Approved

Chapter 4

WATER QUALITY

APPROVED ASSESSMENT REPORT

for the

Northern Bruce Peninsula Source Protection Area

October 15, 2015

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for the
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Table of Contents

List of Figures

List of Tables

List of Maps

Map 4.1.S1.3	IPZ – Aerial Photo
Map 4.1.S1.4	IPZ – Vulnerability
Map 4.1.S1.5	IPZ – Impervious Surfaces
Map 4.1.S1.6	IPZ – Managed Lands
Map 4.1.S1.7	IPZ – Nutrient Units
Map 4.1.S1.8	IPZ – Events-based Area
Map 4.1.S1.9	IPZ – Events-based Area Policy Components

4.0 Water Quality

4.0.1 Guide to Chapter

This chapter describes the risk to water quality for all drinking water systems listed in the Terms of Reference. It lists activities that may pose a threat to raw water quality sources for these systems. Also included are tables that describe the number of occurrences where these activities exist or have the potential to exist.

This chapter is separated into two parts. The first part explains the methods used to identify vulnerable areas and the vulnerability scoring of these areas; methods for the identification of significant threats to drinking water quality and drinking water issues that have worrisome water quality measurements at the well or intake. The second section of this chapter applies these methods to each drinking water system in this Source Protection Area (SPA). The systems are in order by municipality and separated by groundwater and surface water systems.

For each municipality, some general data on population and land use is given. Highly Vulnerable Aquifers (HVAs) and Significant Groundwater Recharge Areas (SGRAs) are then broadly located within each municipality. Each drinking water system is described separately and information is given on the well/intake including the area that influences the well/intake and its vulnerability, and the drinking water threats and issues identified for the system. Finally, significant drinking water threats were summarized for each municipality.

Numbering of Tables and Maps

The second part of this chapter contains a large number of tables and maps, which contain data on each municipality and each drinking water system. There are a total of nine maps for each municipality and between six and thirteen maps for each drinking water system. Each drinking water system also has a set of data tables. This report includes one municipality, one groundwater system and one surface water system, with a total of 29 maps, one figure and 32 tables for this Source Protection Area.

The maps for each municipality are given in Table 4.0.1.

TABLE 4.0.1 – Maps for each Municipality

	Maps
Municipality	
Number	*Content*
M1	Aquifer Intrinsic Susceptibility (ISI)
M2	HVA/SGRA Extent
M3	HVA Vulnerability
M5	Impervious Surfaces for HVAs/SGRAs
M6	HVA Managed Lands
M7	HVA Livestock Density (Nutrient Units)

Coding for Maps by Municipality

Each map has a code that contains the chapter (4), the municipality and the map number. For example, Map 4.1.M3 is in chapter 4, for municipality 1 (Municipality of Northern Bruce Peninsula) and shows the HVA vulnerability.

Coding for Tables and Maps of Drinking Water Systems

To facilitate review, coding is used for all tables and maps associated with municipalities and drinking water systems. They have the following format:

Chapter.Municipality.DrinkingWaterSystem.Number

Further, drinking water systems are numbered within the municipality by occurrence and by type, either groundwater (G) or surface water (S). For example, the first drinking water system from groundwater in a municipality is coded G1, the second surface water system is coded S2, and so on. The final number describes the content of each map or table and is shown in Table 4.0.2.

Two Examples for Coding in Drinking Water Systems

Map 4.1.G1.3 is a map in chapter 4 for municipality 1 (the Municipality of Northern Bruce Peninsula); it is the first groundwater drinking water system in the municipality (Tobermory) and the content is the "WHPA Vulnerability". This system is described in section 4.2.1.2.1.

Table 4.1.S1.2b is a table in chapter 4 for municipality 1 (the Municipality of Northern Bruce Peninsula); it is the first surface water drinking water system in the municipality (Lion's Head) and the content is the "IPZ Vulnerability". This system is described in section 4.2.1.3.1.

TABLE 4.0.2 – Maps and Tables for each Drinking Water System

Maps		***Tables***	
Drinking Water System from Groundwater			
Number	Content	Number	Content
1	WHPA Delineation	1	Description of Drinking Water System
2	WHPA with Aerial Photo	2a	Impervious Surfaces
3	WHPA Vulnerability Score	2b	Managed Lands and Nutrient Units
4	Impervious Surfaces for WHPA	2c	WHPA-E Vulnerability (if applicable)
5	Managed Lands	3	Drinking Water Threats by Activity
6	Livestock Density (Nutrient Units)	4	Summary of Significant Threats
		5	Issues and Conditions
Drinking Water System from Surface Water			
Number	Content	Number	Content
1	Intake Protection Zone Components	1	Description of Drinking Water System
2	IPZ Delineation	1b	Managed Lands, Nutrient Units and Impervious Surfaces
3	IPZ with Aerial Photo	2a	Area Vulnerability Score
4	IPZ Vulnerability Scores	2b	Source Vulnerability Score
5	Impervious Surfaces for IPZ	2c	Vulnerability Score of IPZ
6	Managed Lands	3	Drinking Water Threats by Activity
7	Livestock Density (Nutrient units)	4	Summary of Significant Threats
8	Events-based Area	5	Issues and Conditions
9	Events-based Area Policy Components		

4.1 Background and Methodology

4.1.1 Overview on the Regulatory Context

This chapter portrays how the legislation and rules apply to the Northern Bruce Peninsula Source Protection Area. Under the *Clean Water Act, 2006*, the drinking water sources that must be assessed in a Source Protection Area are wells and surface water intakes that serve municipal drinking water systems for major residential developments as well as any systems elevated by the Ministry of the Environment, Conservation and Parks (MECP). All these systems must be in the Terms of Reference. Vulnerable areas are delineated and the degree of vulnerability scored. For each vulnerable area, those activities and conditions that pose a significant risk to the drinking water are identified.

Vulnerable Areas

Drinking water sources can be impaired by the entry of contaminants. The areas where the potential for contamination is greatest require the highest level of protection. To focus the resources used for Drinking Water Source Protection to the greatest risks, the *Clean Water Act, 2006*, defines four types of vulnerable areas:

- **Highly vulnerable aquifers** (HVAs) are groundwater aquifers that can easily be contaminated from land area above these aquifers.
- **Significant groundwater recharge areas** (SGRAs) are areas that are particularly important for the replenishment of groundwater aquifers. Here, it is desirable to regulate or monitor drinking water threats that may affect the quantity of recharge entering an aquifer or its quality.
- **Intake protection zones** (IPZs) are areas in the vicinity of surface water intakes. Intake protection zones are composed of an in-water (or offshore) component and an on-land (or onshore) component that drains into the offshore component.
- **Wellhead protection areas** (WHPAs) are areas within aquifers that provide water to municipal drinking water wells. Within these areas it is desirable to regulate or monitor drinking water threats.

The Technical Rules (Ontario Ministry of the Environment, Conservation and Parks, 2021. Technical Rules: Assessment Report Made under s. 107, *Clean Water Act*, 2006) indicate how to delineate each type of vulnerable area and how to assess the degree of vulnerability within each area. The *Clean Water Act* (Regulation 287/07) describes 21 drinking water threats, which are listed in Section 4.1.5.2 of this report. As an Addendum to O. Reg. 287/07, the Tables of Drinking Water Threats provide details on specific circumstances for each threat as well as the vulnerability score that would be applicable in order to consider an activity a significant, moderate or low threat.

Vulnerability Scoring in Vulnerable Areas

Each location within a vulnerable area is assigned a specific vulnerability score that ranges between two (lowest vulnerability) and ten (highest vulnerability). This score takes into account the time needed for a contaminant to travel to the drinking water intake or well and the specific characteristics of each location.
For groundwater, these characteristics are determined by the amount of protection that the soil or overburden on top of the aquifer provides. The score also takes into account artificial transport pathways for contaminants, such as wells, or aggregate pits.

For surface water intakes, the vulnerability score takes into account water mixing and flow directions in the water. The vulnerability score of a surface water intake combines the characteristics of the onshore component and its land use and the intrinsic vulnerability of the water body prescribed by the Technical Rules.

Activities and Conditions

The *Clean Water Act, 2006* distinguishes two sources of risk, referred to as activities and conditions, which may jeopardize the quality of drinking water sources. Activities include ongoing and future land uses while conditions refer to situations where contamination occurs due to historical activities. This contamination can occur in surface water, groundwater, soil, or sediment. Every existing or potential land use in a vulnerable area (an activity) is further analyzed to determine the level of risk it poses to drinking water sources.

Threats, Issues and Events

The *Clean Water Act, 2006* describes three basic approaches to determine the risk level of an activity or condition: the threat-based approach, the issue-based approach and the events-based approach.

The **threats-based approach** determines the risk of contamination of a water source based on the vulnerability score within a vulnerable area and the hazard rating of a contaminant/pathogen that is associated with a land use activity. Activities can become “significant” threats even if no negative impact on the drinking water source was recorded.

To apply the **issues-based approach,** the deterioration of water quality of a drinking water source must be demonstrated from measured data. If such deterioration is confirmed for a well or at a surface water intake, and the problem is found to be anthropogenic, a “Drinking Water Quality Issue” can be declared. The local source protection committee decided on thresholds for the determination of an issue for both contaminants and pathogen (SPC Jan 23, 2009, Technical Report 7c, Development of water quality standards for issues evaluation). If an issue was identified in the raw water, then the area that contributes to this issue must be delineated. All activities that contribute to the exceeded threshold are identified and regarded as significant.

The **events-based approach** is reserved for continuous or discrete activities (such as accidents) that occur under extreme weather conditions, such as storms, strong precipitation events or droughts. Any activity or condition that poses a significant risk in such an extreme event must be individually identified.

Under the events-based approach, the activity or condition can be located outside of vulnerable areas as delineated under the threats-based approach. However, scientific justification is required indicating that the contaminant or pathogen can be transported to the intake or well during an extreme event (Technical Rule 68), and that the concentration of that contaminant can cause an interruption of normal operation of the drinking water system. An IPZ-3 may be delineated to capture these additional locations. The area within which individual activities are designated significant threats during an extreme event is called the events-based area for surface water systems.

For surface water intakes in this SPR, the events-based approach can be applied to Type A intakes (Great Lakes) or any other system defined in Technical Rule 68. IPZ-3s for all Great Lakes intakes do not have vulnerability scores and the threats-based approach using threats assessments is not used in this case. For such intakes, the procedure to identify a significant threat requires that modelling, or an equivalent analysis that was accepted by MECP, demonstrates the activity can cause the deterioration of the source of drinking water (Technical Rule 130).

Types of Threats and Risk Rating

Threats are classified into three groups: **chemical**s, **pathogen**s and dense non-aqueous phase liquids (**DNAPLs**). For each activity or condition that may pose a drinking water threat, one of four risk ratings is assigned; none, low, moderate or significant. Each activity that is designated a significant threat must be addressed in the source protection plan, and the *Clean Water Act, 2006* provides more restrictive tools for development of these significant threat policies. For drinking water threats that have a risk rating of low or moderate, the source protection plan may also include policies, although with less restrictive measures available through the *Clean Water Act, 2006*.

Risk rating under the threats-based approach is based on rules that take into account: the category of the threat (chemical, pathogen or DNAPLs, see Section 4.1.5); the hazard rating of the contaminant; the water source (groundwater or surface water); the vulnerable area (highly vulnerable aquifer, significant groundwater recharge area, wellhead protection area, and intake protection zone); the vulnerability at the location of the activity; and the circumstances of a specific land use (an ongoing or future activity, or a condition from historic land uses). A detailed description of risk rating is given in Section 4.1.5.

Hazard and risk ratings are built into the Tables of Drinking Water Threats (2021) and online Threats Tool that provide a vulnerability score that is high enough for an activity/circumstance to be designated a threat. Property owners can identify potential risks on their property by the procedure outlined in Section 4.1.5.7.

Risk rating is not used under the issues-based approach or the events-based approach. The issues-based approach is reserved for situations where contamination is already observed and the events-based approach requires specific analysis for each activity.

4.1.2 Vulnerable Areas: Delineation Methods

4.1.2.1 Intrinsic Vulnerability of Groundwater

Aquifer vulnerability is an important characteristic used to delineate highly vulnerable aquifers and to score vulnerability in wellhead protection areas, significant recharge areas, and the onshore component of intake protection zones.

Intrinsic Susceptibility Index (ISI)

Intrinsic Susceptibility Index (ISI) is a calculated value that estimates the susceptibility of groundwater resources to contamination. The susceptibility of an aquifer to contamination can be correlated to the rate of infiltration of water from the ground surface to the aquifer. This susceptibility can be evaluated at a regional scale using the ISI.

ISI mapping is available for the entire planning region from a number of county groundwater studies, including: Grey and Bruce (2003); Huron (2003); Dufferin (2003); and, Wellington (2006). These studies were undertaken with funding from MECP and utilized a standardized methodology for determining ISI. However, minor modifications to the ISI calculations were incorporated to account for local geological conditions. As a result, minor discrepancies exist along the edges of these mapping products. Wellington County used an alternate yet equivalent methodology (Aquifer Vulnerability Index (AVI) method).

ISI mapping begins by assigning an ISI value to each well within the Water Well Information System (WWIS) for the study area. This is accomplished by summing the product of the thickness of each unit (b) in the well log with a corresponding K-factor (see Watershed Characterization Report 2008, Appendix E), as represented in the equation below.

$$ISI = \sum_i \; b_i \bullet K_{Fi}$$

where:

- i = the number of geologic units recorded in the water well record (borehole)
- b = the thickness of each geologic unit recorded in the water well record
- K_F = the Generic Representative Permeability, or K-Factor for each unit (see MOECC Technical Terms of Reference for Groundwater Studies 2001/2002, Schedule C)

The ISI was calculated at each well from the ground surface to the water table for any unconfined aquifer, or from the ground surface to the top of any confined aquifer.

In identified karst areas (caves, sinkholes, sinking streams, sinking lakes, and karst pavement) ISI was adjusted and assigned a high susceptibility value.

Groundwater Vulnerability Level

Within the uppermost aquifer system, areas of low, medium and high susceptibility were identified using the MECP susceptibility classes (low: ISI >80; medium: 30 < ISI < 80; and high: ISI < 30; see WHI 2003, p. 6).

4.1.2.2 Delineating Highly Vulnerable Aquifers

The areas above aquifers that were designated as having high intrinsic susceptibility (ISI) are considered Highly Vulnerable Aquifers for the purposes of source protection planning.

4.1.2.3 Delineating Significant Groundwater Recharge Areas

Significant groundwater recharge areas were delineated using the water budget tools (see Chapter 3.13, as part of the Water Quantity Stress Assessment). Groundwater recharge was estimated by evaluating surficial geology (soil types and thickness, permeability) and land cover within a hydrologic model. Areas with annual average recharge above 115% of the annual mean recharge for the SPA were designated SGRAs.

For details on the delineation of SGRAs and a discussion on limitations and data gaps, see Chapter 3.13.

4.1.2.4 Delineating Intake Protection Zones (IPZs)

There are nine surface water systems within the planning region but only one in the Northern Bruce Peninsula Source Protection Area, the Lion’s Head intake, which is a Great Lakes (Type A) intake.

Intake protection zones (IPZs) define areas of vulnerability for each intake. The offshore component of an IPZ reflects the flow direction and speed of lake and river currents. The onshore component of an IPZ is generated to identify areas on the land surface where surface water runs off into the water bodies that form part of the offshore.

Offshore Components

Consultants with coastal modelling expertise were selected to undertake the delineation of the offshore component of IPZs. All modelling work and in-water delineation of IPZs was peer reviewed. Delineation of intake protection zones followed the Technical Rules: Assessment Report to the *Clean Water Act* (2009), Part IV.3 and Part IV.4.

The offshore component of IPZ-1 for a Type A intake is defined as a circle with a radius of 1 km around the intake as per the Technical Rules. The IPZ-1 was centered on the intake crib. Where the IPZ-1 abutted land it was extended inland 120 m or to the Conservation Authority's regulation limit, whichever is greater (see discussion below).

Delineation of the offshore component of IPZ-2 is based on two factors: the time required to shut down the water treatment facility in the event of a spill; and, the distance that the contaminant could be transported during that time. This time-of-travel (ToT) was defined by the MECP after consulting with operators and is set at a minimum of 2 hours.

An understanding of the direction and velocity of currents within the water body is required to define the distance and direction that the contaminant may be transported. In the Great Lakes, currents at the lakebed, where the intake is often located, frequently flow in the opposite direction from currents at the lake surface. The currents also vary over time and are dependent on wind conditions. A numerical model, calibrated against field measurements, is the most defensible and practical approach to define an IPZ-2. This type of model allows us to evaluate and understand the flow patterns around the intake under a range of conditions.

Numerical modelling was undertaken to delineate the offshore component of the IPZ-2 within the Great Lakes. For Georgian Bay intakes, the hydrodynamic modelling package Delft3D was used to develop an interim West Georgian Bay Model (WGBM) with a grid size that varies from 70 m close to the shoreline and in areas of complex bathymetry to 2.5 km in the open lake. The boundary conditions (levels and currents) in the open lake were extracted from the Lake Huron Operational Forecast System (LHOFS).

The model was run for two periods of three weeks each, which included several storms documented in 2003. The open boundary conditions for the Delft3D model were defined with the currents and water levels extracted from LHOFS. The model was run in reverse mode with neutrally buoyant particles introduced at the intake. Particles were tracked in reverse mode over a 2-hour period, defined by the WTP operators as the required time to shut down the plant in the event of a spill or threat to the drinking water. The composite areal extent of these particles, based on eight wind scenarios was taken to represent the offshore component of the IPZ-2.

Data from the climate station with the longest period of record, Environment Canada's Wiarton Airport, was used in the extreme value analysis. Hourly meteorological data from the National Data Buoy Centre South Lake Huron Monitoring Buoy date from 1981. This data set includes large gaps, especially in the winter season when the monitoring equipment is removed from the lake. Hourly wind speed and direction data from Wiarton Airport date from 1953 and include the winter season.

Eight constant wind directions are used to estimate the range of variability of currents, as shown in Table 4.1.1. Wind data from the closest measurement station was evaluated for the intensity of a 10-year return period; winds from a constant direction over the full model period was assumed (Stantec, 2009). Finally, the model was calibrated and validated with Acoustic Doppler Current Profiler (ADCP) measurements from three deployments by the MOECC in Lake Huron from May 16, 2003 to November 27, 2003 as part of the Great Lakes Nearshore Monitoring Program (Stantec, 2009).

TABLE 4.1.1 – Directional 10-Year Return Period Wind Speeds at Wiarton Airport

Direction	*Direction From (deg)*	*10-year overland wind speed (m/s)*	*10-year overwater wind speed (m/s)*
North	360	13.4	17.3
Northeast	45	15	19.2
East	90	16	20.3
Southeast	135	13.7	17.6
South	180	17.6	22.2
Southwest	225	19.5	24.4
West	270	18.9	23.7
Northwest	315	14.3	18.3
All directions	all	20.6	25.7

Onshore Components

According to the MECP Technical Rules, the offshore IPZ must be extended onshore. The watershed component of the IPZ is extended along watercourse and subsidiary branches within the 2-hour time-of-travel (Stantec, 2009, Phase 1 Technical Addendum). For the offshore component of the IPZ, including the tributaries that fall into the 2-hour ToT, an onshore offset is delineated from each bank. Areas that include constructed pathways are added if their outlets are within the 2-hour ToT.

<u>Storm Sewer Networks</u>

Areas that can deteriorate water quality of the intake by draining into the storm sewer network must be added to the intake protection zone 2, if the time-of-travel to the intake is two hours or less.

In areas where only storm sewer networks were provided, outfall locations and the digital elevation model were used to estimate the extent of the catchment area. Due to the small size of all of these storm sewer sheds (maximum length 2 km or less), the entire storm sewer catchment areas were included in the onshore component of the IPZ-2.

In the event storm sewer outfalls, networks, or catchments were listed as data gaps, the onshore component of IPZ-2 was delineated using aerial photography and watershed boundaries. In this instance developed areas were included in their entirety; with consideration given to the watershed boundaries.

Tile Drains
All tile drains were assumed to discharge either directly, or through other tile drain networks, to municipal drains or watercourses. Where tile drainage existed next to a municipal drain or watercourse and the municipal drain or watercourse was included in the IPZ-2, the IPZ-2 was extended to include the adjacent tile drained areas, as well as all other tile drain areas that, using the DEM, were assumed to contribute water to that water body (Stantec, 2009).

The onshore component of IPZ-2 is a setback of the greater of 120 m or regulatory limits set by the local Conservation Authority under Ontario Regulation 97/04 - Regulations for Development, Interference with Wetlands and Alterations to Shorelines and Watercourses, also known as the Generic Regulation Limit.

Data sources for onshore delineation are summarized in Table 4.1.2.

TABLE 4.1.2 – Input Data for Onshore Delineation of Intake Protection Zones

Digital Elevation Model	The Provincial Digital Elevation Model (DEM) V.2.0, with 10 m horizontal resolution and 5 m vertical resolution, was obtained from Land Information Ontario (LIO) as a GIS dataset. This dataset was used to infer storm sewer catchments where discrete boundaries were not available and to identify elevation of land as part of the overland flow analysis.
Drawings of Storm Sewer Systems	The lower tier municipalities in the study areas were asked to provide drawings of their storm sewer systems where available. This dataset was complemented with its derivative flow direction grid to delineate watersheds for watercourses within the study areas and to characterize overland flow.
Watercourse Mapping	In accordance with Technical Rule 56, the Water Virtual Flow (WVF) and Water Poly Segment (WPS) datasets were available from the Ministry of Natural Resources and Forestry (MNRF) and were used to identify surface water bodies, including rivers and creeks, within all study areas.
Constructed Drains	Obtained from LIO, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) constructed drain dataset was reviewed to identify closed drains located within the study areas. The dataset indicated that no closed drains were located within the WTP study areas.
Tile Drainage Area Mapping	Tile drainage mapping provided by OMAFRA was used to identify the extent of the tile drainage areas in the onshore extent of the study areas.
Water Treatment Plant Operator Supplemental Interviews	In September 2009, Stantec conducted interviews with operations staff for the study area WTPs. Operators identified problems and concerns that they have experienced with plant operations in relation to the water supply and quality. The interviews provided some information on treatment challenges, raw water quality, treatment concerns, and potential sources of contamination. Some data gaps in the interviews exist where information was not available.

