Water Quantity Threats Ranking Scenarios Guidance Document

Submitted to

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AquaResource Inc.
Integrity • Technology • Solutions

www.AquaResource.ca

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Glossary of Terms

ALLOCATED QUANTITY OF WATER;

"(a) in respect of a surface water intake or well relating to a planned system, the annual mean quantity of water that is anticipated to be taken by the intake or well; and,

(b) in respect of an existing surface water intake or well, the lesser of A and B:

A. The maximum annual quantity of water that can lawfully be taken by the intake or well.

B. The sum of the mean annual quantity of water taken by the intake or well and any additional quantity of water that would have to be taken annually by the intake or well to meet the committed demand of the system." (MOE, 2008)

COMMITTED DEMAND;

"increase in the quantity of water provided by a drinking water system that would be required if the area served by the system were developed in accordance with the official plans for the area to an extent that would result in the greatest use of drinking water". (MOE, 2008)

CONSUMPTIVE ACTIVITY;

"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". (MOE, 2008)

CONSUMPTIVE DEMAND;

The consumptive demand is defined as the amount of water pumped from a specific hydrological unit (aquifer, watercourse) and not returned to that same unit in a reasonable amount of time.

EXPOSURE;

Measure of the ability of the intake or well to pump sufficient water for the community on a monthly basis for groundwater and a daily basis for surface water, once water needs of other users have been accounted for. (adapted from MOE, 2007)

FUTURE DEVELOPMENT;

"development of an area in accordance with the official plans applicable to the area to an extent that would have the most significant impact on the quality of water used for drinking water purposes and the quantity of water available from sources of drinking water". (MOE, 2008)

IPZ- Q

"the area within which one or more consumptive activities affect, or would affect, the ability of the intake to take water at its allocated quantity" (MOE, 2007)

LOCAL AREA;

"(a) in respect of a surface water intake, the drainage area that contributes surface water to the intake and the area that provides recharge to an aquifer that contributes groundwater discharge to the drainage area; and

(b) in respect of a well, the area that is created by combining the following areas:

(i) the cone of influence of the well;

(ii) the cones of influence resulting from other water takings where those cones of influence intersect that of the well; and,

(iii) the areas where a reduction in recharge would have a measurable impact on the cone of influence of the well" (MOE, 2008)

OFFICIAL PLAN;

"official plan prepared in accordance with part III of the Planning Act". (MOE, 2008)

PLANNED SYSTEM;

"planned" means, with respect to a drinking water system, a drinking water system that is to be established, or a part of a drinking water system that is to be established, if,

(a) approval to proceed with the establishment of the system or part has been given under Part II of the Environmental Assessment Act,

(b) the establishment of the system or part has been identified as the preferred solution within a completed planning process conducted in accordance with an approved class environmental assessment under Part II.1 of the Environmental Assessment Act and no order has been issued under subsection 16 (1) of that Act, or,

(c) the system or part would serve a reserve as defined in the Indian Act (Canada). (MOE, 2006)

TIER ONE WATER BUDGET;

"a water budget developed using a geographical information system or equivalent to assess groundwater flows and levels, surface water flows and levels, and the interactions between them". (MOE, 2008)

TIER TWO WATER BUDGET;

"a water budget means a water budget developed using computer based three dimensional groundwater flow models and computer based continuous surface water flow models to assess groundwater flows and levels, surface water flows and levels, and the interactions between them". (MOE, 2008)

TIER THREE WATER BUDGET;

"a water budget developed using computer based three dimensional groundwater flow models and computer based continuous surface water flow models to assess groundwater flows and levels, surface water flows and levels, and the interactions between them, and that includes consideration of the following circumstances:

(a) current and future land cover within the area;
(b) hydraulic flow controls within the area;
(c) water taken by the surface water intakes and wells related to the area;
(d) other uses of water within and downstream of the area;
(e) steady and transient states in groundwater;
(f) drought conditions;
(g) the average daily supply and demand for surface water within the area; and
(h) average monthly supply and average monthly demand for groundwater within the area.". (MOE, 2008)

TOLERANCE;

Measure of the extent to which backup or storage systems such as reservoirs can be used to meet peak demand period. *(adapted from MOE, 2007)*

WHPA- Q1;

"the combined area that is the cone of influence of the well and the whole of the cones of influence of all other wells that intersect that area" (MOE, 2008)

WHPA- Q2;

"the area described as WHPA-Q1 and any area where a future reduction in recharge would significantly impact that area" (MOE, 2008)

1 Introduction

The Province of Ontario introduced the Clean Water Act (Bill 43; MOE, 2006) to ensure that every Ontarian has access to safe drinking water. Bill 43 requires communities create and carry out a Source Protection Plan to protect their municipal drinking water sources. As part of their Source Protection Plans, communities will inventory the existing and potential threats to the quality and quantity of their water sources, and implement the actions necessary to reduce or eliminate the greatest threats.

The Ministry of Environment released the Technical Rules: Assessment Report (MOE, 2008) that describes the technical work required by municipalities to inventory the threats posed on their water supplies. With respect to water quantity, municipalities may be required to complete a Tier Three Water Budget and Local Area Risk Assessment (Tier Three Assessment) to assess the water quantity risk placed on their groundwater or surface water sources. If the water quantity risk within vulnerable areas is classified as *moderate* or *significant* in the Tier Three Assessment, municipalities are required to list the moderate and significant water quantity threats within these areas. This document describes a process to rank the moderate and significant water quantity threats, in order of their relative impact on the water supplies at each municipal groundwater well or surface water intake.

1.1 CLEAN WATER ACT WATER BUDGETS

The Province's approach to completing water budgets and identifying drinking water quantity threats follows a three-tiered approach:

1. Complete a Tier One Water Budget and Stress Assessment to identify subwatersheds that have a moderate or significant potential for stress.
2. Complete Tier Two Water Budget and Subwatershed Stress Assessment for the subwatersheds classified in the Tier One Stress Assessment as having a moderate or significant potential for stress; and,
3. Conduct a Tier Three Water Budget and Local Area Risk Assessment for any municipal water supply systems present within subwatersheds classified as having a moderate or significant potential for stress in the Tier Two Assessment. As part this assessment, municipalities must delineate water quantity vulnerable areas for their drinking water systems, estimate the water quantity risk, and identify moderate or significant drinking water threats within these areas.

Tier One Water Budgets and Subwatershed Stress Assessments are water budget studies that are developed using a GIS, or similar tool, to assess water budget components on a large regional scale. Tier One Assessments classify the water quantity stress for each subwatershed in the study area as '*Low*', '*Moderate*', or '*Significant*'. Subwatersheds classified as having a *moderate* or *significant* potential for stress require a Tier Two Water Budget and Subwatershed Stress Assessment.

Tier Two Water Budgets and Subwatershed Stress Assessments are more detailed water budget studies than the Tier One Assessments. The Tier Two studies use three-dimensional groundwater flow models or continuous surface water flow models to examine the water budget components in the watershed and subwatersheds within the study area. Subwatersheds classified as having a *moderate* or *significant* potential for stress, and contain a drinking water system identified in the Terms of Reference for that Source Protection Area require a Tier Three Assessment.

The Technical Rules: Assessment Report (MOE, 2008) outlines the methodology and scenarios required for the Tier Three Assessment; in general, vulnerable areas (e.g. IPZ-Q, WHPA-Q1, etc.) are delineated and a risk level is assigned based on the results of detailed water budget modelling. If the risk level for the vulnerable area is classified as *significant*, all consumptive water users will be classified as moderate or significant drinking water threats (see MOE, 2008 for details).

This guidance document outlines a methodology to rank the moderate and significant water quantity threats identified in the Tier Three Assessment. This ranking will help Source Protection Committees prioritize the risk management measures necessary to protect the municipal water supplies.

2 Threats Ranking

The following subsections outline the modelling approach and model scenarios (Figure 1) used to rank the significant and moderate groundwater or surface water threats identified in the Tier Three Assessment.

Numerical groundwater or surface water flow models developed in the Tier Three Water Budget will be used to examine the impact of land use changes, or water demands, on the municipal water supplies and other water users. Scenarios that examine the cumulative impact of all current, planned or future consumptive water uses, or land use developments, on municipal water supplies are termed Level I Scenarios. If a Level I Scenario predicts an adverse impact on drinking water supplies or other water users, Sector-Based (Level II) Scenarios or Locally Relevant (Level III) Scenarios will be required to estimate the relative impact from specific consumptive water users. Sector Based (Level II) Scenarios are designed to examine the impact of each sector of water use or land use development (e.g., industrial, agricultural, etc.) on the municipal water supplies and other users. Locally Relevant (Level III) Scenarios are used to rank the impact of individual water takings or land use development changes on municipal water supplies or other water users. The scenarios include permitted and non-permitted, current and future, water users as identified in the Tier Three Assessment. In this study, the term "non-permitted" refers to wells or intakes that extract water at a rate less than 50,000 litres per day; wells that were active prior to the start of the Ontario Permit to take Water process (grandfathered) or those wells or intakes awaiting a new or renewed permit should be considered as permitted wells in this assessment. Several Locally Relevant (Level III) Scenarios may be required in areas where there are several types of water demands or land use developments.

Table 1 summarizes the model scenarios that shall be run using the calibrated surface water or groundwater models. Cells highlighted in yellow represent the threat being assessed in the model scenario. In all instances the first model scenario run is the baseline scenario; the results of this scenario set the benchmark against which all modelling results will be compared.

2.1 GENERAL SCENARIOS (LEVEL I)

The General Scenarios are mandatory scenarios that evaluate the cumulative influence of each the following groups of significant and moderate water quantity threats on the long-term municipal water supplies;

1) all municipal water takings;
2) all non-municipal permitted water takings;
3) all non-municipal non-permitted water takings; and,
4) a cumulative recharge reduction due to land use changes.

If a *moderate* or *significant* risk to water quantity was identified in the Tier Three Assessment, one or more of the groups of stresses listed above will impact the municipal supplies (determined by the incremental drawdown or reduction in water level at the municipal wells or intakes). Level I Scenarios determine which takings, or land use developments, warrant a higher level of investigation, and which have a negligible impact on the municipal water supplies. Each of the four Level I Scenarios must be run, unless the threat does not exist (i.e., there are no projected changes in land use under the Official Plan, or non-municipal permitted water takers, etc).

