHPA-A, high to moderately high in the WHPA-B and moderate to moderately high in the WHPA-C for each of the wells. Adjustments were made to the vulnerability mapping to account for the transport pathways along Wellington Road 22 within WHPA-D due to the high density of high risk wells.

The water quality threats assessment shows that 33 activities on 27 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Guelph Waterworks

The groundwater supply system includes 25~~3~~ groundwater supply wells and one shallow groundwater collector system that serve a population of approximately 135~~115~~,000. Currently 19 wells are in service, with four wells out of service due to quality and maintenance concerns. 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.T~~he wells that supply the City's water are completed within both overburden sediments (1 well), and the underlying Guelph and/or Gasport (formerly Amabel) Formations (22 wells).~~ At Arkell, which is located just outside the City, the groundwater supply is supplemented by an artificial recharge system. Surface water from the Eramosa River is used to recharge and enhance the flow of the Arkell Springs (Glen) Collection System.

Wellhead protection areas were delineated using the City's most current groundwater model that builds upon previous models and includes the most recent hydrogeological investigations undertaken by the City. A large portion of the City of Guelph's land area is contained within the WHPA-B (2-year) and most of the land area is contained within the WHPA-C (5-year).

Vulnerability in the wellhead protection area has been assessed using the Intrinsic Susceptibility Index (GwISI) method. Vulnerability scores are high (10 or 8) in the WHPA-A and portions of the WHPA-B, particularly along the Eramosa and Speed River valleys where overburden is thin. Vulnerability scores through the remainder of the WHPA-B are moderately high to moderate (8 or 6) and, in the WHPA-C, moderately high to low (6 or 4). Vulnerability scores were adjusted to account for transport pathways (buried infrastructure and pits and quarries).

The Glen Collector system, Arkell 1 well and the Carter wells are identified as groundwater under the direct influence of surface water (GUDI). A WHPA-E was delineated for the Carter wellfield in addition to the WHPA-A to D. The WHPA-E has a vulnerability score of 7.2. No WHPA-E was delineated for the Glen Collector system or the Arkell 1 well because these wells are influenced by the Eramosa River and the intake protection zones delineated for the Eramosa intake are relevant for these wells.

The Eramosa River intake that pumps water to the Arkell Recharge System is classified as a Type C intake. The Intake Protection Zone 1 (IPZ-1) is delineated as a 200 metre semi-circle centred on the intake and extending upstream. Where the delineated area abuts land, a setback of 120 m or the Conservation Authority Regulation Limit, whichever is greater, is applied. The IPZ-2 is based on the distance that water will travel at the 95th percentile flow in six hours and was determined in the Eramosa River using a series of dye tracer tests together with a hydraulic model of the river. The IPZ-3 is delineated by identifying all watercourses that supply water to the Arkell intake and applying a lateral setback equal to the greater of 120 m or the Conservation Authority Regulation Limit. The vulnerability score for the IPZ-1 is 10 and for the IPZ-2 is 7. The vulnerability score in the IPZ-3 is 5 for built-up areas, 3 for agricultural areas and 1 for natural areas.

An Issues evaluation was also completed by reviewing water quality data collected from the municipal wells. Nitrate was identified as an issue under Technical Rule 114 at the City of Guelph's Carter wells, while Trichloroethylene (TCE) was identified as an issue at the Membro, Edinburgh, Smallfield, Sacco and Emma wells. Issue Contributing Areas have been delineated for each well at which an Issue has been identified.

The water quality threats assessment shows that 1,830 activities on 1119 properties may be significant threats within WHPA-A, B C, and the Issue Contributing Areas. In addition, 24 conditions have been identified in the City of Guelph.

Region of Waterloo Integrated Urban System (IUS)

The Integrated Urban System (IUS) is a complex network of water sources, treatment, storage and delivery systems serving Cambridge, Kitchener, Waterloo, ~~parts of~~ Elmira, New Hamburg, St. Agatha and St. Jacobs ~~in the Township of Woolwich, and parts of Wilmot Township~~ that serves a total population of approximately 517,030~~(approximately 488,342 persons)~~. The IUS system is comprised of 67 wells (from seven~~ix~~ drinking water systems), completed in both overburden and bedrock, the Hidden Valley surface water intake on the Grand River, and an aquifer storage and recovery system (ASR). During periods of high demand treated surface water is introduced to the IUS in Kitchener and combined with treated water from a variety of groundwater sources. During the seasons of lower demand, treated surface water is injected via ASR wells for storage and pumped out for use during high demand periods.

The two FEFLOW groundwater flow models developed and refined during the Tier 3 Risk Assessment and a third ASR MODFLOW model, were utilized to develop updated WHPAs~~)~~ for the municipal supply wells~~-~~ in the Region. The Regional FEFLOW model encompasses the entire Region of Waterloo and was modified from a pre-existing groundwater flow model with a focus on the overburden groundwater flow systems. The Cambridge FEFLOW Model was developed during the Tier 3 Assessment and focussed on the bedrock stratigraphy in the Cambridge area. The model utilized to generate capture zones at each wellfield was chosen based on which best represented the local conditions. Capture zones for all wells besides the ASR wells were completed using steady-state model conditions. The WHPAs for the ASR wells were delineated using a MODFLOW model run in transient state to simulate the cyclical nature of water injection and withdrawal of this system.

~~Two groundwater flow models were created to simulate groundwater flow and develop capture zones for municipal supply wells in the Region of Waterloo. For all of the wells except for the Aquifer Storage and Recharge (ASR) system, the modeling was undertaken using a steady state Feflow model. The capture zones for the ASR wells were delineated using a MODFLOW model run in transient state to simulate the cyclical nature of water injection and withdrawal of this system.~~

Vulnerability in each of the wellhead protection areas has been assessed using the Intrinsic Susceptibility Index (ISI) method for the applicable aquifer.

The following summarizes the vulnerability assessment, threats assessment and issues evaluation for each of the well fields that are part of the integrated urban system.

Waterloo Area Well Fields

Erb Street Well Field

The water supply for the Erb Street Wellf~~ F~~ield was~~is~~ obtained from Production Wells W~~0~~6A/W~~0~~6B, W~~0~~7 and W~~0~~8. Well W6A has become problematic and a replacement well W6C has been constructed adjacent to W6A but has not yet been connected to the municipal system. ~~Well W06B is a standby well, available to produce water when W06A is not available.~~ All of the production wells are completed within the sand gravel Middle Waterloo Moraine Sands (AFB2)

Shallow Overburden Aquifer underlain by the Maryhill Till at screen depths ranging from 32 m to 56 m below ground surface.

Finalsurface. Final vulnerability scores include 10 in WHPA-As, 10, 8 and 6 in WHPA-Bs, 8, 6 and 4 in WHPA-Cs and 6, 4 and 2 in WHPA-Ds.The Erb Street wellfield is located in an area where the vulnerability is generally low. Vulnerability scores are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D.

The water quality threats assessment shows that 17 8 activities on 74 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

William Street Well Field

The water supply for the William Street Well Field is obtained from Production Wells W01B, W01C and W02. All of the production wells are screened at depths ranging from 20 m to 34 m below ground surface with Pre-Catfish Creek Aquifer the Deep Overburden Aquifer which is overlain intermittently by the Maryhill and Catfish Creek Tills. The overlying aquifers (AFB2 and AFB3) are consequently hydraulically connected to AFD1 in areas where the aquitards pinch out.

Final vulnerability scores include 10 in WHPA-A, 10, 8, 6 in WHPA-B, 6 and 4 in WHPA-C and 6, 4 and 2 in WHPA-D.The William Street well field is located in an area where the vulnerability is generally low. Vulnerability scores are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D. Vulnerability scores were increased to account for transport pathways (several well clusters) within WHPA-A, B and C.

An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. TCE, sodium and chloride have been identified as an Issues for the William Street production wells. The Issue Contributing Area for both the TCE, sodium and chloride Issue is delineated as the 25-year capture zone.

The water quality threats assessment shows that 635334 activities and 53 conditions on 526330 properties may be significant threats within WHPA-A, B, and ICAC and D.

Waterloo North Well Field

The water supply for the Waterloo North well field is obtained from Production Wells W05A and W10. The Region ceased full-time production at W5 in the mid to late 70s due to water quality concerns – mainly elevated TDS, hardness, iron and sulphate – and the well was physically disconnected from the IUS in 2000. A Class Environmental Assessment was completed in 2011 for the addition of a new well adjacent to the Laurel Tank (W25) to the Waterloo North Wellfield. An addendum to the Environmental Assessment was undertaken to limit construction of treatment facilities for only W25 (and not W5A) as demand did not warrant bringing W5A on line in the short term.An Environmental Assessment is currently underway to look at options for bringing W5 back into production. Production well W05 is screened within the Pre-Catfish Deep Overburden Aquifer at a depth of approximately 343 m BGS to 397 m BGS; W25 is screened at a depth of 75 m BGS to 78 m BGS. Production well W10 is screened within Upper Waterloo Moraine Sandsthe Shallow Overburden Aquifer at a depth of approximately 9 m BGS to 18 m

BGS. These two aquifer systems are separated by a confining aquitard corresponding to the Maryhill and Catfish Creek Tills.

Final vulnerability scores include 10 in WHPA-As, 10, 8 and 6 in WHPA-Bs, 8, 6 and 4 in WHPA-Cs and 6, 4 and 2 in WHPA-Ds.~~Well W05 is located in an area where vulnerability is generally low. Vulnerability scores are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D. Vulnerability scores have been increased in the WHPA-A and B to account for transport pathways (two well clusters). Well W10 is located in an area with high to moderate vulnerability. Vulnerability scores are high in WHPA-A, high to moderately high in WHPA-B and moderate to moderately high in WHPA-C.~~

Well W10 is classified as Groundwater under the direct influence of surface water (GUDI) with effective filtration. A WHPA-E was delineated for Well W10 in addition to the WHPA-A to D. The WHPA-E has a vulnerability score of 8.1.

The water quality threats assessment shows that 20~~7~~ activities on 14~~6~~ properties may be significant threats within WHPA-A, ~~and~~ B and E. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Kitchener Area Well Fields

<u>Mannheim Well Field</u>

Water supply for the Mannheim well field is obtained from the following well fields:

- Mannheim East – Wells K21/K21A, K25 and K29 screened from 30 to 52 m bgs in ~~Aquifer 1~~AFB2;
- Mannheim Peaking – Wells K91, K92, K93, and K94 screened from 54 to 75 m bgs in ~~Aquifer 1~~AFB2;
- Mannheim West – Wells ~~K22A,~~ K23, K24 and K26 screened from 20 to 38 m bgs in ~~Aquifer 1~~AFB2;
- Aquifer Storage and Recovery (ASR) wells – Wells ASR~~0~~1, ASR~~0~~2, ASR~~0~~3 and ASR~~0~~4 screened from 52 to 66 m bgs in ~~Aquifer 1~~AFB2; and,
- ASR Recovery Wells – Wells RCW1 and RCW2 screened from 69 to 73 m bgs in ~~Aquifer 1~~AFB2.