Aerial Photography	Southwestern Ontario Orthophotography Project (SWOOP) imagery captured in 2006 by First Base Solutions has 30 cm resolution and was used for general mapping purposes, to identify surface features and to delineate storm sewer catchments of the study areas.

Knowledge Limitations and Data Gaps of IPZ Delineation

The uncertainty of the data sources incorporates an analysis of data variability, quality, relevance, and the spatial resolution of the data.

The data variability refers to the level of consistency among the different datasets reviewed. If a multitude of independent but consistent sources are used for delineation, then level of uncertainty is probably low.

The data quality refers to the accuracy of the data assessed based on the origins of the information. Federal and provincial data are assumed to have a high accuracy level due to regulated quality control measures in place, therefore has an associated high-level of certainty. Other data sources that provide interpretations of data are not considered to have an equal certainty level.

The relevance of the data refers to the applicability of the information to the study area. Site specific and local information is assumed to represent the area well therefore it has a high level of certainty. Unavailable or non-site-specific data lowers this certainty and generally requires that assumptions be made.

Spatial resolution of data and the number and data points available impacts the quality of the model. For example, the number of time series available to calibrate and validate the models used for delineating the IPZs – ranging from climate stations, wind data and flow currents – is relatively low and a core reason for the high uncertainty rating. A larger number of data points would improve the certainty of the analysis.

Modelling uncertainty relates to the ability of the model to accurately depict the flow processes in the hydrological system. The model and employed methods were assessed for each component and overall uncertainties were assigned. While separation of the modelling components is not identified in the Technical Rules, uncertainties have been assessed independently for the purpose of clarity as part of this report.

The extent of the onshore component depends on the residual ToT as determined through in-water modelling. The accuracy of the onshore delineations is limited by the certainty of the in-water modelling.

The 120 m setback and regulatory limits for the onshore component are determined with high certainty. The certainty of the watershed boundaries, storm sewer sheds and tile drained areas each depend on separate data sources, the uncertainty of these data sources directly impact the analysis. Digital data are not available for the exact location of storm sewer shed outfalls or the location of tile drainage outfalls. Finally, many rural developed areas that do not have storm sewers use surface drains (ditches) for the discharge of surface runoff. Data on these surface transport pathways are not available.

Delineation of Intake Protection Zone 3

The modelling completed by Baird & Associates (Baird) for our region's Intake Protection Zone-3 (IPZ-3) and events-based delineation and significant threat identification for local intakes continues on from previous studies completed by Baird. The previous studies, as well as the current study, are included as appendices to this report.

The hydrodynamic models used in the IPZ-3 study were developed in the previous phases. The methodology used is outlined in the 2009 Ministry of the Environment (MOE) Technical Bulletin: Delineation of Intake Protection Zone 3 Using the Event Based Approach. The steps completed were as follows:

- Selection of extreme events
- Selection of spill scenarios based on identified activities of concern
- Calculation of the dilution in spill concentrations from the spill location to the intake
- Determining whether the spill would constitute a drinking water threat at the intake (concentrations exceeding the Ontario Drinking Water Quality Standard (ODWQS) were used in this case)
- Desktop analysis of additional spills
- Recommendations to support IPZ-3 delineation

Modelling

In 2011, the study to complete the supporting modelling for use in defining the IPZ-3 areas *Numerical Modelling in Support of IPZ-3 Delineation, Saugeen, Grey Sauble, Northern Bruce Peninsula* was completed. The following data were used during the study (Baird 2012);

- **Joint Probability Analysis** modelling scenarios based on a combination of wind storm and tributary flow events meeting the definition of an "extreme event" as defined in MOE (2009a).
- **Hydrodynamic Model Runs for Medium-Scale Models**, including the East Lake Huron Model (ELHM) and West Georgian Bay Model (WBGM). The model results provide the boundary conditions for the nested model runs.
- **Hydrodynamic Model Runs for Nested Models** including Kincardine, Southampton, Owen Sound and Meaford. A total of 4 combined scenarios were run for each nested model.

As stated in the Technical Rules, an IPZ-3 must be delineated for type A intakes, where modelling or other methods demonstrate that contaminants released during an extreme event may be transported to the intake. The extreme events that would be most likely to transport a contaminant to the intakes in this region are tributary flows and wind on Lake Huron.

Joint probability and persistence analysis were used to model the extreme events, based on a previous source water studies (Baird, 2012).

The 100-year joint probability events were selected to include the mean and 2-year return period flow events, the return periods of the corresponding wind speeds are shown in Table 4.1.3 (Baird, 2013). For additional information, refer to Baird (2012).

Table 4.1.3 - Model Scenarios with Combined 100-Year Return Period

	East Lake Huron Model		West Georgian Bay Model			
	Southampton and Kincardine Models		Owen Sound Model		Meaford Model	
	NE Wind	SW Wind	NNE Wind	SSW Wind	NW Wind	SE Wind
Wind Storm Duration	36 hrs	43 hrs	111 hrs	43 hrs	49 hrs	74 hrs
Mean Flow	50-Yr Wind (23.7 m/s)	50-Yr Wind (27.3 m/s)	50-Yr Wind (18.9 m/s)	50-Yr Wind (27.3 m/s)	50-Yr Wind (21.1 m/s)	50-Yr Wind (20.4 m/s)
2 Year Flow	0.5-Yr Wind (12.6 m/s)	0.5-Yr Wind (18.9 m/s)	1-Yr Wind (13.9 m/s)	1-Yr Wind (20.2 m/s)	1-Yr Wind (13.4 m/s)	1-Yr Wind (12.3 m/s)

Recommendations for scenarios were developed based on a threats analysis and 38 scenarios were chosen; however, only ten were selected for modelling (see Table 4.1.4). The remaining scenarios were evaluated using a desktop analytical assessment.

Table 4.1.4 – Modelled Spill Scenarios

Spill#	Spill Location	Spill Description	Substance	Volume	Contaminant
1	Owen Sound	Sewage Pumping Station Bypass	E. coli	7,546,000 L	E. coli time series
2	Owen Sound	Marina Fuel	Gasoline	15,000 L	1.5% Benzene
3	Meaford	Marina Fuel	Gasoline	4,500 L	1.5% Benzene
4	Southampton	Bruce Power Fuel Tank	Diesel	750,111 L	0.07% Ethylbenzene
5	Southampton	Marina Fuel	Gasoline	22,500 L	1.5% Benzene
6	Kincardine	Bruce Power Fuel Tank	Diesel	750,111 L	0.07% Ethylbenzene
7	Kincardine	Marina Fuel	Gasoline	15,000 L	1.5% Benzene
8	Lion's Head	Marina Fuel	Gasoline	10,000 L	1.5% Benzene
9	Wiarton	Marina Fuel	Gasoline	10,000 L	1.5% Benzene
10	Thornbury	Marina Fuel	Gasoline	15,000 L	1.5% Benzene

The spill scenarios chosen included fuel tanks and waste water treatment plants. E. coli was the chosen contaminant for the waste water treatment plants. As the ODWQS for e. coli is 0 cfu/100 mL, the operator for the R.H. Neath Water Treatment Plant (Owen Sound) was consulted and it was decided that the recreational standard of 100 cfu/100 mL would be used. Benzene was chosen to be the substance of concern for gas fuel spills because the ODWQS for benzene is low (0.005 mg/L). Diesel contains 0.07% ethylbenzene and only 0.03% benzene; therefore, ethylbenzene was selected as the substance of concern for diesel fuel spills. The objective standard is 0.0024 mg/L for ethylbenzene, set in Table 4 under section 3.2 of the *Technical Support Document for Ontario Drinking-water Quality Standards, Objectives and Guidelines* (2003).

The DELWAQ model was used to model the advection and dispersion of the spills (Baird, 2013). More than one model run was required for some spill scenarios in order to properly evaluate the response for different wind and flow combinations. For example, the Owen Sound marina fuel spill had four different model runs completed in order to include all combinations of two wind conditions and two flow conditions. Additionally, some model runs evaluated more than one intake. For example, the Owen Sound and East Linton intakes are within the same model domain so one model run was used to assess the impact on both intakes.

To be conservative, the Owen Sound Waste Water Treatment Plant release rate was based on the largest bypass event in 2013 (7,546,000 L spill over 21 hours). A conservative approach was adopted and assumptions were made regarding the fuel spills. Marina fuel tanks were assigned a duration of 1 hour; however, the larger fuel tanks at Bruce Power were given a duration of 3 hours (see Table 4.1.5). It was also assumed that there was no evaporation before the fuel entered the water when, in reality, some of the fuel will be lost to evaporation before entering the receiving water and additional evaporation from the surface of the water during the slick phase would occur. In addition, portion will diffuse into the water column to a maximum concentration equal to the equilibrium concentration of the substance in water (Baird, 2013);

- The literature suggests that water in contact with gasoline with about 2% (by weight) benzene will have an equilibrium concentration of dissolved benzene of approximately 58 mg/L. However, maximum concentrations of field samples tend not to exceed 0.2 times the equilibrium saturation unless free product was taken with the sample (Bruce, Miller and Hockman, 1991). Therefore it is reasonable to assume that the equilibrium concentration of benzene is about 12 mg/L in the receiving water.

- The solubility of ethylbenzene varies in accordance with the presence of other petroleum products. The pure compound solubility of ethylbenzene in water is 180 mg/L, while when in diesel fuel its solubility is 0.18 mg/L (Potter, 1993).

The model runs determined that no exceedance of ODWQS was predicted for the spill scenarios related to the fuel tanks at the Bruce Nuclear Power Plant, the Owen Sound sewage pumping station or the marinas in East Linton and Thornbury. However, for the Meaford, Southampton (New), Southampton (Old), Kincardine, Lion’s Head, and Wiarton intakes, the model predicted the concentration of benzene would exceed the ODWQS of 0.005 mg/L. At Owen Sound, the predicted concentration of benzene at the lakebed (0.005 mg/L) equaled the ODWQS, while the predicted concentration at the surface (0.004 mg/L) was just below the ODWQS. Taking into consideration the accuracy of the model, this was considered as a predicted exceedance (Baird,

2013). Figure 4.1.1 shows the pollutograph for the Lion's Head marina spill, which represents a snapshot of the dispersion during the moment of highest concentration at the intake.
In 2021 the Ontario Drinking Water Quality Standard (ODWQS) for benzene was reduced from 0.005 mg/L to 0.001 mg/L. Model predictions for East Linton Intake completed in 2011 demonstrated possible exceedance of the new standard for benzene, therefore resulting in the need to delineate a new Event-based area (EBA) for the East Linton Intake. It is important to note that the other existing EBAs are delineated using the previous ODWQS (0.005 mg/l) and these remain valid under the new ODWQS since the new standard is more stringent.

Table 4.1.5 – Model Run Results

Run#	Spill#	Intakes Evaluated	Spill Description	Contaminant	Wind Direction	Flow Return Period	Spill Duration	Spill Volume
1	1	Owen Sound and East Linton	Sewage Pumping Station Bypass	E. coli Time series	SSW	2 Year	21 hr	7,546,000 L
2					NNW			
3	2	Owen Sound and East Linton	Marina Fuel	1.5% Benzene	SSW	2 Year	1 hr	15,000 L
4					NNE			
5					SSW	Mean	1 hr	
6					NNE			
7	3	Meaford	Marina Fuel	1.5% Benzene	SE	2 Year	1 hr	4,500 L
8						Mean		
9	10	Thornbury	Marina Fuel	1.5% Benzene	SE	2 Year	1 hr	15,000 L
10						Mean		
11	5	Southampton (New) & (Old)	Marina Fuel	1.5% Benzene	SW	2 Year	1 hr	22,500 L
12	7	Kincardine	Marina Fuel	1.5% Benzene	SW	2 Year	1 hr	15,000 L
13	8	Lion's Head	Marina Fuel	1.5% Benzene	SSW	2 Year	1 hr	10,000 L
14	9	Wiarton	Marina Fuel	1.5% Benzene	SSW	2 Year	1 hr	10,000 L
15	4	Southampton (New) & (Old)	Bruce Power Fuel Tank	0.07% Ethylbenzene	SW	2 Year	3 hr	750,111 L
16	6	Kincardine	Bruce Power Fuel Tank	0.07% Ethylbenzene	NE	2 Year	3 hr	750,111 L

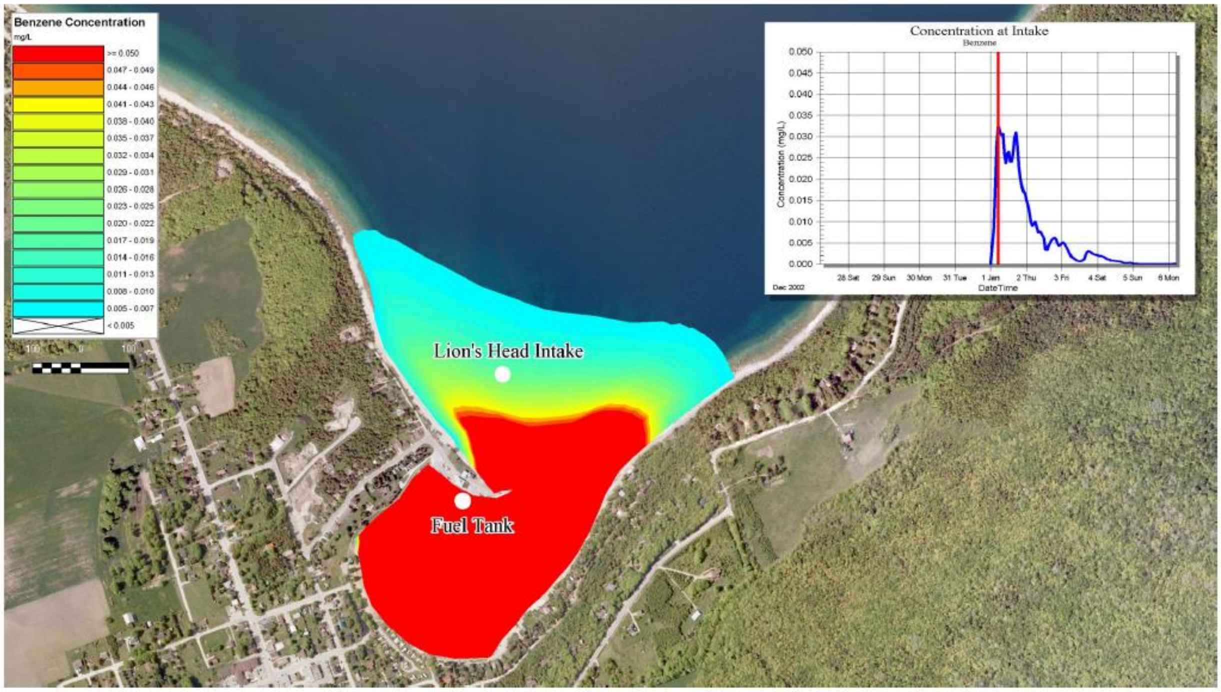

Figure 4.1.1 – Pollutograph for Lion's Head Marina Spill (Baird, 2013)

For limitations on spill modelling, see section 3.6 of *IPZ-3 Modelling for Indentification of Significant Threats Saugeen, Grey Sauble, Northern Bruce Peninsula Region* (Baird, 2013).

Desktop Assessment

The computer model results of spill scenarios generated in the Baird report were used as a basis for a desktop analysis of other potential spill locations. The Baird report contained important pieces of information about the spill scenarios: the volume spilled; the concentration of contaminant; the on-land distance from the spill and along drainage pathways to the outfall at the lakeshore, if applicable; the in-lake distance between the outfall of the spill and the municipal drinking water intake; and the resulting concentration of contaminate in lake water at the intake.

Both fuel and sewage spills were analytically evaluated using the desktop assessment method. The spills modelled using the desktop method all required a flow path from the spill to the lake, as all were located inland. Drainage paths were assumed to follow either storm sewer drains or roadside ditches with a speed of 1 m/s. Baird completed sensitivity testing and determined that reducing the flow speed to 0.3 m/s resulted in a slightly lower assumed concentration at the intake (Baird, 2013), however, whether or not an exceedance was predicted was not affected. While in the drainage path, it was assumed that spill would begin to evaporate. The volume of the spill remaining once the path reached the shoreline was determined using the evaporation rates shown in Figure 4.1.2 and Table 4.1.6. The evaporation rates shown are generally consistent with fresh water, for the purposes of this analysis (Baird, 2013).

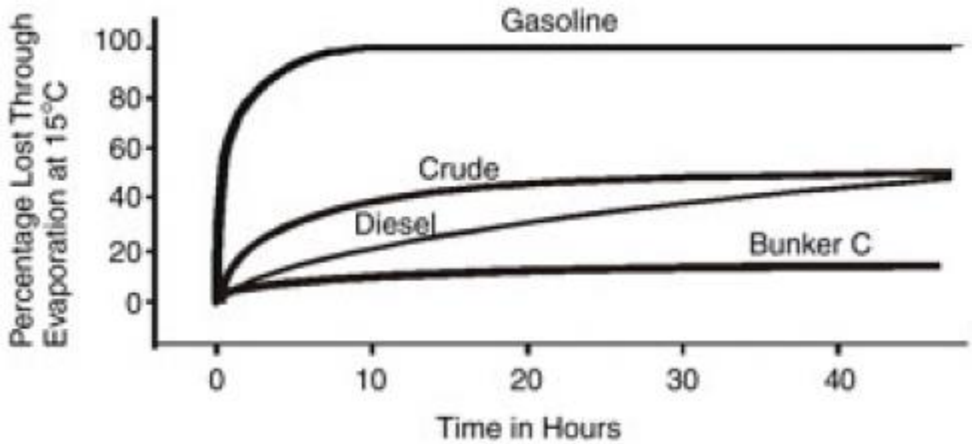

Figure 4.1.2 – Percent Fuel Lost Through Evaporation over Time (Committee on Oil in the Sea 2003)

Table 4.1.6 – Percentage of Fuel Lost Through Evaporation over Time Digitized and Interpolated from Committee on Oil in the Sea (2003)

Time (minutes)	% of benzene evaporated	% of benzene remaining	On-land distance factor
0	0	100	1.00
15	42	58	0.58
30	54	46	0.46
60	67	33	0.33
90	73	27	0.27
120	78	22	0.22
150	82	18	0.18
180	85	15	0.15
240	91	9	0.09
300	96	4	0.04
360	98.6	1.4	0.014
420	99.5	0.5	0.005
480	99.7	0.3	0.003

To determine the final concentration at the intake, an estimated dilution factor was applied for the in-water distance, calculated as factor of the modelled spill per linear metre from the shoreline to the intake, as illustrated by Figure 4.1.3. For the spill scenarios considered in the desktop study, this dilution factor was applied to the in-water travel distance and concentration at the shore to estimate the concentration at the intake. The final concentration was then compared to the ODWQS and checked for exceedance (Baird, 2013).

Figure 4.1.3 – Assumed Drainage and In-water Travel Paths for Desktop Assessment

Desktop analysis done by Baird determined that none of the possible sewage spill scenarios resulted in a predicted exceedance at the intake. Fuel spill exceedances were predicted for Lion's Head, Wiarton, Owen Sound, Meaford, Southampton and Kincardine (Table 4.1.7).

Using the methodology provided by Baird, Source Protection staff examined other points in and around the existing IPZ-2 to determine where to delineate the events-based area (EBA). If the EBA fell outside the existing IPZ-2, an IPZ-3 was delineated. If an area regulated by the Conservation Authority went beyond the IPZ-2 and EBA, an IPZ-3 was delineated. Upon consultation with the MECP, it was determined that not only would a concentration at the intake be calculated, but also a minimum volume required to cause and exceedance. The computer model scenario results were used to predict values from other spill locations by applying three factors:

Table 4.1.7 – Flow Speed Sensitivity Testing and Exceedance Results

Spill#	Spill Location	Descripti	Substance	Volume	Contaminant	Inland Drainage Path Length (m)	In-lake Minimum Distance to Intake (m)	Estimated Concentration at Intake Flows (1 m/s)
11	Lion's Head	Fuel	Gasoline	50,000 L	1.5%Benzene	0	514	**0.098 mg/L**
12	Wiarton	Fuel	Gasoline	50,000 L	1.5%Benzene	836	1,573	**0.041 mg/L**
13	Wiarton	Av. Fuel	Kerosene	50,000 L	0.31% Naphthalene	1043	1,367	**0.012 mg/L**
14	Owen Sound	Fuel	Gasoline	10,000 L	1.5%Benzene	0	1,462	**0.004 mg/L**
	East Linton						6,581	**0.001 mg/L**
15	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	234	2,840	**0.011 mg/L**
	East Linton						7,959	**0.004 mg/L**
16	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	3,342	714	**0.019 mg/L**
	East Linton						5,833	**0.002 mg/L**
17	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	1,355	2,296	**0.011 mg/L**
	East Linton						7,415	**0.003 mg/L**
18	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	136	3,387	**0.009 mg/L**
	East Linton						8,506	**0.004 mg/L**
19	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	198	3,375	**0.009 mg/L**
	East Linton						8,494	**0.004 mg/L**
20	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	1,401	2,225	**0.011 mg/L**
	East Linton						7,344	**0.003 mg/L**
21	Owen Sound	Fuel	Gasoline	50,000 L	1.5%Benzene	1,269	2,225	**0.011 mg/L**
	East Linton						7,344	**0.003 mg/L**
22	Meaford	Fuel	Gasoline	50,000 L	1.5%Benzene	3,357	6,038	**0.026 mg/L**
23	Meaford	Fuel	Gasoline	50,000 L	1.5%Benzene	0	1,700	**0.209 mg/L**
24	Meaford	Fuel	Gasoline	50,000 L	1.5%Benzene	234.5	1,426	**0.239 mg/L**
25	Meaford	Fuel	Gasoline	50,000 L	1.5%Benzene	46.5	2,186	**0.161 mg/L**
26	Meaford	Fuel	Gasoline	50,000 L	1.5%Benzene	1,222	261	**1.083 mg/L**
27	Thornbury	Fuel	Gasoline	50,000 L	1.5%Benzene	284	1,493	**0.003 mg/L**
28	Kincardine	Fuel	Gasoline	50,000 L	1.5%Benzene	691	739	**0.253 mg/L**
29	Kincardine	Fuel	Gasoline	50,000 L	1.5%Benzene	660	4,266	**0.044 mg/L**
30	Kincardine	Fuel	Gasoline	50,000 L	1.5%Benzene	391	900	**0.220 mg/L**
31	Southampton (New)	Fuel	Gasoline	50,000 L	1.5% Benzene	464	3,064	**0.018 mg/L**

Volume factor: The volume of benzene released in a spill is directly proportional to the quantity of the spill. If the volume of the spill scenario is greater than the computer modelled scenario, then the volume factor is greater than 1.0. Where the spill scenario volume is less than the computer modelled scenario, the volume factor is less than 1.0. The volume factor is 1.0 where volumes for the two scenarios are equivalent.

