TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

This page left blank intentionally.

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

Research into the consequences of climate change, modeled as a doubling of CO_2, has been completed in Ontario and the Lake Erie basin with many of the recent studies incorporating 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 on climate change and water resources in the last decade is thought to be more reliable than earlier studies, given that recent studies have been able to incorporate observed changes, and take advantage of better modeling tools (IPCC-TGICA, 2007). Many recent studies agree that greater and more frequent temperature and precipitation extremes are expected in the Lake Erie basin. An annual average increase in both temperature and precipitation are the driving predictions for the differences in water resources for Ontario and the Lake Erie basin (Kling et al., 2003). For the Long Point Region subwatersheds, research in the Lake Erie basin is the most appropriate unit of measurement for local scale impacts of climate change.

Annual average air temperature in the Lake Erie basin (including the Long Point Region subwatersheds) is expected to increase only slightly; McBean and Motiee (2008) estimate a 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, resulting in much warmer winter temperatures (Bruce et al., 2000; Cunderlik and Simonovic, 2004; Jyrkama and Sykes, 2007; Kunkel et al., 2002; Mortsch et al., 2000). Daily temperatures in the summer are projected to gradually increase towards 2030, with a more rapid increase occurring to 2100 that could have daily average summer temperatures 10^0C higher than the 1960-1990 average (Kling et al., 2003).

The projected effects of a doubling of CO_2 on precipitation are extensive. Annual total precipitation is expected to increase over the next 50 years in the Great Lakes basin (McBean and Motiee, 2008), but the distribution throughout the year will be altered. Sharif and Burn (2006) estimate that only the months of January, March and October will have increased monthly precipitation; while the period between April and September, when water demands are highest, may see a decrease. Precipitation is expected to shift from snowfall to rain as winter temperatures rise (Bruce et al., 2000; Mortsch et al., 2000). The extreme events for precipitation will be of higher intensity and frequency (McBean and Motiee, 2008), at the expense of more gentle and persistent rainfall events experienced in the past (Mortsch et al., 2000).

For the Long Point Region Conservation Authority, Staple (1993) summarized the findings of a study of Long Point Bay temperature and precipitation changes from the base of comparison years 1900-1989. The study found that a doubling of CO_2 could lead to the mean air temperature increasing by 5.7^0C; precipitation decreasing by 6.3% to 857 mm annually; and the lake level to drop by 1.35 m. The greatest temperature changes are expected to occur in winter and spring, with increases as high as 10.5^0C. Seasonal precipitation fluctuations are also expected to increase: most concerning of which are the reductions in precipitation of up to 35% in the period from August to December (Staple, 1993). While this study was specific to the Long Point Region watershed area, the data and research is over 15 years old and could be considered out-dated due to the continued scientific findings since 1993.

Warmer winter temperatures are projected to be the most influential change for water resources in the Long Point Region watershed area. 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 weaker spring freshet (Barnett et al., 2005; Bruce et al., 2000;

Environment Canada, 2004a; Jyrkama and Sykes, 2007; Mortsch et al., 2000). Soil moisture will be higher in the spring, but drop lower in summer due to higher evapotranspiration. This will lead to more frequent drought occurrences and greater demands on water resources for irrigation (Brklacich, 1990; McBean and Motiee, 2008). Precipitation trends will change to 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 days with rain or longer dry periods (Mortsch et al., 2000). Net basin water supplies are projected to decrease, following overall 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 averages in temperature, precipitation and evaporation, which will lead to increased variability, and more frequent and intense storm events (Francis and Hengeveld, (1998) in de Loe et al., 2001).

11.1 Potential Effects of Climate Change on Water Quantity and Quality

The predictions on climate change in the Long Point Region watershed area have implications to both water quality and quantity. In terms of water quality, the increase in air temperature and greater occurrence of extreme precipitation events will lead to degraded water quality, including 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), which when 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. Algal blooms will lead to more taste and odour problems in drinking water, higher risk from water-borne diseases, and increased water treatment costs (Chiotti and Lavender, 2008; Hunter, 2003; de Loe and Berg, 2006).

Decreases in runoff and baseflows are also important changes with respect to the dilution of sewage treatment effluent, given that less water will be available for wastewater assimilation (de Loe and Berg, 2006). The problem of reduced wastewater assimilative 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).

From a water quantity perspective, climate change is expected to shift the timing of seasonal events. An earlier and lower spring freshet can be expected. Additionally, Lake Erie levels are expected to rise and fall one month earlier on an annual basis because of increased lake surface temperatures (Lenters, 2001; Lofgren et al., 2002; Millerd, 2006). The longer frost-free periods could lead to increased evapotranspiration and an increase in drought occurrence (Environment Canada, 2004a; McBean and Motiee, 2008), meaning that longer, drier and warmer growing seasons will lower soil moisture and increase 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 leading to drawdowns of between 2 to 7 m will require wells to be drilled deeper, thereby increasing costs to land owners and municipalities. This could also lead to rural domestic and urban water use conflicts (de Loe and Berg, 2006; McLaren and Sudicky, 1993). The predicted changes in climate in the Lake Erie basin could compromise the reliability of water resources. The increased unpredictability of the hydrologic cycle will demand more planning and adaptation by water managers (de Loe and Berg, 2006).

11.2 Potential Impacts of Climate Change on Lake Erie Levels

Climate change impacts on Lake Erie will have important consequences. 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. Net basin water supplies will be diminished (Mortsch, 2006), as increases in precipitation are not expected to overcome the decreases in water due to increased evapotranspiration (Millerd, 2006).

Winter ice formation on Lake Erie is expected to decrease considerably, and in some years be non-existent (Lofgren et al., 2002). Typically, Lake Erie freezes over almost entirely in the months of January and February, which limits lake-effect 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 increases in air temperatures above the 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. This is expected to be most pronounced in the shallower western portion of Lake Erie (Lofgren et al., 2002; Mortsch et al., 2000; de Loe and Kreutzwiser, 2000). According to the results of 3 Canadian GCM scenarios (Millerd, 2006; Mortsch et al., 2000), the decline in annual Lake Erie levels could be as much as 0.60 m to 1.36 m from the International Great Lakes Datum of 1985 of 173.5 m.

Jones et al. (2006) concluded that Lake Erie is possibly the most vulnerable of the Great Lakes to the effects of climate change, as it is the most southerly, shallowest and lowest volume and thus more susceptible to changes in thermal regime and lake levels. The impact of decreasing lake levels to the drinking water intakes in Lake Erie would be costly if dredging or pipe extensions were required. Additionally, with decreasing lake levels, drinking water intakes will be at shallower depths, making the raw water more susceptible to degradation.

11.3 Effect of Projected Climate Changes on Assessment Report Conclusions

Projected climate changes may affect the assessment report conclusions with respect to the groundwater and creek-sourced drinking water supplies in the Long Point Region. The Long Point Region Water Budget and Local Area Risk Assessment (Tier 3 study) shows a significant water quantity risk for the Simcoe water supply system under future drought conditions.

The location and shallow, 0.9 metre depth of the Port Rowan water supply intake make it more vulnerable to declining Lake Erie levels than other Lake Erie intakes. The Port Dover water supply intake, at a depth of 2.9 metres is somewhat less vulnerable to declining Lake Erie levels than the Port Rowan intake. The Nanticoke water supply intakes, at a depth of 6.5 metres are less vulnerable to declining Lake Erie levels than other intakes along Lake Erie.

Increasing nutrient loads and water temperatures, combined with shallower Lake Erie depths, have the potential to increase the occurrence of taste and odour problems, which are currently noted to be of concern, particularly for the Port Rowan and Port Dover water supplies.

12.0 CONSIDERATION OF GREAT LAKES AGREEMENTS

Under the *Clean Water Act, 2006*, 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.

12.1 Long Point Region Watershed Area and Great Lakes Agreements

The Long Point Region watershed area 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's of the Nanticoke, Port Rowan and Port Dover drinking water intakes.

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 Long Point Region 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 Lakewide 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 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 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, 2006*. In particular, the Long Point Region tributaries of Big Creek, Nanticoke Creek, Big Otter Creek and Lynn River contribute approximately 15% of the total Phosphorus loading to the Eastern Basin of Lake Erie (Dolan and McGunagle, 2005). Reducing the loads from these tributaries will be an important focus of long-term water quality objectives for Lake Erie.

Many projects to improve water quality in tributaries of Lake Erie in the Long Point Region watershed area have been undertaken under the Great Lakes Water Quality Agreement and Canada-Ontario Agreement. Projects to improve tributary water quality include tree planting, buffer strips, land acquisition in sensitive areas, sediment flow monitoring and wetland restoration.

One example of a project undertaken with funding provided under the Canada-Ontario Agreement included successfully buffering over 80% of the unbuffered riparian areas in the South Creek subwatershed and tributaries of Hahn Marsh near the base of the Long Point peninsula.

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, 2004b). 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 losses of water from the Great Lakes basin (Ontario Ministry of Natural Resources, 2005a). 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 intakes in Long Point Region are not considered to be intra-basin transfers since wastewater is discharged back into the Lake Erie watershed.

13.0 CONCLUSIONS

The Long Point Region 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 Long Point Region watershed area. Assessment Report findings are used to develop policies for a Source Protection Plan to protect the sources of drinking water for the Elgin, Oxford, Norfolk and Haldimand County water supply drinking water systems within the Long Point Region Watershed.

Watershed Characterization

The Long Point Region Source Protection Area is located in southwestern Ontario and covers an area of approximately 2,900 km^2 draining to Lake Erie. Much of the land of the watershed is used for agriculture. The main urban areas are the towns of Simcoe and Tillsonburg.

