Chapter 3: Water Budget and Water Quantity Risk Assessment Chapter

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Disclaimer: This chapter has not been significantly edited or changed as a result of updated Technical Rules as the water budgets were completed based on the 2008 Technical Rules and have not been redone since. Therefore, this chapter reflects the 2008 Technical Rules and the names of provincial Ministries at that time.

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3 Water Budget and stress assessment summary

A component of the assessment report and ultimately the Source Protection plans will be specific to water quantity management. The goals of this assessment are to identify watershed communities where the sustainability of water supplies is questionable and to highlight key factors that may limit the sustainability, such that appropriate risk management activities can be completed.

A water budget is an understanding and accounting of the movement of water and the uses of water over time, on, through, and below the surface of the earth. The water budget analysis in this chapter addresses all of the following questions.

1) Where is the water (i.e. where are the various watershed hydrologic elements (e.g. soils, aquifers, streams, lakes, located?))
2) How does the water move between these elements? (I.e. what are the pathways through which the water travels?);
3) What and where are the stresses on the water? (i.e. where are the water takings?); and
4) What are the trends (i.e. are levels declining, increasing, or remaining constant over time?).

The water budgets within this Chapter were prepared as per the *Clean Water Act, 2006,* Ontario Regulation 287/07- General and Technical Rules: Assessment Report December, 2008 as amended November, 2009 and have been developed to accommodate all of the following considerations:

- The amount of water within the various reservoirs of the hydrologic cycle, including precipitation, evapotranspiration, runoff, groundwater inflow and outflow, surface water inflow and outflow, change in storage, water withdrawals and water returns.
- A description of groundwater and surface water flow pathways, and temporal, seasonal and annual changes in water quantities within each reservoir.
- Identification of areas of key hydrologic processes and the availability of potential water sources.
- Support for predicted changes in the hydrologic cycle due to trends in climate, land use and additional takings.

Building on a conceptual understanding of the study area, the water quantity assessment is based on a three-tiered approach, with each step being more detailed and providing more certainty than the previous one. These steps include:

1) Conceptual Water Budget
2) Tier One Water Budget and Water Quantity Stress Assessment
3) Tier Two Water Budget and Water Quantity Stress Assessment

4) Tier Three Water Quantity Risk Assessment.

This tiered process ensures watershed communities complete the degree of assessment consistent with local water quantity issues. The Conceptual and Tier One evaluations are required for the entire Source Protection Region, and in areas where the availability of water far outweighs the demand, this simplified approach (Tier One) is sufficient for decision-making and further efforts are not required. Whereas, Tier Two and Tier Three assessments provide a more thorough understanding of the hydrologic system for managing resources but are only required for those subwatersheds where stress is identified in the previous evaluation (e.g. Tier One assessment) and where there is a municipal drinking water supply system within that subwatershed. These detailed assessments are focused on better quantifying the availability of water for water supply (in relation to other permitted and ecological requirements) and the consumptive demand. Assessment scenarios are designed to assess the sustainability of supplies under existing, future and drought conditions. How the subwatersheds and municipalities are moving through the tiered process are summarized on Table 3.0 - 1.

The framework for the Water Budget and Water Quantity Risk Assessment process is illustrated on Figure 3.0- 1. The process involves four stages of evaluation, each on successively advancing the degree of technical complexity. This framework requires a basic level of understanding to effectively address issues and prepare Source Protection Plans. Therefore, a Conceptual Water Budget and Tier One (simple water budget analysis) was completed for the entire Severn Sound Source Protection Area.

Those subwatersheds that were identified as exceeding the prescribed threshold for potential stress and contain municipal drinking water systems advanced to a more complex Tier Two water budget analysis. The goal of the Tier Two assessment is to confirm or negate the stress assignment completed in the Tier One using a more detailed approach that includes complex numerical modeling for groundwater systems and a detailed time-continuous modeling for surface water systems. The role of the Tier Two assessment is to refine the estimation of water budget components to facilitate a more reliable stress assessment and allow subwatersheds with marginal stress levels to avoid the detailed local assessment in Tier Three. Tier Two assessments have been completed for the following subwatersheds:

1) Midland Area
2) Penetanguishene and Tay Point
3) Tiny Coastal Area North West
4) Wye River