On-land distance factor: Fuel, such as gasoline, does evaporate over time with the resultant decrease in the amount of the contaminant, in this case benzene. An evaporation curve was used to determine the proportion of material that would be remaining after a given amount of time of moving downstream to the lake (see Figure 4.1.2). The measured in-land distance was multiplied by an estimated velocity of the water to give the time of travel and then the time of travel was compared to the evaporation curve to give the percent material remaining. The proportion remaining became the on-land distance factor (values range from 1.0 down to 0.0). For example, if the spill location was 600 metres from the outfall, it would take 10 minutes of travel and 85% of the original material would remain; therefore the on-land distance factor would be 0.85. Values are near 1.0 where the spill scenario location is close to the lake and decrease as the upstream distance becomes greater. Values approach 0.0 after 8 hours of travel time.

In-lake distance factor: Since the spill scenario may not reach the same outfall location as the computer modelled scenario, it is necessary to account for the difference in dilution of the spill as it moves in the lake. The distance from the spill outfall location to the municipal water intake was measured and compared to the measurement for the computer modelled spill. There is an inverse relationship for the in-lake distance, meaning that if a spill is closer to the intake then the concentration of benzene would remain higher. For example, if the spill outfall location was 1000 metres from the intake and the computer modelled location was 2000 metres, then the in-lake distance factor would be 2.0. If the outfall for the spill scenario location is closer to the intake than the computer modelled scenario, then the in-lake distance factor is greater than 1.0. Where the distance to the intake from the outfall for the spill scenario is farther than the computer modelled scenario, the in-lake distance factor is less than 1.0. The in-lake distance factor is 1.0 where the in-lake distance for the two scenarios are equivalent.

Calculations

The concentration of benzene at the intake resulting from a spill can be derived for virtually any point in proximity to the intake and computer modelled spill location. The following formula is used:

Benzene concentration at intake from spill scenario (mg/L)	=	Benzene concentration at intake from computer modelled scenario (mg/L)	X	Volume factor	X	On-land distance factor	X	In-lake distance factor

where:

$$\text{Volume factor} = \frac{\text{Volume of spill scenario}}{\text{Volume of computer modelled scenario}}$$

On-land distance factor = Proportion of benzene remaining after evaporation considered for the amount of time travelled

$$\text{In-lake distance factor} = \frac{\text{Distance to intake for computer modelled scenario}}{\text{Distance to intake from outfall of spill scenario}}$$

The concentration formula was used to derive a second formula for determining the minimum volume of a spill that would result in an exceedance of the water quality objective for benzene. The Ontario Drinking Water Quality Standard for benzene is 0.005 mg/L. (If water the intake was to have a concentration of 0.005 mg/L or greater of benzene, then the water quality would be adversely affected and the activity causing this event would be considered a significant drinking water threat.). The calculations used to delineate the East Linton EBA follows the same methodology as the other EBA's, with the exception of using the updated Ontario Drinking Water Quality Standard for benzene of 0.001 mg/L as the exceedance threshold to determine if a given spill volume would be considered a significant drinking water threat.

The formula for calculating the minimum volume of the spill is:

$$\text{Volume of spill scenario} = \frac{\text{Benzene concentration at intake of 0.005 mg/L for spill scenario} \times \text{Volume of computer modelled scenario}}{\text{Benzene concentration at intake for computer modelled scenario (mg/L)} \times \text{On-land distance factor} \times \text{In-lake distance factor}}$$

The effect of the three factors on the resulting concentration at the intake can be illustrated by the following example. Information from the Baird modelling report (Baird, 2013) indicates that a spill near the mouth of the Penetangore River in Kincardine (15,000 L spilled at a site on the lakeshore and the in-lake distance to the intake of 1149 metres) would result in a benzene concentration at the Kincardine intake of 0.055 mg/L. If the spill volume from the same location was doubled, then the calculated concentration would double to 0.110 mg/L. If the spill volume was the same, but the spill location was 1000 metres in-land, then the calculated concentration would decrease because of evaporation to a value of 0.031 mg/L. In addition the information for these two locations could be used to calculate the spill volume necessary to have a concentration of 0.005 mg/L. The location near the river mouth would have a spill volume of 1400 L and the location 1000 metres in-land from the shoreline would have a higher value at 2500L.

Points were then re-evaluated using this method to determine the minimum volumes that cause exceedance of the standards to deteriorate the water quality. These volumes were used to delineate events based areas where certain fuel activities have been identified as significant drinking water threats. Source protection plan will/would include policies to address these significant threats (Figure 4.1.4).

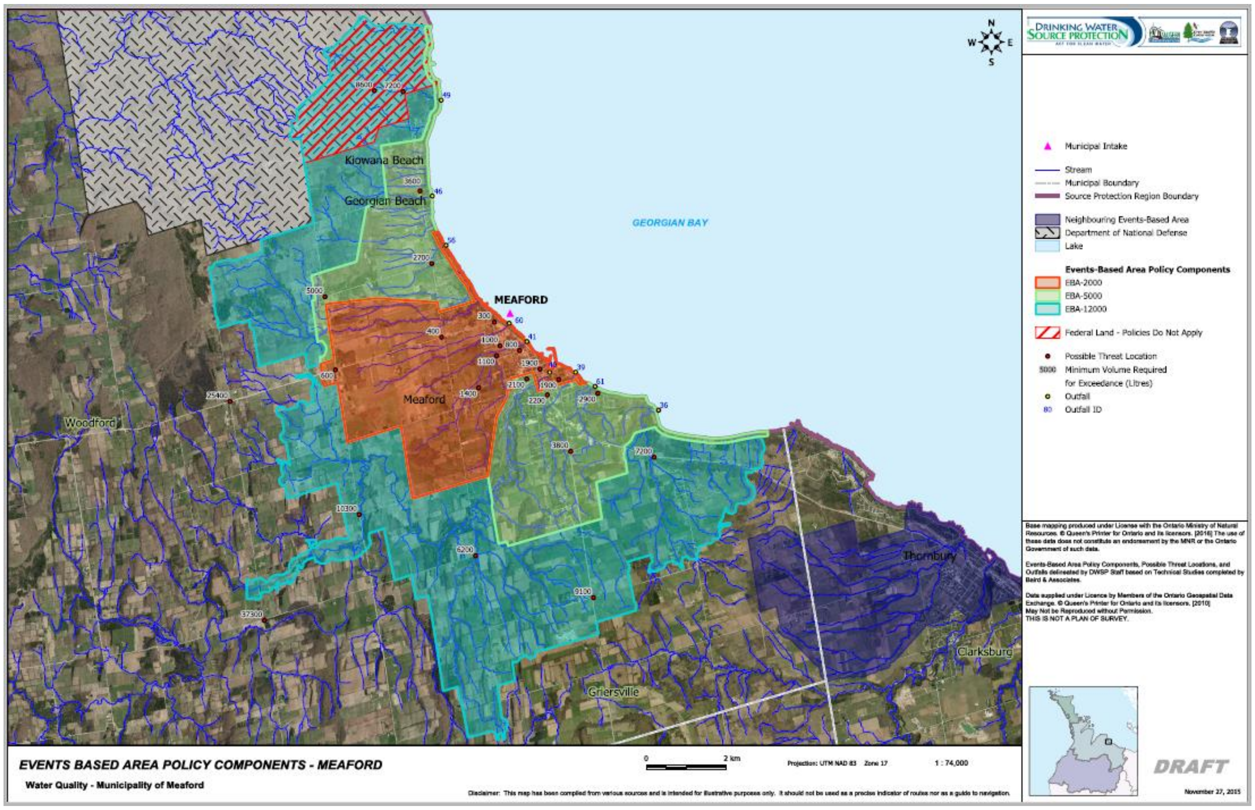

Figure 4.1.4 – Events-based Policy Area for Meaford Intake

4.1.2.5 Delineating Wellhead Protection Areas (WHPAs)

Wellhead Protection Areas (WHPAs)

A wellhead protection area, or WHPA, is the two-dimensional projection onto the ground surface of the three-dimensional volume of groundwater that is pumped from a well field. In other words, it is the area above the aquifer from which groundwater is drawn into the well in a certain time frame under a defined pumping rate.

WHPAs themselves are composed of a number of zones that reflect the time required for water to move to the well from different areas of the aquifer. These zones are called time-of-travel capture zones. Zones were identified as the 100 metre radius, 2-year, 5-year, and 25-year time-of-travel limits. This delineation only considers the time-of-travel within the aquifer and ignores the time-of-travel from the ground surface to the aquifer.

WHPAs were originally generated for the study area as part of the MOECC Groundwater Studies completed for Huron, Bruce, Grey, and Dufferin Counties in 2003 and for Wellington County in 2006. Additional work was undertaken between 2006 and 2009 by the Source Protection program for wellheads when additional information had become available or the circumstances of the well had changed.

Following the Technical Rules, these time-of-travel (ToT) capture zones were applied to all municipal groundwater supplies within the study area as part of the MOECC groundwater studies. The time-of-travel zones as per Technical Rule 51 are:

- WHPA-A: 100 metre radius
- WHPA-B: 2-year ToT capture zone that is not within WHPA-A
- WHPA-C: 5-year ToT capture zone that is not within WHPAs A or B
- WHPA-D: The capture zone where ToT is less than 25 years and not within WHPAs A, B or C
- WHPA-E: For GUDI wells, the 2-hour ToT within the surface water body influencing the well

The WHPA is the composite of WHPA-A, B, C, and D. If the well is under the direct influence of surface water, a WHPA-E is required.

Wells are called under the direct influence of surface water (GUDI) if a hydrogeological study indicates that surface water can rapidly enter into a well or if pathogens expected in surface water are present in the well.

For wells classified as GUDI, an additional protection zone, WHPA-E, must be delineated. This zone contains the 2-hour ToT within the surface water body affecting the well. The delineation method for WHPA-E closely follows that of intake protection zone 2 (IPZ-2). Furthermore, if the water quality of this well shows contamination that can be neither attributed to the total capture zone (WHPAs A-D) nor the surface water in the vicinity (WHPA-E), then a larger contributing area of the influencing surface water may be delineated, called WHPA-F.

The size and shape of all groundwater WHPAs A-D largely depends on the amount of water being pumped, the permeability of the aquifer from which it is being pumped, and the overall regional hydraulic gradient. Large WHPAs occur in areas where there are high gradients, areas with high permeability, areas with bedrock fractures and areas where large volumes of water are being pumped.

It is important to note that an increased pumping rate, perhaps due to new development, will increase the size of a WHPA and alter its shape. However, a conservative pumping rate was assumed, which is a projection of the average pumping rate into the future, assuming continued population growth at the current rate (2001 and 2006 data) and current water use.

Methodology

Delineation of wellhead protection areas is accomplished through the application of numerical groundwater models. The physical relationships governing the movement of groundwater can be

incorporated into numerical models to simulate the existing groundwater flow system. Once calibrated, this model can be used to determine the pathways of groundwater in the aquifer and to calculate the travel time between any two points along those path lines.
ToT capture zones for municipal wells are calculated by releasing many particles into the model that originate in a circle around the well, and running the model in reverse. These capture zone results form the basis for delineating WHPAs for the municipal well.

Knowledge Limitations and Data Gaps of WHPA Delineation

WHPAs produced from numerical models incorporate a number of assumptions, input parameters and boundary conditions. Each model is a representation of the area surrounding the municipal well, and this representation has been simplified to facilitate model development in all cases. The WHPA modelling results represent the best estimate of the actual area which contributes to the well.

As additional information about the hydrogeology becomes available, the numerical models will be revised and WHPAs will be re-evaluated. Furthermore, the taking of water will be different in the future as communities grow and additional groundwater wells are developed.

One important limitation is that the capture zones are projected to ground surface, which does not reflect the time required for water to travel from ground surface to the aquifer. This is particularly true when the wells that are being evaluated pump water from a deep aquifer that is overlain with fine-grain sediments, such as silts and clays. Especially in karst terrains, the applicability of the conventional numerical groundwater models should be re-evaluated due to the high permeability of these aquifers.

4.1.2.6 Identification of Transport Pathways to Groundwater

The intrinsic vulnerability of an aquifer can increase by any land use activity or feature that disturbs the surface above the aquifer or artificially enhances flow to that aquifer. These transport pathways, or short circuits, can be either natural or constructed (CRA, 2009). Natural pathways, such as fracturing and karsts features, are already considered within the regional ISI/AVI mapping. Constructed transport pathways are human-made features or open pathways through the ground that have the potential to increase the vulnerability of a drinking water source to contamination.

Preliminary identification of transport pathways was completed through aerial photo interpretation. Properties and areas of interest were identified from the 2006/2007 photos in a GIS environment. Properties located in the WHPA were also visited as part of a larger effort to evaluate drinking water threats throughout the region. As part of these visits, routine questions were asked of the property owners about the location and condition of any wells on the property. The results of these site visits were entered and stored in a geo-referenced database, facilitating review as part of the transport pathways review.

In this source protection region, transport pathways can be grouped into several categories, namely: pits and quarries; private wells; urban areas; and, private well clusters. Detailed methodology and consideration of these areas are outlined below. In assigning transport pathway adjustments, the hydrogeology of the site and the condition of the pathway were considered, as well as the cumulative impact of transport pathways.

Pits and Quarries

Pits and quarries were primarily identified through aerial photography. Where prudent, these operations were examined by a roadside or windshield survey in order to ascertain the type of operations. There are relatively few pits and quarries in the Region. Where they exist, and dependent on their depth with respect to the water table, aquifer vulnerability was adjusted from low to moderate or high, or from moderate to high.

Private Wells

Private wells were first identified using the WWIS. Additional information was gathered from site visits carried out as part of this review, and stewardship programs to determine if any upgrades had occurred since 2006.

Wells that were not in compliance with existing regulations were identified as being potential conduits for water that increase the vulnerability of the aquifer locally. Vulnerability scores were adjusted in the vicinity of the well, and were adjusted a maximum of one level (i.e. low to moderate; or moderate to high).

Additionally, several properties for which no well record exists, nor any well obvious by site inspection, yet have structures which require water were identified. In these cases, vulnerability scores were adjusted for the property and were elevated a maximum of one level.

Urban Areas and Private Well Clusters

Urban areas inside WHPAs were delineated based on aerial photography. These areas warrant special consideration as potential areas for transport pathway adjustments under Technical Rule 41 (3) as the cumulative effects of a high density of abandoned historic wells are common. Although these areas today are serviced by a municipal well, most were historically serviced by private wells. Additionally, the age of these wells precludes the existence of a record for the wells.

The historical servicing of these urban areas was reviewed, and the areas themselves visited to determine if former private wells could be in existence. Where this information indicates that wells are in existence and are substantially non-compliant, vulnerability scores were adjusted for the areas, and were adjusted a maximum of one level.

4.1.2.7 Delineating Wellhead Protection Area E (GUDI wells only)

The wellhead protection area E (WHPA-E) is delineated for groundwater wells that receive water from aquifers under the direct influence of surface water (GUDI). The Technical Rules lay out the methodology to delineate WHPA-Es and for threats-based risk assessment. Specifically, Part V.3 Technical Rule 47(5) defines how a surface water body shall be identified that is most likely to influence the well. From this point of interaction, the Technical Rules prescribe to follow the rules for surface water intakes (see 4.1.2.4). Following the threats-based approach to water quality risk assessment, vulnerability scores are then assigned to these surface water bodies. Activities on properties located within the WHPA-E may be considered a threat to the drinking water source.

The first step requires the identification of a point of interaction (POI), which is the point within a surface water body where interaction with the groundwater aquifer is most likely. Unless a specific water body was pointed out in the engineering reports and inspection reports, the closest point within a water body was identified.

From the POI, the 2-hour ToT must be delineated. If the POI is located in a surface water body that is sufficiently large, the delineation of the WHPA-E requires the computation of the two-hour ToT considering streamflow velocity, for example using open channel modelling. In cases where surface water bodies were very small, the WHPA-E was extended to the full surface water body. This is the case where, during any 2-year return period runoff event, water from any location in the surface water body can reach the point of interaction with the GUDI well in less than two hours.

With the availability of new and more accurate data, particularly a new digital elevation model available for some areas, Source Protection staff undertook a review of the WHPA-E delineations fall of 2013. It was determined that eight (Tobermory, Oliphant, Huron Woods, Foreman, Pottawatomi, Kimberley, Markdale and Neustadt) included the full extent of nearby watersheds and therefore did not need to be redelineated. Staff undertook work to redelineate the remaining seven WHPA-Es (Amabel-Sauble, Winburk, Tara, Chatsworth, Walters Falls, Chepstow and Durham) using updated methodology.

Updated WHPA-E Methodology

Southwestern Ontario Orthophotography Project 2010 (SWOOP 2010) raw imagery data obtained as part of the Ontario Geospatial Data Exchange was used to create 1 metre digital elevation models (DEMs) using BAE Systems SOCET GXP software. SWOOP 2010 aerial imagery was also used to update watercourse line work and water body polygons.

Velocities were calculated and used to represent a section of stream using the following steps:

a) Streams were broken up into sections at intersections of tributaries and where the characteristics of the stream looked unique on the aerial imagery. The 1 m DEM was used to collect cross-sections in 3D stereo viewing. Any spikes in the profile data were smoothed out where it looked like the software had problems with water reflectance or highly wooded sections.

b) Slopes running along the stream were calculated for representative sections using elevation values off the 1 m DEM. They were calculated using the standard equation for slope; change in height divided by change in distance. The elevation values were collected just beside the visible water surface on the bank so that water reflectance errors would not be an issue. The distance used was the stream length.

c) Roughness values were determined using previous fieldwork photographs and a reference catalogue in the Conveyance Estimation System software. The roughness value depends on the characteristics of the streambed, bank and floodplain. For example, gravel, clay, reeds, trees, etc. will all influence the velocity at which water in the stream will flow.

d) The stream profile, slope and roughness data was all put into modeling software called the Conveyance Estimation System. The resulting output from this is an average velocity (m/s) versus elevation (m) graph for each stream profile. The velocity value used is taken at the elevation of the top of the bank simulating the worst-case scenario of water levels rising to fill the streambed.

The velocity and stream distance for each stream section was used to calculate a portion of an hour of travel time. This was used to go upstream until a 2-hour ToT was reached from the POI.

The following components were then created in order to delineate the WHPA-E:

a) A 120 m buffer was applied to the stream network reaching 2 hours upstream from the well. This buffer was cut in a straight line across the POI because downstream of the well does not need to be included.

b) Conservation Authority regulation limit polygons that intersect the 120 m buffer are included. Some cuts were made for these when they extended significantly past the end of the 2-hour ToT. Meander belt polygons that continued past were often cut across the end of a property representing tile drainage just past the end of the 120 m buffer. Wetland polygons that extended significantly past were often cut along the edge of the nearest crossing road past the end of the 120 m buffer. The Saugeen Valley Conservation Authority does not have regulation limits outside of populated areas so, when absent, the hazard lands polygons were used instead (part of Durham and for Chepstow).

c) Tile drainage was included by taking agricultural properties that are touching the 120 m buffer and including those that look like they have fields that could be in production and could therefore have tile drainage. Any wooded areas larger than one hectare were cut out.

All of these components were then combined to form the WHPA-E delineation. Any holes smaller than one hectare were removed, as they were the result of imperfect alignment of the components. During review by the MECP these small holes were determined to be negligible in segmenting the area of flow towards the water body.

4.1.2.8 Delineating Wellhead Protection Area F (GUDI wells only)

In this source protection area, no WHPA-F has been delineated.

4.1.3 Vulnerability Scoring in Vulnerable Areas

4.1.3.1 Vulnerability of Highly Vulnerable Aquifers (HVAs)

According to the Technical Rules, highly vulnerable aquifer areas outside of wellhead protection areas are assigned a vulnerability score of six.

4.1.3.2 Vulnerability of Significant Groundwater Recharge Areas (SGRAs)

Vulnerability scoring within the significant groundwater recharge areas was completed by combining the aquifer vulnerability mapping with the significant groundwater recharge areas. Significant groundwater recharge areas that have high intrinsic vulnerability (coincident with highly vulnerable aquifers) were given a score of six. Significant groundwater recharge areas that have moderate and low intrinsic vulnerability were given vulnerability scores of four and two respectively. As per the 2021 Amendments to the Technical Rules, vulnerability scoring for significant groundwater recharge areas was removed.

