Figures

Tables

4.0 ASSESSING VULNERABILITY OF DRINKING WATER SOURCES

As documented in **Chapter 2 (Table 2.6** and **Table 2.7)**, approximately 97% of residents within the TRSPA receive their drinking water from Lake Ontario after treatment in municipal plants. The remaining 3% of residents rely on municipally operated groundwater-based drinking water systems (estimated 50,000 residents) or private wells using groundwater as their drinking water source (estimated 60,000 residents).

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:

- Wellhead Protection Areas (WHPAs);
- Highly Vulnerable Aquifers (HVAs);
- Significant Groundwater Recharge areas (SGRAs); and
- Intake Protection Zones (IPZs).

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 source protection areas, 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, where appropriate, for vulnerability 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 TRSPA, areas of high and medium vulnerability generally correspond to shallow unconfined aquifers associated with:

- Surficial stratified sediments;
- Upper aquifers largely comprised of ice-contact drift, Oak Ridges Aquifer Complex/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).

The vulnerability of drinking water to water quantity depletion is assessed under the water budget component of this report. The results of the Aquifer Vulnerability Index (AVI) are used in the delineation and vulnerability scoring of HVAs.

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.

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 D**.

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

The vulnerability of drinking water to water quantity depletion is assessed under the water budget component of this Assessment Report (**Chapter 3**). The results of the AVI are used in the delineation and vulnerability scoring of HVAs.

The TRSPA has selected an advanced AVI approach to delineate 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 D**.

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 **Figure 4.1.** Within HVAs, the groundwater vulnerability is then converted (per *Technical Rules 82-85*) into a vulnerability score, as shown in **Table 4.1**, and this score provides the ultimate expression of the groundwater vulnerability. Each aquifer is scored separately. 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 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*, the vulnerability cannot be increased beyond high.

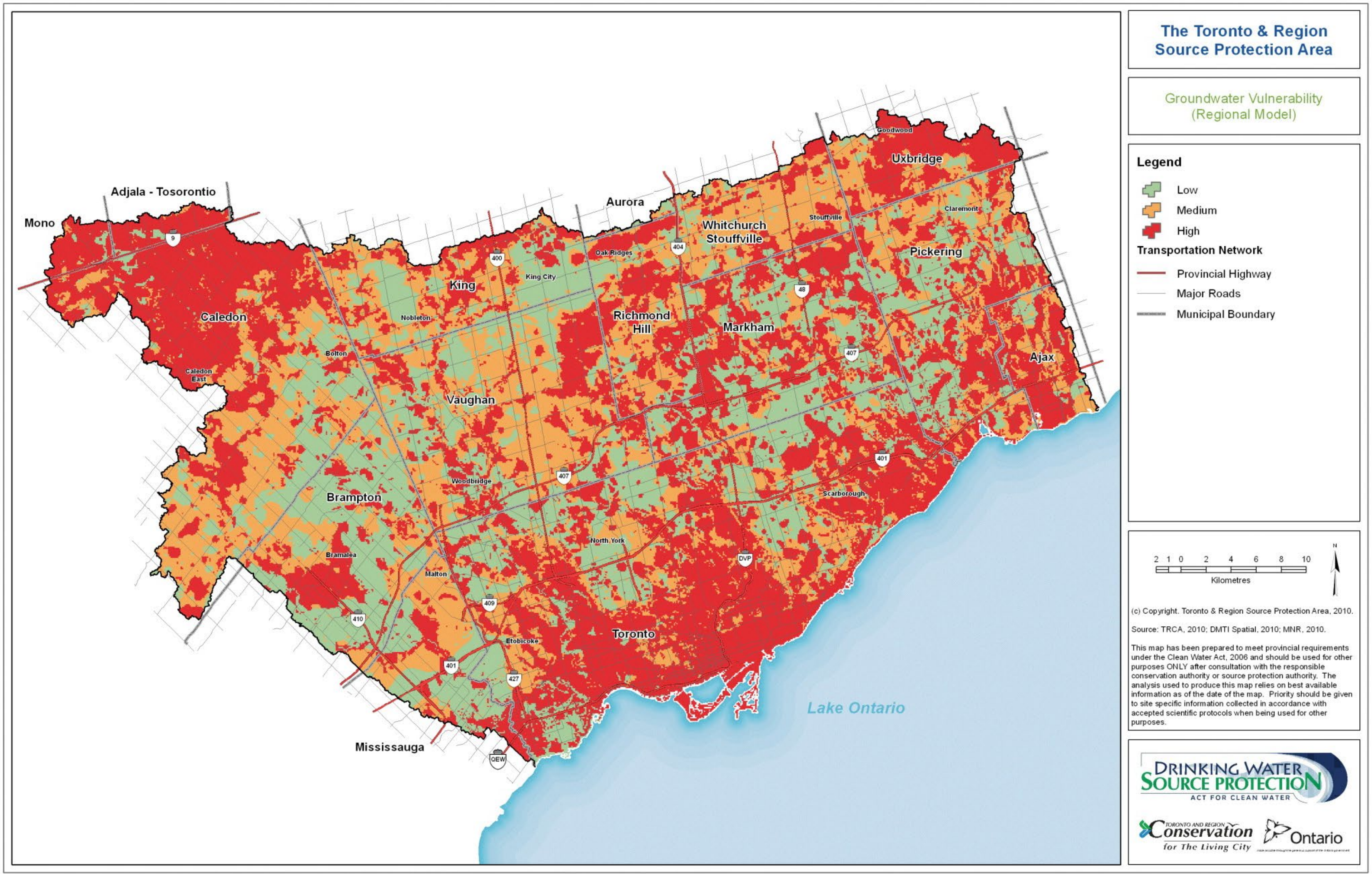

Figure 4.1: Groundwater Vulnerability (Regional Model)

4.1.2 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 vulnerability score of 6 has a ‘high' groundwater vulnerability and is therefore an HVA, as mapped on **Figure 4.2**. 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 D**. These areas represent about 44% of the land area within the TRSPA. The aquifer vulnerability map showing the areas of high, medium, and low vulnerability, along with details of the methodology is presented in **Appendix D2**.

Vulnerability Scoring for HVAs

According the *Technical Rules*, aquifers within the study area that score the lowest using the AVI approach are delineated and mapped as HVAs, and are assigned a high vulnerability score of 6.

4.1.3 Significant Groundwater Recharge Area (SGRA) 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. SGRA modeling in TRSPA was amended in 2018. In TRSPA, SGRAs were located using the GSFLOW model (Groundwater-Surface Water Flow 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 100 x 100 m grid covering the study area based on a 30-year climate normal simulation (1983-2003) of the York Tier 3 model. Because this model does not cover the entire TRSPA jurisdiction, the Tier 1 results were used for the Etobicoke Creek watershed.

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

- *44 (1) if 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) if 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.*

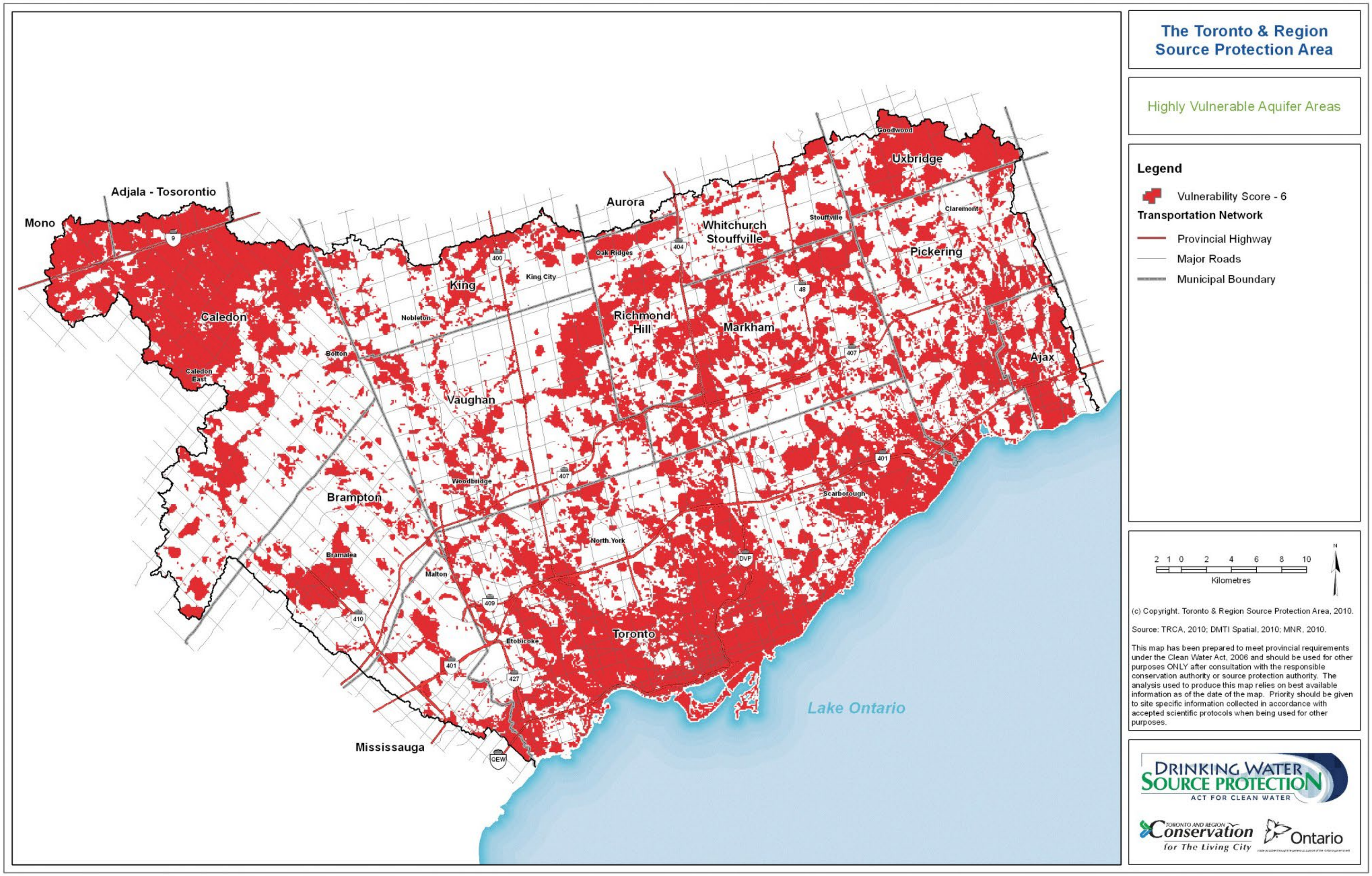

Figure 4.2: Highly Vulnerable Aquifers (HVAs)

In TRSPA, the approach outlined in *Technical Rule 44(1)* was selected. This approach and the rationale for selection are described in more detail in **Appendix D1.**

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

- Average annual recharge for each of the nine major watersheds; and
- Average annual recharge across the entire TRSPA jurisdiction.

The jurisdictional average recharge was chosen as the most consistent with the technical factors most significant to a measure of recharge - surficial geology, stream temperature, and groundwater discharge attributes. The TRSPA watershed average from the Tier 1 and Tier 2 water budget model was 131 mm/yr, and the calculated SGRA threshold for the TRCA jurisdiction was therefore 150 mm/yr. The resultant mapping is provided on **Figure 4.3**. These values were modified during the Tier 3 water budget work, as explained below.

About 15% of the land area of TRSPA is defined as SGRAs. These areas generally cover the surface geology classes associated with the Oak Ridges Moraine deposits, hummocky terrain on the upper portion of the North Slope, exposed Lower Sediment sands, and the Iroquois Beach deposits. The Iroquois Beach deposits are relatively significant to private drinking water systems in the watersheds that receive less recharge from the Oak Ridges Moraine and exposed Lower Sediment deposits.

Tier 3 Refinements

As discussed in **Chapter 3**, the significant recharge areas were remapped within the Tier 3 Local Area. The methodology was the same, but the 30-year climate normal simulation (1983-2003) with the Tier 3 model produced an average recharge rate across the TRSPA of 187 mm/yr. This value was derived by averaging the simulated daily recharge rates over the 30-year period.

The spatial distribution of SGRAs in the TRSPA watersheds, as determined by the Tier 3 model, is relatively insensitive to the choice of SRGA threshold. For example, a threshold ranging between 200 and 250 mm/yr (1.07 and 1.34% of the average) would result in little change in SGRA mapping. Based on the selected methodology, any cell within the TRCA watersheds exceeding 215 mm/yr (1.15 x 187 mm/yr) was deemed a SGRA. Because the Tier 3 model domain did not cover the Etobicoke Creek watershed, the Tier 1 SGRAs were maintained for that watershed. TRCA staff considered this approach the most reasonable way of combining the two datasets.

The results of the Tier 3 SGRA delineation are presented on **Figure 4.4**. This mapping is similar to the Tier 1 and Tier 2 results, but the coverages differ locally due to the differences in models used, thresholds selected, and the difference in the size of the averaging areas. The primary difference between the two model ouputs is the extension of the SGRA area to the northern portion of the South Slope Physiographic Region.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 TRSPA study area, the SGRAs located within the Lake Ontario municipal water service area have been clipped out if no drinking water systems (as defined in the *Safe Drinking Water Act, 2002*) are hydrologically connected to those SGRAs.

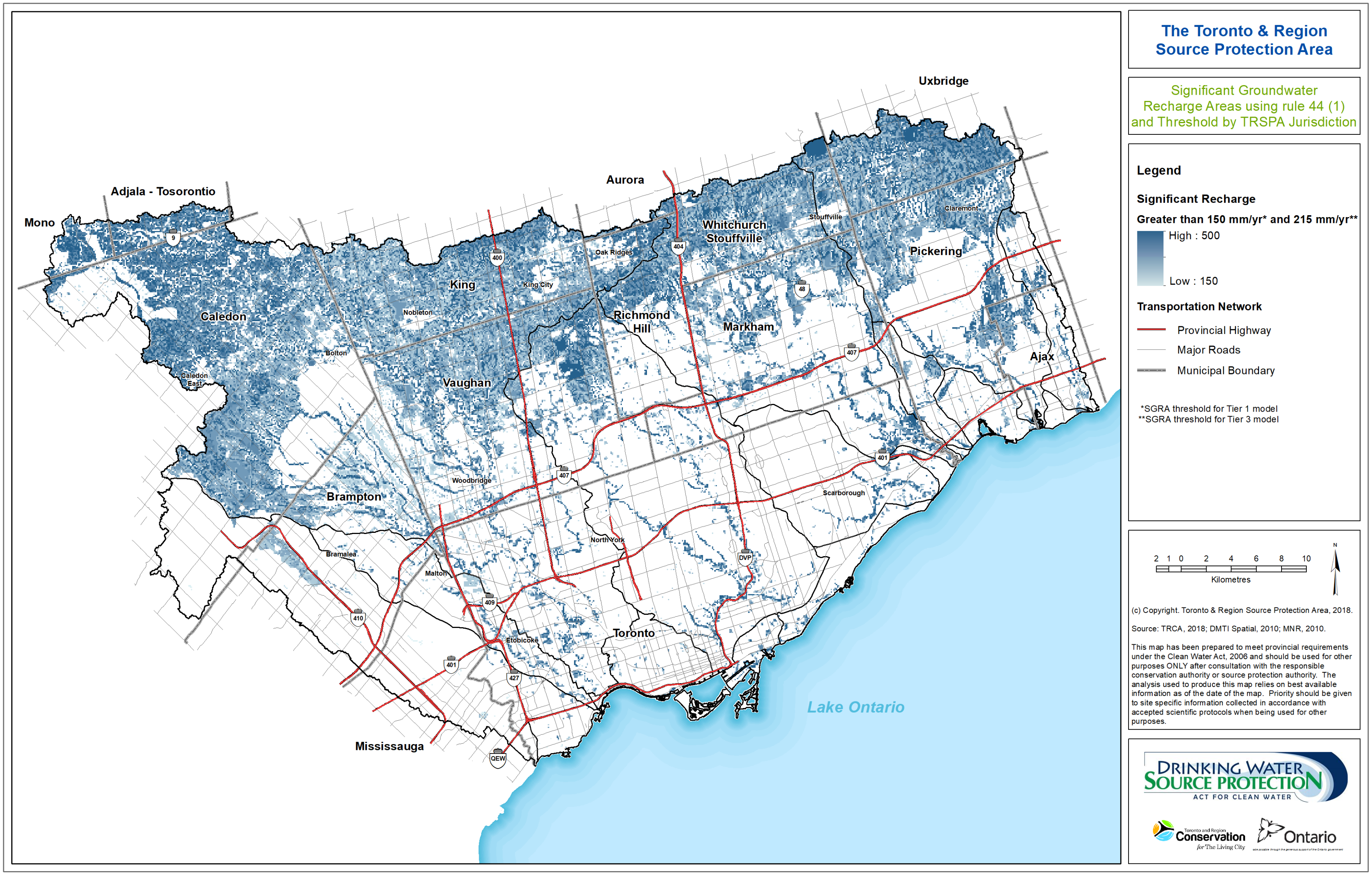

Figure 4.3: Significant Groundwater Recharge Areas using *Rule 44 (1)* and threshold by TRSPA Jurisdiction

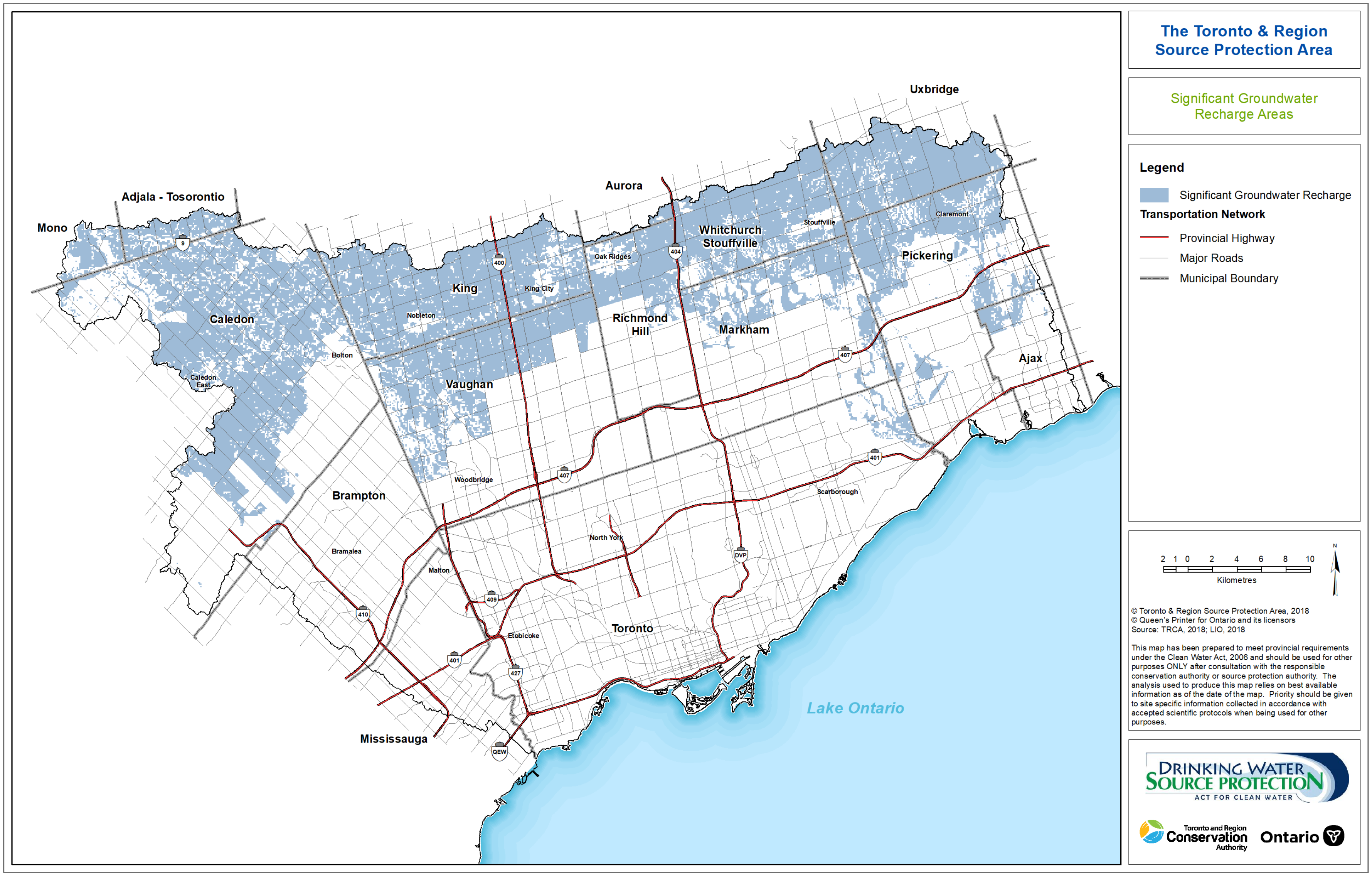

Figure 4.4: Significant Groundwater Recharge Areas

4.1.4 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 TRSPA that could increase the vulnerability of the various aquifers where they circumvent the natural protection that the overlying materials provide. There are private 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 D3** 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 TRSPA 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 the WHPA vulnerability assessments.

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 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.

4.1.5 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 Programhas made significant advances in its understanding of the hydrogeologic 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.

Together, these factors result in a high level of confidence in the results of the groundwater 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 HVA and SGRA analyses are provided in **Appendix D2.** Specific drinking water threats associated with all HVAs must be identified. Activities that pose a threat to the source water in these zones are listed in the Provincial Tables of Circumstances (*Technical Rules, Tables 10, 11, 17 and 18*) and discussed in **Chapter 5** of this document.

4.2 GROUNDWATER VULNERABILITY – WELLHEAD PROTECTION AREAS (WHPA)

The groundwater-based municipal supplies in the TRSPA are currently delivered through seven active water systems which have a total of 20 wells.