The Tier Three Water budget and Water Quantity Risk Assessments will be carried out for municipal groundwater systems that are located within subwatersheds that have been assigned a Tier Two moderate or significant potential level of stress. Water quantity risk refers to the likelihood that threats to water quantity may render an existing or planned drinking water source impaired, unusable or unsustainable. The objective of the Tier Three assessment is to evaluate the risk that a community may not be able to meet its existing or future water demand from a water source (e.g., stream, lake, or aquifer). Several subwatersheds in the Severn Sound watershed have been identified for further evaluation and will be undergoing Tier Three Water Budget and Water Quantity Risk Assessments. Theses subwatersheds include:

1) Midland Area
2) Penetanguishene and Tay Point
3) Copeland Creek
4) Penetang Bay West

The MNR funding agreement to complete the water budget requirement of the Clean Water Act requires each of the water budget studies discussed in this chapter to undergo a peer review process by a team of qualified professionals. The objectives of the peer review process is to ensure consistency with the expectations of the Technical Rules, to ensure appropriate methodologies are utilized and that the technical assumptions are necessary and reasonable and to ensure the products are scientifically defensible. The roles and objectives of the peer review team are discussed further in Section 3.6.

Table 3.0 - 1: Subwatershed and Municipal Summary of the Water Budget and Risk Assessment Process.

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System	Conceptual	Tier 1	Tier 2	Tier 3
Coldwater River	Simcoe County	Township of Oro-Medonte	Yes (GW)	√	√		
Coldwater River	Simcoe County	Township of Severn	Yes (GW)	√	√		
Copeland Creek	Simcoe County	Township of Tiny	Yes (GW)	√	√		
Copeland Creek	Simcoe County	Town of Penetanguishene	Yes (GW)	√	√		
Hogg Bay	Simcoe County	Township of Oro-Medonte	No	√	√		
Hogg Bay	Simcoe County	Township of Tay	Yes (SW)	√	√		
Hogg Bay	Simcoe County	Township of Springwater	No	√	√		
Hogg Bay	Simcoe County	Township of Tiny	No	√	√		
Honey Harbour to Port Severn	Muskoka	Georgian Bay Township	No	√	√		
Lafontaine Creek	Simcoe County	Township of Tiny	No	√	√		
Midland Area	Simcoe County	Town of Midland	Yes (GW)	√	√	√	√
North River	Simcoe County	Township of Oro-Medonte	Yes (GW)	√	√		
North River	Simcoe County	City of Orillia	Yes (GW)	√	√		
North River	Simcoe County	Township of Severn	Yes (GW)	√	√		
Penetang. Bay West	Simcoe County	Town of Penetanguishene	Yes (GW)	√	√		
Penetang. Bay West	Simcoe County	Town of Midland	Yes (GW)	√	√		
Penetanguishene and Tay Point	Simcoe County	Town of Penetanguishene	Yes (GW)	√	√	√	√
Penetanguishene and Tay Point	Simcoe County	Town of Midland	Yes (GW)	√	√	√	√
Port Severn and Matchedash Bay N	Simcoe County	Township of Severn	No	√	√		
Port Severn and Matchedash Bay N	Simcoe County	Township of Tay	Yes (SW)	√	√		
Sturgeon River	Simcoe County	Township of Springwater	Yes (GW)	√	√		
Tiffin Basin and Port McNicoll	Simcoe County	Township of Tay	Yes (GW)	√	√		
Tiny Coastal Area NW	Simcoe County	Township of Tiny	Yes (GW)	√	√	√	

Subwatershed	Upper Tier Municipality	Lower Tier Municipality	Municipal Drinking Water System	Conceptual	Tier 1	Tier 2	Tier 3
Tiny Coastal Area S	Simcoe County	Township of Tiny	Yes (GW)	√	√		
Tiny Coastal Area W Central	Simcoe County	Township of Tiny	Yes (GW)	√	√		
Tiny Coastal Area NE	Simcoe County	Township of Tiny	Yes (GW)	√	√		
Victoria Harbour Area	Simcoe County	Township of Tay	Yes (GW)	√	√		
Waubaushene and Matchedash	Simcoe County	Township of Tay	Yes (GW)	√			
Wye River	Simcoe County	Town of Midland	Yes (GW)	√	√	√	√
Wye River	Simcoe County	Township of Tiny	Yes (GW)	√	√	√	
Wye River	Simcoe County	Township of Springwater	Yes (GW)	√	√	√	

*Note: All subwatersheds are required to undergo a Conceptual and Tier 1 analysis. Subwatershed that are not moving beyond the Tier 1 analysis do not have a municipal groundwater system, and/or were found not to be stressed.