4.1.3.3 Vulnerability of Drinking Water Systems that Use Groundwater

To determine the vulnerability of groundwater wells, the map of a wellhead protection area (WHPA) is combined with the intrinsic groundwater vulnerability. This intrinsic vulnerability is expressed with the Intrinsic Vulnerability Index and its susceptibility classes (ISI see Section 4.1.2.1). Aquifer susceptibility can be low, medium and high.

In accordance with Part VII.3, Technical Rule 83, WHPA vulnerability scores can range from two, for low vulnerability, to ten, for high vulnerability (see Table 4.1.8). Based on the combination of the WHPA maps and the intrinsic groundwater susceptibility, scores were generated across each WHPA. The resulting scores provide an indication of how likely it is that contamination from drinking water quality threats can reach a well (i.e. surface or near surface sources of contamination within the WHPA). Typically, vulnerability scores are higher closer to the well.

TABLE 4.1.8 – Vulnerability Scoring in Wellhead Protection Areas (WHPAs)

WHPA Protection Zone	*Intrinsic Groundwater Vulnerability*		
	High	*Medium*	*Low*
WHPA-A: 100 m radius	10	10	10
WHPA-B: 2-year ToT	10	8	6
WHPA-C: 5-year ToT	8	6	4
WHPA-D: 25-year ToT	6	4	2

4.1.3.4 Vulnerability Adjustment for Transport Pathways

Transport pathways are features resulting from human activities that have removed layers of material that provide natural protection to pumped aquifers. These features, which include gravel pits, quarries and improperly constructed wells have the potential to allow the rapid movement of contaminants from the ground surface into these aquifers. The location, density and likelihood of these features to impact the aquifers was evaluated for all WHPAs (see Section 4.1.2.6). As a result of this evaluation, ISI/AVI index mapping values were increased in areas where potential impacts were considered possible in accordance with the Technical Rules (Part IV.1, Technical Rules 39 to 41).

4.1.3.5 Vulnerability of Surface Water Intakes

The vulnerability score is based on the attributes of the intake such as distance from shore and depth, the type of water body, the physical characteristics of the environment, and the influences on source water. It is essentially qualitative, based on scores assigned to the contributing factors. Vulnerability scores are derived for each intake protection zone.

A vulnerability score is assigned to each IPZ-1, IPZ-2 and each area of an IPZ-3 that is associated with a Type C or Type D intake. It is calculated by combining the Area Vulnerability Factor (Part VIII.2, Technical Rule 92), which depends on the IPZ zoning, and the Source Vulnerability Factor (Part VIII.3, Technical Rule 95), which describes the inherent vulnerability of the intake.

Vulnerability Score = Area Vulnerability Factor x Source Vulnerability Factor

This formula does not take into consideration the biological, chemical or physical properties of potential contaminants. The vulnerability score, area vulnerability factor and the source vulnerability factor are unit-less.

The Technical Rules outline applicable vulnerability scoring for intakes in all types of surface water sources. The water treatment plants (WTPs) located on Lake Huron, which includes Georgian Bay, are classified as Type A (Great Lakes) intakes.

The Technical Rules provide the sub factors required to assess the area vulnerability factor and source vulnerability factors. The criteria to evaluate and weigh the sub factors are not provided in the Technical Rules; therefore, a methodology has been developed in the form of a decision matrix.

The area vulnerability factor, the source vulnerability factor and their sub-factors are considered and discussed below.

Area Vulnerability Factor

The Area Vulnerability Factor for IPZ-1 is set by the Technical Rules and is always ten (Part VIII.2, Technical Rule 88). The area vulnerability factor for IPZ-2 must be assigned a whole number ranging from seven to nine (Technical Rule 89) and it must consider the following factors (for detailed description on how each of these is computed, see Stantec, 2009, Phase 1 Technical Addendum):

1. The percentage of land within IPZ-2

2. The land cover, soil type, permeability of the land, and the slope of any setbacks
3. The hydrological and hydro-geological conditions in the area that contribute water to the area through transport pathways

The area vulnerability factor score is the average of these components.

Source Vulnerability Factor

The Source Vulnerability Factor ranges from 0.5 to 1.0 and must take into consideration the depth of the intake from the top of the water surface, the distance of the intake from land and the number of recorded drinking water issues related to the intake. The source vulnerability factor score is then the average of these three components. The values set out in the Technical Rules are shown below in Table 4.1.9. (Part VIII.3, Technical Rule 92(3)).

TABLE 4.1.9 – Source Vulnerability Factor of an Intake Protection Zone 2 (IPZ-2)

Intake Type	*Source Vulnerability Factor*
A (Great Lakes)	0.5 to 0.7
B (connecting channels)	0.7 to 0.9
C (rivers)	0.9 or 1
D (others)	0.8 to 1

4.1.3.6 Vulnerability Scoring for Groundwater Systems Under the Direct Influence of Surface Water (WHPA-E)

Vulnerability scoring for wellhead protection area E (WHPA-E) associated with wells under the direct influence of surface water follows the procedure outlined for intake protection zones (Section 4.1.3.5). Separate scores are determined for the area vulnerability, which contributes runoff to the surface water, and the source vulnerability at the well itself, which measures the likelihood that contamination enters from the surface water body into the well. Both factors are then multiplied together.

Area vulnerability was determined as described for intake protection zones, taking into account: the percentage of land within the WHPA-E; land characteristics, such as the land cover, soil type, permeability of the land, and the slope of any setbacks; and the hydrological and hydro-geological conditions in the area that contribute water to the area through transport pathways.

To determine the source vulnerability factor, groundwater systems under the direct influence of surface water (GUDI) are best described as Type D (other) systems. The source vulnerability score is 0.8 (low), 0.9 (moderate) and 1.0 (high).

4.1.3.7 Limitations of Vulnerability Scoring

Vulnerability scoring of all vulnerable areas is limited by the accumulative effect of its three components:

- Limitations of the aquifer vulnerability and intrinsic susceptibility (see section 4.1.2.1), which is the basis for vulnerability scoring;
- Uncertainty regarding the spatial extent of the vulnerable areas (see section 4.1.2.2-5, and 4.1.2.7); and
- Limitations related to the identification of transport pathways in groundwater (see section 4.1.2.6) and as part of the onshore component of the intake protection zone (see section 4.1.2.4), which lead to an adjustment of the vulnerability score.

4.1.4 Managed Lands, Livestock Density and Impervious Surfaces

Managed lands are lands to which nutrients are applied. Managed lands can be categorized into two groups: agricultural managed land and non-agricultural managed land (definition in Technical Rule 1(1)). Agricultural managed land includes areas of cropland, fallow and improved pasture that may receive nutrients. Non-agricultural managed land includes golf courses, sports fields, lawns, and other grassed areas that may receive nutrients, which is primarily commercial fertilizer. Determining the location and percentage of managed lands, the location of agricultural managed lands and the calculation of livestock density can determine whether the application of agricultural source material (ASM), non-agricultural source material (NASM) and commercial fertilizers are significant threats within a vulnerable area.

Livestock density is determined by "dividing the nutrient units generated in each area by the number of acres of agricultural managed land in that area where agricultural source material is applied." (Technical Rule 16(10)).

4.1.4.1 Managed Lands and Methodology

A proposed methodology for calculating the percentage of managed lands and livestock density for the application of ASM, NASM and commercial fertilizers was outlined in an MOECC Technical Bulletin (2009b).

Agricultural Managed Lands

For each agricultural parcel within a wellhead protection area (WHPA), the percentage of managed land was estimated, based on review of aerial photography, as the total area that is cropped plus the area devoted to animal land use. The portion of the property within the WHPA was estimated using the MPAC parcel layer and the DWSP delineation of the WHPA. The total area of agricultural lands within a vulnerable area is calculated by adding all agricultural parcels within the vulnerable area, weighted with the percentage of each property that is managed.

Each agricultural parcel within an intake protection zone (IPZ), highly vulnerable aquifer (HVA) or significant groundwater recharge area (SGRA) was evaluated using the same rules. For intake protection zones, only the onshore component of the IPZ was taken into consideration.

Non-Agricultural Managed Lands

Non-agricultural properties considered managed lands include municipal parks, sport complexes, large school playgrounds, ski hills, golf courses and residential lawns. To determine the areas of residential lawn within a vulnerable area, only 55% of their original parcels size was considered. The full parcel size was used for all non-residential, non-agricultural managed land parcels, such as municipal parks and golf courses.

Input Data for Managed Lands

- MPAC parcel fabric
- DWSP delineated layer of Recreation Polygons consisting of golf courses, ski hills and sports complexes, digitized from aerial photography
- SOLRIS (Southern Ontario Land Resource Information System) "Built-Up Areas"

Separating Areas with Elevated Vulnerability

Agricultural and non-agricultural managed lands were computed for each vulnerable area but only those areas with an elevated vulnerability score were further considered, as well as the total size of each vulnerable area. For WHPAs, this threshold is a vulnerability score of six or more. For IPZs, this threshold is 4.2 or more. For HVAs, only the areas with a vulnerability of six were considered. Areas identified with an elevated vulnerability were then added by each sub area to create one score for each WHPA-A, WHPA-B, WHPA-C, WHPA-D, IPZ-1 and IPZ-2, and HVA. These areas were used for all further computations.

Calculations of managed lands used to determine water quality risks in HVAs remain valid with the removal of SGRA scores given the fact that the same threshold vulnerability of six or more was used for both areas.

Calculation of Managed Lands Percentage

For each vulnerable area WHPA-A, WHPA-B, WHPA-C, WHPA-D, IPZ-1 and IPZ-2, the percentage of managed lands was computed by dividing the hectares of managed lands by the hectares in the vulnerable area zone and multiplying by 100.

4.1.4.2 Livestock Density and Methodology

The calculation of livestock density within vulnerable areas (WHPAs, IPZs, SGRAs, and HVAs) uses the index nutrient units per acre (NU/acre), using only the area of agricultural managed lands as a denominator. Separate scores were computed for WHPA-A, WHPA-B, WHPA-C, WHPA-D, IPZ-1 and IPZ-2. The same areas with elevated vulnerability were used as previously described for managed lands.

Nutrient Units Estimate for Agricultural Parcels with Barns

To determine the nutrient units, each parcel of land that intersects the vulnerable areas was assessed for the presence of a livestock barn. The size of the barn was used as a surrogate for the number of livestock and the amount of nutrients that could be generated by the livestock on that farm. The description in the MPAC farm code was initially used to screen for the livestock parcels to determine the livestock type.

Livestock housing areas were estimated for barns on these parcels. Partial coverage of building footprints was available for the study area, but where data gaps existed, the buildings on parcels having a farm code were measured based on 2006 air photos.

Each type of livestock has its own nutrient unit conversion factor to determine the number of animals that generate 1 NU. For instance, one beef cow produces 1 NU and requires 100 square feet or nine square metres of living space in a barn, so the relationship for beef barns is 100 ft^2/NU. The ratio assumes that the capacity of each livestock barn is at maximum capacity in order to generate, or have the potential to generate, that amount of nutrients.

The number of animals on each parcel was determined using Table 4.1.10. The NU value was multiplied by the NU conversion factor to generate the number of animals on each parcel.

The distinction between beef cow and beef feeders was made based on a visual review of the property; pasture areas are consistent with beef cow production and livestock yards are consistent with beef feeders. NU was then multiplied by the appropriate conversion factor as each parcel was reviewed. The chart information was extracted and condensed from the memorandum that contains Technical Bulletins supplied by the Ministry of the Environment and Climate Change (2009b).

TABLE 4.1.10 – Nutrient Unit Conversion Factors for Poultry, Cattle and Swine and Other Types of Livestock

Livestock Category	***Description***	***NU Conversion Factor***	***Animal Conversion Factor***
Cattle	Beef cow	1 animal/NU	1
	Beef feeder	3 animals/NU	3
	Dairy	2 animals/NU	2
Swine	Average	8 animals/NU	8
Sheep	Average	12 animals/NU	12
Other	Horse	1 animal/NU	1
	Goat	8 animals/NU	8

Source: Technical Bulletin: Managed Lands and Livestock Density, Table 2 (MOECC, 2009b)

Through air photo interpretation, the type of livestock housed in each barn was determined and the area of the housing was measured. A table included in the technical memorandum provided by the MECP summarizes the relationship between barn area, livestock type and nutrient units generated, see Table 4.1.11. To determine the total number of nutrient units per farm the following calculation was made for each parcel; multiplying the area of the barn by the nutrient unit per area ratio.

TABLE 4.1.11 – Barn/Nutrient Unit Relationship

Livestock Type	***Nutrient Units per Barn Area [m^2/NU]***	***Nutrient Units per Barn Area [ft^2/NU]***
Dairy	11	120

Beef	9	100
Swine	7	70
Horse	26	275
Sheep	14	150
Goat	19	200
Chickens	25	267
Turkeys	24	260
Fur	223	2400
Mixed	13	140

Source: Technical Bulletin: Managed Lands and Livestock Density, Table 1 (MOECC, 2009b)

Nutrient Units Estimate for Agricultural Parcels without Barns

For pastures located within agricultural parcels located within vulnerable areas that do not contain a barn, it is assumed these are used as permanent pastures.

The percentage of each agricultural parcel used as livestock pastures was estimated using 2006 aerial photography. The number of nutrient units was estimated using the area of the parcel, multiplied by the percentage used as livestock pastures in order to derive the total nutrient units per parcel. For each hectare, a nutrient unit count of 1.5 NU/hectare was assumed. (OMAFRA, 2000).

Calculation of Livestock Density

For each vulnerable area (SGRA and HVA within each municipality, WHPA-A, WHPA-B, WHPA-C, WHPA-D, IPZ-1 and IPZ-2), the nutrient units within the vulnerable area were estimated by summing all nutrient units for each parcel weighted with the portion of each parcel that is located within the vulnerable area. The total nutrient unit value within each vulnerable area was then divided by the total area of agricultural managed lands in acres within that vulnerable area. Livestock density is given as nutrient units per acre of agricultural managed land.

For WHPAs, IPZs, and HVAs, livestock density was computed for all areas that have a vulnerability score of six or higher. For WHPAs, the nutrient unit per acre values were calculated for each zone and vulnerability score. If values landed in the same category for two or more contiguous areas within a zone, they were merged. For IPZs, one average value was computed for each zone within vulnerable area onshore, regardless of any other borders, such as municipalities and source protection areas. For HVAs, the average value was computed separately for each municipality.

Calculations of livestock density used to determine water quality risks in HVAs remain valid with the removal of SGRA scores given the fact that the same threshold vulnerability of six or more was used for both areas.

Input Data for Livestock Density

- MPAC parcel fabric (improved by DWSP using SWOOP imagery and windshield survey)
- WHPA delineation
- IPZ delineation
- HVA delineation
- SGRA delineation

Knowledge Limitations and Data Gaps for Managed Lands and Livestock Density

The property code and farm operation code values used to identify a candidate parcel is a single descriptor assigned by MPAC during the generation of the tax assessment record. It does not necessarily represent the current land use activities on each property.

None of the data used as input for the analysis was verified in the field. A quantitative estimate of data accuracy is not known; therefore, the results should be considered approximate. The input data layers used to identify the non-managed land areas (wetlands, water bodies, wooded areas) have spatial and content accuracies of varied and unknown degrees. The provincial data are intended to represent a 1:10,000 scale of hardcopy mapping.

The data layers were acquired from Land Information Ontario and represent the best available data for their thematic content at the time of analysis.

The values of nutrient unit per square metre of livestock type were generated by the Ontario Ministry of Agriculture, Food and Rural Affairs. The values are meant to approximate the maximum potential nutrient unit production for the size of the livestock barn structure. The livestock nutrient unit calculations were not field verified and; therefore, the results should be considered approximate.

The estimation of barn size was also approximate, as air photo interpretation cannot decipher between areas of the barn that house livestock and areas that do not. Also, the ability to determine whether the barn had one storey or two storeys was impossible through air photo interpretation and all barns were assumed to be single storey. Interpretation of the imagery was done to the best of the interpreter's ability.

Verification of the livestock type and size of actual livestock housing area is suggested for more accurate results.

4.1.4.3 Percentage of Impervious Surfaces for Vulnerable Areas

The Technical Rules define the total impervious surface area as the surface area of all highways and other impervious land surfaces used for vehicular traffic and parking, as well as all pedestrian paths (Definitions in Technical Rules, August 2009).

The percentage of impervious surface was calculated for one square kilometre grid cells under the guidance provided by section 16(11) of the amended Technical Rules (August 2009). The SWOOP one km tile grid was used.

To estimate the impervious surface area, the land cover classification data from the Southern Ontario Interim Landcover (SIL) was used. This continuous grid data has 1,000 x 1,000 metre cells and contains impervious surfaces as well as roads and highway transportation routes. Pedestrian paths and parking areas where road salt is probably applied regularly are not distinguished from other impervious surfaces such as roofs. For the purpose of estimating the "total impervious surface area" as defined above, all impervious land surfaces were assumed as areas with the potential for road salt application, weighing the size of a typical house against the length of driveways, pedestrian paths and parking spaces on each property. Table 4.1.12 provides a list of the input data used in evaluating impervious surfaces.

TABLE 4.1.12 – Input Data for Impervious Surfaces in Vulnerable Areas

Data Input	***Description***	***Source***	***Purpose***
Areas with potential for road salt application (vectorized raster)	The Southern Ontario Interim Landcover (SIL) is a composite of the best available datasets depicting land classes that have been merged to formulate an updated seamless land cover for southern Ontario (MNR Frequently Asked Questions)	Ontario Ministry of Natural Resources (MNR)	Continuous 1,000 x 1,000 metre cells that represent surface areas with build-up areas, transportation, agricultural, and other rural land uses
1 km x 1 km	For the full source protection region, a one km grid that corresponded to the one km SWOOP 2006 tiles was used	Own data	Impervious Surfaces
Vulnerable areas (WHPA, IPZ , HVA, SGRA)	Wellhead Protection Area, Intake Protection Zone, Highly Vulnerable Aquifer, and Significant Groundwater Recharge Area polygons	Own data	Boundary of reporting unit

The percentage was computed by assigning a value of one to all cells that are roads or impervious areas, adding the area in each grid cell and dividing it by the cell size. The percentage value was classified into four intervals, as defined in the provincial tables of drinking water threats:

1	0 % – <1%
2	1% – <8%
3	8% – < 80%
4	>= 80%

The 2021 Technical Rule amendments identified the option to change impervious surface area calculations where salt handling and storage activities could be considered a significant risk at 30% for Wellhead Protection Areas with a vulnerability score of 10, 6% for Intake Protection Zones (IPZ) with a score of 10 and 8% for IPZ with a score of 9 or 10. Furthermore, this change to the Technical Rules permits the calculation of percent impervious surface area in a vulnerable area as a whole, or in a sub-area within the vulnerable area, where the road salt is applied.

4.1.4.4 Implications of Managed Lands, Livestock Density and Impervious Surface Percentage for Risk Level Analysis

The risk rating of some activities takes into account the percentage of managed land, the livestock density and the percentage of impervious surfaces within each farm unit.

The Table of Drinking Water Threats considers the intensity of farm operations for risk rating. The assessment level is either related to the full vulnerable area, especially if the risk accumulates, or to the specific farm. The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard is considered on the basis of the livestock density on a farm unit. The percentage of managed lands and livestock density on a vulnerable area basis is considered for: the application of agricultural source material to land; the application of non-agricultural source material to land; and the application of commercial fertilizer.

The percentage of impervious surfaces on a vulnerable area basis is considered in the risk rating for the application of road salt.

4.1.5 Drinking Water Quality Threats: Threat-Based Approach

4.1.5.1 Legal Requirements for Assessing Drinking Water Quality Threats

The *Clean Water Act, 2006* (O.Reg. 287/07 s. 13) provides a list of information that is to be included in the Assessment Report. As described in previous sections, areas were identified where activities may be considered drinking water threats (Section 4.1.2). For these vulnerable areas, the vulnerability was scored (Section 4.1.3) and managed lands as well as livestock density were estimated (Section 4.1.4). The following section of text describes how the Technical Rules determine the threat level of activities and conditions.

According to subsection 13(1)(6), the assessment report is to include:

> "For each vulnerable area identified under clause 15 (2) (d) or (e) of the Act,
>
> i. the number of locations at which a person is engaging in an activity listed under subclause 15(2)(g)(i) of the Act that <u>is or would be</u> a significant drinking water threat, and
>
> ii. the number of locations at which a condition listed under subclause 15(2)(g)(ii) of the Act <u>is</u> a significant drinking water threat." (O.Reg 287/07)

It is specified further in the Technical Rule 9(1), which requires:

e) "the number of locations at which an activity that is a significant drinking water threat is being engaged in, and
f) the number of locations at which a condition resulting from a past activity is a significant drinking water threat." (Technical Rules)

Direction provided by the MECP for interpreting these rules advised that the word "is" in subclause i or ii (above) should be interpreted to mean where an activity is currently known to occur. The wording "would be" (see above) should be interpreted to refer to a situation where infrastructure is in place to allow an activity to occur. In some cases, these are or would be threats were inferred, not based on site specific information collected from a property survey, and based only on a review of available records, land use assessment data, aerial photographs, and information collected from windshield surveys.

Further, the Technical Rules define how to identify an activity, either from those prescribed by the province in the Table of Drinking Water Threats (Part XI.2, Technical Rule 118.1) or as new activity (Part XI.2, Technical Rule 119-125). For every activity that is prescribed by the province, the Table of Drinking Water Threats specifies many circumstances and assigns a threat rating to each of those circumstances dependent on the vulnerable area and its vulnerability score.

The Technical Rules Part XI.3 defines when conditions that result from historic land uses are considered a drinking water threat and shall be listed (see section 4.1.5.6).

4.1.5.2 List of Activities that May Pose Drinking Water Threats

The *Clean Water Act, 2006* defines activities and land uses that can potentially threaten drinking water sources. These are identified in O.Reg. 287/07, s. 1.1(1) as shown in Table 4.1.13 below, and are referred to as Prescribed Drinking Water Threats. The Source Protection Committee can identify further activities specific to this Source Protection Region that are not part of the prescribed list of threats and submit them to MECP for approval.