Residents in the Long Point Region watershed receive drinking water supplies from both private and municipal supplies. Groundwater and surface municipal water systems provide water to the majority of the population in the watershed. In Oxford County, Tillsonburg and the villages of Dereham Centre, Otterville, Springford and Norwich are serviced by municipal groundwater wells (note: the communities of Otterville, Springford and Norwich form the Oxford South water system). In Norfolk County, Simcoe, Waterford, Courtland and Delhi are serviced by municipal groundwater wells. Port Rowan and Port Dover are serviced by intakes from Lake Erie. In Haldimand County, the Nanticoke intake provides water to a number of communities including the Nanticoke Industrial Park, Jarvis, and Hagersville in the Long Point Region and the Mississaugas of the New Credit Reserve in the Grand River watershed. In Elgin County the village of Richmond is serviced by municipal groundwater wells. Municipal water, from sources outside the Source Protection Area, provide water to residents of the communities of Mount Elgin, Port Burwell and Vienna.

The geology of the Long Point Region watershed is dominated in the west and central portions by the Norfolk Sand Plain and in the east by the Haldimand Clay Plain. The northern portion of the watershed is comprised of low to moderate relief till moraines of the Horseshoe Moraine/Mount Elgin Ridges.

The Norfolk Sand Plain is characterized as a low-relief, silty sand and gravel sand plain, rich in water, with high infiltration, high groundwater recharge and good baseflows in the creeks. It is intensively used as an irrigation source for both mixed farming and cash crops. Two overburden aquifers are the main source of water for water supplies. However, since the soils are more permeable, this also allows for superficially applied chemicals to more easily enter the shallower groundwater aquifers and impact well supplies.

The Haldimand Clay Plain east of the communities of Waterford and Simcoe 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 drinking water supplies have tended in more recent years to be sourced from Lake Erie.

Stream water quality and temperature are influenced by the geology and current land use. The Haldimand Clay Plain and moraine areas support livestock operations and general cash crop production. Lack of riparian cover can result in higher water temperatures and phosphorus concentrations from runoff. The specialty crops and high irrigation and nutrient application rates in the Norfolk Sand Plain result in elevated nitrate levels due to infiltration and runoff. However, high groundwater recharge and discharge rates create sufficient water quality to support cold water fisheries. Nutrient levels, primarily nitrate, phosphorus and non-filterable residue, are the main surface water quality concerns throughout the Long Point Region watershed.

Water Quantity Stress and Risk Assessment

The Long Point Region has among the highest density of Provincial Permits to Take Water in Southern Ontario. Most of these permits are for agricultural irrigation. Water demands in the Long Point Region watershed are high. The surface water subwatershed stress assessment classifies eight subwatersheds as having a moderate potential for stress under existing conditions (South Otter, Big Creek Above Cement Road, Big Creek Above Delhi, Venison Creek, Dedrick Creek, Lynn River, Nanticoke Upper and Stoney Creek) and two subwatersheds a significant potential for stress under existing conditions (North Creek and Young/Hay Creeks).

The Tier 2 Water Budget and Stress Assessment classified four subwatersheds as having a moderate potential for stress under existing conditions (Big Creek Above Delhi, Big Creek Above Minnow Creek, North Creek and Lynn River), one subwatershed moderate potential for stress under future conditions (Otter Creek at Tillsonburg) and two subwatersheds significant potential for stress under existing conditions (Big Creek Above Kelvin Gauge and Nanticoke Upper). The Tier 3 Water Quantity Risk Assessment for these three systems was completed in April 2015. The Tier 3 Assessment identified a “significant” water quantity risk for the Simcoe water supply. A technical study, also called a Risk Management Measures Evaluation Process (RMMEP) was undertaken and completed in November 2016. This process is used to rank the water quantity threats and select and evaluate Water Quantity Risk Management Measures (RMM), using the water budget model developed in the Tier 3 Assessment, to determine what measures can be used to manage the water quantity risks to drinking water.

Water Quality Risk Assessment

Aquifer vulnerability was assessed across the watershed using the Surface to Aquifer Advection Time (SAAT) method. The resulting analysis shows areas of medium and high aquifer vulnerability over most of the watershed area, roughly coincident with the shallow, unconfined aquifer of the Norfolk Sand Plain. The northern extents of the watershed coinciding with the Horseshoe Moraines/Mount Elgin Ridges, and the eastern portion of the watershed, coinciding with the Haldimand Clay Plain, were assessed as low vulnerability.

Given that the maximum vulnerability score a Highly Vulnerable Aquifer can receive is a 6, activities cannot become significant threats within Highly Vulnerable Aquifers. To date, no drinking water Issues have been identified in the Highly Vulnerable Aquifers.

Significant Groundwater Recharge Areas were delineated using water budget tools. Groundwater recharge was estimated using a hydrologic model.

Dereham Centre, Oxford County

The Dereham Centre municipal water supply system includes one well completed in the intermediate overburden aquifer that services a population of approximately 47. Four Wellhead Protection Areas were 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. The wells are located in an area of low/medium intrinsic vulnerability, which results in vulnerability scores of 2 and 4 in WHPA-D and WHPA-C, 6 in WHPA-B, and a vulnerability score of 10 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.

Oxford South, Oxford County

The Norwich and Otterville–Springford water systems operated as independent systems until November, 2013, when a transmission main connecting Norwich to Otterville and Springford was commissioned forming the Oxford South Water System.

The Norwich area includes three wells; the serviced population in Norwich approximately 3,195. Two wells (Well 2 and Well 5) are located at the water works facility in the centre of town; one well (Well 4) is located to the east of the town. All three wells are completed in the bedrock aquifer.

The wells are located in an area of low intrinsic vulnerability, which results in vulnerability scores of 2 in WHPA-C and –WHPA-D and scores of 6 and 10 in WHPA-B and WHPA-A, respectively.. Adjustments were made to the vulnerability mapping to account for potential transport pathways (concentrations of private wells and sewage disposal systems located adjacent to Highway 59 north of the Town and in the village of Burgessville).

The water quality threats assessment shows that 15 activities on 9 properties may be significant threats within WHPA-A and WHPA-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 Norwich.

The Otterville-Springford area includes two wells (Well 3 and Well 4) to the east of the village of Otterville and two wells (Well 4 and Well 5) located on the west edge of the village of Springford. The serviced population of Otterville and Springford is approximately 1,580. The Otterville wells are completed in the shallow overburden aquifer system with high intrinsic vulnerability. As a result, the vulnerability scores are 10 in WHPA-A and B, 8 in WHPA-C and 6 in WHPA-D. The Springford wells are completed in the intermediate overburden aquifer system with low intrinsic vulnerability, which results in 6, 4 and 2 vulnerability scores in most of the wellhead protection areas, and a vulnerability score of 10 within the 100-metre area around the wells.

The water quality threats assessment shows that 88 activities on 25 properties may be significant threats within WHPA-A, WHPA-B, WHPA-C and the ICA in Otterville, and 7 activities on 6 properties may be significant threats within WHPA-A in Springford. An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. A nitrate Issue-based threat was identified within the Otterville WHPAs. No Issue-based threats were identified within the Springford WHPAs.

Tillsonburg, Oxford County

The Tillsonburg water supply system includes 10 wells (Wells 1A, 2, 4, 5, 6A, 7A, 9, 10, 11 and 12) that service a population of approximately 16,340 and one additional planned well (well 3). The wells are completed in the overburden aquifer system.

The aquifer supplying the group of wells located to the southeast of the Town (1A, 2, 9, 10, 11 and 12) is mainly unconfined. The aquifer supplying the group of wells to the north (3, 4, 5, 6A and 7A) is mainly semi-confined. For the group of wells to the southeast, vulnerability scoring indicates the following: scores of 10 to 8 in WHPA-B; 8 to 6 in WHPA-C; 4 to 2 in WHPA-D. For the group of wells to the north, vulnerability scoring indicates the following: scores of 6 to 10 in WHPA-B; 2 to 8 in WHPA-C; 2 to 4 in WHPA-D. The aquifer vulnerability within a portion of the WHPA in the north along Plank Line was increased to account for possible transport pathways (concentration of private wells and private sewage systems).

Wells 1A, 2, 4, 5, 7A, 9 and 10 have been classified as groundwater under the direct influence of surface water (GUDI). Wells 4, 5 and 7A had WHPA-E's delineated in addition to the WHPA-A to D. The WHPA-E for wells 4 and 5 has a vulnerability score of 6.3. The WHPA-E for well 7A has a vulnerability score of 7.2.

The water quality threats assessment shows that 89 activities on 38 properties may be significant threats in Oxford County within WHPA-A, B, C and the ICA, and 32 activities on 20 properties may be significant threats in Norfolk County 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. The Issue Contributing Area for the Nitrate Issue for the Northern well fields is delineated as the area within the wellhead protection areas that is currently contributing water to the wells (using existing pumping rates), and the enumerated threats are included in the totals above.

Delhi-Courtland, Norfolk County

Norfolk County provides municipal drinking water to approximately 6,262 users in the communities of Delhi and Courtland via a drinking water system that distributes treated water from four groundwater supply wells (Wells 1, 2, 3a, & 3b) (Norfolk County, 2017). Wells 1 and 2 have a planned pumping capacity of 2,290 m^3/day. They are 39 metres deep and pump from an extensive unconfined aquifer consisting of glaciolacustrine sands and gravels. Wells 3a and 3b, each with a pumping capacity of 1,145 m^3/day, were drilled in 2016 to provide increased capacity to the Delhi system. These wells are 39 metres deep and pump from the same unconfined aquifer as Wells 1 and 2, and were brought online in 2020. Intrinsic vulnerability in the wellhead protection area, assessed using the Surface to Aquifer Advection Time (SAAT) methodology, is high; vulnerability scoring is 10 in the WHPA-A and B and 8 in the WHPA-C.