The Mannheim wells are all constructed within the Middle Waterloo Moraine Sands (AFB2) and generally positioned just above the Maryhill Till. AFB2 is overlain by a discontinuous, fine-grained, aquitard unit (ATB2) throughout the Mannheim area. ATB2 is overlain by AFB1, which outcrops in various locations throughout Mannheim. It is of note that AFB1 and AFB2 are hydraulically connected in the vicinity of the Mannheim West Wellfield and modeled particle pathlines during the capture zone assessment indicated particles extended predominantly through both aquifers. This was the rationale for applying AFB1 as the aquifer for intrinsic vulnerability mapping.

The Peaking wells historically were primarily used in the summer months to meet peak water demands with either one of K91/K92 and K93/K94 pumping at any given time. The ASR wells were designed to inject treated water from the Grand River into the Middle Waterloo Moraine

Sands (AFB2) during periods of low demand and then pump it out again when the water is needed, similar to the peaking wells. The ASR wells are capable of both pumping and injection whereas the RCW wells are only capable of pumping. The Mannheim wells contribute water to the IUS.

At Mannheim East, K25 typically provides the most water followed by K29 and K21. The Peaking wells are only used in the summer months to meet peak water demands with either one of K91/K92 and K93/K94 pumping at any given time. Typically, the highest pumping rates at Mannheim are observed at the ASR wells. The ASR wells were designed to inject treated water from the Grand River into the Shallow Overburden Aquifer during periods of low demand and then pump it out again when the water is needed, similar to the peaking wells. Typically, more water is injected than is recovered. The ASR wells are capable of both pumping and injection whereas the RCW wells are only capable of pumping. At Mannheim West, K26 is the largest producer with the smallest producer being K22A. The Mannheim wells are all constructed within the Shallow Overburden Aquifer, which outcrops in various locations throughout Mannheim and is often separated into upper and lower Aquifer systems through the presence of a discontinuous, fine-grained, Aquitard unit. Production wells are generally screened below this Aquitard unit, just above the Maryhill Till.

The intrinsic vulnerability in the area of the Mannheim wells is generally medium to high. Final vulnerability scores include 10 in WHPA-A, 10, 8, 6 in WHPA-B, 8, 6 and 4 in WHPA-C and 6, 4 and 2 in WHPA-D. Vulnerability scores are high in the WHPA-A, moderately high to moderate in WHPA-B and moderate in WHPA-C. Vulnerability scores have been increased in the wellhead protection area to account for transport pathways: an aggregate operation within WHPA-C and D of wells K25 and K26 and clusters of wells, septic systems and underground services throughout the WHPA.

Wells K22A and K23 isare classified as Groundwater under the direct influence of surface water (GUDI)GUDI with effective filtration. A WHPA-E was delineated for Wells K22A and K23 in addition to the WHPA-A and B. The WHPA-E has a vulnerability score of 6.3.

Nitrate has been identified as an Issue for the K23, K24 and K26 wells. The Issue Contributing Area for well K24 and K26 has been delineated as the 25-year capture zone; the Issue Contributing Area for well K23 has been delineated as the 25-year capture zone plus the area of the WHPA-E zone for this well.

The water quality threats assessment shows that 59446 activities on 36021 properties may be significant threats within WHPA-A, B, C, D and E, or ICA..

Lancaster Well Field

The water supply for the Lancaster well field is obtained from production wells K41 and K42A. Both wells ceased production in 1991 due to water quality concerns – mainly iron and manganese – and have since been disconnected from the IUS. All of the production wells are screened within the Deep Overburden Aquifer at depths ranging from 30 m to 52 m below ground surface, and are overlain by an extensive aquitard unit consisting of the Maryhill and Catfish Creek Tills, with the Shallow Overburden Aquifer at ground surface.

Well K42A is located in an area where vulnerability is generally low. Vulnerability scores are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D. Well K41 is located in an area with low to moderate vulnerability. Vulnerability scores are high in WHPA-A,

~~moderately high to moderate in WHPA-B and moderate to low in WHPA-C. Vulnerability scores have been increased in the WHPA-A and D to account for transport pathways (six well clusters).~~

~~The water quality threats assessment shows that 14 activities on 8 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.~~

Greenbrook Well Field

The water supply for the Greenbrook well field is obtained from production wells K~~0~~1A, K~~0~~2A, K~~0~~4B, K~~0~~5A, and K~~0~~8 which are screened from approximately 33 to 50 m ~~below ground surface~~bgs. All of the production wells are completed within the Pre-Catfish Creek Aquifer (AFD1)~~Deep Overburden Aquifer~~ and are overlain by an extensive aquitard unit comprised of the Maryhill and Catfish Creek Tills.

~~The vulnerability of the aquifer in the area of the Greenbrook well field is low to moderate.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderately high to moderate in WHPA-B and low in WHPA-C.~~ include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Vulnerability scores have been increased to account for transport pathways (several clusters of wells and underground services).

Greenbrook has been classified as a provisionally GUDI well field with effective filtration, due to the windows in the Maryhill Till identified near the production wells. As such, a WHPA-E zone has been delineated for the Greenbrook well~~-~~field in addition to the WHPA-A to D. The vulnerability score of the WHPA-E is 8.1.

Chloride has been identified as an issue for the Greenbrook wells. The Issue Contributing Area has been delineated as the 25-year capture zone plus the area of the WHPA-E zone for this well~~s~~ field.

The water quality threats assessment shows that 480~~192~~ activities on 383~~174~~ properties, and 1 condition, may be significant threats within WHPA-A, B, C, D and E, or ICA.~~.~~

Strange Street Well Field

The water supply for the Strange Street well field is obtained from production wells K10A, K11, K13A, K18 and K19. The production wells are screened at depths ranging from approximately 17 m to 38 m ~~below ground surface~~bgs within the Middle Waterloo Moraine Sands (AFB2). AFB1 is typically identified at ground surface near the site and is often separated from AFB2 by the presence of a fine-grained aquitard unit~~Shallow Overburden Aquifer, which is typically identified at ground surface near the site and is often separated into upper and lower aquifer systems by the presence of a fine-grained aquitard unit~~. The production wells are screened below this aquitard unit, near the top of the Maryhill Till.

~~The intrinsic vulnerability of the aquifer in the area of the Strange Street well field is low to moderate. Vulnerability scores are high in the WHPA-A, moderately high to high in the WHPA-B and moderate to moderately high in the WHPA-C.~~ Final vulnerability scores include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Vulnerability scores have been increased areas of WHPA-B and D to account for transport pathways (well and underground servicing clusters).

An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. Chloride has been identified as an Issue for the Strange Street wells. The Issue Contributing Area for the chloride issue is delineated as the 25-year capture zone for K10A.

The water quality threats assessment shows that 149~~19~~ activities conditions on 108~~14~~ properties may be significant threats within WHPA-A, B, C and D, or ICA.

Parkway Well Field

The water supply for the Parkway well~~-~~field is obtained from production wells K31, K32 and K33. All of the production wells are screened across depths ranging from approximately 24 m to 34 m below ground surface within the Pre-Catfish Creek Aquifer (AFD1)~~Deep Overburden Aquifer~~, which is overlain by an extensive confining to semi-confining aquitard unit consisting of the Maryhill and Catfish Creek Tills.

~~The intrinsic vulnerability of the aquifer in the area of the Parkway well field is low.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A~~include~~, moderate in WHPA-B and low in WHPA-C and D~~: WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 4 and WHPA-D, 2. ~~-~~Vulnerability scores have been increased ~~in parts of WHPA-B and C~~ to account for transport pathways (several well and underground service pathways).

Sodium and chloride been identified as Issues for the Parkway wells. The Issue Contributing Area has been delineated as the 25-year capture zone for this well field.

The water quality threats assessment shows that 972~~330~~ activities on 830~~288~~ properties may be significant threats within WHPA-A, B, C, D and E. ~~One Significant Condition was identified in the Parkway wellfield.~~

Strasburg Well Field

The water supply for the Strasburg well field is obtained from production wells K34 and K36. K34 is pumped at a higher rate and more consistently than K36 ~~The highest pumping rates are found at well K34 as K36 was disconnected in 2005.~~ The production wells are screened from approximately 28 to 50 m bgs within the Pre-Catfish Creek Aquifer (AFD1),~~Deep Overburden Aquifer~~, which is overlain by an extensive confining to semi-confining aquitard unit consisting of the Maryhill and Catfish Creek Tills.

~~The intrinsic vulnerability of the aquifer in the area of the Strasburg well field is low~~. Final v~~V~~ulnerability scores include: WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 6 and 4, WHPA-D, 2.~~are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D.~~

The water quality threats assessment shows that 4~~2~~ activities on 2 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats have been identified for this well field.

Pompeii / ~~Forwell~~ Well Field

The water supply for the Pompeii/~~Forwell~~ well field is obtained from production wells ~~K70, K71,~~ K72, K73, K74 and K75. ~~The Forwell well field includes horizontal collector wells K70 and K71~~

~~while~~ T~~t~~he Pompeii well field includes ~~vertical~~ production wells K72, K73, K74 and K75. None of the wells are currently connected to the IUS; however, an update to the Updated Water Supply Master Plan included these wells in long-term water supply plans.~~however, an update to the Grand Reservoir EA will soon be underway to evaluate options to construct a new reservoir and connect the wells to the system.~~ All of the production wells are screened over depths ranging from approximately 9 m to 15 m below ground surface within the Pre-Catfish Creek Aquifer (AFD1)~~Deep Overburden Aquifer~~ in the Grand River Valley. Many of the upper moraine units, including the Upper and Middle Waterloo Moraine Sands,~~Shallow Overburden Aquifer~~, have been eroded away by glaciofluvial processes in the Grand River Valley, resulting in the Pre-Catfish Creek Aquifer (AFD1) ~~Deep Overburden Aquifer~~ being present near ground surface; hence, despite their shallow depths, the wells at the Pompeii~~/Forwell~~ Wellf~~ F~~ield are screened in the Pre-Catfish Creek Aquifer (AFD1).~~Deep Overburden Aquifer.~~

~~The vulnerability of the aquifer in the area of the Pompeii/Forwell well field is generally high~~. Final v~~V~~ulnerability scores include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2.~~are high in the WHPA-A and portions of the WHPA-B, particularly along the Grand River valley. Vulnerability scores through the remainder of the WHPA-B are moderately high and, in the WHPA-C, moderately high to low. Vulnerability scores have been adjusted to account for transport pathways (an aggregate operation, several clusters of wells and underground services).~~ Analysis of the attributes of each potential transport pathway in the Pompeii Wellfield resulted in the identification of two gravel pits found adjacent to the Pompeii wells and several clusters of wells and underground services which warranted an increased ISI within WHPAs A through D.

The Pompeii~~/Forwell~~ well field has been classified as a GUDI well field with effective filtration. As such, a WHPA-E zone has been delineated for the well field in addition to the WHPA-A to D. The vulnerability score of the WHPA-E is 7.2.

The water quality threats assessment shows that 28~~0~~ activities on ~~8~~ 6 properties~~, and 1 condition,~~ may be significant threats within WHPA-A and~~,~~ B~~ and C~~. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats have been identified for this well field.

<u>Woolner Well Field</u>

The water supply for the Woolner well field is obtained from Production Wells K80, K81 and K82. The production wells are screened within the Pre-Catfish Creek Aquifer (AFD1) ~~Deep Overburden Aquifer~~ from approximately 6 m to 12 m below ground surface and are located in the Grand River Valley, where many of the upper moraine units, including the Pre-Catfish Creek Aquifer (AFD1)~~ Shallow Overburden Aquifer~~, have been eroded away by glaciofluvial processes, resulting in the presence of the Pre-Catfish Creek Aquifer (AFD1) at or near the ground surface. Similar to the Pompeii wells, despite their shallow depths, the Woolner wells are also screened in the Pre-Catfish Creek Aquifer (AFD1).