Based on such a request, MECP added two activities as local threats in this Source Protection Region related to the storage and handling of Tritium, communicated in letter dated January 26, 2011 to the SPC (see Table 4.1.14). Under the events-based approach, these activities were evaluated for two drinking water systems in the Saugeen Valley SPA and found not to be significant drinking water threats.

No further threats have been identified by the Saugeen, Grey Sauble, and Northern Bruce Peninsula Source Protection Committee.

TABLE 4.1.13 – List of Prescribed Drinking Water Threats in Ontario Regulation 287/07, Section 1.1(1)

Approved

ID	Legal Name	Short Name*
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Waste disposal site
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats, or disposes of sewage.	Sewage systems - Collection, storage, transmittance, treatment, or disposal
3	The application of agricultural source material to land.	Agricultural source material - Application to land
4	The storage of agricultural source material.	Agricultural source material - Storage
5	The management of agricultural source material. **	Management Of Agricultural Source Material - Aquaculture
6	The application of non-agricultural source material to land.	Non-agricultural source material - Application to land
7	The handling and storage of non-agricultural source material.	Non-agricultural source material - Handling and storage
8	The application of commercial fertilizer to land.	Commercial fertilizer - Application to land
9	The handling and storage of commercial fertilizer.	Commercial fertilizer - Handling and storage
10	The application of pesticide to land.	Pesticide - Application to land
11	The handling and storage of pesticide.	Pesticide - Handling and storage
12	The application of road salt.	Road salt - Application
13	The handling and storage of road salt.	Road salt - Handling and storage
14	The storage of snow.	Snow - Storage
15	The handling and storage of fuel.	Fuel - Handling and storage
16	The handling and storage of a dense non-aqueous phase liquid.	Dense non-aqueous phase liquid - Handling and storage
17	The handling and storage of an organic solvent.	Organic solvent - Handling and storage
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	De-icing chemicals - Runoff from airports
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.	Water takings without returning the water to the same water body
20	An activity that reduces the recharge of an aquifer.	An activity that reduces the recharge of an aquifer
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	Pastures or other farm-animal yards - Livestock grazing
22	The establishment and operation of a liquid hydrocarbon pipeline	Liquid hydrocarbon pipeline

* *The short name is used in drinking water threat tables for all drinking water systems.*

** *Prescribed Activity No. 5 ("The management of agricultural source material") is only associated with the threat subcategory of aquaculture, which is not a significant threat occurring in any vulnerable area of this assessment report.*

TABLE 4.1.14 – List of Local Drinking Water Threats as requested by the Source Protection Committee and approved by MECP

Legal Name	*Circumstances*
The storage and handling of Tritium	• The above grade handling of tritium in tanks and facilities that <u>are not</u> required to report to the NPRI * • A spill of the tritium may result in the presence of tritium in groundwater or surface water
The storage and handling of Tritium	• The above grade handling of tritium in tanks and facilities that <u>are</u> required to report to the NPRI * • A spill of the tritium may result in the presence of tritium in groundwater or surface water

* *The National Pollutant Release Inventory (NPRI) is Canada's legislated, publicly accessible inventory of pollutant releases (to air, water and land), disposals and transfers for recycling.*

4.1.5.3 Risk Scoring within the Threat-Based Approach

Risk Rating and Risk Score

Within the threat-based approach, a risk rating is attributed to each activity or condition that may pose a drinking water threat. The risk rating has four categories: none, low, moderate, and significant. To determine this risk level, a risk score is first calculated for each activity that takes into account the vulnerability of the water source in the vulnerable area and the hazard rating of a specific activity using the following formula:

RISK SCORE = AREA VULNERABILITY SCORE x HAZARD RATING

The rules for hazard rating differ between (existing or future) activities and conditions that result from historic land uses.

It is pointed out again that hazard and risk rating is built into the Tables of Drinking Water Threats and the circumstances therein which provide a vulnerability score that is high enough for an activity or a circumstance to be deemed a threat.

Hazard Rating for Activities

To determine the risk level of existing or future activities, specific circumstances are specified for each activity. Threats are classified into three groups: chemicals, pathogens and dense non-aqueous phase liquids (DNAPLs). For all prescribed activities, the Ministry of the Environment, Conservation and Parks provides Tables of Drinking Water Threats (2021) in which a hazard rating is assigned for a list of circumstances, with differences in hazard ratings.

For chemical threats, the table lists details such as the substance, the quantity of this substance, the vulnerable area, and the vulnerability score of the vulnerable area. Finally, the hazard rating is defined and the risk rating is listed for each vulnerable area and vulnerability score. Chemical threats can exist in any vulnerable area, but the risk rating decreases with lower vulnerability scores.

DNAPL threats are a sub-category of chemical threats. Due to their adverse transport behaviour in groundwater aquifers as well as their high toxicity and persistence, the risk rating for these chemicals is significant at any quantity if the vulnerability score is at least four and the activity is located in a WHPA-A, B or C. In other areas, risk rating is the same as for chemical threats.

Pathogen threat ratings take a similar approach; however, the circumstances do not specify minimum storage or application quantities for pathogen threats. To account for relatively short survival times of pathogens, the risk rating is none if the time-of-travel from the activity to the intake or well exceeds two years. Thus, pathogen threats can only exist in WHPAs A and B and when surface water can influence the intake in IPZs 1, 2, 3 and in WHPAs E and F).

Hazard Rating for Conditions that Result from Historic Land Uses

The Source Protection Committee may also identify conditions that constitute a risk to drinking water sources. Conditions include contaminated lands that have either been abandoned or are still in use, sediments, groundwater, surface water, or other media that pose a threat to drinking water quality. The Source Protection Committee has not identified any high-risk conditions within highly vulnerable areas.

As per Technical Rule 139 (Nov. 2009), the hazard rating of a condition from historic land use is:

- Ten (10) if there is evidence that the situation causes contamination outside of the property
- Ten (10) if the condition is located on a property where a well, intake or monitoring well exists or is planned and included in the Terms of Reference
- Six (6) in any other case.

4.1.5.4 Inventory of Activities that Pose Drinking Water Threats

As result of the low vulnerability scores of all Great Lakes IPZs, none of these include activities that score high enough to rate significant in this SPR. Significant threats identified in this study, therefore all refer to groundwater supply systems.

To identify significant threats to a drinking water supply in each vulnerable area, the following procedure was followed (CRA, 2009):

- Activities prescribed in Ontario Regulation 287/07, Section 1.1(1) were listed (Table 4.1.5).
- For each property, the land use was defined using the Municipal Property Assessment Corporation (MPAC) property codes.

- Each property in a WHPA was associated with a North American Industrial Classification System (NAICS) code. This analysis started with the MPAC property code, which was cross-checked with aerial photography and windshield surveys.
- Each NAICS code was associated with a list of prescribed threats. This was accomplished using the Ministry of the Environment and Climate Change's Threats Lookup Table (LUT v6.1), which associates threats to NAICS codes and vice versa.
- This threats inventory was stored in a central geospatial database and each record was linked to a location.

Each record in the threat inventory was spatially associated with vulnerability score areas and circumstances with a geospatial reference (such as parcel area, percent managed lands, etc.) in order to derive a list of activities that are coupled with their circumstances based on vulnerability scoring areas. Pathogens can only be a threat within the WHPA-A and WHPA-B; therefore, only scoring from six to ten in these zones is applicable. Chemical threats were assessed within the 25-year time-of-travel zone where the vulnerability score was higher than four, since a risk score greater than 40 is needed for a threat to be a significant, moderate or low drinking water threat. DNAPL activities are always considered significant drinking water threats within WHPA-A, WHPA-B and WHPA-C for groundwater systems. They also have the potential to represent a low to moderate drinking water threat within WHPA-D with a vulnerability score of six. DNAPL threats were reported separately from the other pathogen and chemical threats.

Given the level of information we have for each land use activity, the worst-case scenario was assumed for all other circumstances identified in the MECP's Table of Drinking Water Threats when assigning threat categories. Storage and handling quantities were also assumed (based on the worst-case scenario), as was the type of storage, such as above or below ground surface. In some instances, volume and quantity values were reported in available databases and the appropriate circumstance was applied.

Threat 2 as per O.Reg 287/07 s. 1(1) is the establishment, operation or maintenance of a system that collects, stores, transmits, treats, or disposes of sewage. This activity is further categorized into several sub categories, each of which is associated with separate quantity circumstances; septic system holding tank, storage of sewage (e.g. treatment plant tanks), industrial effluent discharges, sanitary sewers and related pipes, septic systems, sewage treatment plant bypass discharges to surface water, sewage treatment plant effluent discharges (including lagoons), combined sewer discharge from stormwater outlets to surface water, and the discharge of untreated stormwater from a stormwater retention pond.

Properties with private septic systems count as a pathogen threat if located within WHPA-A or WHPA-B and as a chemical threat if the vulnerability score is 10. If private properties are connected to sanitary sewer lines, then the connecting line from the house to the municipal sewer line also counts as a potential threat in these areas. For chemical threats, the quantity is assumed to be far below the significance threshold.

For residential properties, the potential for heating-related fuel storage was assumed. Also, the sub category Waste Disposal Site - Storage of wastes described under the definition of hazardous waste and the prescribed activity the handling and storage of a dense non-aqueous phase liquid were left as is since both are independent of the quantity of the material. Among others, this waste storage sub category deals with chemicals such as cadmium, lead, mercury, and selenium, which are often used in batteries. It also covers herbicides such as 2,4-Dichlorophenoxyacetic acid (2,4-D) and Trichlorophenoxyacetic acid-2,4,5, the disposal of which is not regulated elsewhere.

DNAPLs (dense non-aqueous phase liquids) are heavier than water and do not dissolve or mix with it. As a result, DNAPLs can quickly enter groundwater aquifers, especially along transport pathways. They form persistent lenses at the bottom of an aquifer and are difficult to monitor or remediate. Many DNAPLs are highly toxic and carcinogenic, such as Dioxane-1,4 and other polycyclic aromatic hydrocarbons (PAHs), tetrachloroethylene (PCE), trichloroethylene or other chemicals that degrade to it, and vinyl chloride or other chemicals that degrade to vinyl chloride. DNAPLs are used as coolants, as organic solvents for degreasing and dry cleaning and as paint strippers and spot removers. These widely used and highly hazardous chemicals may be not only be used in industrial facilities but they may be used and disposed of on every residential property.

Definition of land uses

- Residential - includes single and multi-family residential units, seasonal dwellings, mobile homes, and residences with commercial/industrial use buildings.
- Farm Residential - includes parcels used for agricultural purposes with residential occupation [i.e., house(s)]. Agricultural land use class includes both cash crop and livestock operations.
- Agricultural - includes parcels used strictly for agricultural purposes with no residential occupation (i.e., no house). Agricultural land use class includes both cash crop and livestock operations.
- Commercial - includes all land uses associated with retail or commercial operations, including parking areas, shopping centres, offices, banks, restaurants, gas stations, hotels, motels, lodges, resorts, and campgrounds.
- Industrial - includes all land uses associated with industrial operations, including manufacturing, warehousing and aggregate extraction.
- Institutional - includes schools, day care centres, retirement/nursing homes, hospitals, correction facilities, and places of worship.
- Recreational - includes sports complexes, community halls, amusement parks, golf courses, ski resorts, marinas, casinos, and other recreational facilities.
- Vacant Land - includes all vacant residential, commercial, and industrial lands, undeveloped properties, and park lands.
- Transportation Corridors - includes all roadways and undesignated parcels.
- Other - includes all municipal or other government related buildings and infrastructure, such as ambulance and police stations, fire halls, post offices, military buildings, and airports.

Textbox 1: From Municipal Property Assessment Corporation (MPAC) data of land uses

The circumstances and assumptions, under which an activity in the list of threats is significant, moderate or low, were recorded in the database for future reference. Site visits may be warranted in areas where the potential for a significant drinking water threat was identified in order to verify the circumstance that triggers the activity as significant (CRA, 2009).

Further to identifying areas within vulnerable areas as significant, moderate or low drinking water quality threats, Technical Rule 9 of the Technical Rules and Section 13(1)(6) of O. Reg. 287/07 requires that the number of locations where an activity has the potential to be a significant drinking water threat be inventoried and reported.

These tables are given for each drinking water system and eventually separated by vulnerable area.

All groundwater systems that were assessed by Conestoga-Rovers followed the methodology outlined here. For a detailed description, please see the original studies cited for each drinking water system.

For the Revised Assessment Report, threats verification work was done by DWSP staff. Windshield surveys were done of all properties within the WHPA-A, B and C to determine whether waste, DNAPL or fuel storage threats were warranted.

A DNAPL storage and a DNAPL handling threat were given to those properties whose land use suggested there might by DNAPLs on the premises; hardware stores, antiques dealers and woodshops, car dealers or garages, restaurants, all municipal/ institutional properties such as hospitals, churches and schools, and any residential properties that look like they might repair cars or do wood working or furniture restoration. All the remaining properties in the WHPA-A, B or C were flagged with “Possible DNAPL threat”.

All properties with a vulnerability score of 10 where fuel could be stored were assumed to have fuel storage threats, unless the windshield survey determined otherwise. DWSP staff also sent out fuel surveys to all properties that could not be eliminated as fuel threats from the windshield surveys. The response rate was about 36%. All remaining properties received a fuel storage threat.

All waste threats were removed as no properties were found to warrant one.

The local threat storage and handling of Tritiated Deuterium (Tritium), as described in the Director’s opinion regarding the addition of the operation of the Nuclear Generating Station where nuclear reactions are being moderated by deuterium (Heavy Water) in any quantity (January 26, 2011), could result in low or moderate drinking water threats in WHPAs A-E and IPZs 1-3.

4.1.5.5 Confidence in List of Activities that Pose Significant Drinking Water Threats

Threats evaluation and the assignment of risk ratings are determined through Regulations and the Technical Rules. On a practical basis, the enumeration of threats is based on land use classification. Thus, a number of sources of uncertainty are applicable to the enumeration of threats, namely: assigning a NAICS land use code to each property; translating this NAICS code into an “is or would be” threat based on local infrastructure; and, determining the quantity of a hazardous material that poses this threat.

Land use identification is limited by the accuracy of information obtained from property owners, windshield surveys and the land use information of the MPAC database. A total of approximately 12,000 threats were evaluated within the Source Protection Region, usually with more than one potential prescribed drinking water threat associated with each property. Of all land use activities that resulted in the identification of moderate or significant threats, only 20% were confirmed by property owners (21% of all significant and 14% of the all moderate threats). Additionally, approximately 60% of all threats were identified based on the MPAC property code alone. The remaining Land Use Activities were derived from the EcoLog database, from both aerial photos and windshield surveys or from aerial photos alone.

Confidence levels for the threats enumeration are assumed high if threats are linked to sewers due to the quality and availability of the data. Land use classifications, and the derived threats, were also assigned "high certainty" if property owners were consulted and the activity was confirmed. For all other data sources used to identify the threat, confidence is determined to be moderate. In cases where the threat rating was based on MPAC codes in conjunction with aerial photography a low confidence level was assigned. In general, approximately half of all threats were given a low confidence rating.

Given the multiple sources of data used to enumerate threats and the confidence in those sources, the overall confidence for the enumeration of significant threats is considered to be low.

The threats verification windshield and fuel surveys increase the confidence in determining both land use and existing activities. This increases the confidence in the delineation of threats to a moderate.

4.1.5.6 Conditions from Historical Land Uses

Conditions are defined as drinking water threats in relation to water quality that result from past activities (in accordance with Part XI.). Drinking Water Threats Analysis, Part I.2, 2(4) requires that such conditions be listed. Further, Part I.2, 8(5) requires the identification of "….those areas where conditions that result from past activities….are significant, moderate or low drinking water threats in accordance with Part XI.5" (Technical Rules).

The Source Protection Committee must identify any condition that results from historic land uses of which it is aware. Conditions must be located within vulnerable areas: intake protection zones; wellhead protection areas; highly vulnerable areas; and, significant recharge areas. A risk score must be computed for these conditions based on the vulnerability score of the area and the hazard rating of the specific site, following the rules described in Section 4.1.5.3.

The objective of the Source Protection Plan is to reduce the risk level of the drinking water threats identified in this Assessment Report. For every significant threat, the *Clean Water Act* requires the SPC to develop policies that reduce the risk rating to a point where they are no longer significant. The SPC may also develop policies for moderate and low drinking water threats.

4.1.5.6.1 Conditions Related to Groundwater Systems

Types of Contaminants and Concentration Limits

The Technical Rules: Assessment Report identifies the types of situations when contamination from historic land uses may be considered a condition. Conditions that result from a historic land uses and include the following situations within a vulnerable area related to groundwater (highly vulnerable aquifers, and wellhead protection areas):

1. the presence of any single mass of *non-aqueous phase liquid*,
2. the presence of a contaminant in groundwater if the contaminant
   - is listed in Table 2 of the *Soil, Ground Water and Sediment Standards* and
   - is present at a concentration that *exceeds the potable groundwater standard* set out for the contaminant in that Table and
3. the presence of a contaminant in sediment if the contaminant
   - is listed *in* Table 1 *of* the *Soil, Ground Water and Sediment Standards* and
   - is present at a *concentration that exceeds the sediment standard* set out for the contaminant in that Table.

Information Used to Identify Conditions of Historical Land Uses

To identify conditions that may pose drinking water threats, existing information was screened to determine those locations where contaminants are present and, if applicable, their concentration exceeds the relevant standards. Three sources of information were used for the preliminary identification of locations of concern; information provided by the Ministry of the Environment and Climate Change, municipal technical reports and studies, and observations from stakeholders, consultants and the public.

The Ecolog Environmental Risk Information Services (ERIS) database reports were evaluated for existing databases on spills and contamination. Ecolog records from the Occurrence Reporting Information System (1988-2002) were also reviewed to identify reported spills and occurrences within each WHPA that have the potential to contaminant groundwater.

Observations were made through the use of windshield surveys and/or property visits in the year 2006 to confirm the existing and past land uses stated within the 2008 Municipal Property Assessment Corporation (MPAC) parcel information. Air photo interpretation was also used. In general, the locations of historic gasoline stations, automotive repair shops, abandoned pits, hardware stores, dry cleaners, air strips, and mills were identified within nine of the WHPAs in this study. Furthermore, concerns from members of the Source Protection Committee, being local experts, were incorporated.

Summary of Studies Done and Preliminary Findings

As identified in the CRA 2009 report, CRA is unaware of any existing groundwater conditions resulting from these past activities or spills that have caused the deterioration of drinking water in any of the systems listed in the Terms of Reference.
Ecolog records from the Occurrence Reporting Information System (1988-2002) were examined for spills or contaminations. Based on the analysis of this data, no contaminated sites were identified in the Northern Bruce Peninsula Source Protection Area that meets the tests in

Technical Rule 126, and therefore, become conditions that can be identified as drinking water threats.

4.1.5.6.2 Conditions Related to Surface Water Intakes

Types of Contaminants and Concentration Limits

The Technical Rules: Assessment Report identifies the types of situations when contamination from historic land uses may be considered a condition. Conditions that result from historic land uses include the following situations within a vulnerable area related to surface water (intake protection zone):

1. the presence of any single mass of more than 100 litres of one or more *dense non-aqueous phase liquids* in surface water,
2. the presence of a contaminant in surface soil in a surface water intake protection zone if the contaminant
   - is listed in Table 4 of the *Soil, Ground Water and Sediment Standards* and
   - is present at a concentration that exceeds the *surface soil standard for industrial/ commercial/community property use* set out for the contaminant in that Table and
3. the presence of a contaminant in sediment if the contaminant
   - is listed in Table 1 of the *Soil, Ground Water and Sediment Standards* and
   - is present at a concentration that exceeds the *sediment standard* set out for the contaminant in that Table.

Summary of Studies Done and Preliminary Findings

For the identification and risk rating of conditions, a preliminary review of data made available by the Ministry of the Environment and Climate Change and other sources was undertaken, as part of the Threats and Risk Assessment. Stantec Consulting Limited was the primary consultant for this study (Stantec 2009 - Phase 2 Report). For this assessment report, only the preliminary review was finalized. Risk rating could not be performed because no data were available to provide evidence whether the situation causes contamination outside of the property or not.

Environment Canada (EC) report Sediment Quality in Canadian Lake Huron Tributaries: A Screening – Level Survey (Burniston *et al.*, 2006) detailed sediment data sampled at tributaries discharging into the Kincardine, Southampton (Primary Intake), East Linton, Meaford, and Thornbury WTP vulnerable areas. Tributaries discharging into the Lion's Head, R.H. Neath, and Wiarton WTP vulnerable areas were not sampled as part of this report. Additional sediment data for these areas were unavailable.

Following Technical Rule 126 (5), the sample data from the tributaries discharging into the WTP vulnerable areas were compared to Table 1 of the Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the *Environmental Protection Act, 1999*. During this screening, the following parameters exceeded sediment standards in one or more location: Chromium (total), Nickel and Copper.

In attempts to further identify the presence of conditions within the IPZs, the following sources were reviewed:

- Provincial Brownfield Sites Registry (MOE, 2009c); and
- The Federal Contaminated Inventory (TBCS, 2009).

Based on this analysis of this data, no contaminated sites were identified in the Northern Bruce Peninsula Source Protection Area in these databases. No contamination meets the tests in Technical Rule 126, and therefore, become conditions that can be identified as drinking water threats.

4.1.5.7 Identifying Specific Circumstances for Drinking Water Threats

This section outlines the procedure to identify whether or not a land use activity on a property poses a risk to drinking water sources and is thus considered a drinking water threat under the threats-based approach. This is done using a risk rating of that activity, taking into account the type of the vulnerable area, the vulnerability score at the location where the activity is or would be carried out, and specific circumstances of the activity. Note that activities can also be associated with significant risk levels under the issues-based approach, Section 4.1.6. and under the events-based approach, Section 4.1.7. See Section 4.1.1 for a summary.