A wellhead is the physical structure of the well above the ground. A wellhead protection area is the area that surrounds the well through which contaminants are reasonably likely to move toward or reach the well. The size of the area is determined by using a computer model that estimates the time it takes groundwater to travel within the aquifer to the well based on rate the water is pumped out of the well, the type of geological materials around the well, and the speed that groundwater travels. Pollutants from a variety of activities can seep into the ground and move toward a well. The following four WHPA have been determined for each groundwater well listed in the *TRSPA Terms of Reference*:

- WHPA-A: the area within 100 m radius of the well - The area where the risk to the well is highest and the greatest care should be taken in handling any potential contaminant.
- WHPA-B: the area where groundwater is estimated to take up to 2 years to reach the well from within the aquifer. This second ring is important to protect from bacteria and viruses from human and animal waste as well as hazardous chemicals.
- WHPA-C: the area where groundwater is estimated to take up to 5 years to reach the well from within the aquifer. Although biological contaminants are less of a concern in the third ring, chemical pollutants remain a concern.
- WHPA-D: the area where groundwater is estimated to take up to 25 years to reach the well from within the aquifer. In this outer ring, the most persistent and hazardous pollutants remain a concern.

Two other WHPA (WHPA-E and WHPA-F) are delineated to include the area in and around the surface water body that is influencing a *GUDI well*. WHPA-E is delineated the same way as the IPZ-2 for a surface water intake (see **Section 4.6)** from the point of interaction between the aquifer and the surface water body. If the point of interaction is not known, the WHPA-E is delineated from the point of interaction between the aquifer and the surface water body that is nearest to the well. In the TRSPA, Stouffville Wells 5 and 6 have been classified as GUDI. The WHPA-Es' for the Stouffville wells are contained within the WHPA-A and B zones.

WHPA-F zones are delineated where an issue has been confirmed for a GUDI well. No WHPA-Fs have been delineated in the TRSPA.

GUDI Well: Groundwater Under the Direct Influence of Surface Water. The Drinking Water Systems Regulations (Ont. Reg. 170/03) under the *Safe Drinking Water Act, 2002* defines specific circumstances under which a groundwater supply is considered to be GUDI. These wells are more susceptible to contamination than non-GUDI wells because they can be affected by short-term water quality issues associated with surface water sources.

Porosity: The percent of open spaces or voids occurring between mineral grains or in fractures of bedrock. It is a measure of the potential volume of water that can be stored in the geologic material.

Permeability: The ability of a material to transmit a fluid, a measure of how quickly fluid will flow through the rock or sediment. This is determined by the size of open spaces and degree to which they are connected.

Mapping of WHPAs has been completed by consultants working for the respective regional municipalities and then peer reviewed by consultants under the direction of the CTC SPC. The WHPAs have been mapped for all of the following 20 municipal wells in the TRSPA watersheds:

- Caledon East (3 wells);

- Palgrave (3 wells);
- Nobleton (3 wells);
- Kleinburg (2 wells);
- King City (2 wells);
- Whitchurch-Stouffville (5 wells); and
- Uxville (2 wells).

The WHPAs have been incorporated by municipalities into the appropriate Official Plans. For all of the above wells the WHPAs, other than the fixed distance WHPA-A, were estimated based on groundwater modelling that determines where and how far groundwater will flow in an aquifer over a period of time, under permitted pumping conditions. The information required to construct a representative groundwater flow model that will calculate time of travel includes:

- Types, thickness, geometry, and interrelationships between geologic layers;
- Hydraulic properties of geologic layers (*porosity*, *permeability*);
- Rate of groundwater recharge; and
- Interaction of groundwater with streams and lake.

The models were developed using the United States Geological Survey (USGS) code referred to as MODFLOW (three dimensional MODular FLOW modelling system) and MODPATH, a particle-tracking postprocessor model for MODFLOW (Wayne and Harbaugh, 2000). The time of travel associated with WHPA-B through WHPA-D do not necessarily represent a time of travel from the ground surface to the well intake. In many cases, the time of travel associated with WHPA-B through WHPA-D represents the time of travel within the aquifer. The extent of the WHPA is then projected vertically to the ground surface. The WHPA zones determined across the TRSPA are shown together on **Figure 4.5.**

WHPAs A to D were delineated per *Technical Rule 47 (1*) to *(4)* and *Technical Rule 48 (3)*, using three-dimensional flow modelling. This involved the creation of numerical models, as done for the Tier 2 water budget study (see **Chapter 3**). The modelling package used for the analysis varied amongst the municipalities. Most groundwater consultants used the three dimensional MODFLOW modelling system, while others used the Finite element FLOW (FeFLOW) model.

WHPAs A-D for all wells in the TRSPA were delineated through a time of travel assessment, using *backward particle tracking* analysis. Forward particle tracking analysis was used to cross-check the WHPA delineation.

The WHPAs were delineated by pumping each well to *steady state* at rates determined to be the maximum future average annual groundwater demand that can be sustained by the wells. The rates were chosen through consultation with individual municipalities.

Backward particle tracking analysis: A modelling technique where water particles are released at the wellhead, and tracked back to their point of origin. The times-of-travel for particles are assigned based on the location of the originating cell.

Steady state: To determine steady-state capture, every particle is traced back to the location it entered the groundwater system. This represents the complete capture of the well.

4.2.1 WHPA Vulnerability Assessment

For all TRSPA WHPAs, the score for each grid cell was then converted into a value of high, medium, or low, based on thresholds in the *Technical Rules* provided in **Table 4.2**. If the model suggested that flow from a cell never reached the well, the lowest vulnerability score was applied. The WHPA delineations for all of the TRSPA wellfields are presented in more detail below, along with the associated vulnerability scores, based on the SWAT scoring system shown in **Table 4.2.**

The vulnerability maps for the TRSPA's WHPA zones were all based on complex hydrogeologic models. All were developed using a modified Surface to Well Advection Time (SWAT) approach, except for the Uxville wellfield, which was assessed using the ISI approach to vulnerability. The modified approach assumed a zero time-of-travel in the unsaturated zone, as approved by the MOECC Director (**Appendix D3**) as per the *Technical Rule 38(3)*. The original source of all of the geologic and hydrogeologic data for these models was the Conservation Authorities Moraine Coalition (CAMC) geologic model (Version 3) produced in 2006 (Kassenaar and Wexler, 2006). The underlying data and numeric models were updated to account for more recent wells, water level data, and aquifer tests.

Vulnerability within WHPA-E is also assessed using the *Technical Rules* relevant to the IPZ-2. The range of applicable vulnerability scores within the WHPA-E is shown on **Table 4.3**.

For the wellheads within the Region of Peel, the hydrogeologic understanding had to be expanded to the west, since the boundary of existing CAMC model does not include the wellhead areas for Caledon East and Palgrave. For the wellheads in York Region, the CAMC hydrogeologic understanding was enhanced through intensive investigations conducted by York Region.

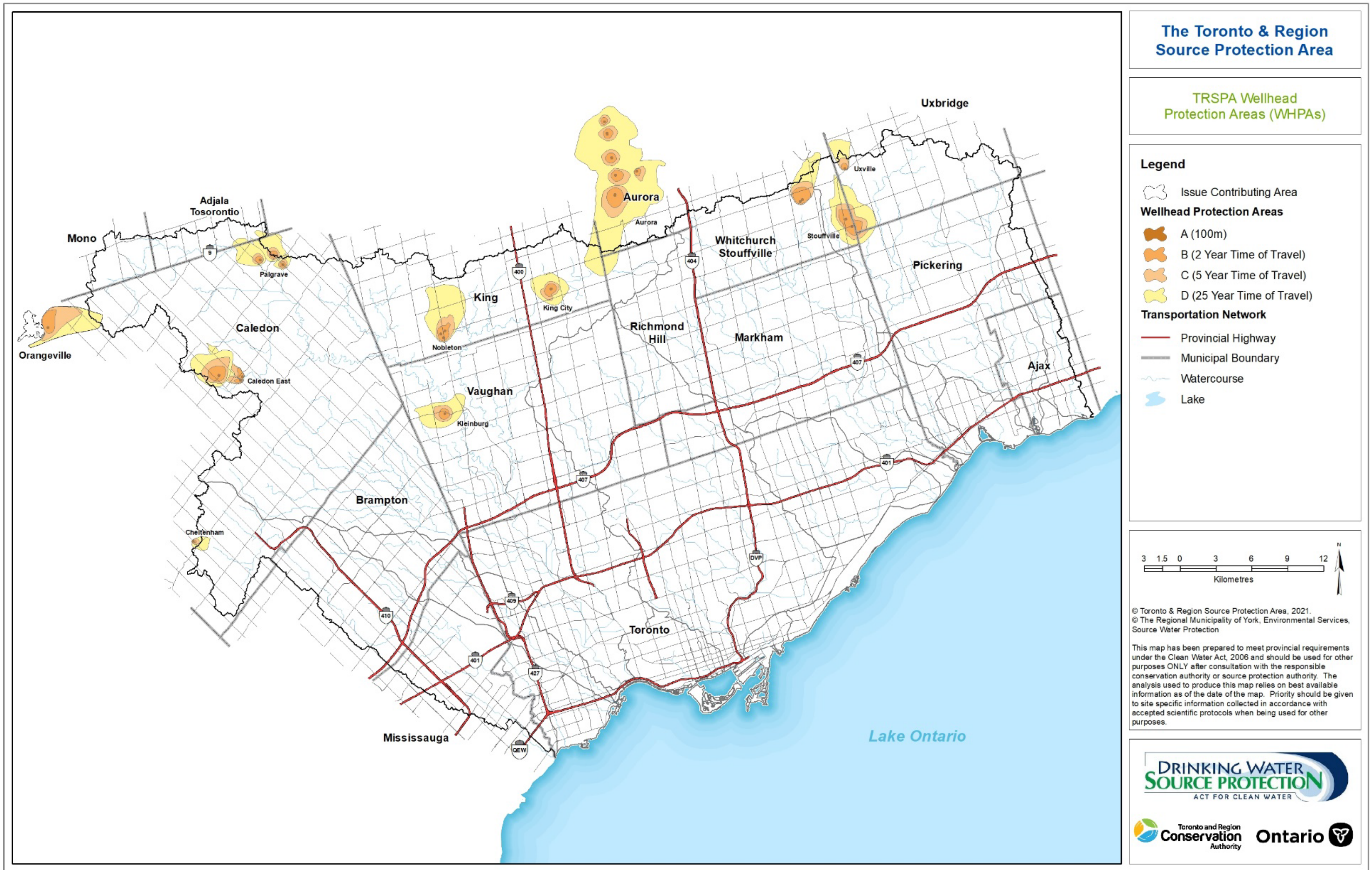

Figure 4.5: TRSPA Wellhead Protection Areas

Table 4.2: Vulnerability Categories and Wellhead Protection Area Vulnerability Scoring

WHPA Zone	Vulnerability Score by SWAT Methodology			Vulnerability Score by (ISI) Methodology		
	Low (>25 years)	Medium (5-25 years)	High (< 5 years)	Low (>80)	Medium (40-80)	High (<40)
Zone A	10	10	10	10	10	10
Zone B	6	8	10	6	8	10
Zone C	2	6	8	4	6	8
Zone D	2	4	6	2	4	6

Table 4.3: Range of Vulnerability Scores in Wellhead Protection Area E

WHPA E	Range of Vulnerability Scores
Inland Lakes	5.6, 6.3, 6.4, 7.0, 7.2, 8.0, 8.1, 9.0
Inland Rivers and Streams	6.3, 7.0, 7.2, 8.0, 8.1, 9.0

4.2.2 Transport Pathways

The *Technical Rules* allow for adjustments to the vulnerability scoring to account for the presence of transport pathways. Examples of potential pathways include subsurface utilities, aggregate operations, and clusters of private water wells. Adjustments to the vulnerability to account for the presence of transport pathways were considered.

Subsurface Utilities

Information on the location of sewers and other subsurface utilities was reviewed. Where a utility was thought to represent a possibility of becoming a transport pathway the vulnerability rating of the underlying aquifer was increased to the next category.

Aggregate Operations

Information on the locations, and status of aggregate operations was reviewed. Aggregate operations may create or enhance a transport pathway to groundwater increasing the vulnerability of the aquifer.

Water Wells

Domestic water wells are the most common transport pathway in rural areas. Improper construction can potentially introduce a cumulative impact to drinking water sources, especially when the casing deteriorates. If the well is no longer in use, improper abandonment also provides a pathway for a contaminant to impact a drinking water source.

A review of the MOECC WWIS was undertaken to identify older, unused domestic wells. However, as many are decades old, it is not known if their status has been updated in the WWIS since being drilled, if they still exist, or if they have been decommissioned. Also, the *Technical Rules* do not provide guidance on how they should be considered. As a result, different consultants have applied a wide range of assumptions and standards in their assessments.

An analysis was applied to assess the effect of clusters of water wells as transport pathways. The methodology that was applied is described in **Appendix D4**. Based on this analysis, the CTC SPC opted against the inclusion of such pathways since the unreliability of the database used and the high uncertainty associated with the analyses were too high to defend in a reasonable manner. The adjustments considered across the TRSPA are discussed by wellfield, below.

4.3 REGION OF PEEL – TOWN OF CALEDON EAST AND PALGRAVE

The communities of Caledon East and Palgrave are located at the headwaters of the Humber River in the TRSPA. The Region of Peel operates one groundwater-based municipal drinking water supply system within the TRSPA. The system includes:

- Caledon East (3 wells); and
- Palgrave (3 wells).

Palgrave has one wellhead located north of the TRSPA, but is included because the WHPAs extend into the TRSPA, **Figure 4.5.** An additional system is also located in Cheltenham, where the wellhead is located in the CVSPA, but the WHPA zones extend into the TRSPA. The WHPA zones for a Town of Orangeville well also extend into the TRSPA. The vulnerability analysis, scoring, and threats analysis for the Cheltenham and Orangeville systems are included in the *Updated Assessment Report: CVSPA*.

4.3.1 Geological Setting

Caledon East Well 3 is screened in the Oak Ridges Aquifer, and wells 4 and 4A are screened in the Thorncliffe Aquifer. Palgrave Well 2 is screened in the Oak Ridges Aquifer, while Well 3 and Well 4 are screened in the Thorncliffe Aquifer.

4.3.2 Data Sources and Study Methodology

The scoring methodology for all of the Peel well systems was based on the numerical flow model using the Surface-to-Well advection time based on forward particle tracking. Because of uncertainties in modelling groundwater flow in the unsaturated zone, and to ensure that the values were conservative a travel time of “zero” was assumed above the water table.

The modelling for the Caledon East wellfield was completed by Earthfx Inc. in 2007 and 2008, using a MODFLOW-based groundwater flow model which was discussed in **Chapter 2** of this report (Earthfx, 2007a; Earthfx 2008b). This model, known as the “West Model” was based on a groundwater model developed for the Oak Ridges Moraine by the YPDT groundwater management study team in 2006 and was peer reviewed by AMEC Earth and Environmental in 2009 (AMEC, 2010). WHPA delineations and vulnerability scoring for CE-4A was completed by Matrix Solutions Inc. (Matrix 2018; Matrix 2015).

The modelling for the Palgrave wellfield was completed by Earthfx Inc. in 2007 and 2008 (Earthfx 2007a; Earthfx, 2008) and was peer reviewed by AMEC Earth and Environmental in 2009 (AMEC, 2010). The model and methodology used were the same as the Caledon East wellfield.

Documents published prior to 2015 have been subject to extensive peer review by a panel of municipal representatives, private consultants, and the TRCA prior to acceptance by the CTC SPC, and inclusion in this *Updated Assessment Report: TRSPA*. Reports prepared after 2015 to amend the Assessment Report to reflect wells being brought on-line were at a minimum reviewed by a qualified professional. The following is a summary of these reports. Technical information on model construction and calibration are summarized in the foundation reports referenced above.

4.3.3 Caledon East WHPA A-D Delineation and Vulnerability Scoring

The groundwater flow rate calculations were based on reverse particle tracking from each well under maximum permitted pumping conditions. Although the wells are not currently pumping at their permitted rates, the flow rates were considered to be a reasonable estimation of potential future water use, given the rapidly growing population in this area. The vulnerability scores were assigned to the respective WHPA zones based on the values in **Table 4.2**. **Figure 4.6** illustrates the WHPA delineations, while **Figure 4.7** provides the vulnerability assessment and **Figure 4.8** illustrates the final vulnerability scores for all wells in the Caledon East wellfield.

4.3.4 Palgrave WHPA A-D Delineation and Vulnerability Scoring

The Palgrave WHPAs were determined concurrently with those for Caledon East, by the same consultant with the same numerical model. The resultant WHPAs are shown on **Figure 4.9**, while the vulnerability is shown on **Figure 4.10** and the vulnerability scores are shown in **Figure 4.11**.

4.3.5 Transport Pathways

Although a transport pathway adjustment was considered for the Caledon East wellfield to account for a large diameter sanitary sewer that crosses into the WHPA-A for Well 3, the area was already considered high vulnerability, so no adjustment was made. No transport pathway adjustment was required for the Palgrave wells.

4.3.6 Uncertainty Assessment

WHPAs A-D for the Region of Peel wells were delineated through the use of complex numerical models based on the best available hydrogeologic data. These studies benefited from the most recent enhancement of the conceptual, hydrostratigraphic and numerical models of the area, and represent the most recent refinements in the numerical modelling for headwaters area of the Humber Watershed.

The dimensions and vulnerability scoring of WHPA-A, are set within the *Technical Rules*. With the other WHPAs, however, there is an intrinsic level of uncertainty in the analysis, given the complexity of the study area and the limited data available in some areas. The vulnerability assessment also has a certain level of uncertainty associated with it.

Uncertainty associated with Peel's wellfield assessments is found in **Table 4.4**, and further discussed in **Appendix D**. The uncertainty is summarized as follows:

- The WHPAs were delineated with a regional scale model with good calibration. A sensitivity analysis was completed to account for variation in model parameters. The uncertainty in the WHPAs is low.
- Considering the variability in the density of the data used to create the AVI mapping and that the well database has inherent uncertainty, the vulnerability mapping of the area is considered to have high uncertainty.

Table 4.4: Uncertainty Assessments - Region of Peel

Well	Uncertainty Type	Level of Uncertainty				
		WHPA-A	WHPA-B	WHPA-C	WHPA-D	WHPA-E
Caledon East	Delineation of WHPA	Low	Low	Low	Low	n/a
	Vulnerability Score	Low	Low	Low	Low	n/a
	Overall – Vulnerability Scores	**Low**	**Low**	**Low**	**Low**	**n/a**
Palgrave	Delineation of WHPA	Low	Low	Low	Low	n/a
	Vulnerability Score	Low	Low	Low	Low	n/a
	Overall – Vulnerability Scores	**Low**	**Low**	**Low**	**Low**	**n/a**