Even though the Delhi well 1 is identified as groundwater under the influence of surface water (GUDI), there is no evidence of a connection to 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 this well.

The water quality threats assessment shows that 74 activities on 13 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. No significant conditions based threats have been identified for the Delhi sources.

Simcoe, Norfolk County

Norfolk County provides municipal drinking water to approximately 15,040 users in the community of Simcoe from three separate overburden wellfields (Norfolk County, 2017).

The Cedar Street wellfield consists of five wells (Cedar 1A, 2A, 3, 4 and 5) and an infiltration gallery. The wellfield is located along the banks of Kent Creek. The Cedar Street wells are groundwater under the influence of surface water (GUDI) and a WHPA-E was delineated in addition to WHPAs A through D. The WHPAs were mapped as having a high intrinsic vulnerability and the vulnerability scores are as follows; 10 in WHPA-A and B and 8 in the WHPA-C. The WHPA-E has a vulnerability score of 6.3.

The Northwest Wellfield consists of two wells (Northwest 2 and 3) in proximity to Patterson Creek and former aggregate producing operation, now ponds. Since the Northwest Wellfield wells are also GUDI, a WHPA-E was delineated in addition to WHPAs A through D. The intrinsic vulnerability in the WHPAs ranges from high to low, with a vulnerability score of 10 in WHPA-A, 8-10 in the WHPA-B and scores varying from 2 to 8 in the WHPA-C. The WHPA-E has a vulnerability score of 6.3.

The Chapel Street Wellfield consists of a single well located within the community of Simcoe. Vulnerability in the wellhead protection area is high-moderate, with vulnerability scores between 8 and10 in WHPA-B and between 6 and 8 in WHPA-C.

The Simcoe water quality threats assessment resulted in 11 activities on 4 properties that may be significant threats within the Northwest Wellfield WHPAs. A total of 225 activities located on 68 properties were identified as potential significant threats within the Cedar Street WHPAs, and 31 activities on 21 properties were identified within the Chapel Street WHPAs. Thirty one activities for fourteen properties were identified within Chapel and Cedar Street WHPAs combined.

An Issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. Nitrate was identified as an Issue for the Simcoe Water Supply. Nitrate Issue Contributing Areas for the Cedar Street and Chapel Street wellfields were mapped using a similar method to delineating WHPAs, but using existing pumping rates within the Tier 3 groundwater flow model instead of projected future rates. A threats enumeration identified 53 potential nitrate-related threats within the two ICAs. No conditions were identified at the time of this report.

Waterford, Norfolk County

The municipal water supply for Waterford consists of two shallow groundwater wells (Thompson Road Wells 3 and 4) that serve approximately 3,315 users (Norfolk County, 2017). The primary aquifer supplying the Waterford wells consists of local unconfined gravel and sand deposits with a thickness ranging from 4 to 8 metres. The Waterford wells are classified as GUDI and a WHPA-E has been delineated in addition to WHPAs A through D. The municipal supply aquifer in the Waterford area has a high intrinsic vulnerability; vulnerability scores are 10 in WHPA-A and B and 8 in WHPA-C. The WHPA-E has a vulnerability score of 5.6. The water quality threats assessment within the Waterford WHPAs resulted in 15 activities on 6 properties may be significant threats. No Issues or significant condition-based threats were identified.

Port Dover, Norfolk County

The Port Dover water treatment plant serves a population of about 7,089users in the community of Port Dover and through the municipal bulk water depot (Norfolk County, 2017). The intake is located approximately 457 metres off-shore at a depth of 2.9 metres.

An Intake Protection Zone 1 (IPZ-1) has been delineated as a radius of 1,000 metres centred on the crib of the intake with a setback equal to the greater of 120 metres or the Conservation Authority Regulation Limit where the circle intersected land. The vulnerability score for the IPZ-1 is 6.0. An IPZ-2 was delineated based on a travel time to the intake of two hours. The vulnerability score for the IPZ-2 is 5.4. No activities have been identified as significant threats. An Issues-based threats analysis was also completed through a review of water quality data, and no Issues were identified.

Port Rowan, Norfolk County

The Port Rowan water treatment plant serves a population of approximately 2,312people in the towns of Port Rowan and St. Williams (Norfolk County, 2017). The intake is located approximately 365 metres off-shore at a depth of 0.9 metres in the Long Point inner Bay.

An Intake Protection Zone 1 (IPZ-1) has been delineated as a radius of 1,000 metres centred on the crib of the intake with a setback equal to the greater of 120 metres or the Conservation Authority Regulation Limit where the circle intersected land. An IPZ-2 was delineated based on a travel time to the intake of two hours. Because the IPZ-2 is totally contained within the IPZ-1, there is no IPZ-2 for the Port Rowan intake. The vulnerability score for the IPZ-1 is 7.0. No activities have been identified as significant threats. An Issues-based threats analysis was also completed through a review of water quality data, and no Issues were identified.

Nanticoke, Haldimand County

The Nanticoke Water Supply System is a municipal drinking water system serving approximately 10,000 people in the towns of Hagersville, Jarvis, Townsend, Mississaugas of the New Credit Reserve, and the Lake Erie Industrial Park. Two in-lake intake cribs are located approximately 500 and 520 metres offshore at a depth of approximately 6.3 metres. Water flows via gravity to the power generation facility forebay. A channel located in the west bank of the forebay connects to the industrial pumping station (IPS) wet well and the submersible low lift pumps for the water treatment plant.

The Intake Protection Zone 1 (IPZ-1) was delineated as a circle with a 1000 m radius centred on each of the intake cribs. A 120 metre setback was included where the IPZ-1 intersected with land. The resulting IPZ-1 was given a vulnerability score of 5.0. An IPZ-1 was also delineated around the industrial pumping station forebay with a 120 metre setback adjusted for local drainage characteristics. The IPZ-1 was given a vulnerability score of 10. An IPZ-2 was delineated for the in-lake intakes using a two-hour travel time. The delineated area includes both in-water and on-shore areas. The vulnerability of IPZ-2 was found to be low, and was given a score of 4.0. An IPZ-2 was also delineated for the industrial pumping station based on assumptions of the forebay hydraulics and using the general extent of the power generation facility forebay with a setback of 120 metres. The vulnerability of the IPZ-2 for the industrial pumping station is high and has been given a score of 9.0.

The water quality threats assessment shows that 4 activities on 2 properties may be significant threats in the IPZ-1 and IPZ-2 for the industrial pumping station. Elevated sediment concentrations of chromium (total), copper, nickel and zinc in the IPZ-1 for the industrial pumping station are also considered a significant drinking water threat condition. An Issues-based threats analysis was also completed through a review of water quality data, and no Issues were identified.

Richmond, Elgin County

The Richmond water supply is a municipal drinking water system serving approximately 50 residences in the village of Richmond. The system is groundwater-based and consists of three pumping wells: one deep bedrock well used for backup supply: and two shallow wells screened in an unconfined, overburden aquifer. The overburden wells are classified as GUDI without effective in-situ filtration.

The Richmond WHPAs were delineated using the Long Point Tier 3 groundwater flow model.

Intrinsic vulnerability in WHPA-A to C is medium. WHPA-A has a vulnerability score of 10, WHPA-B has a vulnerability score of 8, and WHPA-Chas a vulnerability score of 6. Intrinsic vulnerability is low in WHPA-D with vulnerability scores ranging from 2 to 4.

A water quality threats assessment within the Richmond WHPAs resulted in 8 activities located on 3 properties within the WHPA-A which may be significant threats. Nitrate was identified as an Issue for the overburden wells, and in ICA was mapped to align with WHPAs A and B. The Township has implemented a monthly nitrate sampling program for the overburden municipal wells and is developing annual nitrate monitoring reports.

Table 13-1: Summary Enumeration of Significant Water Quality Threats in the Long Point Region Source Protection Area

	Dereham	*Norwich*	*Otterville*	*Springford*	*Tillsonburg*	*Delhi*	*Simcoe*	*Waterford*	*Port Dover*	*Port Rowan*	*Nanticoke*	*Richmond*	*Total*
Waste disposal site		*1*				*1*	*17*						***19***
System that collect, stores, transmits, treats or disposes of sewage	*2*	*2*	*22*	*5*	*18*	*8*	*66*	*6*			*3*	*4*	***136***
Application of agricultural source material (ASM)	*1*	*2*	*18*	*1*	*38*	*7*	*29*	*2*				*1*	***99***
Storage of ASM						*1*	*6*						***7***
Management of ASM			*9*										***9***
Application of non-agricultural source material (NASM)												*1*	***1***
Handling & storage of NASM													***0***
Application of commercial fertilizer	*3*		*18*		*31*		*35*					***1***	***87***

	Dereham	Norwich	Otterville	Springford	Tillsonburg	Delhi	Simcoe	Waterford	Port Dover	Port Rowan	Nanticoke	Richmond	Total
Handling and storage of commercial fertilizer			9		1	3	10						**23**
Application of pesticide to land	1	2	4	1	18	5	9					1	**41**
Handling and storage of pesticide		1	2		1	3	6						**13**
Application of road salt													**0**
Handling and storage of road salt													**0**
Storage of snow													**0**
Handling and storage of fuel	2	1	3		6	8	31				1		**52**
Handling and storage of a DNAPL		5	1		8		66	2					**82**
Handling and storage of an organic solvent		1					23						**25**
Management of runoff that contains aircraft de-icing chemicals													
Livestock grazing, pasturing, farm-animal yard			2			2		2					**6**
The establishment and operation of a liquid hydrocarbon pipeline													**0**
Condition due to past activity											1		**1**
Total # activities and conditions that may be significant threats	**9**	**15**	**88**	**7**	**121**	**38**	**298**	**12**	**0**	**0**	**5**	**8**	**601**

Table 13-2: Summary Enumeration of Significant Water Quantity Threats in the Long Point Region Source Protection Area

Threat Activity / Water Quantity Vulnerable Area	19. An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water	20. An activity that reduces the recharge of an aquifer.
Long Point WHPA-Q-A	9	0.14 km^2
Total	9	0.14 km^2

Effects of Climate Change on Assessment Report Conclusions

Climate change could affect the assessment report conclusions with respect to the groundwater and creek-sourced drinking water supplies in the Long Point Region. The Long Point Region Water Budget and Local Area Risk Assessment (Tier 3 study) identified a significant water quantity risk for the Simcoe water supply system during all groundwater risk scenarios (see Section 10 for more detail).