~~resulting in the Deep Overburden Aquifer occurring near the ground surface. Hence, despite their shallow depths, the wells at the Woolner well field are screened in the Deep Overburden Aquifer.~~

~~The vulnerability of the aquifer in the area of the Woolner well field is generally high.~~ Final v~~V~~ulnerability scores include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 4 and 2, WHPA-D, 6, 4 and 2. ~~are high in the WHPA-A and portions of the WHPA-B, particularly along the~~

~~Grand River valley. Vulnerability scores through the remainder of the WHPA-B are moderately high and, in the WHPA-C, moderately high to low.~~ Vulnerability scores have been adjusted to account for transport pathways (an aggregate operation, closely spaced underground services and a cluster of wells).

Woolner has been classified as a GUDI well field. As such, a WHPA-E zone has been delineated for the well field in addition to the WHPA-A to D. The vulnerability score of the WHPA-E is 7.2.

The water quality threats assessment shows that 15~~9~~ activities on 7~~6~~ properties may be significant threats within WHPA-B. An issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats have been identified for this well field.

<u>Wilmot Centre – Region of Waterloo</u>

The water supply for the Wilmot Centre well field is obtained from Production Wells K50 and K51 Well K52 was recently constructed on the same property and is planned to be connected to the supply system shortly. The three production wells are screened within the Middle Waterloo Moraine Sands (AFB2) at depths ranging from 30 m BGS to 40 m BGS.~~with the highest pumping rates observed at well K50. All of the production wells are screened within the Shallow Overburden Aquifer at depths ranging from 30 m BGS to 40 m BGS.~~ This aquifer behaves as a semi-confined aquifer system as it is overlain by clay till in the area immediately surrounding the wells~~This aquifer behaves as a confined to semi-confined aquifer system as it is overlain by a clayey silt till.~~

~~The intrinsic vulnerability of the aquifer ranges from low to high.~~ Final v~~V~~ulnerability scores include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8 and 6, WHPA-D, 6, 4 and 2. ~~are high in WHPA-A, moderately high to high in WHPA-B, moderate to moderately high for WHPA-C, and low to moderate in WHPA-D.~~ Analysis of the attributes of each potential transport pathway in the Wilmot Centre WHPA resulted in the identification of ~~one~~ several well and septic system clusters, a length of road along Bleams Rd. with closely spaced utility services, and one aggregate licensed property within the WHPA-~~C~~ B ~~and~~ through D, which warranted ~~an~~ increases to the ISI.~~Vulnerability scores have been increased in WHPA-C and D to account for transport pathways (one well and septic system cluster and one aggregate licensed property).~~

Wilmot Centre has been classified as a GUDI well field. As such, a WHPA-E zone has been delineated for the well field in addition to the WHPA-A to D. The vulnerability score of the WHPA-E is 6.3. Nitrate has been identified as issue for the Wilmot Centre well field.

The water quality threats assessment shows that 158~~63~~ activities on 84~~9~~ properties may be significant threats within WHPA-A, B ~~, D~~ and the Nitrate Issue Contributing Area.

Cambridge Area Well Fields

<u>Hespeler Well Field</u>

The water supply for the Hespeler well field is obtained from production Wells ~~H03~~H3, H3A, ~~H04~~H4A, ~~and~~ H5 and ~~H05~~H5A. The production wells have screened depths ranging from approximately ~~10~~ 31 m BGS to ~~64~~ 121 m BGS in the bedrock of the Gasport Formation. Overburden was variable from well to well in this Wellfield, with the Waterloo Moraine Sands

(AFB1/AFB2) identified at or near ground surface, followed by the Maryhill and/or Catfish Creek Tills, which directly overly bedrock. A ~~small~~ portion of the WHPA-C and WHPA-D from the Hespeler Wellfield extends into ~~T~~The County of Wellington.

~~The production wells have screened depths ranging from approximately 10 m to 64 m below ground surface in the Bedrock Aquifer. Overburden varies from well to well in this well field, with the Shallow Overburden Aquifer identified at or near ground surface, followed by the Maryhill and/or Catfish Creek Tills, which directly overly bedrock. A small portion of the WHPA-D from the Hespeler Well Field extends into The County of Wellington.~~

~~The intrinsic vulnerability is generally low with some areas of moderate vulnerability near the Speed River valley.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderately high to high in WHPA-B and low to moderate in WHPA-C.~~include: WHPA-A,10, WHPA-B, 10 and 8, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Vulnerability scores have been increased ~~in parts of the WHPA-D for well H03~~ to account for transport pathways (several~~a~~ clusters of wells and underground services).

Chloride has been identified as an Issue for wells H3, H3A and H4A~~H03 and H04~~. ~~Sodium and nitrate have been identified as Issues for H04.~~ The Issue Contributing Area has been delineated as the 25-year capture zone for chloride~~, sodium and nitrate Issues identified at wells H04 and H03.~~.

The water quality threats assessment shows that 207~~142~~ activities on ~~105~~ 150 properties and 1 condition may be significant threats within WHPA-A, B and the Issue Contributing Area. ~~may be significant threats within WHPA-A.~~

Pinebush Well Field

The water supply for the Pinebush well field is obtained from production well G~~0~~5, G5A, P10/P10B, P11, P17, P15/P15A, and P~~0~~9, ~~G05, P10, P11, P17, P15 and P09 with the highest pumping rates at well P10~~. The production wells are ~~screened~~ open hole over depths of approximately 2~~1~~2 m BGS to ~~111~~ 135 m BGS, within the ~~Bedrock Aquifer~~Guelph, Eramosa, Goat Island and Gasport bedrock formations, with overlying overburden material consisting primarily of fine grained sediments~~The production wells are screened over depths of approximately 21 m to 111 m below ground surface within the Bedrock Aquifer, with overlying overburden material consisting primarily of fine grained sediments.~~ ~~p~~Portions of the WHPA-B through WHPA-D extend~~s~~ into The County of Wellington. ~~A small portion of the WHPA-D extends into The County of Wellington.~~

~~The intrinsic vulnerability is generally low with some areas of moderate vulnerability near the Speed River valley.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderate to moderately high in WHPA-B and low to moderate in WHPA-C~~include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Vulnerability scores have been ~~increased in parts of the WHPA-D for well H03~~ to account for transport pathways (clusters of wells, septic systems and underground services).

Well G5 has designated chloride and sodium *Issues* due to increasing impacts of de-icing salt on groundwater at this well. The Issue Contributing Area is delineated as the 25 year time-of-travel (WHPA-D) for supply well G5. The new and deeper well G5A has lower chloride and sodium impacts and does not have a designated *Issue*.

~~Sodium and chloride has been identified as Issues for wells G05. The corresponding Issue Contributing Area has been delineated as the 25-year capture zone for well G05.~~

The water quality threats assessment shows that 396~~109~~ activities on 269~~94~~ properties, and ~~1~~ 2 condition, may be significant threats within WHPA-A, B, C and the Issue Contributing Area.

Blair Road Well Field

The water supply for the Blair Road Wellfield is obtained from production well G4 and G4A. The production wells are open hole within the within the Guelph, Eramosa and Gasport bedrock formations from 31 m BGS to 83 m BGS with a thin layer of overburden outwash deposits directly overlying the bedrock.

~~The water supply for the Blair Road well field is obtained from production well G04. The production well is screened within the Bedrock Aquifer from 5 m to 61 m below ground surface with a thin layer of overburden outwash deposits directly overlying the bedrock.~~

~~The intrinsic vulnerability is generally moderate with some areas of high vulnerability near the Grand River valley.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderately high to high in WHPA-B, moderate to moderately high in WHPA-C and low to moderate in WHPA-D.~~ include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 6 and 4, WHPA-D, 4 and 2. Analysis of the attributes of each potential transport pathway in the Blair Road WHPA identified a cluster of wells and underground services within WHPA-B and another cluster of wells and septic systems in WHPA-D which warranted increased ISI.

The Blair Road wells are classified as GUDI with effective filtration. The delineated WHPA-E focused on identifying the upstream points within Devil's Creek which, under bankfull or 2-year peak flow conditions, lie at the two-hour time of travel distance from the shallow overburden zone of influence for G4/~~-~~G4A.

~~Vulnerability scores have been increased in parts of the WHPA-D for well H03 to account for transport pathways (clusters of wells, septic systems and underground services).~~

The water quality threats assessment shows that 21~~1~~ activities on 9~~1~~ properties, and 1 significant condition, may be a significant threat within WHPA-A, B and E. No water quality Issues or Issue-based threats have been identified.

Clemens Mill Well Field

The Clemens Mill well field consists of Production Wells G~~0~~6, G16, G17 and G18. ~~However, the water supply is obtained primarily from Production Well G06.~~ The production wells are open hole within the Guelph, Eramosa Goat Island and Gasport bedrock formations from approximately 28 m BGS to 127 m BGS ~~The production wells are screened within the Bedrock Aquifer from approximately 28 m to 121 m below ground surface.~~ ~~p~~Portions of the WHPA-B through WHPA-D extend~~s~~ into The County of Wellington. ~~A small portion of the WHPA-D extends into The County of Wellington.~~

~~The intrinsic vulnerability for the aquifer in the vicinity of the well field is low.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D~~include; WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Vulnerability scores were increased ~~in parts of WHPA-D~~ to account for transport pathways (several clusters of wells and underground utility services).

The water quality threats assessment shows that 29~~18~~ activities on 17~~3~~ properties, and 1 condition, may be significant threats within WHPA-A and B. No water quality Issues or Issue-based threats have been identified.

~~Dunbar Road Well Field~~

~~The water supply for the Dunbar Road well field is obtained from Production Well P06. The production well is screened from approximately 6 m to 88 m below ground surface within the Bedrock Aquifer, which is overlain by a thin layer of sand and gravel deposits.~~

~~The intrinsic vulnerability of the aquifer in the area of the well field is high. Vulnerability scores are high in WHPA-A and B, moderately high in WHPA-C and moderate in WHPA-D.~~

~~The water quality threats assessment shows that 2 activities on 2 properties may be significant threats within WHPA-A and B. No water quality Issues or Issue-based threats have been identified.~~

Elgin Street Well Field

The water supply for the Elgin Street well field is obtained from production well G~~0~~9. The production well is open hole~~screened~~ from approximately 25 m to 78 m below ground surface within the ~~Bedrock Aquifer~~Guelph and Eramosa bedrock formations, with sand and gravel deposits overlying bedrock in this area.

~~The intrinsic vulnerability of the aquifer in the vicinity of the well is moderate.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderately high in WHPA-B and moderate to low in WHPA-C and D.~~include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Analysis of the attributes of each potential transport pathway in the Elgin Street WHPA resulted in the identification of several well clusters, closely spaced septic systems and numerous underground utility services found within the WHPA-B through D zones, which warranted an increased ISI.

Trichloroethylene (TCE), sodium and chloride have been identified as issues for wells G~~0~~9. The corresponding Issue Contributing Area has been delineated as the 25-year capture zone for well G~~0~~9.