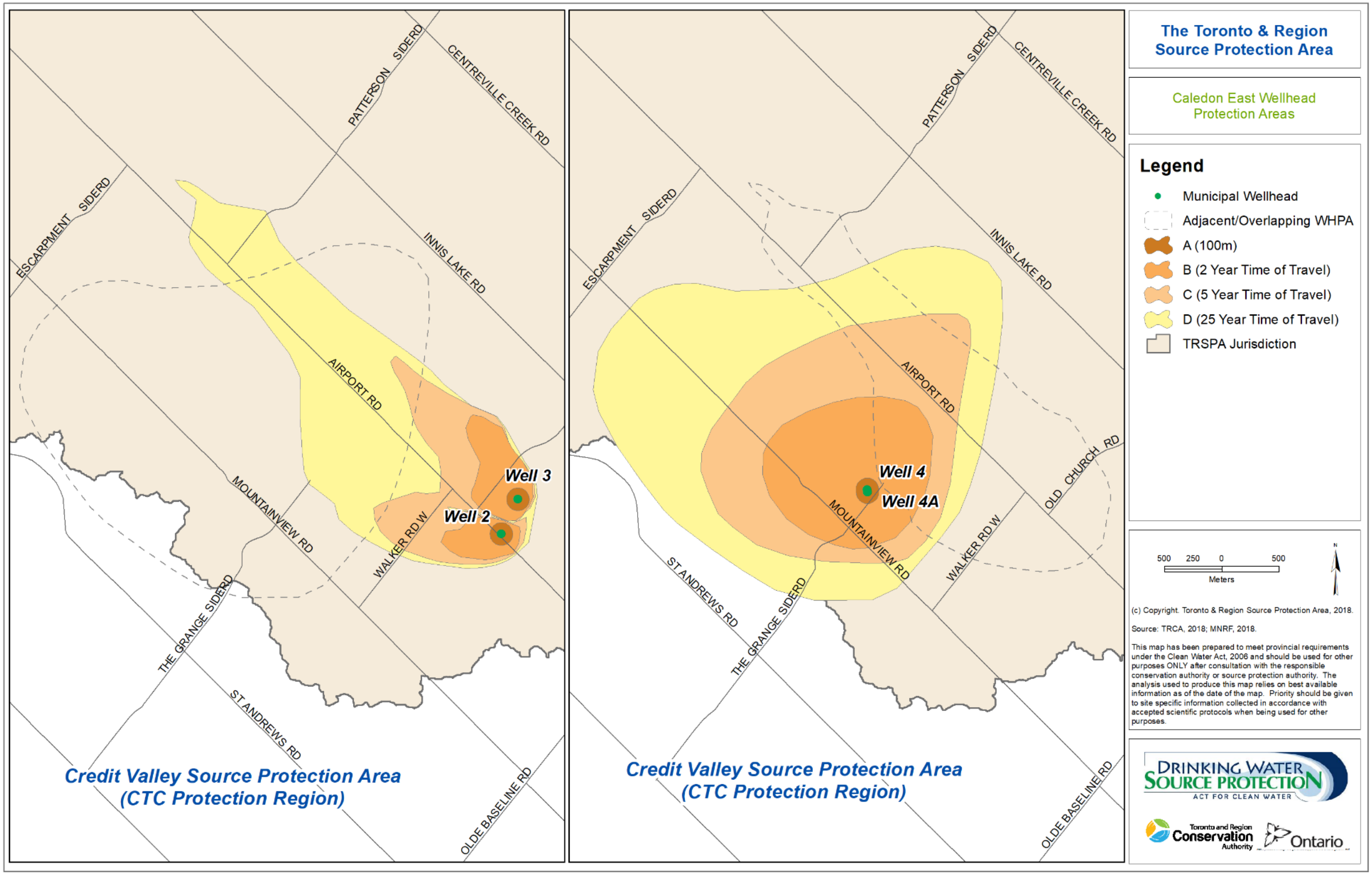

Figure 4.6: Caledon East Wellhead Protection Areas

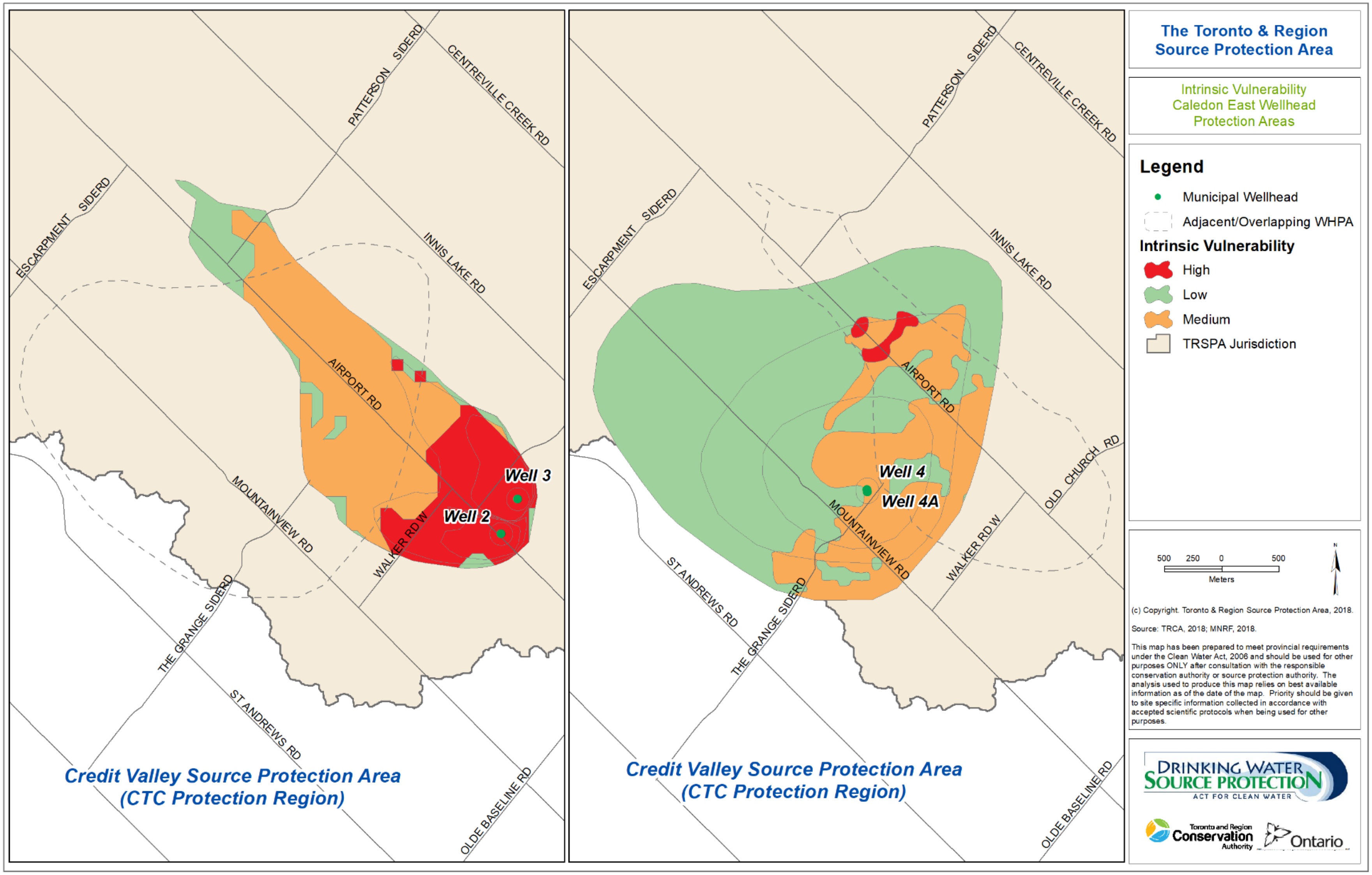

Figure 4.7: Intrinsic Vulnerability - Caledon East Wellhead Protection Area

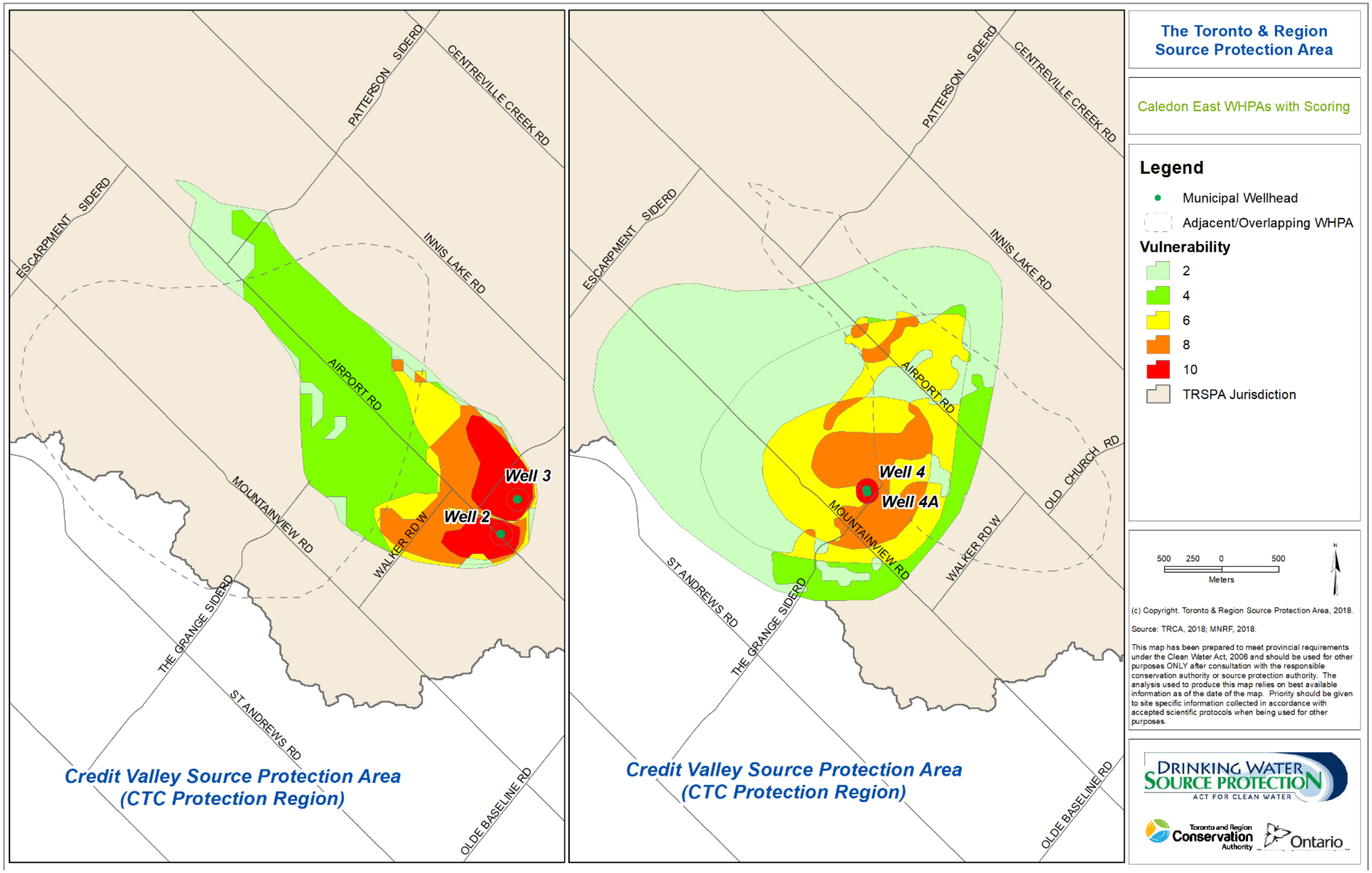

Figure 4.8: Caledon East Wellhead Protection Areas with Scoring

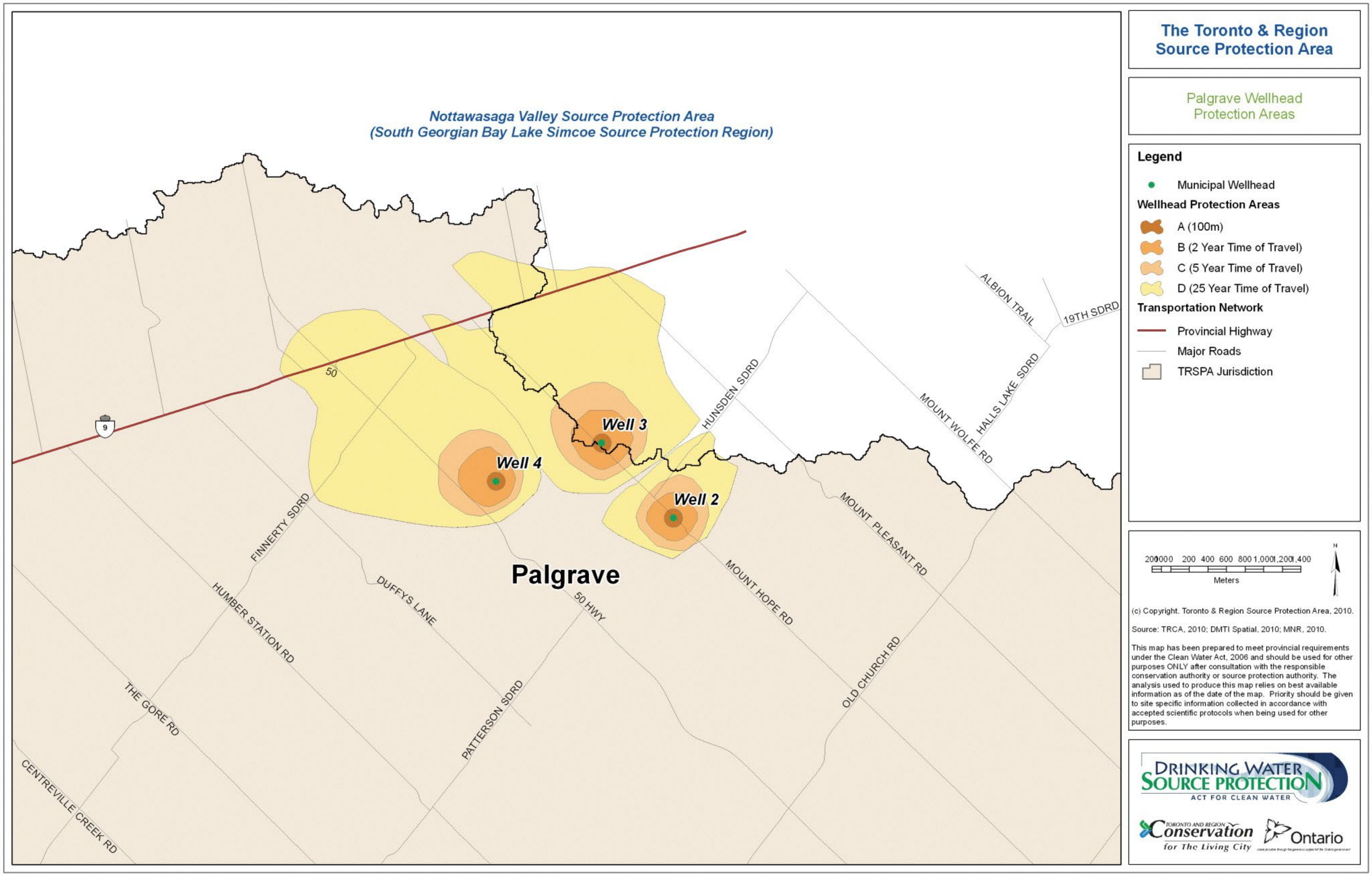

Figure 4.9: Palgrave Wellhead Protection Areas

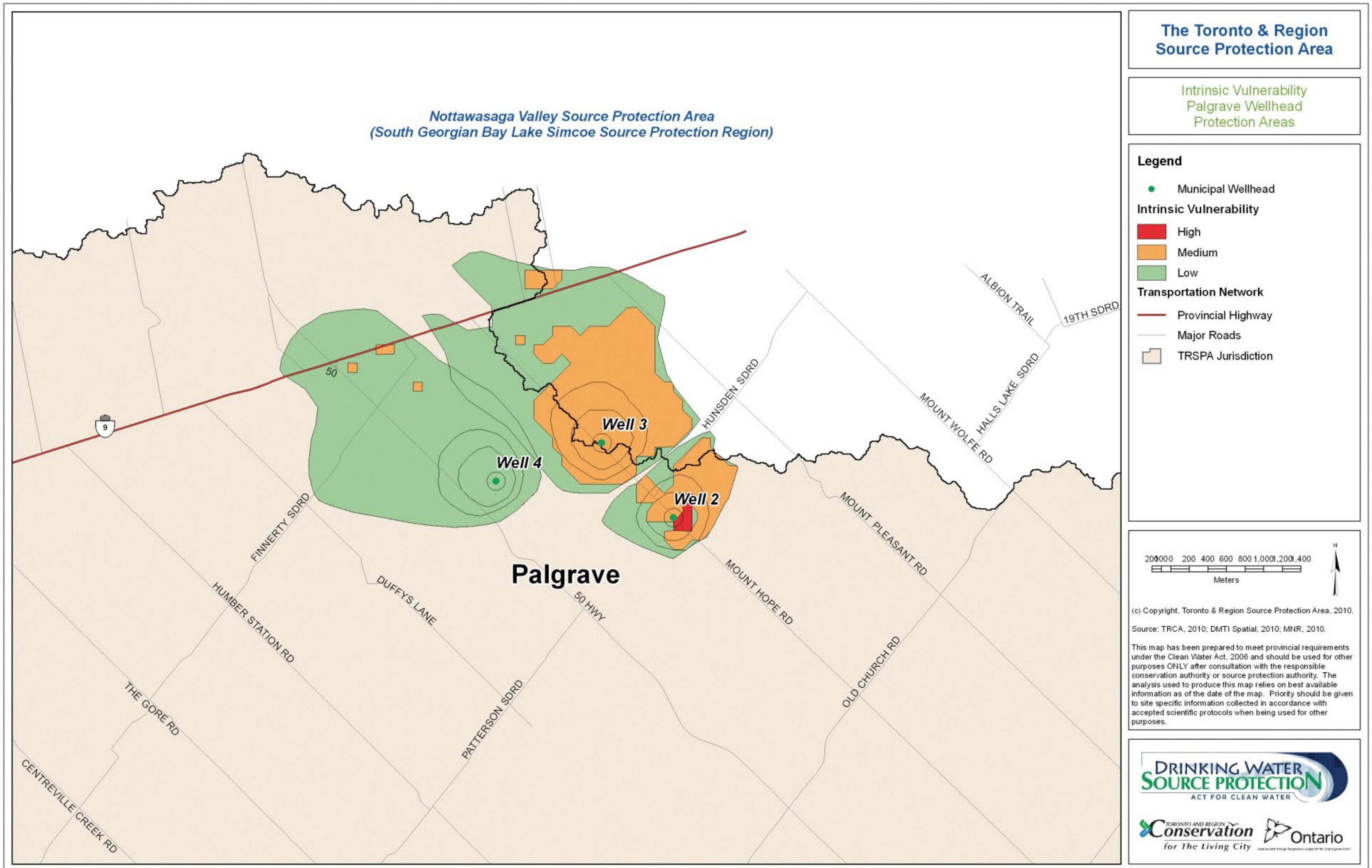

Figure 4.10: Intrinsic Vulnerability Palgrave Wellhead Protection Area

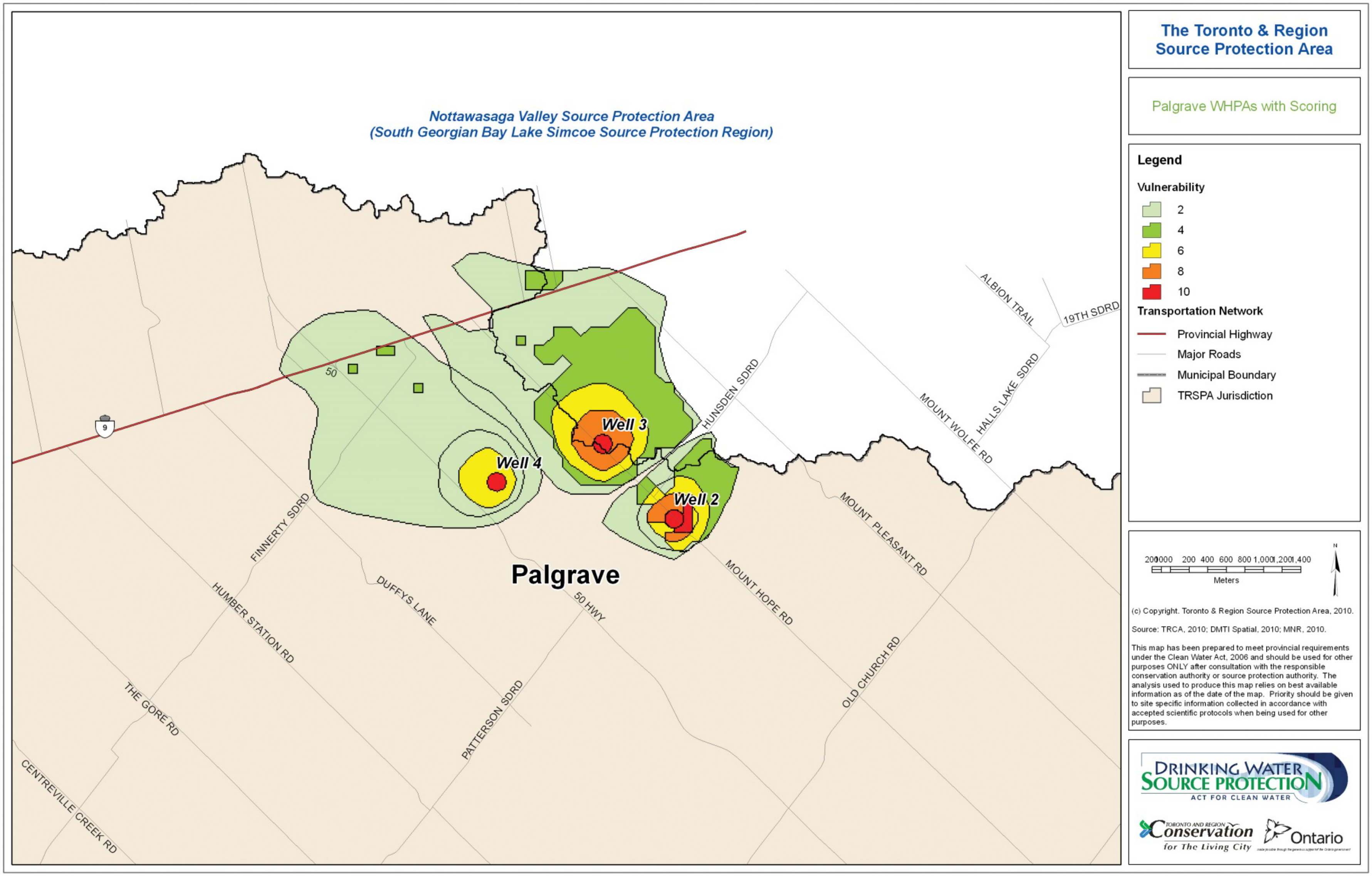

Figure 4.11: Palgrave Wellhead Protection Areas with Scoring

4.4 YORK REGION – TOWNS OF NOBLETON, KLEINBURG, KING, AND WHITCHURCH-STOUFFVILLE

4.4.1 Geological Setting

York Region operates four groundwater-based municipal drinking water supplies within the TRSPA. These systems include:

- Nobleton (3 wells);
- Kleinburg (2 wells);
- King City (2 wells); and
- Whitchurch-Stouffville (5 wells).

These systems are located in the headwaters of the Humber River System, with the exception of Whitchurch-Stouffville, which is in the headwaters of both the Rouge River and Duffins Creek watersheds. All of the wells are screened in the overburden, with depths ranging up to 100 m below grade. Further details on the setting for each wellfield are provided below.

The wells for York Region's Aurora-Newmarket wellfield are located in the South Georgian Bay – Lake Simcoe Source Proteciton Region, outside of the Toronto and Region Source Proteciton Area. However, the wellhead protection area for Aurora well 7 extends into TRSPA and is shown on **Figure 4.5**. The part of the wellhead protection area that extends into TRSPA has a vulnerability score of 2 (low).

4.4.2 Data Sources and Study Methodology

The vulnerability scoring methodology for all four systems was based on a complex numerical groundwater flow model using the Surface-to-Well advection time with forward particle tracking. Because of uncertainties in modelling groundwater flow in the unsaturated zone, and to ensure that the values were conservative a travel time of "zero" was assumed above the water table, as approved by the MOECC Director (letter in **Appendix D3**) under *Technical Rule 38(3).* Therefore, the numerical method applied was sufficiently conservative that transport pathway adjustment was not required.

