4.0 Assessing Vulnerability of Drinking Water Sources........................ 4-1

4.1 Groundwater Vulnerability Analysis – Highly Vulnerable Aquifer (HVA) and Significant Groundwater Recharge Area (SGRA) 4-3

4.1.1 Groundwater Vulnerability Assessment 4-3

4.1.2 Significant Groundwater Recharge Areas Delineation.......... 4-8

4.1.3 Transport Pathways 4-14

4.1.4 Uncertainty Assessment 4-14

4.2 Groundwater Vulnerability - Wellhead Protection Areas (WHPAs)...........4-15

4.3 Surface Water Vulnerability Analysis - Intake Protection Zones (IPZs) 4-15

4.3.1 Intake Protection Zone Delineation................................4-16

4.3.2 Vulnerability Scoring for IPZs 4-22

4.3.3 Uncertainty Assessment 4-26

4.4 Summary 4-30

FIGURES

Figure 4.1: Aquifer Vulnerability Index (AVI) (Score 6, 4 and 2 of high, medium and low) 4-6

Figure 4.2: High Vulnerability Aquifers with Vulnerability Scoring (HVAs Score 6 of high) 4-7

Figure 4.3: Tier 3 Significant Groundwater Recharge Areas (SGRAs) 4-11

Figure 4.4: Combined Significant Groundwater Recharge Areas (SGRAs) 4-12

Figure 4.5: WHPA Q1/Q2 – York Tier 3 CLOSPA 4-13

Figure 4.6: Intake Protection Zones with Vulnerability Scoring (IPZs for the Ajax, Whitby, Oshawa, Bowmanville, and Newcastle WTPs (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*) 4-29

TABLES

Table 4.1: Translation of Groundwater Vulnerability to Vulnerability Score 4-4

Table 4.2: Summarizes the Extents of IPZ-2 as they pertain to each Intake involved in the Study (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*) 4-20

Table 4.3: Summarizes the Vulnerability Assessment for all the Intakes Involved in this Study (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011)* 4-25

Table 4.4: Uncertainty Assessments of Vulnerability Scores. Vulnerability scores below 6 are considered low. (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*) 4-27

4.0 Assessing Vulnerability of Drinking Water Sources

In the CLOSPA study area, 95% of the population receives drinking water from municipal plants that use Lake Ontario as a source. The rest of the population within the study area uses private wells (groundwater) as a source of drinking water.

Under the *Clean Water Act, 2006* (*CWA*), all sources of drinking water must be assessed for vulnerability. Surface water and groundwater that is used for drinking may be naturally vulnerable to depletion (a reduction in quantity), and/or contamination (a reduction in quality).

The *Technical Rules* require that the source protection committees (SPC) identify four types of vulnerable areas within each source protection area (SPA). These vulnerable areas include:

- Highly Vulnerable Aquifers (HVAs);
- Significant Groundwater Recharge Areas (SGRAs);
- Intake Protection Zones (IPZs); and
- Wellhead Protection Areas (WHPAs) - ***Not applicable to CLOSPA.***

Once vulnerable sources are identified, they are assessed and assigned a vulnerability score of high, medium, or low. The faster a contaminant can travel to a well or intake without being diluted or rendered less harmful, the more vulnerable the source water. The vulnerability scores are determined by factors such as:

- How deep/thick the aquifer is;
- What types of soil are present;
- How quickly water can travel through the ground (time of travel); and
- How fast a contaminant can travel to an intake given run-off patterns and surface water conditions.

Typically, shallow aquifers at or near the ground surface are considered vulnerable. Deeper aquifers, which are often the source of municipal drinking water supplies, tend to be less vulnerable. Under the *CWA*, vulnerability assessment of municipal wells, where they exist, entails more detailed well-specific analyses. Surface water intakes in rivers and small lakes are more vulnerable than those in the Great Lakes which are located further from shore and in deeper water.

Man-made transport pathways are also considered, such as pits, quarries, mines, road cuts, ditches, storm water, pipelines, sewers, and poorly constructed wells. These pathways can bypass the natural system, resulting in faster pathways to intakes. If any of these constructed pathways exist in a water source, the vulnerability score increases by one or two steps (i.e., from low to medium, from medium to high, or from low to high). The decision to increase the vulnerability score should be supported by data, and is subject to professional judgment.

An uncertainty assessment is also required as part of the analysis. This assessment shows whether information gaps exist, and identifies ways that the science behind the vulnerability assessment could be improved. Continuous improvement is expected in the areas with the greatest risk and/or uncertainty.

In SPAs, vulnerability scores are used to evaluate and determine risk in the next step, i.e., drinking water threats related to water quantity or/and quality would be rated significant, moderate, or low (see **Chapter 5**). In **Chapter 5**, the natural vulnerability of an area is considered along with specific contaminants to determine risk, as contaminant behaviour varies based on surrounding environmental factors. The threat score (risk) takes these factors into account.

Under the Source Water Protection initiative, the following groundwater-based source water protection areas must be delineated, where they exist, and scored for vulnerability (where appropriate) in terms of water quality:

- All areas within the jurisdiction that are naturally vulnerable to contamination (as opposed to supply depletion) are designated as HVAs;
- Areas with heightened importance to groundwater recharge are designated as SGRAs; and
- The specific capture zones for the municipal drinking water wells are designated WHPAs.

In the CLOSPA, areas of high and medium vulnerability generally correspond to shallow unconfined aquifers associated with:

- Surficial stratified sediments;
- Upper aquifer largely comprised of ice-contact drift, Oak Ridges Moraine/Mackinaw Interstadial equivalent; and
- Lower sediments (Thorncliffe, Sunnybrook, and Scarborough Formations).

The areas that are low vulnerability are:

- Upper Till (Halton Till); and
- Intermediate Till (Newmarket Till)

4.1 Groundwater Vulnerability Analysis – Highly Vulnerable Aquifer (HVA) and Significant Groundwater Recharge Area (SGRA)

4.1.1 Groundwater Vulnerability Assessment

Most groundwater vulnerability assessments focus on estimating how hydrologic features let water particles move down through the ground to an aquifer. There are several ways to estimate the flow attributes of hydrologic features. The groundwater vulnerability as delineated in accordance with *Technical Rules (37 or 38) (Part IV)* take into account the best available understanding of the natural geological layers in relation to delineated aquifers.

The following approaches are outlined in the *Technical Rules:*

- Aquifer Vulnerability Index (AVI)—This index value is based on mapping products (e.g., depth to aquifer, soil type and thickness, etc.). It measures the relative amount of protection provided by the type of materials above the aquifer.
- Intrinsic Susceptibility Index (ISI)—An index value is given to each well (e.g., MOECC Water Well Information System (WWIS)). This information is used to produce a vulnerability map. Unlike AVI, this method takes into account water table or water level information that is captured in the WWIS records.
- Surface to Aquifer Advection Time (SAAT)—This is the travel time from the ground surface to the top of aquifer or water table.
- Surface to Well Advection Time (SWAT)—This is the travel time from the ground surface to the well intake.

MOECC Water Well Information System (WWIS)—A database of geology, water levels, and pumping capacity from water wells installed across Ontario, maintained by the MECP.

The Province endorses all of the above approaches for assessing the vulnerability of water sources. Many factors determine the best approach to use, including data/model availability, level of understanding, and system complexity. These approaches are described in more detail in **Appendix E**.

The vulnerability of drinking water to water quantity depletion is assessed under the water budget component of this Assessment Report. The results of the AVI are used in the delineation and vulnerability scoring of HVAs.

The CLOSPA has selected an advanced AVI approach for HVAs and SGRAs. This approach uses the interpreted products of geological and numerical models (three dimensional geologic layers) produced for the study area, rather than the raw data available in the provincial *WWIS*. Estimates of vertical and horizontal flow directions and flux are also considered. This advanced AVI approach is approved by the Province. A more detailed description of the methodology used to delineate the HVAs is presented in **Appendix E**.

The AVI method produces a numerical index representing the relative vulnerability of an aquifer, based on the type and thickness of the soil above. The index quantifies the natural vulnerability of aquifers to sources of contamination at or near the surface, and through a translation process, categorizes groundwater vulnerability as high, medium, or low, as shown in **Table 4.1** and **Figure 4.1,** respectively**.** Within HVAs, the groundwater vulnerability is then converted (per *Technical Rules 82-85*) into vulnerability score, and this score provides the ultimate expression of the groundwater vulnerability. Each aquifer is scored separately (see **Table 4.1**). The vulnerability scores of deeper aquifers take into account the protection afforded by overlying materials (aquifers and aquitards).

Table 4.1: Translation of Groundwater Vulnerability to Vulnerability Score

Groundwater Vulnerability	Vulnerability Score
High	6
Medium	4
Low	2

This chapter considers factors affecting the vulnerability of a source protection area, as well as man-made transport pathways (where the data are available) using a consistent and systematic approach *Technical Rules (39-41) (Part IV)* provide an opportunity to consider situations where man-made or anthropogenic influences can increase the natural vulnerability by decreasing the time required for contaminants to move down to the water supply aquifer. The vulnerability score can be increased from medium to high, low to medium, or from low to high in accordance with the potential for artificial transport pathways to increase the observed vulnerability. Under the *Technical Rules*, vulnerability cannot be increased beyond high.