The water quality threats assessment shows that 151~~69~~ activities on 119~~61~~ properties~~, and 1 condition,~~ may be significant threats within WHPA-A, B, C and D.

Middleton Street Well Field

The water supply for the Middleton Street well field is obtained from Production Wells G~~0~~1, G~~0~~1A, G~~0~~2, G~~0~~3 and G14. The production wells are open hole~~screened~~ within the ~~Bedrock Aquifer~~Guelph, Eramosa and Gasport bedrock formations from approximately 29 m to 60 m below ground surface. This well field, located adjacent to the Grand River, is characterized by only a couple meters of outwash deposits overlying bedrock.

~~The intrinsic vulnerability of the aquifer in the area of the well field is high, particularly in the area along the Grand River valley.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderately high to high in WHPA-B and moderate to low in WHPA-C~~include: WHPA-A, 10, WHPA-B, 10, 8, and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2. Analysis of the attributes of each potential transport pathway in the Middleton WHPA resulted in the identification of a few well clusters, septic system clusters and numerous underground service clusters within the WHPA-B through WHPA-~~WHPA-~~D zones, which warranted an increased ISI.~~Vulnerability scores were increase within WHPA-D to account for transport pathways (clusters of wells, septic systems and underground services).~~

Although the Middleton Street wells are classified as GUDI with effective filtration, there is a lack of evidence of connection between the Middleton Street wells and the Grand River and, therefore, no WHPA-E zone has been delineated for the Middleton Street wells.

Trichloroethylene (TCE), sodium and chloride have been identified as Issues for the Middleton Street wells. The corresponding Issue Contributing Area has been delineated as the 25-year capture zone for the Middleton Street wellfield.

The water quality threats assessment shows that 955~~702~~ activities on 681~~44~~ properties, and ~~10~~ 9 conditions, may be significant threats within WHPA-A, B, ~~C and D~~and ICA.

<u>Shades Mill Well Field</u>

The water supply for the Shades Mill well field is obtained from production wells G~~0~~7, G~~0~~8, G38 and G39. The production wells are completed within the Grand River Outwash Sediments Aquifer (AFA2) and screened from 14 m BGS to 43 m BGS.~~The production wells are completed within the Uppermost Significant Aquifer, consisting of Grand River Valley outwash deposits screened from 3 m to 43 m below ground surface.~~

~~The intrinsic vulnerability in the area of the well field is generally high.~~ Final v~~V~~ulnerability ~~is high in the WHPA-A, moderately high to high in WHPA-B and moderate to moderately high in WHPA-C~~scores include; WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8 and 6, WHPA-D, 6, 4 and 2. Several clusters of wells, septic systems and underground services were identified in the Shades Mills Wellhead Protection area within the WHPA-B through WHPA-D of the production wells, which warranted an increased ISI.~~Several clusters of wells, septic systems and underground services were identified in WHPA-D and WHPA-A of G38, G39 and G08, which warranted an increase in the vulnerability score.~~

Wells G38 and G39 are classified as GUDI wells with effective filtration due to their proximity to the Shades Mill Reservoir. As such, a WHPA-E zone has been delineated in addition to the WHPA-A to D. The vulnerability score of the WHPA-E is 6.3.

The water quality threats assessment shows that ~~26~~ 152 activities on 63~~11~~ properties, and ~~2~~ 3 conditions, may be significant threats within WHPA-A and B~~, B and C~~. No water quality Issues or Issue-based threats have been identified.

<u>Fountain Street Well Field</u>

The water supply for the Fountain Street well field is obtained from production well P16. A Class Environmental Assessment was completed in 2014 for the addition of a new well on Maple Grove Rd. (P18) to the Fountain Street Wellfield (MTE, 2014). Production well P16 is screened from approximately 33 m BGS to 38 m BGS, while P18 is screened from approximately 43 to 53 m BGS. Both wells are screened within the Pre-Catfish Creek Aquifer (AFD1).~~The production well is screened from approximately 33 m to 38 m below ground surface within the Deep Overburden Aquifer. The aquifer is overlain by a thick sequence of aquitard material including the Port Stanley, Lower Maryhill and Catfish Creek Tills.~~

~~The intrinsic vulnerability of the aquifer in the area of the Fountain Street well field is low.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderate in WHPA-B and low in WHPA-C and D.~~include; WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 6 and 4, WHPA-D 4 and 2. Vulnerability scores have been increased in parts of WHPA-B~~C~~ through~~and~~ D to account for transport pathways (several clusters of wells, septic systems underground services).

The water quality threats assessment shows that 19~~1~~ activities~~y~~ on 6~~1~~ properties~~y~~ may be a significant threat within WHPA-A. No water quality Issues or Issue-based threats have been identified.

<u>Willard Well Field</u>

The water supply for the Willard well field is obtained from production well G15 with a screen depth of approximately 28~~11~~ to 58~~2~~ m below ground surface in the bedrock aquifer. A thin layer of gravel deposits is found overlying the bedrock in this area.

The Willard Wellfield has been classified as GUDI with effective filtration, and thus a WHPA-E protection zone has been delineated with a score of 8.1.

~~The intrinsic vulnerability of the aquifer varies from low to high, with the higher vulnerability occurring in the vicinity of the Grand River valley.~~ Final v~~V~~ulnerability scores ~~are high in the WHPA-A, moderately high to high in WHPA-B, moderate to moderately high in WHPA-C and low to moderate in WHPA-D~~include; WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 6, 4 and 2, WHPA-D, 4 and 2. Analysis of the attributes of each potential transport pathway in the Willard WHPA identified well and septic system clusters within the WHPA-A through D zones that warranted increases to the ISI. Similarly, analysis of the attributes of each potential transport pathway in the Willard WHPA-E resulted in the identification of numerous storm sewers which were incorporated into the final WHPA-E delineation.

~~Vulnerability scores have been increased in WHPA B and D zones to account for transport pathways (clusters of wells and septic systems).~~

The water quality threats assessment shows that 54~~33~~ activities on 42~~26~~ properties ~~, and 11 conditions,~~ may be significant threats within the WHPA-A, B and E. No Issues or Issues-based threats have been identified.

Ayr – Region of Waterloo

The water supply for the Ayr well field is obtained from production wells A~~0~~1, A~~0~~2 and A~~0~~3. All of the production wells are screened from approximately 43 to 51 m below ground surface within the Pre-Catfish Creek Aquifer (AFD1)~~deep overburden aquifer~~, which is overlain by an aquitard and aquifer sequence including the Middle Maryhill Till (ATB2) and Waterloo Moraine Sands (AFB1/AFB2)~~shallow overburden aquifer~~. The Ayr water supply system supplies water to approximately 4,337~~000~~ people.

~~The intrinsic vulnerability of the aquifer varies from low to medium.~~ Final v~~V~~ulnerability scores ~~are high in WHPA-A, moderate to moderately high in WHPA-B, and low to moderate in WHPA-C and D.~~include; WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 6 and 4, WHPA-D, 6, 4 and 2. Analysis of the attributes of each potential transport pathway in the Ayr WHPA resulted in the identification of well clusters within the WHPA-B through WHPA-D and two adjacent areas defined as aggregate resources in the WHPA-D which warranted an increase to the ISI.~~Vulnerability scores have been increased in WHPA – B, C and D to account to account for transport pathways (clusters of wells and a large aggregate resource).~~

The water quality threats assessment shows that 14~~1~~ activit~~y~~ies on 9~~1~~ propert~~y~~ies may be a significant threat within WHPA-A and B. No Issues or Issue-based threats were identified within the municipal groundwater system.

~~***Baden – Region of Waterloo***~~

~~The water supply for the Baden well field is obtained from production wells B01 and B02. The production wells are screened in the shallow overburden aquifer at depths ranging from 35 m 42 m below ground surface. This aquifer typically behaves as a confined to semi-confined aquifer system as it is overlain by clayey silt till.~~

~~The intrinsic vulnerability of the aquifer varies from low to high. Vulnerability scores are high in WHPA-A, moderately high to high in WHPA-B, moderate to moderately high in WHPA-C and low to moderate in WHPA-D. There were no increases in the vulnerability scoring to account for transport pathways.~~

~~Nitrate has been identified as Issue for the Baden well. The corresponding Issue Contributing Area has been delineated as the steady state capture zone of the Baden well field, which is the 25-year capture zone with an additional significant groundwater recharge area.~~

~~The water quality threats assessment shows that 129 activities on 66 properties may be significant threats within WHPA-A, B, and the Issue Contributing Area.~~

Branchton Meadows – Region of Waterloo

The water supply for the Branchton Meadows well field is obtained from production wells BM~~0~~1, BM2 and BM3~~02~~. BM1 and BM2 wells are open hole within a dense sand and gravel conglomerate unit approximately 29 m to 34 m BGS. BM3 was completed slightly deeper as open hole from 39 to 47 m BGS in the Guelph Formation bedrock aquifer~~All of the production wells are screened within the bedrock aquifer at depths ranging from approximately 29 m 34 m below ground surface.~~ Near the wells, a vertically extensive surficial aquitard overlies the dense sand and gravel conglomerate. ~~A vertically extensive surficial aquitard is present near these production wells, with an aquifer unit directly overlying bedrock.~~

~~The Branchton Meadows well field extracts water from the upper part of the Guelph Amabel Formation (RMOW, 1999). The bedrock aquifer is locally overlain by 25 m of sandy silt till of the Wentworth Till and produces an aquifer under confined to semi-confined conditions near the wells.~~ The Branchton Meadows system supplies water to approximately ~~125~~ 121 people.

~~The intrinsic vulnerability of the aquifer is low.~~ Final v~~V~~ulnerability scores include; WHPA-A, 10, WHPA-B, 6, WHPA-C, 4, WHPA-D, 4 and 2.~~are high in WHPA-A, moderate in WHPA-B, and low in WHPA-C and D~~. Several septic systems are located adjacent to the wells within WHPA-

A and WHPA-D zones that warranted an increase to the ISI at this wellfield.~~There were no increases in the vulnerability scoring to account for transport pathways~~

Chloride has been identified as Issue for the Branchton Meadows well. The corresponding Issue Contributing Area has been delineated as the 25-year capture zone for the Branchton Meadows well~~-~~field.

The water quality threats assessment shows that 10 activities on 7~~10~~ properties may be significant threats within WHPA-A and the Issue Contributing Area.