The groundwater modelling was completed by Earthfx Inc. in 2009 using a MODFLOW-based groundwater flow model (Earthfx, 2009b). The model was based on a groundwater model, the Core Model, developed for the Oak Ridges Moraine by the YPDT study team in 2006 (Kassenaar and Wexler, 2006), and peer reviewed by Conestoga Rovers and Associates in 2010 (CRA, 2010). Technical information on model construction and calibration are summarized in the foundation reports referenced above. Foundational documents have been subject to extensive peer review by a panel of municipal representatives, private consultants, and the TRCA prior to acceptance by the CTC SPC, and inclusion in this Assessment Report. The following is a summary of these reports.

WHPAs A-D were delineated through particle tracking analysis, pumping each well to steady state at rates determined with the town to be the maximum future average annual groundwater demand that can be sustained by the wells.

4.4.3 Nobleton WHPA Delineation and Vulnerability Scoring

The Regional Municipality of York operates three wells in Nobleton that are screened in the Scarborough Formation or Aquifer and are permitted for producing about 3,500 m^3 of water per day. The groundwater flow calculations were based on reverse particle tracking from each well under maximum permitted pumping conditions. Alternative scenarios with single well pumping at the maximum wellfield rate were also conducted to ensure that the capture zones would include these variations. Although the wells are not currently pumping at their permitted rates, the flow rates were considered to be a reasonable estimation of potential future water use, given the rapidly growing population in this area. Based on professional judgment by York Region staff, with the concurrence of the peer reviewers, no transport pathway adjustments were made for these wells. The resultant WHPA map is shown on **Figure 4.12**, while the vulnerability is shown on **Figure 4.13.** The vulnerability scores for the all three wells in the Nobleton wellfield is shown on **Figure 4.14**.

The vulnerability scoring was completed using the same methodology as for the Region of Peel municipal water systems described above.

4.4.4 Kleinburg WHPA Delineation and Vulnerability Scoring

The Regional Municipality of York operates two wells in Kleinburg, with an average yield close to 1,000 m^3 of water per day. All of the water is drawn from the Scarborough Aquifer (Marshall, Macklin, Monaghan, 2006).

Modelling was completed by Earthfx Inc. in 2009 using a MODFLOW-based groundwater flow model (Earthfx, 2009). This model was based on the YPDT groundwater flow model discussed above and was peer reviewed by Conestoga Rovers and Associates in 2010 (CRA, 2010).

The groundwater time of travel (TOT) calculations were based on reverse particle tracking from each well under maximum permitted pumping conditions. Alternative scenarios with single well pumping at the maximum wellfield rate were also conducted to ensure that the capture zones would include these variations. Although the wells are not currently pumping at their permitted rates, the flow rates were considered to be a reasonable estimation of potential future water use, given the rapidly growing population in this area.

No transport pathway adjustments were made for these wells. The resultant WHPA map is shown on Figure 4.15, while the vulnerability is shown on **Figure 4.16**. The vulnerability scores is shown on **Figure 4.17**.

4.4.5 King City WHPA Delineation and Vulnerability Scoring

King City currently has two operating wells that produce about 2,000 m^3 of water per day. Both of these wells are screened in the Thorncliffe Aquifer (Marshall Macklin Monaghan Limited, 2006). The modelling work was completed by Earthfx Inc. in 2009 using a MODFLOW-based groundwater flow model (Earthfx, 2009). This model was based on the YPDT groundwater flow model discussed above and was peer reviewed by Conestoga Rovers and Associates in 2010 (CRA, 2010).

The groundwater TOT calculations were based on reverse particle tracking from each well under maximum permitted pumping conditions. Alternative scenarios with single well pumping at the maximum wellfield rate were also conducted to ensure that the capture zones would include these variations. Although the wells are not currently pumping at their permitted rates, the flow rates were considered to be a reasonable estimation of potential future water use, given the rapidly growing population in this area.

No transport pathway adjustments were made for these wells. The resultant WHPA map is shown on **Figure 4.18**, while the vulnerability is shown on **Figure 4.19** and the final vulnerability scores for the King City wellfield are shown on **Figure 4.20**.

4.4.6 Whitchurch-Stouffville WHPA Delineation and Vulnerability Scoring

Data provided by the Regional Municipality of York showed that the average annual groundwater taking from the five Stouffville wells presently totals over 5,500 m^3 of water per day (Marshall MacklinMonaghan Limited, 2006). Stouffville groundwater withdrawals are from the Oak Ridges Aquifer (Wells 3, 5, and 6) and the Thorncliffe Aquifer (Wells 1 and 2).

Modelling was completed by Earthfx Inc. in 2009 using a MODFLOW-based groundwater flow model (Earthfx, 2009). This model was based on the YPDT groundwater flow model discussed above and was peer reviewed by Conestoga Rovers and Associates in 2010 (CRA, 2010). The groundwater TOT calculations were based on reverse particle tracking from each well under maximum permitted pumping conditions. The resultant WHPA map is shown on **Figure 4.21**, while the mapping of vulnerability is shown on **Figure 4.22**. The final map showing the vulnerability scores for the Whitchurch-Stouffville wellfield is shown on **Figure 4.23**.

4.4.7 Uncertainty Assessment

The dimensions of WHPA-A and the vulnerability scoring are set within the *Technical Rules* (. Delineating WHAP-B, C, and D includes an intrinsic level of uncertainty in the analysis given the complexity of the study area and data gaps in certain instances. The vulnerability scoring also has a certain level of uncertainty associated with it. The overall uncertainty associated with York Region's wellfield assessments is found in **Table 4.5**, and further discussed in **Appendix D**. The uncertainty can be summarized as follows:

- The WHPAs were delineated with a sub-regional scale model and had good calibration. A sensitivity analysis was completed to account for variation in model parameters. The uncertainty in the WHPAs is low.
- The surface-to-well advection time was undertaken in a conservative manner, and therefore, the vulnerability scoring is considered to have low uncertainty.