Highly Vulnerable Aquifer (HVA) and Vulnerability Scoring

This analysis assumes that the vulnerability of the aquifer increases as the relative amount of protection provided by the overlying geological materials decreases. The type and thickness of the overlying material is crucial to the scoring.

According to the AVI methodology and *Technical Rule (38) and (43),* an area with a vulnerability score of 6 has a ‘high' groundwater vulnerability and is, therefore, an HVA, as shown in **Table 4.1**. This analysis assumes that the vulnerability of the aquifer increases as the relative amount of protection provided by the overlying geological materials decreases. The type and thickness of the overlying material is crucial to the scoring. The vulnerability scores of deeper aquifers take into account the protection afforded by overlying materials (aquifers and aquitards). The details of the methodology are presented in **Appendix E**.

Figure 4.1 shows the groundwater vulnerability utilizing the AVI methodology and including the transport pathways assessment. The CLOSPA HVA map, **Figure 4.2,** shows the vulnerability of all aquifers (shallow and deep) that have a vulnerability score of 6 (high). These areas represent about 47% of the land area within the CLOSPA.

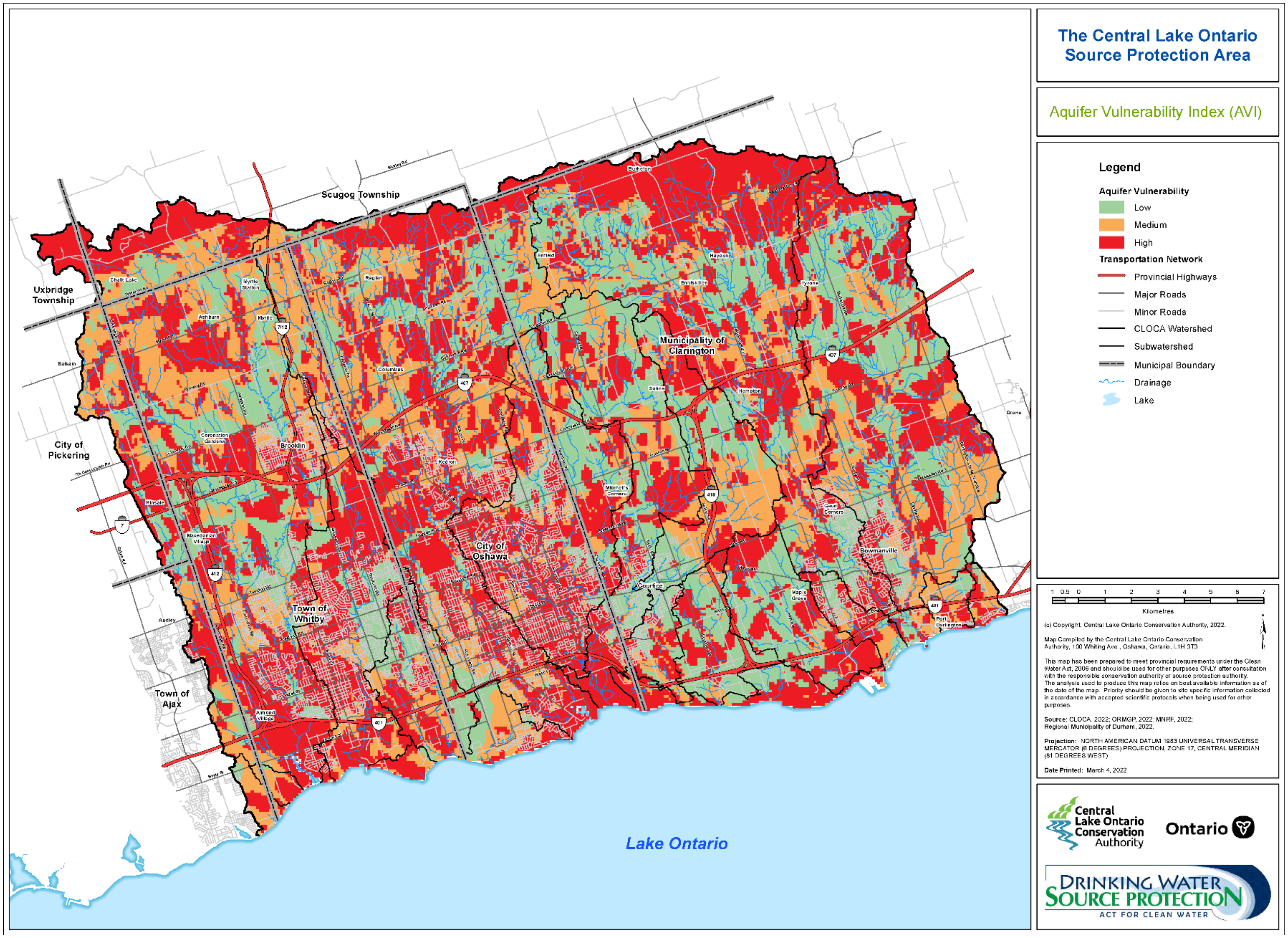

Figure 4.1: Aquifer Vulnerability Index (AVI) (Score 6, 4 and 2 of high, medium and low)

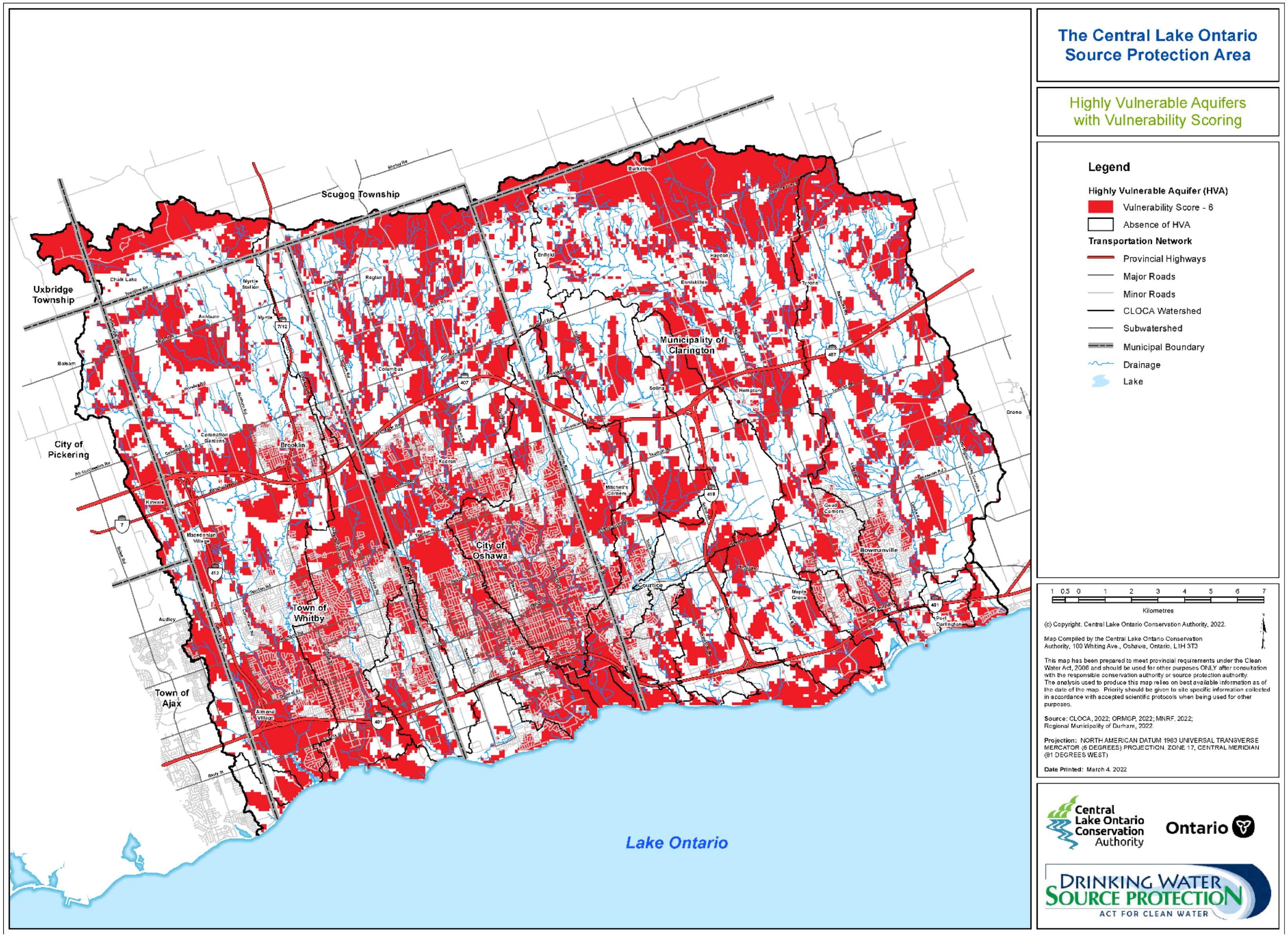

Figure 4.2: High Vulnerability Aquifers with Vulnerability Scoring (HVAs Score 6 of high)

4.1.2 Significant Groundwater Recharge Areas Delineation

The land area where the rain or snow seeps down into the ground and flows to an aquifer is called a recharge area. Recharge areas often have loose or permeable soil, such as sand or gravel, which allows the water to seep easily into the ground. Areas of bedrock without much covering soil, and where a lot of fractures or cracks exist, are also often recharge areas. Areas of hummocky topography also tend to have increased recharge rates. These areas are delineated using the recharge results from the water budget process described in **Chapter 3** of this Assessment Report. The areas with the highest volumes of groundwater recharge linked to drinking water systems, including private wells are SGRAs. The SGRAs must be delineated and protected under the *CWA.*

SGRAs are identified by measuring and comparing the volumes of water that infiltrate the ground across a watershed. In CLOSPA, SGRAs were located using the PRMS model (Precipitation-Runoff Modelling System, U.S. Geological Survey—see **Chapter 3: Water Budget and Stress Assessment** for more details). Results are based on the annual average recharge over a 25 x 25 m grid covering the study area.