~~***Conestogo – Region of Waterloo***~~

~~The water supply for the Conestogo well field is obtained from production wells C03, C04, C05 and C06. Production wells C05 and C06 are referred to as the Conestogo Golf well field, while wells C03 and C04 are collectively referred to as the Conestogo Plains well field. These two well fields are found on opposite sides of the Grand River from each other. Conestogo Golf is on the west side of the river, and Conestogo Plains in on the east side of the river. All of the production wells are screened at depths ranging from 15 m BGS to 33 m BGS within the Deep Overburden Aquifer, which is a confined aquifer system separated from surface and the overlying Shallow Overburden Aquifer by an extensive aquitard unit corresponding to the Maryhill and Catfish Creek Tills.~~

~~The Conestogo Golf well field serves a population of 411 people, while the Conestogo Plaines well field serves a population of 367 people (Stantec, 2002).~~

~~The intrinsic vulnerability of the Conestogo Golf well field is low. Vulnerability scores are high in WHPA-A, moderate in WHPA-B and low in WHPA-C and D. There were no increases in the vulnerability scoring to account for transport pathways.~~

~~The intrinsic vulnerability of the Conestogo Plains well field ranges from low to moderate. Vulnerability scores are high for WHPA-A, moderately high to high for WHPA-B, low to moderately high for WHPA-C and low to moderate for WHPA-D. Vulnerability scores have been increased in WHPA – B, C and D to account for transport pathways (clusters of wells and underground service).~~

~~The water quality threats assessment shows that 40 activities on 32 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.~~

Elmira – Region of Waterloo

The water supply for the Elmira well field is obtained from production well E10. The production well is completed with a screened interval of approximately 45 to 53 m below ground surface within the Pre-Catfish Creek Aquifer (AFD1), which overlies bedrock~~The production well is completed at a depth of approximately 53 m below ground surface within the deep overburden aquifer, which overlies bedrock.~~

~~The intrinsic vulnerability ranges from low to high.~~ Final v~~V~~ulnerability scores ~~are high in WHPA-A, moderate to high in WHPA-B, low to moderately high in WHPA-C and low to moderate in WHPA-D~~include: WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 8, 6 and 4, WHPA-D, 6, 4 and 2.. Analysis of the attributes of each potential transport pathway in the Elmira WHPA resulted in the identification of well and septic system clusters situated in the WHPA-A through WHPA-D that warranted increases to the ISI.~~The vulnerability score has been increased in sections of WHPA-D to account for transport pathways (clusters of wells and septic systems).~~

The water quality threats assessment shows that 34~~28~~ activities on 7~~5~~ properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Foxboro Green – Region of Waterloo

The water supply for the Foxboro Green well~~-~~field is obtained from production wells FG~~0~~1, FG~~0~~2A, and FG~~0~~4. All of the production wells are open hole at depths ranging from 47 m BGS to 67 m BGS within the Salina bedrock aquifer. The bedrock is overlain by units consistent with the Pre-Catfish Creek Aquifer (AFD1), Catfish Creek (ATC1), the Maryhill Tills (ATB1 & ATB2) and the Waterloo Moraine Sands present near ground surface ~~All of the production wells are screened at depths ranging from 47 m BGS to 67 m below ground surface within the bedrock aquifer, which is overlain by units consistent with the deep overburden aquifer, Catfish Creek, the Maryhill Tills and the shallow overburden aquifer present near ground surface.~~ The Foxboro water supply system serves a population of approximately 410~~398~~.

~~The intrinsic vulnerability of the aquifer is low. The~~Final vulnerability scores include: WHPA-A, 10, WHPA-B, 6, WHPA-C, 4, WHPA-D, 2. ~~is high in WHPA-A, moderate in WHPA-B, and low in WHPA-C and D~~. There were no increases in the vulnerability scoring to account for transport pathways

The water quality threats assessment shows that ~~5~~ 1 activities on ~~2~~ 1 property~~ies~~ may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Heildelberg – Region of Waterloo

The water supply for the Heidelberg well field is obtained from production wells HD~~0~~1 and HD~~0~~2~~, with the highest pumping rates at well HD01.~~. All of the production wells are screened at depths ranging from approximately 54 m to 60 m below ground surface within the Pre-Catfish Creek Aquifer (AFD1), which is overlain by stratigraphic units consistent with the Catfish Creek (ATC1) and Maryhill Tills (ATB2) and the Waterloo Moraine Sands (AFB1/AFB2) near ground surface ~~All of the production wells are screened at depths ranging from approximately 54 m to 60 m below ground surface within the deep overburden aquifer, which is overlain by stratigraphic units consistent with the Catfish Creek and Maryhill Tills and the shallow overburden aquifer near ground surface.~~ The Heidelberg water supply system serves a population of approximately 1,013~~60~~.

~~The intrinsic vulnerability of the aquifer is low. The~~Final vulnerability scores include; WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 4, WHPA-D, 2. ~~is high in WHPA-A, moderate in WHPA-B and low in WHPA- C and D~~. Analysis of the potential transport pathways in the Heidelberg WHPAs identified several clusters of septic systems and wells in WHPA-A and WHPA-B that warranted increases to the ISI.There were no increases in the vulnerability scoring to account for transport pathways.

The water quality threats assessment shows that 252 activities on 14 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Linwood – Region of Waterloo

The water supply for the Linwood well field is obtained from production wells L01A and L02, with the highest pumping rates at well L01A. These production wells are open hole within bedrock of the Bois Blanc/Salina formations at depths ranging from 64 m to 80 m below ground surfaceAll of the production wells are screened within the bedrock aquifer at depths ranging from 64 m to 80 m below ground surface. The Linwood wells draw water from the Salina Formation, the uppermost bedrock formation in the area (RMOW, 2001). It supplies water to approximately 781814 people.

The intrinsic vulnerability of the aquifer is low. The Final vulnerability scores include: WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 4 and WHPA-D, 2. is high in WHPA-A, moderate in WHPA-B and low in WHPA- C and D. Analysis of the potential transport pathways in the Linwood WHPA noted several clusters of septic systems and wells within the WHPA-A through WHPA-C zones that warranted increases to the ISI.There were no increases in the vulnerability scoring to account for transport pathways.

The water quality threats assessment shows that 271 activities on 1517 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Maryhill – Region of Waterloo

The water supply for the Maryhill well field is obtained from production wells MH01, MH02, MH03 and MH04A. There are two separate distribution systems that cover only a portion of the settlement area. MH1 and MH2 (Maryhill) distribute water to approximately 141 people, while MH3 and MH4A (Maryhill Heights) distribute to approximately 143 people. All of the production wells are screened within sand and gravel in the Pre-Catfish Creek Aquifer (AFD1) at depths ranging from 18 m to 33 m below ground surface. MH04 is not currently used for water supply with wells MH01 and MH02 acting as the primary production wells. All of the production wells are screened within sand and gravel in the deep overburden aquifer at depths ranging from 18 m to 45 m below ground surface. The Maryhill water supply system serves a population of approximately 315.

The intrinsic vulnerability of the aquifer ranges from low to high. Final vVulnerability scores include; WHPA-A, 10, WHPA-B, 10, 8 and 6, WHPA-C, 6 and 4, WHPA-D, 4 and 2.are high for WHPA-A, moderate to high in WHPA-B, low to moderately high in WHPA-C and low to moderate in WHPA-D. Analysis of the potential transport pathways in the WHPAs for the Maryhill wells located several clusters of septic systems and wells in WHPA-A through WHPA-D that warranted increases to the ISI.There were no increases in the vulnerability scoring to account for transport pathways.

The water quality threats assessment shows that 42~~33~~ activities on 25~~4~~ properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

New Dundee – Region of Waterloo

The water supply for the New Dundee well field is obtained from Production Wells ND~~0~~4 and ND~~0~~5. The production wells are screened at depths ranging from 14 m BGS to 16 m BGS within the Middle Waterloo Moraine Sands (AFB2). AFB2 is between the Maryhill Till (ATB2) aquitard and the overlying Upper Waterloo Moraine Sands (AFB1~~The production wells are screened at depths ranging from 14 m BGS to 16 m BGS within the Shallow Overburden Aquifer, which lies below a surficial aquitard unit, and overlies the Maryhill Till.~~ Since the Upper Maryhill Till (ATB1) is not present in this area, AFB2 and AFB1 act as a single aquifer in the area resulting in the use of AFB1 for the vulnerability scoring at this Wellfield. The New Dundee water supply system serves a population of approximately 1,049~~132~~.

~~The intrinsic vulnerability of the aquifer ranges from low to high.~~ Final v~~V~~ulnerability scores include; WHPA-A, 10, WHPA-B, 10 and 8, WHPA-C, 8 and 6, WHPA-D, 6 and 4. ~~are high in WHPA-A, moderately high to high in WHPA-B, moderate to moderately high in WHPA-C and low to moderate in WHPA-D.~~ Since the Upper Maryhill Till (ATB1) is not present in this area, AFB2 and AFB1 act as a single aquifer in the area resulting in the use of AFB1 for the vulnerability scoring at this Wellfield.~~There were no increases in the vulnerability scoring to account for transport pathways.~~

The water quality threats assessment shows that 43~~8~~ activities on 26~~32~~ properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

New Hamburg – Region of Waterloo

The water supply for the New Hamburg well field is obtained from Production Well NH~~0~~3, with NH4 installed for operational redundancy~~.~~ This production wells are open hole from approximately 57 to 76 m BGS within the bedrock of Salina Formation. Overlying material corresponds to Catfish Creek Till (ATC1) and pre-Catfish Creek (AFD1) aquifer deposits. A portion of WHPA-B through WHPA-D extends into the Township of Perth East.~~The production well is screened from approximately 57 to 76 m BGS within the Bedrock Aquifer, with overlying material corresponding to Catfish Creek Till and pre-Catfish Creek aquifer deposits. A small portion of the WHPA-D extends into the Township of Perth East. Water can also be supplemented from wells K50 and K51 which normally supply the Region of Waterloo Integrated Urban System. K50 and K51 are completed within the Shallow Overburden Aquifer at depths ranging from 30 m to 40 m below ground surface. This aquifer behaves as a confined to semi-confined aquifer system as it is overlain by a clayey silt till (Stantec, 2001). Together with the Baden well, the water supply system serves a population of approximately 9,370.~~

~~The intrinsic vulnerability of the aquifer is low. The~~ Final vulnerability scores include: WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 4, WHPA-D, 2. ~~is high in WHPA-A, moderate in WHPA-B, and low in WHPA-C and D.~~ Analysis of the potential transport pathways within the WHPA areas noted several clusters of septic systems and wells within the WHPA-B zone that warranted increases to the ISIThere were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that 160 activities on 75 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Roseville – Region of Waterloo

The water supply for the Roseville well field is obtained from production wells R05 and R06. The production wells have screen depths ranging from 48 to 52 m below ground surface within Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3), and are overlain by the Catfish Creek (ATC1) and Maryhill Till (ATB2) units, with the Waterloo Moraine Sands (AFB1/AFB2) identified near ground surfacethe deep overburden aquifer, and are overlain by the Catfish Creek and Maryhill Till units, with the shallow overburden aquifer identified near ground surface. The Roseville system supplies water to approximately 2905 people.

The intrinsic vulnerability of the aquifer is low. FinalThe vulnerability scores include; WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 6 and 4, WHPA-D, 4 and 2.is high in WHPA-A, and low in WHPA-C and D. Analysis of the potential transport pathways within the WHPA areas noted several clusters of septic systems and wells within the WHPA-A through WHPA-D zones that warranted increases to the ISI.There were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that 254 activities on 21 22 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

St. Agatha – Region of Waterloo

A water supply pipeline has been constructed from Waterloo to replace three water supply systems in St. Agatha in accordance with the St. Agatha Water Supply System Study completed in March 2005. The systems include the St. Agatha system, the St. Agatha – Swartzentruber system and the St. Agatha – Sararas system. As part of this project the existing water supply wells will be decommissioned. These well systems have been removed from the Source Protection Program, as per the Regional council resolution included in Section 9.5.14.