Activities, conditions, vulnerable area type, and vulnerability scores are combined in the Table of Drinking Water Threats (2021) by the Ministry of the Environment, Conservation and Parks. This table lists activities and circumstances, and sets out hazard scores and risk levels. It is important for all property owners to identify which activities that are or could be carried out on their property can pose threats to drinking water sources. To determine where an activity is a significant, moderate, or low threat, and the circumstances that make them significant, moderate, or low, requires a person to look at the vulnerability scores for an area, and then look through the Table of Drinking Water Threats to determine whether an activity or a circumstance is significant, moderate, or low in any given area.

The MECP also provides a tool to support property owners and practitioners, the Tables of Drinking Water Threats and online Threats Tool. Tables of Drinking Water Threats for Pathogens and Chemicals lists all activities and circumstances for a specific vulnerable area, vulnerability score, type of contaminant (Chemical/DNAPL/Pathogen), and threat level (low/moderate/significant). It also specifies the type of contaminant (Chemical/DNAPL/Pathogen), the vulnerable area, the vulnerability score, and the significance level. For example, one table pinpoints all activities or circumstances that are or would be significant chemical threats in a WHPA-B where the vulnerability score at one location is eight.

. This Table also contains the circumstances for: highly vulnerable aquifers (Table 4.1.15); wellhead protection areas (Table 4.1.5.16); and surface water bodies (intake protection zones and WHPA-Es, Table 4.1.5.17). Furthermore, the Threats Tool is separated into two categories: chemical\and pathogen threats, and are also separated by risk level (low, moderate, significant).

Procedure to Identify Activities and Circumstances that are or would be Significant at a Location

Approved

The Threats Tool and the vulnerability maps can be used in combination with the Ministry of the Environment, Conservation and Park'sTables of Drinking Water Threats to determine the types of activities that would be deemed a significant, moderate and low drinking water threat in each area.

A four-step procedure is used to identify specific circumstances under which an activity is considered a drinking water threat:

1. Identify the vulnerable zone that the property is in using either the municipal maps M1 (HVA, SGRA) or the maps for each drinking water system (for example WHPA-A or C, IPZ-1 or 2).
2. Identify the vulnerability score of that location using the vulnerability maps.
3. Determine the name of the circumstance you need, using the reference tables in this section.
4. Download the Provincial Tables of Drinking Water Threats and online Threats Tool posted by the MECP (see below). The table lists all activities and circumstances of the specified threat rating (significant, moderate, low) for a particular vulnerable area with a certain vulnerability score. This table will exactly define under which circumstances a risk is designated as a low, moderate or significant threat.

https://www.ontario.ca/page/tables-drinking-water-threats

TABLE 4.1.15 – Reference Tables of Drinking Water Threats for Pathogens and Chemicals for areas within Highly Vulnerable Aquifers (HVA)

Highly Vulnerable Aquifers					
Threat	*Zone*	*Vulnerability Score*	*Threat Level Possible*		
			Significant	*Moderate*	*Low*
Chemical and DNAPL	**HVA**	6			
		<6			
Pathogen		2 – 6			

TABLE 4.1.16 – Reference Tables of Drinking Water Threats for Pathogens and Chemicals for areas within the Capture Zones of Wells (WHPA A-D)

Wellhead Protection Area (WHPA) A-D					
Threat	*Zone*	*Vulnerability Score*	*Threat Level Possible*		
			Significant	*Moderate*	*Low*
Chemical	**WHPA A, B, C, C1**	10			
		8			
		6			

Wellhead Protection Area (WHPA) A-D					
Threat	*Zone*	*Vulnerability Score*	*Threat Level Possible*		
			Significant	*Moderate*	*Low*
		<6			
		<4.2			
Pathogen	**WHPA-A, B**	10			
		8			
		6			
	WHPA-C, C1, D	2 – 8			
DNAPL	**WHPA A, B, C, C1**	4 – 10			
	WHPA-D	6			
		<6			

TABLE 4.1.17 – Reference Tables of Drinking Water Threats for Pathogens and Chemicals for areas within the Intake Protection Zones (IPZ) and along Surface Water Bodies that Influence Wells (WHPA-E)

Intake Protection Zones (IPZ) and WHPA-E					
Threat	*Zone*	*Vulnerability Score*	*Threat Level Possible*		
			Significant	*Moderate*	*Low*
Chemical and DNAPL	**IPZ-1, IPZ-2, IPZ-3, WHPA-E**	8 – 10			
		6 – 7.2			
		4.2 – 5.6			
Pathogen	**IPZ-1, IPZ-2, IPZ-3, WHPA-E**	8 – 10			
		6 – 7.2			
		4.2-5.6			

4.1.6 Drinking Water Quality and the Issues-Based Approach

A Drinking Water Quality Issue is defined as the deterioration of water quality of a drinking water source. This deterioration of water quality must be measured in raw water directly at a drinking water source or at a monitoring well related to the system. An example of an issue would be the contamination of an aquifer with gasoline that threatens to exceed drinking water standards. Another example could be an unusually high occurrence of anthropogenic bacteria (human or animal) or nitrates within a lake that is a municipal drinking water source. If such an issue was identified at a well or an intake, activities that cause the water quality deterioration must be identified. The Source Protection Committee must then consider policies to mitigate such an issue.

Technical Rule 114 states that the Source Protection Committee can define an issue at an intake or well that is listed in the Terms of Reference (Technical Rule 114(1) and (2)) and at other drinking water systems that are *not* listed in the Terms of Reference (Technical Rule 114(3)).

On January 23, 2009, the Source Protection Committee passed a motion to approve thresholds for microbiological, chemical and radionuclide parameters as well as for aesthetic objectives and operational guidelines (memo "Development of Water Quality Thresholds for Issues Evaluation", also listed in Appendix I):

- For chemical and radionuclide parameters, 50% of the Maximum Acceptable Concentration was adopted, as defined in Table 2 and 3 of Ontario Regulation 169/03.
- For aesthetic objectives and operational guidelines, Table 4 Ontario Regulation 169/03 was adopted.
- For microbial parameters, a standard of 0 cfu/100 mL total coliforms and *E. coli* was adopted. It was acknowledged that these thresholds are neither realistic for GUDI wells nor for surface water intakes, so further investigation is needed for systems where these thresholds are flagged.

These thresholds were developed with input from municipal water treatment plant operators, and correspond to thresholds which require an increase in the frequency of monitoring under the *Safe Drinking Water Act, 2002* and associated regulations. If a measurement of raw water at a drinking water intake or well exceeds, or threatens to exceed, one of these standards, further investigation is required to confirm the deterioration of water quality. As part of these analyses, existing data are compiled and reviewed to identify any exceedances or trends in water quality data.

In the case of a municipal drinking water system, operators and operation managers are contacted and a recommendation to the SPC is expected. After notification, the SPC can formally adopt a drinking water quality issue, taking into account the threshold values identified by the SPC (Jan 23, 2009, Technical Report 7c) and the recommendations of the operator and other local knowledge.

If such an issue was defined accordingly and it "*is the result of, or partially the result of, anthropogenic causes*", then Technical Rule 115 lists the information that must be compiled:

> "(1) The parameter or pathogen concerned.
>
> (2) The surface water intake, well or monitoring well at which the presence of the parameter or pathogen has occurred.

> (3) The area within a vulnerable area where activities, conditions that result from past activities, and naturally occurring conditions may contribute to the parameter or pathogen and this area shall be identified as the "issue contributing area", and;
>
> (4) The identification of the drinking water threats listed.…that contribute or may contribute to the parameter or pathogen of concern." (Technical Rules)

All activities that contribute to an issue identified under Technical Rule 114(1) or (2) are automatically considered significant drinking water threats.

If an issue was identified in the raw water of a *municipal drinking water system* (or any other system listed in the Terms of Reference), it is discussed in Section 4.2 - Risk Assessment by Municipality. In this source protection area, no issues related to municipal systems were declared.

For *non-municipal drinking water systems*, no issues have been identified under Technical Rule 114(3). Public Health Units are undertaking risk assessments of all small drinking water systems, and through that process may identify possible issues for a future Assessment Report. If such issue is identified under Technical Rule 114(3) and it is at least partly anthropogenic, these activities will automatically be moderate drinking water threats.

4.1.7 Drinking Water Quality and the Events-Based Approach

If modelling of an extreme event shows that a contaminant could reach an intake, an area known as an IPZ-3 will be delineated, composed of the land area that drains into the surface water body, allowing contaminant to reach the intake (Technical Rule 68). The on land area must include 120 m setback from the high water mark along the shoreline, or the regulation limit, whichever is greater (Technical Rule 68(2)).

Once the IPZ-3 is delineated, an events-based area (EBA) can be determined for each intake. This area allows potential significant drinking water threats to be identified. Using modelling and other forms of analysis, any area that is determined could cause an exceedance of contaminant at the intake can be included. The identification of activities as significant drinking water threats is done under Technical Rule 130.

4.1.8 Uncertainty of Vulnerable Area Delineation and Vulnerability Scoring

Uncertainty related to the identification of significant groundwater recharge areas (SGRAs) is discussed in Chapter 3, Section 3.14.3. Uncertainty related to the delineation of highly vulnerable aquifers (HVAs) is related to data limitations of the Intrinsic Susceptibility Index (ISI), which is addressed in Section 4.1.2.1. This section discusses uncertainty related to wellhead protection areas of groundwater systems and to intake protection zones of surface water systems.

4.1.8.1 Uncertainty in the Assessment of Groundwater Systems

Vulnerability Uncertainty

The Technical Rules: Assessment Report (*Clean Water Act*, *2006*) requires an assessment of uncertainty as part of the vulnerability assessment. The uncertainty assessment seeks to provide a qualitative summary of data and analyzes reliability as performed during the study. Uncertainty associated with a vulnerability assessment can be attributed to a number of factors including:

- Density of input data
- Quality and reliability of data
- Assumptions made when reducing or synthesizing data

The evaluation of uncertainty conducted as part of this study involves the following components:

- An evaluation of the uncertainty of the delineation of the WHPAs
- An evaluation of the uncertainty of the determination of aquifer vulnerability
- Assignment of an aggregate uncertainty rating for each water system

Uncertainty of the Tobermory Wellhead Protection Area

The delineation of the Tobermory Community Centre WHPA was completed through the use of the MODFLOW groundwater model as part of the 2008 study completed by Conestoga-Rovers and Associates (2008). The model was completed based on a number of simplifying assumptions that incorporate some level of uncertainty dependent on the nature, spatial distribution and density of available data.

The groundwater model was calibrated to represent steady state conditions in the aquifer using static water levels from available water well records (with a normalized root-mean-square error for the calibration within the acceptable limits of less than 10% for numerical models). The model calibration results were compared to reported pumping tests at the well and showed a reasonable fit to the observed groundwater conditions recorded in the tests. Stream flow data were also used for calibration. The calibration process found that the hydraulic conductivities of the geological units, simulated flow pattern within the bedrock aquifer, and modelled base flows are in agreement with site specific information.

Uncertainties within the model are associated with limitations in the availability of subsurface information and can be related to projected variability in the aquifer properties (e.g. hydraulic conductivity, porosity) or uncertainties with the conceptual model (e.g. groundwater-surface water interactions, location of flow boundaries, recharge rates, continuity in aquitards, direction of regional groundwater flow). To account for some of these uncertainties, hydrogeological parameters were adjusted and multiple particle-tracking simulations were run in order to develop a more robust WHPA. Based on known variations in hydraulic properties, this approach does not adequately address the issue of uncertainty as it is known that slight variations of aquifer properties (hydraulic conductivity, effective porosity, observed water levels, etc.) may impact the shape and orientation of the capture zones.

In WHPAs that have relatively low pumping rates, therefore small cones of depression, the shape of the WHPA is largely determined by regional groundwater flow. These tend to produce elongated, thin WHPAs in which more accurate observed water levels could cause dramatic changes in the orientation of the WHPA. Similarly, slight changes in effective porosity and hydraulic conductivity can dramatically alter the size of WHPAs for wells with higher pumping rates.

Although the calibration results were good for all models, the potential for dramatic changes in the shape and orientation of WHPAs due to slight variations in aquifer properties suggests that uncertainty should be considered high for the WHPA delineation.

Uncertainty of Vulnerability Assessment

Vulnerability assessment was completed using the Intrinsic Susceptibility Index (ISI) mapping developed by WHI (2003). The ISI calculation was based on an empirical formula provided by the Ministry of the Environment and Climate Change for completion of groundwater studies (MOECC, 2001). Detailed descriptions of the methodology and associated assumptions for these calculations are included in the Grey and Bruce County Groundwater Study (WHI, 2003).

The ISI mapping utilized existing well records within the Water Well Information System (WWIS). These records were screened to remove wells with poor locations based on location codes provided in the WWIS. ISI was calculated on a well-to-well basis and kriging methodology was used to interpolate between individual wells. The resultant mapping provided was a grid with 200 x 200 metre squares.

It is important to understand the limitations of the ISI mapping when assessing the uncertainty of the aquifer vulnerability mapping of a given WHPA. Although ISI mapping is a well-documented and accepted methodology in Ontario for assessing aquifer vulnerability, it does have a number of limitations including:

- ISI mapping is intended to be viewed and interpreted on a regional scale and is not intended to be interpreted on a property or site-specific scale.
- The primary source of data for calculating ISI is the WWIS, which is known to have several deficiencies in both the lack of records for existing wells and in the location of the existing records.
- ISI does not take into account hydrogeological properties of aquifers, which may make them more or less susceptible.
- ISI is interpolated between known data points and does not take into account geological features or boundaries that may be the cause of significant differences between the points.

With these limitations in mind, ISI is a useful tool in evaluating the overall susceptibility of a given aquifer at a regional scale. However, ISI should not be substituted for comprehensive site-specific investigation.

Based on these facts, the uncertainty of the aquifer vulnerability mapping can be considered low on a regional scale. However, on a WHPA scale, the ISI mapping can be highly sensitive to relatively few data points and should be considered highly uncertain as a result. Additionally, due to the interpolation methodology and the resultant coarse resolution of the ISI mapping, the uncertainty of the aquifer vulnerability mapping on a property scale must be considered high. Despite the inherent uncertainty associated with applying ISI at the WHPA and property scales, the ISI mapping is likely reasonable in areas where the geology, and thus ISI, is consistent and predictable. Alternatively, ISI is least reasonable in areas with highly variable geology and ISI values.

Uncertainty Ratings

The Technical Guidance outlines that each vulnerable area should be assigned an uncertainty of high or low to identify where information gaps exist. This process will assist in addressing data quality problems in future source water protection planning.

Table 4.1.18 summarizes the uncertainty assigned to the WHPAs in the Northern Bruce Peninsula Source Protection Area.

TABLE 4.1.18 – Uncertainty Assessment for Groundwater Systems – Northern Bruce Peninsula

Uncertainty Type	***WHPAs***	***Steady-State***
WHPA Delineation	High	High
Aquifer Vulnerability Mapping (ISI)	High	High
Overall – Vulnerability Scores	High	High

Uncertainty for the WHPAs in the Northern Bruce Peninsula Source Protection Area is summarized as follows:

- Due to the potential changes in the shape of the WHPAs based on slight variations of aquifer properties, the uncertainty of the WHPAs is high.
- Due to the reliability of the WWIS, the interpolation methodology and the coarse resolution of the ISI mapping, the uncertainty of the aquifer vulnerability mapping at the WHPA scale is high.

The uncertainty of the vulnerability scores for the WHPAs, which are developed from the WHPA delineation and the ISI mapping, can be considered high.

4.1.8.2 Uncertainty in the Assessment of Great Lakes Surface Water Systems

The Technical Rules have outlined five uncertainty factors to be considered in determining the uncertainty level for IPZ delineations and vulnerability scores. Not all of the five factors apply to both the delineation uncertainty and the vulnerability uncertainty prescribed to each IPZ; however each factor as it pertains to the IPZ uncertainty analysis is addressed in the appropriate section.

Data

The uncertainty relating to the data sources incorporates an analysis of: variability, quality, and relevance of the data. The Technical Rules prescribe an analysis of the distribution of the data as well; however distribution of the datasets is not relevant in delineation as delineation utilizes the most current available data.

The variability of data relates to the number of datasets reviewed for information. Multiple sources of data relating to the parameters used in vulnerability scoring and delineation produce a low level of uncertainty. For the delineation of the in-water IPZ using numerical modelling, multiple sources of data were not available for any of the systems. Therefore, a high level of uncertainty must be assigned to the variability of data.

The quality of data is related to the accuracy of the data assessed based upon the origins of the information. Federal and provincial data are assumed to have a high level of accuracy due to regulated quality control measures in place and therefore have an associated high level of confidence at the scale that was originally intended for their interpretation. Datasets that describe regulation limits and other legislative boundaries are assumed to have a high level of accuracy. Data sources that provide interpretations of the data are not considered to have an equal confidence level. For all surface water systems, data were gathered from provincial and municipal sources and by the Conservation Authorities. A high level of confidence in the quality of the data was established based on the assumption that adequate quality control programs are in place for these sources.

The relevance of the data relates to the applicability of the information to the study area. Site-specific and local information is assumed to represent the area well and therefore has an associated high level of confidence. Unavailable or non-site-specific data lowers the confidence and generally requires assumptions to be made. The majority of available datasets used in the delineation of all IPZs were relevant to the study area; however due to the availability of data, some alternative datasets were required to be used.

For the models of the Georgian Bay intakes, Acoustic Doppler Current Profiler (ADCP) data were not available and parameters were used from the calibrated Lake Huron model. It is important to note that the processes in the semi-enclosed bay of Owen Sound and Wiarton are quite different from the Lake Huron sites for which ADCP data were used. A low level of confidence has been established for the relevance of the data used in the in-water delineation.

Stream flow discharge data were obtained from Environment Canada. Velocities were not available for most rivers and tributaries. Side-slopes and cross-width measurements were needed to calculate the velocity and up-tributary extent of all watercourses. These data were obtained from 2006 Aerial Photography. In most cases, tributary cross-section data were limited to the information supplied in the bathymetry dataset. Much of the bathymetry data are not recent. For many locations this is not an issue, as the bathymetry has not changed significantly, however it may be an issue at some locations including river mouths and locations that are more dynamic. Due to the lack of any additional upstream bathymetry, it was assumed that upstream river cross-sections were the same as the river mouth. Catchment area extents were not available and were estimated using the Provincial DEM, watershed boundaries and the location of the developed area based on 2006 aerial photography.

Data on sediment load, especially during storm events, are not available. Also, measurement on water currents was taken under mild weather conditions, so that these data are only relevant for a limited range of weather conditions.

Storm sewer networks were provided for some systems; however the locations of outfalls were inferred. More detailed storm sewer network information would decrease the uncertainty related to data relevance. Tile drainage data provided by the province is generally regarded as incomplete and thus a high uncertainty was assigned. The problem of increased mixing due to negatively buoyant plumes also translates to discharges from storm sewers and runoff from drainage and other transport pathways.

Distribution of data as it pertains to the vulnerability uncertainty analysis relates to the time series available for a dataset. A greater distribution of data provides a lower level of uncertainty in the analysis.

Reasonable assumptions were made to determine the delineation of the in–water and onshore extent for all surface water systems located within the Great Lakes. If data were incomplete, then it was automatically high.

The uncertainty is high for all the datasets used.

Modelling

Overview

Modelling uncertainty relates to the ability of the model to accurately depict the flow processes in the hydrological system. The IPZ-2 has two components; in-water and onshore. Isolated methods were used to delineate each component. The model and employed methods were assessed for each component, and overall uncertainties were assigned. While separation of the modelling components is not identified in the Technical Rules, uncertainties have been assessed independently for the purpose of clarity as part of this report. In-water modelling determines the residual ToT and therefore the extents of the onshore delineations calculated for each Great Lakes system. The accuracy of the onshore delineations are dependent upon the confidence of the in-water modelling. Therefore despite the confidence in the onshore delineation, the confidence in the tributary extents is limited to the confidence in the in-water delineations.

The Delft3D hydrodynamic model was used to evaluate current velocities in the vicinity of all Great Lakes intakes in this region. The following data were obtained, analyzed, and used in the model calibration, processes evaluation, and model runs undertaken to delineate the in-water IPZ-2:

- Bathymetry;
- Water levels;
- Recorded and modelled wind data; and
- Measured currents and tributary flows.

The Lake Huron Operational Forecast System was used to define the boundary conditions for area modelled with the Delft3D modelling software.

On the Lake Huron shore, the Delft3D model was calibrated with measured current data from three ADCPs deployed by the MOECC in Lake Huron from May 16, 2003 to November 27, 2003.
In Georgian Bay, measured calibration data for the Delft3D model was not available, so parameters determined for the Lake Huron shore model was also used there.

Particle Tracking and Area Delineation
Reverse particle tracking with a 10-year return was used to delineate the in-water IPZ-2, and neutrally buoyant particles were introduced at the intake to provide a site-specific representation of the lake processes about the intake. There was a significant difference between the particle tracking results for surface and bottom released particles at this site. The most conservative results were used to delineate the IPZ-2.

Datasets employed in the model run were obtained from federal and provincial sources (i.e. Canadian Hydrographic Service (CHS), National Oceanic and Atmospheric Administration (NOAA), and Great Lakes Environmental Research Laboratory (GLERL)) and have an associated high level of confidence.

Forward particle tracking methods were used with the model runs to evaluate site specific processes and conditions that increase the risk of contamination at the intake. The forward particle tracking results include output for model runs extending beyond the 2-hour limit used for the IPZ-2 delineations. The identification and understanding of the processes that are impacting each site improves the level of confidence in the delineation.