The location and shallow, 0.9 metre depth of the Port Rowan water supply intake make it more vulnerable to declining Lake Erie levels than other Lake Erie intakes. The Port Dover water supply intake, at a depth of 2.9 metres is somewhat less vulnerable to declining Lake Erie levels. The Nanticoke water supply intakes, at a depth of 6.5 metres are less vulnerable to declining Lake Erie levels than other intakes along Lake Erie. Increasing nutrient loads and water temperatures, combined with shallower Lake Erie depths, have the potential to increase the occurrence of taste and odour problems, which are currently noted to be of concern, particularly for the Port Rowan and Port Dover water supplies.

Next Steps

The results of the technical studies were used to develop policies to protect sources of municipal drinking water. Policies were developed by municipalities, conservation authorities, property and business owners, farmers, industry, health officials, community groups and others working together to develop a fair, practical and implementable Source Protection Plan.

Public input and consultation play a significant role throughout the process. A formal public consultation will be held for the Source Protection Plan prior to finalization and submission to the Minister of the Environment, Conservation and Parks at the beginning of 2020.

14.0 REFERENCES

AquaResource Inc., 2005. A Method for Assessing Water Use in Ontario Watersheds. Report to the Ontario Ministry of Environment. Ontario: AquaResource Inc. 33p.

AquaResource Inc., 2009a. Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget-Final Report. Report to Lake Erie Source Protection Region. Breslau, ON: AquaResource Inc. 174 p.

AquaResource Inc., 2009b. Long Point Region, Catfish Creek and Kettle Creek Tier 2 Water Quantity Stress Assessment-Final Report. Report to Lake Erie Source Protection Region. Breslau, ON: AquaResource Inc. 88 p.

ARL Groundwater Resources Ltd. 2010. Report on the Groundwater Vulnerability Assessment for the Wellhead Protection Areas in the County of Oxford (Draft Final Version October 13, 2010).

Armstrong D.K. and T.R. Carter. 2010. “The subsurface Paleozoic stratigraphy of southern Ontario.” Ontario Geological Survey. Special Volume 7, 301p.

Banks, W, Strynatka, S., Patterson, T. and Piggott, A.R 2007. Long Point Region groundwater resources study; Ontario Geological Survey, Groundwater Resources Study 4, 142p

Barn Identification. 2009. [Internet]. Ontario Ministry of Agriculture, Food and Rural Affairs. Ontario: Queen's Printer for Ontario. Available from: http://www.omafra.gov.on.ca/english/landuse/mds_p7.htm

Barnett, P.J. 1978. Quaternary Geology of the Simcoe Area, southern Ontario; Ontario Division of Mines, Report 162, 74 p.

Barnett, P.J. 1982. Quaternary Geology of the Tillsonburg Area, southern Ontario; Ontario Geological Survey Report 220. 87 p.

Barnett, P.J. 1992. Quaternary Geology of Ontario; in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part2, p.1011-1090.

Barnett, P.J. 1993. Quaternary Geology of the Long Point- Port Burwell area, Ontario; Ontario Geological Survey, Open File Report 5873, 212 p.

Barnett, PJ and Girard, CK. 1982. Quaternary Geology of the Tillsonburg Area. Map. Toronto, ON: Ontario Geological Survey.

Barnett T, J Adam, and D Lettenmaier. 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438: 303-309.

Bellamy S. and Boyd D. 2005. Water Use in the Grand River Watershed. Grand River Conservation Authority. Cambridge, ON: GRCA. 33 p.

Bellamy S. and Wong A., 2005. Water Use in the Long Point Region Conservation Authority. Draft. Cambridge, ON: GRCA. 28 p.

Beukeboom, T, Ontario Ministry of Environment. (personal communication).

Blackport & Associates. 1997. Groundwater Quality Survey Evaluation for the Regional Municipality of Haldimand-Norfolk. Waterloo, ON. 15 p.

BlueMetric Environmental. 2017. 2016 Nitrate Monitoring Report – Richmond Wellfield Municipality of Bayham, Long Point Region Source Protection Plan. Kitchener, ON. 36p.

Brabec E., Shulte S. and P.L. Richards. 2002. “Impervious surfaces and water quality: a review of current literature and its implications for watershed planning.” Journal of Planning Literature 16 (4): 499-514.

Brklacich M. 1990. Climatic Warming and potential demands for irrigation water in southwest Ontario, in Climate Change: Implications for Water and Ecological Resources. ed. by G. Wall and M. Sanderson. pp. 269-274. Department of Geography Publication Series, Occasional Paper no. 11 Waterloo, ON: Department of Geography, University of Waterloo.

Bruce J, I Burton, H Martin, B Mills, and L Mortsch. 2000. Water Sector: Vulnerability and Adaptation to Climate Change. Climate Change Impacts and Adaptation Program. Final Report submitted to Natural Resources Canada Ottawa, ON: Natural Resources Canada. 144 p.

Bruce J, W Dickinson, and D Lean. 2006. Planning for Extremes: Adapting to Impacts on Soil and Water from Higher Intensity Rains with Climate Change in the Great Lakes Basin, in Planning for Extremes Workshop. pp. 69. Milwaukee, Wisconsin: Ontario Chapter of the Soil and Water Conservation Society. [online] Available from: http://www.swcs.org/documents/filelibrary/PFE_Canada.pdf. (Accessed 15 October 2009).

Burnside & Associates Limited. 1999. County of Oxford Springford Community Water System, Water Level Monitoring at Springford Well No. 2, BE File: H-1662. Available from Oxford County Public Works Department, Report#: SPD-1.

Burnside & Associates Limited. 2015. Threats Assessment, Village of Richmond. Prepared for the Grand River Conservation Authority. 144p.

CH2MHILL. 2010. Updated Surface Water Vulnerability Assessments and Initial Threats Inventory for the Port Dover and Port Rowan Water Treatment Plants, May 2010. Prepared for the Corporation of Norfolk County.

Chapman, LJ. and Putnam, DF. 1984. The Physiography of Southern Ontario. 3rd ed, (Ontario Geological Survey. Special volume 2). Toronto: Ontario Ministry of Natural Resources. 270 p. Accompanied by Map P.2715 (coloured), scale 1:600 000.

Chiotti Q and B Lavender. 2008. Ontario, in From Impacts to Adaptation: Canada in a Changing Climate 2007. ed. by D.S. Lemmen, F.J. Warren, J. Lacroix and E. Bush. pp. 227-274. Ottawa, ON: Government of Canada.

Council of Great Lakes Governors. 1985a. The Great Lakes Charter-Principles for the Management of Great Lakes Water Resources, February 11, 1985. Council of Great Lakes Governors.

Council of Great Lakes Governors. 1985b. The Great Lakes Charter-Principles for the Management of Great Lakes Water Resources, February 11, 1985. Annex 2001. Council of Great Lakes Governors.

Council of Great Lakes Governors. 2005. Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement and Compact, December 13, 2005. Council of Great Lakes Governors.

County of Oxford. [Online]. Land Related Information System. Woodstock, ON: County of Oxford. Available from: http://www.county.oxford.on.ca/site/688/default.aspx

County of Oxford, 1995. County of Oxford Official Plan, December 13, 1995.

County of Oxford, 2004. County of Oxford Groundwater Protection Pilot Project, Land Use and Chemical Occurrence (LUCO) Inventory, July 2004. Woodstock, ON: Oxford County.

County of Oxford. 2007. County of Oxford On-line Directory (COOLOxford)-2002. Woodstock, ON: Oxford County. Available from: www.cooloxford.ca

County of Oxford. 2009a. Report on the Groundwater Vulnerability Assessment for the Wellhead Protection Areas, Draft of October 20, 2009. Source Protection Technical Studies Program. Woodstock, ON: County of Oxford. 24 p.

County of Oxford, 2009b. Source Water Protection Drinking Water Systems Issues Evaluation, October 2009. Woodstock, ON: Oxford County Public Works Department. 26 p.

County of Oxford, 2010. LPRSPA: Dereham Centre, Norwich, Otterville, Springford and Tillsonburg Well Systems Threats Assessment, July 2010. Woodstock, ON: County of Oxford Community and Strategic Planning Office.

County of Oxford Public Works Department. 2009. Oxford County Water System Reports, 2009. [Accessed July 7, 2010]. Available from: http://www.oxfordcounty.ca/site/2683/default.aspx.

Cridland, W. 1997. Shoreline Water Quality Study Port Burwell to Long Point, Lake Erie. Long Point Conservation Authority, Environment Canada Great Lakes 2000 Clean Fund. Simcoe, ON: Long Point Region Conservation Authority. 18pgs.

Cunderlik JM, and SP Simonovic. 2004. Inverse Modeling of Water Resources Risk and Vulnerability to Changing Climatic Conditions, in 57th Canadian Water Resources Association Annual Congress. Montreal, QC., June 16-18, 2004. pp. 1-6. Montreal, QC: Canadian Water Resources Association.

