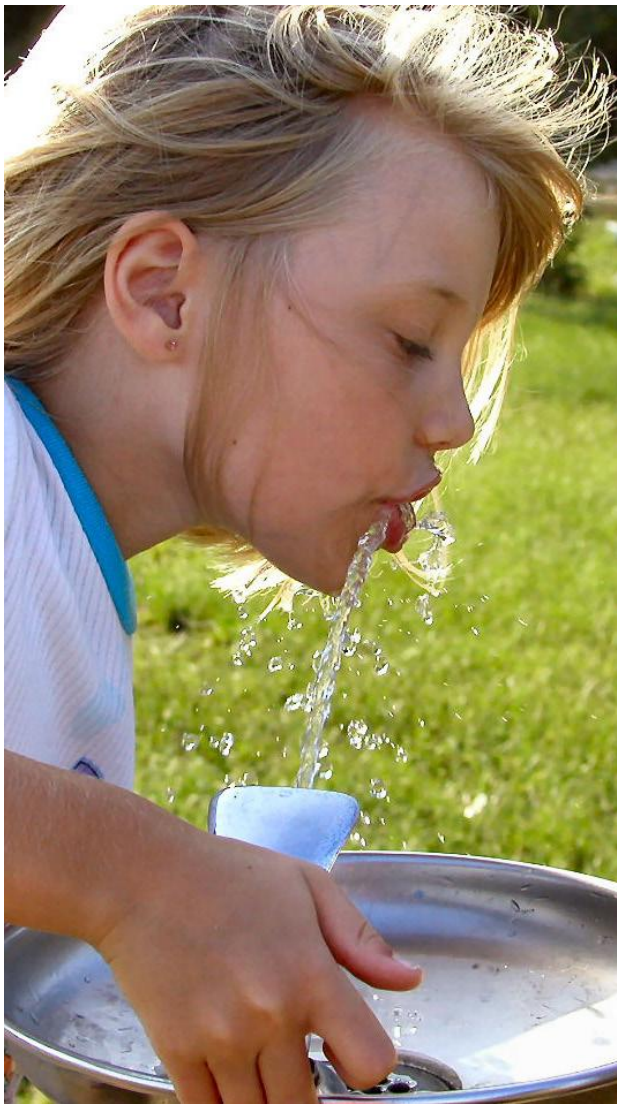
Part One

Report Overview and Methodology



This Assessment Report provides the technical material upon which the Source Protection Plan is based. It has been prepared according to current requirements under the *Clean Water Act,* and according to current technical direction and data availability.

Approved on September 2, 2014
Minor revision on March 1, 2017

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Chapter 1 - Overview of the Assessment Report

1.1 Report Components

The assessment report consists of 10 parts and a total of 55 chapters. Part One describes the methodology for completing the water quality risk assessment and the water quantity risk assessment, which comprise the material presented in this report. Part Two provides an overview of the Greater Sudbury Source Protection Area. It describes the drinking water systems in the area, the physical and human geography, the geology and the climate of the planning area. The three major watersheds that make up the source protection area are described, including the main surface water flows, groundwater flows and surface water and groundwater interactions. Conceptual water budget and Tier 1 water budget information for each of the three major watersheds is presented in Part Two, as well as a description of water quality sampling programs and results to date. A brief description of aquatic ecology is also provided.

The remaining eight parts of the assessment report describe each of the municipal residential drinking water systems in the source protection area. Each part has a chapter describing the drinking water system, an assessment of the vulnerability of the source water, an assessment of the threats to the source water, a water quantity assessment or a water budget, and an evaluation of the uncertainty and data gaps associated with the assessment of each system.

The appendices include the glossary, the technical reports that were completed to help meet the requirements of this report, references, public consultation information and instructions to understand which threat circumstances are significant, moderate or low in vulnerable areas.

1.2 Source Protection Committee

The Greater Sudbury Source Protection Committee consists of nine members plus the chair. The chair was appointed by the Minister of the Environment and members were appointed by the Greater Sudbury Source Protection Authority in 2007. The Province of Ontario regulates the size of the committee, and stipulates that it must consist of one third municipal members, one third local economic sector members and one third other members, such as environmental, academic, public, or other local representation.

The Greater Sudbury Source Protection Committee has three staff members from the City of Greater Sudbury, a local mining representative, a Chamber of Commerce representative, a local land developer, an environmental representative and two public members at large. Both local First Nations and liaison members from the Greater Sudbury Source Protection Authority, Sudbury & District Health Unit and Ministry of the Environment and Climate Change also participate on the committee. Table 1.1 shows source protection Committee membership and First Nations representation.

The committee met approximately once a month from its inception in 2007 until 2011 when most of the technical work for the assessment report was completed and the related policy base for the first source protection plan was completed. Since then it the committee has met as required. All meetings are open to the public. The committee's role is to oversee the development of the source protection plan, which started with preparing the terms of reference, and then this assessment

report. Committee members represent their sectors and their role is to develop practical policies that can be implemented to protect drinking water sources in this area. The source protection plan was prepared and submitted to the Ministry of the Environment and Climate Change on August 20, 2012 and is currently being amended in conjunction with this assessment report update to include water quantity policies.

Table 1.1 Members of the Greater Sudbury Source Protection Committee and First Nation representation

Name	Sector	Expertise/Background
Nels Conroy	Chair	Water Resources and Facilitation
Nick Benkovich	Municipal	Director, Municipal Water/Wastewater Services
Stephen Monet	Municipal	Manager of Environmental Planning Initiatives
Paul Baskcomb	Municipal	Director of Planning Services
Wendy Wisniewski	Economic/Mining	Vale, Environmental Analyst
Luc Bock	Economic/Land Development	Sudbury & District Home Builder's Association, L&S Bock Development
Greg Haddad	Economic/Small Business/Commercial	Greater Sudbury Chamber of Commerce, Uptown Cleaners and Sudbury Steam Dry Cleaners Ltd, Owner
Lilly Noble	Other/Environmental NGO	Coalition for a Liveable Sudbury
Richard Bois	Other/Public Member	Retired Chief Administrative Officer/Clerk, Town of Walden
Tim Worton	Other/Public Member	Retired from the Sudbury & District Health Unit
Cheryl Recollet	First Nations	Wahnapitae First Nation, Environmental Coordinator
Heather Swandon	First Nations	Atikameksheng Anishnawbek (Whitefish Lake First Nation), Natural Resources Coordinator

1.3 Source Protection Authority

With the passage of the *Clean Water Act* in 2006, the board of the Nickel District Conservation Authority became the Greater Sudbury Source Protection Authority for the purposes of meeting conservation authority obligations under the *Clean Water Act*. In some parts of the province, several conservation authorities joined to form one source protection region governed by one source protection authority. The Greater Sudbury Source Protection Authority has five public members and four elected municipal councillors, who provide a strong and necessary link to the Greater Sudbury City Council.