If the risk to the municipal water supplies is *moderate* or *significant* under existing municipal pumping conditions, then existing municipal pumping will not be simulated in the baseline scenario and other scenarios identified in Table 1. This will result in the scenarios evaluating the impact of existing municipal pumping on drawdown (or stream flow/ water levels for surface water systems). If the risk is *moderate* or *significant* under future conditions (including increase of municipal pumping to planned or committed rates), then existing municipal pumping will be simulated in the model scenarios (Table 1). This will result in the scenarios evaluating the impact of additional municipal pumping on drawdown or reductions in stream flow or water levels.

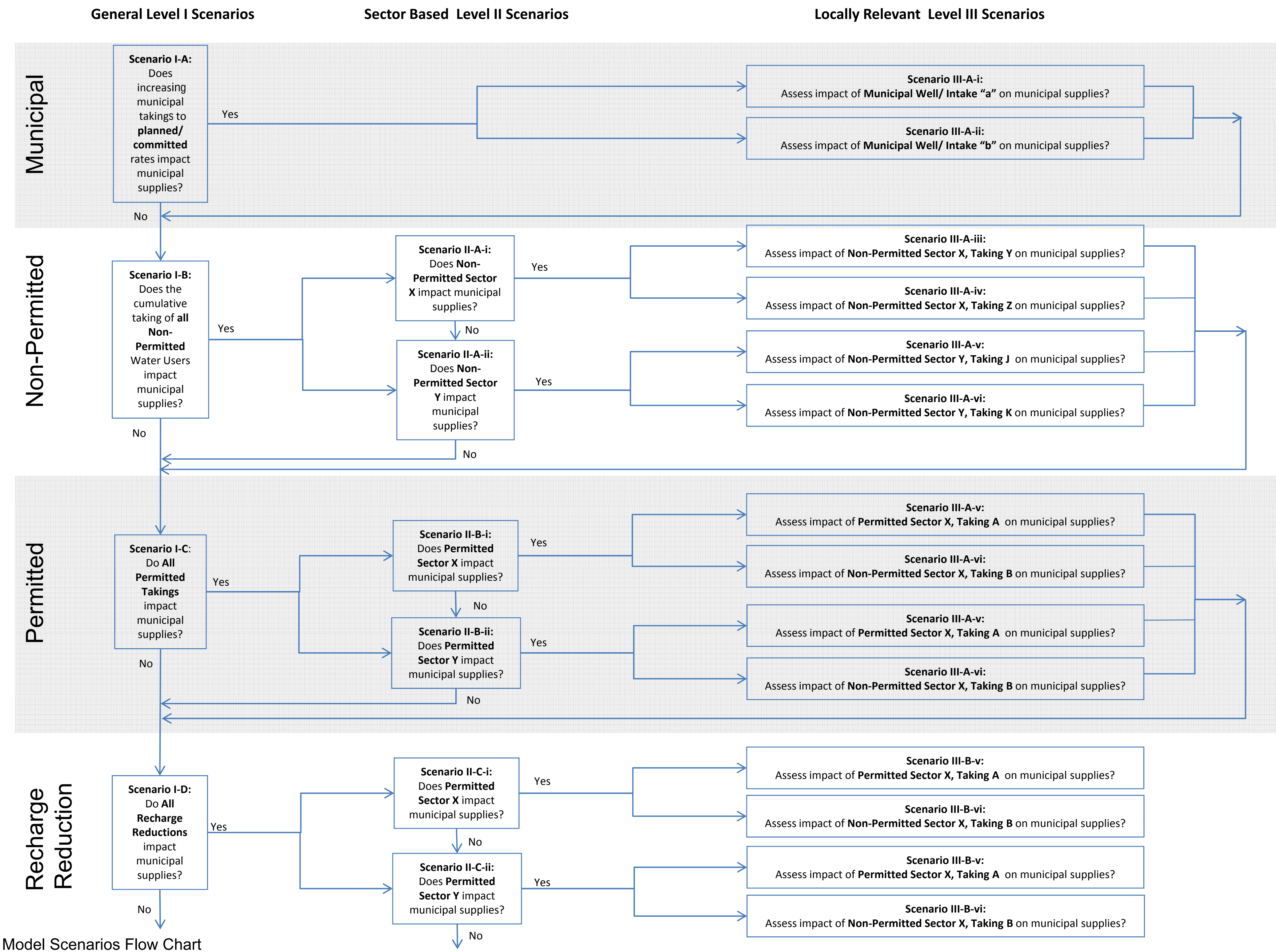

Figure 1: Model Scenarios Flow Chart

Table 1: Model Scenarios

Scenario	Description	Municipal Takings[1]	Permitted Takings	Non Permitted Takings	Land Use	Rationale
Baseline	Baseline Scenario	Existing or None	None	None	Existing	This scenario forms the baseline to which the model scenarios below will be compared.
I-A	Municipal Water Use (Committed or Planned Rates)	Committed or Planned Rates	None	None	Existing	Quantify the impact of increasing municipal pumping to Committed or Planned Pumping Rates (from existing rates) on the municipal supplies.
I-B	All Non-Permitted Takings	Existing or None	None	Existing, Max Practical, or Future Consumptive	Existing	Quantify the impact of **all non-permitted** demands on the water supplies.
I-C	All Permitted Takings	Existing or None	Existing, Max Practical, or Future Consumptive	None	Existing	Quantify the impact of **all permitted** water demands on municipal water supplies.
I-D	Recharge Reduction – Official Plan	Existing or None	None	None	Official Plan	Quantify the **cumulative** impact of recharge reduction from all developments in the Official Plan on municipal water supplies.
II-A-x	Non-Permitted Takings - Sector Based (Sector X)	Existing or None	Consumptive Sector X[2]	None	Existing	Quantify the impact of **each non-permitted sector** (e.g. agricultural, domestic, etc.) on municipal water supplies
II-B-x	Permitted Takings - Sector Based –Sector X	Existing or None	Consumptive Sector X[2]	None	Existing	Quantify the impact of **each permitted sector** (e.g. industrial, commercial) on municipal water supplies
II-C-x	Recharge Reduction – Sector Based (Official Plan)	Existing or None	None	None	Official Plan Land Use Section X	Quantify the impact due to recharge reduction from **each development sector** (e.g. industrial, commercial) on municipal water supplies.
III-A-i	Local Water Demand Scenario – Consumptive Water Taking X	Existing or None	Consumptive User X[2]	None	Existing	Quantify the impact of individual permits (III-A) or developments (III-B) on the municipal water supplies.
III-B-i	Local Groundwater Recharge Reduction Scenario- Activity Y	Existing or None	None	None	Official Plan Land Use Activity Y	

1 – If the municipal system was assigned a risk level of *moderate* or *significant* for existing demands, the Baseline Scenario will not include any municipal demands. If the municipal system was assigned a risk level of *moderate* or *significant* for planned or committed demands, then existing municipal demands should be used in the baseline scenario.

2 – Professional judgment should be used to determine if maximum practical or future consumptive demand are more appropriate to use.

2.1.1 Scenario I-A. Municipal Water Use

Scenario I-A assesses the impact of increasing the municipal pumping from existing conditions to the municipality's planned and/or committed rates. ***Committed rates*** are defined as the total water demand needed to meet the requirements of municipally approved residential, commercial, and industrial developments. ***Planned system rates*** are defined as the groundwater or surface water pumping rates used for a drinking water system that is established, or is planned to be established with one of the following approvals: an individual Environmental Assessment (EA) approval; or if the system has been identified as the preferred solution within a completed planning process with an approved Class EA; or the system would serve a First Nation Community as defined in the Indian Act; Canada (MOE, 2006). The planned system may represent the water demand associated with a population projection ranging from a few years in the future to over 20 years into the future, depending on the status of the municipality's drinking water and municipal EA planning processes.

In this scenario, non-municipal water takings and changes to land use developments are not simulated (Table 1); only the increased municipal demands (committed or planned rates) are simulated. If the planned or committed rates for a municipal water supply system have an impact on the municipal water supplies (Scenario I-A), then Locally Relevant (Level III) scenarios are required to determine the impact of the increased takings of each municipal well or intake on the surrounding municipal wells or intakes. If the committed or planned system rates do not have an influence on the municipal water supplies, Level III Scenarios are not necessary as they do not provide any additional needed information; however, the remaining Level I Scenarios (I-B, I-C, I-D) must be undertaken (Figure 1) to identify if permitted water takings, non-permitted water takings or land use development changes are causing the elevated risk to the municipal supplies. (Level I Scenarios are mandatory, where applicable).

2.1.2 Scenario I-B. All Non-Permitted Water Takings

Scenario I-B assesses the cumulative impact of all non-permitted water takings (e.g. domestic, agricultural, etc.) on municipal water supplies within the vulnerable area. Non-permitted water demands may be poorly understood; however, domestic water use can be estimated using data from Environment Canada and MOE: Environment Canada estimated the national average domestic water demand to be 335 L/day per household (in 2001; Environment Canada, 2007), and the MOE recommends a 0.2 consumptive use factor (MOE, 2008). Water demand in Ontario was lower than the National average and estimated to be 260 L/day per household (Environment Canada, 2007). These values may be used as a guide in areas where local data is unavailable.

If the non-permitted water takings have a negligible impact on the municipal water supplies, then Level II (Scenario II-A) or Level III (Level III-A) Scenarios that examine the impact of individual or sectors of non-permitted water takings on the supplies, are not required. However, the remaining Level I Scenarios (Scenario I-C, and Scenario I-D) are required, where applicable (Figure 1).

If the non-permitted water takers impact municipal water supplies, Sector Based (Level II-A) Scenarios, or Locally Relevant (Level III) Scenarios are required, depending on the nature of the non-permitted water takers (Figure 1).

2.1.3 Scenario I-C. All Permitted Water Takings

Scenario I-C evaluates the cumulative impact of all non-municipal permitted water takings on the municipal supplies. If the results of this scenario indicate that the permitted takings have a significant impact on municipal water supply sources, Sector-Based (Level II; II-B-x), or Locally Relevant (Level III-A-x) Scenarios are required to assess the impact of sectors of permits, or individual permits, on the municipal water supplies.