There are two ways to identify SGRAs, as outlined in the *Technical Rule (44):*

- 44 (1) the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or
- 44 (2) the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evaporation for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

In CLOSPA, the approach outlined in *Rule 44(1)* was selected. This approach and the rationale for selection are described in more detail in **Appendix D**.

The three options were evaluated to derive the average annual recharge to calculate the SGRA threshold:

- Major watershed boundaries;
- Physiographic regions; and
- Jurisdictional average.

The jurisdictional average of 158 millimetres of recharge per year was chosen as most consistent with the technical factors that are most significant to a measure of recharge - surficial geology, stream temperature, and found water discharge attributes. The calculated SGRA threshold was therefore 182 millimetres per year. Reverse particle tracking from high discharge areas was also used to confirm the areas of significant recharge areas.

Alluvium: clay or silt or gravel carried by rushing streams and then deposited where the stream slows down.

More than 25% of the study area of CLOSPA is defined as SGRAs. These areas generally cover the surface geology classes associated with the Oak Ridges Moraine deposits, exposed Lower Sediment sands, and much of the Iroquois Beach deposits. Although recharge in the *alluvium* within the river valleys is important to sustain stream flow, these areas are considered areas of interflow, where infiltrating water discharges quickly to the stream. These river valleys are therefore not considered significant recharge areas. The Iroquois Beach deposits also delineated as SGRAs are relatively significant to drinking water systems in the watersheds that receive less recharge from the Oak Ridges Moraine and exposed Lower Sediment deposits. The Iroquois Beach deposits are, however, generally less significant than areas on the Oak Ridges Moraine because of the shallow water table and high evapotranspiration losses.

- The SGRAs within the CLOSPA area were checked with reverse particle track analyses from key features and areas of significant discharge (USGS MODPATH code). They were also confirmed by a review of aerial thermography data and brook trout occurrence, as described in **Chapter 3: Water Budget and Stress Assessment**.

Tier 3 Refinement

As discussed in **Chapter 3**, the York Region Tier 3 model produced different estimates of the various water budget parameters as compared to the Tier 1 and 2 models in York Region. As the Tier 3 area only extends into a very small portion of the CLOSPA, however, the jurisdictional average that was used to delineate SGRAs in the CLOSPA Tier 1 analysis was not changed or recalculated for the whole of CLOSPA. The Tier 3 recharge grid was used to re-delineate the SGRA in the area that the model covers CLOSPA using the Tier 1 jurisdictional average of 182mm. This use of a single value for all catchments is consistent with the methodology selected by CLOSPA for its Tier 1 study.

The SGRAs were revised for the Tier 3 area that covers the CLOSPA jurisdiction as follows:

- **Figure 4.3** shows the revised SGRAs in the Tier 3 area.
- **Figure 4.4** shows the revised SGRA in the Tier 3 area combined with the SGRAs for the rest of CLOCA. This map will represent the revised SGRA mapping for the full CLOCA jurisdiction.
- **Figure 4.5** shows the Tier 3 WHPA Q1/Q2 coverage in CLOSPA.

Clipping SGRAs

The jurisdictional identification of SGRAs was approved by the SPC. However, *Technical Rule (45)* requires that "an area shall NOT be delineated as a SGRA area unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system." This includes private systems (O. Reg. 170/03). This *Technical Rule* introduces the idea of clipping out SGRAs that are of no significance from a drinking water point of view. These areas may be important in other contexts, but they are not considered significant under the *CWA*. In the CLOSPA study area, the SGRAs located within the municipal service boundary that are on the Lake Ontario shoreline and sourced from Lake Ontario have been clipped out if no drinking water systems (as defined in the *Safe Drinking Water Act, 2002*) depend on those SGRAs.

Property fabric data for the serviced area was also assessed. SGRAs were clipped from the SGRA map for the study area if no private wells used as a sole drinking water supply existed within them. Where drinking water systems are located downgradient of a municipal service area, such as in Brooklin, the SGRAs within the service area are kept in the SGRA analysis.

SGRAs are primarily confined to the upper portions of the watersheds, coincident largely with the limits of the Oak Ridges Moraine. Areas on the Iroquois Beach physiographic region where surface sands can be relatively thick are also areas of significant recharge in the CLOSPA jurisdiction. These areas with aquifers at the surface are generally most vulnerable.

Areas with no colour are not significant groundwater recharge areas.

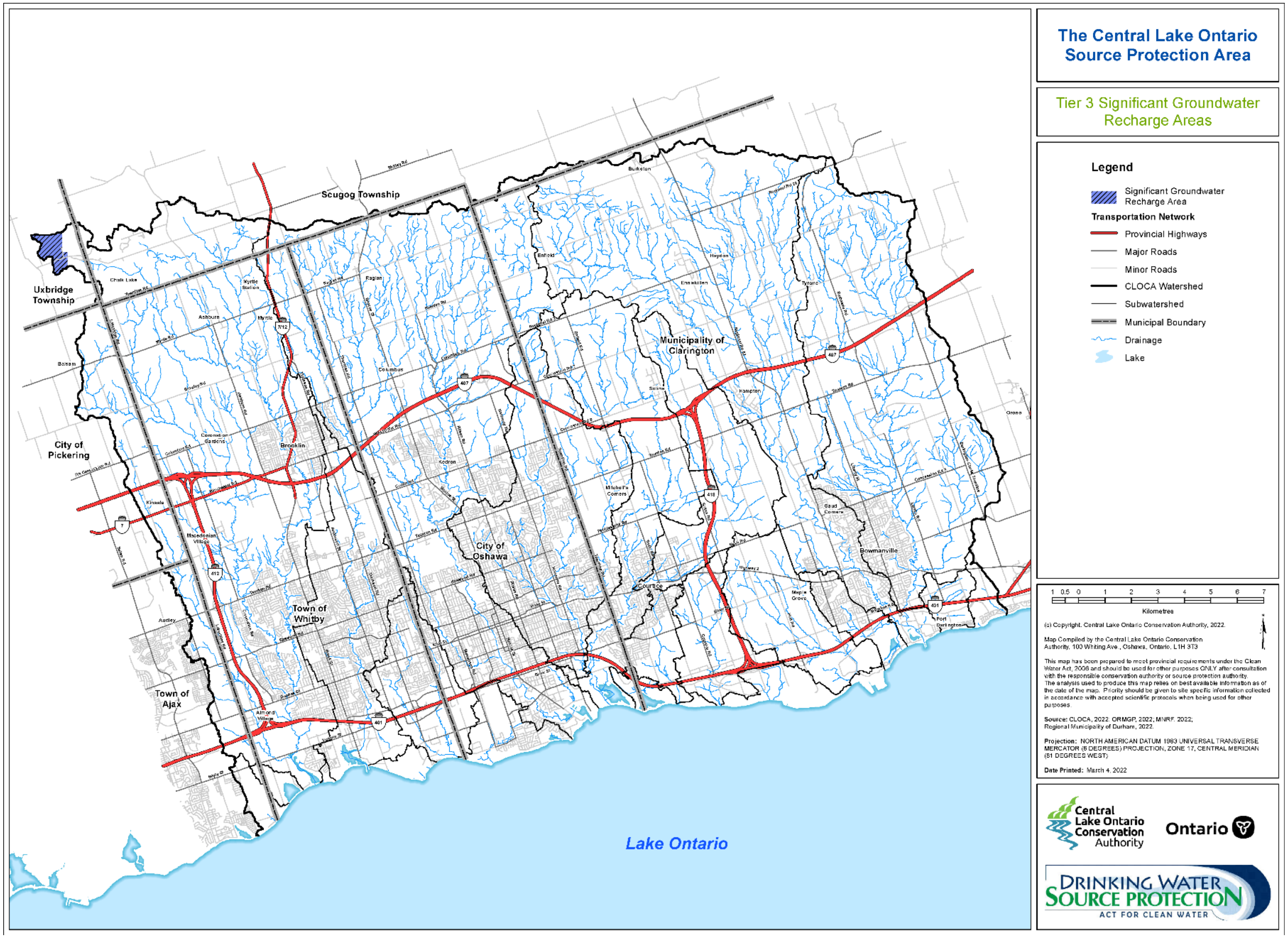

Figure 4.3: Tier 3 Significant Groundwater Recharge Areas (SGRAs)