1.4 Public Consultation

Public consultation is an integral part of the development of the assessment report. Public comments received by mail, email, telephone and at two public meetings that were held during the development of the terms of reference, highlighted many local concerns about threats to local drinking water sources. These local concerns are reflected in the addition of a local threat (the

transportation of hazardous substances along transportation corridors), in the identification of sodium and Microcystin LR (blue green algae) as issues for the Ramsey Lake system, and also as other local concerns described in Chapter 14.5.

The source protection authority and source protection committee are committed to reflecting local public concerns about protecting drinking water sources in both the assessment report and the source protection plan. Public consultation requirements for the assessment report are being met by hosting five public meetings during the consultation periods, by publishing the draft, proposed, amended and final assessment report on the Conservation Authority website, by making copies available in local libraries and the Conservation Authority office, by publishing notices in English and French language newspapers, by providing notice to the two local First Nations and to each municipality listed in the terms of reference, and by considering public comments in the preparation of the report. Appendix 4 provides a summary of public consultation on the assessment report.

1.5 Technical Team and Peer Review Process

This assessment report was prepared according to a set of Technical Rules developed by the Ontario Ministry of the Environment and Climate Change specifically for the assessment reports. The work presented in this report was done by a number of different technical experts. The province mandated that all water budget work be peer reviewed and also provided for the delineation and scoring of vulnerable areas to be peer reviewed. Work commenced in 2005, when some components of draft technical guidance first became available from the province and proceeded as more guidance subsequently became available. This report complies with the November 20, 2008, Drinking Water Source Protection Assessment Report Technical Rules and Regulations, as amended November 16, 2009, and with all Ministry of the Environment and Climate Change source protection technical bulletins issued up to February 25, 2010. This amendment complies with the MOECC Technical Bulleting, Water Budget and Water Quantity Risk Assessment Tier 2 Subwatershed Stress Assessment and Tier 3 Local Area Risk Assessment, April 2010.

A water budget peer review team was established in 2005 to prepare the conceptual water budget. This team stayed on to prepare the Tier 1, Tier 2 and Tier 3 water budgets. The first peer review meeting was in January 2006. This group met approximately every six weeks until the Tier 3 water budget work was completed. A record of peer review was completed after the conceptual water budget was completed, as well as after Tier 1, Tier 2 and Tier 3 work was completed.

Work for water quality assessment proceeded as guidance for the required products became available. The vulnerability assessment work started in June 2006, and peer review started as soon as funding became available from the province in January 2008.

1.6 Continuous Improvement for the Assessment Report

This assessment report provides the technical material upon which the source protection plan is based. It has been prepared according to current requirements under the *Clean Water Act*, according to current technical direction and data availability. It will be updated as determined by the Greater Sudbury Source Protection Authority, the Greater Sudbury Source Protection Committee and the Ontario Ministry of the Environment and Climate Change.

As new information arises, either from increased or continuous monitoring, improved models, or a change in methodology, the results from this report will need to be updated to reflect new information. In addition to data gaps that have been identified for certain drinking water systems in those relevant sections of this report, there are also some types of future work that could improve the analyses for subsequent assessment reports. For the groundwater systems, the following work would be beneficial:

- Modeling of the wellhead protection areas was based on actual pumping rates between the years 2002 through 2007. These rates will have to be revisited on a regular basis to reflect any changes in usage in order for the protection zones to accurately reflect the current system;
- Updated and additional water level data throughout the contributing area would improve the calibration of the groundwater models developed for this assessment;
- The installation of monitoring wells within the municipal well field would improve water quality and quantity assessments; and
- Improved monitoring of sodium levels to determine if sodium is a drinking water quality issue.

For the Wanapitei surface water system, it would be useful to study the flow dynamics in the vicinity of the intake and the influence of wind to ascertain the potential for contamination from an accidental spill on the rail line or highway. For the Ramsey Lake surface water system, the following work would be useful:

- Circulation modeling for Ramsey Lake to update and further refine IPZ-1, 2 and 3 delineations;
- Continued water quality monitoring to determine any long term impacts of increased sodium and chloride;
- Continued monitoring of the presence of cyanobacterial blooms and the potential local conditions to trigger a bloom;
- Continued monitoring of inflows and outflows to refine water balance calculations;
- Increased monitoring of quality and quantity of inflows with respect to storm events;
- Improved mapping and monitoring of storm drainage in the watershed; and
- Improved information management of local climate stations within the Ramsey Lake watershed.

Chapter 2 - Water Quality Risk Assessment

A water quality risk assessment is conducted for each surface and groundwater municipal system. This consists of delineating vulnerable areas, assigning a vulnerability score to those areas and identifying and assessing potential water quality threats to the drinking water supply. The following sections will describe the surface water and groundwater methodology to determine vulnerable areas and water quality threats.

2.1 Surface Water Vulnerable Area Delineation and Scoring

Vulnerability for surface water intakes was originally assessed by AMEC for the three surface water intakes in the Greater Sudbury Source Protection Area. The study was completed in early 2008 and subsequently the Technical Rules were not finalized until December 2009. Consequently, many of the results needed to be re-evaluated and changed to reflect the final rules. The full studies conducted by AMEC are referenced in Appendix 2.

Intake protection zones (IPZ) are delineated for all surface water municipal intakes. The type of intake it is (A, B, C or D) determines how the IPZs are delineated.

In the Greater Sudbury Source Protection Area there are three surface water intakes. Two intakes, the Vermilion and Wanapitei, are classified as a Type C. The David Street intake is classified as a Type D (See Rule 55).

Type C Intake Protection Zone Delineation

Table 1.2 describes the methodology for each IPZ for Type C intakes.

Table 1.2 – Description of intake protection zones for a Type C (river) intake

Intake Protection Zone	Description
Intake Protection Zone 1*	A semi-circle that has a radius of 200 m extending upstream from the centre point of every intake that serves as the source or entry point of raw water supply for the system and a rectangle with a length of 400 m and a width of 10 m extending downstream from the centre point.
Intake Protection Zone 2	Extends from the IPZ-1 to include areas within each surface water body and storm sewershed that reflect the response time for a water treatment plant operator to respond to adverse conditions (minimum 2 hour travel time). Where IPZ-2 abuts land, a maximum 120 m setback from the high water mark and the area of the regulation limit. IPZ-2 may be extended to include an area that contributes water through a transport pathway.
Intake Protection Zone 3	Includes the area within each surface water body that may contribute water to the intake. Where it abuts land, a 120 m setback from the high water mark and the area of the Regulation Limit will be included. IPZ-3 may extend to include a transport pathway.