Permitted water demands may be examined on a current or future perspective, depending on the nature of the water taking and if the taking is expected to remain at current rates or increase with time. Non-municipal rates can be estimated as follows: **Existing Consumptive**, **Maximum Practical Consumptive,** and **Future**

Consumptive. In all instances the consumptive use (consumptive for the unit or source) is applied in the model, as opposed to simulating the actual or permitted water use.

Existing Consumptive demand refers to the current consumptive water use. *Maximum Practical Consumptive* demands should be used in areas where permitted users are extracting water at a rate less than the permitted rate on an average annual basis due to seasonal changes in water use operations. *Future Consumptive* rates are used for future water takers that do not currently exist, but were identified as significant threats in the Tier Three Assessment. These future consumptive takings are associated with proposed land use changes in the local area, as outlined in the Official Plan. For example, a proposed golf course may require water takings for irrigation and water supply. Although water taking permits may not exist for the future land use developments, the future consumptive demand of those developments (permitted and non-permitted) should be simulated using rates outlined in the Tier Three Assessment. The time period with the highest consumptive water use rates will be assessed.

2.1.4 <u>Scenario I-D. Recharge Reduction – Official Plan</u>

Scenario I-D evaluates the cumulative impact of all potential groundwater recharge reductions, due to all future land use developments, on the municipal water supplies. Groundwater recharge reductions simulated in this scenario include all potential land use changes or developments outlined in a municipality's Official Plan. Permitted (non-municipal) and non-permitted water takings are not simulated in this scenario; only the existing municipal water takings are simulated (or no municipal takings, depending on the system; see footnote 1 of Table 1).

Scenario I-D does not account for best management practices that manage runoff or enhance groundwater recharge, as these are risk management measures. If the results of this scenario indicate that land use developments impact the municipal water supplies, Sector Based (Level II-C-x), or Locally Relevant (Level III-B-x) Scenarios will be required to evaluate the impact of sectors of land use developments (Level II) or individual land use developments (Level III) on the municipal water supplies. Although it may not be common, surface water flows may be affected by changes in land use; as such, the impact of recharge reduction due to changes in land use should be considered a threat to both groundwater and surface water systems.

2.2 SECTOR-BASED MODELLING SCENARIOS (LEVEL II)

The objective of the Sector-Based Scenarios (Level II) is to identify the potential impact that various sectors or classes of permitted and non-permitted water takers, and future land use developments, have on the municipal water supplies (Table 2). Examples of sectors of water takers or land use developments that may be examined are outlined in Table 2.

Table 2: Examples of Water Use and Land Development Sectors

Water Use Sectors	Agricultural	Commercial	Construction	Dewatering	Remediation
	Recreational	Industrial	Institutional	Miscellaneous	Domestic
Land Development Sectors	Agricultural	Commercial	Industrial	Rural Development	Residential
	Water Supply	Institutional			

Sector-Based Scenarios (Level II) are required if the municipal water supplies were impacted by **all** non-permitted water takings (Scenario I-B), or **all** non-municipal permitted (Scenario I-C), or by all reductions in recharge due to land use development changes (Scenario I-D) outlined in the Official Plan(s). Sector Based Scenarios assess the impact of each sector of water taking, or land development, on the municipal water supplies. If a sector is found to impact the municipal water supplies, Locally Relevant Scenarios (Level III) are required to assess the impact of individual takings within the sector on the municipal water supplies.

2.2.1 Scenario II-A-x. Sector-Based Non-Permitted Takings

Scenario II-A-x evaluates the influence of each sector of non-permitted water takings on the municipal supplies, when there is more than one water use sector identified in the Tier Three Assessment. An example may be an area where there are a number of residential subdivisions and agricultural lands located near a municipal well. In this example, Scenario II-A-i may examine the impact of all residential takings on the municipal well, while Scenario II-A-ii may examine the impact of all agricultural takings on the municipal well. If the cumulative impact of all residential (domestic) takings or all agricultural takings impact the municipal supplies, then Level III Scenarios may be required. In some instances, it may be easier to implement risk management measures to the entire sector (i.e., all agricultural users within an area) rather than pinpoint individuals who impact the supplies the greatest (determined in Level III Scenarios). Professional judgment should be used to determine if Locally Relevant (Level III) Scenarios are necessary, or if the results of the Level II Scenarios provide sufficient information for the ranking process.

2.2.2 Scenario II-B-x. Sector-Based Non-Municipal Permitted Takings

Scenario II-B-x evaluates the influence of each sector of non-municipal permitted water takings on the municipal water supplies. These scenarios are undertaken if the cumulative impact of all permitted takings (Scenario I-C) impact the municipal water supplies.

Each major water use sector within the vulnerable area is assessed in a different model scenario. For example, the impact of all permitted industrial water takings may be assessed in one scenario, and the impact of all permitted commercial water takings may be assessed in another model scenario. If an impact is noted at the municipal wells or intakes, Level III Scenarios shall be run to assess the influence of individual water takings (within that sector) on the supplies (Figure 1). If a sector has a negligible impact on the municipal water supplies, then that particular sector does not require further Level III assessments to examine the impact of individual permitted water taker within the sector on the supplies.

2.2.3 Scenario II-C-x. Sector-Based Land Use Developments

Scenario II-C-x evaluates the influence of each sector of future land use development on the municipal water supplies. These scenarios are evaluated if the cumulative impact of all future potential land use developments outlined in the Official Plan (Scenario I-D) impact the municipal water supplies. For example, if the cumulative impact of several commercial, industrial and residential developments located near of a surface water intake was found in Scenario I-D to impact the water level at the intake, then Sector Based Land Use Development Scenarios would be run to examine the impact of each sector on the supplies. For example, Scenario II-C-i may examine the impact of all industrial land developments on the supplies, while Scenario II-C-ii and Scenario II-C-iii would be run to examine the impact of all commercial and residential land developments on the supplies.

Where there are multiple future developments sectors that have an impact on the supplies, then additional Level III Scenarios (Level III-B-x) may be evaluated, to determine the impact of individual developments on the municipal supplies. If only a few threats are identified in the Tier Three Assessment, the Sector Based (Level II) Scenarios may be bypassed and the impact of the individual threats may be assessed using the Locally Relevant (Level III) Scenarios. Professional judgment should be used to determine the scenarios necessary to provide sufficient information to the Source Protection Committee.

2.3 LOCALLY RELEVANT MODELLING SCENARIOS (LEVEL III)

Locally Relevant (Level III) Scenarios are used to examine the influence of specific water users or land use changes on municipal groundwater wells or surface water intakes. These scenarios are undertaken in one of three instances:

1. Results of the Level I-A (Municipal Demand) scenario indicate that the increase in municipal pumping to planned or to committed pumping rates impacts the municipal water supplies (III-A-x; Figure 1);

2. Results of a Level II Sector-Based Scenario identifies a non-permitted (Scenario II-B) or permitted (Scenario II-C) water use sector(s) to have an impact on the municipal supplies (III-A-x; Figure 1); or,

3. Results of the Level I-D (Local Recharge Reduction) scenario indicate that the unmitigated impacts of increased imperviousness (according to land use development specified in the Official Plan) may impact the supply at a well or intake (III-B-x; Figure 1).

Locally Relevant (Level III) Scenarios are used to estimate the influence of an individual water taker or land use development on the municipal water supplies. The Locally Relevant (Level III) Scenarios should be designed to represent site-specific conditions and address existing or future water demand periods.

There may be instances where a water use sector examined in the Level II Scenarios impacts the municipal water supplies but Level III Scenarios are not necessary. An example is several online ponds used for irrigation that all take comparable quantities of water from an upstream catchment. In this instance, Level III Scenarios may give no additional information as each taker is already known to contribute equally to the impact observed at the municipal intake. Similarly, five proposed commercial developments located in a recharge area upgradient of a municipal well may equally contribute to the impact observed at the municipal well. In these cases, risk management measures may be applied equally and effectively to all of the water quantity threats to manage the potential impact on the municipal supplies.

3 Threats Ranking

The threats ranking is undertaken where the Tier Three Assessment estimated the exposure at municipal intakes or groundwater wells to be high, and the threat within the vulnerable area to be classed as *moderate* or *significant*.

3.1 GROUNDWATER SYSTEMS

For groundwater systems, the impact of land use changes or non-municipal groundwater demands (*significant* or *moderate* threats) on the municipal water supplies will be assessed using the calibrated groundwater flow model developed in the Tier Three Assessment. In general, the scenarios evaluated for the Threats Ranking project should mirror the Tier Three scenarios; however, additional information may be obtained following the completion of the Tier Three Assessment, and the threats ranking task should consider all relevant information where possible. New information may include new permits to take water, changes to existing permits to take water, updates to a municipality's Official Plan, or additional information relating to specific land developments.

A baseline scenario simulating existing municipal pumping and land use will be run to record the hydraulic head(s) in the municipal aquifer(s) at each municipal well. This scenario will be similar to the 'Existing Conditions' scenario evaluated in the Tier Three Assessment. For groundwater supplies, it is assumed that the threats ranking scenarios will be completed using a steady-state model. For surface water supplies it is assumed that the climate data period be the same as that used for the Tier Three 'Existing Conditions' scenario.

Additional model scenarios (see Figure 1) will examine the impact of *significant* and *moderate* threats and future potential land use developments and activities on the municipal water supplies (as compared to the results of the baseline scenario). The model scenarios will focus on individual threats or sectors of threats, with the change in hydraulic head recorded at each municipal well, under each model scenario. The difference in hydraulic head between the baseline scenario and the updated model scenario that simulates the threat, is referred to as *incremental drawdown:* it will be compared to the safe available drawdown for the municipal well in each model scenario (Equation 1). Wherever possible, the additional model scenarios should be consistent with the Tier Three Assessment (e.g., same consumptive demand and/or recharge reduction estimates). This may not always be the case as new information may become available and should be incorporated as long as the new information does not change the initial results of the Tier Three Assessment. The additional groundwater scenarios will be completed using the steady-state groundwater flow model (existing recharge). The Tier Three drought scenario is not considered. Surface water scenarios will use the same long-term climate data period used for the Tier Three Assessment.

The safe available drawdown in a municipal well is the drawdown available at the well that will allow the well to pump at an unrestricted rate, even during peak water use periods. The value is based on aquifer and well construction properties and as such, the value should be developed in consultation with the municipality.