St. Clements – Region of Waterloo

The water supply for the St. Clements well field is obtained from production wells SC02, SC3 and SC403. wellsSC2 and SC3 are screened over depths ranging from 15 m to 20 m below ground surface within the Upper Waterloo Moraine Sands (AFB1/AFB2), which and resulted in the application of AFB1 for vulnerability scoring. SC4 is screened deeper in the Middle Waterloo Moraine Sands (AFB2) from approximately 30 to 37 m BGS but is hydraulically connected to the AFB1 unit due to the absence of the ATB1 till unit.All of the production wells are screened over depths ranging from 15 m to 20 m below ground surface within the shallow overburden aquifer, which is underlain by the Maryhill Till. The aquifer behaves in an unconfined nature at this location (Waterloo Hydrogeologic, 2000). The St. Clements water supply system serves a population of approximately 1,267410.

The intrinsic vulnerability of the aquifer ranges from low to high. Final vVulnerability scores include: WHPA-A, 10, WHPA-B, 10, WHPA-C, 8 and 6, WHPA-D, 6, 4, and 2. are high in WHPA-A, moderate to moderately high for WHPA-B, low to moderately high for WHPA-C and low to moderate for WHPA-D. Vulnerability scores have been increased in WHPA – C and DWHPA-A through D to account for transport pathways (clusters of wells and septic systems).

The water quality threats assessment shows that 7346 activities on 6241 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Wellesley – Region of Waterloo

The water supply for the Wellesley well field is obtained from Production Wells WY01 and WY05. The highest pumping rates are observed at well WY01 during most years. The WY1 is screened within a sand and gravel unit corresponding to the Pre-Catfish Creek Aquifer (AFD1) from 45 m BGS to 54 m BGS, while WY5 is screened across both theaquifer Pre-Catfish Creek Aquifer (AFD1) and approximately 3 m of Limestone dolostone bedrock from 45 to 54 m BGS production wells are screened within a sand and gravel unit corresponding to the Deep Overburden Aquifer from 45 m to 54 m below ground surface. The aquifer is confined by 30 to 50 m of dense till cover. The Wellesley water supply system serves a population of approximately 3,4722,150.

The intrinsic vulnerability of the aquifer is low. Final vVulnerability scores include: WHPA-A, 10, WHPA-B, 8 and 6, WHPA-C, 4, WHPA-D, 6 and 2.are high in WHPA-A, moderate to moderately high in WHPA-B, and low in WHPA-C and D. Analysis of the attributes of each potential transport pathway in the Wellesley WHPA resulted in the identification of two aggregate properties within WHPA-D, and several well clusters within the WHPA-A and WHPA-B zones, that warrant increased ISI.Vulnerability scores have been increased in WHPA-B to account for transport pathways (clusters of wells).

The water quality threats assessment shows that 210 activities on 64 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

West Montrose – Region of Waterloo

The West Montrose well field contains production wells WM01, WM02, WM03, and WM04, screened from approximately 3 to 4 m below ground surface within the Uppermost Significant Aquifer, consisting of Grand River Valley outwash deposits. The only production well currently used for supply at the West Montrose Well Field is well WM04. The West Montrose well field is located approximately 19 m from the Grand River within the GRCA Regulatory floodplain. The production wells at this well field are classified as infiltration wells under the Certificate of Approval (CofA). The West Montrose system serves a population of 180.

The intrinsic vulnerability of the aquifer is moderate. Vulnerability scores are high for WHPA-A, moderately high for WHPA-B, moderate to moderately high for WHPA-C and low to moderate for WHPA-D. There were no increases to the vulnerability scoring to account for transport pathways.

~~The West Montrose wells are classified as GUDI wells with effective filtration due to their proximity to the Grand River. As such, a WHPA-E zone has been delineated in addition to the WHPA-A to D. The vulnerability score of the WHPA-E is 6.3.~~

~~The water quality threats assessment shows that 6 activities on 4 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.~~

Hidden Valley

The Hidden Valley intake is located on the Grand River, supplies the Mannheim Water Treatment Plant and is part of the Integrated Urban System (IUS) that serves approximately 488,342 (2009) people.

-The source vulnerability factor of 0.9 has been assigned to this Type C intake. The overall vulnerability scores are 9 for IPZ-1 and 7.2 for IPZ-2. The IPZ-3 for the Hidden Valley intake extends up the Grand and Conestogo Rivers. Vulnerability scores for the IPZ-3 range from 7.2 in close proximity with urban runoff potential to 0.9 for far proximity undeveloped lands such as wetlands and forests.

The water quality threats assessment shows that no significant threats were identified for the Hidden Valley intake. An issues-based threats analysis was also completed through a review of water quality data collected from the intake. No issue-based threats were identified for this municipal surface water system.

Acton – Town of Halton Hills

The Community of Acton has six~~five~~ wells which serve a population of approximately 9~~8~~,500, all located in the Credit Valley Source Protection Area. Portions of WHPA-B, C, D for these wells cross into the Grand River Source Protection Area, with vulnerability scores of 2 - 8. Nitrate has been identified as an issue for one of these wells (Davidson Well 1), and the Issue Contributing Area delineated for it partly overlaps into the Grand River Source Protection Area as well.

The water quality threats assessment shows 21 activities on 3 properties may be significant drinking water threats, within the Grand River Source Protection Area. Both threats-based and issue-based threats have been enumerated and are located within the WHPA-B, WHPA-C, and Issue Contributing Area.

Milverton – Township of Perth East

The Milverton municipal well, located in the Village of Milverton in the Township of Perth East, serves a population of approximately 1,750 people. The drinking water system consists of two bedrock wells: Well 4 and Well 6. Both wells are completed in the Amherstburg Formation. The bedrock is reached at a depth of approximately 40 m.

Final vulnerability scores include 10 in WHPA-A, 6 in WHPA-B, and 2 in WHPA-C and D.~~The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection areas, and an area of high vulnerability within the 100-metre area around the wells.~~ There were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that 4 activities on 3 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Bright – County of Oxford

The Bright water system in the County of Oxford includes two wells, referred to as Well 4A and Well 5, located at a site in the west part of the village. Well 5 is completed to a depth of 25.9 m below ground surface (bgs) in the Waterloo Moraine sand and gravel aquifer. Well 4A is completed to a depth of 26.7 m bgs and is screened across the Waterloo Moraine sand and gravel aquifer. ~~Both wells draw water from an intermediate aquifer and are screened at 21 to 25m below ground surface. The Bright water system serves a population of approximately 366.~~ Final vulnerability scores include 10 in WHPA-A, 10 and 8 in WHPA-B, 8, 6 and 2 in WHPA-C and 4 and 2 in WHPA-D.~~The vulnerability, assessed using the Aquifer Vulnerability Index (AVI) method, is low. Vulnerability scores in most of the wellhead protection are medium to low with an area of high vulnerability within the 100-metre area around the wells.~~ There were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that ~~11~~ 32 activities on ~~9~~ 31 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Drumbo-Princeton – County of Oxford

The community of Drumbo and Princeton are~~is~~ supplied by groundwater from three~~wo~~ wells: Well 1, Well 2A and Well 3~~ which tap a deep, semi-confined, overburden aquifer. The water system services an estimated population of 510 people.~~ Well 1 is screened over a depth interval of 33 to 37 m bgs. Water well records indicate that the approximate screen depth intervals are 40 to 44 m bgs at Well 2A and 26 to 32 m bgs at Well 3. The well completion zones were considered to be part of the deep overburden sand silty aquifer Final vulnerability scores include 10 in WHPA-As, 6 in WHPA-Bs, 4 in WHPA-Cs and 2 in WHPA-Ds.~~The vulnerability, assessed using the Aquifer Vulnerability Index (AVI) method, is low. Vulnerability scores in most of the wellhead protection are medium to low with an area of high vulnerability within the 100-metre area around the wells.~~ There were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that 16 activities on 8 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Plattsville – County of Oxford

The Plattsville water system is supplied by two overburden wells located on the western edge of the community. ~~Within the community of Plattsville, two wells service an estimated population of 1,146 people.~~ Both wells, completed at depths ranging from 12 to 15 m below ground surface, tap an unconfined, shallow overburden aquifer. Final vulnerability scores include 10 in WHPA-A, and B, 8 in WHPA-C and 6 and 4 in WHPA-D.Vulnerability in the area is high, with vulnerability scores that are high in the WHPA-A and B, moderately high in WHPA-C and moderate in WHPA-D. There were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that 13 activities on 6 properties may be significant threats within WHPA-A and B. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Village of Lynden – City of Hamilton

The City of Hamilton operates a groundwater source water supply system in the hamlet of Lynden that serves 380 people. The water supply system is comprised of two wells which draw water from a confined gravel aquifer that is situated directly on the bedrock surface. Vulnerability, assessed using the SAAT method, is low. Vulnerability scores in most of the wellhead protection are moderate to low with an area of high vulnerability within the 100-metre area around the wells.

The water quality threats assessment shows that 26 activities on 7 properties may be significant threats within WHPA-A. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Airport – County of Brant

The Airport groundwater supply provides water to 764 users. The water supply source at the Airport site consists of one operational pumping well that is completed in an unconfined sand and gravel aquifer. A second pumping well was constructed in 2014 to meet projected future demands in addition to providing redundancy during maintenance and fire flow conditions; this well is in the process of being connected to the existing water distribution system. Intrinsic vulnerability, assessed using the surface to aquifer advection time (SAAT) method, is high. Vulnerability scores are high in the WHPA-A, B and C and medium in WHPA-D. There were no increases to the vulnerability to account for transport pathways.

The water quality threats assessment shows that 79 activities on 21 properties may be significant threats within WHPA-A, B and C. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No Issue-based threats were identified within the municipal groundwater system.

Mount Pleasant – County of Brant

The Mount Pleasant groundwater supply provides water to 801 users. The Mount Pleasant well field consists of two wells completed in a sand and gravel aquifer that exists under unconfined conditions in the vicinity of the well site. The aquifer is overlain by a glacial till aquitard with a thickness up to 65 metres in the vicinity of the wells. Intrinsic vulnerability, assessed using the SAAT method, is medium to high. In general, vulnerability scores are high in the WHPA-A, B and C and medium in WHPA-D. Vulnerability scores were adjusted within the aggregate operation limits (primarily within WHPA-D) to reflect the increased risks posed by the potential reduced surface to well travel times.

An Issues evaluation was also completed through a review of water quality data collected from the municipal wells. Chloride concentrations have declined since 2008 and is no longer identified as an Issue for the Mount Pleasant well supply system.

The water quality threats assessment shows that 38 activities on 9 properties may be significant threats within WHPA-A, B and C.

St. George – County of Brant

The St. George well field provides water to 572 users in the former village of St. George. The water supply system consists of the three wells located in one pumping station. The St. George wells, which flow under non-pumping conditions, are completed in a confined to semi-confined sand and gravel aquifer. Intrinsic vulnerability, assessed using the SAAT method, is primarily medium to high. Vulnerability scores are high in the WHPA-A, B and C and generally medium in WHPA-D. There were no increases to the vulnerability to account for transport pathways.

An Issues evaluation was also completed through a review of water quality data collected from the municipal wells. Nitrate is identified as an Issue for the St. George wells. The 25-year capture zone has been delineated as the Issue Contributing Area for the wells.

The water quality threats assessment shows that 218 activities and on 93 properties, and 2 conditions, may be significant threats within WHPA-A, B, and the Issue Contributing Area in the overburden well supply; 10 activities on 3 properties may be significant threats within WHPA-A and Bin the bedrock well supply.