Davidson, RGD, 1988. Temporal and spatial controls on beach/dune interaction, Long Point, Lake Erie. Journal of Coastal Research. Special Issue No. 3: 131-136.

Davidson, RGD and Van Heyningen, AG. 2003. Migration and sedimentology of longshore sandwaves, Long Point, Lake Erie, Canada. Sedimentology 50: 1123-1137..

de Loë R and R Kreutzwiser. 2000. Climate variability, climate change and water resource management in the Great Lakes. Climatic Change, 45(1): 163-179.

de Loë RC, RD Kreutzwiser and L Moraru. 2001. Adaptation options for the near term: climate change and the Canadian water sector. Global Environmental Change. 11(3): 231-245.

de Loë R, and A Berg. 2006. Mainstreaming Climate Change in drinking water source protection in Ontario. Ottawa, ON: Pollution Probe and the Canadian Water Resources Association (Ontario Branch). 51 p.

DeVries H, and Dreimanis A. 1960. Finite Radiocarbon Dates of the Port Talbot *Interstadial Deposits in Southern Ontario*: Science 131 (3415): 1738-1739.

DHI Water & Environment (DHI). 2012a. FEFLOW. Version 6.1. DHI-WASY Software. Accessed in December 2013.

DHI Water & Environment (DHI). 2012b. MIKE SHE. DHI Software. Accessed in December 2013.

Dillon Consulting. 2011. WHPA-E Delineation and Vulnerability Assessment Thamesford, Woodstock and Tillsonburg Municipal Water Supply Systems. London ON. Dillon Consulting Inc.

Dolan DM and McGunagle KP. 2005. Lake Erie Total Phosphorus Loading Analysis and Update: 1996-2002. J. Great Lakes Res. 31(Suppl. 2):11–22.

Dove A, Painter S, and Kraft J. 2002. Sediment Quality in Canadian Lake Erie Tributaries: A Screening Level Survey. Ecosystem Health Division, Ontario Region, Environmental Conservation Branch, Environment Canada. Report No. ECB/EHD-OR/02-05/I.

Dreimanis, A. and RP Goldthwait, 1973. *Wisconsin Glaciation in the Huron, Erie and Ontario Lobes. The Wisconsonian Stage.* Geological Society of America, Memoir 136: 71-106.

Dreimanis, A. 1982. *Two origins of the stratified Catfish Creek Till at Plum Point, Ontario, Canada.* Boreas 11 (2): 173-180.

Earthfx Inc. 2008. Aquifer Vulnerability Mapping for Norfolk County, County of Brant, Catfish Creek and Kettle Creek Watersheds. Toronto, ON: Earthfx Inc.

EcoLogERIS, 2014. EcoLog ERIS Report: Richmond WHPA, Hwy #38 / Heritage Lane, Richmond, ON, EcoLog Environmental Risk Information Services Ltd, November 12, 2014.

Edmonds, B. et al. 1976. The Young Creek Watershed Study. Report submitted by The Junior Conservationist Award Program to the OMNR. Ontario Ministry of Natural Resources. 66 p.

Environment Canada, 2004a. Threats to Water Availability in Canada. NWRI Scientific Assessment Report Series No. 3. Burlington: National Water Research Institute. 128 p. [online] Available from: http://www.ec.gc.ca/inre-nwri/default.asp?lang=En&n=0CD66675-1.

Environment Canada, 2004b. Canada-Ontario Agreement (COA) Respecting the Great Lakes Basin Ecosystem, 2007. Retrieved October 19, 2009 from: http://www.on.ec.gc.ca/greatlakes/default.asp?lang=En&n=D11109CB-1

Environment Canada, 2005. Lakewide Management Plans. Retrieved October 19, 2009 from: http://www.on.ec.gc.ca/greatlakes/default.asp?lang=En&n=324C092F-1

Environment Canada. [Internet]. National Climate Data and Information Archive. Ottawa, ON: Environment Canada. Available from: http://climate.weather.gc.ca/historical_data/search_historic_data_e.html

Etienne, J. 2009. Kettle Creek/Catfish Creek/Long Point Region Water Budget and Water Quantity Stress Assessment Peer Review Summary Report-August 2009. Cambridgt, ON: Grand River Conservation Authority.

Evans, S. 2007. Water Quality in the Long Point Region: A Summary of the 2002-2005 Conditions and Trends. Grand River Conservation Authority.

Farm Issues Virtual Tour. 2009. [Internet]. Ontario: Ontario Farm Animal Council. Available from: http://www.farmissues.com/virtualTour/

Fausto, J.A. and S.D. Finucan. 1992. Clean Up Rural Beaches: CURB Plan for Hay, Dedrich and Big Otter Creek Watersheds. Simcoe, ON: Long Point Conservation Authority. 84p.

Fields, Bob, Corporation of Norfolk County. (personal communication).

FIRSTBASESOLUTIONS. 2006. South Western Ontario Orthophotography Project (SWOOP): Orthoimagery 2006. (computer file). Ontario.

Francis D and H Hengeveld. 1998. Extreme Weather and Climate Change. Minister of Supply and Services Canada, Ottawa.

Freeze, R.A and J.A. Cherry. 1979. Groundwater. Upper Saddle River, New Jersey: Prentice-Hall Inc. 604 p.

G. Douglas Vallee Ltd. 2004. Environmental Impact Study Waterford Water Pollution Control Plant. Simcoe, ON: G.D.Vallee Ltd. 20p.

Gagnon, P. 1995. Fisheries Management Report, 1994 Reservoir Monitoring Program for Long Point Region Conservation Authority Reservoirs. Simcoe, ON: LPRCA. 49 p.

Gagnon, P and Giles E. 2004. Lynn River State of the Watershed Project: Final Report. Long Point Region Conservation Authority. Simcoe, Ontario: LPRCA. 232 p.

Genivar Ontario Ltd. 2009. Nanticoke Grand Valley Area Water Supply Feasibility Study. Markham, ON: Genivar Ontario Ltd.

Gagnon P, Long Point Region Conservation Authority. (personal communication).

Golder Associates. 2001. Groundwater Protection Study, Phase II, County of Oxford. London, ON. 189 p.

Golder Associates, 2005. Vulnerability (SWAT) Pilot Study (2005). London, ON.

Government of Canada, 2007. Industry Canada. Date Modified: October 19, 2009. Available from: http://www.ic.gc.ca/ic_wp-pa.htm

Government of Ontario, 2002a. Safe Drinking Water Act, Ontario Regulation 170/03-Drinking Water Systems. Ontario: Queen's Printer for Ontario.

Government of Ontario, 2002b. Safe Drinking Water Act, Ontario Regulation 169/03-Ontario Drinking Water Quality Standards. Ontario: Queen's Printer for Ontario.

Government of Ontario, 2006a. Clean Water Act, 2006, S.O. 2006, Chapter 22. Ontario: Queen's Printer for Ontario

Government of Ontario, 2006b. Clean Water Act, 2006, Ontario Regulation 287/07-General. Ontario: Queen's Printer for Ontario.

Government of Ontario, 2006c. Clean Water Act, Ontario Regulation 284/07-Source Protection Areas and Regions. Ontario: Queen's Printer for Ontario.

Grand River Conservation Authority, 2009. Preliminary Technical Memo issued by GRCA for Lake Erie Region Technical studies: Managed Lands and Livestock Density-September 23, 2009. Cambridge, ON: Grand River Conservation Authority. 10 p.

Grand River Conservation Authority, 2014. Addendum: Long Point Region Water Quantity Stress Assessment Otter Creek at Tillsonburg Subwatershed – Groundwater. Cambridge, ON: Grand River Conservation Authority.

GSP Group Inc., 2010. Grand River, Long Point Region, Catfish Creek and Kettle Creek Watershed Areas: Population Forecasts. Kitchener, ON. 60 p.

Heilman PE. 1990. Forest management challenged in the Pacific Northwest. Journal of Forestry. 88 (11):16-23.

Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water (3rd ed.). U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Henson BL, Brodribb KE, and Riley JL. 2005. Great Lake Conservation Blueprint Project for Terrestrial Biodiversity. Produced by the Nature Conservancy of Canada for the Ontario Ministry of Natural Resources. Ontario: Queen's Printer for Ontario.

Hewitt DF. 1972. Paleozoic Geology of Southern Ontario. Ontario Division of Mines, Geological Report 105. 18p.

Hunter P. 2003. Climate change and waterborne and vector-borne disease. Journal of Applied Microbiology, 94: 37-46.

Hydromantis Inc., Minnow Environmental Inc., University of Waterloo Dept. of Civil Engineering. 2005. Review of the State of Knowledge of Municipal Effluent Science and Research: Review of Effluent Substances. Report Number PN 1356. Canadian Council of Ministers of the Environment, Ottawa, ON. 93p.

International Joint Commission United States and Canada. 1978. Great Lakes Water Quality Agreement of 1978, Amended 1987. Ottawa, ON: International Joint Commission United States and Canada.

IPCC-TGICA. 2007. General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment, in Version 2. Prepared by T.R. Carter. pp. 66. Helsinki, Finland: Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Assessment.

Isidoro D, Quílez D, and R Aragüés, 2003. Water Balance and Irrigation Performance Analysis: La Violada Irrigation District (Spain) As a Case Study. Agricultural Water Management 64(2): 123-142.

IWS. 1989. Norwich PUC Report, Construction and Testing Well No. 3, Otterville, ON. Barrie, ON. Available from Oxford County Public Works Department, Report#: OVL-5.

IWS. 1993. Tillsonburg PUC, Groundwater Resource Study. Barrie, ON. Available from Oxford County Public Works Department, Report#: TSG-20.