Equation 1 – Calculating Percent Impact at a Municipal Groundwater Well

$$\text{Percent Impact} = \frac{\text{Incremental Drawdown (Scenario '}a\text{')}}{\text{Safe Available Drawdown}} \times 100\% = \frac{Z_{\text{Scenario a}}}{Z_{\text{safe}}} \times 100\%$$

Where: ***Percent Impact*** is the modelled drawdown resulting from the simulation of a water quantity threat, relative to the total safe available drawdown.
Incremental Drawdown (Scenario 'a') (**$Z_{\text{Scenario a}}$**) is the difference between the simulated potentiometric surface in the aquifer at the municipal well under baseline conditions, and the simulated potentiometric surface in the aquifer at the municipal well for a particular scenario.

Safe Available Drawdown (Z_{Safe}) is the average distance (measured at the municipal supply well) between the elevation of the potentiometric surface at the municipal well in the baseline condition and the minimum elevation at which the well can pump at an unrestricted rate. This value should take into account seasonal water level fluctuations and other relevant factors.

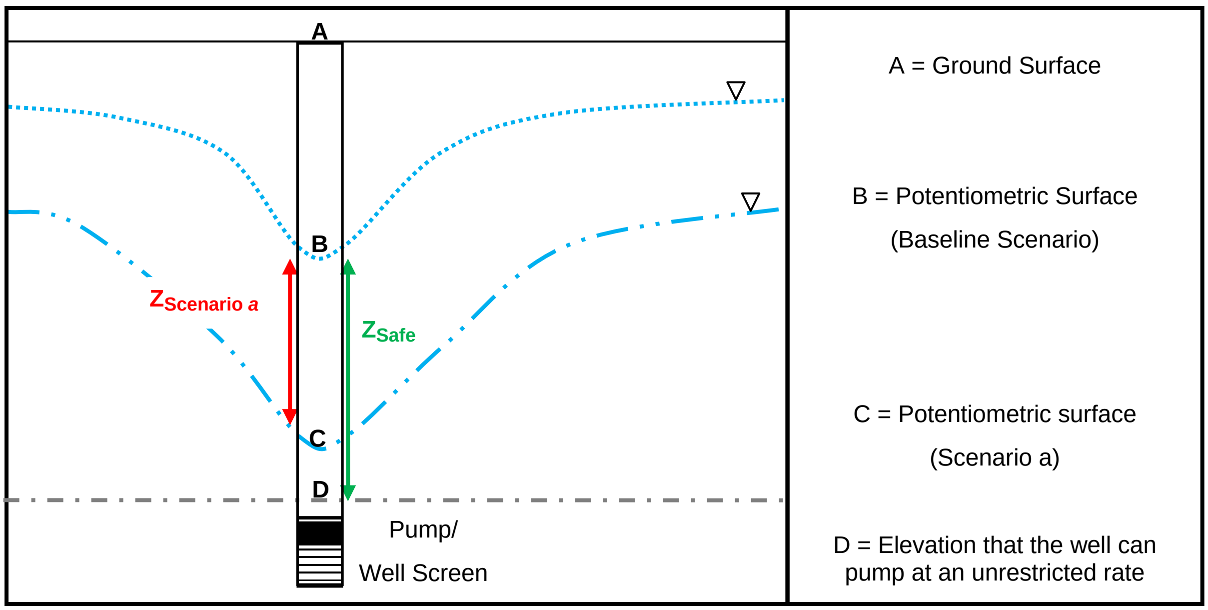

Figure 2: Municipal Water Well Schematic

The "safe available drawdown" (Z_{Safe}), referred to in Equation 1 and Figure 2, is the average distance (measured at the municipal supply well) between the elevation of the potentiometric surface at the municipal well in the baseline condition and the minimum elevation at which the well can pump at an unrestricted rate. The elevation may correspond to the top of the well screen or pump, plus a safety margin to account for peak water use periods, as the numerical models may simulate average annual municipal pumping rates. The elevation should be determined in consultation with the municipality.

As noted above, the incremental drawdown ($Z_{Scenario\ a}$) is the difference between the simulated baseline potentiometric surface in the aquifer at the municipal well, and the resulting simulated potentiometric surface in the aquifer at the municipal well for a particular scenario (i.e., Scenario 'a').

Steady state groundwater models are considered appropriate in most instances, except where seasonal water takings dominate (i.e. summer irrigation in an agriculturally dominated area). In these cases, transient groundwater modelling may be needed to properly assess and rank the stresses on the municipal water supplies. Professional judgment should prevail to ensure the modelling is rigorous enough to adequately assess the threats placed on the municipal water supply sources.

3.2 SURFACE WATER SYSTEMS

The impact of land use developments, groundwater takings, or surface water takings on the municipal intakes will be evaluated using the continuous surface water flow model developed and refined in the Tier Three Assessment. The model simulation period must be sufficiently long enough to simulate at least one historic drought period, consistent with the continuous scenarios developed for the Tier Three Assessment. For surface water intakes, the Tier Three Assessment identifies whether the risk is based on minimum water levels at the intake, or minimum stream flow. The analysis used to rank the surface water threats shall be consistent with the Tier Three Assessment and focus on either stream flow or water level reductions at the intake.

Professional judgment is required to determine the temporal period required to examine the impact of consumptive water takings on the surface water intake(s); for example, if a municipal intake is located in a relatively small river, the maximum instantaneous flow reduction or reduction in water level should be calculated to assess the impacts and rank the threats. Monthly average water takings may be suitable for a municipal intake located in a large lake. The nature of the surface water takings and the surface water complexities should dictate the most appropriate temporal period of assessment needed to calculate the impact on the water supplies and the subsequent threats ranking.

3.2.1 Elevation-Controlled Systems

If the municipal water supply intake is located within a lake or a river, where the water quantity risk was induced by low water levels, the impact of the surface or groundwater threats on the municipal supplies will be assessed by examining the estimated water levels (at the municipal water supply intake) under the various model scenarios. Specifically, the predicted reduction in water level at the intake will be compared to a pre-determined acceptable, or safe, water level reduction (Eqn. 2; Figure 3);

Equation 2 – Calculating Percent Impact in a Lake Based System

$$\text{Percent Impact} = \frac{\text{Water Level Reduction (“}\textit{Scenario a}\text{”)}}{\text{Safe Water Level Reduction}} \times 100\% \quad = \frac{Z_{\text{Scenario a}}}{Z_{\text{Safe}}} \times 100\%$$

Where: ***Percent Impact*** is the modelled surface water level reduction resulting from the simulation of a water quantity threat, relative to the safe water level reduction.
Water Level Reduction (“Scenario a”) (= $Z_{Scenario\ a}$) is maximum monthly difference between the predicted baseline water level at the municipal intake, and the simulated water level at the intake for a particular scenario.
Safe Water Level Reduction (= Z_{Safe}) is the distance (measured at the municipal intake) between the water surface elevation simulated in the baseline scenario and the lowest acceptable elevation. This value is calculated on a monthly basis using the monthly 7Q20 flow (minimum 7-day flow within a month, with a 20-year return period.

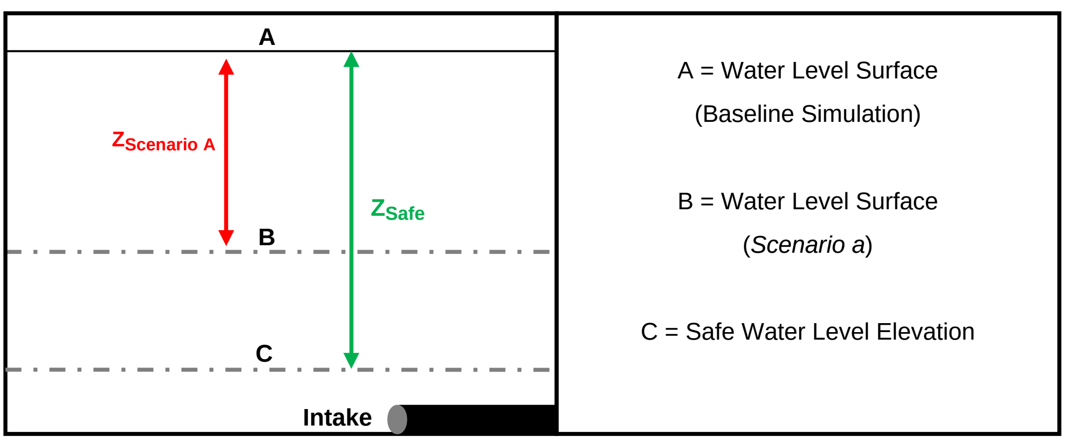

Figure 3: Municipal Lake Based Surface Water Intake Schematic

The “safe water level reduction” (Z_{Safe}) referred to in Equation 2 is the distance (measured at the municipal intake) between the water surface elevation simulated in the baseline scenario and the lowest acceptable elevation. This value is calculated on a monthly basis using the monthly 7Q20 (i.e. the minimum 7 day, 1 in 20 year flow for each month). The 7Q20 statistic is calculated from a time series of either simulated or observed daily streamflows. The 7Q20 is selected as a reference point to compare surface water demands against supply, as the flow statistic is representative of minimum streamflow conditions; therefore, the Percent Impact is calculated as the maximum possible value given historical climate conditions. The safe water level reduction may include a measure of safety to account for peak water use periods or variable lake water levels (as the model may be simulating average annual municipal extraction rates).

If possible, given the modelling approach developed for the Tier Three Assessment, the safe water level reduction could also be estimated using the results of the continuous simulations calculated as the minimum 7 day, 1 in 20 year, distance between the simulated water surface elevation and the lowest acceptable elevation.

The Percent Impact calculation is completed on a daily basis for the duration of the model simulation period, and the highest Percent Impact recorded in each month is reported. Only the months identified in the Tier Three Assessment where exposure was found to be high (high risk months) will be carried forward to the threats ranking (Section 3.3).

3.2.2 Flow-Controlled Systems

The impact of each threat or sector of water quantity threats on a river intake (without a control structure) shall be assessed by comparing the reduction in flow in the river under the model scenarios outlined in Table 1 to the monthly 7Q20 flow derived in the baseline model downstream of the intake (Equation 3; Figure 4).