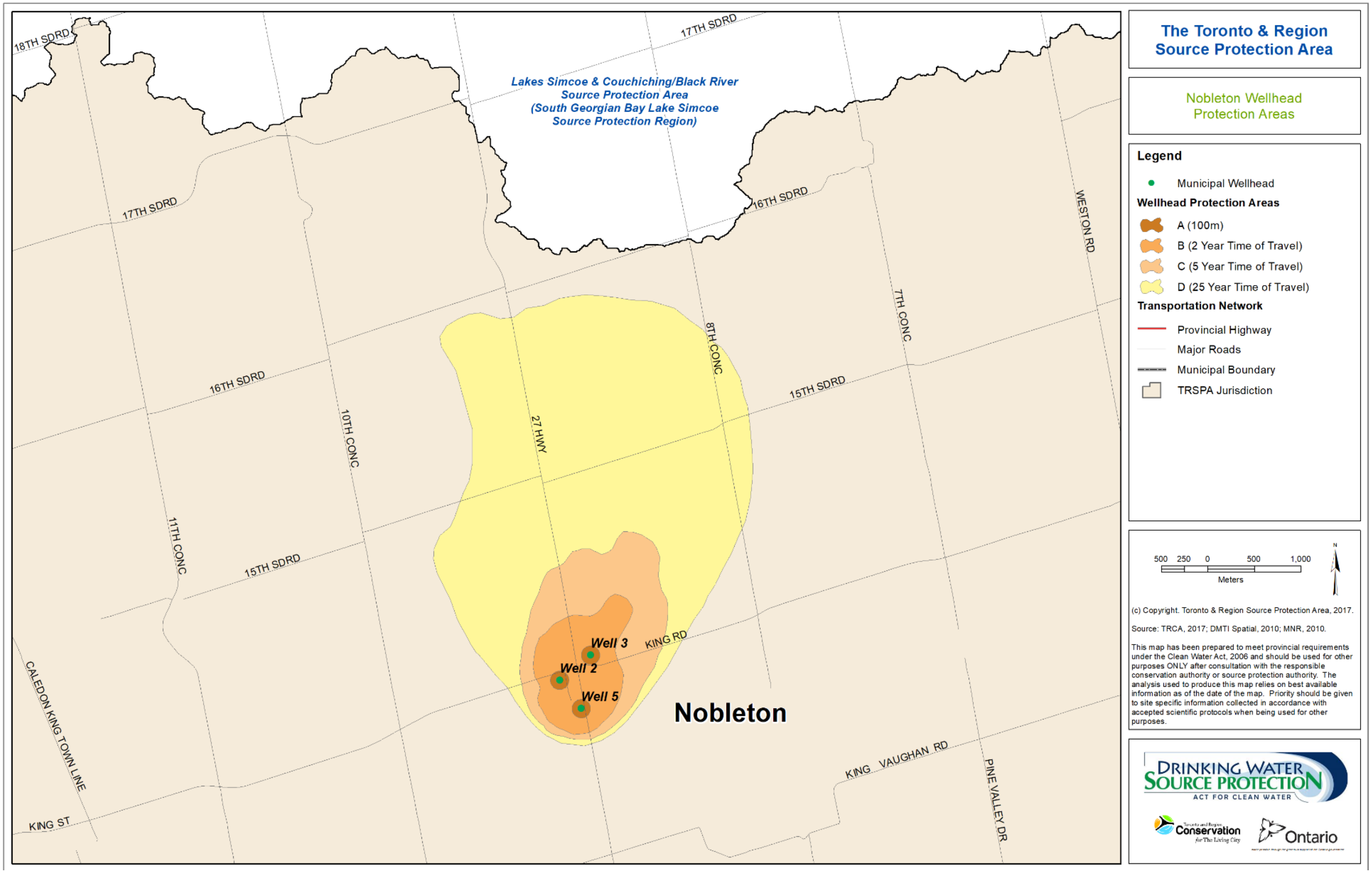

Figure 4.12: Nobleton Wellhead Protection Areas

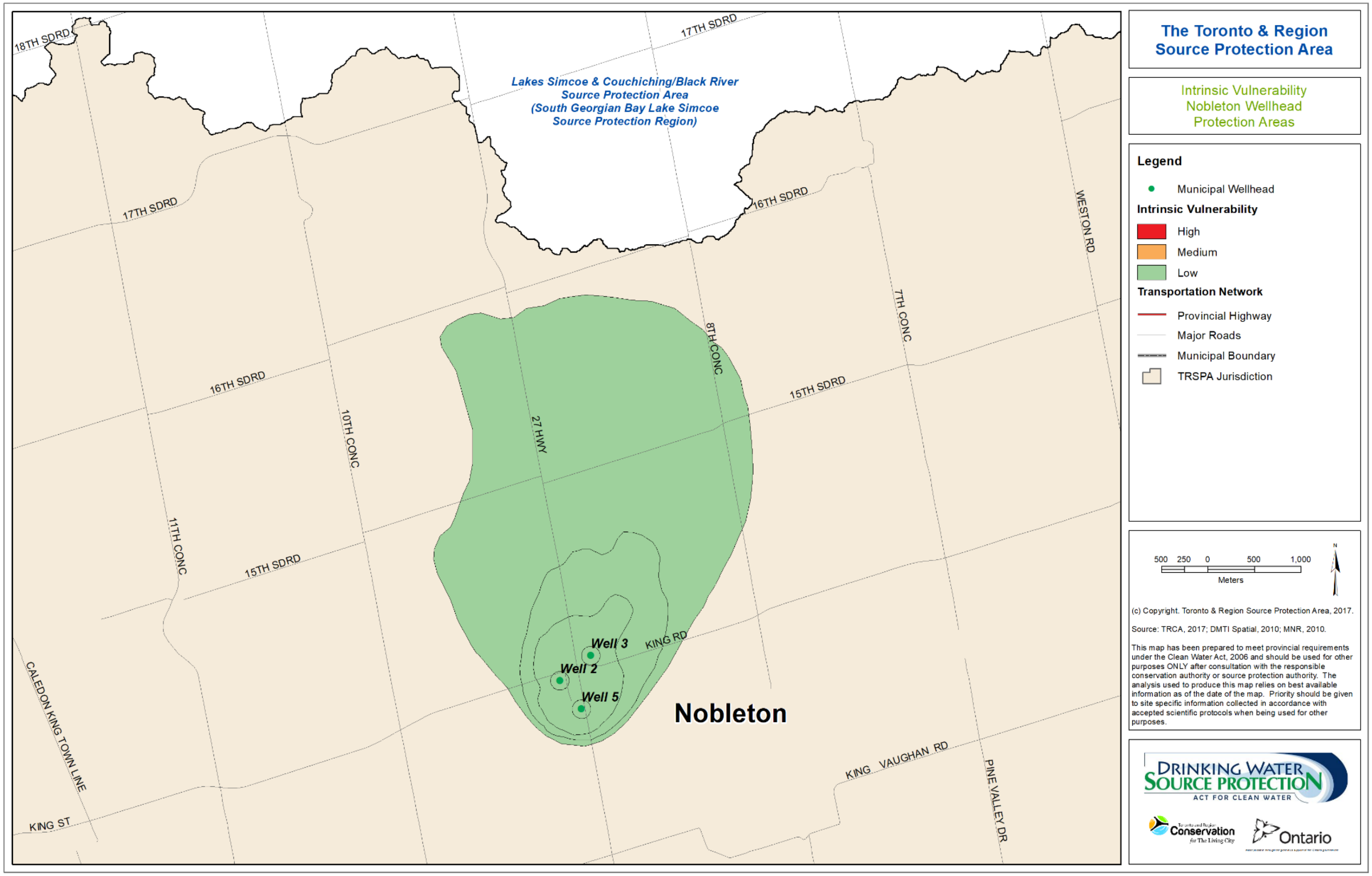

Figure 4.13: Intrinsic Vulnerability Nobleton Wellhead Protection Area

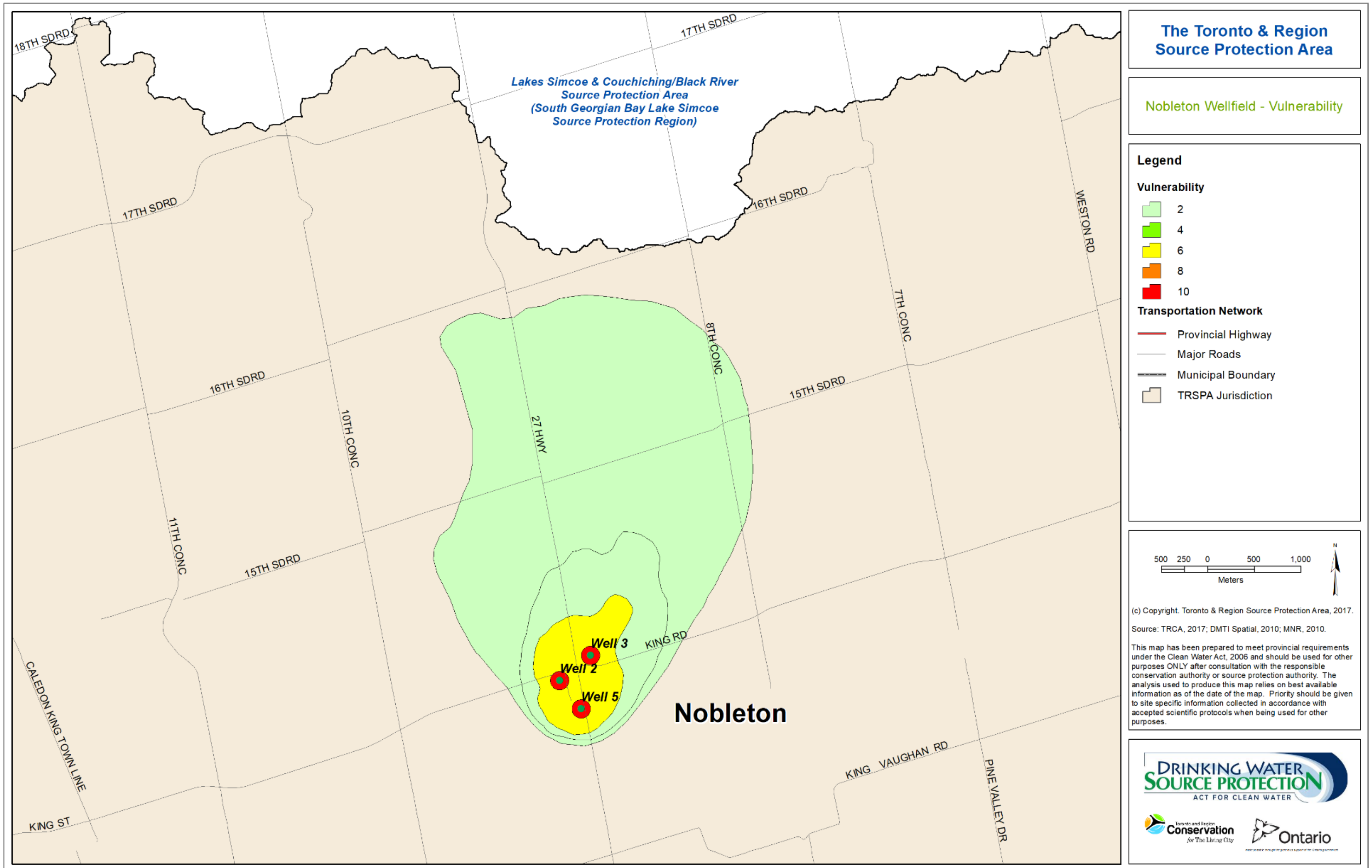

Figure 4.14: Nobleton Wellhead Protection Areas with Scoring

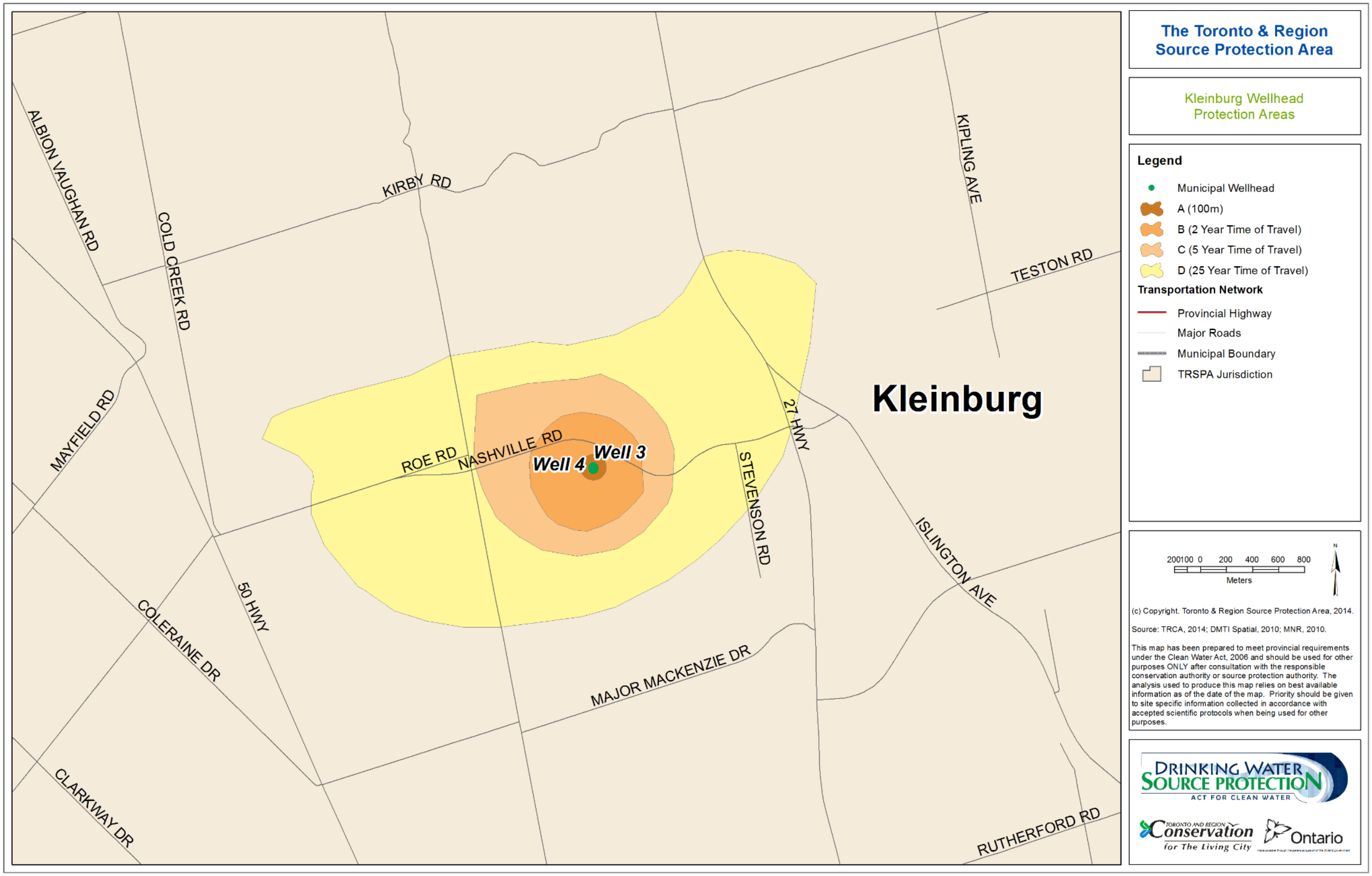

Figure 4.15: Kleinburg Wellhead Protection Areas

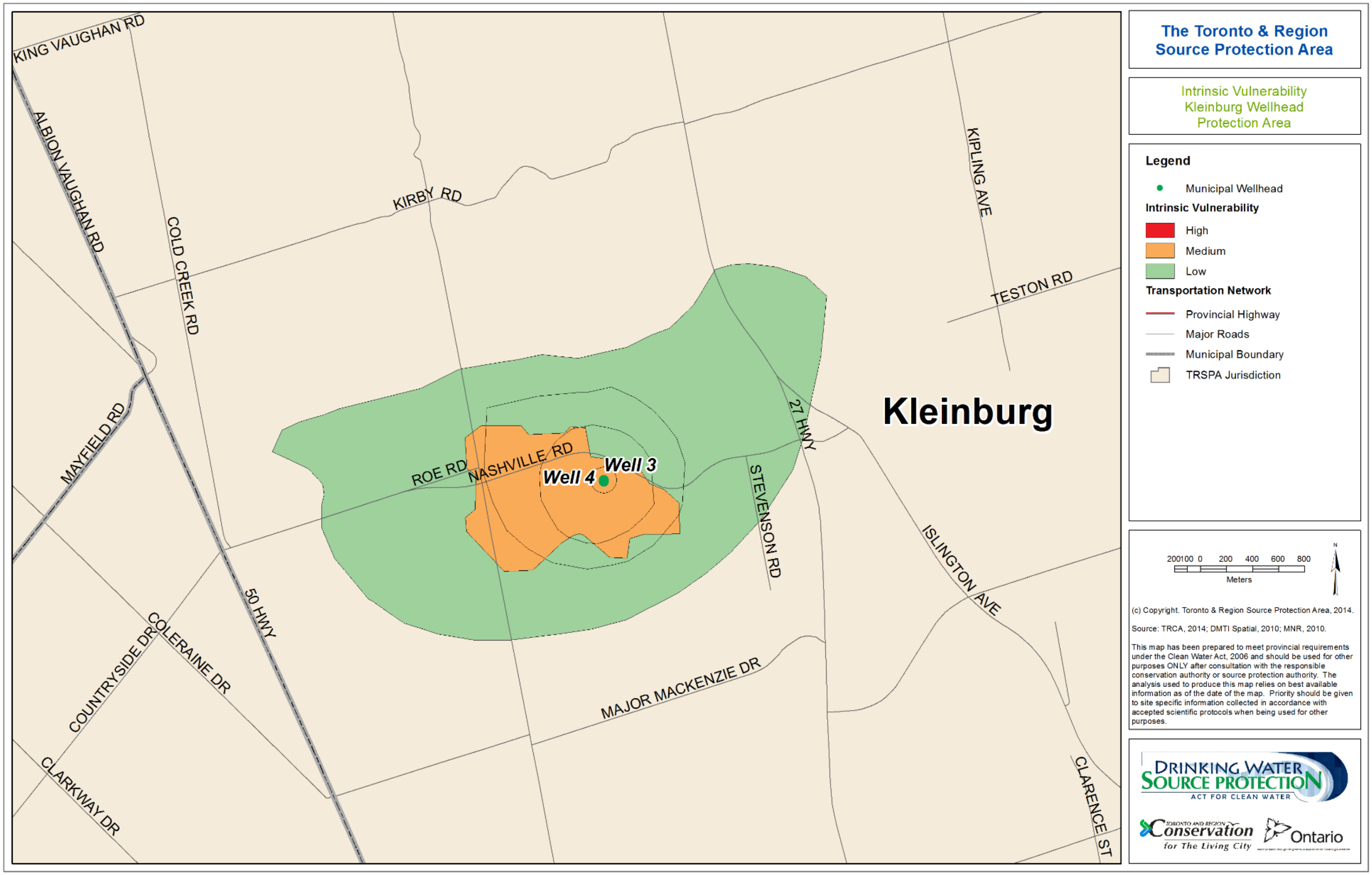

Figure 4.16: Intrinsic Vulnerability Kleinburg Wellhead Protection Area

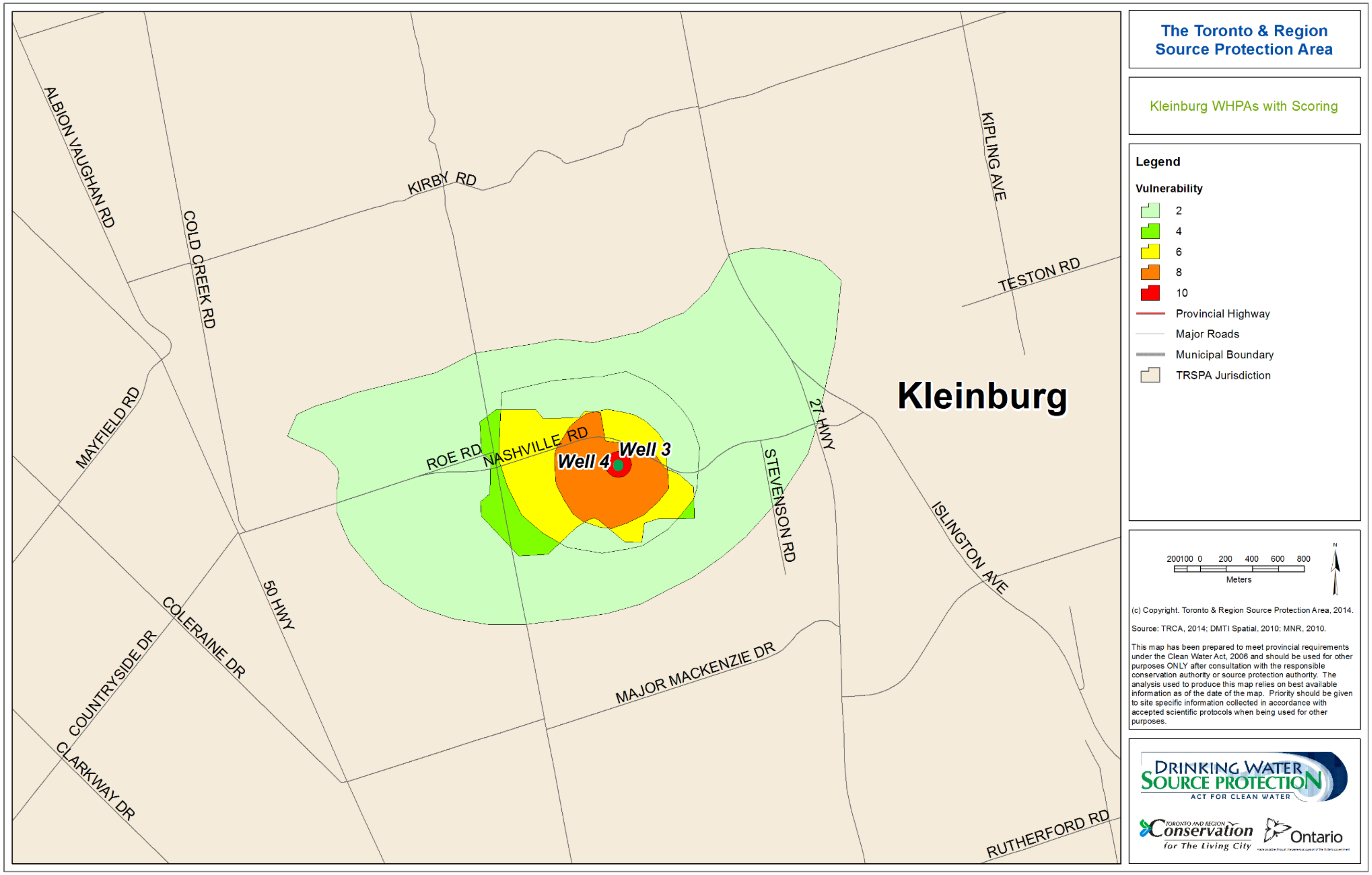

Figure 4.17: Kleinburg Wellhead Protection Areas with Scoring

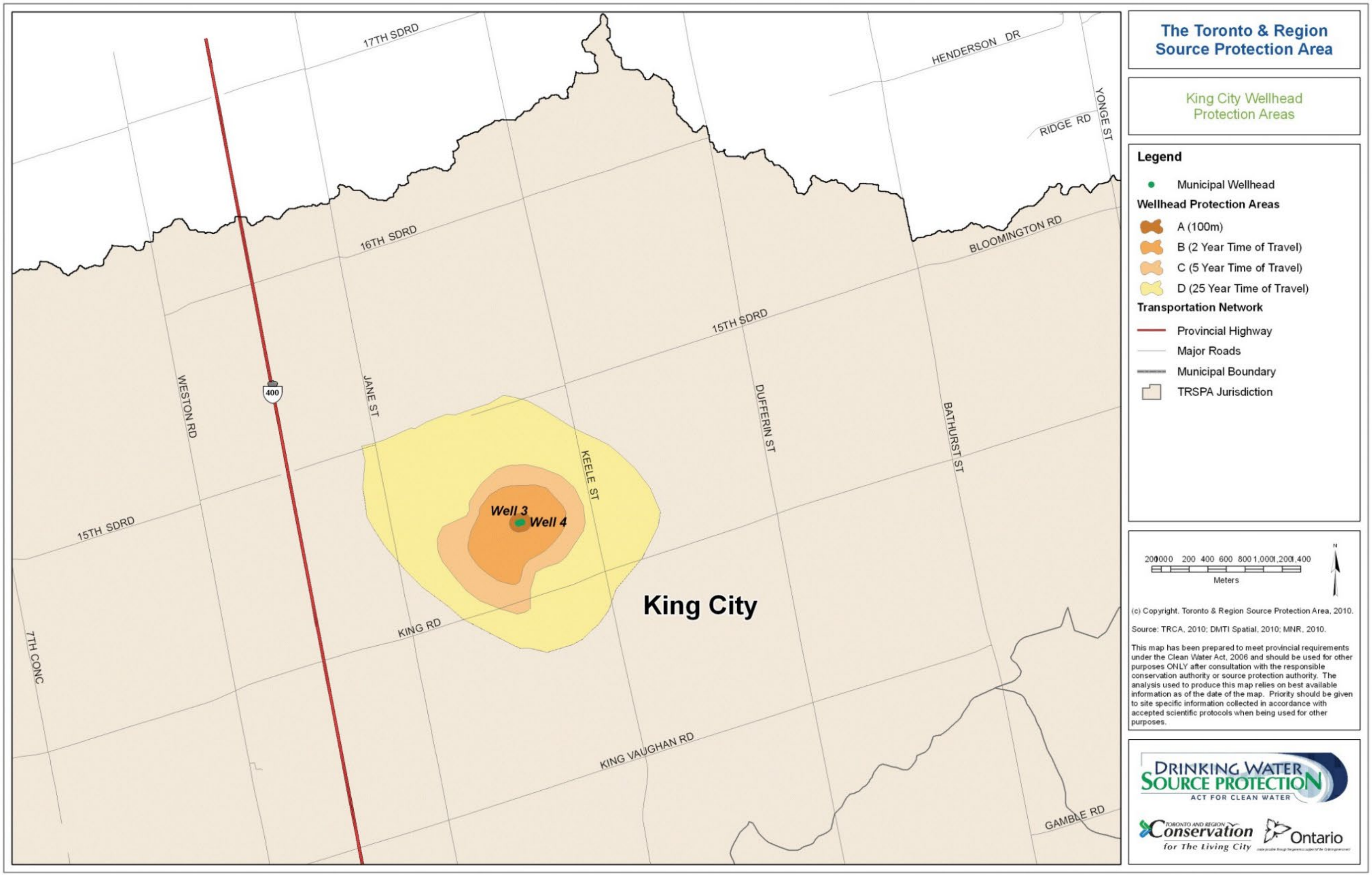

Figure 4.18: King City Wellhead Protection Areas

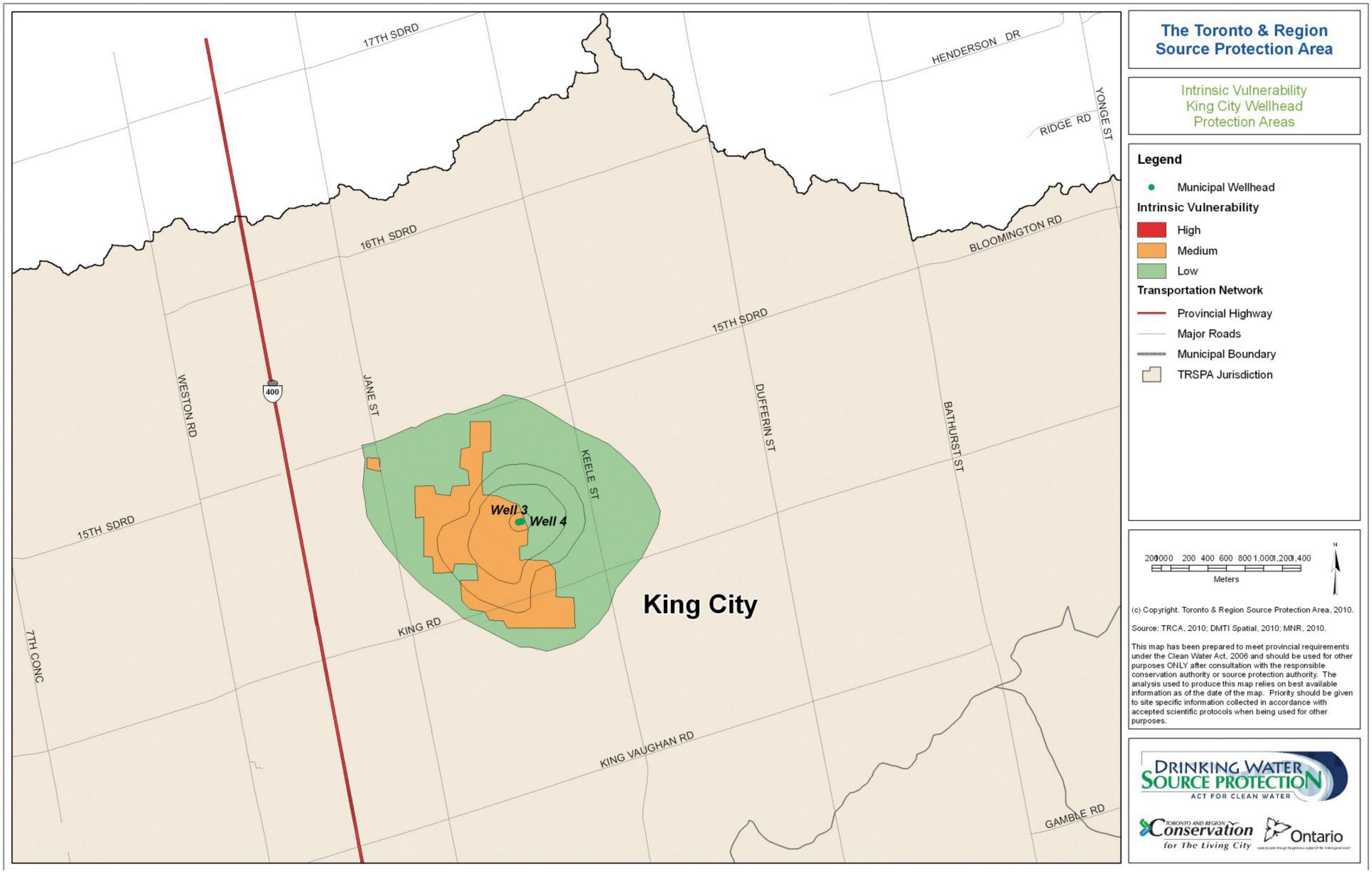

Figure 4.19: Intrinsic Vulnerability King City Wellhead Protection Area

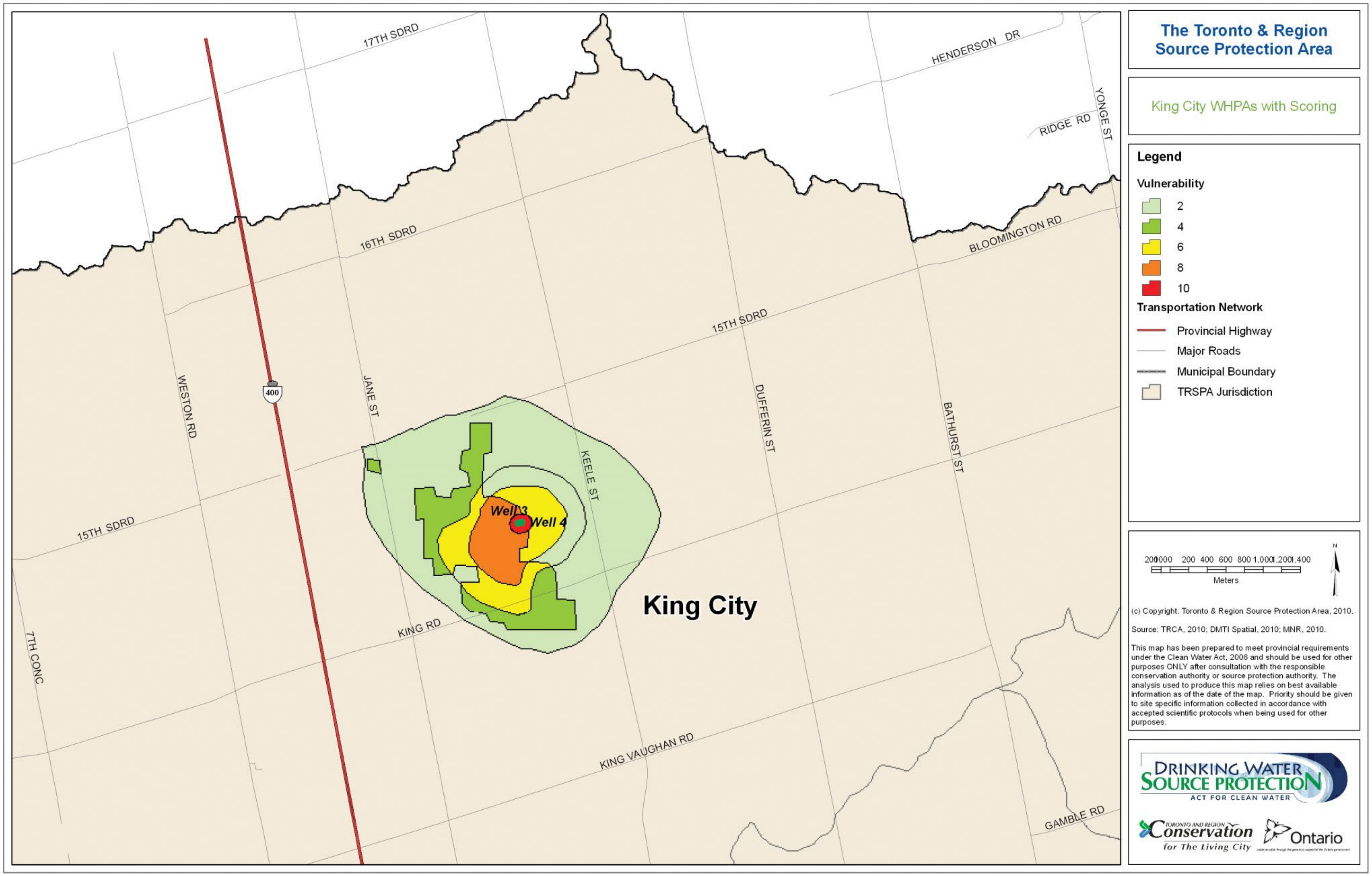

Figure 4.20: King City Wellhead Protection Areas with Scoring

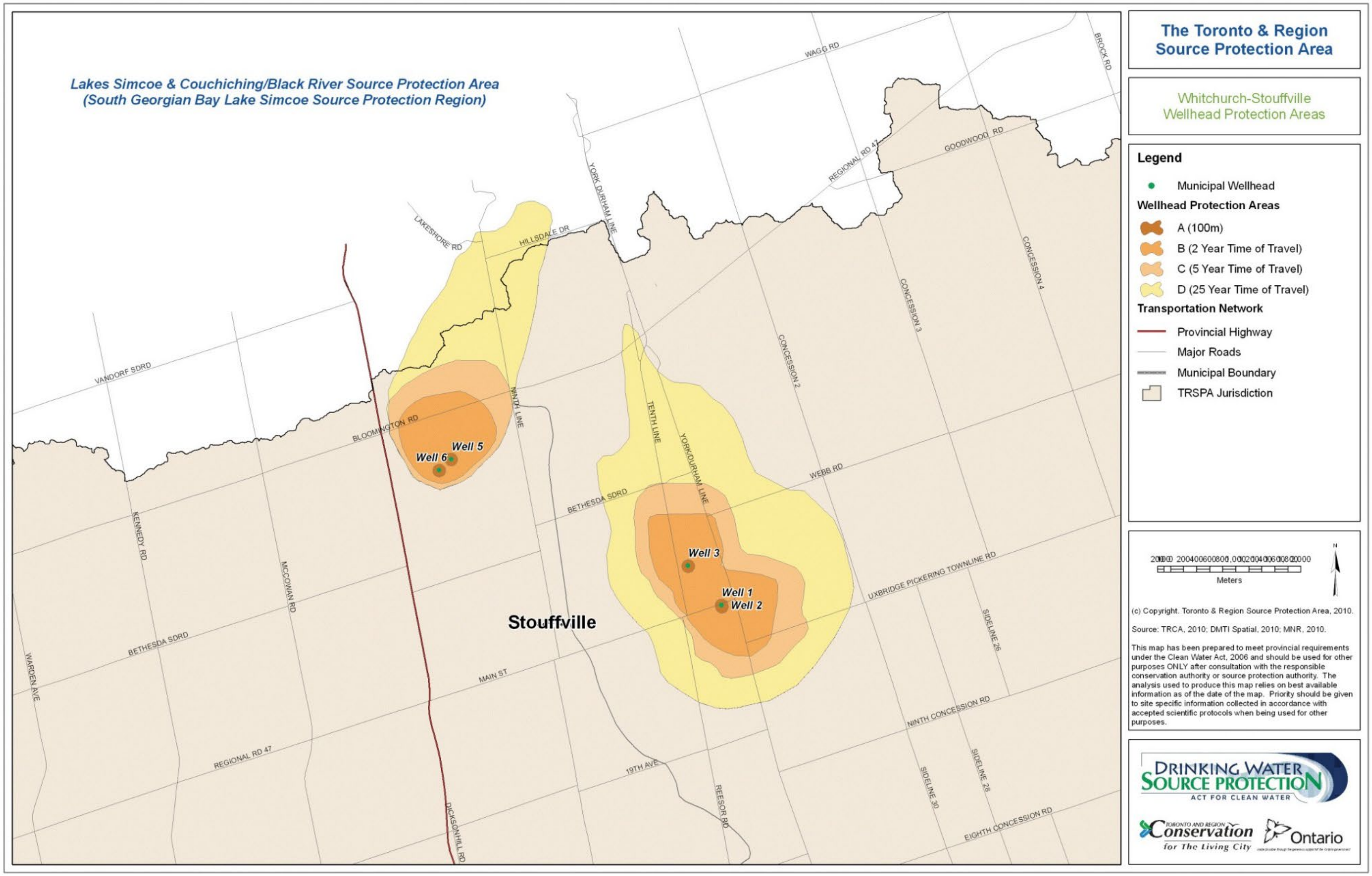

Figure 4.21: Whitchurch-Stouffville Wellhead Protection Areas

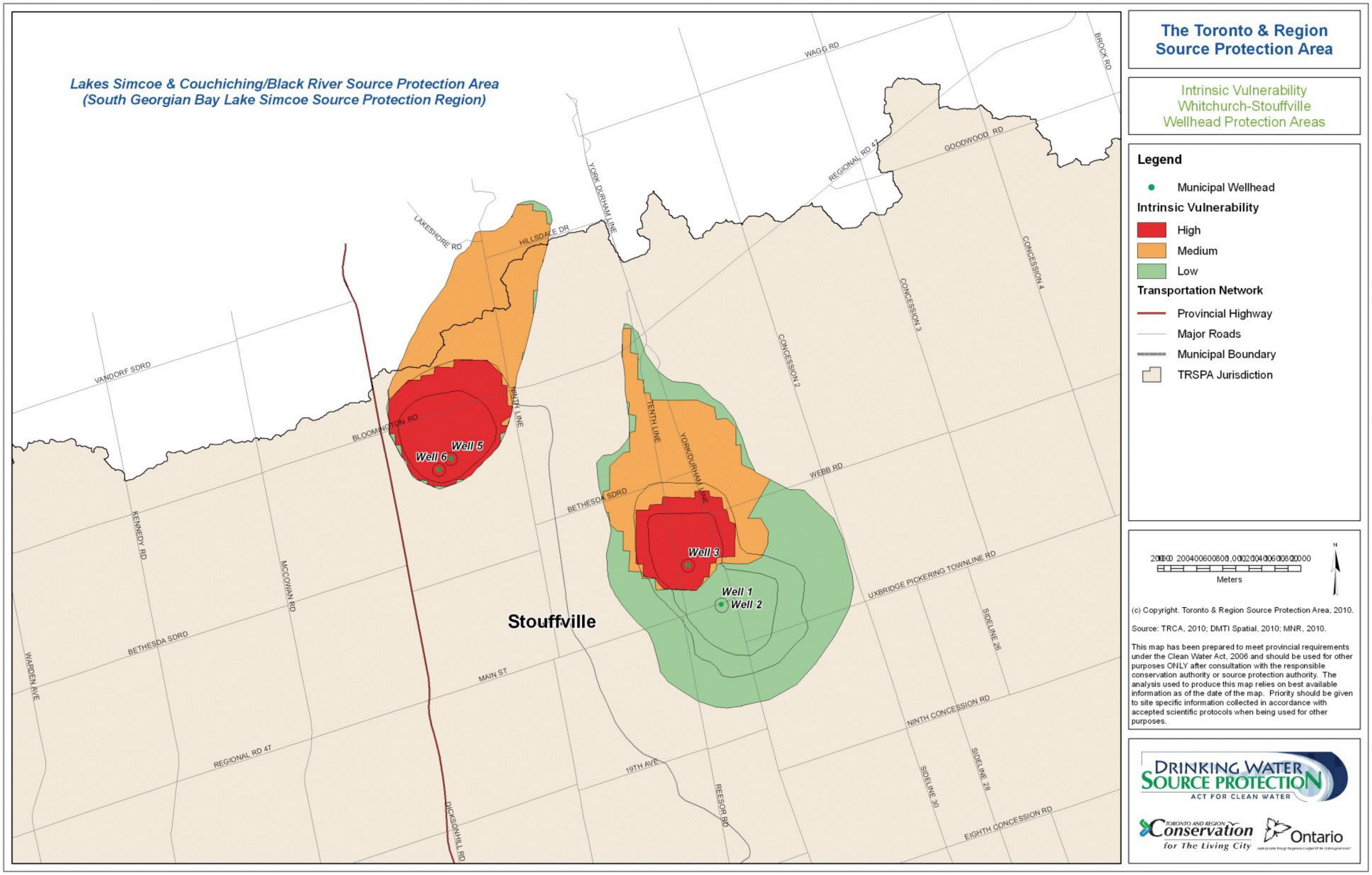

Figure 4.22: Intrinsic Vulnerability Whitchurch-Stouffville Wellhead Protection Area

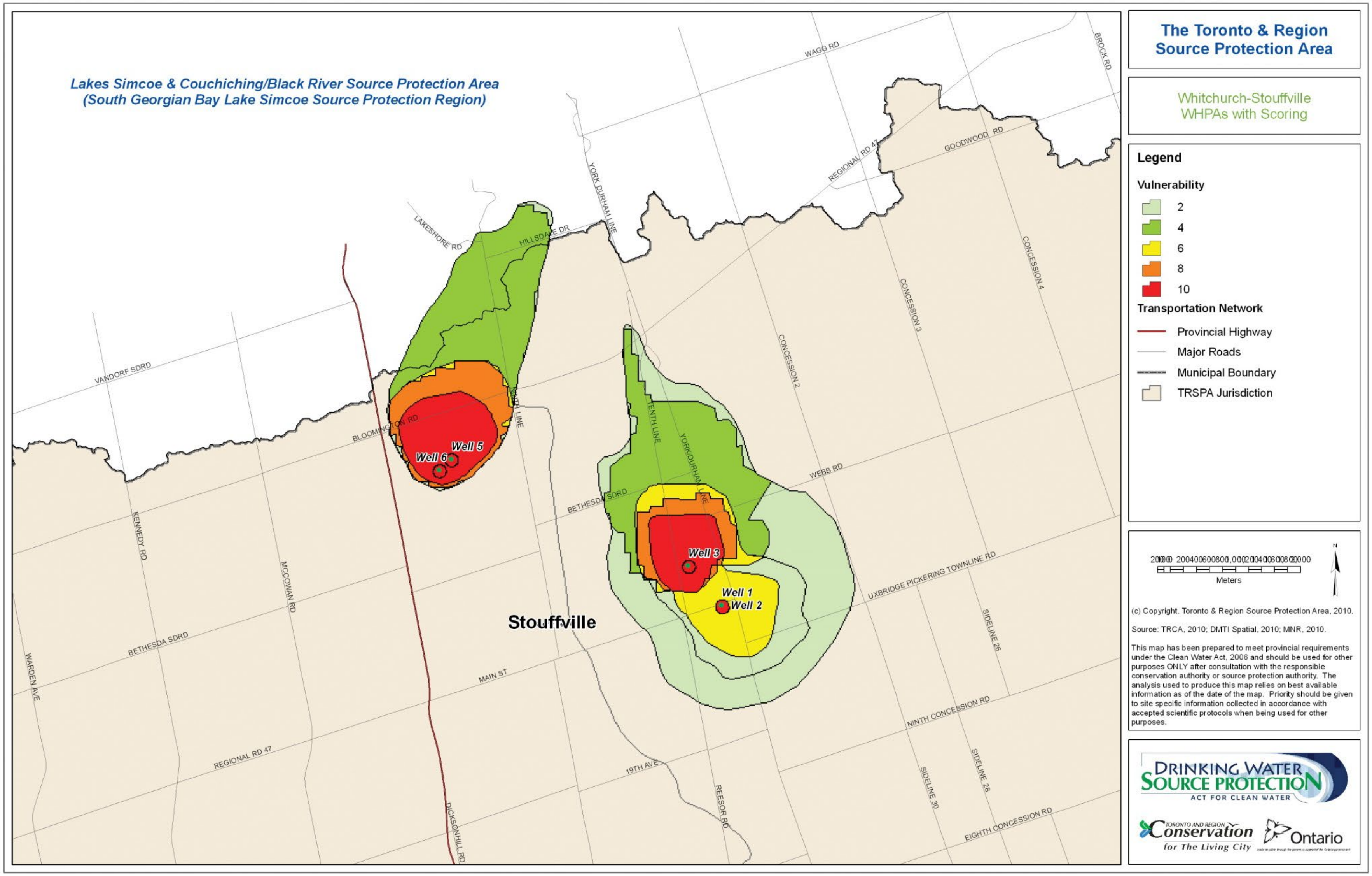

Figure 4.23: Whitchurch-Stouffville Wellhead Protection Areas with Scoring

Table 4.5: Uncertainty Assessments - York Region

Well	Uncertainty Type	WHPA-A	WHPA-B	WHPA-C	WHPA-D
Nobleton	Delineation of WHPA	Low	Low	Low	Low
	Vulnerability Scoring	Low	Low	Low	Low
	Overall – Vulnerability Scores	**Low**	**Low**	**Low**	**Low**
Kleinburg	Delineation of WHPA	Low	Low	Low	Low
	Vulnerability Scoring	Low	Low	High	Low
	Overall – Vulnerability Scores	**Low**	**Low**	**Low**	**Low**
King City	Delineation of WHPA	Low	Low	Low	Low
	Vulnerability Scoring	Low	Low	Low	Low
	Overall – Vulnerability Scores	**Low**	**Low**	**Low**	**Low**
Whitchurch-Stouffville	Delineation of WHPA	Low	Low	Low	Low
	AVI computation	Low	Low	Low	Low
	Overall – Vulnerability Scores	**Low**	**Low**	**Low**	**Low**

4.5 DURHAM REGION – UXVILLE INDUSTRIAL PARK

4.5.1 Geological Setting

The Durham Region operates the Uxville water system that supplies an industrial park south of the community of Uxbridge, in the headwaters of the Duffins Creek watershed. The system comprises two wells, and although it does not service residential customers, was designated by a Council Resolution by the Durham Region for inclusion in this report. The wells are located in the Thorncliffe Aquifer, at about 100 m below ground surface.

4.5.2 Data Sources and Methodology

For the Uxville wells, the AVI methodology, as described earlier, was used to complete the vulnerability scoring. The data source of the geologic and hydrogeologic information was the CAMC model from 2006, with updated interpretation by AECOM (AECOM, 2009).

Modelling was completed by AECOM in 2003 and 2004 using a MODFLOW-based groundwater flow model based on a regional geologic model prepared by the Geological Survey of Canada in 2000. The groundwater TOT calculations were based on reverse particle tracking from each well under maximum permitted pumping conditions.