*An IPZ-1 can be modified to reflect local hydrodynamic conditions affecting stream flow (Rule 64).

The IPZ-1 in the Vermilion River intake was modified to reflect the local hydrodynamic conditions of the river. The modification was based on the results of drogue studies conducted in 2006 by

AMEC. A full description of the modification is in Chapter 29. The delineation of the IPZ-1 for the Wanapitei River remained consistent with the Technical Rules.

Intake protection zone 2 for the Vermilion and Wanapitei Rivers was delineated based on models developed in HEC-River Analysis System (HEC-RAS) by Golder Associates (Golder 2011). The model used surveyed cross sections from river reaches and hydraulic properties such as slope and elevation to simulate water levels for various discharge scenarios.

The river reaches were previously modeled by the Nickel District Conservation Authority for flood mapping purposes using HEC-2, an early version of modeling software. Previously estimated IPZ-2 distances were based on earlier flood plain analysis, and it was recognized that the modeled reaches and river profiles were not necessarily reflective of the actual conditions. Also the uncertainty reflected in the IPZ-2 delineations was very high. Following the initial IPZ-2 analysis additional field work was carried out on the Wanapitei and Vermilion Rivers in order to reduce uncertainty. The river bed cross sections and velocity profiles were collected to improve the local understanding of river geometry upstream of the WTP intakes. The surveyed reach extended upstream of the WTP intake until rapids were encountered.

Discrete manual cross sections and velocity profiles were completed at three locations on the Vermilion River and four locations on the Wanapitei River. Manual cross section measurements were conducted with a graduated tagline strung across the river, and river depth was measured at 5 m intervals using a weighted sounding line which was compared to the sonar reading at that location. Velocity was measured at each 5 m interval with a Valeport (BFM001) impeller-type flow meter and suspension kit. The collected field data was used to construct a Digital Terrain Model (DTM) as well as a 2-Dimensional model in the hydraulic simulation program HEC-River Analysis System v. 4.0.

Several scenarios were simulated in the model to estimate the velocity required to determine the 2 hour time of travel to delineate the IPZ-2. The 1 in 2 year flood was considered an appropriate scenario to estimate the travel time. The results of the HEC-RAS analysis provide an estimate of travel time through the modeled river reach without the effect of contaminant mixing. IPZ-2 for the Wanapitei intake was extended to include transport pathways.

The IPZ-3 for the Vermilion and Wanapitei River intakes were delineated based on the Technical Rules.

Type D Intake Protection Zone Delineation

The David Street intake is the only Type D intake in Greater Sudbury and is located in Ramsey Lake. Table 1.3 describes the methodology for delineating intake protection zones in a Type D intake.

The IPZ-1 for the David Street intake was delineated based on the Technical Rules. In order to determine the IPZ-2, current and drogue studies were conducted in 2006 by AMEC as part of the surface water technical studies. The delineation of IPZ-2 was based these studies, which also considered transport pathways such as storm sewers. Chapter 19 describes the results of the AMEC study and the complete study is located in Appendix 2. The IPZ-3 was delineated based on the Technical Rules and included transport pathways such as storm sewers.

Table 1.3 – Description of intake protection zones for a Type D (inland lake) intake

Intake Protection Zone	Description
Intake Protection Zone 1*	Area within a surface water body with a circle of a 1 km radius centered on the intake. Where it abuts land, the IPZ-1 will be a 120 m setback from the high water mark and the area of the Regulation Limit along the abutted land.
Intake Protection Zone 2	Extends from the IPZ-1 to include areas within each surface water body and storm sewershed that reflect the response time for a water treatment plant operator to respond to adverse conditions (minimum 2 hour travel time). Where IPZ-2 abuts land, a maximum 120 m setback from the high water mark and the area of the regulation limit. IPZ-2 may be extended to include an area that contributes water through a transport pathway.
Intake Protection Zone 3	Includes the area within each surface water body that may contribute water to the intake. Where it abuts land, a 120 m setback from the high water mark and the area of the Regulation Limit will be included. IPZ-3 may extend to include a transport pathway.

*An IPZ-1 can be modified to reflect local hydrodynamic conditions affecting stream flow (Rule 64).

Intake Protection Zone Vulnerability Scoring

Each vulnerable area is scored by multiplying two factors: the Source Vulnerability Factor and the Area Vulnerability Factor.

Source Vulnerability Factor x **Area** Vulnerability Factor = **Vulnerability Score**

The **source** vulnerability factor refers to the specific vulnerability of the intake. This is based on the depth of the intake, the distance of the intake from shore and if there have been any drinking water issues present.

The **area** vulnerability factor refers to the degree of vulnerability to contamination in the protection zone. This factor is based on land characteristics (i.e. slope, soil type, and land cover), distance to the intake, the presence of transport pathways and the percentage of land within the protection zone. The area vulnerability factor for an IPZ-3 cannot be greater than the factor assigned to IPZ-2 (Rule 91).

Table 1.4 summarizes the vulnerability scoring for Type C and D intakes (See Rules 86 - 96). The technical team took a qualitative approach to assess the vulnerability factors based on local knowledge and professional judgment for each intake.

2.2 Groundwater Vulnerable Area Delineation and Scoring

There are two types of vulnerable areas to be delineated in accordance with the Technical Rules for groundwater quality vulnerability: wellhead protection areas and highly vulnerable aquifers. Wellhead protection areas relate to municipal wells and highly vulnerable aquifers apply to the entire Greater Sudbury Source Protection Area.

Groundwater vulnerable areas were first delineated for the City of Greater Sudbury as part of the provincially directed municipal groundwater studies completed in 2005. Golder Associates performed the research and analysis for the report based on the MOECC Terms of Reference for the municipal groundwater studies (MOECC, 2001). The study is described further in the section below.

The drinking water source protection Technical Rules, finalized in December 2009, included some changes to the original study parameters and therefore necessitated an update to the vulnerable areas to integrate with the requirements of the *Clean Water Act*. Golder Associates and WESA Inc. collaborated in providing the updated groundwater vulnerable areas for the Greater Sudbury Source Protection Area. The results are described later in this section.

Table 1.4 – Summary of intake protection zone vulnerability scoring

Type	Source Vulnerability Factor	Area Vulnerability Factor		
		IPZ-1	IPZ-2	IPZ-3
Type C	0.9 or 1.0	10	7 – 9	1 – 9
Type D	0.8 – 1.0	10	7 – 9	1 – 9

Municipal Groundwater Studies

As part of the MOECC Municipal Groundwater studies, groundwater flow models for all municipal water supply wells within the City of Greater Sudbury were created in accordance with the Technical Terms of Reference for Municipal Groundwater Studies (MOECC, 2001). The three-dimensional numerical groundwater flow modeling code MODFLOW/MODPATH was selected to estimate time-related capture zones for the wells within the city. Conceptual geologic models were developed for each area and were based on the MOECC Water Well Information System and other available geologic and hydrogeologic data.