Johnson, M.D., Armstrong, D.K., Sanford, B.V., Telford, P.G., and Rutka, M.A., 1992. *Paleozoic and Mesozoic Geology of Ontario*: in Geology of Ontario, OGS Special Vol. 4, Pt. 2, Chapter 20, p. 907- 1010.

Jones ML, Y Zhao, JD Stockwell, and BJ Shuter. 2006. Forecasting effects of climate change on Great Lakes fisheries: Models that link habitat supply to population dynamics can help. Canadian Journal of Fisheries and Aquatic Sciences, 63(2): 457-468.

Jyrkama MI and JF Sykes. 2007. The impact of climate change on spatially varying groundwater recharge in the Grand River watershed (Ontario). Journal of Hydrology, 338(3): 237-250.

Kimmins JP. 1992. Balancing Act: Environmental Issues in Forestry. Vancouver: UBC Press. 244p.

Kling G et al. 2003. Confronting Climate Change in the Great Lakes Region: Impacts on Our Communities and Ecosystems. Washington, D.C.: Cambridge, Massachusetts: Union of Concerned Scientists.

Kreutzwiser, RD and de Loë, RC. 1999. Agricultural and Rural Water Use in Ontario. Revised. A Report to the National Soil and Water Conservation Program, August 31, 999. Guelph, ON: Rural Water Management Group, Department of Geography, University of Guelph. 43 pp.

Kunkel KE, NE Westcott, and DAR Kristovich. 2002. Assessment of potential effects of climate change on heavy lake-effect snowstorms near Lake Erie. Journal of Great Lakes Research, 28(4): 521-536.

Kunkel KE, L Ensor, M Palecki, D Easterling, D Robinson, KG Hubbard, and K Redmond. 2009. A new look at lake-effect snowfall trends in the Laurentian Great Lakes using a temporally homogeneous data set. Journal of Great Lakes Research, 35(1): 23-29.

Lake Erie Region Source Protection Committee. 2009. Long Point Region Source Protection Area-Work Plan for Development of the Assessment Report and Source Protection Plan. Version 1.1 Cambridge, ON: Lake Erie Source Protection Region. 56 p.

Lake Erie Source Protection Region (LESPR). 2006. Terms of Reference-Peer Review Process for the Long Point Region, Catfish Creek and Kettle Creek Tier 2 Water Budget & Water Quantity Stress Assessment. Cambridge, ON: Grand River Conservation Authority.

Lake Erie Source Protection Region (LESPR). 2010. Long Point Region Tier Three Local Area Water Budget and Risk Assessment: Terms of Reference, June 2010. Cambridge, ON: Grand River Conservation Authority. 56 p.

Lake Erie Source Protection Region Technical Team (Lake Erie SPRTT). 2008. Long Point Region Watershed Characterization Report. Draft. January 2008.

Lenters JD. 2001. Long-term trends in the seasonal cycle of Great Lakes water levels. Journal of Great Lakes Research, 27(3): 342-353.

Lofgren B. 2006. Land surface roughness effects on lake effect precipitation. Journal of Great Lakes Research, 32(4): 839-851.

Lofgren BM, FH Quinn, AH Clites, RA Assel, AJ Eberhardt, and CL Luukkonen. 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs. Journal of Great Lakes Research, 28(4): 537-554.

Lotowater Ltd. 2000a. Technical Memorandum (Dec. 7, 2000)-Norwich Well#2 Pumping Test. Prepared by Lotowater Ltd. for Golder Associates as part of Oxford County Phase II Groundwater Protection Study.

Lotowater Ltd. 2000b. Technical Memorandum (Dec. 11, 2000)-Springford Test Well and Pumping Test. Prepared by Lotowater Ltd. for Golder Associates as part of Oxford County Phase II Groundwater Protection Study.

Lotowater Ltd. 2002. Norfolk County Municipal Well System – Hydrogeologic Study (GUDI). Prepared for G. Douglas Vallee. May 15, 2002.

Long Point Region Conservation Authority (LPRCA). 1979a. Background Study: Nanticoke Creek Watershed. Simcoe, ON: Long Point Region Conservation Authority. 97 p.

Long Point Region Conservation Authority (LPRCA). 1979b. Background Study: Sandusk-Stoney Creek Watershed. Simcoe, ON: Long Point Region Conservation Authority. 81 p.

Long Point Region Conservation Authority (LPRCA). 1979c. Background Study: Dedrick–Young Creek Watershed. Simcoe, ON: Long Point Region Conservation Authority. 115 p.

Long Point Region Conservation Authority (LPRCA). 2008. Long Point Region Watershed Characterization Report. Draft. Cambridge, ON: Grand River Conservation Authority.

MacViro. 2002a. GUDI Hydrogeological Study for Delhi Municipal Water Supply System. Prepared for the Corporation of Norfolk County. April 2002.

MacViro. 2002b. GUDI Hydrogeological Study for Simcoe Municipal Water Supply System. Prepared for the Corporation of Norfolk County. June 2002.

Matrix Solutions Inc. 2013. Tier Three Water Budget and Local Area Risk Assessment, Long Point Region, Model Development and Calibration Report. Report Prepared for Lake Erie Source Protection Region. Waterloo, Ontario. 212 p.

Matrix Solutions Inc. (Matrix). 2013. Tier Three Water Budget and Local Area Risk Assessment, Long Point Region, Physical Characterization Report – REVISED 2. Report prepared for Lake Erie Source Protection Region. Waterloo, Ontario. July 2013.

Matrix Solutions Inc. 2013b. Technical Memorandum: Final Tabor 2/4 and Tillsonburg 4/5 Municipal Well Nitrate Contributing Areas, December 20, 2013. Waterloo, Ontario.

Matrix Solutions Inc. 2014. Wellhead Protection Area Delineation and Vulnerability Assessment Report: Town of Tillsonburg North Wells. Waterloo, Ontario. 34p.

Matrix Solutions Inc. (Matrix). 2015. Tier Three Water Budget and Local Area Risk Assessment, Long Point Region, Risk Assessment Report. Report prepared for Lake Erie Source Protection Region. Waterloo, Ontario. April 2015.

Matrix Solutions Inc. 2019. Wellhead Protection Area Delineation, Issue Contributing Area Delineation, and Threats Assessment for the Otterville Well Field. Report prepared for County of Oxford. Guelph, Ontario. March 2019.

McBean E and H Motiee. 2008. Assessment of impact of climate change on water resources: A long term analysis of the Great Lakes of North America. Hydrology and Earth System Sciences, 12(1): 239-255.

McCarron J & McCoy K. 1992. Silver Creek Water Quality Inventory. CCCA publication. 37 p.

McLaren R and E Sudicky. 1993. The Impact of Climate Change on Groundwater, in The Impact of Climate Change on Water in the Grand River Basin, Ontario. ed. by M. Sanderson. pp. 53-67. Publication Series No. 40 Waterloo, ON: Department of Geography, University of Waterloo.

Millerd F. 2006. Possible locations for adaptation to climate change by Canadian commercial navigation on the great lakes. 2006 IEEE EIC Climate Change Technology Conference.

Morse, A, B Janssen and T VanOostrom. 1982. Young Creek/Sandusk Creek Watershed Study. Simcoe, ON: Long Point Region Conservation Authority. 96 p.

Mortsch L, H Hengeveld, M Lister, B Lofgren, F Quinn, M Slivitzky, and . Wenger. 2000. Climate Change Impacts on the Hydrology of the Great Lakes-St. Lawrence System. Canadian Water Resources Journal, 25(2): 153-180.

Mortsch L. 2006. Great Lakes coastal wetland communities: vulnerabilities to climate change and response to adaptation strategies. Ottawa, ON: Environment Canada.

NAICS Association. 2007. NAICS Association. 1998-2009. Available from: www.naics.com

Norfolk County, 2017. Norfolk County's Quality Management System Operational Plans. Available from: http://www.norfolkcounty.ca/download/living/Operational-Plan-2017.pdf

Novakovic B. 1978. Memo Re: Proposed Protection Zone Around Police Village of Otterville, Water Supply Well No. 2, Norwich Township, Oxford County. Available from Oxford County Public Works Department, Report#: OVL-2

Ontario Geological Survey. 2003. Surficial Geology of Southern Ontario 1:50,000. Ontario Geological Survey, Miscellaneous Data Release 128.

Ontario Geological Survey. 2007. Long Point Region Groundwater Resources Study. Ontario Geological Survey, Groundwater Resources Study 4.

Ontario Ministry of the Environment. 2001. Groundwater Studies 2001/2002 Technical Terms of Reference. Ontario: Queen's Printer for Ontario. 46 p.

Ontario Ministry of the Environment. 2005. Peer Review Water Budget Interim Direction, Version 2.0 (DRAFT) (dated August 9, 2005). Ontario: Queen's Printer for Ontario.

Ontario Ministry of the Environment (MOE). 2006a. Technical Support Document for Ontario Drinking Water; Standards, Objectives and Guidelines. 2006 Revision. Ontario: Queen's Printer for Ontario. 40 p.

Ontario Ministry of the Environment (MOE). 2006b. Assessment Report: Draft Guidance Module 3-Groundwater Vulnerability Analysis (October 2006). Ontario: Queen's Printer for Ontario. 95 p.

Ontario Ministry of the Environment (MOE), 2006c. Assessment Report: Draft Guidance Module 5-Issues Evaluation and Threats Inventory (October 2006). Ontario: Queen's Printer for Ontario. 59 p.

Ontario Ministry of the Environment (MOE). 2008a. Technical Rules: Assessment Report, Clean Water Act 2006. Ontario: Queen's Printer for Ontario. 58 p.