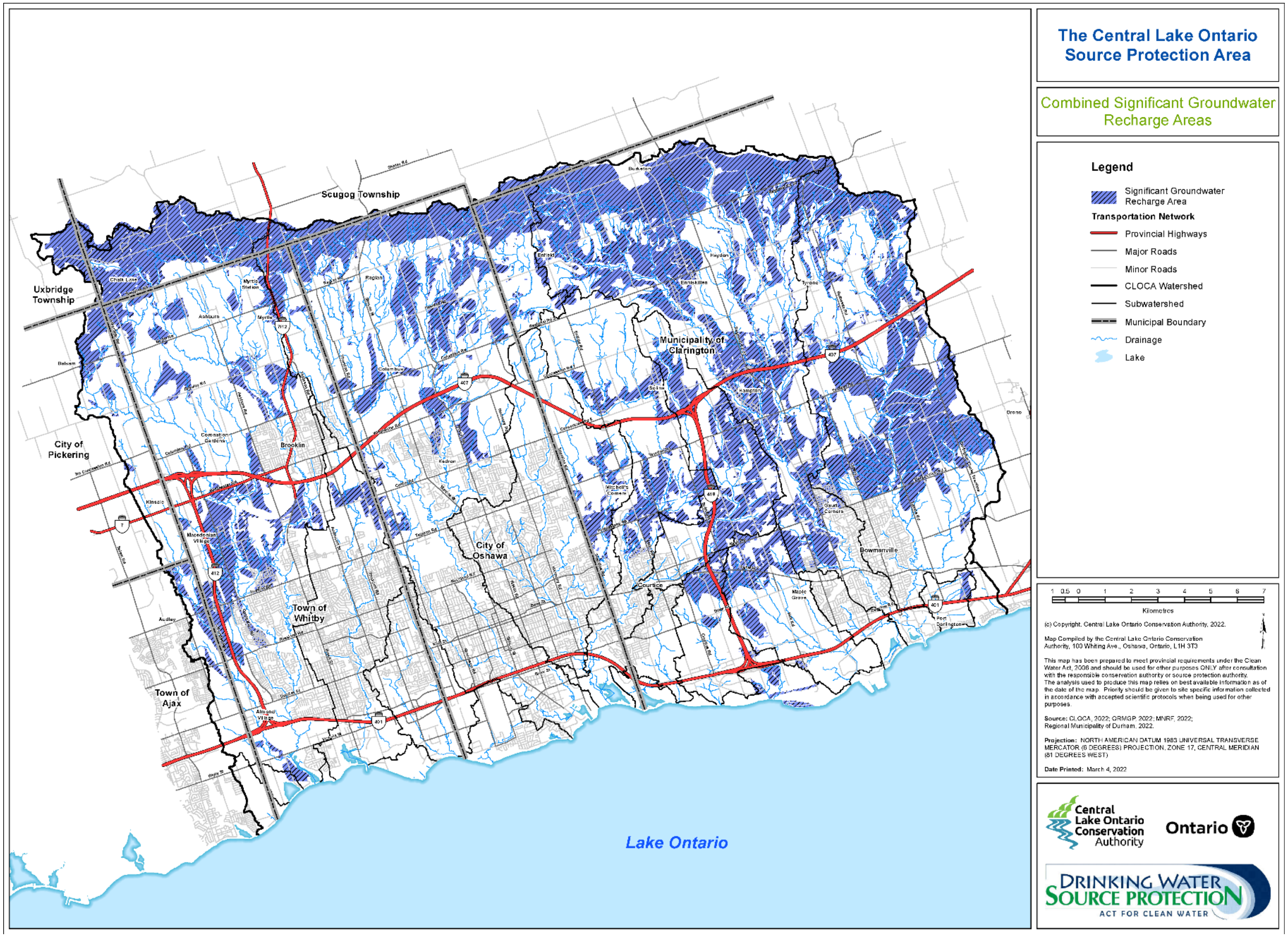

Figure 4.4: Combined Significant Groundwater Recharge Areas (SGRAs)

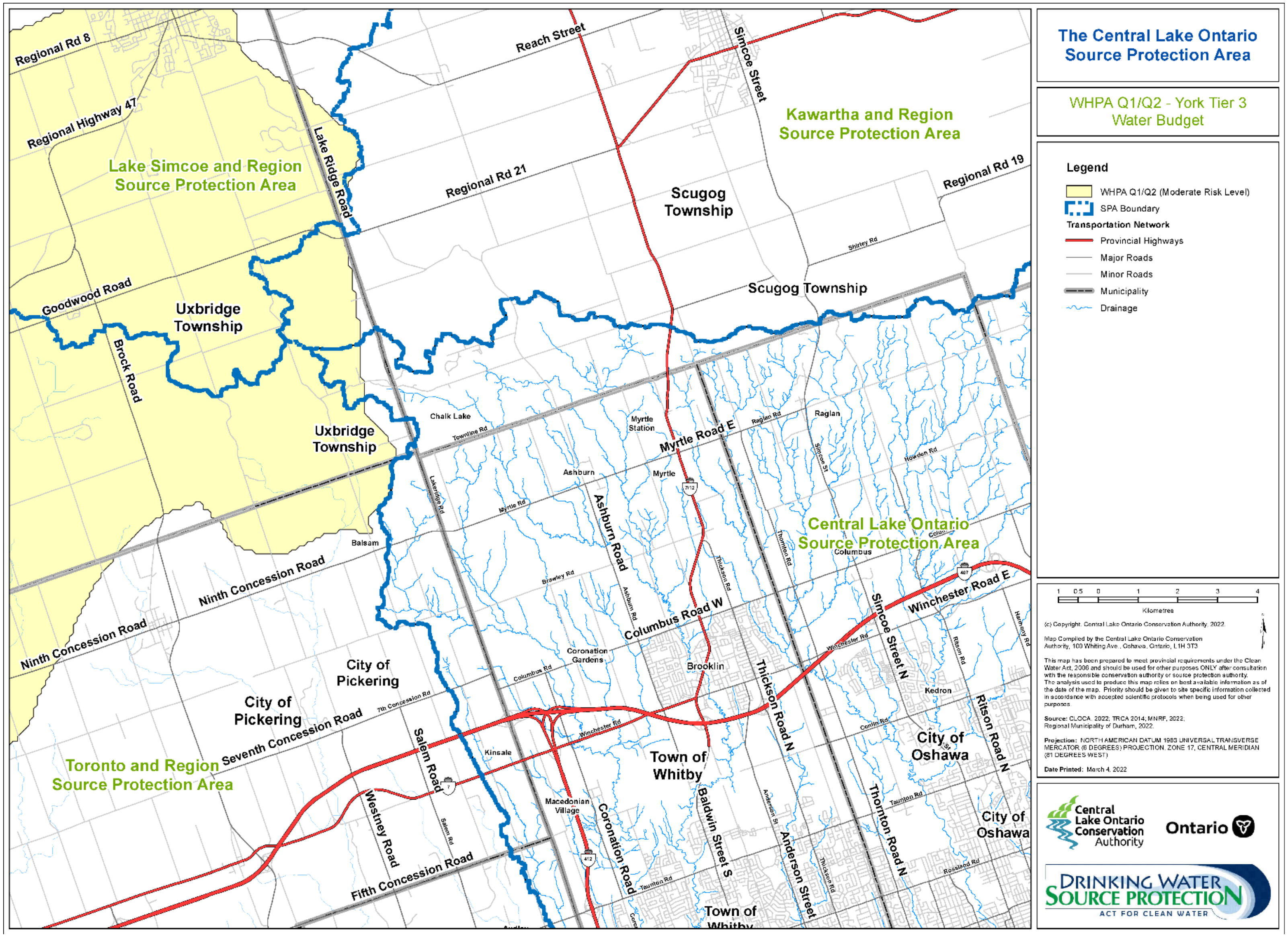

Figure 4.5: WHPA Q1/Q2 – York Tier 3 CLOSPA

4.1.3 Transport Pathways

Under the *CWA*, man-made structures such as improperly maintained or abandoned wells, aggregate pits, quarries, and storm water ponds may affect the natural vulnerability in a system and are termed "transport pathways." There are indeed several such structures and features within the CLOSPA that could increase the vulnerability of the various aquifers where they circumvent the natural protection that the overlying materials provide. There are private water wells that may be improperly maintained or left abandoned, quarries that may remove protective material, and horizontal structures, such as trunk sewers, that may provide a shorter pathway for potential contaminants to travel to drinking water sources.