Equation 3: Calculating Percent Impact in a River System (without Control Structure)

$$\text{Percent Impact} = \frac{\text{Flow Reduction (“Scenario a”)}}{\text{Baseline Monthly 7Q20 Flow}} \times 100\% \quad = \frac{Q_{\text{threat A}}}{Q_{7Q20}} \times 100\%$$

Where: ***Percent Impact*** is the estimated relative stream flow reduction resulting from the simulation of a water quantity threat, relative to the baseline monthly 7Q20 streamflow.
Flow Reduction (“Scenario a”) = $Q_{\text{threat A}}$ is the estimated change in surface water streamflow at the intake location for a particular scenario (i.e., Scenario a).
Baseline Monthly 7Q20 Flow (= Q_{7Q20}) is the monthly 7Q20 flow calculated in the baseline model scenario (Table 1) estimated downstream of the intake.

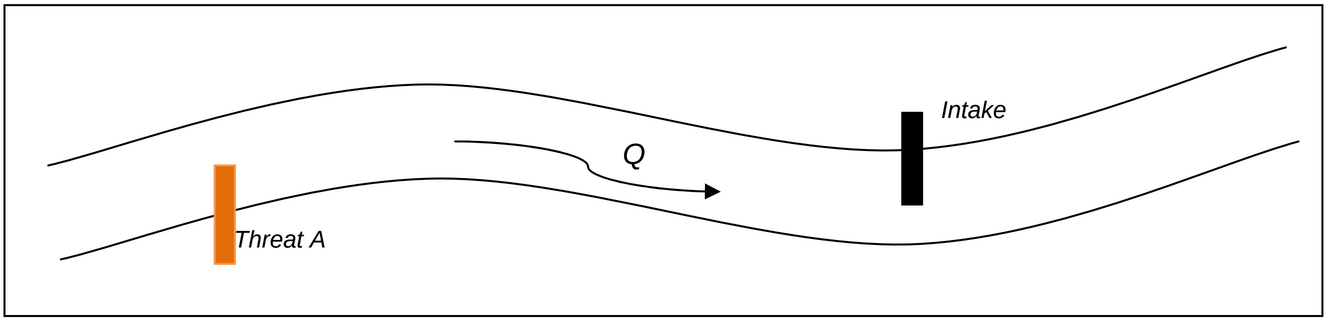

Figure 4: Riverine Surface Water Supply System Schematic

The baseline scenario considers only existing municipal takings (or no municipal takings) and existing land use; no additional groundwater or surface water takings will be simulated in this scenario (Table 1). This scenario will be used to estimate the monthly 7Q20 stream flow immediately downstream of the municipal intake. Additional model scenarios (outlined in Table 1) will examine the impact of land use changes and non-municipal water demands (surface and groundwater) on the municipal water supplies. The simulated stream flow or water level at the municipal intake in these model scenarios will then be recorded, and the resulting change in flow or water level compared to the baseline monthly 7Q20 flow will be calculated, forming the basis of the surface water threats ranking. Monthly 7Q20 values are used to account for the seasonal variability of low flow conditions. Large consumptive water takings active during the spring freshet, for example, may not have a large impact on the supplies due to higher flow conditions, while smaller consumptive water takings in September, under low flow conditions, may pose a greater threat to the municipal supplies.

The ‘Flow Reduction (Scenario a)’ in Equation 3, is the estimated change in surface water streamflow at the intake location resulting from the threat simulated in Scenario a; it is the difference between the model simulated streamflow in the baseline condition and under ‘Scenario a’ (Table 1), which includes a water quantity threat. This calculation is conducted using estimate daily flows within the calibration period; however, the results are reported as the maximum reduction for each month. Ultimately, the threats ranking is only completed for the months where the Tier Three Assessment estimated the exposure at the municipal intake to be high.

3.3 THREATS RANKING

The *Percent Impact* calculated at the municipal wells or intakes is used to rank the water quantity threats within each WHPA-Q1/Q2 or IPZ-Q area. The *Percent Impact* is assessed on a well by well (or intake by intake) basis; however, the threats ranking is completed on a WHPA-Q1/ Q2 or IPZ-Q basis. This is because any increase in water taking or reduction in recharge within the WHPA-Q2 (or IPZ-Q) has the potential to impact all municipal wells or intakes within that area. Therefore, threats that impact more than one municipal well or intake will be ranked based on the greatest percent impact at any well or intake within the WHPA-Q1/Q2 or IPZ-Q.

3.3.1 <u>Groundwater Systems</u>

The Percent Impact at each municipal well or surface water intake for each scenario is tabulated after evaluating the model scenarios. The Percent Impact values are then used to rank the water quantity threats; threats with a large Percent Impact are ranked higher than those with a smaller Percent Impact.

Table 3 is an example of tabulated results from the Level I Scenarios for three municipal groundwater wells (Well 1, Well 2, and Well 3) located in one WHPA-Q1/Q2. The increase in municipal takings from existing to the planned system rates caused a significant impact on the municipal wells (Percent Impact of 50% on Well 1; 57% on Well 2; 14% on Well 3; Table 3). As such, Level III Scenarios were considered necessary to examine the impact of individual increased takings on each of the wells in the WHPA-Q1/Q2. The results of the Level III Scenarios are outlined on Table 4.

Table 3: Example Level I Scenario Results for a WHPA-Q1/Q2 Area

Municipal Supply Well	Well 1		Well 2		Well 3		Greatest Percent Impact
Safe Available Drawdown	10 m		3.5 m		5 m		
Model Scenario	Incremental Drawdown						
	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	
I-A: Municipal Planned	5.0	50%	2.0	57%	0.7	14%	57%
I-B: All Non-Permitted	-	-	-	-	-	-	0%
I-C: All Permitted (Future)	2.0	20%	2.0	57%	0.4	8%	57%
I-D: Recharge (OP)	0.0	0%	0.0	0%	1.8	36%	36%
Total	7.0	70%	4.0	114%	2.9	58%	

No non-permitted water takers exist within the WHPA-Q1/Q2, and as such, the Percent Impact for Scenario I-B was zero; scenarios that further examine the impact of non-permitted water takers are not required.

The impact of all permitted water takers was examined in Scenario I-C; all of the permitted (non-municipal) takings led to a 2 m, and 0.4 m reduction at Wells 1 and 3, respectively (Table 3). This equated to a percent impact of 20% at Well 1 (2 m/ 10 m of safe available drawdown), and 8% at Well 3 (0.4 m/ 3.5 m; Table 3). Additional scenarios were necessary to determine which of the permitted wells, or sectors of permits has the greatest impact the wells. In this case, there were only 3 permits, so Locally Relevant Scenarios (Level III-A) were run to determine the impact of the individual permits on the municipal supplies. Results of the Level III Scenarios are outlined on Table 4.

The reduction in recharge associated with **all** land use development specified in the Official Plan was estimated to lead to a 1.8 m reduction in head in the municipal aquifer at Well 3 (Table 3). There is 5 m of available drawdown at Well 3, so the Percent Impact at Well 3 is calculated as the head reduction due to the threat (1.8 m) divided by the safe available drawdown (5 m). The Percent Impact was calculated to be 36% (1.8 m/ 5 m = 36%; Table 3). Given this elevated Percent Impact, additional modelling scenarios were necessary to further examine the impact of the recharge reductions. In this example, there were two land use developments; one commercial and one industrial, and as these developments are individual, Locally Relevant (Level III-B) Scenarios were run to examine the impact of each development in isolation on the municipal well supplies (Table 4). If there were 10 industrial and 5 commercial developments, Level II (Sector Based) Scenarios may be run to examine the impact of the two sectors of permits on the municipal supplies.

Table 4 outlines the results of the Locally Relevant (Level III) Scenarios. The total Percent Impact simulated at each municipal well is the same in Table 3 (results of Level I Scenarios) as Table 4 (results of Level III Scenarios).

Table 4: Example Level III Scenario Results for a WHPA-Q1/Q2 Area

Municipal Supply Well	Well 1		Well 2		Well 3		Greatest Percent Impact
Safe Available Drawdown	10 m		3.5 m		5 m		
Model Scenario	Incremental Drawdown						
	(m)	(% Impact)	(m)	(% Impact)	(m)	(% Impact)	
III-A: Municipal Planned							
III-A-i; Well 1	5.0	50%	2.0	57%	0.0	0%	57%
III-A-ii; Well 2	0.0	0%	0.0	0%	0.0	0%	0%
III-A-iii; Well 3	0.0	0%	0.0	0%	0.7	14%	14%
III-A: All Permitted (Future)							
III-A-iv: Permit A	1.9	19%	1.9	54%	-	-	54%
III-A-v: Permit B	0.1	1%	0.1	3%	-	-	3%
III-A-iv: Permit C	-	-	-	-	0.4	8%	8%
III-B: Recharge (OP)							
III-B-i: Commercial	0.0	0%	0.0	0%	0.9	18%	18%
III-B-ii: Industrial	0.0	0%	0.0	0%	0.9	18%	18%
Total	7.0	70%	4.0	114%	2.9	58%	

Locally Relevant (Level III) Scenarios were completed to determine the impact of increased pumping of each municipal well on the other pumping wells. Scenario III-A-i assessed the impact of increasing pumping of Well 1 from current to planned rates on itself, Well 2 and Well 3 (Table 4). The increase in pumping at Well 1 results in a 5.0 m drawdown at Well 1, a 2.0 m drawdown at Well 2, and there is no predicted impact at Well 3 (Percent Impact of 50%, 57% and 0%, respectively; Table 4).

All of the permitted takers have a combined Percent Impact of 20% on Well 1, and 54% on Well 2 (Scenario I-C; Table 3). As there were only two permits, Sector Based (Level II) Scenarios were not conducted; however, Level III (Locally Relevant) Scenarios were undertaken to examine the impact of each taking on the municipal supplies. Scenario III-A-i, ii, and iii illustrate the impact of Permits A, B and C in isolation on the individual municipal supply wells (Table 2). If all the water quantity threats are present in the future, Well 2 would no longer be able to extract water because the sum of the incremental drawdown resulting from the individual threats (4.0 m; Table 4) is greater than the available drawdown (3.5 m).