The work was peer reviewed by Conestoga Rovers and Associates in 2010 (CRA, 2010), with the recommendation that the WHPA delineation and scoring be updated as part of the Tier 3 water budget for the Whitchurch-Stouffville and Uxville wellfields.

4.5.3 Uxville WHPA Delineation and Vulnerability Scoring

The resultant WHPA map is shown on **Figure 4.24**, while the mapping of vulnerability is shown on **Figure 4.25**. The final map showing the vulnerability scores for the Whitchurch-Stouffville wellfield is shown on **Figure 4.26**.

4.5.4 Transport Pathways

The vulnerability scores were increased one level for transport pathways from the municipal sewer and a gravel pit to the north.

4.5.5 Uncertainty Assessment

The dimensions of WHPA-A and the vulnerability scoring are set within the *Technical Rules*. Delineating WHAP-B, C, and D includes an intrinsic level of uncertainty in the analysis given the complexity of the study area and data gaps in certain instances. The vulnerability assessment also has a certain level of uncertainty associated with it.

Uncertainty associated with Uxville's wellfield assessment is found in **Table 4.6** and further discussed in **Appendix D.** Uncertainty is summarized as follows:

- The WHPAs were delineated with a sub-regional scale model and had good calibration. A sensitivity analysis was completed to account for variation in model parameters. The uncertainty in the WHPAs is low.
- Considering the variability in the density of the data used to create the AVI mapping and that the well database has inherent uncertainty, the vulnerability mapping of the area is considered to have high uncertainty.

Table 4.6: Uncertainty Assessments - Durham Region

Well	Uncertainty Type	WHPA-A	WHPA-B	WHPA-C	WHPA-D	WHPA-E
Uxville	Delineation of WHPA	Low	Low	Low	Low	n/a
	AVI computation	Low	Low	High	High	n/a
	Overall – Vulnerability Scores	**Low**	**Low**	**High**	**High**	**n/a**

4.6 SURFACE WATER VULNERABILITY ANALYSIS

The focus of the *CWA* is on municipal drinking water supplies. The source of drinking water for 97% of the population in the TRSPA jurisdiction is from Lake Ontario. The surface water vulnerability analysis for the Lake Ontario municipal intakes was undertaken by Stantec Consulting Ltd. (Lake Ontario Collaborative—Surface Water Vulnerability Assessment, Phase 1 and 2, 2008, 2010 & 2011) under the leadership of the Region of Peel. This included the analysis of the vulnerability of these two intakes and nine others supplying municipalities along Lake Ontario - from Niagara in the west to Prince Edward County in the east. Under the *CW*A, vulnerable areas for surface water are referred to as Intake Protection Zones (IPZs). 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 Lake Ontario municipal intakes extend up to five kilometres offshore, the IPZs for these intakes do not all extend onto land.