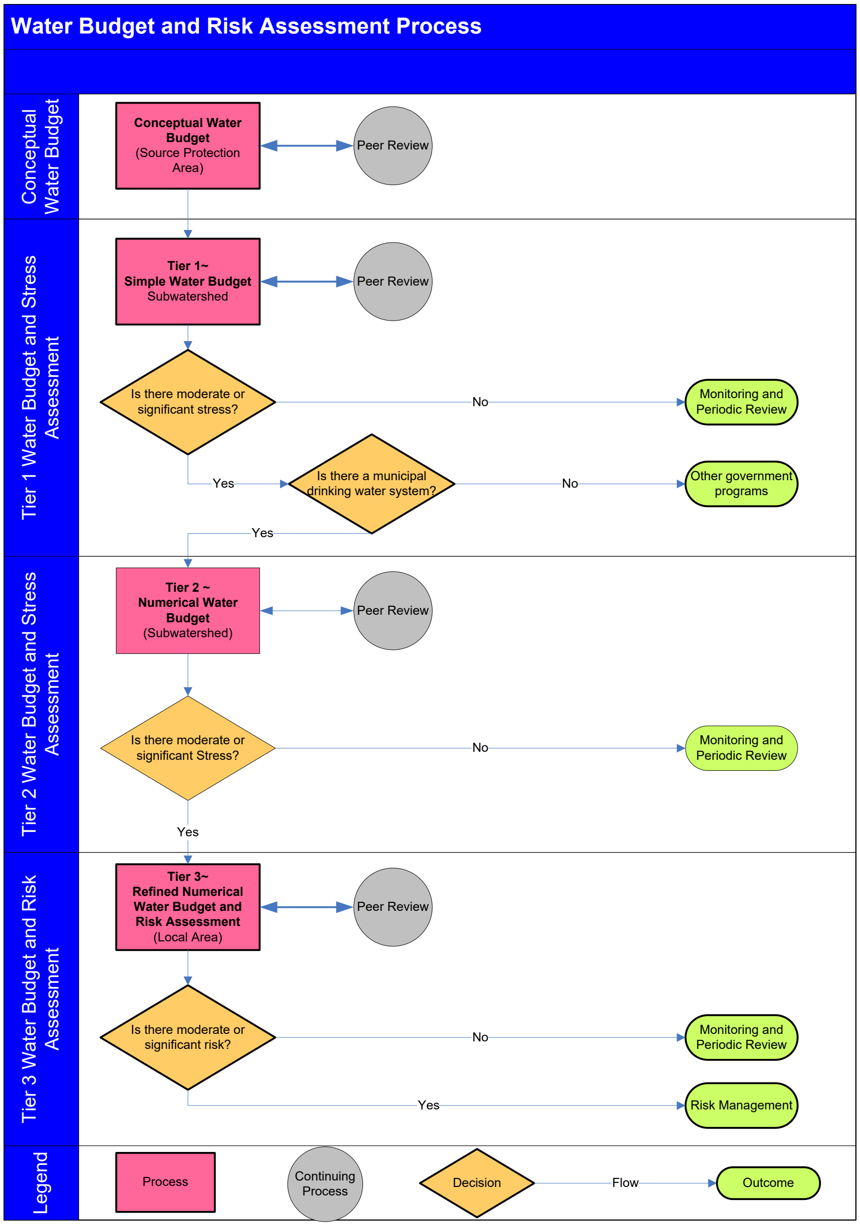

Figure 3.0- 1: Water Budget and Risk Assessment Process

3.1 Conceptual water budget

The Conceptual Water Budget is the initial step in the water quantity and risk assessment process. It provides an overview of how the flow system functions and quantifies the amount of water moving within various components of the hydrologic cycle. These components include:

- Precipitation, evaporation and transpiration;
- Infiltration (water that moves from the ground surface vertically downward into the soil);
- Recharge (water that infiltrates into the ground and becomes part of the groundwater flow system);
- Runoff

In addition to estimating the above inputs and outputs within the watershed, the Conceptual Water Budget must include an understanding of the hydrologic regime and therefore describe:

- Physiography and geology;
- Surface water and groundwater features;
- Land cover;
- Human-made structures (dams, channel diversion, etc); and
- Water takings.