Results of the Level III Land Development Scenario (III-B-i and III-B-ii) show an equal impact on the wells from the two developments (Table 4). After the impacts are tabulated, the threats are ranked by WHPA-Q1/Q2 according to the greatest Percent Impact for each threat; the threat with the greatest percentage impact receives a higher priority than a threat with a lower Percent Impact. Under Scenario I-A in the above example, the increase in takings from Well 1 (from existing to planned rates) has a 50% impact on Well 1, 57% on Well 2, and no impact on PW3. Consequently, the Percent Impact of 57% was carried forward to the threats ranking table as shown below (Table 5).

Table 5: Threats Ranking Example

Water Quantity Threat	Greatest Percent Impact	Threats Ranking
Municipal Well 1	57%	1
Permit A	54%	2
Recharge Reduction (Commercial)	18%	3
Recharge Reduction (Industrial)	18%	3
Municipal Well 3	14%	5
Permit C	8%	6
Permit B	3%	7
Municipal Well 2	0%	n/a

As noted in Table 5, the Percent Impact is assessed on a well by well (or intake by intake) basis; however, the threats ranking is completed on a WHPA-Q1/Q2 basis. As noted earlier, any increase in water taking, or reduction in recharge, within the WHPA-Q2 (or IPZ-Q) has the potential to impact all municipal wells or intakes within that area. Therefore, threats that impact more than one municipal well or intake will be ranked on the greatest percent impact at any well or intake within the WHPA-Q1/Q2 or IPZ-Q.

3.3.2 Simple Surface Water Systems

Surface water modelling may not be required when consumptive water takings within the contributing area are understood to have a direct influence on the amount of water available at the drinking water intake. A model would be required, however, if the impact of land use development on streamflow is perceived to be an issue, or if there is not a clear relationship between consumptive water takings and streamflow at the drinking water intake. Professional judgment should prevail to ensure the ranking is rigorous and provides the SPC with all the information necessary to implement risk management measures.

The impact associated with consumptive water use or land use changes on drinking water supplies will be evaluated in terms of either stream flow at the intake or water elevation at the intake. Table 6 provides an example of the ranking of water quantity threats at a surface water intake.

Table 6: Simple Surface Water System Threats Ranking

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline 7Q20 Flow (m^3/s)	1.50	2.00	4.00	5.00	5.00	3.00	2.00	1.10	1.00	1.50	1.60	2.10
Streamflow Impacts from Water Quantity Threats Scenarios (m^3/s)												
I-A: Planned Municipal	0.30	0.30	0.30	0.30	0.32	0.35	0.40	0.45	0.40	0.30	0.30	0.30
I-D: Imperviousness	-0.03	-0.04	-0.05	-0.02	-0.03	0.00	0.02	0.05	0.02	0.00	0.00	-0.01
III-A-i: Agricultural Irrigation						0.15	0.15	0.15				
III-A-ii: Snow Making	0.05	0.05	0.05									0.05
Percent Impact Results												
I-A. Municipal Pumping	20%	15%	8%	6%	6%	12%	20%	41%	40%	20%	19%	14%
I-D. Imperviousness	-2%	-2%	-1%	0%	-1%	0%	1%	5%	2%	0%	0%	0%
III-A-i. Agricultural Irrigation	0%	0%	0%	0%	0%	5%	8%	14%	0%	0%	0%	0%
III-A-ii. Snow Making	3%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Threats Ranking												
Municipal Pumping								1 (41%)				
Reduction in Recharge (increase in Imperviousness)								3 (5%)				
Agricultural Irrigation								2 (14%)				
Snow Making								4 (0%)				

The second row of Table 6 contains the 7Q20 flow calculated downstream of the municipal intake in the baseline scenario. The 7Q20 flow represents minimum flow conditions, and is used as the baseline reference to rank the impact of all water quantity threats. The underlying rows in the table list the impact on streamflow at the intake from four water quantity threats. Note that the water takings vary by month, depending on the nature of the threat. For example, agricultural irrigation impacts streamflow in the summer months, whereas snow making impacts streamflow in the winter months.

In this example, the Tier Three Assessment noted that only the month of August was determined to have a high exposure. As such, the Percent Impact results during August were used to rank the threats and the Percent Impact is listed in the third section of Table 5. The results show that in comparison to the August baseline flow, the Percent Impact of the planned municipal system is 41% which ranks this as the largest of the four threats. The Percent Impact of Snow Making is 0% given that this permitted water use is not active during the month when there is a water quantity risk (August).

4 Deliverables

4.1 PRIORITIZING THREATS

At the end of this process, at a minimum, a ranked list of threats for each WHPA-Q1/2 or IPZ-Q will be provided to the Source Protection Committee (SPC) to assist the committee in prioritizing the development and implementation of risk management measures. It is expected that additional information will be developed as part of the Risk Management Evaluation Process in relation to appropriate and practical risk management measures for each specific sector or specific threat whenever possible. This information may include recommendations on the cost effectiveness and feasibility of applying various risk management measures, and possibly the estimated performance of measures applied to the ranked threats with the goal of achieving an overall minimum impact on the ability of drinking water systems to meet the allocated or committed rates. Additional considerations that might be taken into account during the decision making processes are listed below.

4.1.1 Multiple Wells or Intakes

Depending on the results of the Threats Ranking task, a municipality may be required to manage risk at multiple wells or intakes. Where this is the case, the Threats Ranking report should identify the threats that have an impact on multiple wells or intakes versus those that impact individual wells or intakes. In some instances, applying risk management measures to a water quantity threat that potentially impacts several municipal wells or intakes may be a higher priority than a threat that impacts only one municipal well or intake.

4.1.2 Municipal Water Demands

Municipal pumping rates for each production well or intake should also be provided to the SPC, to provide context to the threats ranking. If a municipal well or intake supplies 90% of the water supply for the municipality, the threats placed on that well or intake may be given an higher priority than threats that impact municipal wells or intakes that provide only a small proportion of the municipality's water supply.

4.1.3 Threat Classification

The Threats Ranking report should also provide information to the SPC on whether the threats are permitted or non-permitted or if the threats are future potential threats that may be developed in the future (e.g. threat based on a change in land use as outlined in the Official Plan). Prioritization of threats may be adjusted by the SPC to account for different types of threats.

4.1.4 Considerations to "Other Uses"

Any residual impacts to other users must be identified for the Risk Management Evaluation Process. The preferred alternative (measure or group of measures) may result in a *moderate* or *significant* risk, while meeting the allocated water demand, but impacting other uses. The SPC may consider the residual impacts of the preferred alternative to other water users, during the decision making process of preparing the Risk Management Plans.

4.2 UNCERTAINTY

Numerical models are a simplification of real world conditions, and their predictions have a degree of uncertainty that may influence the Threats Ranking results. Uncertainties associated with numerical models and with the modelling of threats should be summarized for the Source Protection Committees.

Model uncertainties to note include uncertainties associated with model input parameters such as hydraulic conductivities in a groundwater flow model, or the depth of reservoir in a surface water flow model. In addition, there may be uncertainty with the pumping rates used to simulate the water takings (threats). Whenever possible, actual pumping data should be used, and the SPC should be informed when pumping rates are poorly understood, or estimated from limited data or literature sources.

There is also uncertainty associated with consumptive use factors. The factors are based on professional judgment and assessment of the best available information; however, in many cases industry standards have been applied. As such, there is a margin of error associated with those values as some water takers will operate with varying levels of efficiency.

All future water takings simulated in the models will bear a degree of uncertainty. In some areas wells or intakes may exist, and a permit may also exist; however, in multi-aquifer systems it may not be obvious which water supply aquifer will be used by a future development, nor will the pumping rate associated with the development be known. As such, future threats should be regarded as having a much higher degree of uncertainty than existing threats.

In several of the models, the Official Plan has been recommended for use in prescribing the future land use changes. There is uncertainty associated not only with the Official Plans (as they can be amended over time) but there is also uncertainty with the resulting reduction in recharge that may arise from future developments. Therefore, as noted above, the uncertainty associated with future developments should be considered when ranking or prioritizing the threats to municipal supplies.

To the greatest extent possible, the potential influence of uncertainty on the Threats Ranking results should be clearly presented in the Threats Ranking report. The influence of uncertainty can be better understood by completing a sensitivity analysis, which would involve running a scenario under various sets of plausible assumptions to estimate a range of outcomes. As an example, the Percent Impact of two different threats may be shown to be 15% and 18%, respectively. However, given the uncertainty it may not be prudent to prioritize one of these threats over the other. Where this situation occurs it should be documented in the Threats Ranking report. Conversely, threats identified with a high level of confidence, such as those confirmed with field observations, should be highlighted in the Threats Rankin report for the SPC.

5 References

Environment Canada, 2007. 2007 Municipal Water Use Report; Municipal Water Use 2004 Statistics. Accessible at: http://www.ec.gc.ca/water/en/info/pubs/e_pubs.htm

Ontario Ministry of the Environment. 2006. Clean Water Act (Ontario Regulation 287/07). Queen's Printer for Ontario, 2006.

Ontario Ministry of the Environment. 2008. Clean Water Act, 2006, Technical Rules: Assessment Report. October 2008.

Appendix A. Groundwater Threats Example

This section outlines a fictitious example of a groundwater based municipal drinking water system that was identified in the Tier Three Assessment to have a WHPA-Q1 vulnerable area with high exposure and low tolerance (therefore, '*significant*' risk level). Consequently, the consumptive water uses within the WHPA-Q1 area were designated as significant drinking water threats. For this example, it is assumed that the WHPA-Q2 area is coincident with the WHPA-Q1 area. The following subsections outline the model scenarios used to rank the drinking water threats, and the resulting ranking and output that would be provided to the SPC at the conclusion of the study.

A.1 SETTING

The municipal groundwater supply system consists of three groundwater wells referred to as PW1, PW2 and PW3 (Figure A1). PW1 and PW2 are located only a few hundred meters from one another and draw from the same bedrock aquifer. A WHPA-Q1/Q2 area for the PW1 and PW2 wells was delineated in the Tier Three Assessment.