In accordance with the terms of reference, the pumping rates used in the models were the maximum permitted pumping rates defined in the relevant permits to take water. The capture zones delineated included the 50-day, 2-yr, 10-yr and 25-yr time of travel zones.

The previous municipal groundwater study did not delineate a 5 year time of travel (WHPA-C) and did not include a 100 m buffer around the well (WHPA-A). Golder Associates updated each model to include these new vulnerable areas to be consistent with the Technical Rules. WHPA-E and Fs were also not delineated for wells designated as GUDI (Groundwater Under the Direct Influence of Surface Water). WESA Inc. delineated WHPA-Es based on HEC-RAS modeling and professional judgment as described in the surface water vulnerability process for the delineation of intake protection zone 2. It was not necessary to delineate any WHPA-Fs because no drinking water issues were identified for the GUDI wells. Further details are provided in Part 6 and Part 10 where GUDI wells are assessed.

Additionally, the municipal groundwater studies were modeled based on the maximum permitted pumping rates for each well as required by the terms of reference. This requirement was not part of the new Technical Rules and professional judgment can be applied to determine appropriate pumping rates to use in the groundwater models for the municipal wells. After considerable discussion, the technical team considered these pumping rates to be overly conservative because they are generally significantly higher than the observed recent pumping rates. Conversely, the average monthly pumping rate was considered inappropriate because it does not allow for any growth in the pumping rate or any uncertainty in the protection areas.

Wellhead Protection Area Delineation

The Technical Rules, finalized in December 2009 as part of the *Clean Water Act*, defined the wellhead protection areas based on different criteria than the original municipal groundwater studies. Rules 47 – 50 define how the wellhead protection areas to be delineated. Table 1.5 summarizes the delineation of each wellhead protection area.

The team decided to assess the protection areas based on the 95th percentile of the observed historic monthly pumping rates, or a pumping rate that was not exceeded 95% of the time. Use of these rates eliminates outlying data points without omitting a significant portion of the data. The resulting wellhead protection areas are conservative estimates based on actual pumping rates. Appendix 2 provides the details of the selection of appropriate pumping rates.

Subsequent to completion of the municipal groundwater study, WESA Inc. completed field investigations for the Vale Garson Mine Groundwater Characterization Study. Groundwater elevation data collected during the field investigations indicated that dewatering of the Garson mine affects groundwater flow directions in the vicinity of the municipal water supply wells. The original model created for the Garson municipal water supply wells did not incorporate this information and therefore, the resulting wellhead protection areas required updating. WESA Inc. updated the modeling for the Garson wells to include the additional information.

Table 1.5 – Description of wellhead protection areas for a Type I system. (See Rules 47 - 50)

Wellhead Protection Area	Description
WHPA-A	100 m radius centered on the well
WHPA-B	The time of travel is less than or equal to 2 years and excludes WHPA- A.
WHPA-C	The time of travel is less than or equal to 5 years, but greater than 2 years.
WHPA-D	The time of travel is less than or equal to 25 years but greater than 5 years.
WHPA-E	Applies only to GUDI* wells. An IPZ-2 is delineated as if an intake for the system were located: a) At the point of interaction between the groundwater supply and surface water directly influencing the supply; or b) At the point in the surface water body that is closest in proximity to the well if is not known.
WHPA-F	Applies only to GUDI* wells. An IPZ-3 is delineated as if an intake for the system were located in the surface water body in closest proximity to the well.

*GUDI refers to Groundwater Under the Direct Influence of Surface Water

Groundwater Vulnerability Assessment

To assess groundwater vulnerability, the Intrinsic Susceptibility Index (or ISI) was used. The index is based on the MOECC Water Well Information System (WWIS) database to produce a numerical score for each well in the database. The score is derived from the overburden soil type, thickness above the aquifer and the static water level in the well. The scores are then interpolated between the well locations to produce a spatial assessment of intrinsic vulnerability of groundwater.

Groundwater vulnerability in the Source Protection Area was assessed based on the WWIS where the density of wells provided some confidence in the results and surficial geology maps were used in areas that had sparse well records. Well density within most of the residential and agricultural areas of the City of Greater Sudbury was sufficient to allow the use of the well database. Well density outside of the residential and agricultural areas of the City of Greater Sudbury was sparse or zero and, therefore, aquifer vulnerability was assessed based on surficial geology. The resulting aquifer vulnerability for all areas was reviewed using professional judgment and local knowledge to ensure consistency with the intent of the Technical Rules. Aquifer vulnerability was assigned as low, medium or high based on available surficial geology maps, soil descriptions and local knowledge of the depositional environments.

The Technical Rules categorize aquifers into high, medium or low vulnerability (Rule 38). Using the ISI scores:

- Areas with **high** vulnerability are those with ISI scores that are **less than 30**,
- Areas with **medium** vulnerability are those with ISI scores that are **greater than or equal to 30 and less than or equal to 80**, and
- Areas with **low** vulnerability are those areas with ISI scores that are **greater than 80**.

For a full report regarding the specifics of the vulnerability assessment, please refer to Appendix 2. According to Rule 84, the vulnerability score within a WHPA- E must be defined following the rules for an IPZ-2. It is calculated as the product of the area vulnerability factor, which is defined based on the vulnerability area within the WHPA- E and the source vulnerability factor, which is defined based on the vulnerability of the intake.

Significant Groundwater Recharge Area Vulnerability Scores

Significant groundwater recharge areas are delineated as part of the Tier 1, Tier 2 and Tier 3 water budget process and vulnerability scores are assigned as part of the water quality risk assessment process. The methodology and results of the delineation and vulnerability assessment are in Chapter 12 for the Tier 1 results for the entire source protection area, and in Chapter 18 for Ramsey Lake Tier 1/2 and Tier 3 results and Chapter 33 for Valley East Tier 2 and Tier 3 results.

A summary of the data sources used for the groundwater vulnerability studies in provided in Appendix 6.

Highly Vulnerable Aquifer Delineation and Vulnerability Score

A highly vulnerable aquifer as defined in the Technical Rules is an area that has been identified with high vulnerability (Rule 43). A vulnerability score of 6 is given to this area (Rule 79). The highly vulnerable aquifers are delineated across the entire Greater Sudbury Source Protection Area.

Wellhead Protection Area Vulnerability Scores

Vulnerability for the wellhead protection areas is assessed based on Rules 82 to 84 of the Technical Rules. The results of the intrinsic susceptibility index method are used to give a numerical score to the wellhead protection area. Table 1.6 illustrates the scoring system used in this report.