The following subsections discuss the elements of the Conceptual Water Budget. The Conceptual Water Budget prepared for the South Georgian Bay-Lake Simcoe Source Protection Region was used as the guiding document for this section of the assessment report.

3.1.1 Geology and Physiography

This section of the report provides an overview of the physiographic regions and discusses the bedrock and Quaternary geology present within the Lake Simcoe watershed. An understanding of the relationships that make up the physical setting is paramount, as these relationships are the building blocks used to create a digital three-dimensional (3D) geologic and/or hydrostratigraphic frame work models within the Tier Two and Tier Three studies. It is anticipated that these 3D models will be used as tools in the Permit to Take Water Process (PTTW), a variety of planning and land-use applications, groundwater exploration programs, and more importantly, to ensure that sufficient quantities of potable water exist for future use.

Physiography

Physiography is the study of the physical structure of the surface of the land. The study of physiography is important from a drinking water perspective as the knowledge gained from knowing the land compositions aids hydrogeologists in understanding the groundwater and surface water flow systems. Information used to complete this section of the report has been obtained from Chapman and Putnam [1](1984). The physiographic regions identified by Chapman and Putnam (1984) were the results of a regional scale investigation that encompassed all of Southern and Eastern Ontario.

The Severn Sound watershed is located within three (3) regional-scale physiographic regions as defined by Chapman and Putnam (1984; (Figure 3.1- 1 ; figures are located at the end of each water budget)). These include the Carden plain, Simcoe Uplands and the Georgian Bay Fringe.

Carden Plain

The Carden Plain, also referred to informally as Barren Terrain, is an extensive limestone plain that extends east of Lake Couchiching to the community of Burnt River. Outcrops of limestone and dolostone that occur at surface display numerous fractures (*that are oriented orthogonal to primary bedding planes*), dissolution weathering features, and pop-up structures are commonly associated with Karst terrain. Glacial sediments within the plain occur as a discontinuous veneer of diamicton (slightly silty to silty sand) that is typically less than 1 m in thickness. Landforms associated with glacial Lake Algonquin, such as beach ridges, wave-cut notches, are present within the regime but are considered rare.

Simcoe Uplands

The Simcoe Uplands comprise of a series of broad, rolling drumlinized till plains that are separated by numerous steep-walled, flat-floored valleys. The Simcoe Uplands have also been referred to as the Algonquin Islands by Deane (1950). As suggested by the name these regions formed islands within glacial Lake Algonquin. The uplands occupy a total surface area of 1,035 km^2 and are located south of the community of Barrie, north of Alliston and in the northern portions of Oro-Medonte and Springwater Townships. The uplands are commonly encircled by numerous shorelines and other morphological features associated with glacial Lake Algonquin and its successors. Shorelines and wave-cut notches located above the highest Lake Algonquin water plain are associated with glacial Lake Schomberg or possibly the Main Algonquin phase of glacial Lake Algonquin.

Georgian Bay Fringe

The Georgian Bay fringe is a broad physiographic regime bordering Georgian Bay. It is characterized by outcrops of Precambrian-aged bedrock and a discontinuous veneer of sediment, typically less than 1 m in thickness. The lack of sediment within this regime is based on two main factors. First, areas in the northern portion of the regime are topographically higher than the highest lake level of glacial Lake Algonquin; therefore, fine-grained glaciolacustrine deposits commonly found in adjacent physiographic regimes are not present. Second, the southern portion of this regime, although topographically lower than the highest Algonquin lake level, is predominantly composed of exposed outcrops of bare bedrock. These

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[1] Chapman and Putnam were the first leading researchers to map the physiography of Southern Ontario. There work has been and still is considered to be a vital reference in understanding the physical structure of Southern Ontario.

have been interpreted as being “washed” products of glacial Lake Algonquin (Chapman and Putnam, 1984).

Topography

Ground surface topography within the Severn Sound watershed ranges from approximately 380 metres above sea level (mASL) to 180 mASL. The topography of the watershed closely corresponds to the physiographic regions that make up the watershed. Areas of hummocky topography with their associated closed depressions are unique areas, typically found in moraines. They are important from a groundwater perspective in that they tend to focus recharge (Davies et al, 2008). The topography of the Severn Sound watershed is depicted on Figure 3.1-2 and the Hummocky topography of the watershed is depicted on Figure 3.1-3.