The methodology followed to determine whether a vulnerability score increase is warranted due to transport pathways is described in more detail in **Appendix E** of this Assessment Report. The *Technical Rules,* indicate that a SPC may conclude that the data available may be insufficient or of too poor quality to justify an increase in vulnerability. Several datasets for pathway features were reviewed in an attempt to assess transport pathways within the CTC Source Protection Region including the CLOSPA jurisdiction. Only the data for pits and quarries was accurate enough to adjust the vulnerability to delineate HVAs. This adjustment for pits and quarries was done consistently with what had been done previously in WHPAs.

The CTC SPC recommends that additional data be collected on pathways to re-visit the vulnerability assessment in a future iteration of this Assessment Report. The conservatism built into the current assessment provides assurance that vulnerability of the aquifers is sufficient at this time. Pits and quarries as transport pathways resulted in a small significant change 0.48% (increase) in the area identified as HVAs.

4.1.4 Uncertainty Assessment

Confidence with the aquifer vulnerability mapping (AVI) depends on the density of data, the accuracy and currency of the surface geology mapping, and interpretations and assumptions made in the development of three-dimensional models. Over the last decade the Oak Ridges Moraine Groundwater Monitoring Program (ORMGP) study team, has made significant advances in its understanding of the hydrogeological system adding new high integrity data sources, refining existing data, and developing cutting edge tools and products. As well, there is a relatively high density of data for the area of the CTC watershed region compared to other source protection regions.

The delineation of the SGRA mapping was based on a complex surface water model linked to a complex, three-dimensional groundwater flow model, and both models were calibrated to the satisfaction of external peer reviewers. Further discussion on the uncertainty with respect to the Tier 3 model relevant to the area that is within CLOSPA is documented in **Chapter 3** in the Section on the Tier 3 Water Budget.

Together, these factors result in a high level of confidence in the results of the vulnerability analyses for the CTC Region. Therefore, the level of uncertainty is considered to be low. The reader is cautioned, however, that there is always a certain level of uncertainty, particularly in studies involving the subsurface, which cannot be observed directly. These studies are also regional in nature; site-specific information should always be used where available to determine local vulnerability. Data (quality and quantity) and knowledge gaps are complex.

Data on uncertainty factors surrounding HVAs analyses are provided in **Appendix D**.

4.2 Groundwater Vulnerability - Wellhead Protection Areas (WHPAs)

There are no wellhead protection areas (WHPAs) located within the CLOSPA jurisdiction.

4.3 Surface Water Vulnerability Analysis - Intake Protection Zones (IPZs)

The focus of the *CWA* is on municipal drinking water supplies. The drinking water supplies for the CLOSPA jurisdiction are sourced from Lake Ontario. Major settlements within the area, such as Whitby, Brooklin, Oshawa, Bowmanville, and Courtice, are serviced by water treatment plants sourced from Lake Ontario. Outside of the serviced areas, drinking water supplies come from privately owned wells. Wellhead Protection Areas are not required to be delineated for non-municipal wells (unless where designated under the *CWA*.

Under the *CWA,* vulnerable areas for surface water are referred to as Intake Protection Zones (IPZ). For municipalities to protect the area around their intakes, they must protect the surrounding water and, in most cases, the land area nearest the intakes. Since a number of Lake Ontario municipal intakes are located several kilometres offshore, the IPZs for these intakes do not all extend onto land.

This Surface Water Vulnerability Analysis was undertaken by Stantec Consulting Ltd. for the Region of Durham Water Treatment Plants (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*—See **Appendix D** for more detail). It was conducted under the Lake Ontario Collaborative to meet the requirements of the *Clean Water Act, 2006*. The following analyses were performed using the guidelines from the MOECC and the *Technical Rules* concerning Surface Water Vulnerability:

- The Water Treatment Plant (WTP) intakes and near areas were characterized;
- Vulnerable areas around the intake—IPZs—were determined; and
- The vulnerability of the intakes were scored.

The Surface Water Vulnerability Analysis looks at the likelihood that surface water will become contaminated, especially in the areas around drinking water intake systems at WTPs. To conduct the analyses, vulnerable areas must be delineated around intake pipes for each surface water intake associated with Class 1, 2, and 3 municipal water supplies.

Like the groundwater systems, the IPZs are assessed for their vulnerability to contamination. The relative vulnerability of a given zone is a function of the contributing area’s hydrological and environmental characteristics. The existence of natural and man-made preferential pathways is also considered in the assessment of intake zone vulnerability.

4.3.1 Intake Protection Zone Delineation

Protecting the area around a surface water intake means protecting the surrounding water and in most cases, the land adjacent to the body of water. Under the *CWA,* these areas of water and land are known as water quality IPZs. Intake protection zones in a large lake where the intake pipe is located far from shore, such as a Great Lake, often never touch shore. IPZs in smaller lakes or on rivers may also include the land surrounding it, as well as several smaller feeder rivers or tributaries. There are three surface water intakes located in the CLOSPA, including the following (see **Figure 4.6**):

- Whitby WTP;
- Oshawa WTP; and
- Bowmanville WTP.

Under the *Clean Water Act,* the Province of Ontario has required that several water quality IPZs be identified. The size of each area varies depending on where the intake is located, currents, contributing area, loadings, etc. CLOSPA’s intakes are all municipally owned and operated, and all are located in Lake Ontario. Great Lake intakes are designated Type A under the *Technical Rules*, with the associated technical requirements outlined. The following short descriptions clarify the zones around intakes. Great Lake intake protection zones (IPZs) associated with the Great Lakes intakes include:

- **IPZ-1**—This zone represents the area immediately adjacent to the drinking water intake. According to the *Technical Rules*, it is a circle with a radius of 1 km measured from the entry point where raw water enters the system. The IPZ-1 for the Bowmanville WTP has been revised as per information received from the Municipality regarding intake location. It is generally considered the most vulnerable zone because it is so close to the intake, and because contaminants discharged within this area are presumably undiluted (see **Figure 4.6**).
- Per *Technical Rule (62),* “If the area delineated in accordance with rule 61 (delineation of IPZ 1 as described) includes any land, the IPZ-1 shall only include a setback on the land that is the greater of,
  - (1) The area of land that drains into the surface water body is measured from the high water mark and the area must not exceed 120 metres. The term ‘high water mark’ under the Director’s Technical Rules is consistent with the definition of ‘ordinary high water mark’ as defined by DFO-Fact Sheet T-6, Fisheries and Ocean Canada, as the usual or average level to which a body of water rises at its highest point and remains for sufficient time so as to change the characteristics of the land; and

- (2) If a Conservation Authority Regulation Limit is in effect in the IPZ-1, the area of land that is within the Conservation Authority Regulation Limit.

- **IPZ-2**—This zone represents the area, both on land and in water, where a spill of a contaminant might reach the intake before the pl*ant operator* can respond. In CLOSPA, the minimum response time, as specified in the *Technical Rules*, is 2-hours, which has been used for all intakes. The IPZ-2 is comprised of two components, in lake and upland, which are described below. The two elements for each intake are summarized in **Table 4.2** and **Figure 4.6.**
  - In-Lake - This component of the IPZ-2 was calculated using *hydrodynamic models* to calculate the distance that a particle released at the surface would travel in 2-hours. Inputs to the models include but are not limited to: wind and wave data; *bathymetry* data; as well as water quality parameters at the intake. In CLOPSA, the IPZ-2 is based on estimating the distance a contaminant might move in 2-hours along the water surface, calculated from the water intake crib outwards under wind conditions that reflect a one year return period to the east and a three year return period to the west. In locations where the in lake IPZ-2 does not reach the shore, it has been extended from the outer limits to the shore at an angle perpendicular to the model. This extension was recommended by the modelling team to ensure a more conservative approach, recognizing that there is a level of uncertainty within the model.
  - Upland – This component has two sub-components - setbacks and transport pathways. The setbacks are determined as the Conservation Authority Regulated Limit or the administratively set limit of 120 metres from a watercourse or water body, whichever is greater. The transport pathways component includes areas that are drained by storm sewers and watercourses. The upper limit of this latter component is determined based on the 2-hour time of travel (TOT) of a particle within the transport pathway, beginning at the water surface over the intake. A modelled "bank full" flow event was assumed to complete the 2-hour TOT analysis. In CLOSPA, modelled flow conditions were selected in the absence of streamflow monitoring stations on the tributaries that are in close proximity to the intake. A full description of this analysis is found in reference **Appendix D.**
- **IPZ-3**—A number of spill scenarios were modelled as part of the Lake Ontario Collaborative to determine if certain land-based sources activities could pose a potential drinking water threat to these intakes. Any scenario that identifies conditions under which a contaminant could exceed a threshold in the raw water is identified as a significant drinking water threat. An IPZ-3 was delineated using the required setbacks from the point of its release in the tributary to a point representing the maximum landward extent of the IPZ-2. A dashed line is also drawn from the point of entry at the lake to the affected intake. This line is termed the "spill collector" and represents the shortest transport path between the shoreline and the affected intakes. An IPZ-3 that falls in the lake such as a spill at

a WWTP is represented by a spill collector dashed line only. This work is reported in **Chapter 5: Drinking Water Threats Assessment** of this Assessment Report.