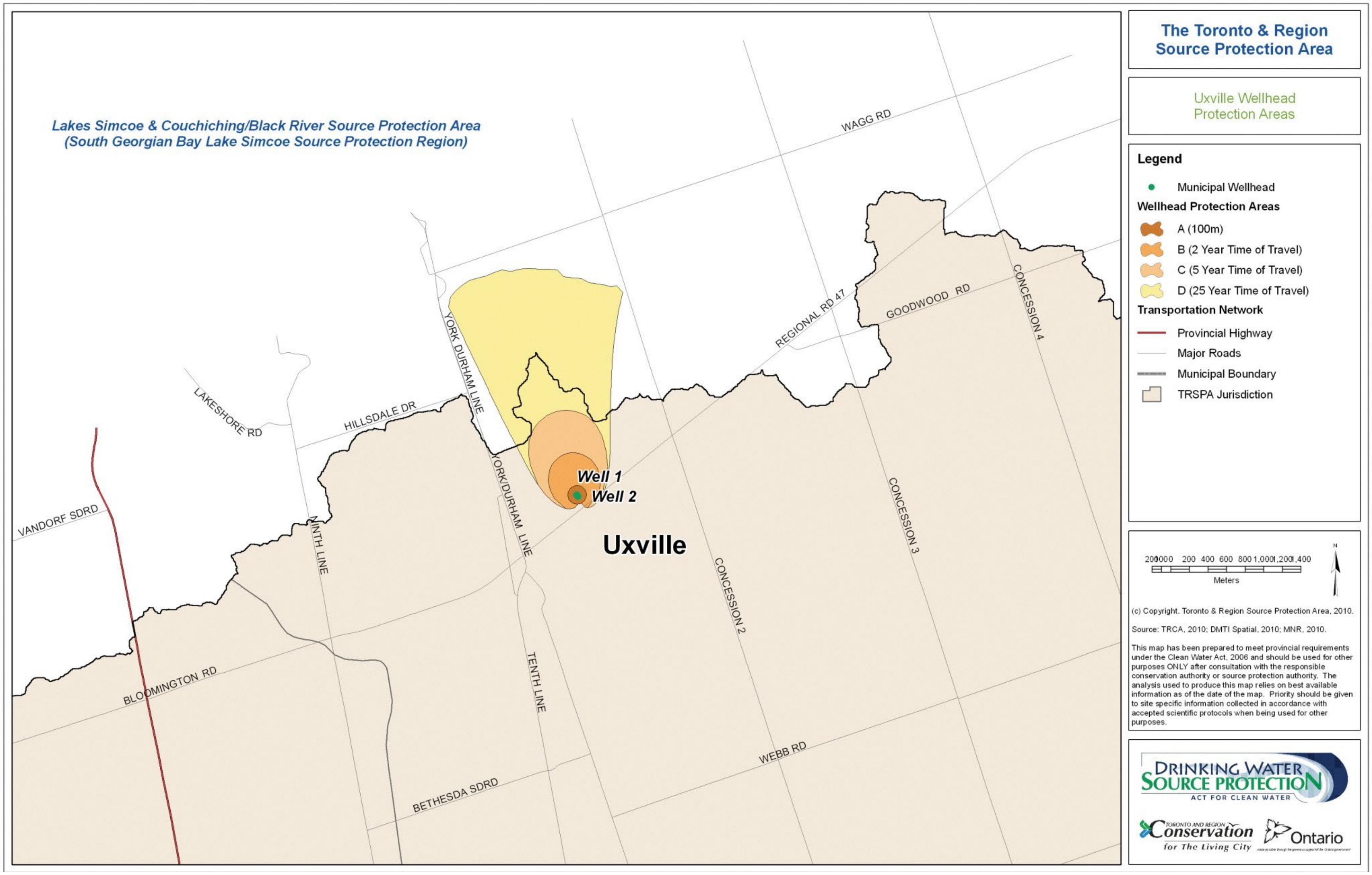

Figure 4.24: Uxville Wellhead Protection Areas

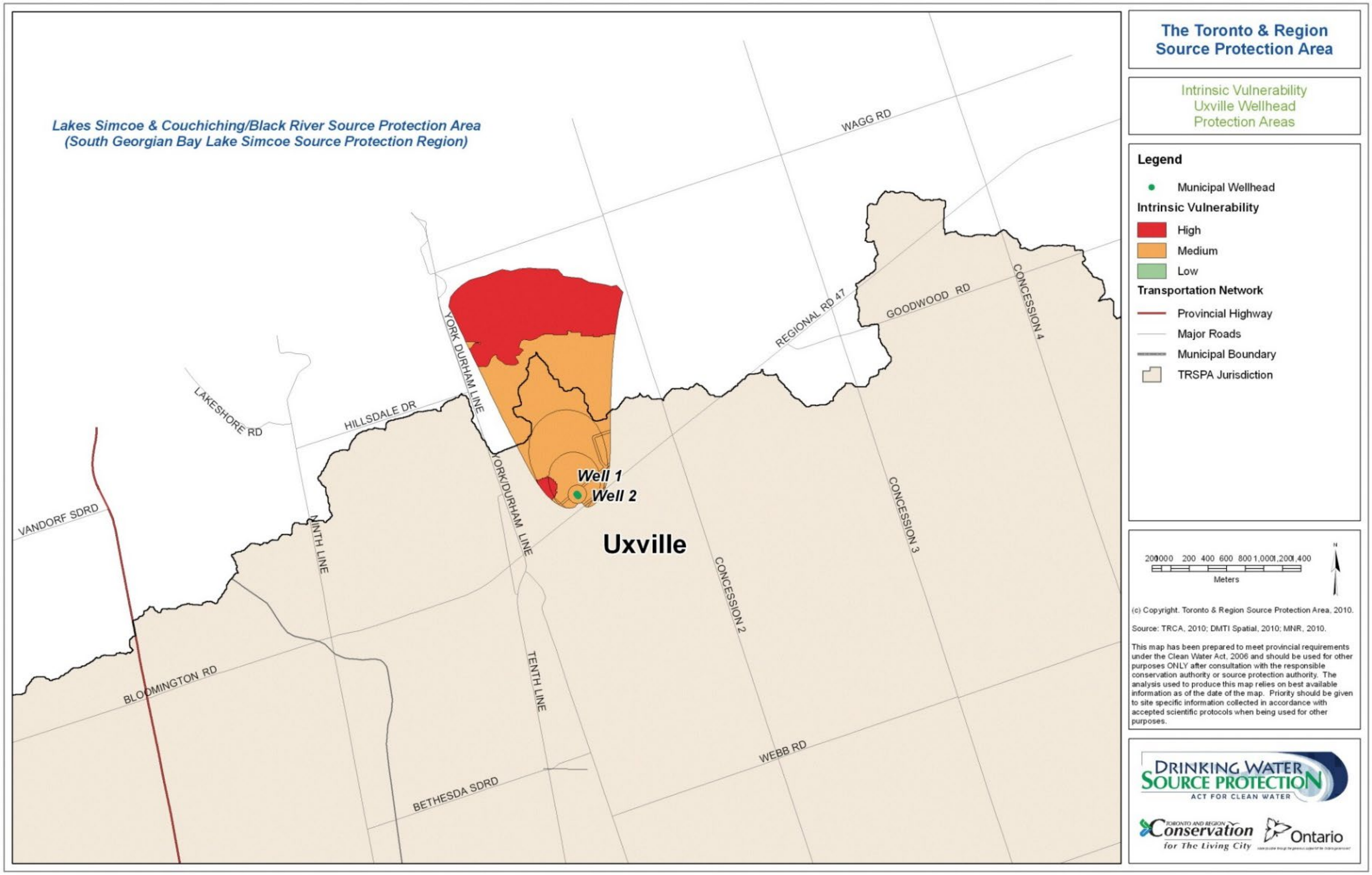

Figure 4.25: Intrinsic Vulnerability Uxville Wellhead Protection Area

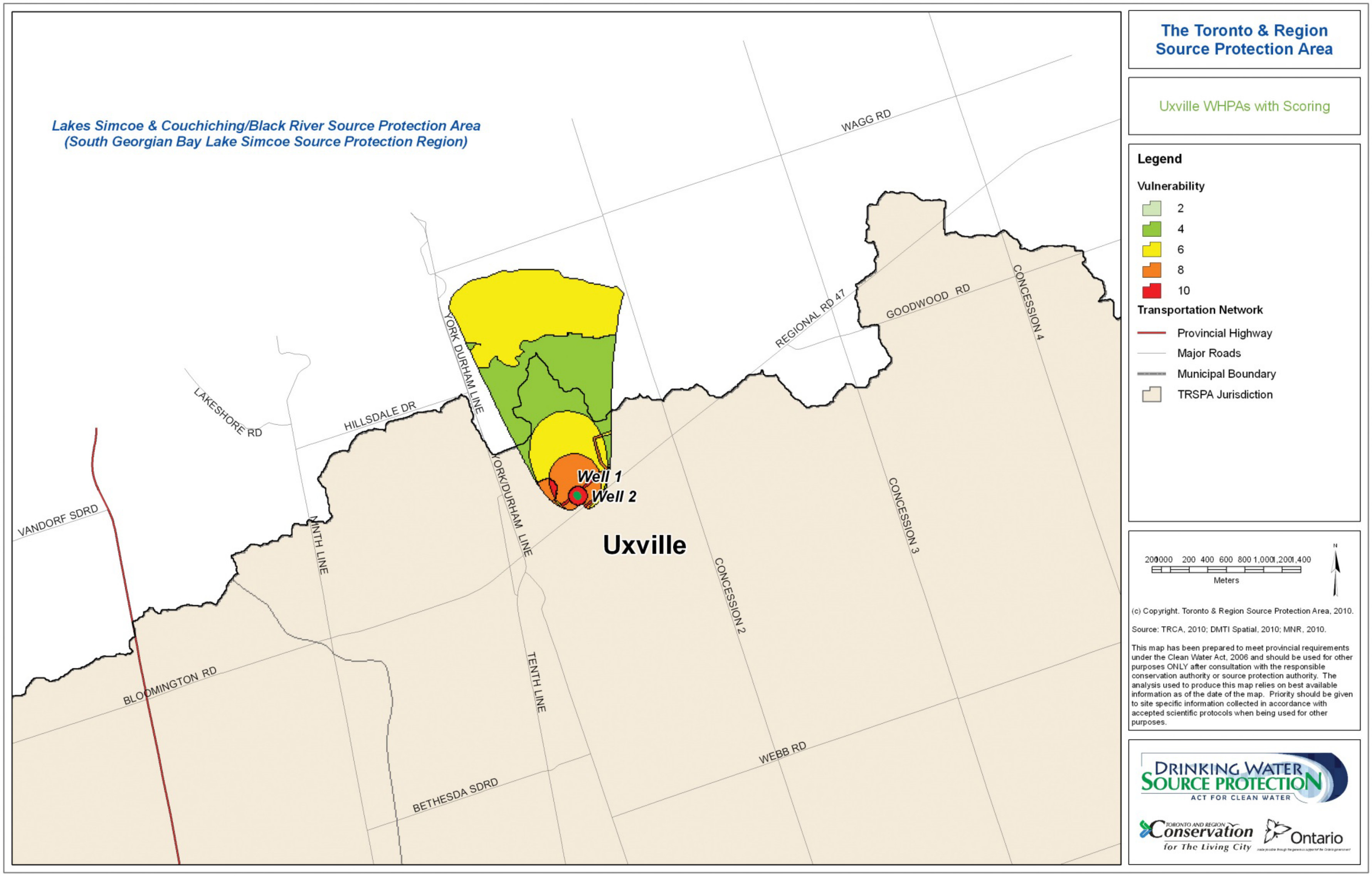

Figure 4.26: Uxville Wellhead Protection Areas with Scoring

The vulnerability analysis included a characterization of the intakes and near shore areas, delineation of IPZ-1 and IPZ-2 zones for each intake, and scoring of vulnerability of each intake to contamination. The IPZ-1 is based on a circular area that extends 1 kilometre away from the intake. The IPZ-2 for each intake was delineated using complex *hydrodynamic* models. These computer-based models were constructed using data inputs such as water current direction and speed, wind direction and speed, water temperature profiles, etc. The surface water vulnerability analysis assesses the likelihood that surface water can become contaminated, particularly in the areas surrounding the intakes of water treatment plants. Vulnerability analysis considered:

- Characterization of the intakes and near areas;
- Delineation of vulnerable areas around intakes—Intake Protection Zones (IPZs); and
- Assessment of raw water vulnerability around intakes, and the assignment of vulnerability scores.

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

Bathymetry: The shape of the bottom of a lake.

The study also assesses storm-sewer systems (per *Technical Rule 65 (2)*) and transport pathways (per *Technical Rule 72*) within the IPZs, that could potentially allow contaminants to reach an intake at a quicker rate.

4.6.1 Intake Protection Zones 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.

Under the *CWA*, the Province of Ontario has required that three IPZ areas be identified. The size of each area varies depending on where the intake is located, *bathymetry*, currents, contributing area, loadings, etc. TRSPA's intakes are all located in Lake Ontario and are municipally owned and operated. Great Lake intakes are designated as "Type A" under the *Technical Rules*. The following short descriptions clarify the zones around intakes. Great Lake 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. It is generally considered the most vulnerable zone because it is adjacent to the intake and because contaminants discharged within this area are presumably undiluted.

  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 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 plant operator can respond. In TRSPA, the minimum response time, as specified in the *Technical Rules*, is two 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 4.7** and **Table 4.8.** Details regarding the methodology are provided in **Appendix D1**, while the supporting documentation is found in the foundation document (Stantec, 2008).

    - 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 TRSPA, 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 modeling 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 greater of 120 m, or the Conservation Authority Regulated Limit measured from the high 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 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 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. Local tributaries were defined in the model and a 2-year return period flow was used in all runs. In this phase of the study only gauged tributaries were defined in the model and the flows at the mouths of the rivers were based on the gauged data.

- **IPZ-3** - A number of spill scenarios were modeled as part of the Lake Ontario Collaborative to determine if certain land-based 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** of this Assessment Report.

The discussion of the models and approach used to determine the IPZ-2 and IPZ-3 areas are found in *Lake Ontario Vulnerability Assessment Surface Water, Phase 1 and Phase 2, 2008, and 2011* and summarized in **Appendix D1** and **Appendix E6** of this Assessment Report.

The only IPZ-1 zones that extend to the shore are for the shallow Toronto Island intakes that are maintained as backup systems.

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 lower depths. Downwelling can bring surface contaminants down to the depth where the intakes are located.

Summary – IPZ-2 Delineation

Table 4.7 summarizes the information on the IPZ-2s for intakes in the TRSPA. A description of IPZs for the Arthur P Kennedy (formerly Lakeview) Water Treatment Plant, located in the CVSPA has also been included, because it extends into the TRSPA. For a full discussion of the Arthur P Kennedy (formerly Lakeview) Water Treatment Plant, please consult the *Approved Updated Assessment Report: CVSPA.*

Mapping of IPZs and vulnerability scores for the TRSPA are shown on **Figure 4.27** (R.L. Clark), **Figure 4.28** (Toronto Island), **Figure 4.29** (R.C. Harris), **Figure 4.30** (F.J. Horgan), and **Figure 4.31** (Ajax).

The IPZ-3 delineations are provided in **Chapter 5**, with a summary of the methodology in **Appendix E6**.

4.6.2 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*:

$$V = Vf_z \times Vf_s$$

The zone vulnerability factors (Vf_z) 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 (Vf_s) 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 2.6**.

The formula does not consider specific contaminants, their respective properties, or their behaviours. The vulnerability score (V) and assigned Vf_z and Vf_s scores, do not have units. Additional discussion on the vulnerability scoring for lake-based intakes is provided in **Appendix E6.**

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.
Once the IPZs have been delineated, the assignment of a vulnerability score is derived from the equation given in Part VIII of the *Technical Rules*, which provides for a possible range of scores.

Table 4.7: Extent of IPZ-2 in the Toronto and Region Source Protection Area

SPA/SPR	WTP	In-Lake Extent	Upland Extent
CVSPA/CTC	Arthur P. Kennedy (formerly Lakeview)	Extends approximately 3.2 km northeast and 2.9 km southwest of the intake. Particle tracking indicates that the IPZ does not touch the shoreline.	The IPZ-2 was extended to the shoreline and upland to encompass stormshed boundaries, and the following Etobicoke Creek watercourse that contributes to the source water intake area.
TRSPA/CTC	R.L. Clark	The IPZ-2 extends approximately 3.6 km northeast and 3 km southwest of the intake. Particle tracking indicates that the IPZ-2 extends to the shore between the TRSPA boundary and Humber Bay Park.	Extends to the west and east of the decommissioned Lakeview Generating Station, and as far north as the QEW.
	Toronto Island (Shallow)	The IPZ-2 is a complex polygon that extends approximately 1.5 km northwest and 2.5 km northeast of each intake. The total length of the IPZ-2 zone is about 4.5 km, and covers about 3 km of the shoreline of Toronto Island. Both the IPZ-1 and 2 extend to and include the northern shoreline of the Toronto Island.	The northern extent of IPZ-2 has an administratively set limit of 120 m as the landward extent along this section of shoreline of Toronto Island. The 120 m extent on-shore is approximately 3 km in length. No sewer-sheds or tributaries exist on the affected portion of Toronto Island.
	Toronto Island (Deep)	The IPZ-2 extends approximately 6 km along the lakeshore. The IPZ-2 is not connected to the shore, indicating that contaminants are unlikely to be transported to the intake from shore within the 2-hr time-of-travel.	Because the IPZ-2 from the deep Island intakes do not reach even the shore of Toronto Island, there is no upland extent for these IPZ-2 zones.
	R.C. Harris	Currents in this area are predominantly parallel to shore and the in-water IPZ-2 extends approximately 4.5 km northeast and 3.6 km southwest of the intake. It is estimated that the IPZ-2 for the northeast intake would extend approximately 360 m further to the northeast. The particle tracking indicates that the IPZ-2 does not extend to shore, potentially significantly reducing the threats within the 2-hr time-of-travel	The western extent of the IPZ-2, when projected onto the shore, intersects the shoreline at Ashbridges Bay Park. The IPZ-2 then follows Woodbine Avenue north just past the Danforth. It extends east to Kingston Road. From that point, the IPZ-2 winds through to Cliffcrest Drive. From the end of Cliffcrest Drive the IPZ-2 follows the shoreline at a distance of 120 m until Bluffers Park where it connects to the shoreline.
	F.J. Horgan	Currents in this area are predominantly parallel to shore and the in-water IPZ-2 extends approximately 3.3 km in either direction from the intake. The particle tracking indicates that the IPZ-2 does not extend to shore, potentially significantly reducing the threats within the 2-hr time-of-travel.	The IPZ-2 intersects the shoreline near Bellamy Road, and extends north towards Kingston Road. It cuts northeast past Guildwood Parkway to Galloway Road, then extends north towards Lawrence Avenue, then northeasterly to Highland Creek, then follows the creek to its mouth in Lake Ontario.

SPA/SPR	WTP	In-Lake Extent	Upland Extent
	Ajax	The in-lake IPZ-2 extends approximately 3 km northeast of the intake and 3.5 km southwest of the intake. The particle tracking indicates that the IPZ-2 extends approximately 500 m from shore, but does not extend to the shoreline.	Ajax WTP IPZ-2 extended to include Duffins Creek WPCP and its outfall on the zones western boundary. Western boundary extended to include the Pickering Ontario Power Generating Station, recognizing the potential risk in the event of a spill. The eastern boundary extends to the western borders of Cranberry Marsh. The IPZ-2 extends upstream in Duffins Creek and Carruthers Creek conservatively to ensure inclusion of major transportation corridors. The zones most northerly boundary is Hwy 401 and the Canadian National (CN) rail line. On either side of both streams a 120 m buffer zone was also included in the IPZ-2.

Table 4.8: Vulnerability Scores and Uncertainty, for Intake Protection Zone-1s and Intake Protection Zone-2s of Lake Ontario Intakes

Municipality	Intake Location	IPZ	Vulnerability			Uncertainty Level Rating		
			Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score	IPZ Delineation	Vulnerability Score	Combined
Region of Peel	Arthur P Kennedy (formerly Lakeview)	IPZ-1	10	0.5	5.0	Low	Low	Low
		IPZ-2	9	0.5	4.5	High	Low	High
City of Toronto	R.L. Clark WTP	IPZ-1	10	0.5	5.0	Low	Low	Low
		IPZ-2	9	0.5	4.5	High	Low	High
	Island WTP (Deep Intakes)	IPZ-1	10	0.5	5.0	Low	Low	Low
		IPZ-2	7	0.5	3.5	Low	Low	Low
	Island WTP (Shallow Intakes)	IPZ-1	10	0.6	6.0	Low	Low	Low
		IPZ-2	8	0.6	4.8	High	Low	High
	R.C. Harris WTP	IPZ-1	10	0.6	6.0	Low	Low	Low
		IPZ-2	8	0.6	4.8	High	Low	High
	F.J. Horgan WTP	IPZ-1	10	0.5	5.0	Low	Low	Low
		IPZ-2	9	0.5	4.5	High	Low	High

Municipality	Intake Location	IPZ	Vulnerability			Uncertainty Level Rating		
			Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score	IPZ Delineation	Vulnerability Score	Combined
Durham Region	Ajax WTP	IPZ-1	10	0.5	5.0	Low	Low	Low
		IPZ-2	9	0.5	4.5	High	Low	High

WTP = Water Treatment Plant

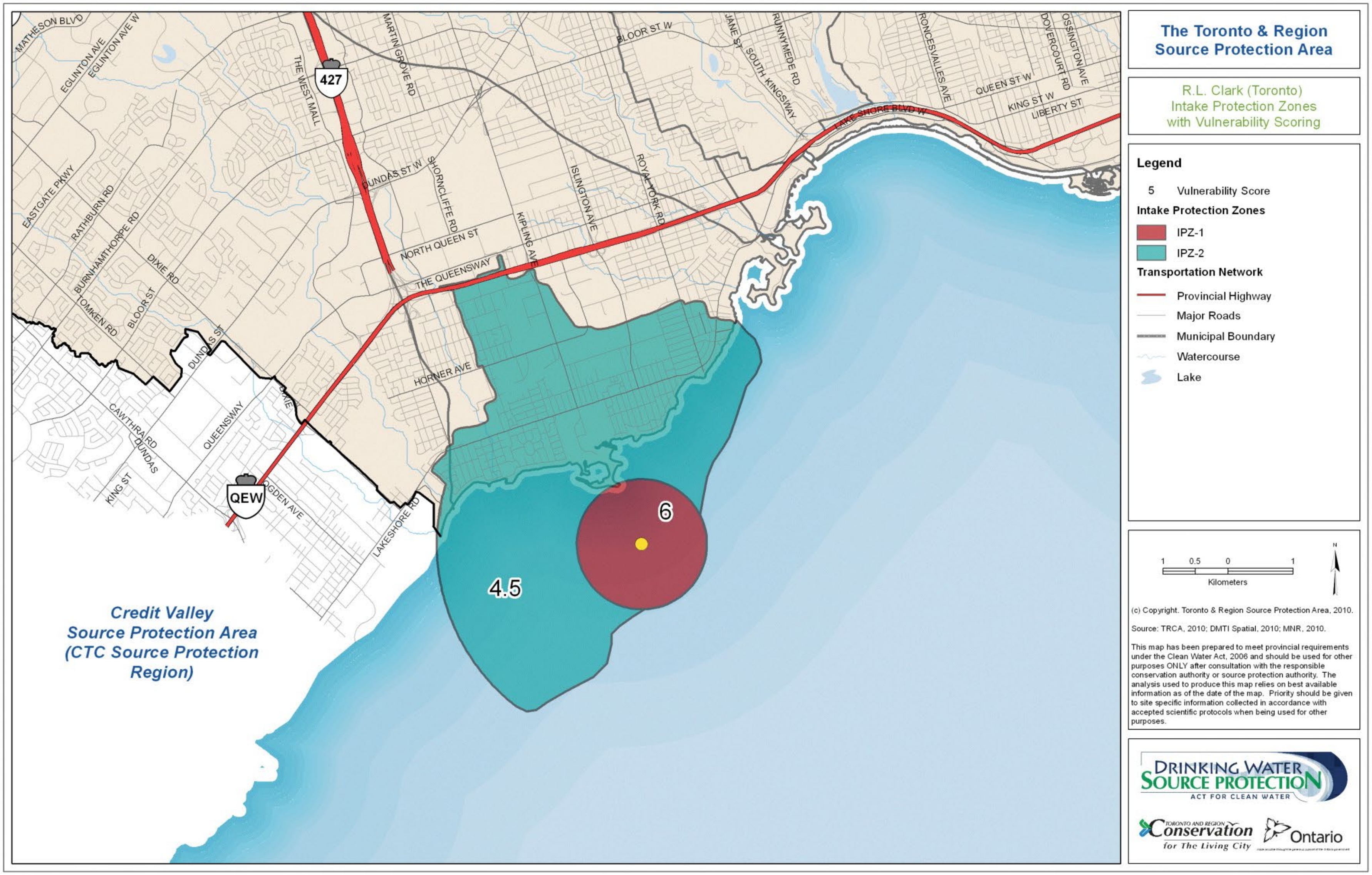

Figure 4.27: R.L. Clark (Toronto) Intake Protection Zones with Vulnerability Scoring

Figure 4.28: Toronto Islands (Toronto) Intake Protection Zones with Vulnerability Scoring

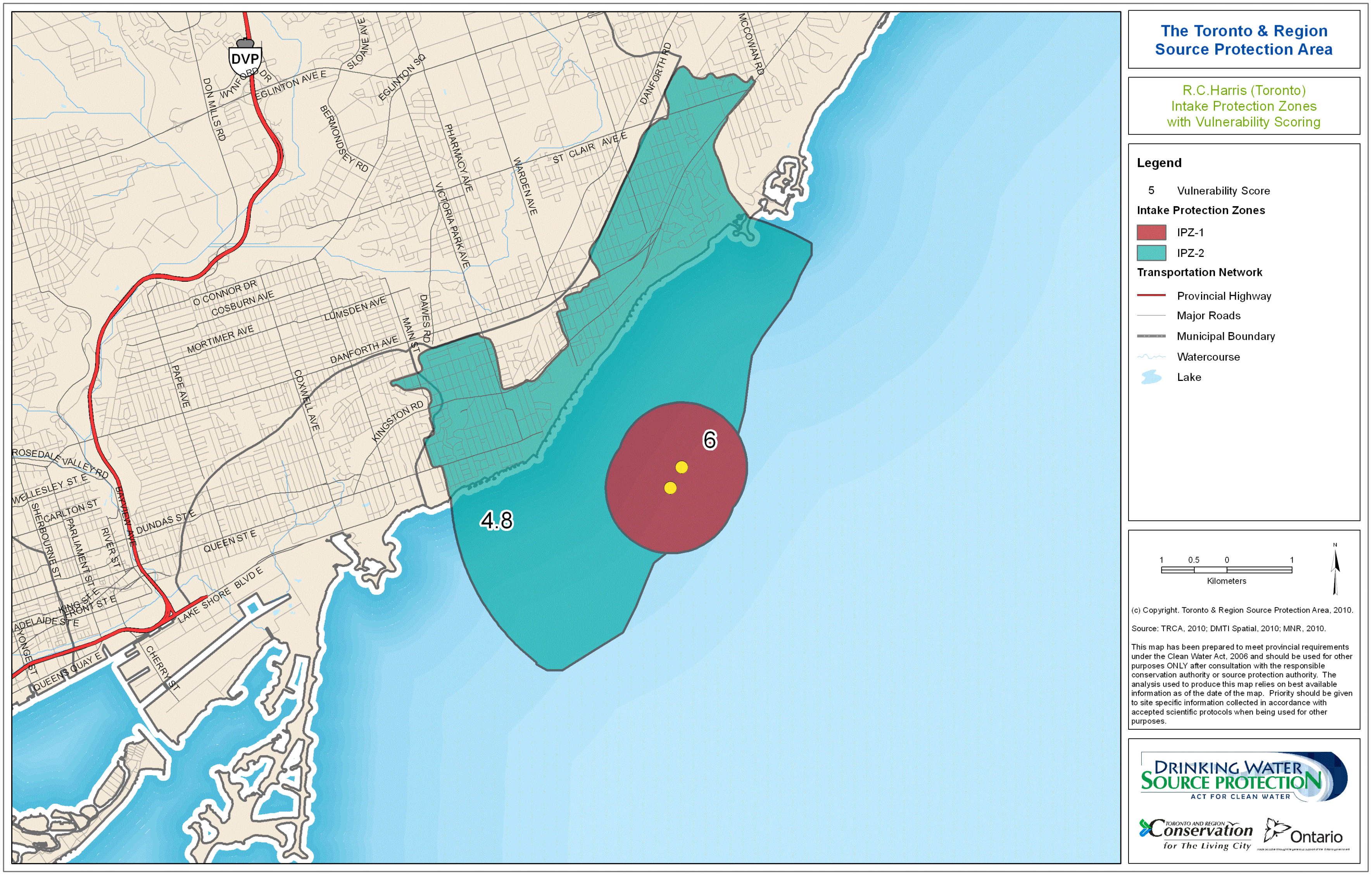

Figure 4.29: R.C. Harris (Toronto) Intake Protection Zones with Vulnerability Scoring