Table 1.6 – Wellhead protection area vulnerability scores using the ISI method

Groundwater Vulnerability Category for the Area	WHPA-A	WHPA-B	WHPA-C	WHPA-D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

2.3 Water Quality Threats Assessment

The final step in determining the risk to water quality is a threats assessment. In the Technical Rules, there are three approaches to determining a threat to water quality. They are:

1. Drinking Water Quality Issues
2. Drinking Water Threat Activities
3. Drinking Water Condition

The methodologies for these approaches are described on the next page.

Drinking Water Quality Issues Approach

Rule 114 in the Technical Rules states that the presence of a parameter in water at a surface water intake or in a well is said to be a drinking water issue if the parameter is listed in schedule 1, 2 or 3 of the Ontario Drinking Water Standards or Table 4 of the Technical Support Document for the Ontario Drinking Water Standards and Guidelines and:

a) The parameter is present at a concentration that may result in the deterioration of the water quality of the water for use as a source of drinking water; or
b) There is a trend of increasing concentrations of the parameter at the surface water intake, well or monitoring well and a continuation of that trend would result in the deterioration of the quality.

To determine the existence of drinking water quality issues in the municipal wells and surface water intakes, raw water quality data collected from the drinking water supplies through the MOECC Drinking Water Surveillance Program (DWSP) was assessed. Data for the period 1991 to 2007 was subjected to trend analysis and compared to the Ontario Drinking Water Standards. Recorded confirmation of toxic cyanobacterial blooms (blue green algae) were also used to identify issues.

If an issue is identified, an issues contributing area is defined. The issues contributing area is the area where an activity or condition can contribute to the issue. Any activities listed in Table 1.7 or conditions that could contribute to the issue are identified as significant threats.

Drinking Water Threats Activities Approach

A drinking water threat is considered an activity or past activity that has the potential to impact drinking water quality.

There are four steps in identifying a drinking water threat through the threats activities approach. They are:

1. Listing of prescribed activities that are or would be drinking water threats
2. List circumstances for all is or would be significant, moderate or low drinking water threats for all vulnerable areas
3. Identify areas for significant, moderate and low drinking water threats
4. Enumeration of significant, moderate and low drinking water threats

List of Prescribed Drinking Water Threats

The list of prescribed drinking water threats is referenced in O.Reg. 287/07 s.1.1 paragraphs 1 through 18 and paragraph 21. Table 1.7 presents the prescribed drinking water threats.

List of Circumstances of Significant, Moderate and Low Threats

As required under Rule 111 and 112, a list of circumstances for all is or would be significant, moderate or low threats is to be generated for every vulnerable area. The threats tables list all prescribed threats with their associated circumstances that determine if a threat is significant, moderate or low. A hazard rating is given to each circumstance that is based on toxicity, environmental fate, method of release, quantity of chemical of concern and type of vulnerable area. The hazard score is then multiplied by the vulnerability score to determine the level of risk.

Hazard Score x **Vulnerability Score** = **Risk Score**

If the risk score is 80 or greater, the threat is significant. If the score is 60 but less than 80, the threat is moderate. If the risk score is 40 but less than 60, the threat is low.

As the list of associated circumstances for each vulnerable area is quite large, the MOECC has developed a list of reference tables for each combination of vulnerability score. These references are accessible via the source protection homepage at Ontario.ca or on the website http://swpip.ca/.

Table 1.7 – List of prescribed drinking water quality threats under O.Reg. 287/07 s.1.1

1	The establishment, operation, or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act.*
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.
3	The application of agricultural source material to land.
4	The storage of agricultural source material.
5	The management of agricultural source material.
6	The application of non-agricultural source material to land.
7	The handling and storage of non-agricultural source material.
8	The application of commercial fertilizer to land.
9	The handling and storage of commercial fertilizer.
10	The application of pesticide to land.
11	The handling and storage of pesticide.
12	The application of road salt.
13	The handling and storage of road salt.
14	The storage of snow.
15	The handling and storage of fuel.
16	The handling and storage of a dense non-aqueous phase liquid.
17	The handling and storage of an organic solvent.
18	The management of runoff that contains chemicals used in the de-icing of aircraft.
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s.3.

Identification of areas where significant, moderate or low threats can occur

- Areas with a vulnerability score of 8 or greater can have the potential for a significant, moderate or low threat.
- Areas with a vulnerability score of 6 or greater can have the potential for a moderate or low threat to occur.*
- Areas with a vulnerability score of 4 or greater can have the potential for a low threat to occur.*
- Areas with a vulnerability score of less than 4 cannot contain a drinking water threat.*

*DNAPLs are an exception because they are always a significant threat in WHPA-A, B, C/C1 regardless of the vulnerability score.

Enumeration of Significant, Moderate and Low Threats

The enumeration of threats takes into consideration the number of locations at which a person is engaging in an activity that is or would be a drinking water threat.

According to Rule 9 of the Technical Rules, an inventory of drinking water threats is required to be conducted for the vulnerable areas where a significant threat could occur. Initially, a prescreening was conducted to determine the circumstances and the areas where a significant threat could occur. A short list of properties where a significant threat could occur was generated based on orthophotos, municipal property information and vulnerability mapping. The short listed properties received notification via mail noting that a Nickel District Conservation Authority staff person may conduct a site visit to identify potential drinking water threats on their property. Site visits were conducted in the summer and fall of 2009.

Moderate and low threats were enumerated using a similar methodology. Prescreening using orthophotos, GIS layers, municipal property information and existing databases was used to identify properties were a threat may be occurring. Drive-by surveys were used to verify the threats in all WHPAs and IPZs. The exceptions were the SGRA and HVA where threats were not verified by field surveys due to the high quantity of threats and the time required to drive to these very large vulnerable areas.

Drinking Water Conditions Approach

A drinking water condition is a result from a past activity where any of the following situations occur:

1. The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area, or wellhead protection area.

2. The presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquids in surface water in a surface water intake protection zone.

3. The presence of a contaminant in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or a wellhead protection area, 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.

4. 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 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.

5. 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.

If there is evidence of off-site contamination, the condition is given a hazard score of 10. If there is no evidence, the condition is given a hazard score of 6.

Conditions may occur throughout the Greater Sudbury Source Protection Area, however, at the time of report production no information existed regarding evidence of off-site contamination and therefore were not included in this report.

Managed Lands

The percentage of managed lands was calculated for all vulnerable areas in order to evaluate this type of non-point source threat, as per Technical Rule 16. Percent of managed land was calculated using guidance from the Technical Bulletin entitled "Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers" issued by the Ontario Ministry of the Environment and Climate Change in December 2009. A separate percentage of managed land was calculated for each vulnerable area with a score of 6 or above.