Town of Paris – County of Brant

The community of Paris is supplied by three well fields; Bethel, Gilbert and Telfer that provide water to 12,651 users. Within the north Paris area, there are three general hydrogeologic units: an upper, unconfined aquifer, an intermediate unit that has been characterized as an aquitard (primarily glacial till consisting of Catfish Creek and Port Stanley Till units) with some aquifer units within it, and a lower bedrock aquifer. These two aquifer units form the two groundwater supply sources for the north Paris wellfields.

The Gilbert well field consists of 8 wells; 6 wells are completed in the upper overburden aquifer, and 2 wells are completed in the upper bedrock (Salina Formation).

Three wells comprise the Telfer well field, P31, P32 and P36. Wells P31 and P32 are bedrock wells, while P36 is an overburden well that is currently inactive.

The thickness of the overburden varies up to approximately 60 m and locally along parts of the Grand River the overburden is absent. The surficial overburden deposits are mostly sand and gravel.

Vulnerability for the overburden wells was assessed using the SAAT method. The overburden Gilbert wells are in an area of high intrinsic vulnerability. Vulnerability scores are high in the WHPA-A and WHPA-B, and high to medium in the WHPA-C. Vulnerability for the bedrock wells was assessed using the intrinsic susceptibility index (ISI) method. The vulnerability of the bedrock wells is generally low. Vulnerability scores are high in the WHPA-A but drop to medium in the WHPA-B and low in the WHPA-C and D except where the wellhead protection areas are overlain by the wellhead protection areas for other north Paris overburden wells. Vulnerability scores in the WHPA-D for the bedrock aquifer have been adjusted to account for transport pathways (aggregate pits), although there is no change to the final mapping as the overburden aquifer was already a high vulnerability.

Four wells at the Bethel Road site are completed in the intermediate to deep overburden sediments and are considered to be groundwater under the direct influence of surface water (GUDI) with effective filtration due to the unconfined nature of the aquifer that would allow for relatively rapid infiltration of surface water. In general, vulnerability for the Bethel Road wellfield is high. Vulnerability scores are high in the WHPA and B, high to medium in WHPA-C and medium in WHPA-D.

An Issues evaluation was also completed through a review of water quality data collected from the municipal wells. Nitrate is identified as an Issue for the Gilbert overburden wells and the Telfer wells. For the Gilbert overburden wells and Telfer wells, the 25-year capture zone, based on average current pumping rates, has been delineated as the Issue Contributing Area for the wells.

The water quality threats assessment shows that 257 activities on 74 properties may be significant threats within the WHPA-A, B, C, and the Issue Contributing Areas for the north Paris wellfields (Gilbert and Telfer). 46 activities on 7 properties may be significant threats within the WHPA-A, and B for the Bethel Road wells.

~~Brantford~~ – Water Treatment Plan Brantford ~~(Holmedale)~~

The Brantford~~Holmedale~~ Water Treatment Plant is owned and operated by the City of Brantford and treats water from the Grand River via the Holmedale Canal. The Brantford Water Treatment Plant is a class IV facility~~conventional treatment plant~~ servicing the City of Brantford and the town~~Village~~ of Cainsville, County of Brant, with a population of approximately 99~~3~~,000. This plant has a rated capacity of 100,000 m^3/day. The raw water access to the Holmedale Canal is located approximately 1.5 km upstream of the water treatment plant.

The source vulnerability factor of 1.0 was assigned to this Type C intake. The overall vulnerability scores are 10 for IPZ-1 and 9 for IPZ-2. The IPZ-3 for the Holmedale Water Treatment Plant extends up the Grand, Nith, Speed and Conestogo Rivers. Vulnerability scores for the IPZ-3 range from 8 for close proximity with an urban runoff potential to 1 for far proximity with a low runoff potential.

An issues evaluation was also completed through a review of water quality data collected from the drinking water intake. Organic nitrogen and E. coli were identified as parameters of concern for the Brantford~~Holmedale~~ Water Treatment Plant~~TP~~ water supply that require further, more detailed spatial and temporal monitoring before a determination can be made whether these parameters are Issues under Technical Rule 114.

The water quality threats assessment shows that 273 activities on 195 properties may be significant threats within IPZ-1, 2 and 3.

Six Nations (Ohsweken)

Six Nations uses the Grand River as a source of water for a communal water system at Ohsweken. This water system is a First Nations system, but under a resolution from Six Nations requesting the Minister of the Environment to request the Lieutenant Governor in Council to make a regulation the Six Nations' Grand River intake at Ohsweken was brought into the Grand River Assessment Report. The water treatment plant has a design capacity of 1,040 m^3/day and serves a population of approximately 2,000.

The source vulnerability factor of 1.0 was assigned to this Type C intake. The overall vulnerability scores are 10 for IPZ-1 and 8 for IPZ-2. The IPZ-3 for Ohsweken extends up the Grand, Nith, Speed and Conestogo Rivers, Fairchild Creek, and well as other smaller tributaries. Vulnerability scores for the IPZ-3 range from 8 for close proximity with an urban runoff potential to 1 for far proximity with a low runoff potential.

An Issues-based threat analysis was also completed using water quality from upstream locations as very little data exists for the raw water quality at the Ohsweken Water Treatment Plant. No Issue-based threats were identified, but there is a high uncertainty associated with this assessment. It is recommended that further, more intensive sampling of the raw water at the Ohsweken WTP be completed.

The water quality threats assessment shows that 52 activities on 25 properties may be significant threats within the IPZ-2 (off-reserve) and IPZ-3.

Dunnville – County of Haldimand

Lake Erie Intake

The Dunnville Water System, operated by the Corporation of Haldimand County, is situated on the shore of Lake Erie at the mouth of the Grand River. Raw water is collected from a pumping station 10km away in Port Maitland through an intake pipe located in Lake Erie approximately 460m offshore. The pumping station has a design capacity of 26,400 m^3/day and supplies both the Dunnville Water Treatment Plant and the Port Maitland industrial area. The Dunnville plant has a design capacity of 14,500 m^3/day and serves a population of approximately 11,300.

The source vulnerability factor of 0.7 was assigned to this Type A intake. The overall vulnerability scores are 7 for IPZ-1 and 4.9 for IPZ-2.

There are no significant drinking water threats for the Dunnville Water System.

Grand River Emergency Intake

In addition to the Lake Erie Intake and emergency drinking water intake is located in the Grand River. This intake is only operated under extreme circumstances. The source vulnerability factor of 1.0 was assigned to the Type D intake. The overall vulnerability scores is 10 for IPZ-1 and 8 for IPZ-2.

The water quality threats assessment shows that there are 12 activities on 6 properties that may be significant drinking water threats. All activities are located in IPZ-1. There were no significant drinking water threats enumerated in IPZ-2.

Table 26-1: Summary Enumeration of Significant Threats for the Grand River Source Protection Area

Threat Activity[2] / Municipality - Well System	1. Waste Disposal Sites	2. Sewage Systems or Sewage Works	3. Application of ASM to Land	4. Handling and Storage of ASM	6. Application of NASM to Land	7. Handling and Storage of NASM	8. Application of Commercial Fertilizer to Land	9. Handling and Storage of Commercial Fertilizer	10. Application of Pesticide to Land	11. Handling and Storage of Pesticide	12. Application of Road Salt	13. Handling and Storage of Road Salt	14. Storage of Snow	15. Handling and Storage of Fuel	16. Handling and Storage of DNAPLs	17. Handling and Storage of Organic Solvents	19. Taking Water from an aquifer/waterbody without returning it to the same body	21. Livestock Grazing / Pasturing, Outdoor Confinement Areas	**22.** The establishment and operation of a liquid hydrocarbon pipeline	**Total**
Southgate - Dundalk	~~0~~1	~~3~~1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**~~3~~2**
Melancthon - Shelburne	0	0	2	0	0	0	~~2~~0	0	2	0	0	0	0	~~1~~0	0	0	0	0	**0**	**~~7~~4**
Grand Valley - Grand Valley	0	1	0	0	0	0	0	0	0	0	0	0	0	22	6	0	0	0	**0**	**29**
Amaranth - Waldemar	1	35	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	**0**	**39**
East Garafraxa - Marsville	0	7	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	**0**	**10**
Orangeville - Orangeville	0	0	0	0	0	0	0	0	0	0	~~23~~11	7~~15~~	~~0~~5	0	~~2~~9	0	44	0	**0**	**~~84~~76**
Wellington North - Arthur	1	2	3	0	0	0	2	0	3	0	0	0	0	0	2	1	0	0	**0**	**14**
Mapleton - Drayton	4	2	0	0	0	0	0	0	0	0	0	0	0	1	7	4	0	0	**0**	**18**
Mapleton - Moorefield	1	1	2	0	0	0	0	0	2	0	0	0	0	1	1	1	0	0	**0**	**9**
Centre Wellington - Fergus/Elora	30	26	5	0	0	0	2	0	5	0	0	0	1	1	109	30	0	0	**0**	**209**
Guelph/ Eramosa - Rockwood	7	37	21	8	0	0	17	8	21	8	0	0	0	0	9	7	0	8	**0**	**151**
Guelph Eramosa - Hamilton Drive	2	23	1	0	0	0	1	0	1	0	0	0	0	0	3	2	0	0	**0**	**33**
Guelph - Guelph	60	471	68	19	0	4	2	27	67	38	0	0	2	284	608	160	0	20	**0**	**1830**

Threat Activity[2] / Municipality - Well System	1. Waste Disposal Sites	2. Sewage Systems or Sewage Works	3. Application of ASM to Land	4. Handling and Storage of ASM	6. Application of NASM to Land	7. Handling and Storage of NASM	8. Application of Commercial Fertilizer to Land	9. Handling and Storage of Commercial Fertilizer	10. Application of Pesticide to Land	11. Handling and Storage of Pesticide	12. Application of Road Salt	13. Handling and Storage of Road Salt	14. Storage of Snow	15. Handling and Storage of Fuel	16. Handling and Storage of DNAPLs	17. Handling and Storage of Organic Solvents	19. Taking Water from an aquifer/waterbody without returning it to the same body	21. Livestock Grazing / Pasturing, Outdoor Confinement Areas	**22.** The establishment and operation of a liquid hydrocarbon pipeline	**Total**
Halton -	0	3	2	2	0	0	3	3	2	1	0	0	0	1	0	1	0	3	**0**	**21**
Region of Waterloo - Waterloo	1	45~~32~~	~~0~~1	~~0~~1	0	0	2	3~~1~~	5~~3~~	3~~0~~	525~~316~~	72~~2~~	1	10~~0~~	3~~1~~	0	0	0	**0**	**672~~359~~**
Region of Waterloo - Kitchener	9~~2~~	~~522~~583	~~49~~46	~~47~~39	~~5~~3	3~~5~~	80~~76~~	~~48~~45	~~16~~27	~~11~~9	~~432~~1285	~~8~~176	~~15~~17	~~8~~34	~~8~~5	~~4~~3	0	25~~39~~	**0**	**2389~~1295~~**
Region of Waterloo - Cambridge	29~~0~~	~~121~~246	~~9~~19	~~7~~21	1~~0~~	~~2~~3	~~3~~3	~~1~~55	~~6~~19	~~13~~56	~~847~~1214	~~18~~199	~~18~~12	~~23~~82	~~7~~9	~~7~~11	0	5~~1~~	**0**	**~~1103~~1984**
Region of Waterloo - Ayr	0	1	0	0	0	0	0	1~~0~~	0	~~0~~1	~~0~~8	0	0	~~0~~3	0	0	0	0	**0**	**14**
~~Region of Waterloo - Baden~~	~~0~~	~~62~~	~~12~~	~~11~~	~~1~~	~~0~~	~~17~~	~~7~~	~~1~~	~~2~~	~~5~~	~~0~~	~~0~~	~~2~~	~~0~~	~~0~~	~~0~~	~~9~~	**~~0~~**	**~~129~~**
Region of Waterloo - Branchton Meadows	0	8~~9~~	0	0	0	0	0	0	0	0	~~1~~1	0	0	~~0~~1	0	0	0	0	**0**	**10**
~~Region of Waterloo - Conestogo~~	~~0~~	~~31~~	~~0~~	~~0~~	~~0~~	~~0~~	~~2~~	~~2~~	~~0~~	~~2~~	~~1~~	~~0~~	~~0~~	~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	**~~0~~**	**~~40~~**
Region of Waterloo - Elmira	0	2~~0~~	5	2~~4~~	0	0	5	3~~1~~	5	2	~~0~~3	0	0	~~0~~2	0	0	0	~~6~~5	**0**	**34~~28~~**
Region of Waterloo - Foxboro Green	0	1~~2~~	0	0	0	0	0~~1~~	0	1	0~~1~~	0	0	0	0	0	0	0	0	**0**	**2~~5~~**