Near-Shore Currents
Currents inshore of the surf zone are complex and are not well defined by existing numerical models. However, it is recognized that there is potential for currents in the surf zone to transport a contaminant in an offshore direction from the shoreline. This methodology was used to define the shore connection for the IPZ-2s and travel time isopleths. This methodology is assumed appropriate; however it presents a limitation in the model with an associated level of uncertainty.

If stream flow discharges are denser than the receiving water body, then negatively buoyant (hyperpycnal) river plumes result. Especially in conditions of the Great Lakes, these are common because the salinity difference between river discharge and the receiving water body is very small. For example during spring, when lake and river waters are near the temperature of maximum fresh water density (4°C), then relatively warm river discharge is often denser than the colder receiving lake water. Groundwater discharge may also create river water that is colder than lake water, especially when lakeshores are shallow. Furthermore, density of discharging water increases drastically with sediment load, especially after erosive precipitation events (Churchill et al., 2003). Negatively buoyant river plumes that are caused by sediment load were not considered in the model, because data on sediment load, especially during storm events, is not available.

Conclusion on Modelling Uncertainty

As directed in the Technical Rules, an uncertainty rating of high or low must be assigned to the level of uncertainty associated with hydrodynamic modelling. Regardless of the high level of confidence associated with the model input data, provisions must be made to include uncertainty associated with the model application and limitations of model outputs. A high level of uncertainty is associated with the methodology of in-water IPZ-2 delineations and therefore for all Great Lakes models.

Quality Assurance and Quality Control (QA/QC)

Quality assurance (QA) and quality control (QC) measures were applied to model outputs and calculations of all Great Lakes surface water delineations. Delineations were reviewed and the confidence in the data, models, and calculations used in the delineation was assessed to be low for the Great Lakes systems.

QA/QC measures were also applied to the sub factor outputs for the vulnerability analysis. Vulnerability factors were reviewed throughout the analysis process and as such the confidence in the data and the calculations used in the vulnerability analysis were assessed for the Great Lakes systems and is low.

Calibration and Validation

Calibration and validation of the modelling of the in-water and onshore components of the delineations were reviewed for the uncertainty analysis. If the in-water modelling and onshore calculations were calibrated using site-specific data of a reasonable time series and the outputs of the model were validated with actual measurements, a low level of uncertainty was assigned.

Overall, the uncertainty associated to the calibration and validation of the models and methods used in the delineation of Great Lake Intakes is high.

Accuracy of the Vulnerability Factors

Accuracy of the area and source vulnerability factors is dependent on the data used in the factor analysis. The confidence in the density, extent, distribution, and relevance of data concerning the intake system, water quality records and shoreline, and onshore features is considered. A high level of confidence in the supporting data relates to high confidence in the accuracy of the vulnerability factors. The accuracy of the vulnerability factors was assessed for each Great Lakes system separately.

Uncertainty of the Events-based Area and IPZ-3

The limitations of the delineation of intake protection zones and events based areas with regards to the events-based delineations are outlined by Baird in their 2013 report.

Modelling

Modelling was used to determine whether a spill under the conditions set out in the model would result in a predicted exceedance. The approach used is consistent with the methodologies outlined in MOE (2009b). However, there were limitations to modelling. Time and budget limited the number of model runs that could be completed for each event, and a limited number of events could be modelled. Due to the lack of data, many assumptions were made, including spill duration and spill volume. In Georgian Bay, data related to lake currents were incomplete. Further, the DELWAQ modelling software does not account for some of the physical processes with regards to fuel evaporation and dispersal, therefore it was assumed that no evaporation took place once the spill entered the water.

Desktop Analysis

The desktop analysis done was used to evaluate whether spills that occurred inland would reach the intake within the two hour time-of-travel or a bit longer and cause a predicted exceedance, as prescribed in the technical rules 68 and 130. Where a spill, outside IPZ-1 and IPZ-2, caused deterioration of the water quality, an IPZ-3 was delineated. For the desktop assessment done by Baird, all scenarios were evaluated based on the distance to the lake, and then used the spill scenarios that were modelled to estimate the dilution of the chemical parameter. Therefore, all limitations for the modelling apply to the desktop analysis. Additionally, flow speed was assumed to be 1 m/s, with no accounting for roughness, vegetation, travel slope and other factors that might contribute or reduce the flow speed. Further, the inherent simplicity in the linear modelling method used for the inland spill locations creates high uncertainty. Finally, advection with limited mixing of benzene in water was the only mechanism used for transportation was assumed in the drainage path, no evaporation was assumed in the lake and absorption into groundwater and soil were not considered.

Summary of Uncertainty Considerations

The uncertainty sub-factors results are displayed in Table 4.1.19. For all Great Lakes systems, these factors are equal. For IPZ-1, uncertainty in the area delineation rating is low, because it is fully prescribed by the Technical Rules. The rating of the IPZ-2 delineation is high, partly because of uncertainties embedded within the numerical modelling itself, and partly because the data required for validating these models has high uncertainty. The ratings of the IPZ-3 and EBA are high due to the previously stated uncertainty of the modelling. Further, the ratings are high for the desktop assessment due to the use of linear modelling and the many unknowns that were assumed, such as flow speed, dilution and a full understanding of the lake current circulations at a larger scale.

The overall uncertainty related to the vulnerability of the intake protection zones is high.

TABLE 4.1.19 – Uncertainty Rating for Great Lakes Intakes (Type A)

Uncertainty Component	***Consideration Factor***	***IPZ-1 Rating***	***IPZ-2 Rating***	***IPZ-3 Rating***	***EBA Component Rating***
Delineation of the surface water intake protection zones.	*Data*	*Low*	*High*	*High*	*High*
	Modelling	*n/a*	*High*	*High*	*High*
	QA/QC	*Low*	*Low*	*High*	*High*
	Calibration and validation	*n/a*	*High*	*High*	*High*
	Overall	**Low**	**High**	**High**	**High**
The assessment of the	*Data*	*Low*	*High*	*n/a*	*n/a*
	QA/QC	*Low*	*Low*	*n/a*	*n/a*

Vulnerability of the intake protection zones	*Accuracy of the vulnerability factors*	*Low*	*Low*	*n/a*	*n/a*
	Overall	**Low**	**Low**	**n/a**	**n/a**

n/a – (not applicable) modelling is not required for the delineation of the IPZ-1.

4.1.8.3 Uncertainty in the Assessment of WHPA-Es Associated with GUDI Wells

Identification of Point of Interaction

The point of interaction between the surface water and the well was not known in most GUDI systems in this source protection area. Technical Rule 47(5a) was applied and the point closest to the well was identified.

The hydrological uncertainty of this approach is high.

Hydraulic Analysis

No hydraulic modelling was necessary in this source protection area. In consequence, the uncertainty associated with the delineation of the 2-hour ToT is low.

Data uncertainty remains for the identification of surface water bodies, such as streams and wetlands. This uncertainty is considered medium.

The uncertainty of the WHPA-E delineation impacts those properties at the tail end of the WHPA-E. The overall uncertainty of the time-of-travel distance and WHPA-E area delineation is the cumulative effect of our knowledge on the point of interaction, the data uncertainty, and the methodological uncertainty.

Due to the uncertainty associated with the knowledge of the point of interaction, the overall uncertainty of WHPA-E delineation is high.

Uncertainty of Vulnerability Rating

<u>Area Vulnerability</u>
The area vulnerability rating is very robust. While sub factors are varying, the overall area vulnerability is moderate for all systems. Thus, the uncertainty attributed to the area vulnerability factor is considered low.

<u>Source Vulnerability</u>
Source vulnerability varies considerably among wells, ranging from low to high. Data used for source vulnerability rating is the distance to surfacing karst, the overburden thickness and the casing depth.

Due to the relevant impact of data uncertainty on the overall vulnerability rating, uncertainty related to source vulnerability is high for all systems.

Accumulative Uncertainty

Taking into account all uncertainties mentioned, the accumulative uncertainty related to WHPA-E threats analysis is high for all systems.

More detailed consideration factors to determine the uncertainty for all systems in this source protection area are given in Table 4.1.20.

TABLE 4.1.20 – Uncertainty Rating for WHPA-Es

Uncertainty Component	**Delineation** of the wellhead protection area E					The assessment of the **Vulnerability** of the wellhead protection area E				
Consideration Factor	*Point of inter-action*	*Hydraulic Analysis*			**Overall**	*Area Vulnerability*		*Source Vulnerability*		**Overall**
		Data	*Modelling*	*Calibration*		*Data*	*Method*	*Data*	*Method*	
Tobermory	*High*	*High*	*Low*	*Low*	**High**	*High*	*Low*	*High*	*High*	**High**

4.2 Risk Assessment by Municipality: Threats and Issues

4.2.1 Municipality of Northern Bruce Peninsula

The Municipality of Northern Bruce Peninsula is in the Northern Bruce Peninsula Source Protection Authority jurisdiction and makes up the northern most part of Bruce County. The waters of Lake Huron borders the west shores with Georgian Bay bordering the east shore. The Municipality contains the Fathom Five National Marine Park, Bruce Peninsula National Park, the Bruce Trail, Cabot Head and Lion’s Head Nature Reserves, two First Nation Hunting Reserves, and a large Bruce County Forest Tract.

The Municipality was amalgamated in January 1999 and is composed of the former Townships of St. Edmunds, Lindsay, Eastnor, and the Village of Lion's Head. It is currently home to the communities of Tobermory, Dyer's Bay, Miller Lake, Stokes Bay, Lion's Head, Ferndale, and Barrow Bay. The total population was 3999 in 2016, which is an increase of 10% from 2006 (Statistics Canada, 2016b). With a land area of 781.51 km^2, the population density is 5.1 people per square kilometre. Seasonal residents add to the population during peak periods due to 4870 private dwellings, which reflects the importance of tourism for this area. The main towns are Lion’s Head (population 500) and Tobermory (population 350). Smaller villages include Dyer’s Bay, Miller Lake, Stokes Bay, Barrow Bay, Ferndale, and Pike Bay (NBP, 2006).

The Municipality of Northern Bruce Peninsula has one Great Lake surface water intake servicing the town of Lion's Head. It is located on the western shore of Georgian Bay in an inlet called Isthmus Bay.

This Municipality also operates two municipal non-residential water systems, one servicing the Marina Harbour for the Northlands Transport Ferry Service in Tobermory (surface water based) and one servicing the fire hall, community centre and municipal concession stand in Tobermory (groundwater-based).

Agricultural land use in Northern Bruce Peninsula includes 85 farms managing a total land area of 16,471 ha (average farm size 194 ha), of which 27.5% are cropped according to the Agricultural Census (Statistics Canada, 2006a). From this cropped area, alfalfa and other fodder crops take up 41.4% of the land, barley takes up 10% and other crops (corn, wheat, etc.) take up 4.6%. The total livestock density is 0.03 nutrient units per acre. According to the same census, there are 26 chickens on three farms (Statistics Canada, 2006a). The total number of cattle is 9960 (100% beef) on 55 farms. Further, there are 147 horses and no pigs, sheep or goats reported in this municipality.

No new drinking water systems are planned.

4.2.1.1 Highly Vulnerable Aquifers & Significant Groundwater Recharge Areas

Map 4.1.M2 shows the locations of highly vulnerable aquifers (HVAs) and significant groundwater recharge areas (SGRAs) in this municipality. The Municipality is characterized by two bedrock strata that are covered by a very thin overburden. To the west of the peninsula, bedrocks are associated with the Guelph formation, which consists of sandstone, shale, dolostone, and siltstone. To the east of the peninsula, bedrocks are associated with the Amabel Formation, which is mostly dolostone. Both formations are known for their karstic character. They surface and can be seen in many parts of this source protection area.

All areas in this SPA are considered highly vulnerable aquifers because the overburden is very thin.

All HVAs outside of WHPAs/IPZs have a groundwater vulnerability score of six (Map 4.1.M3).

In this municipality, the total area of SGRAs is 103.9 km^2 and the total area of HVAs is 742.3 km^2. For the purposes of calculating managed lands and livestock density, only the portion of the SGRAs where the vulnerability score is 6 are used in the calculations. The percentage of managed lands located within the SGRAs and HVAs is less than 40%. The livestock density is less than 0.5 NU/acre. Only 1-8% of all surfaces in SGRAs and HVAs are classified as impervious (Table 4.2.1.1).

The vulnerability mapping can be used in conjunction with the Tables of Drinking Water Threats to determine which activities pose a significant, moderate, or low threat to drinking water, and under which circumstances. Section 4.1.5.7 gives directions how to consider the type of vulnerable area, the contaminant, and the vulnerability score at any location.

TABLE 4.2.1.1 – Highly Vulnerable Aquifers and Significant Groundwater Recharge Areas within the Municipality of Northern Bruce Peninsula

SGRA	Total area of SGRA	103.9 km^2
	Managed Land and Livestock Density	ML% <40%, NU/acre <0.5
	Impervious Surfaces (average)	1-8 %
HVA	Total Area of HVA	742.3 km^2
	Managed Land and Livestock Density	ML% <40%, NU/acre <0.5
	Impervious Surfaces (average)	1-8 %

Note: Total areas relate to the full source protection region.

4.2.1.2 Groundwater Municipal Systems

4.2.1.2.1 Tobermory Community Centre/Fire Hall/Municipal Concession Stand

The Municipality of Northern Bruce Peninsula operates one groundwater-based non-residential municipal drinking water supply system, which services the fire hall, community centre and municipal concession stand in Tobermory (CRA, 2008 – Round 2).

This single well was installed in the Guelph Formation bedrock aquifer to a depth of 67.4 metres (m) in 1991. A well casing was installed to a depth of 16.2 m. Originally, the Tobermory Community Centre maintained the private groundwater pumping well located on–site; however, the Municipality of Northern Bruce Peninsula has since assumed responsibility for the well. The Tobermory Community Centre well is designated a Type 1 well under the *Clean Water Act, 2006*. It falls under the category of "Small Municipal Non-residential" under Ontario Regulation 170/03 (CRA 2008 – Round 2). The rated capacity of the well is limited to 0.79 L/s; however, there have been no reports of dissatisfaction with the current supply volume.

In general, the bedrock aquifer can be characterized as primarily fractured, which contributes to increased vulnerability. The bedrock material in the study area is primarily dolostone in different sub-geological units including the Guelph, Amabel and Fossil Hill formations. These formations are known to be highly conductive of water. The surface of the bedrock is solution-weathered, irregular and commonly exposed. There are weathered, karstic bedrock features on the surface (WHI, 2005) but not expected to persist in depth. According to the Engineer's report, water quality appears to be affected by storm events (Henderson and Paddon, 2004), indicating that the groundwater is highly vulnerable to surface contamination.

The Tobermory Community Centre well is considered Groundwater Under the Direct Influence of Surface Water (GUDI). Long term raw water bacteriological and turbidity data are not available to properly assess raw water quality during adverse conditions such as wet weather periods. Total coliforms have been detected in the raw water samples available. Tested chemical/physical parameters of the raw water indicate that special precautions are required in using the well as a raw water source for drinking water. The Engineering report thus recommends that the respective well should be classified as GUDI (Henderson and Paddon, 2004).

The limited overburden in the Tobermory area is discontinuous and situated over bedrock deposits. The overburden consists of glacial and post-glacial clay, silt, sand, and gravel deposits. Small isolated pockets of organic materials, such as peat and muck, are found in poorly drained, low-lying areas (Ontario Geological Survey, 2007). A 1.5 km radial deposit of glaciolacustrine material is found approximately 3 km to the southeast of the Tobermory Community Centre well (Ontario Geologic Survey, 2007). This deposit is the only substantial overburden feature in the former Township of St. Edmunds, which composes the northern half of the Municipality of Northern Bruce Peninsula.

A wellhead protection area (WHPA) for the Tobermory Community Centre well was first developed by CRA (2008 – Appendix A) by creating a new groundwater model for the area. Threats and issues analysis were performed by CRA and were included in the Round 2

Groundwater Technical Studies (2008). The threats were redelineated by Drinking Water Source Protection staff in 2014.

TABLE 4.1.G1.1 – Description of the Drinking Water System

Well Name	Tobermory
Drinking Water System ID	n/a
SPA of Well and Vulnerable Area (WHPA)	Municipality of Northern Bruce Peninsula
Northing/Easting	5011263.4 / 447952.9
Year Constructed	1991
Well Depth	67.4 m
Uncased Interval	16.2 - 67.4 m
Aquifer	Guelph Formation bedrock
GUDI	Yes
Number of Users Served	Community centre, tourists and visitors, fire hall and baseball diamonds on the property
Design Capacity (CoA)	not known
Permitted Rate (PTTW)	not known
Average Annual Usage	not known
Modelled Pumping Rate	68.3 m^3/day
Treatment	Chlorination

Managed Land, Livestock Density and Impervious Surfaces

Following the methodology outlined in Section 4.1.4, the percentage of managed land, the livestock density (nutrient units per acre) and the percentage of impervious surfaces were computed for each wellhead protection area. For the purposes of calculating managed lands and livestock density, only the portion of the SGRAs where the vulnerability score is 6 are used in the calculations. Computation results are listed in Table 4.1.G1.2 and on Maps 4.1.G1.4, 5 and 6. In this WHPA, the percentage of managed land in the vulnerable area is less than 40% and the livestock density is less than 0.5 NU/acre. This classification impacts the risk rating of some activities (see Section 4.1.4.4).

TABLE 4.1.G1.2a – Impervious Surfaces

General	Code for WHPA	Tobermory
	Total Area [hectare]	25.27
Impervious Surfaces Area [ha]	0 % – <1%	0.00
	1% – <8%	3.56
	8% – < 80%	21.71
	Larger or equal than 80%	-

Note: Total areas relate to the full WHPA, even if located in other municipalities

TABLE 4.1.G1.2b – Managed Land and Livestock Density

WHPA_NAME	**Tobermory Community Centre**			
Well Name	Tobermory			
Zone	A	B	C	D
Livestock Density Category (<0.5, 0.5-1.0, >1.0)	<0.5	<0.5	<0.5	<0.5
% Managed Lands (<40%, 40-80%, >80%)	<40%	<40%	<40%	<40%

Wellhead Protection Area

The wellhead protection area (WHPA) was estimated following the methodology described in Section 4.1.2.5. From the community centre, the WHPA extends southwest. The total area of the 25-year ToT capture zone for the Tobermory WHPA is 25.3 hectares (ha). It crosses Provincial Highway 6, as well as numerous light residential and commercial structures; however, most of the 25-year ToT capture zone is covered by undeveloped bush terrain.

WHPA-E was delineated in the surface water body that influences this GUDI well. To identify the point of interaction, Technical Rule 47(5a) was applied and the point of interaction located in the closest surface water body is part of an unnamed creek, approximately 30 metres south of the well. The WHPA-E extends 0.8 km upstream until the source of the creek, which is still within the 2-hour ToT. A 120 metres setback or the regulation limit, and areas with agricultural tile drainage were added (for details, see Section 4.1.2.7).

Maps 4.1.G1.1 and 4.1.G1.2 show the location of the wellhead protection area (WHPA).

Transport Pathways

The vulnerability of the WHPA must be increased if pathways exist that transport contaminants from the surface into the aquifer that is a source for drinking water (see Section 4.1.2.5), unless the vulnerability is already rated high.

The Tobermory WHPA is characterized by light commercial and residential properties, which are serviced by private wells and septic systems. In addition to private residential and commercial wells, several other MECP water well records exist. A municipal sewer line was installed in the 1990s that follows Highway 6 through WHPA-A and WHPA-B.

No further transport pathway adjustment to aquifer vulnerability was made in the Tobermory WHPA. Aquifer vulnerability within the entire Tobermory WHPA area is rated high, therefore aquifer vulnerability cannot be further increased to account for Transport Pathways.

Vulnerability

Aquifer vulnerability, based on ISI, is considered high in the entire area (Map 4.1.M1). This is due to the lack of significant overburden overlying the bedrock aquifers in this region, as well as the prevalence of karstic features in the area.

WHPA A-D
After overlaying the intrinsic susceptibility index (Map 4.1.M1) on the delineation of wellhead capture zones, vulnerability scores were determined. The vulnerability is shown on Map 4.1.G1.3.

Area shares for the WHPA are summarized in Table 4.1.G1.2 with both original scoring and with transport pathway adjustments. Groundwater vulnerability is categorized as high across the region, but the vulnerability scores show that groundwater vulnerability decreases with distance from the supply well. WHPA-A (Wellhead Security/Prohibition Zone) is mapped as one continuously sensitive area based solely on proximity to the supply well and is assigned a vulnerability score of ten to reflect the high vulnerability that the groundwater in this area has to contamination from surface conditions or activities. The remaining sensitivity areas have a relatively high vulnerability, ranging from six to ten (the maximum scores that can be assigned within each zone), as a result of the high intrinsic vulnerability of the groundwater across the WHPA.

WHPA-E
The total vulnerability of the WHPA-E associated with the Tobermory Community Centre well is relatively high (8.0). This score was determined by multiplying the area vulnerability score with the source vulnerability scores (see Table 4.1.G1.2c). The area vulnerability describes the propensity of the on-land area to contribute runoff (percentage of land, land characteristics and transport pathways), which is 8 (moderate) for the WHPA-E areas, with the source vulnerability score of 1.0 (high) due to a minimum of overburden protection.

Threats and Risks

Land uses and activities within the wellhead protection area were rated under the threat-based approach to identify those activities that pose a significant or moderate risk for drinking water quality. The methodology was described in Section 4.1.5.

The vulnerability mapping can be used in conjunction with the Tables of Drinking Water Threats to determine which activities pose a significant, moderate, or low threat to drinking water, and under which circumstances. Section 4.1.5.7 gives directions how to consider the type of vulnerable area, the contaminant, and the vulnerability score at any location.

WHPA A-D
There are 38 “are or would be significant” threats in the Tobermory wellhead protection area. These threats include 15 related to the potential for pathogen contamination, and 23 related hazardous chemicals. The total number of properties with threats is 15, of which eight are residential, and seven are other land uses (see detailed Table 4.1.G1.3 and summary Table 4.1.G1.4).