Hydrodynamic Model: A tool able to describe or represent the motion of water.

Bathymetry: Shape of the bottom of the lake.

The discussion of the models and approaches used to determine the IPZ-1 and IPZ-2 areas are found in the *Lake Ontario Vulnerability Assessment Surface Water, Phase 1 and Phase 2, 2008, & 2011* and in **Appendix D** of this document.

SPA/SPR	Intake Location WTP	In-Lake Extent (*)	Upland Extent (*)
TRSPA/CTC	Ajax	Extends approximately 3 km northeast of the intake and 3.5 km southwest of the intake. Particle tracking indicates that the IPZ-2 extends approximately 500 m from shore, but does not extend to the shoreline.	The IPZ-2 was extended to the shoreline and upland to include watercourses that contribute to the source water intake area, WPCP outfalls, and the Pickering Power Generating Plant as well as along major transportation corridors such as Hwy 401 and CN rail line.
CLOSPA/CTC	Whitby	Extends approximately 2.4 km northeast of the intake and 3 km southwest of the intake. Particle tracking indicates that the IPZ-2 does not extend to shore.	The IPZ-2 was extended to the shoreline and upland to include watercourses that contribute to the source water intake area, WPCP outfalls, as well as along major transportation corridors such as Hwy 401 CN rail line, and CP rail line.
	Oshawa	There are two in lake IPZ-2s that have been merged together for the Oshawa WTP, as there are two intakes. The East intake IPZ-2 extends approximately 2 km northeast of the intake and 4.7 km southwest of the intake. The IPZ for the west intake would extend approximately 150 m further to the west. Particle tracking indicates that the IPZ-2 does not extend to shore.	There are two upland IPZ-2s that have been merged together for the Oshawa WTP, as there are two intakes. The IPZ-2 was extended to shore and upland to include watercourses that contribute to the source water intake area, WPCP outfalls, industrial outfalls, as well as along major transportation corridors such as Hwy 401 CN/CP rail lines.

SPA/SPR	Intake Location WTP	In-Lake Extent (*)	Upland Extent (*)
	Bowmanville	Extends approximately 2.4 km northeast of the intake and 3.8 km southwest of the intake. Particle tracking indicates that the IPZ-2 does not extend to shore.	The IPZ-2 was extended to shore and upland to include watercourses that contribute to the source water intake area, WPCP outfalls, industrial outfalls, Darlington Nuclear Power Generating plant, as well as along major transportation corridors such as Hwy 401 CN/CP rail lines. The zone also encompasses the entire Town of Bowmanville.
Ganaraska/ Trent Conservation Coalition	Newcastle	Extends approximately 2 km northeast of the intake and 4 km southwest of the intake. Particle tracking indicates that the IPZ-2 does not extend to shore.	The IPZ-2 was extended to shore and upland to include watercourses that contribute to the source water intake area, WPCP outfalls, agricultural tile drain outfalls, as well as along major transportation corridors such as Hwy 401 CN/CP rail lines. The zone also encompasses the entire Town of Newcastle.

(*) Delineation and landward extension details are provided in Appendix D.

Table 4.2: Summarizes the Extents of IPZ-2 as they pertain to each Intake involved in the Study (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*)

The model results show that near shore current patterns are strongly correlated to wind directions, which are primarily westerly and easterly. Particularly at the western end of Lake Ontario the current patterns within the lake are three dimensional. While surface water is moving in one direction, the currents near the bottom move in the reverse direction, which can also cause upwelling of bottom water to the surface, and downwelling of surface water to tower depths. Downwelling can bring surface contaminants down to the depth where the intakes are located. A summary of the IPZ-2 delineation and the vulnerability scoring is summarized in **Table 4.2** with details by water system. Mapping of the Intake Protection Zones and vulnerability scores for the CLOSPA are shown in **6**.

The Ajax and Newcastle WTP IPZ locations and vulnerability scores are also included in this Assessment Report because the IPZ-2s extend into the CLOSPA. The plants and intake cribs themselves are located in the Toronto and Region (TRSPA) and Ganaraska Region (GRSPA) Source Protection Areas respectively and are discussed in more detail in the Assessment Report for those source protection areas. The delineation and vulnerability scoring for both the Ajax and Newcastle WTPs was done by the same consultant (Stantec) under the Lake Ontario Collaborative Study using the same methodology detailed in this Assessment Report for the Whitby, Oshawa and Bowmanville WTPs.

4.3.2 Vulnerability Scoring for IPZs

Once water quality IPZs are delineated, scientific calculations, along with professional experience, are used to determine how vulnerable each IPZ is to contamination. This vulnerability score (V) is essentially qualitative and derived from the formula provided in *Technical Rules*:

V = Vfz x Vfs

The zone vulnerability factors (Vfz) are assigned to each IPZ according to its susceptibility to becoming contaminated. Zone vulnerability factors depend on varying circumstances, such as the surrounding environmental conditions, the percentage of the area that is land, and how water flows through the area. As indicated earlier, transport pathways (conduits by which potential contaminants might enter the IPZ) are also considered. Natural pathways such as small channels, gullies, or fractured rock that create an opening for contaminants may also increase vulnerability.

Each intake is assigned a source vulnerability factor (Vfs) between 0.5 and 0.7. This score depends on factors such as the type of intake, the depth and length of the intake, and the number of past incidents of exceeding the water quality guidance/standards. Water quality and trends are summarized in **Chapter 2.** Also, information about intake depth and intake distance from shoreline is shown in **Table 4.2.**

The formula does not consider specific contaminants, their respective properties, or their behaviours. The vulnerability score (V) and assigned Vfz and Vfs scores, do not have units. Additional discussion on the vulnerability scoring for lake-based intakes is provided in **Appendix D.**

The vulnerability score for each intake is assigned a score based on the following criteria:

- Low vulnerability ($V \leq 5$);
- Moderate vulnerability ($5 < V \leq 6$); and
- High vulnerability ($V > 6$).

IPZ-3s related to the Type A intakes (Great Lakes) in the study area have been delineated and are reported in **Chapter 5** of this Assessment Report.

Vulnerability Analysis Summary - Whitby WTP Intake

Zone Vulnerability Factor (Vfz)

The IPZ-1 Vf_z is assigned a value of 10 in accordance with *Technical Rules.*

The IPZ-2 Vf_z is assigned a high value of 8, as summarized in **Table 4.2**. The preliminary scoping level assessment of the vulnerability of IPZ-2 for the Whitby WTP results in a score of 8 as it contains three significant creek influences that have known PCB and PAH contaminate d sediments, Corbett Creek WPCP and outfall, Pringle Creek WPCP and outfall, a marina (Whitby Harbour), as well as numerous industrial operations along the shoreline. Major transportation corridors (Hwy 401, CN/CP rail) also exist in the zone and increase the potential for a contaminant to reach the source water. The zone is highly industrialized and urban, with very minimal agricultural areas. Soils in the area generally have low infiltration rates, which can increase runoff and the likelihood of potential contaminants reaching the source water.

Source Vulnerability Modifying Factor (Vfs)

The Whitby intake was given a Vf_s of 0.5 (low). The intake is 1,710 m from the shore, and located 16 m below the surface of the lake. This is significantly greater than the 10 m preferred depth established by the MOECC, and well within the Michigan deep water, offshore intake classification category. Historical water records reviewed and discussions with plant operators indicate that this is an excellent source of water with minimal usage complications.

Vulnerability Score (V)

The vulnerability score was determined to be 5 for IPZ-1, resulting in a low level of vulnerability.

The vulnerability score for (V) for the Whitby WTP IPZ-2 was determined to be 4.0. This results in a low level of vulnerability.

Vulnerability Analysis Summary – Oshawa WTP Intakes

Zone Vulnerability Factor (Vfz)

The IPZ-1 Vf_z is assigned a value of 10 in accordance with *Technical Rules*. There are two IPZ-1s that have been merged together for the Oshawa WTP, as there are two intakes.

The IPZ-2 is assigned a high value of 9, as summarized in **Table 4.2**. Similar to the IPZ-1, there are two IPZ-2s that have been merged together for the Oshawa WTP, one for each intake. The in-lake IPZ-2 was modelled for the east intake and is deemed to be representative of both intakes as the intakes are separated by a distance of only 150 m. The up-land IPZ-2s were determined individually for both the east and west intakes. The preliminary scoping level assessment of the vulnerability of IPZ-2 for the Oshawa WTP results in a score of 9 as it contains four (4) significant creek influences that have known

PCB, PAH and DDT plus metabolites contaminated sediments, Corbett Creek WPCP and outfall, Harmony Creek WPCP and outfall, as well as numerous industrial operations along the shoreline. Major transportation corridors (Hwy 401, CN rail and CP rail) also exist in the zone and increase the potential for a contaminant to reach the intake. The zone is highly industrialized and urban, with very minimal agricultural areas. The soil in the area generally has low infiltration rates, which can increase runoff and the likelihood that a potential contaminant can reach the source water. Oshawa harbour is contained within the zone and is used as a federal shipping port and has bulk chemical storage near the shoreline. These maritime activities increase the possibility of potential contaminants reaching the source water, and therefore increase the Vf_z score.