The following steps were used to calculate the percentage of managed lands:

1. Managed lands were categorized into two groups: agricultural managed land and non-agricultural managed land. Agricultural managed land includes areas of cropland, and fallow and improved pasture that may receive nutrients. Non-agricultural managed land includes golf courses, sports fields, lawns in residential areas and other built-up grassed areas that may receive nutrients, primarily commercial fertilizer (MOECC Technical Bulletin, 2009).

   A Ministry of Natural Resources and Forestry land cover database was used to calculate the amount of agricultural land. Visual inspection using 2007 orthophotography was used to define non-agricultural lands that could receive nutrients. For residential areas it was estimated that grassed areas comprised 60% of the property.

2. The amount of agricultural land and non-agricultural land that could receive nutrients was calculated for each vulnerable area. It was divided by the size of the vulnerable area to obtain the percentage of managed land.

3. Each vulnerable area fell into one of three risk categories:
   - Low potential risk – managed lands < 40% of vulnerable area;
   - Moderate potential risk – managed lands between 40% to 80% of vulnerable area; and
   - High potential risk – managed lands > 80% of vulnerable area.

Livestock Density

Nutrient units per acre were calculated for all vulnerable areas in order to evaluate this type of non-point source threat, as per Technical Rule 16. The method for calculating livestock density follows the Technical Bulletin entitled "Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density for Land Application of Agricultural Source of Material, Non-Agricultural Source of Material and Commercial Fertilizers" issued by the Ontario Ministry of the Environment and Climate Change in December 2009. A separate percentage of managed land was calculated for each vulnerable area with a score of 6 or above.

The calculation of livestock density involved three steps (MOECC Technical Bulletin, 2009) and was estimated as follows:

1. Estimate the number of each category of animals present within the specified area. In the absence of existing information about number of livestock, a Municipal Property Assessment Corporation (MPAC) database was used to identify agricultural properties. Barn size on the property was used as an indicator of livestock density. An estimate of barn size was calculated.

2. Convert the number of each category present into nutrient units in order to compare all livestock on an equivalent unit of measure in terms of nutrients produced.

   This was done using conversion factors from the MOECC Technical Bulletin.

3. Sum the total nutrient units of all categories and divide the resulting nutrient unit's value by the area of agricultural managed land within the same area. A nutrient unit per acre value was calculated for all vulnerable areas. Results can fall into one of three categories: < 0.5 NU/acre, 0.5 to <1 NU/acre, and >1NU/acre.

Impervious Surfaces

The percentage of impervious surface areas was calculated for all vulnerable areas in order to evaluate road salt as a non-point source threat, as per Technical Rule 16. A map was created for each vulnerable area showing the percentage of impervious surface area per square kilometre where road salt can be applied.

The percentage of impervious area was calculated using a one kilometre grid overlay. Residential roads were given a width of 8 meters and major roads were given a width of 10 meters. Information on parking lots, pedestrian walkways and other related surfaces that may also receive road salt were not considered as data was not available for these features within the study area. The exception is within the Ramsey Lake watershed where information of these features was available from the City of Greater Sudbury.

The percentage of impervious surface for each grid square was calculated and fell into one of four categories: < 1% impervious; 1% to < 8% impervious; 8% to < 80% impervious and ≥ 80% impervious.

Addition of a Local Threat – Transportation Corridors

In addition to the 21 water quality and water quantity threats identified in the MOECC table of drinking water threats, source protection committees have the ability to request that local threats be added to their assessment report.

Under Technical Rule 119, a source protection committee can request that the Director allow an activity to be listed as a threat if:

1. The activity has been identified by the source protection committee as an activity that may be a drinking water threat; and

2. The Director indicates that the chemical hazard or pathogen hazard rating of the activity is greater than 4.

The Greater Sudbury Source Protection Committee had concerns regarding major transportation corridors which run through many of the municipal drinking water vulnerable areas within the Greater Sudbury Source Protection Area. These include railway corridors within IPZs 1, 2 and 3 of the Ramsey Lake watershed, IPZs 1 and 2 for the Wanapitei River intake, WHPA C of the Capreol wellhead areas and WHPA-B of the Onaping wellhead area. A number of major roadways also cross through vulnerable areas in the Ramsey Lake watershed, the Wanapitei River watershed, the Valley well fields, and the Garson and Dowling well areas. Dangerous and/or hazardous goods are transported on both the railway corridors and the roadways, and the potential exists for a spill.

Due to the potential for a spill to occur, the Greater Sudbury Source Protection Committee requested that the transportation of hazardous substances along transportation corridors be included in the Greater Sudbury Source Protection Area Assessment Report as a non-prescribed threat. The Committee felt it was important that the transportation of hazardous substances in areas of close proximity to municipal drinking water sources be considered a significant threat to enable the inclusion of appropriate mandatory policies in the source protection plan.

The Director of the Source Protection Programs Branch agreed to allow the local threat of transportation of hazardous substances along transportation corridors to be considered a drinking water threat in the Greater Sudbury Source Protection Area. Transportation of hazardous materials as a threat considers the following circumstances:

- Transportation of sulphuric acid by freight tank
- Transportation of liquid fuel by tanker truck
- Transportation of liquid fuel by freight tank
- Transportation of septage

A copy of the request letter and rationale from the Greater Sudbury Source Protection Committee and the response letter from the Director are in Appendix 7. The documentation in Appendix 7 also includes the circumstances and hazard rating of included activities.

Chapter 3 - Water Quantity Risk Assessment

A water balance in its simplest term is an evaluation of the inputs and outputs of a system. In theory, the inputs and outputs should balance over a period of time. If the inputs are less than the outputs, the water supply is depleted and can become limited. The Water Quantity Risk Assessment is a process to evaluate if the supply system is under threat of not having sufficient water to adequately meet capacity demands.

A water budget can be described as:

$$\Delta S = P + Q_{SIN} + Q_{GIN} + Anth_{IN} - ET - Q_{SOUT} - Q_{GOUT} - Anth_{OUT}$$

where ΔS is change in storage, P is precipitation, Q_{SIN} is surface water input, Q_{GIN} is groundwater input, $Anth_{IN}$ is anthropogenic input, Q_{SOUT} is surface water output, Q_{GOUT} is groundwater output and $Anth_{OUT}$ is anthropogenic output. Evapotranspiration (ET) occurs at its potential rate (PET) when water is freely available and the evaporating air mass is stable. aSoil moisture conditions can restrict evapotranspiration to an actual rate (AET). Over the course of a month or a day, these terms vary in their contributions to change in storage (ΔS).