Geology

An understanding of how water moves through a watershed is at the heart of Source Water Protection. In order to assess groundwater processes, as well as, interactions between groundwater and surface water, a thorough understanding of the geological setting in a watershed is necessary. The bedrock, sediments and soils present in the watershed will determine how and where the groundwater will flow. They will also influence the vulnerability an aquifer may have to potential contaminants. For example, an aquifer capped with a non-porous material such as clay will have a lower vulnerability score than one capped with a porous material. This is to due to inability of many materials to readily move though non-porous materials. The geology of the Severn Sound watershed can be generally described as being comprised of unconsolidated overburden, deposited during the Quaternary Period, overlying Paleozoic and Precambrian bedrock. Some bedrock outcropping occurs in the northern portion of the study area. Below is a more detailed explanation of both the bedrock and quaternary geology.

Bedrock Geology

The bedrock geology within the Severn Sound watershed is illustrated on Figure 3.1-4 , and the bedrock topography can be seen on Figure 3.1-5. The bedrock geology of the Severn Sound watershed consists of Precambrian bedrock at depth overlain by Paleozoic bedrock of middle Ordovician age.

Precambrian Geology

Outliers of Precambrian bedrock are present only in the northern part of the study area. In the Township of Oro-Medonte, numerous outcrops consisting of granites, gneisses and migmatite are present (Liberty, 1969; Sanford and Baer, 1981). According to Chapman and Putnam (1984), outcrops of Precambrian aged metavolcanics also occur at surface in this area.

Precambrian aged rocks of the Grenville Structural Province that occur within the study area are subdivided into the Grenville Front Tectonic Zone, the Central Gneiss Belt and the Central Metasedimentary Belt (Sanford and Baer, 1981). Rocks of the Central Gneiss Belt are located in the north and northwestern regions of the study area and are separated from rocks of the Central Medisedimentary Belt trend by a series of north-west trending faults. Outliers of metasedimentary rocks outcrop at surface in the northeastern portion of the study area. The Central Metasedimentary Belt is comprised of the following units in the area: (1) clastic metasedimentary rocks, predominantly conglomerates, wackestones, limestones and mudstones and (2) early felsic plutonic rocks such as granodiorite and derived gneisses (Sanford and Baer, 1981).

The Central Gneiss Belt is predominantly composed of three different rock units within the study area. These are (1) undifferentiated gneisses and migmatites; (2) anorthosites and alkalic igneous rocks; and (3) felsic igneous rocks that may contain tonalite, granodiorite, monzonite, syenite and derived gneisses (Sanford and Baer, 1981). In the western portion of the study area, rocks of the Grenville Structural Province are separated from the main body of Paleozoic rocks by the Black River Escarpment. This structure can be traced from Uhthoff, westward through Foxmead to Fesserton (Liberty, 1969). South of the escarpment, younger Paleozoic (Middle Ordovician) rocks of the Simcoe Group unconformably overlie Precambrian rocks. These include the Shadow Lake, Gull River, Bobcaygeon, and Verulam Formations (Johnson et al., 1992).

Palaeozoic Geology

The Palaeozoic Geology of the Severn Sound watershed consists of the Shadow Lake and Simcoe Group formations. The Shadow Lake Formation has been referred to as part of the 'Basal Group' by Liberty (1969); as it forms the upper-most unit of a group of sandstones and arkoses that uncomfortably overlie Precambrian aged rocks of the Laurentian Shield. The formation is characterized by greenish-grey, coarse-grained sandstones (calcareous arkoses), that are overlain by red and green erinaceous mudstones.

The Shadow Lake Formation is overlain by the Gull River, Bobcaygeon, and Verulam formations, which are collectively referred to as the Simcoe Group. The Simcoe Group predominantly composed of argillaceous and sub lithographic, or lithographic limestone and calcarenite with minor mudstone and claystone (Liberty, 1969; Johnson et al., 1992).

Quaternary Geology

The quaternary geology is represented as the surficial geology within the Severn Sound watershed. The surficial geology consists of glacial sediments deposited in the Quaternary period (Figure 3.1-6). The glacial deposits in the study area were most likely deposited from the Northern and Georgian Bay lobes of the Laurentide Ice Sheet (LIS) during or after the Port Bruce Stadial (Deane, 1950; Gravenor, 1957). However, pre-Late Wisconsinan deposits likely exist at depth (Barnett, 1991). A detailed discussion on the Glacial History of the South Georgian Bay-Lake Simcoe Source Protection Area is found in the 2007 SGBLS Conceptual Water Budget (SGBLS).