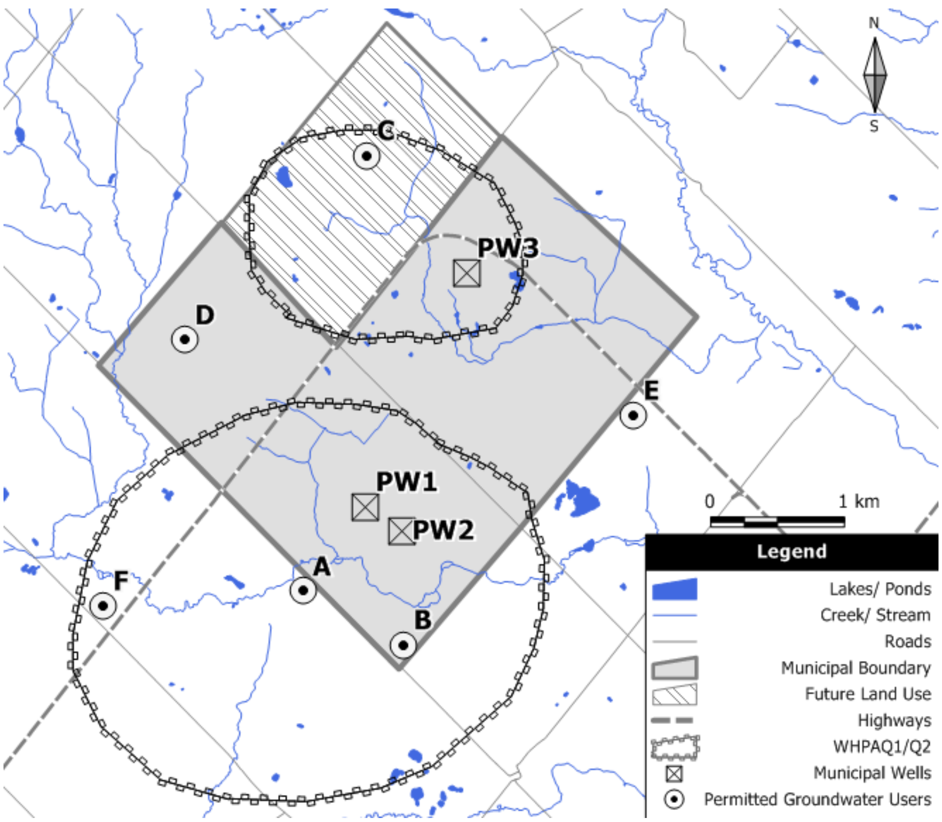

Figure A1: Groundwater Threats

PW3 is located approximately 1 km from PW1 and PW2, and it is completed in the same bedrock aquifer; however, the WHPA-Q1/ Q2 for PW3 does not overlap with the WHPA-Q1/Q2 for PW1 and PW2. According to the results of the Tier Three Assessment, the water quantity risk associated with the WHPA-Q1 area for PW3 is low, and as a result, the threats ranking exercise is not required for this vulnerable area.

The safe available drawdown for PW1 and PW2 were determined in consultation with the municipality and are as follows: 10.0 m for PW 1 and 3.5 m for PW2. The current and planned pumping rates for the municipal wells are outlined in Table A1.

Table A1: Municipal Pumping Rates

Municipal Well	Current Pumping Rates (m^3/day)	Planned System Pumping Rates (m^3/d)
PW1	250	2,000
PW2	1,000	1,250

Under existing conditions the municipality is extracting a total of 1,250 m^3/day of groundwater from PW1 and PW2. However, with the expansion of the municipality, and the addition of several residential subdivisions within the Future Development Area (Figure A1), the planned system pumping rates were estimated in the Tier Three Assessment to increase to 3,250 m^3/day (Table A1).

A.2 DRINKING WATER THREATS

In addition to the municipal wells, six permitted groundwater takers lie close to the Municipality (Figure A1), with three permits (A, B and F) lying within the WHPA-Q1/Q2 for PW1 and PW2 (Table A2).

Table A2: Consumptive Groundwater Demand

Permitted Well	Current Consumptive Use Pumping Rates (m^3/day)	Maximum Practical Consumptive Use Pumping Rates (m^3/day)
A	250	2500
B	50	100
F	175	175

While Permit A has an estimated current consumptive demand equal to 250 m^3/day the Tier Three Assessment estimated a maximum practical consumptive rate for the permit of 2,500 m^3/day. Permit B is predicted to have a nominal increase in consumptive water use over the existing rates, and Permit F is expected to have the same consumptive water use into the future (Table A2).

One hundred rural residents reside in a rural estate subdivision located outside the municipality, within the WHPA-Q1/Q2 for PW1/PW2. Each resident has a groundwater well that takes less than 50,000 L/d, and as such permits are not required.

A.3 MODEL SCENARIOS

A.3.1 LEVEL 1- MANDATORY MODELLING SCENARIOS

The first modelling scenario (Scenario I-A) examined the impact of increasing the municipal pumping from existing rates to the planned system rates. The planned system rates are larger than the committed municipal rates; accordingly, only the planned system rates were examined.

The impact of the 100 non-permitted domestic water users was examined in Scenario I-B. The Tier Three Assessment estimated each household is extracting groundwater from shallow aquifers at a rate of 335 l/d, and discharging the pumped water to individual household septics systems (estimated 20% consumptive use factor). As such, the consumptive use for the subdivision is estimated to be 6,700 l/d (6.7 m^3/d; 20% x 33,500 l/d). The cumulative impact of the private domestic well takings was undertaken in Scenario I-B, by reducing the groundwater recharge in the subdivision footprint area (by 6.7 m^3/d), and assessing the resultant impact on the municipal wells.

Scenario I-C assessed the impact of all permitted water demands on the municipal water supplies. In this example, the greatest pumping rates occurred in the maximum practical consumptive demand scenario, and as such, these rates were used in Scenario I-C.

The third modelling scenario (Scenario I-D) looked at the impact of the recharge reduction associated with the Future Development Area (residential development) on the municipal supplies. The recharge reduction specified in the Tier Three Assessment was used to examine the impact of development on the supplies. The results of the four modelling scenarios are outlined in Table A3.

Table A3: Results of Level I Modelling Scenarios

	PW 1		PW 2	
Safe Available Drawdown	10.0 m		3.5 m	
Level I Model Scenarios	**Incremental Drawdown (m)**	**% Impact**	**Incremental Drawdown (m)**	**% Impact**
I-A: Municipal Planned System	6.0	60%	2.5	71%
I-B: Non-Permitted Water Takers	0.0	0%	0.0	0%
I-C: All Non-Municipal Permitted (Max Practical Consumptive Use)	2.0	20%	2.0	57%
I-D: Recharge Reduction (OP)	0.0	0%	0.0	0%
Total	**8.0**	**80%**	**4.5**	**128%**

Results for Scenario I-B illustrate that the non-permitted water takers do not impact the municipal water supplies (Table A3). As such, additional scenarios that examine non-permitted water takers are unnecessary as they would not provide any additional information or insight. Similarly, the reduction in recharge due to land use development had no impact on the municipal supplies, so additional Sector Based (Level II) or Locally Relevant (Level III) Scenarios that examine the impact of reductions in recharge on the municipal supplies are not required.

A.3.3 LOCALLY RELEVANT SCENARIOS

The increase in demand due to municipal takings at each of the municipal wells was significant (Percent Impact of 60% on PW1 and 71% impact on PW2). As such, Locally Relevant Scenarios were developed to estimate the impact of increasing the pumping from the existing rates to the planned system rates from each well in isolation on the other municipal wells (Table A5). Results of the Locally Relevant (Level III) indicate the impact on the municipal supplies is due to both the takings from PW1 and PW2.

Table A4: Results of Level III Model Scenarios

Municipal Supply Well		**PW1**		**PW2**		**Maximum Percent Impact**
Pumping Rate (m^3/d)		2,000		1,250		
Safe Drawdown (m)		10.0		3.5		
Model Scenario	**Threat**	**Drawdown (m)**	**% Impact**	**Drawdown (m)**	**% Impact**	**WHPA-Q1 PW1/ PW2**
III-A-x: Municipal Planned	PW1	5.0	50%	2.0	57%	57%
	PW2	1.0	10%	0.5	14%	14%
III-A: Locally Relevant (Max Practical Use)	Permit B	0.0	0%	0.0	0%	0%
	Permit A	1.9	19%	1.9	54%	54%
	Permit F	0.1	1%	0.1	3%	3%
Total		**8.0**	**80%**	**4.0**	**114%**	

The bottom line in Table A4 represents the total percent impact, or the total drawdown resulting from the application of all water quantity threats within the vulnerable areas; these totals equate to the total drawdown in Table A3 (results of Level I Scenarios). The permitted water takers impact the municipal water supplies. As there were only three permits, Locally Relevant (Level III) Scenarios were run to assess the impact of each individual taking on the municipal wells (Table A4).

A.4 THREATS RANKING

The percent impact for each threat present within the WHPA-Q1/Q2 vulnerable area is ranked by the maximum Percent Impact for each threat (Table A5). The results indicate that increased pumping at PW1 has the greatest Percent Impact, followed by the maximum practical consumptive demand from Permit A. The Percent Impact of PW2 is 14%, and Permit F is 3%, giving them a ranking of 3 and 4, respectively (Table A5).

Table A5: Ranked Threats within the WHPA-Q1/Q2 for PW1/ PW2

WHPA-Q1/ Q2 for PW1/ PW2		
Threat	**Percent Impact**	**Rank**
Municipal PW1	57%	1
Permit A	54%	2
Municipal PW2	14%	3
Permit F	3%	4
Recharge Reduction	0%	-

Appendix B Surface Water Threats Example

This section outlines an example of a municipal drinking water intake with an IPZ-Q vulnerable area classified in the Tier Three Assessment as having a *significant* water quantity risk level. Consequently, all consumptive water users within the IPZ-Q area were classified as '*significant*' drinking water threats. The following subsections outline the hypothetical situation, the methodology used to rank the drinking water threats, and the ranking and output that would be provided to the SPC at the conclusion of the study.

B.1 SETTING

A fictitious municipality has a drinking water intake in a river as illustrated on Figure B1. The upstream catchment for the intake is also illustrated on Figure B1.