Source Vulnerability Modifying Factor (Vfs)

The Oshawa intakes have been assigned a moderate Vf_s of 0.5 (low). The intakes are 924 m and 831 m from the shore, and located approximately 10 m and 7.5 m below the surface of the lake. They both meet the minimum requirement of depth greater than 3 m determined by the MOECC, however only the east intake meets the preferred criteria of 10 m depth. Both intakes are within the Michigan deep water, offshore intake classification category. Historical water records reviewed and discussions with plant operators indicate that the water is of good quality.

Vulnerability Score (V)

The vulnerability score was determined to be 5 for IPZ-1, resulting in a low level of vulnerability.

The vulnerability score (V) for the Oshawa WTP IPZ-2 was determined to be 4.5. This results in a low level of vulnerability.

Vulnerability Analysis Summary – Bowmanville WTP Intake

Zone Vulnerability Factor (Vfz)

The IPZ-1 Vf_z is assigned a value of 10 in accordance with *Technical Rules.*

The IPZ-2 Vf_z is assigned a moderate value of 8, as summarized in **Table 4.2**. It warrants a moderate level vulnerability as it contains two significant creek influences contaminated with PAH and DDT plus metabolites, Port Darlington WPCP and outfall, aggregate operations, and Darlington Nuclear Generating Station. Major transportation corridors (Hwy 401, CN/CP rail, Hwy 2) also exist in the zone and increase the potential for a contaminant to reach the intake. The zone comprises of moderately urban and industrialized areas with agricultural parcels surrounding the town. Sandy clay loam soils found in the area have low infiltration rates and impede water percolation. This has the potential to cause an increase in surface runoff and the likelihood of contaminants reaching the source water.

Source Vulnerability Modifying Factor (Vfs)

The Bowmanville intake was given a Vf_s of 0.5 (low). The intake is 1,260 m from the shore, and located 12 m below the surface of the lake. This depth is greater than the 10 m preferred depth established by the MOECC, and well within the Michigan deep water, offshore intake classification category. Historical water records reviewed and discussions with plant operators indicate that this is an excellent source of water with minimal usage complications.

Vulnerability Score (V)

The vulnerability score was determined to be 5 for IPZ-1, resulting in a low level of vulnerability.

The vulnerability score for (V) for the Bowmanville WTP IPZ-2 was determined to be 4. This results in a low level of vulnerability.

Table 4.3 summarizes the vulnerability assessments for all intakes involved in this study area. The IPZ-2 for the Ajax and the Newcastle Water Treatment Plants, which are located in the Toronto Region and Ganaraska Source Protection Areas respectively extend into the CLOSPA study area and are therefore included in the following table.

Table 4.3: Summarizes the Vulnerability Assessment for all the Intakes Involved in this Study (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*)

SPA/SPR	Intake Location (WTP)	Area Vulnerability Factor (V_{fz})		Source Vulnerability Modifying Factor (V_{fs})	Vulnerability Score (V)			
		IPZ-1	IPZ-2		IPZ-1		IPZ-2	
TRSPA/CTC	Ajax	10	9	0.5	5.0	LOW	4.5	LOW
CLOSPA/CTC	Whitby	10	8	0.5	5.0		4.0	
	Oshawa	10	9	0.5	5.0		4.5	
	Bowmanville	10	8	0.5	5.0		4.0	
Ganaraska/ Trent Conservation Coalition	Newcastle	10	8	0.5	5.0		4.0	

The Vf_z is scored as 10 (high) for all IPZ-1s as prescribed by the *Technical Rules.* The Vf_z for IPZ-2 ranged from 8 (medium) to 9 (high). The Vf_s was set at 0.5 (low) for all intakes.

The calculated vulnerability score for al IPZ-1 was 5 (low) and the range for IPZ-2 was 4 (low) to 4.5 (low).

4.3.3 Uncertainty Assessment

The uncertainty level for IPZ-1 in all WTPs is low (meaning a high level of confidence). The IPZ-2 for the in lake component for each WTP was calculated using a hydrodynamic model which included data inputs from water movement, winds, currents and temperatures. The uncertainty level for all the IPZ-2 in lake zones for the Durham Region intakes located in CLOSPA is high (meaning a low level of confidence) due to the general lack of data to calibrate the model suites, as well as the limited data used to drive the model and reach steady state conditions.

More detailed hydraulic data is required to run a variety of scenarios and effectively model water movement in the study area. In addition, there is high uncertainty associated with the extension of the IPZ-2 to the shore as the in-water modelling did not originally include a connection to the shore. The uncertainty level for the IPZ-2 for the upland component for each WTP is also high. The 2-hour TOT within the creek systems was based on modelled velocities, where models were available, and conservative estimates, where models were not available.

As mentioned above, the hydrologic (flow) models are conservative and were selected due to the absence of streamflow monitoring stations that are located in close proximity to the lake. The 2-hour TOT within the storm sewers was based on an estimated and somewhat high velocity to ensure that IPZ was delineated in a conservative manner. As a result of the above, the combined uncertainty is high for all Durham Region intakes located in CLOSPA, even though the critical data needed to delineate the vulnerability zones and score the intake vulnerability was sufficient.

Overall, the information available at the time of writing was of sufficient density, quality, and quantity to adequately complete a surface water vulnerability analysis at a scoping level. The uncertainty associated with IPZ delineation and vulnerability scores for Ajax, Whitby, Oshawa, Bowmanville and Newcastle WTPs are shown in **Table 4.4.** A discussion of the factors influencing the uncertainty in the delineation and vulnerability scoring are presented in **Appendix D.**

Table 4.4: Uncertainty Assessments of Vulnerability Scores. Vulnerability scores below 6 are considered low. (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*)

SPA/SPR	Intake Location		Vulnerability Score	IPZ Uncertainty Level Rating		
				IPZ Delineation	Vulnerability Score	Combined
TRSPA/CTC	Ajax	IPZ-1	5.0	Low	Low	LOW
		IPZ-2	4.5	High	Low	HIGH
CLOSPA CTC	Whitby	IPZ-1	5.0	Low	Low	LOW
		IPZ-2	4.0	High	Low	HIGH
	Oshawa	IPZ-1	5.0	Low	Low	LOW
		IPZ-2	4.5	High	Low	HIGH
	Bowmanville	IPZ-1	5.0	Low	Low	LOW
		IPZ-2	4.0	High	Low	HIGH
Ganaraska/ Trent Conservation Coalition	Newcastle	IPZ-1	5.0	Low	Low	LOW
		IPZ-2	4.0	High	Low	HIGH

The IPZ-2 upland was delineated based on a conservative methodology in order to provide a scoping level delineation. In determining the landward and up-tributary extent of the IPZ-2 the following uncertainties have been noted:

- Due to the conservative nature of the HEC-RAS data, the up-tributary delineations have a moderate level of uncertainty; and
- Catchment areas for storm sewer networks were not available, so were therefore estimated. Velocity data for the storm sewers were also not available. There is low uncertainty as to which storm networks ought to be included, but high uncertainty as to the extent of the network that should be included.

Also, the potential for high volumes of runoff to be produced within the study area and the channelling of runoff into nearby water courses, the absence of flow data, stream flow velocities and other watercourses characteristics leads to a high uncertainty in the upland extent component for the IPZ-2. The IPZ-2 upland was delineated based on a conservative methodology in order to provide a scoping level delineation.

The uncertainties associated with the in-lake and alongshore IPZ-2 delineation and the data gaps identified with respect to the information used for the determination of the landward and up tributary IPZ-2 component necessitate a high level of uncertainty.

Site specific data contributing to the vulnerability factor are from ongoing provincial monitoring programs, federal monitoring programs, as well as, input from the WTP operators and conservation authorities. They are not of sufficient quality and frequency to impart high confidence in the vulnerability scoring.