Ontario Ministry of the Environment (MOE). 2008b. Clean Water Act, 2006, Tables of Drinking Water Threats. Ontario: Queen's Printer for Ontario. 490 p.

Ontario Ministry of the Environment (MOE). 2009a. Technical Rules: Assessment Report, Clean Water Act 2006, Amended November 2009. Ontario: Queen's Printer for Ontario. 65 p.

Ontario Ministry of Environment (MOE), 2009b. Technical Bulletin: Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers. Ontario: Queen's Printer for Ontario. 21 p.

Ontario Ministry of Environment (MOE), 2009c. Technical Bulletin: Assessment and Issues Evaluation, February 2010. Ontario: Queen's Printer for Ontario. 23 p.

Ontario Ministry of the Environment (MOE). 2009d. Clean Water Act, 2006, Tables of Drinking Water Threats, Amended November 16, 2009. Ontario: Queen's Printer for Ontario. 438 p.

Ontario Ministry of the Environment (MOE), 2010. Technical Bulletin: Groundwater Vulnerability, June 2010. Ontario: Queen's Printer for Ontario. 6 p.

Ontario Ministry of the Environment and Climate Change (MOECC), 2015. Well Record dataset(s) [Canada] [administrative records]. Toronto, Ontario: Ministry of the Environment, Government of Ontario [producer and distributor].

Ontario Ministry of the Environment and Climate Change. (MOECC), 2016. Technical Rules: Assessment Report, Clean Water Act, 2006. November 20, 2008. Amended on December 12, 2008 (administrative amendments), November 16, 2009 (EBR Posting Number EBRO10-7573), and December 2, 2013 (Technical Bulletin). Updated on May 19, 2016. Available from: https://www.ontario.ca/page/technical-rules-assessment-report Ontario Ministry of Natural Resources (MNR), 1990a. Aylmer District Fisheries Management Plan 1987-2000. Ontario Ministry of Natural Resources.

Ontario Ministry of Natural Resources (MNR), 1990b. Simcoe District Fisheries Management Plan 1987-2000. Ontario Ministry of Natural Resources.

Ontario Ministry of Natural Resources, 2005a. Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement, 2005 Supporting Documents. Retrieved October 19, 2009 from: http://www.mnr.gov.on.ca/200040.pdf

Ontario Ministry of Natural Resources. 2005b. Digital Elevation Model-Version 2.0- Provincial Tiled Dataset (DEM). Ontario: Queen's Printer for Ontario.

Rungis G, Grand River Conservation Authority. (personal communication). 2009.

Schlumberger Water Services (SWS) Inc. 2009. Norfolk County Source Water Protection Team, Vulnerability Assessment, November 2009. Prepared for the Corporation of Norfolk County.

Schlumberger Water Services (SWS) Inc. 2010. Delhi, Simcoe and Waterford Source Protection Study Preliminary Threats Assessment and Issues Identification Report #2, May 2010. Prepared for Grand River Conservation Authority.

Schlumberger Water Services (SWS) Inc. 2011. Update of Simcoe well fields model with current pump rate data, January 2011. Prepared for Grand River Conservation Authority.

Schroeter and Associates. 1996. Guelph All-Weather Sequential-Events Runoff Model (GAWSER) Version 6.5, Training Guide and Reference Manual. Submitted to the Grand River Conservation Authority and the Ontario Ministry of Natural Resources.

Schroeter & Associates, 2006a, Catfish Creek Watershed Hydrology Model for Catfish Creek Conservation Authority, Ref. 05-12. Prepared for Catfish Creek Conservation Authority.

Schroeter & Associates, 2006b, Kettle Creek Watershed Hydrology Model for Kettle Creek Conservation Authority, Ref 05-13. Prepared for Kettle Creek Conservation Authority.

Schroeter & Associates, 2006c, Long Point Region Watershed Hydrologic Model for Long Point Region Conservation Authority, Ref. 02-05. Prepared for Long Point Region Conservation Authority.

Sharif M, and DH Burn. 2006. Simulating climate change scenarios using an improved K-nearest neighbor model. Journal of Hydrology, 325(1-4): 179-196.

Shifflett SJ. 2007. Status Report on Municipal Long Term Water Supply Strategies: Part 1-Future Demand Estimations and Current Capacity Evaluations. Prepared for the Lake Erie Source Water Protection Region. Cambridge, ON: Grand River Conservation Authority.

Singer SN, Cheng CK, and MG Scafe. 2003. Hydrogeology of Southern Ontario, Second Edition. Ministry of the Environment. Hydrogeology of Ontario Series, Report 1. Ontario: Queen's Printer for Ontario. 200 p.

Species at Risk in Ontario (SARO) List. 2009. [Internet]. Ontario Ministry of Nautural Resources. Ontario: Queen's Printer for Ontario; [cited Sept. 10, 2009]. Available from: http://www.mnr.gov.on.ca/en/Business/Species/2ColumnSubPage/276722.html

Stantec, 2010a. Wellhead Protection Area “E” Delineation and Vulnerability Scoring for GUDI Wells in Norfolk County. March 2010. Prepared for the Grand River Conservation Authority. Kitchener, ON: Stantec Consulting Ltd.

Stantec, 2010b. Phase I Update Report: Surface Water Vulnerability Assessment Study Update for the Dunnville and Nanticoke Water Treatment Plants. Prepared for Haldimand County. Kitchener, ON: Stantec Consulting Ltd.

Stantec, 2010c. Phase II Update. Issues Evaluation, Threats Inventory and Threat Level Assessment for the Nanticoke Water Treatment Plant. Prepared for Haldimand County. Kitchener, ON: Stantec Consulting Ltd.

Stantec. 2011. Surface Water Vulnerability Assessment for the Nanticoke Water Treatment Plant – Industrial Pump Station Intake.

Stantec. 2011 Revision to Delineation and Vulnerability Scoring of the East and West Intake for the Nanticoke WTP

Stantec. 2013. Richmond Well Construction and Effective Filtration Assessment, Village of Richmond Water Supply System.

Stantec Consulting Ltd (Stantec), Groundwater Science, and Blackport and Associates. 2015. Field Program Summary, Tier Three Local Area Water Budget and Risk Assessment, Long Point Region.

Staple T. 1993. Climate Change and Long Point Bay: A Preliminary Analysis with Some Implications. ed. by J. Gordon Nelson and Patrick L. Lawrence. Long Point Environmental Folio Publication Series, Working Paper 2. Waterloo, ON: Heritage Resource Centre, University of Waterloo. 20 p.

Statistics Canada. 2001. [Internet]. *2001 Census of Agriculture.* Ottawa, ON: Statistics Canada. Available from: http://www.statcan.gc.ca/ca-ra2001/index-eng.htm

Statistics Canada. 2006. [Internet]. *2006 Census, Community Profiles*. Ottawa, ON: Statistics Canada. Available from: http://www12.statcan.ca/census-recensement/2006/dp-pd/prof/92-591/index.cfm?Lang=E

Statistics Canada. 2006. [Internet]. *2016 Census, Community Profiles*. Ottawa, ON: Statistics Canada. Available from: http://www12.statcan.gc.ca/census-recensement/index-eng.cfm

Stenson, R. 1993. *The Long Point Area: An Abiotic Perspective Long Point*. Environment Folio Publication Series (Nelson,J.G. and Lawrence, P.L., eds). Heritage Resources Centre, University of Waterloo: Waterloo, Ontario. 41 p.

Stone, F.A. 1993. Sediment and Nutrient Transport Dynamics in Two Lake Erie Tributaries: Implications for External Phosphorus Loading Estimates. PhD Thesis. University of Waterloo, Department of Geography. Waterloo, Ontario. 156p.

Telford, P.G. and Tarrant, G.A., 1975. Paleozoic Geology of the Dunnville Area, Southern Ontario; Ontario Division of Mines, Preliminary Map P.988. Geol. Serv., scale 1:50,000. Geology 1974.

Terraqua Investigations Ltd. 1987. Potential Well Interference Study, Gehring Fish Farm, Otterville, Ontario. Available from Oxford County Public Works Department, Report#: OVL-1.

Thames-Sydenham Source Protection Region. 2009. Issues Evaluation Methodology, Version 2.0 (May 14, 2009). London, ON: Thames-Sydenham and Region Source Protection Region.

Todd DK. 1980. Groundwater Hydrology, 2nd Edition. 535p. New York: John Wiley and Sons. 552 p.

United States Environmental Protection Agency, 2006. Lake Erie Lakewide Management Plan (LaMP) 2000. Retrieved March 18, 2010 from http://www.epa.gov/glnpo/lakeerie/lamp2000/index.html.

United States Environmental Protection Agency, 2010. Lake Erie Lakewide Management Plan Draft Annual Report 2010.

Van De Lande, R. 1987. Water Quality Report. Simcoe, ON: Long Point Region Conservation Authority. 34 p.

Vallee Consulting Engineers, Architects and Planners (Vallee). 2012. Schedule ‘B’ Class Environmental Assessment, Delhi Water System, Delhi, Norfolk County. March 2012.

Vandierendonck M, and B Mitchell. 1997. Water Use Information for Sustainable Water Management: Building Blocks and the Ontario Situation. Canadian Water Resources Journal, 22(4): 395-415.

Waterloo Hydrogeologic Inc. 2007. Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds. Report to the Grand River Conservation Authority.

Waterloo Hydrogeologic, Inc., Applegate Groundwater Consultants, Gamsby and Mannerow Ltd., K. Bruce MacDonald Consulting, MacViro Consultants Inc. and Tunnock Consulting Ltd., 2003. *Norfolk Municipal Groundwater Study Final Report*. Prepared for: The Corporation of Norfolk County, Long Point Region Conservation Authority, and Haldimand-Norfolk Health Unit.