Water quantity stress assessments for this report were calculated using the formula:

$$WaterQuantityStress\,(\%) = \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} x100$$

where Q_{DEMAND} is the consumptive demand, Q_{SUPPLY} is the water supply, and $Q_{RESERVE}$ is the water reserve.

3.1 Overview of Water Budget and Stress Assessment Framework

The water budget and stress assessment followed a tiered approach. Figure 1.1 outlines the process. A conceptual water budget outlines the basic movement of water throughout the Greater Sudbury Source Protection Area. Next, a Tier 1 water budget and stress assessment was completed for the three main watersheds: the Vermilion, Wanapitei and Whitefish River watersheds. In addition, due to the isolated nature of the municipal water supplies, a Tier 1 assessment was completed for each drinking water system. The Tier 1 used a simple water budget to calculate stress within each watershed based on a series of scenarios as listed in Table 1.8. If the system was deemed to be a significant or moderate stress, it progressed to a Tier 2 water budget and stress assessment.

A Tier 2 water budget and stress assessment was completed for the David Street and the Valley East drinking water systems. The Tier 2 refined the water budget and assessed the level of stress based on scenarios A to I as listed in the following table. Both of these systems progressed to a Tier 3 level based on the evaluated level of stress.

The Tier 3 or Local Area Risk Assessment delineates water quantity vulnerable areas. An intake protection zone – Q (IPZ-Q) is delineated for surface intakes and a wellhead protection area – Q

(WHPA-Q) is delineated for municipal wells. Exposure and tolerance of the intake or well based on certain scenarios are assessed to determine level of risk. If a significant water quantity risk is assessed, water quantity threats are evaluated.

Significant groundwater recharge areas are delineated as part of the Tier 1, Tier 2 and Tier 3 water budget process and vulnerability scores are assigned as part of the water quality risk assessment process.

Full details for the methodology and results for the Tier 1, Tier 2 and Tier 3 work are in Appendix 2. The methodology and results of the delineation and vulnerability assessment are in Chapter 12 for the Tier 1 results for the entire source protection area, and in Chapter 18 for Ramsey Lake Tier 1/2 and Tier 3 results and Chapter 33 for Valley East Tier 2 and the Valley Tier 3 results.

A summary of data sources used for the water budget studies is provided in Appendix 6.

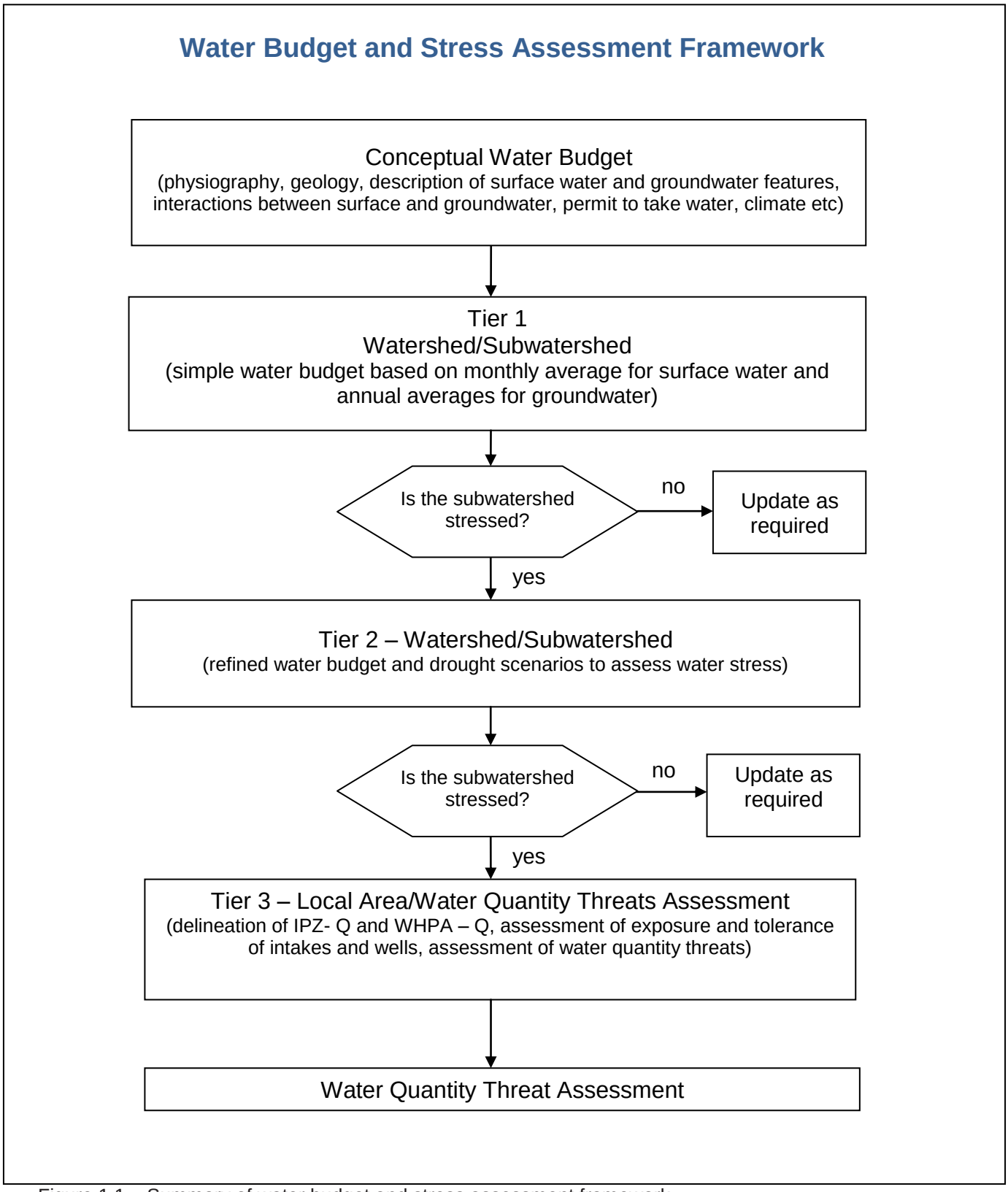

Figure 1.1 – Summary of water budget and stress assessment framework

Table 1.8 – Summary of water budget and stress scenarios used for Tier 1 and Tier 2