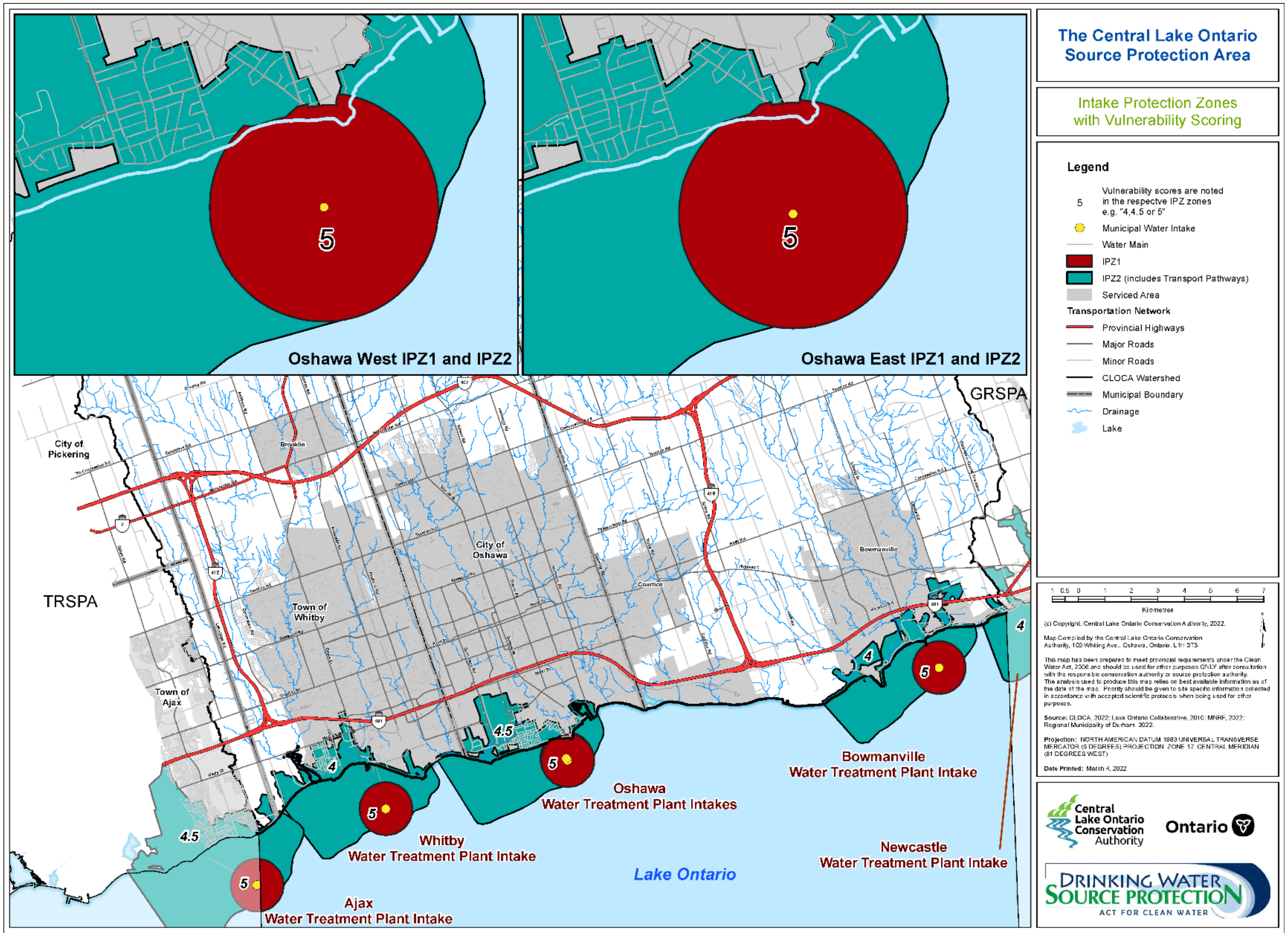

Figure 4.6: Intake Protection Zones with Vulnerability Scoring (IPZs for the Ajax, Whitby, Oshawa, Bowmanville, and Newcastle WTPs (*Lake Ontario Collaborative—Surface Water Vulnerability Assessment 2008, 2010 & 2011*)

4.4 Summary

The CWA requires the mapping and assessment of the natural vulnerability in vulnerable source water areas located within the CLOSPA jurisdiction – HVAs, SGRAs, and IPZs. These areas can be vulnerable based on water quantity or water quality considerations, or both. The natural vulnerability of these areas is assessed and scored high, medium, or low, using approved provincial methodologies. The vulnerability scoring is required in the determination of risk to the sources when assessing the different land-uses and activities that exist on the landscape. To calculate the hazard rating for each land use activity, the Province made a series of assumptions that have an uncertainty associated with them. In their analysis, it was assumed that any possible threats associated with an activity were present and that all potential chemicals were present. The circumstances and quantity for each threat were assigned based on available knowledge, such as typical storage practices, typical chemical quantities, and typical waste disposal practices for that particular land use activity. Risk is determined using the vulnerability score and hazard scores assigned to the different activities and their associated chemicals and pathogens, as outlined in **Chapter 5: Drinking Water Threats Assessment.**

In the CLOSPA jurisdiction 95% of the population receives its drinking water from municipal systems, all of which use Lake Ontario as the water source.

HVAs are areas susceptible to contamination moving from the surface into the groundwater. In the CLOSPA jurisdiction, there are large areas covered by saturated sand deposits that support many shallow wells. These aquifers are considered vulnerable to contamination that may cause deterioration of the water quality in water wells that use this source. Areas of high vulnerability are those with a score of 6 per the *Technical Rules.* The features associated with the transport pathways were assessed for vulnerability adjustment. Pits and quarries were the only pathways with sufficient data to justify vulnerability adjustment. Incidentally, shallow wells that are most vulnerable to water quality impacts are also vulnerable to water quantity impacts during periods of drought. Deeper aquifers that are thicker, and/or have a dense protective layer such as a till overlying them, are generally less vulnerable. Where these aquifers are closer to the surface (closer to the Lake Ontario shoreline) or are exposed, such as in river valleys like the Enniskillen Valley; they are more vulnerable.

The vulnerability of the HVAs was assessed using the Aquifer Vulnerability Index (AVI) method. The vulnerability in the affected areas was increased by on level. Where this resulted in a change from a vulnerability score of 4 to 6, the zone was defined as a HVA. Although minimum water well construction standards are set up in O. Reg. 903 under the *Ontario Water Resources Act, 1990*, extra caution should be taken when constructing wells in vulnerable aquifer areas.

SGRAs are areas where the highest volume of recharge to the aquifers occurs and are delineated as part of the water budget process (see **Chapter 3**). SGRAs are important water quantity areas—replenishing the aquifers that serve as a source of drinking water (including both municipal and other drinking water uses, such as private wells).

There are no municipal groundwater supplies within the CLOSPA jurisdiction. A WHPA Q1/Q2, which was delineated as a result of a York Region Tier 3 Water Budget study, extends into a small area in the northwest area of CLOSPA. The SGRA analysis was re-run to include this area and a revised map produced for this report. The HVA mapping was unrevised as the vulnerability in the Tier 3 area did not change from previous mapping (high).

IPZs are vulnerable areas around the Lake Ontario drinking water intakes. The IPZ-1 is delineated based on a one kilometre radius measured from the entry point where raw water enters the system. IPZ-2 in-lake component was delineated using hydrodynamic models to estimate the distance that a contaminant could travel in two hours. The models include estimating such factors as wind direction and speed, stream loadings, and lake currents.

The IPZ-2 upland component was determined by a combination of administratively selected setbacks and areas that are drained by transport pathways (storm sewers and water courses). The upper limits of the area drained by transport pathways were determined by the distance a contaminant could travel in two hours. According to the Director's Rules, the setbacks are the greater of 120 metres or the CA Regulation limit measured from the high water mark. The measured high water mark is based on the CGVD28 (Canadian Geographic Vertical Datum) converted from the IGLD (International Great Lakes Datum 1985). The high water mark was delineated and setback extended from this datum.

The vulnerability for IPZ-1 and IPZ-2 areas is scored based on factors set out in the *Technical Rules*. The IPZ-1s located in the CLOSPA jurisdiction (associated with the Whitby, Oshawa, and Bowmanville water treatment plants) all scored 5 (low vulnerability). The vulnerability scores for IPZ-2s were either 4 or 4.5 (both low vulnerability).

Additional work was completed to model the potential impacts of a number of scenarios to determine if there are land-based sources of contaminants that could pose a potential drinking water threat to these intakes. The delineated IPZ-3 is shown by a straight dashed line to marks the connection from the shoreline to the affected intakes. The dashed line is labelled a “spill collector” to show the connection between the threat and the intake. As per the *CWA 2006, Rule (75),* the delineated IPZ-3 cannot contain any part of the IPZ-1 or 2 and so the IPZ-3 are clipped to the furthest extent of the IPZ-2. The dashed line remains as a component of the IPZ-3. This work is reported in **Chapter 5** of this Assessment Report.

Analyses of uncertainty have been carried out for all vulnerable areas. The vulnerable area delineation and vulnerability assessments for groundwater were based on a combination of a complex surface water model linked to a complex, three-dimensional groundwater flow model, and in each case, the models were deemed to be calibrated to the satisfaction of external peer reviewers. Together, these factors result in a high level of confidence in the results of this vulnerability analyses for the CTC Region.

The uncertainties associated with in-lake and alongshore IPZ-2 delineation and the data gaps identified with respect to the information used for the determination of the landward and up tributary IPZ-2 component necessitate a high level of uncertainty. Uncertainty information for the event-based modelling and IPZ-3 delineation is also provided in **Chapter 5**.

Finally, the reader is cautioned that there is always a certain level of uncertainty in regional assessments, and where available site-specific information should always be used to determine local vulnerability.