Yellow Pages. 2007. Yellow Pages. Date Modified: 2009. Available from: www.yellowpages.ca.

Zhang X, L Vincent, W Hogg, and A Niitsoo. 2000. Temperature and precipitation trends in Canada during the 20th century. Atmosphere Ocean, 38: 395-429.

.

15.0 MAP CITATIONS AND REFERENCES

These maps are for information purposes only and the Long Point Region Conservation Authority takes no responsibility for, nor guarantees, the accuracy of all the information contained within these maps.

The following references apply to all maps, unless otherwise noted:

Produced using information provided by the Ministry of Northern Development, Mines, Natural Resources and Forestry, Copyright © Queen's Printer, 2022.

Map #	Map Title	Reference
Map 2-3	Physiography of Long Point Watershed Area	Physiography of Southern 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 2-4	Hummocky Topography	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 2-7:	Bedrock Geology	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 2-8:	Quaternary (Surficial) Geology	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 2-9:	Overburden Thickness	Waterloo Hydrogeologic Inc. May 2003. Norfolk Municipal Groundwater Study.
Map 2-10:	Water Table Surface	Waterloo Hydrogeologic Inc. May 2003. Norfolk Municipal Groundwater Study.
Map 2-11:	Bedrock Potentiometric Surface	Waterloo Hydrogeologic Inc. May 2003. Norfolk Municipal Groundwater Study.
Map 2-20	Permits To Take Water	Mapping based partially on data contained within Permits to Take Water issued by the Ontario Ministry of the Environment.

Appendix A

Public Consultation Comments

Draft Updated Long Point Region Assessment Report
Summary of Public Comments and How Comments were Addressed

No comments were received during the September 23 to October 27, 2019 public consultation period for the draft Updated Long Point Region Assessment Report.

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

Appendix B

Requests for Approval of Alternative Approaches

Ministry of the Environment
Source Protection Programs Branch
8th Floor
2 St. Clair Ave. West
Toronto ON M4V 1L5

Ministère de l'Environnement
Direction des programmes de protection des sources
8e étage
2, avenue St. Clair Ouest
Toronto (Ontario) M4V 1L5

Ontario

Log: ENV1174IT-2010-191

August 9, 2010

Mr. Martin Keller.
Source Protection Program Manager
Grand River Conservation Authority
400 Clyde Road
Cambridge ON N1R 5W6

Dear Mr. Keller:

I am responding to your July 15, 2010 e-mail regarding your request to use alternate methods under Rule 15.1 of the Director's Technical Rules (Rules) for the completion of the assessment report under the *Clean Water Act* (CWA) for the Long Point Region source protection area.

Variation from Rule 38(1)(a) – Vulnerability Mapping

As set out in your correspondence, your proposal is to use an alternative method to complete vulnerability mapping in the Dereham Centre and Springford-Otterville Wellhead Protection Areas using the AVI method with score thresholds of <24, 24-80, and >80 to identify areas of high, medium and low vulnerability. Technical Rule 38(1)(a) requires that a threshold of <30 be used to identify areas of high vulnerability when using the AVI method.

As stated in your e-mail, the Wellhead Protection Areas were completed in advance of the CWA through the MOE-funded Municipal Groundwater Protection Studies.

We accept your opinion, subject to recalculation and review, that the different threshold will not change the vulnerability mapping within the WHPAs with an anticipated correction to the appropriate methodology threshold of 30. It is likely, however, that areas of high groundwater vulnerability across the region may be reduced marginally to medium vulnerability with the change from the threshold of 24 to 30. This affect must be accurately and correctly documented in both the current and updated Assessment Reports. We acknowledge that work is currently underway to update the vulnerability with the correct threshold and that this will be provided in an amended Assessment Report.

Variation from Rule 17 – Impervious Areas

As set out in your correspondence, your proposal is to use an alternative method to calculate the impervious surface area with respect to where road salt can be applied, using the area of IPZ-1 rather than a 1 km by 1 km grid, and then dividing the area of paved surfaces by the total area of IPZ-1.

We concur with your opinion that the use of this proposed alternative method will not impact the implementation of the Rule, as the area of IPZ-1 is less than 1 km^2. Given the small size of IPZ-1, this approach is considered equivalent to the method currently required by Rule 17.

Variation from Rules 47(5) and 65 – Setbacks

As set out in your correspondence, your proposal is to use an alternative method to determine the setback on land for the Waterford WHPA-E (delineated around a number of small surface water ponds), which would reduce the setback to 120 m or less to include only the areas that are considered to drain toward the ponds from the north, east and south sides.

We concur with your opinion that the complexity of the Regulation Limit, due to the relatively flat topography and the direction of drainage around the ponds, suggests that a setback of 120 m or less is more appropriate. As only land is hydraulically connected to the wellfield will be included this approach is considered equivalent to the method required by the Rules.

Variation from Rule 17 – Impervious Areas

As set out in your correspondence, your proposal is to use an alternative methodology to generate the grid to be used to estimate the Percentage of Impervious Surface Area, with a node of the grid centred on the centroid of the vulnerable area (WHPA/IPZ) instead of centring the node on the source protection area as required by Rule 17.

We concur with your opinion that the use of this proposed alternative grid centroid will not impact the implementation of the Rule, other than to centre the calculations on the areas of particular interest. Therefore, this approach is equivalent to the method currently required by Rule 17.

In accordance with my authority under Rule 15.1, I hereby provide Director's approval for the use of these alternate methods for the Long Point Region source protection area.

Your rationale for the use of the alternative methods and how they are being applied must be included in your assessment report.

We thank you for your efforts in completing the technical studies in support of the assessment report under the CWA. If you have any questions or require additional information, please contact our office.

Sincerely,

Ian Smith, Director
Source Protection Programs Branch
Ministry of the Environment

cc: Craig Ashbaugh, Chair, Source Protection Committee
Heather Malcolmson, Manager, Source Protection Planning
Keith Willson, Manager, Source Protection Approvals
Kate Turner, Liaison Officer, Source Protection Implementation
Melanie Ward, Source Protection Approvals

Ministry of
the Environment
Source Protection Programs
Branch
14th Floor
40 St. Clair Ave. West
Toronto ON M4V 1M2

Ministère de
l'Environnement
Direction des programmes de
protection des sources
14e étage
40, avenue St. Clair Ouest
Toronto (Ontario) M4V 1M2

Ontario

ENV1174IT-2011-26

April 1, 2011

Mr. Martin Keller
Source Protection Program Manager
Grand River Conservation Authority
400 Clyde Road, Cambridge, ON N1R 5W6

Dear Mr. Keller:

Thank you for your email request of March 9, 2011 to use an alternate method under sub-Rule 15(1) of the Director's Technical Rules (Rules) for the completion of assessment reports under the Clean Water Act (CWA) for specific drinking water systems in the Grand River Source Protection Area and the Long Point Region Source Protection Area.

As set out in your correspondence, your proposal is to use information on land cover classification from the Southern Ontario Land Resource Information System (SOLRIS) to calculate the percent impervious surfaces for specific drinking water systems in the two source protection area. The alternative method is as follows:

- Provided land use information, including road and highway transportation routes, as continuous 15x15 metre grid cells across the entire Source Protection Area.
- All the cells that represent highways and other impervious surfaces used for vehicular traffic were re-coded with a cell value of 1 and all other land cover classifications were given a value of 0, to identify impervious surface areas.
- For each 15x15 metre cell, the total number of neighbouring grid cells coded as impervious, within a 1x1 kilometre search area, was calculated.
- This total was then converted into the percentage of impervious surface by land area, using the area of each cell (225 sq. m) and the area of the moving window (1 sq. km).
- This provides a 1x1 kilometre moving window calculation of percent impervious surface, represented in 15x15 metre spatial increments.
- This dataset was calculated for the entire Source Protection Area, but was clipped to show those results only in the Wellhead Protection Areas and Intake Protection Zones.

- The analysis is a more representative analysis of road density and is equivalent or better than the requirements of the Technical Rules.

In our opinion the use of this alternative method complies with Rule 15.1 by providing a method that is "equivalent to or better than the approach or method prescribed in the rules". The method is a refinement of the scale used to identify impervious areas related to road salt applications within the WHPAs and IPZs, and we agree that it is more representative of the road density in *1x1 kilometre* grid for a specific location than the method described in the Technical Rules 16 (11) and 17.

In accordance with my authority under sub-Rule 15(1), I hereby provide Director's approval for the use of this alternate method for the following:

- Within the Grand River Source Protection Area: the IPZ-3s for all surface water systems except those in the Regional Municipality of Waterloo, the vulnerable areas for Brant County systems (Airport, Mount Pleasant, Paris, and St. George Well Supplies, and the Brantford (Holmedale) Water Treatment Plant), and the vulnerable areas for the Bright, Drumbo, Milverton, Dundalk, Elora, Fergus, and Arthur groundwater systems.
- Within the Long Point Region Source Protection Area: the: vulnerable areas associated with the Port Rowan, Port Dover, Delhi, and Nanticoke surface water systems.

Your rationale for the use of an alternative method, the methodology itself, and how it is being applied must be included in your assessment report.

I thank you for your efforts in completing the technical studies in support of the assessment report under the CWA. If you have any questions or require additional information, please contact our office.

We understand that work using this approach will be completed in time for the submission of an updated or amended assessment report.

Sincerely,

Ian Smith, Director
Source Protection Programs Branch
Ministry of the Environment

cc: Heather Malcolmson, Manager, Source Protection Planning
Keith Willson, Manager, Source Protection Approvals
Melanie Ward, Group Leader, Source Protection Approvals
Katie Fairman, Supervisor, Source Protection Implementation
Kate Turner, Liaison Officer, Lake Erie Source Protection Committee