Scenario	Description of the Scenario	Data Restrictions - Demand	Data Restrictions - Supply and Reserve
A	Existing system-average		Data related to climate and stream flow shall be the historical data set for climate and stream flow.
B	Existing system-future demand	Data related to demand, associated with an existing type I, II or III system within the subwatershed shall be reflective of the demand that would exist in the year that the planned system will be operational.	Data related to climate and stream flow shall be historical data set for climate and stream flow. Data related to land cover shall be reflective of the future development in the subwatershed.
C	Planned system demand – operational year	Data related to demand associated with an existing type I, II or III system within the subwatershed shall be reflective of the demand that would exist in the year that the planned system will be operational.	Data set related to climate and stream flow shall be the historical data set for climate and stream flow. Data related land cover shall be reflective of the year that the planned system will be operational.
D	Existing system – two year drought		Data related to climate and stream flow shall be reflective of the two year drought period.
E	Existing system – future two year drought	Data related to demand associated with an existing type I, II or III system within the subwatershed shall be reflective of the future development in the subwatershed.	Data related to climate and stream flow shall be reflective of the two year drought period. Data related to land cover shall be reflective of the future development in the subwatershed.
F	Planned system – operational year – two year drought	Data related to demand associated with an existing type I, II or III system within the subwatershed shall be reflective of the demand that would exist in the year that the planned system will be operational.	Data related to climate and stream flow shall be reflective of the two year drought period. Data related to land cover shall be reflective of the future development that would exist in the subwatershed in the year that the planned system will be operational.
G	Existing system – ten year drought		Data related to climate and stream flow shall be reflective of the ten year drought period.
H	Existing system – future ten year drought	Data related to demand associated with an existing type I, II, or III system within the subwatershed shall be reflective of the future development in the subwatershed.	Data related to climate and stream flow shall be reflective of the ten year drought period. Data related to land cover shall be reflective of the future development in the subwatershed.
I	Planned system – operational year – ten year drought	Data related to demand associated with an existing type I, II, or III system within the subwatershed shall be reflective of the demand that would exist in the year that the planned system will be operational.	Data related to climate and stream flow shall be reflective of the ten year drought period. Data related to land cover shall be reflective of the future development that would exist in the subwatershed in the year that the planned system will be operational.

Conceptual Water Budget

The conceptual water budget for the Greater Sudbury Source Protection Area was completed in 2006. It contains general information about the flow, volume and bodies of water within the Vermilion, Wanapitei and Whitefish River watersheds. Appendix 2 contains the full report.

Components of the conceptual water budget report can be found in Part 2 of this document. In particular, the geology, hydrology, hydrogeology and water use chapters describe the findings of the conceptual water budget.

Tier 1 Water Budget and Stress Assessment

The Tier 1 Water Budget and Stress Assessment were calculated for the Vermilion, Wanapitei and Whitefish River watersheds by Golder Associates. The results are found in Part 2, Chapter 13 of this report. Tier 1 water budgets and stress assessments were also calculated for each drinking water system due to the isolated nature of each system. For the full report, please refer to Appendix 2.

Separate stress assessments were performed for surface water and groundwater systems in each study subwatershed. The Tier 1 stress assessment is a screening level calculation to define subwatersheds that may be at risk of failing to provide a sustainable supply of water. Stress at each study subwatershed was calculated under two scenarios: 1) current water supply and demand; and 2) future water supply and demand.

Water Budget Model Structure

All terms for the Tier 1 water budget calculations were integrated over a catchment area and reported as equivalent water depths (mm), volumes (m3) or water fluxes (m3/s).

A spreadsheet model was constructed and monthly and annual water budgets were prepared using a soil moisture balance (Holmes and Robertson 1959; Strahler and Strahler 1997). The soil moisture balance was used because it requires data readily available for the Sudbury area (e.g. temperature, precipitation, streamflow). This spreadsheet-type model presents an average measure of the conditions over a watershed and does not account for spatial heterogeneity within the study area.

The model was run for a 35-year period (1970-2005) and utilized a monthly water budget to estimate recharge, evapotranspiration, and surface soil storage capacity. Subsequent sections in this assessment report describe the model structure and specific data requirements for Tier 1 model inputs.

The general model procedure was as follows:

1. Soil water holding capacity was estimated by weighting surficial geology type over the study watershed.

2. Precipitation (P) was applied to the watershed; either as rainfall or snowmelt on a monthly basis.

3. Potential Evapotranspiration (PET) was determined by the Thornthwaite temperature index model as described in (Thornthwaite and Mather 1957). If P>PET, the water surplus was calculated as P-PET. If P<PET, water is removed from soil at actual evapotranspiration (AET), where AET<PET. The water deficit was calculated as P-AET.

4. Streamflow (QS) was separated into baseflow (QB) and surface runoff (RO).

If a water surplus was predicted when P-AET-RO>0, water was first used to fill soil water storage. If soil water holding capacity was at its maximum, the remaining water was assigned to groundwater recharge (QR). Recharge did not occur during December, January or February when soils were assumed frozen.

Water Stress Assessment

At the Tier 1 level, it was assumed that the current water supply was equivalent to the future water supply. It was also assumed that only municipal demand could be forecast based on 20-year population scenarios. Other water demands, such as industrial or agricultural, were not forecast due to the associated high uncertainty.

Stress levels were assigned based on the percent water demand as listed in Table 1.9.

Table 1.9 – Water stress level assignments for surface water and groundwater for scenarios A and B

	Surface Water	Groundwater	
	Maximum Monthly % Water Demand	Annual % Water Demand	Maximum Monthly % Water Demand
Significant	≥50%	≥25%	≥50%
Moderate	>20% to <50%	>10% to <25%	>25% to <50%
Low	≤20%	≤10%	≤25%

Tier 2 Water Budget and Stress Assessment

Within the Greater Sudbury Source Protection Area, two drinking water systems, the Valley East wells and the David Street intake in Ramsey Lake proceeded to the Tier 2 water budget and stress assessment process.

In general, the Tier 2 Water Budget and Stress Assessment aimed to refine the water budget analysis and include Scenarios A to I to assess stress to the water supply.

As the methodology for these two systems differed greatly, the process is described in greater detail in Part 3 – David Street Drinking Water System and Part 6 – Valley Drinking Water System.

Tier 3 Water Budget and Local Area Risk Assessment

After completion of the Tier 2 analysis, both the Valley system and the David Street intake proceeded to the Tier 3 water budget and stress assessment process.

The Tier 3 Water Budget and Risk Assessment broadly aimed at providing simulated water levels and water removals for the Valley system and David Street intake. These analyses, including the scenarios used, and the results are described in Part 3 – David Street Drinking Water System and Part 6 – Valley Drinking Water System.

A significant water quantity risk was assessed for the Valley drinking water system, so water quantity threats were evaluated. Table 1.10 shows the two water quantity threats (prescribed threats # 19 and # 20) under the *Clean Water Act*.

Table 1.10 – Prescribed drinking water quantity threats under O.Reg. 287/07 s.1.1

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.
20	An activity that reduces recharge to an aquifer.

Part X, Table 5 of the Technical Rules lists the circumstances for the water quantity threats.