Threat Activity[2] / Municipality - Well System	1. Waste Disposal Sites	2. Sewage Systems or Sewage Works	3. Application of ASM to Land	4. Handling and Storage of ASM	6. Application of NASM to Land	7. Handling and Storage of NASM	8. Application of Commercial Fertilizer to Land	9. Handling and Storage of Commercial Fertilizer	10. Application of Pesticide to Land	11. Handling and Storage of Pesticide	12. Application of Road Salt	13. Handling and Storage of Road Salt	14. Storage of Snow	15. Handling and Storage of Fuel	16. Handling and Storage of DNAPLs	17. Handling and Storage of Organic Solvents	19. Taking Water from an aquifer/waterbody without returning it to the same body	21. Livestock Grazing / Pasturing, Outdoor Confinement Areas	**22.** The establishment and operation of a liquid hydrocarbon pipeline	**Total**
Region of Waterloo - Heidelberg	0	14~~5~~	1	1	0	0	1	0	1	~~0~~1	~~0~~1	0	0	~~1~~3	0	0	0	2	**0**	**25~~22~~**
Region of Waterloo - Linwood	0	14~~7~~	0	0	0	0	0	~~0~~1	0	~~0~~1	~~0~~4	0	0	~~0~~2	~~0~~1	0	0	4	**0**	**27~~1~~**
Region of Waterloo - Maryhill	0	25~~2~~	3	0	0	0	3	0	2	~~0~~3	~~0~~4	0	0	~~0~~2	0	1	0	2	**0**	**45~~33~~**
Region of Waterloo - New Dundee	0	28~~35~~	~~2~~2	2	0	0	1	1	~~2~~1	1	0	0	0	~~1~~4	0	0	0	3	**0**	**~~48~~43**
Region of Waterloo - New Hamburg	0	6~~4~~	1	1	0	0	~~1~~2	1	1	1	~~0~~1	0	0	2~~0~~	0	0	0	0	**0**	**16~~0~~**
Region of Waterloo - Roseville	0	23	0	0	0	0	0	0	0	0	0	0	0	2~~1~~	0	0	0	0	**0**	**25~~4~~**
Region of Waterloo - St. Clements	0	67~~45~~	0	0	0	0	0	0	0	0	1~~0~~	0	0	~~0~~4	0	1	0	0	**0**	**73~~46~~**
Region of Waterloo - Wellesley	0	1	1	1~~0~~	0	0	1	~~0~~2	1	2	~~0~~6	0	0	~~2~~3	0	0	0	2	**0**	**20~~10~~**
~~Region of Waterloo - West Montrose~~	~~0~~	~~5~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	**~~0~~**	**~~6~~**
Region of Waterloo - Hidden Valley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**

Municipality - Well System \ Threat Activity[2]	1. Waste Disposal Sites	2. Sewage Systems or Sewage Works	3. Application of ASM to Land	4. Handling and Storage of ASM	6. Application of NASM to Land	7. Handling and Storage of NASM	8. Application of Commercial Fertilizer to Land	9. Handling and Storage of Commercial Fertilizer	10. Application of Pesticide to Land	11. Handling and Storage of Pesticide	12. Application of Road Salt	13. Handling and Storage of Road Salt	14. Storage of Snow	15. Handling and Storage of Fuel	16. Handling and Storage of DNAPLs	17. Handling and Storage of Organic Solvents	19. Taking Water from an aquifer/waterbody without returning it to the same body	21. Livestock Grazing / Pasturing, Outdoor Confinement Areas	**22.** The establishment and operation of a liquid hydrocarbon pipeline	**Total**
Perth East - Milverton	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	**0**	**4**
Oxford - Bright	0	~~7~~29	1	0	0	0	~~1~~0	0	1	0	0	0	0	0	1	0	0	0	**0**	**~~11~~32**
Oxford - Drumbo-Princeton	0	7	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	**0**	**16**
Oxford - Plattsville	1	1	2	0	0	0	0	0	1	0	0	0	0	3	3	2	0	0	**0**	**13**
Hamilton - Lynden	0	5	6	0	0	0	0	2	6	0	0	0	0	6	0	0	0	1	**0**	**26**
Brant - Airport	9	21	3	3	0	0	0	0	3	1	0	0	0	16	18	5	0	0	**0**	**79**
Brant - Mount Pleasant	0	10	7	4	0	0	1	0	3	0	3	3	0	5	1	1	0	0	**0**	**38**
Brant - St. George	4	77	31	21	0	0	39	17	6	4	0	0	0	12	3	3	0	12	**1**	**~~228~~230**
Brant - Paris	12	45	42	37	0	0	37	13	31	11	0	0	0	26	20	6	0	17	**2**	**~~303~~299**
Brantford - Homedale	0	11	29	34	0	0	0	0	192	0	0	0	1	0	0	2	0	4	**0**	**273**
Six Nations - Ohsweken	0	2	10	8	10	0	0	0	0	0	0	0	0	0	0	0	0	22	**0**	**52**
Haldimand - Dunnville L. Erie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Haldimand - Dunnville Grand R.	0	4	0	0	0	0	0	1	0	1	2	0	1	0	2	1	0	0	**0**	**12**
Total	**~~159~~172**	**1885~~1724~~**	**~~304~~320**	**~~201~~204**	**~~25~~15**	**10~~13~~**	**~~205~~207**	**183**	**~~375~~411**	**~~96~~144**	**~~1652~~3069**	**~~67~~457**	**~~39~~40**	**~~390~~533**	**~~801~~823**	**~~234~~242**	**44**	**~~143~~136**	**3**	**8898~~599~~**

1. Values above were determined by adding the subcategory values together for each Prescribed Drinking Water Threat category, as shown in the Significant Drinking Water Quality Threats tables for each drinking water system.

2. There are no existing occurrences of Prescribed Drinking Water Threats numbers 5, 18 or 20 within the Grand River Source Protection Area.
3.~~2:~~ Conditions and local threats are not included.

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28.0 MAP REFERENCES

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Additional references for specific maps are given in the table below:

Map #	Map Title	Reference
Map 2-5:	Population and Population Density in Watershed by Municipality and Reserve	~~Base map produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ Grand River Conservation Authority, August 2018. Summary of Population Statistics for Grand River Watershed. ~~GSP Group Incorporated, 2009. Grand River, Long Point Region, Catfish Creek and Kettle Creek Watershed Areas: Population Forecasts, 2009.~~
Map 2-7~~6~~:	Physiography of Grand River Watershed Area	~~Produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ Physiography of Southern Ontario Ontario Geological Survey dataset MRD228, Chapman, L.J. and Putnam, D.F. 2007. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.
Map 2-8~~7~~:	Hummocky Topography	~~Produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2003.
Map 2-10~~9~~:	Bedrock Topography	~~Base map produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~Gao, C., Shirota, J., Kelly, R.I., Brunton, F.R. and van Haaften, S. 2006. Bedrock topography and overburden thickness mapping, southern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 207.

Map #	Map Title	Reference
Map 2-110:	Bedrock Geology	~~Produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ Paleozoic Geology of Southern Ontario, Ontario Geological Survey dataset MRD219, Armstrong, D.K., Dodge, J.E.P., 2007. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.
Map 2-121:	Quaternary (Surficial) Geology	~~Produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.
Map 2-132:	Overburden Thickness	~~Base map produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ Holysh, S., Pitcher, J., and Boyd, D. 2001. *Grand River Regional Groundwater Study.* Grand River Conservation Authority, Cambridge, ON.
Map 2-143:	Water Table Surface of the Grand River Watershed	~~Base map produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ AquaResource Inc. 2009a. Integrated Water Budget Report, Grand River Watershed: Final Report , June 2009.~~Holysh, S., Pitcher, J., and Boyd, D. 2001. *Grand River Regional Groundwater Study.* Grand River Conservation Authority, Cambridge, ON.~~
Map 2-154:	Potentiometric Surface of the Grand River Watershed	~~Base map produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.~~ AquaResource Inc. 2009a. Integrated Water Budget Report, Grand River Watershed: Final Report , June 2009.~~Holysh, S., Pitcher, J., and Boyd, D. 2001. *Grand River Regional Groundwater Study.* Grand River Conservation Authority, Cambridge, ON.~~
Map 2-16:	Significant Groundwater Recharge Areas	Base map produced using information provided by the Ministry of Natural Resources, Copyright © Queen's Printer, 2010.
Map 2-17:	Groundwater Discharge Map	Groundwater Discharge derived from Figure 70 (page 169) of: AquaResource Inc., June 2009. Final GRCA Integrated Water Budget Report.

Map #	Map Title	Reference
Map 2-18:	Average Annual Temperature	Based on Environment and Climate Change Canada data. Produced using information under License with the Grand River Conservation Authority © Grand River Conservation Authority, 2019.
Map 2-19:	Average Annual Precipitation	Based on Environment and Climate Change Canada data. Produced using information under License with the Grand River Conservation Authority © Grand River Conservation Authority, 2019.

APPENDIX A

Public Consultation Comments

Draft Updated Grand River Source Protection Plan

Summary of Public Comments and How Comments were Addressed

~~No comments were received during the February 12 to March 18, 2019 public consultation period for the draft updated Grand River Assessment Report.~~The public consultation period is scheduled for April 8 to May 21, 2019.

Detailed public consultation comments and how they were addressed for previous iterations of the Grand River Assessment Report are available upon request.

APPENDIX B

Written Notice from Director Classifying Intakes per Technical Rule 55.1

Requests for Approval of Alternative Approach

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APPENDIX C

Correspondence Regarding Excavation that Breaches the Aquitard

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~~APPENDIX D:~~

~~Director's Letter of Approval for the Conveyance of Oil by way of Underground Pipeline as a local threat~~

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