WHPA-E
No threats were identified in association with WHPA-E.

Moderate and Low Threats
Moderate and low threats are not counted individually even if identified. Section 4.1.5.7 helps to identify the circumstances that would pose a moderate, low or significant drinking water threat for each vulnerable area and vulnerability score.

Quality of Raw Water at the Well

At this point in time, no data on raw water quality is available for the Community Centre Well.

TABLE 4.1.G1.2c – Vulnerability of WHPA-E associated with the Tobermory Community Centre Well

Name of WHPA	**TOBERMORY**	
DWIS_ID	n/a	
Area (Total), hectares	22.38	
Vulnerability (Total)	**8.0**	
Source Vulnerability	**1.0**	
SV - Distance to surfacing Karst [m]	> 500 m	0.8
SV - Overburden Protection	3.4 m	1.0
Area Vulnerability **	**8 (8.5)**	
AV - Percent Land: Score	**9**	
AV - Percentage of Land	> 70%	9
AV - Land Characteristics	**8.4**	
Land Cover *	20% Developed, 80% Natural	7.4
Soil type	90% bedrock	9.0
Soil permeability *	no classification	8.0
Slope [%]	6.3%	9.0
AV Transport Pathways	**8.0**	
Tile Drainage [% of land area]	46.1%	8
Storm Catchment	None	7
Number of Watercourses/1000 ha	9.0	

** Area disregarded if classified "Not categorized"*
*** The Area Vulnerability Score is rounded to full number. In brackets, value rounded to 1 digit is shown.*

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TABLE 4.1.G1.3 – Tobermory Community Centre: Significant Drinking Water Threats by Activity and Land Use in WHPA A-D (Chemical, Pathogen and DNAPL)

Prescribed Threat **WHPA: TOBERMORY** *For full legal name of prescribed threat, see Table 4.1.5*		**Land use Category**									
		Agricultural	Commercial	Industrial	Infrastructure	Institutional	Municipal/Utilities/ Federal	Recreational	Residential	Others	Grand Total
	CHEMICALS										
1	Waste disposal site										
2	Sewage systems - Collection, storage, transmittance, treatment or disposal		4				3		8		**15**
3	Agricultural source material - Application to land										
6	Non-agricultural source material - Application to land										
8	Commercial fertilizer - Application to land										
9	Commercial fertilizer - Handling and storage										
10	Pesticide - Application to land										
11	Pesticide - Handling and storage										
12	Road Salt – Application						1				**1**
13	Road Salt – Handling and Storage						1				**1**
14	Snow - Storage										
15	Fuel - Handling and storage						3				**3**
17	Organic solvent - Handling and storage						3				**3**
18	De-icing chemicals - Runoff from airports										
21	Pastures or other farm-animal yards - Livestock grazing										
	DNAPLs										
16	Dense non-aqueous phase liquid - Handling and storage		2				6				**8**
	PATHOGENS										
2	Sewage systems - Collection, storage, transmittance, treatment or disposal		4				3		8		**15**
3	Agricultural source material - Application to land										
4	Agricultural source material - Storage										
6	Non-agricultural source material - Application to land										
7	Non-agricultural source material - Handling and storage										
21	Pastures or other farm-animal yards - Livestock grazing										

TABLE 4.1.G1.4 – Tobermory Community Centre WHPA: Summary of Significant Drinking Water Threats

	Number of "are or would be significant" threats				**Number of *properties* with "are or would be significant" threats**			
TOBERMORY	Chemical	DNAPL	Pathogen	Total	Agri-cultural	Resid-ential	Others	Total
WHPA A-D	23	0	15	38	0	8	7	15
WHPA-E				0				0

Drinking Water Issues and Conditions

Based on available data and knowledge on raw water quality, no drinking water quality issues were identified for this water system that would result from ongoing or past activities (Table 4.1.G1.5). Also, no conditions resulting from past activities were identified within the WHPA that meet the conditions of Technical Rule 126 (see Section 4.1.5.6).

TABLE 4.1.G1.5 – Tobermory Community Centre: Issues and Conditions

Drinking Water Issue	**Parameter**
None	None
Drinking Water Condition	**Threat**
None	None

4.2.1.3 Intake Protection Zones

4.2.1.3.1 Lion's Head Water Treatment Plant

The town of Lion's Head is located on Isthmus Bay, an inlet of Georgian Bay. This town receives water from a municipal drinking water system that draws water from an Isthmus Bay intake, which is classified as a Type A - Great Lakes intake. There are no major river or stream discharges located in Isthmus Bay within the community. Whippoorwill Bay, which is connected to Isthmus Bay to the north, receives discharge from Swan Lake Drain. The Lion's Head Water Treatment Plant is classified as a Large Municipal Residential drinking water system because it services over 300 private residents and commercial users.

The intake pipe was constructed in 1992 and is located outside of the marina facing Dock Street (Map 4.1.S1.1, Table 4.1.S1.1). The length of the intake pipe is 165 m (Stantec, 2008; Certificate of Approval in MOECC, 2006b). While the most recent Certificate of Approval states that the depth of the intake crib is 8.4 m, but other sources suggest a shallower depth. A conservative estimate of 6.8 m (top of intake crib) was used for the vulnerability analysis. The intake pipe has a diameter of 300 mm and a capacity of 7960 m^3/day (Paragon Engineering Ltd, 1993). The intake is protected from zebra mussels by chlorine dosing at the intake. The intake structure is reinforced with stone to protect it against ice scour and wave action and its design was based on a fifty-year period.

TABLE 4.1.S1.1 – Description of the Drinking Water System

Intake Name	Lion's Head WTP
Drinking Water System ID	220002672
SPA of Intake and Vulnerable Area (IPZ)	Northern Bruce Peninsula
Intake Type	A (Great Lakes)
Northing/Easting of Intake	480419.69 / 4982136.15
Intake Pipe Length	165 m
Lake Depth at Intake *	7.8 m
Depth of Top of Intake Crib *	6.8 m
Number of Users Served	600 persons
Intake Capacity	not known
Average Annual Usage **	386 m^3/day
Maximum Usage **	640 m^3/day

** Stantec 2009, Phase 1 Technical Addendum*
*** Flow data from DWIS*

Raw water is gravity fed into a 3.6 m diameter wet well. Three low lift centrifugal pumps with variable speed drives pump raw water via a 150 mm diameter pipe to the water treatment plant (WTP), which is located at the intersection of Ida and Helen Streets. The plant has two parallel membrane filtration package systems with a total design capacity of 15.63L/s. Each system consists of hollow-fibre filter modules, filter feed pump, backwash pump, turbidity analyzer, and particle counter. The plant also has two concrete chlorine contact tanks and two concrete reservoirs with treated water flow to the high lift well. The high lift pumping station has five vertical turbine high lift pumps, which discharge into a 150 mm diameter treated water header connected to the distribution system. Chemical feed systems include a sodium hypochlorite feed system, a chlorine dosing system and an acid feed system. The plant has backwash/wastewater facilities that consist of a backwash settling tank and pumps that transfer the supernatant to the storm sewer, which discharges at an unknown number of locations into Isthmus Bay. The drinking water system has a rated capacity of 1351 m^3/day (MOECC, 2006b).

Managed Land, Livestock Density and Impervious Surfaces

Following the methodology outlined in Section 4.1.4, the percentage of managed land, the livestock density (nutrient units per acre) and the percentage of impervious surfaces were computed for each wellhead protection area. Computation results are listed in Table 4.1.S1.1b and in Maps 4.1.S1.5, 6 and 7.

The Lion's Head WTP intake protection zone is classified as an area where the percentage of managed land of the vulnerable area are less than 40% and the livestock density is less than 0.5 NU/acre. This classification impacts the risk rating of some activities (see Section 4.1.4.4).

TABLE 4.1.S1.1b – Managed Land, Livestock Density and Impervious Surfaces.

	IPZ ID	LIONS_HEAD
General	Area Total [hectare]	533.58
	Area Offshore [hectare]	339.91
	Area Onshore [hectare]	193.67
IPZ 1 Managed Land and Livestock Density	Vulnerable Land Area [hectare]	39.155
	Livestock Density [NU/Acre]	0.00
	Managed Land Area [hectare]	10.82
	% Managed Lands	27.62
	Category	**ML% <40%, NU/acre <0.5**
IPZ 2 Managed Land and Livestock Density	Vulnerable Land Area [hectare]	152.40
	Livestock Density [NU/Acre]	0.05
	Managed Land Area [hectare]	62.02
	% Managed Lands	40.70
	Category	**ML% 40%-80%, NU/acre <0.5**
Impervious Surface: Area per category [hectare]	0 % – <1%	28.42
	1% – <8%	74.92
	8% – < 80%	88.21
	Larger or equal than 80%	0.00

Note: All areas relate to the full IPZ including other municipalities.

Intake Protection Zone

The in-water portion of the IPZ-1 was delineated based on guidance provided in the Technical Rules that states a Type A intake be delineated from the entry point where raw water enters the drinking water system (see Section 4.1.2.6 for details). Where an IPZ-1 abuts land and is not impacted by a riverine or transport pathway, it may be extended 120 m inland or to the area of the regulation limit. The Lion's Head IPZ is not located within the jurisdiction of a Conservation Authority for a regulation limit to be delineated; therefore, it extends inland 120 m over a shoreline of 3,400 m. For IPZ-1, the on-land area is 0.3 km^2 and the in water area of 4.8 km^2. The length of this shoreline on-land area is approximately 3,500 m long and includes the bay and the marina. The IPZ-1 was delineated by DWSP staff.

The IPZ-2 was delineated based on the criteria of time-of-travel, which is 2 hours or less with moderate conditions of flow and wind (see Section 4.1.2.4 for details). It extends 3,500 m northwest of the intake, 2,400 m northeast of the intake, 1,600 m offshore at its furthest point, and approximately 7,250 m inland. The Swan Lake Drain is the only tributary that drains into the IPZ-2 along the shore. It drains the community of Ferndale and discharges into Whippoorwill Bay north of Isthmus Bay. The length of this shoreline is approximately 8,000 m long.
The full IPZ is shown on Map 4.1.S1.2 and on 4.1.S1.3 with underlying aerial photography.

An IPZ-3 and an EBA were delineated for based on modelled spill scenarios and desktop assessment. Using the methodology described in section 4.1.2.4, minimum volumes that would result in exceedances were determined for locations distributed throughout Lion's Head and around the IPZ-2. Volumes ranged from 700 L to 22,500 L and were split into three EBA categories (see map 4.1.S1.1.9);

- 5,000 L and greater
- 7,500 L and greater
- 22,500 L and greater

Storm Sewer Systems and Transport Pathways

The onshore component of the intake protection zone includes properties that drain into storm sewersheds within a 2-hour ToT, and other transport pathways (the method is outlined in Section 4.1.2.4).

Local storm drains discharge into Lion's Head Harbour. Due to lack of data, the catchment of the storm sewer network was estimated to include all areas of developed land in their entirety (Stantec, 2009, Phase 1 Technical Addendum). Lion's Head Harbour has a very small-scale local fishing industry, but there are no commercial shipping routes in the area. The soil drainage in the area is imperfect, generating moderate natural runoff potential (Stantec, 2008). The resulting area is shown on Map 4.1.S1.1.

For IPZ-2, the resulting onshore area is 1.2 km^2 and the in-water area is 3.4 km^2.

Vulnerability

Vulnerability of the protection zone of the surface water intake was delineated following the methodology described in Section 4.1.3.5. Two factors measuring the vulnerability of the area and of the raw water source are computed separately and then multiplied with each other.

Area Vulnerability Factor
The area vulnerability factor for IPZ-1 is ten, as prescribed by the Technical Rules. For IPZ -2, the area vulnerability factor was determined by averaging the percentage of land, land characteristics and transport pathways sub factors (Table 4.1.S1.2a).

Percentage of Land
The % land sub-factor has been divided equally between the three ranges outlined in the Technical Rules (< 33% = 7, 33% to 66% = 8, > 66% = 9). The Lion's Head intake protection zone has approximately 42% land area; therefore, the % land sub factor has a score of 8.

Land Characteristics
The land characteristic sub-factor has the components; land cover, soil type, permeability, and slope. The land characteristics sub factor can be derived from the average of the ratings for the four components.

Land Cover The land cover rating ranges from seven to nine and has been divided into; mainly vegetated (7), mixed vegetated and developed (8) and mainly developed (9). Land in the onshore portion of the IPZ-2 is primarily comprised of natural areas, rural development (cottages), and the community of Lion's Head. Based on the available SOLRIS GIS dataset, the land cover type is 61% natural green areas and agricultural fields. Therefore, a land cover component rating of 7 was prescribed for the Lion's Head WTP.

Soil Type The soil type rating ranges from seven to nine and has been divided into; sandy soils (7), silty clay (8), and clay soils (9). Information provided by the Ontario Soil Survey of Bruce County (Hoffman and Richards, 1954) identified the soils of the onshore IPZ-2 as stone-free sandy loam with pockets of silt loam, and occasional areas of shallow muck. These soils are described as having imperfect drainage. The soil type component rating is 8.

Permeability The permeability rating ranges from seven to nine and has been divided into; highly permeable (> 66% = 7), moderately permeable (33% to 66% = 8), and largely impervious (< 33% = 9). The onshore area of the Lion's Head IPZ is 152 ha of land with 93 ha (61%) of pervious cover. The impervious land cover was determined using SOLRIS (2009) information. Therefore, the permeability component rating is 8.

Setback Slope The setback slope rating ranges from seven to nine and has been divided equally into; < 2% slope (7), 2% to 5% (8), and > 5% (9). The topography of the Lion's Head IPZ onshore IPZ-2 is described as rolling bedrock plains with a gentle slope towards Isthmus Bay. The slope of the study area ranges from 1.9% to 3.0%. This was determined using OBM contours. As a conservative approach, the greatest slope range (3.0%) was used to assign the component rating. These area features may increase runoff directly to the lake within the vulnerable zone. The slope component rating is 8.

Land Characteristics (Summary) The resulting land characteristics sub factor, calculated using an average equal representation of each component listed above is 7.8.

<u>Transport Pathways</u>

The transport pathway sub factor has the components; storm catchment areas, storm outfalls, watercourses and drains, and tile drained areas.

Storm Catchment Areas Storm catchment areas are rated based on the percent of land area that is drained by a storm sewer system. The rating ranges from seven to nine and has been divided equally into; < 33% area (7), 33% to 66% area (8) and > 66% area (9). Storm sewer catchment areas, networks, and outfalls were unavailable for the Lion's Head IPZ study area. Storm sewer catchments were assumed based on the area of the developed land. The area of the developed land was based on the SWOOP 2006 data. The onshore area was determined to be 49% (74 ha) storm sewer drained. This resulted in a component rating of 8.

Storm Outfalls, Watercourses and Drains For the purpose of rating the number of storm outfalls, watercourses and drains, a standardized method was applied to the data. The number of outfalls per 1,000 ha of land was calculated for the Lion's Head IPZ-2 using the WVF Provincial Dataset. The rating range has been set for 0-3 /1000 ha in the zone (7), 4 to 7 /1,000 ha in the zone (8) and > 7/1,000 ha in the zone (9). One transport pathway (Swan Lake Drain) and an unknown number of outfalls discharge into Georgian Bay within the IPZ-2. Taking into account the presence of Swan Lake Drain only, this results in a calculated 7 outfalls per 1,000 ha of land, and a sub-factor of 8 has been assigned.

Tile Drained Area Tile drained area is based on the percent land artificially drained as indicated by the Tile Drainage Areas GIS dataset (OMAFRA, 2009). The rating ranges from seven to nine and has been divided into; < 33% area (7), 33% to 66% area (8), and > 66% area (9). There are no tile drained areas in the Lion's Head IPZ onshore IPZ-2 and therefore, a component rating of 7 has been assigned.

Transport Pathways (Summary) The resulting transport pathways sub factor, calculated using an averaged equal representation of the components listed above is 7.7.

The area vulnerability factor is determined by averaging an equal representation of the % land, land characteristics, and transport pathways sub factors. The resulting area factor rating for the Lion's Head IPZ-2 is eight.

<u>Source Vulnerability Factor</u>

The source vulnerability factor for the Lion's Head intake combines design characteristics, such as depth and length of pipe, and past water quality concerns. The intake crib depth is 6.8 m and its vulnerability sub score is 0.5. The Lion's Head intake is located approximately 165 m (Stantec, 2009, Phase 1 Technical Addendum) from the shoreline and scores 0.7. The Ontario Drinking Water Quality Standards were not exceeded according to available data. Turbidity

levels in the raw water measured above operational guidelines. Operators indicated that the elevated turbidity levels are correlated to spring and fall storm events as well as prolonged northeast or east winds. The elevated levels occur occasionally, averaging six times per year with a duration of 2.7 days. Based on a review of available data, there appears to be no recorded drinking water issues, which results in a sub factor of 0.5.
The source vulnerability factor is determined by averaging the above listed sub factors. The source factor rating for the Lion's Head IPZ is 0.6 (Table 4.1.S1.2b).

Resulting Vulnerability of the Intake Protection Zone

The resulting vulnerability for IPZ-1 is six and for IPZ-2 is 4.8 (Table 4.1.S1.2c).

TABLE 4.1.S1.2a – Area Vulnerability Factor for the Lion's Head Intake

Area Vulnerability Factor Rating *(Rounded average of percentage of land, land characteristics and transport pathways)*	**8**
Percentage of Land	**8**
Land Characteristics	**7.8**
Land Cover	7
Soil Type	8
Permeability	8
Setback Slope	8
Transport Pathways	**7.7**
Storm Catchment Areas *(more than 33% but less than 66 %)*	8
Storm Outfalls, Watercourses, Drains *(The number of storm outfalls, watercourses and drains per 1,000 ha is 4 to 7)*	8
Tile Drained Area *(less than 33 %)*	7

TABLE 4.1.S1.2b – Source Vulnerability Factor for the Lion's Head Intake

Sub Factor	**Score**
Intake Depth	0.5
Length of Pipe (offshore)	0.7
Recorded Water Quality	0.5
Source Vulnerability Factor	**0.6**

TABLE 4.1.S1.2c – Vulnerability Score of the Lion's Head Intake Protection Zone (IPZ)

Intake Type	**Area Vulnerability Factor**		**Source Vulnerability Factor**	**Overall Vulnerability Score**	
	IPZ-1	**IPZ-2**		**IPZ-1**	**IPZ-2**
A (Great Lakes)	10	8	0.6	6	4.8

Uncertainty Rating

The uncertainty rating for the area delineation of IPZ-1 is low, because rules are prescribed by the Technical Rules.

Numerical modelling and the delineation of on-land areas was peer reviewed. However, the uncertainty rating for the delineation of IPZ-2 is high, partly because of uncertainties embedded within the numerical modelling itself, and partly because the data required for validating these models has high uncertainty (for details, see Section 4.1.8.2).

Threats and Risks

Land uses and activities within the wellhead protection area were rated under the threat-based approach to identify those activities that pose a significant or moderate risk for drinking water quality. The methodology was described in Section 4.1.5.

The vulnerability mapping can be used in conjunction with the Tables of Drinking Water Threats to determine which activities pose a significant, moderate, or low threat to drinking water, and under which circumstances. Section 4.1.5.7 gives directions how to consider the type of vulnerable area, the contaminant, and the vulnerability score at any location.

Table 4.1.S1.4 indicates that no surface water threats are rated at a "significant" level for DNAPLs or pathogens. The vulnerability score for Great Lakes intakes (both IPZ-1 and IPZ-2) is always smaller than eight. However, moderate threats were identified in the vulnerable area (Stantec 2009, Phase 2 Report). One existing significant drinking water threat was identified through events-based modelling (see detailed Table 4.1.S1.3 and summary Table 4.1.S1.4).

TABLE 4.1.S1.3 – Lion's Head IPZ: Significant Drinking Water Threats for Events-based Area

Prescribed Threat **IPZ: LION'S HEAD** *For full legal name of prescribed threat, see Table 4.1.5*		**Land use Category**									
		Agricultural	Commercial	Industrial	Infrastructure	Institutional	Municipal/Utilities/ Federal	Recreational	Residential	Others	Grand Total
	CHEMICALS										
15	Fuel - Handling and storage						1				**1**

<u>Moderate and Low Threats</u>

There are other properties located within the intake protection zone that, under the threat-based approach, have a drinking water risk level of moderate. Moderate and low threats are not counted individually even if identified. Section 4.1.5.7 helps to identify the circumstances that would pose a moderate, low or significant drinking water threat for each vulnerable area and vulnerability score.

TABLE 4.1.S1.4 – Lion's Head IPZ: Count of Significant Drinking Water Threats for Chemical, Pathogen and DNAPLs

	Number of "are or would be significant" threats			
IPZ Name	Pathogen	Chemical	DNAPL	Total
Lion's Head	0	1	0	1

Quality of Raw Water at the Intake

In the water treatment plant (WTP) annual report for 2001, there was one documented case of a comparison of the raw water to the Ontario Drinking Water Quality Standards (ODWQS) as part of a water supply assessment. Many of the levels were not detectable and no standards were exceeded.

Other reports included sampling results for inorganic and organic parameters in treated water. Since this WTP does not specifically target the removal of metals and pesticides, these results give some insight into the state of the raw source water. The ODWQS levels of both inorganic and organic parameters were not exceeded at the Lion's Head WTP.

Drinking Water Issues and Conditions

Based on available data and knowledge on raw water quality, no drinking water quality issues were identified for this water system that would result from ongoing or past activities (Table 4.1.S1.5). Also, no conditions resulting from past activities were identified within the WHPA that meet the conditions of Technical Rule 126 (see Section 4.1.5.6).

TABLE 4.1.S1.5 – Lion's Head: Issues and Conditions

Drinking Water Issue	**Parameter**
None	None
Drinking Water Condition	**Threat**
None	None

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