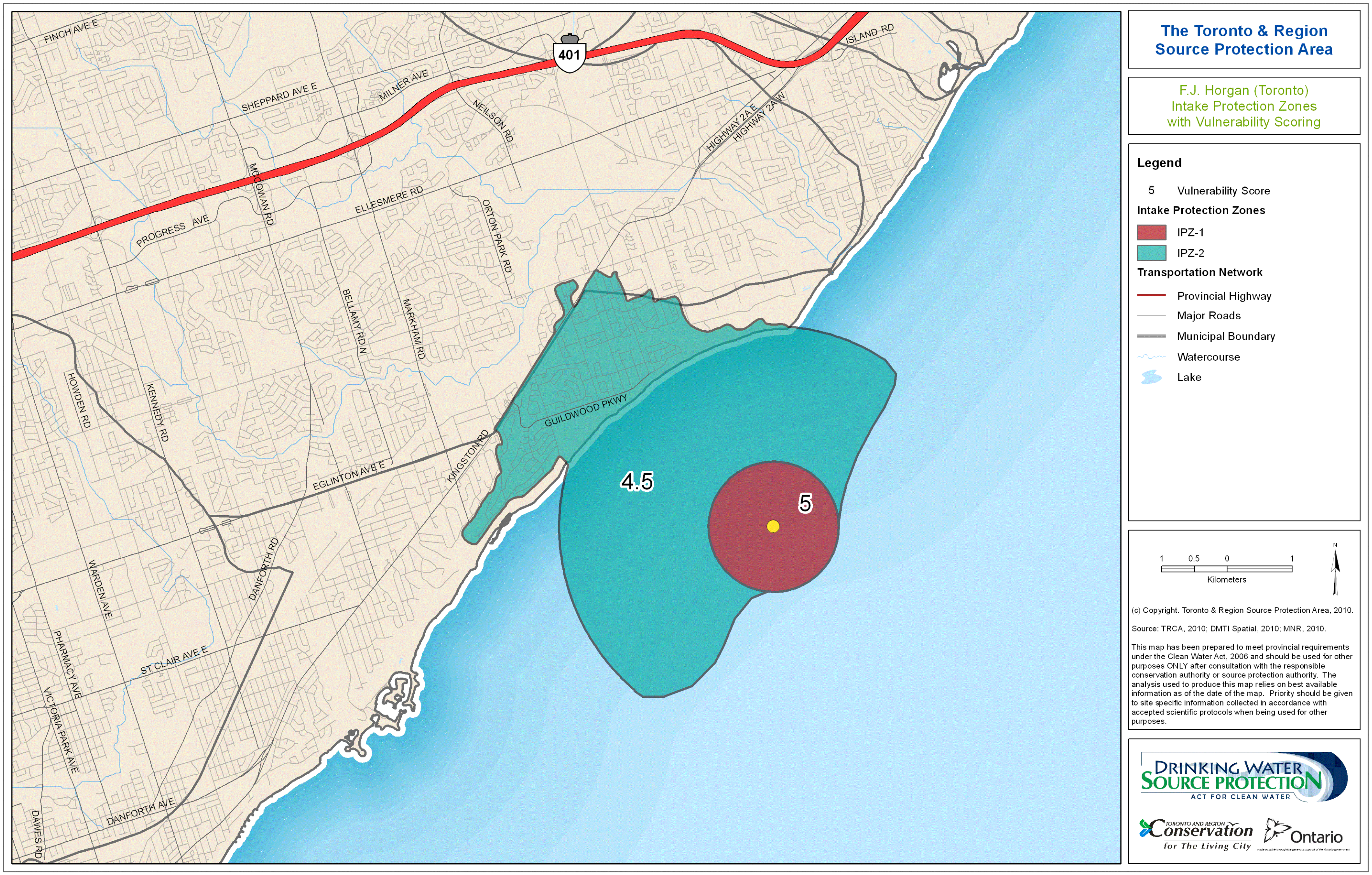

Figure 4.30: F.J. Horgan (Toronto) Intake Protection Zones with Vulnerability Scoring

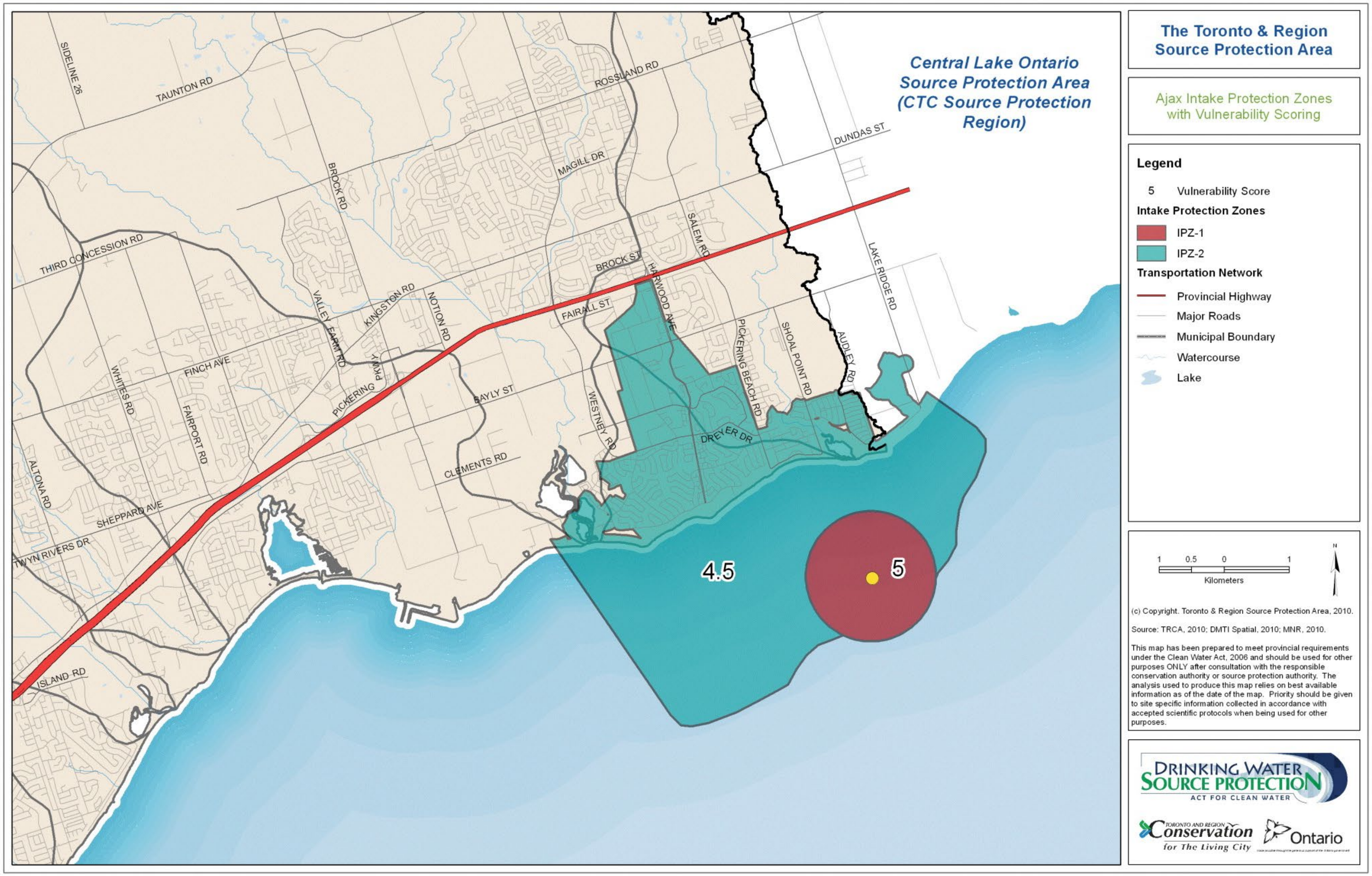

Figure 4.31: Ajax Intake Protection Zones with Vulnerability Scoring

R.L. Clark

The R.L. Clark water treatment plant (WTP) is located in a highly urbanized area between the Etobicoke Creek and Mimico Creek outlets into Lake Ontario. As was mentioned in **Section 2.3.1**, the intake for this facility extends 1.6 km offshore at a depth of about 11 m. The vulnerability score for lake-based intakes is based upon the zone vulnerability factor (Vf_z). This factor does not consider the nature of a contaminant, but rather the ability of a contaminant to reach the source water body – in this case, Lake Ontario. The IPZ-2 delineation based on modelling came near to the shore, and to be consistent with other intakes within the Lake Ontario Collaborative, was projected onto shore as shown in **Figure 4.27**. The IPZ-1 for the Clark WTP was assigned a Vf_z of 10 in accordance with *Rule 88*, which states that all IPZ-1s shall be assigned an area vulnerability factor of 10.

The *Technical Rules* require that IPZ-2s shall be assigned an area vulnerability factor not less than 7 and not more than 9 (*Rule 89*) based on both natural and anthropogenic influences. The natural characteristics that were considered by the Lake Ontario Collaborative in determining the Vf_z within the IPZ-2 included the slope of the upland environment and the discharges from both Etobicoke and Mimico creeks. Surface water runoff may transport sediment, salt, oil and other contaminants into either of these creeks or directly into Lake Ontario.

The area surrounding the R.L. Clark WTP is highly urbanized, which has resulted in large quantities of storm and surface water runoff. Anthropogenic pathways in the IPZ-2 include large surface runoff volumes from urban areas and transportation routes, and discharges from storm sewers and CSOs. Transportation routes to consider in this area include: Lakeshore Boulevard West, QEW/Gardiner Expressway, Browns Line, Kipling Avenue, Islington Avenue, and Royal York Road, as well as various residential roads located within the IPZ-2 area. Additional sites of concern located within the IPZ-2 include the decommissioned Lakeview Generating Station, and the railway switching yards.

Given these conditions, the natural and anthropogenic characteristics of the area around the intake provide for the discharge of contaminants into the lake. The Vf_z is assigned a high rating of 9 based on these findings.

The second component of the overall vulnerability score for surface water intakes is the source vulnerability factor (Vf_s). This factor varies from 0.5 to 0.7 for Great Lakes (Type A) intakes, with 0.7 being the highest vulnerability. The MOECC guidelines for the Design of Water Treatment Works (MOE, 1982) prescribes a minimum submergence of 3 m with a preference of 10 m or deeper. Overall, it was determined that this WTP has an area vulnerability similar to the other four plants in the Toronto drinking water system (Stantec, 2008a). With the general drift of the lake, from east to west, the other three plants can be used as indicators for this plant to prepare and make adjustments if necessary. As a result of these factors, the R.L. Clark WTP was given a Vf_s score of 0.5 (Stantec, 2008a). The net vulnerability scores assigned for the R.L. Clark IPZ-1 and IPZ-2 are 5.0 and 4.5, respectively.

Toronto Island (Shallow):

Although the Toronto Island shallow intakes are not in active use, they are being maintained as backup water sources. Therefore, vulnerability zones were calculated and scored for these two intakes. The IPZ-1s for these shallow intakes were assigned a Vf_z of 10 in accordance with *Rule 88*.

The natural characteristics that were considered by the Lake Ontario Collaborative in determining the Vf_z within the IPZ-2 included the slope of the upland environment and discharges from the Don River. Surface water runoff may transport sediment, salt, oil and other contaminants into the Don River, the Toronto Harbour, or directly into Lake Ontario.

The land mass associated with the IPZ-2 projection is a portion of the Toronto Islands which are not urbanized. The land area is mainly parkland, with some cottages located to the eastern end, whose drainage generally flows to the Inner Harbour. As such, the area vulnerability score is projected to be less than that for the other intakes.

The shallow Toronto Island IPZ-2 is adjacent to the Toronto Harbour, which was included on the International Joint Commission's list of 42 Areas of Concern for the Great Lakes in 1987. The area surrounding the harbour is highly urbanized, but the only hydrological pathways by which contaminants can be transported to the IPZ-2 area is through the Inner Harbour, which are addressed through the IPZ-3 analysis. Anthropogenic pathways outside the IPZ-2 area include large volumes of storm and surface water runoff from urban areas (which originates mainly from the Don River) and transportation routes. Transportation routes to consider in this area include: Lakeshore Boulevard and the Gardiner Expressway. Additional sites of concern located within the IPZ-2 include the decommissioned Queens Quay incinerator, and the port area in general.

Because of the natural and anthropogenic characteristics of the area around the intake, and the large anthropogenic characteristics of the area beyond the IPZ-2, which discharge contaminants into the lake, the Vf_z is assigned a rating of 8.

The second component of the overall vulnerability score for surface water intakes is the source vulnerability factor (Vf_s). This factor varies from 0.5 to 0.7 for Great Lakes (Type A) intakes, with 0.7 being the highest vulnerability. Overall, it was determined that this WTP is one of the most sensitive of the four plants in the Toronto drinking water system. As a result of these factors, the shallow intakes of the Toronto Island WTP were given a Vf_s score of 0.6. The vulnerability scores for the shallow Island intakes IPZ-1 and IPZ-2 are 6.0 and 4.8, respectively.

Toronto Island (Deep)

The IPZ-1s for the three deep intakes associated with the Toronto Island WTP were assigned a Vf_z of 10 in accordance with *Rule 88*. The natural characteristics of the upland environment, and anthropogenic pathways within the study area were determined not to influence the deep Island WTP intakes, and therefore, the Toronto Island WTP IPZ-2 Vf_z was determined to be 7 (low) (Stantec, 2008a).

The deep island intakes extend 5,400 m into Lake Ontario, 83 m below the water surface. The depth of these intakes was established based on physical limnological input from the National Research Institute, which indicated that this depth should provide a constant temperature for cooling purposes. Operators described the raw water entering the plant as good with virtually no variation in characteristics. Operators also indicated that the intakes were isolated from shoreline influences. Slight temperature changes do occur as a result of seasonal upwelling and downwelling associated with normalization of lake water densities and subsequent turnover, which typically occurs in the fall, and occasionally spring seasons.

Annual reports for the last two years do not indicate exceedances for any of the testing parameters. Because there are no significant concerns regarding the source vulnerability for these three intakes, the Vf_s for all three deep intakes was assessed to be 0.5 (low). The resultant vulnerability score for the IPZ-1 and IPZ-2 are 5.0 and 3.5 respectively, as shown on **Figure 4.28** represents the minimum value for all intakes in the Great Lakes because of the depth and off-shore distance of these intakes.

R.C. Harris

The R.C. Harris WTP is located on the edge of the Scarborough Bluffs, which is characterized by a gentle slope approaching the lake and a sharp drop-off close to the shoreline. The plant has two intakes that extend about 2 km into the lake, at a depth of about 15 m.

The IPZ-1 Vf_z for both intakes for this plant were assigned a value of 10 in accordance with *Rule 88*. Anthropogenic pathways in the IPZ-2 consist of surface runoff from urban areas, transportation routes, storm sewers, and CSOs. High volumes of storm runoff occur as a result of the high level of urbanization in the study area. Storm runoff may transport sediment, salt, oil and other contaminants into the lake through the 12 CSOs and five storm sewers discharging close to these intakes. Transportation routes to consider in this area include: Lakeshore Boulevard East, Queen Street East, Kingston Road, and the railway line farther inland. The natural and anthropogenic characteristic pathways, along with transportation routes, provide opportunity for contaminants to reach the lake. Therefore, the IPZ-2 Vf_z was determined to be 8 (moderate) based on natural and anthropogenic characteristics of the environment contained within the zone. This value represents an upper limit because the in-lake modelling analysis delimited the 2-hour time-of-travel to lie within the lake itself – projection onto land resulted in the IPZ-2 including the drainage areas shown on **Figure 4.29**.

The length and depth of the R.C. Harris WTP intakes exceed the minimum MOECC preference for surface water intakes. The historical water quality records from the Annual Report for this plant indicate that on several occasions there have been issues with sodium in the water. These sodium levels are linked mainly to excursions of effluent from the Ashbridges Waste Water Treatment Plant (WWTP). In previous decades, elevated *E. coli* levels were noted in the R.C. Harris intake from the Ashbridges WWTP discharge, which ceased when year-round disinfection was implemented. The Ashbridges WWTP is located about 1 km from the IPZ-2 boundary to the west of the R.C. Harris intakes, as shown on **Figure 4.29**. The Ashbridges WWTP has a capacity of 818,000 m^3/day and discharges through a pipe extending 600 m into Lake Ontario.

The elevated sodium may also be linked to de-icing salt, used on the roadways in the winter, discharging out the sewer outfalls during the spring melt, indicating onshore influences to the source water. As supported in the operator interview, WWTP effluent is a suggested source of excess free ammonia in the source water. While occasional WWTP influences to the source water have been identified, the length and depth of the R.C. Harris WTP intake pipe result in the assignment of a moderate Vf_s (0.6), and IPZ-1 and IPZ-2 vulnerability score of 6.0 and 4.8 respectively.

F.J. Horgan

As presented in **Section 2.3.1**, the surface water intake pipe for the F.J. Horgan WTP extends 3,200 m into Lake Ontario at about 18 m below the water surface. The IPZ-1 for the F.J. Horgan WTP was assigned a Vf_z of 10 in accordance with *Rule 88*.

The natural characteristics that affect the Vf_z estimation around the F.J. Horgan WTP are such that the natural landscape has minimal influence because the surrounding area is highly urbanized with residential and industrial land uses. Approximately 3 km of Highland Creek has been included in the upland extents to incorporate any overland flow that may have originated from the residential and industrial areas. Highland Creek was also assumed to be the outfall for any sewersheds that are situated in the industrial or residential areas based on the general topography of the area. An administratively set limit of 120 m was followed along the north and east sides of the watercourse. The remaining boundaries are formed through the transportation corridors of Kingston Road and Lawrence Avenue East. Overall, the IPZ-2 was assigned a Vf_z of 9 (high) based on natural and anthropogenic characteristics of the surrounding area. This value represents an upper limit because the in-lake modelling analysis delimited the 2-hour time-of-travel to lie within the lake – projection onto land resulted in the IPZ-2 (including the drainage areas) shown on **Figure 4.30**.

The F.J. Horgan WTP intakes are offshore, deep water intakes, and historical water quality records indicate that for the last two years there have been no issues with water quality. Operators have also indicated that the consistency of the water is very stable, with only small parameter changes during seasonal upwelling and downwelling. The water quality is very good and predictable, making it very easy to treat. Creek, river, and piped discharges were not identified as influencing the source water. Therefore, a low Vf_s score of 0.5 has been assigned to the IPZ-2 intakes, with resultant vulnerability scores for the IPZ-1 and IPZ-2 of 5.0 and 4.5 respectively.

Ajax

As discussed in **Section 2.3.1**, the Ajax WTP intake is located 2,451 m offshore, about 18 m below the surface of the lake, as shown in **Figure 4.31**. The IPZ-1 was assigned a Vf_z of 10 in accordance with *Rule 88*.

The IPZ-2 for the Ajax WTP was assigned a Vf_z of 9 (high) as it contains two significant creek influences that have known Polycyclic aromatic hydrocarbon contaminated sediments (refer to **Section 4.2**), the Pickering Nuclear Generating Station, Duffin Creek Water Pollution Control Plant (WPCP) and outfall, as well as numerous industrial operations along the shoreline. Major transportation corridors (Hwy 401 and CN rail) also exist in the zone and increase the potential for a contaminant to reach the intake. The zone west of Duffins Creek is highly industrialized with the remaining area mostly urban with very minimal agricultural. The area’s soil has low permeability, which can increase runoff and the likelihood of potential contaminants reaching the source water.

The intake depth is significantly greater then the 10 m preferred depth established by the MOECC. Reviewed historical water records and discussions with plant operators indicate that this is an excellent source of water with minimal usage complications. Therefore, the Ajax intake was assigned a Vf_s of 0.5 (low), with resultant vulnerability scores for IPZ-1 and IPZ-2 of 5.0 and 4.0 respectively.

4.6.3 Uncertainty Assessment

The uncertainty level is a qualitative assessment of the confidence in the validity of delineation of the IPZs and their associated vulnerability scores. The uncertainty scores for the IPZs are presented in **Table 4.8**. Information gathered in subsequent studies may decrease the uncertainty level for any factor that has received a high uncertainty score. At this time the IPZ-2 delineations and the associated vulnerability scores meet the minimum requirements of the *CWA*, but may be refined during the next assessment report cycle.

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 was high (meaning a low level of confidence) for the all of the intakes, except the deep Toronto Island intakes. High uncertainty was 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 modeling 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 watercourse 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 IPZs were delineated in a conservative manner. As a result, the combined uncertainty is high for CTC Source Protection Region intakes located in TRSPA, even though the critical data needed to delineate the vulnerability zones and score the intake vulnerability was sufficient.

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.

High uncertainty in the upland extent component for the IPZ-2 is also caused by the potential for high volumes of runoff to be produced within the study area and the channelling of runoff into nearby watercourses, and the absence of flow data, stream flow velocities and other watercourse characteristics. 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 along-shore 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 necessitates a high level of uncertainty.

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

4.7 SUMMARY

The *CWA* requires the mapping and assessment of the natural vulnerability in vulnerable source water areas located within the TRSPA jurisdiction – HVAs, WHPAs, 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**.

In the TRSPA jurisdiction, about 98.5 % of the population receives its drinking water from municipal systems serviced either from Lake Ontario (97%) or from municipal wells (groundwater - 1.5%).

HVAs are areas susceptible to contamination moving from the surface into the groundwater. In the TRSPA 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. Although minimum water well construction standards are set out in O. Reg. 903, under the *Ontario Water Resources Act, 1990*, extra caution should be taken when constructing wells in vulnerable aquifer areas. Incidentally, these wells 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 Rouge and the Don rivers, they are more vulnerable.

The vulnerability of the HVAs was assessed using the AVI method. Highly vulnerable aquifers are assigned a vulnerability score of 6 as per the *Technical Rules.* The features associated with the transport pathways were determined based on the existence of pits and quarries. The vulnerability in the affected areas was increased by one level. Where this resulted in a change of vulnerability score of 4 to 6, the zone was defined as an HVA.

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).

WHPAs are zones drawn around the wellheads of municipal wells. WHPAs can be susceptible to contamination moving from the surface into the groundwater. They are delineated in order to estimate the horizontal TOT of water particles as they travel from a given point in an aquifer, toward the associated municipal well. Water in the furthest zone (WHPA-D) takes the longest period of time (up to 25 yrs) to arrive at the wellhead. The vulnerability of the WHPAs were assessed using a variety of methodologies such as the Aquifer Vulnerability Index, to the Intrinsic Susceptibility Index, and the Surface to Well Advection Time (SWAT). In addition, a WHPA-E is delineated where the well is under the direct influence of surface water (GUDI). The WHPA-E is the area where contamination can move within the watercourse to the point closest to the well within 2 hours.

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-2s 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 2 hours. According to the Director's Rules, the setbacks are the greater of 120 metres or the CARegulation 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 TRSPA jurisdiction (associated with the Ajax, R.C. Harris, F.J. Horgan, R.L. Clark, and Toronto Island WTPs) all scored 5 or 6 (low vulnerability). The vulnerability scores for IPZ-2s ranged from 3.5 to 4.0 (low vulnerability).

Additional work has been 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 along-shore 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 necessitates 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.