Overburden Thickness

The Quaternary sediment thickness reflects the difference between the ground surface and the interpolated bedrock surface. The Quaternary sediment thickness map for the watershed is illustrated on Figure 3.1-7. In a similar fashion to how the top of the Precambrian surface influenced the accumulation of Paleozoic sediment, the Paleozoic bedrock topography also appears to strongly influence the overlying Quaternary sediment thickness distribution creating the Hummocky Topography (Figure 3.1-3). Thicker Quaternary sediment deposits occur in the bedrock topographical lows to the west and south sides of the watershed.

Stratigraphy

The stratigraphy of the Severn Sound watershed is dominated by glacial deposits underlaid by weathered bedrock, the exception being the Northern extent of the watershed where Precambrian bedrock exists at the surface. Surficial mapping of glacial tills is useful in understanding the glacial history of an area; it is also helpful in determining groundwater resources. The types of material present in the subsurface affect the storage, flow direction and rates of groundwater.

The following table represents the stratigraphy of Severn Sound watershed. A north-south cross section of the watershed is displayed on Figure 3.1-8 and an east-west cross section is displayed on Figure 3.1-9.

Table 3.1 - 1: Stratigraphy of the Severn Sound Watershed (AquaResource and Golder, 2009).

Current Name	LSRCA Name	Upland Complex Stratigraphy	Tunnel Channel Complex Stratigraphy
SA1	Unit 3a	Identified as coarse-grained material (sand and gravel) deposited in glacial Lake Algonquin	Identified as coarse-grained materials (sand and gravel) deposited in glacial Lake Algonquin
SC1	Unit 4a	Identified as fine-grained material (silt and clay) deposited in glacial Lake- Algonquin. This unit also includes diamict that occur at surface (i.e. Northern till, Kettleby till, etc.)	Identified as fine-grained material (silt and clay) deposited in glacial Lake Algonquin.
SA2	Unit 3b	Identified as subaquatic-fan complexes (sand and gravel)	Identified as coarse-grained material (sand and gravel) deposited in tunnel-channel complexes.
SC2	Unit 4b	Identified as silty sand to sandy silt, stone-rich diamicton.	This unit is not considered a formation. It has been identified as a lense-shaped deposit composed of fine-grained material (silt and clay) within tunnel-channel complexes.
SA3	Unit3c	This unit is not considered a formation. It has been identified as a lense-like deposit composed of coarse-grained material (sand and gravel) within upland complexes.	This unit is not considered a formation. It has been identified as a lense-shaped deposit composed of coarse-grained material (sand and gravel) within tunnel-channel complexes.
SC3	Unit 4c	Identified as fine-grained material (silt and clay) deposited in a glacial lake.	Identified as fine-grained material (silt and clay) deposited in tunnel channel complexes.

Current Name	LSRCA Name	Upland Complex Stratigraphy	Tunnel Channel Complex Stratigraphy
SA4	Unit 3d	Identified as coarse-grained material (sand and gravel) deposited in a glacial lake.	Identified as coarse-grained material (sand and gravel) deposited in tunnel-channel complexes.
SC4	Unit 4d	Identified as silty sand to sandy silt, stone-rich diamicton.	Identified as fine-grained material (silt and clay) deposited in tunnel channel complexes.
Not included	Unit 3e	Identified as coarse-grained material (sand and gravel)- unknown origin (glaciofluvial?)	This unit is not considered a formation. It has been identified as a lense-shaped deposit composed of coarse-grained material (sand and gravel) within tunnel-channel complexes.
Not included	Unit 3f	Identified as coarse-grained material (sand and gravel)-unknown origin (glaciofluvial?)	Identified as coarse-grained material (sand and gravel) deposited in tunnel-channel complexes.
Not included	Unit 4f	Identified as silty sand to sandy silt, stone-poor diamicton. Also identified as basal formation in tunnel-channel complexes.	Identified as silty sand to sandy silt, stone-poor diamicton. Also identified as basal formation is Upland sequences.