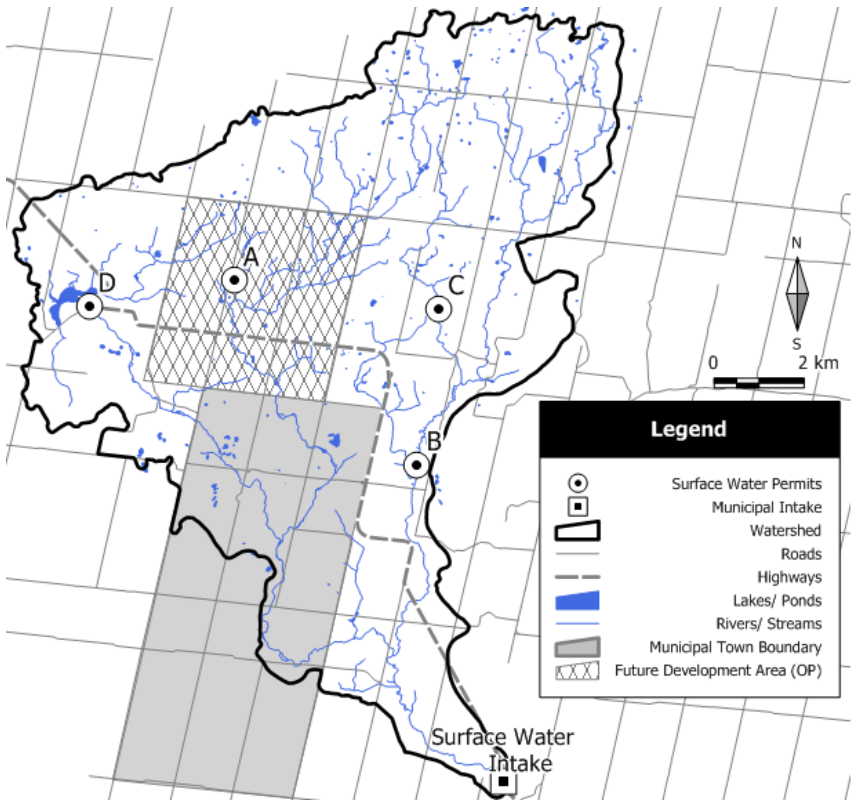

Figure B1: Physical Setting and Location of Water Quantity Threats

According to the municipality's Permit to Take Water, the municipality can only pump water from the intake when the flow in the river is greater than or equal to 0.3 m^3/s, or 25,920 m^3/day. Under existing conditions the municipality extracts a total of 3,400 m^3/day of surface water for their municipal supply needs. However, with the expansion of the municipality within the Future Development Area (Figure B1), the planned system pumping rates were estimated (in the Tier Three Assessment) to increase to 6,400 m^3/day.

Figure B2 contains the streamflow hydrograph downstream of the municipal intake and illustrates that there are several instances where streamflow is below the 0.3 m^3/s threshold under existing pumping conditions. The Tier Three Assessment concluded that there is a high exposure, specifically when other threats are considered and streamflow is shown to drop well below the threshold in the months of January and August. The Tier Three Assessment also concluded that the municipality did not have sufficient storage facilities to address supply deficiency when the intake would be shut off, and as a result, the water quantity risk for the IPZ-Q is *significant*.

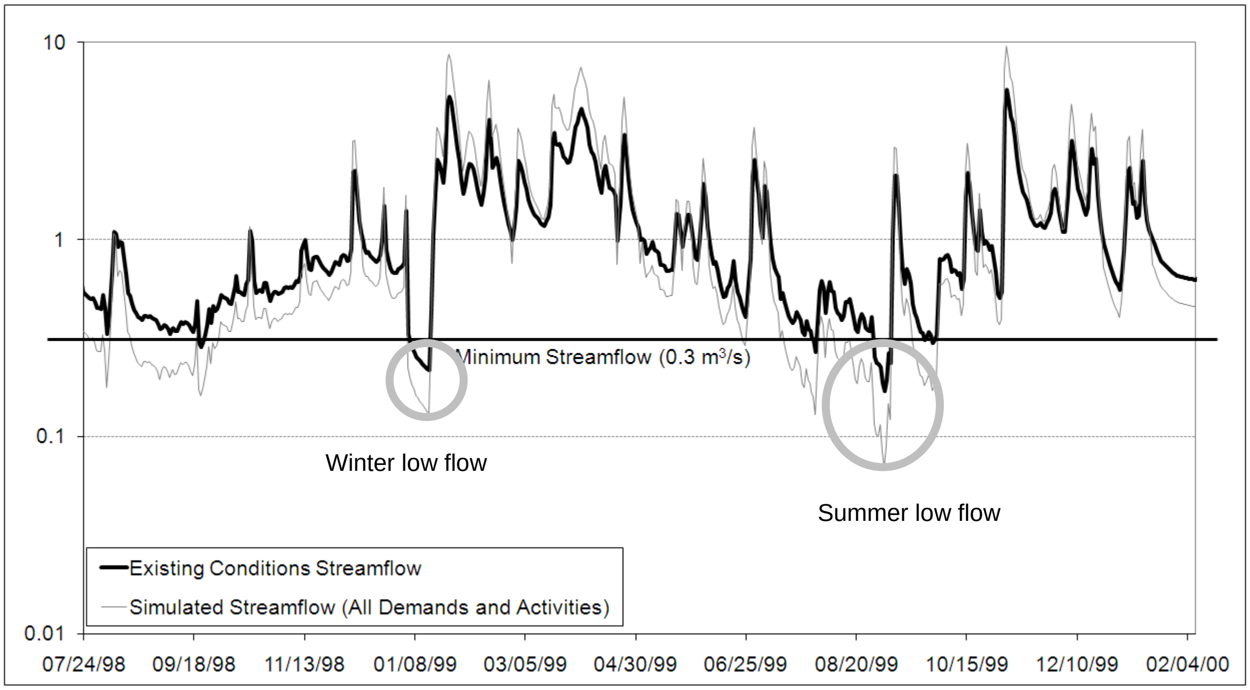

Figure B2: Surface Water Flow under Existing Conditions and All Demands/ Activities

B.2 DRINKING WATER THREATS

Four permitted surface water takers exist in the subwatershed upgradient of the surface water intake (Figure B1). The consumptive demands and the water taking period for these permits are listed in Table B1.

Table B 1: Consumptive Surface Water Demands

Intake Permit	Permitted Water User	Current Consumptive Use Pumping Rates (m^3/day)	Maximum Practical Consumptive Use Pumping Rates (m^3/day)	Water Taking Period
A	Golf Course	1,900	2,592	June – September
B	Agricultural	1,500	1,728	June – September
C	Ski Hill (snowmaking)	500	500	December – February
D	Aquaculture	50	75	June – September

Permit A is designated for a golf course located in within the municipality. The maximum practical consumptive demand for this golf course was estimated to be 2,592 m^3/day; most of this water taking is for golf course irrigation, and is active from June to September of each year. Permit B is an agricultural water user that is currently taking at 1,500 m^3/day, with a maximum practical demand of 1,728 m^3/day. This user is generally active during the summer growing months from June to September. Permit C is for snowmaking for a small ski hill located near the municipality. The maximum practical consumptive use for the ski hill was estimated in the Tier Three Assessment to be 500 m^3/day, with takings occurring between the months of December and February. Permit D is an aquaculture permit that is currently taking 50 m^3/day, but may potentially increase to 75 m^3/day in the future as outlined in the Tier Three Assessment (Table B1).

No non-permitted water takers lie within the IPZ-Q area upgradient of the municipal intake, and as such they were not considered in this exercise.

B.3 MODEL SCENARIOS

Table B2 summarizes the Threats Ranking scenarios for this example. The top row of the table lists the monthly 7Q20 baseline flows for each of the months where the exposure is high (January and August).

The first modelling scenario (Scenario I-A) assesses the impact of increasing the existing rates to the planned system rates, on the municipal supplies. This scenario assumes that the increase in the planned municipal rates will be the same in both high-risk months (January and August).

The second modelling scenario (Scenario I-B) evaluates the impact of land development on streamflow. The continuous surface water flow model was used to estimate the maximum reduction in streamflow during the high-risk months as a result of land use developments.

As this example has few permitted users, Locally Relevant (Level III) Scenarios were set up to assess the impact of each permitted water user on the municipal supplies. The estimated reduction in streamflow at the municipal intake due to each of the permitted users is listed in the table.

Table B2: Surface Water Scenario Results (Level I, II) for Winter and Summer Low Flow Periods

Scenario	Streamflow in January (m^3/d)	Streamflow in August (m^3/d)
Baseline Flow (7Q20)	27,648	26,266
Impact To Streamflow		
I-A: Municipal Planned System	3,024	3,024
I-B: Official Plan Land use	200	4,579
III-A-i: Permit A: Golf Course	0	1,728
III-A-ii: Permit B: Agricultural Irrigation	0	2,592
III-A-iii: Permit C: Snow Making	432	0
III-A-iv: Permit D: Aquaculture	0	0
Total	3,656	11,923

Using the estimated reductions in streamflow, the Percent Impact for each scenario was calculated as the reduction in streamflow divided by the baseline 7Q20 for each high risk month (January and August). Results are illustrated on Table B3 for each of the high-risk months.

Table B3: Percent Impact Results

Scenario	January Percent Impact	August Percent Impact
I-A: Municipal Planned System	11%	12%
I-B: Official Plan Land use	1%	17%
III-A-i: Permit A: Golf Course	0%	7%
III-A-ii: Permit B: Agricultural Irrigation	0%	10%
III-A-iii: Permit C: Snow Making	2%	0%
III-A-iv: Permit D: Aquaculture	0%	0%
Total	**13%**	**45%**

B.4 THREATS RANKING

Table B4 ranks the water quantity threats for each of the months identified in the Tier Three Assessment as having a high risk. In January, the planned municipal demands are ranked highest, and the influence of the snow making permit and the land development is shown to be minimal. In August, the influence of land development is ranked as the greatest water quantity threat, followed by planned municipal demands, agricultural irrigation, and golf course irrigation (Table B4).

Table B4: Threats Ranking

Water Quantity Threat	January- Threats Ranking	August- Threats Ranking
Municipal Planned System	**1**	**2**
Official Plan Land use	3	1
Permit A: Golf Course	n/a	4
Permit B: Agricultural Irrigation	n/a	3
Permit C: Snow Making	2	n/a
Permit D: Aquaculture	n/a	n/a