Soils

Soils are an integral part of the environment as they support vegetation communities. They also influence the quality and quantity of water entering the ground and running along the surface. Traditionally, soils within the watershed have been characterized based on the coarseness of their texture. Soil texture influences the rate at which water can infiltrate or seep into the ground. Generally, coarse-textured soils (gravel and sand) allow water to infiltrate better than finer-textured soils (silty loam, clay) do. This property of soil texture is extremely important because it has a major influence on the landscape's ability to generate runoff. For example, during a heavy thunderstorm, rainfall that cannot infiltrate the ground will pool on the surface. Once enough water has collected it will begin to flow overland as a result of gravity and in so doing can erode soil particles, washing them into ditches, streams and lakes.

Figure 3.1-10 depicts the spatial distribution of soil types throughout the watersheds in the study area. Future work will consider the attributes of the soils map, and the textural data included within the quaternary geological mapping from the Ontario Geologic Survey (OGS), in terms of which is a more appropriate data set to utilize for runoff estimation. For the purposes of this document and the runoff calculations herein, the soils map and associated hydraulic attributes were used. For a more detailed description of soil classification, and hydraulic attributes the reader is referred to the 2007 South Georgian Bay Lake Simcoe Conceptual Water Budget (SGBLS, 2007).

3.1.2 Surface Water

Surface Water System

The Severn Sound watershed has a drainage area of approximately 1,380 km^2. It has been divided into 19 subwatersheds (as described in Section 2.2), which allows for more detailed analysis and research, including modeling the influence of land use on water quality and quantity. Figure 3.1-11 illustrates the bathymetry and shoreline of Severn Sound in Georgian Bay.

Of the 19 subwatersheds six are considered to be small draining from the north and south along the shore of the Sound. The six small subwatersheds are the North River, Coldwater River, Sturgeon and Wye Rivers, and Hog Creek. The streams occupy the flat-floored valley within the watershed and many of them appear to be fed largely by springs along the valley sides. The drainage areas of the six subwatersheds are given in Table 2-1.

The North River is the largest drainage system in the study area. It rises in a hilly plateau to the north of Bass Lake. The river flows in a south-north direction until a point located about 2 km north of Hampshire Mills, where it changes its course into a north-westerly direction until it reaches Lovering. From Lovering, the river flows in a south-westerly direction to its outlet into Matchedash Bay. The river has three major tributaries: Purbrook, Bear and Silver Creeks; 25 second order tributaries, and numerous lower order tributaries.

The Coldwater River originates near the community of Coulson and flows from the south to the north before it enters into Matchedash Bay. The river has 22 first order tributaries and numerous second and third order tributaries.

The Sturgeon River originates in a hilly plateau near Hillsdale and flows in a northerly direction before it empties into Sturgeon Bay. The river is fed by ten first order tributaries and a few second order tributaries.

Hog Creek originates in the Township of Oro-Medonte, and flows in a northerly direction through Tay Township, where it empties into Hog Bay in Severn Sound. The creek has cut a shallow channel in a flat-floored valley and is fed largely by springs along the valley's sides. Hog Creek has 15 first order tributaries and numerous second and third order tributaries.

The Wye River originates to the north of the Cook's Hill area in Springwater Township and flows from south to north to its outlet into Georgian Bay. The river has 16 first order tributaries and numerous second and third order tributaries. A major tributary to Wye River is McMahon Creek.

Copeland Creek originates from Lalligan Lake in Tiny Township and flows in a north-westerly direction to its outlet into Penetang Harbour. The creek has 16 small tributaries.

Surface Water Monitoring Network

Streamflow monitoring is an essential means of obtaining and maintaining records of a watershed's surface water resources. Information collected within the study area is used in Source Protection Planning to develop resource targets, identify current conditions, determine trends over time and evaluate the effectiveness of remedial activities. Monitoring is also used to calibrate analytical models, which predict the impact of possible contaminants, especially during low flows, and to evaluate the impact on water resources of the changes in land use or management activities.

Water Survey Canada (WSC), in partnership with the Ontario Ministry of Natural Resources (MNR) and Conservation Authorities, has developed a comprehensive surface water monitoring program within the watersheds of the South Georgian Bay-Lake Simcoe Source Protection Region. However, the existing network was not built for the Source Water Protection program, and it may be necessary to evaluate the adequacy of the existing network for Source Water Protection projects. Due to the high cost of installing stream gauging equipment and provincial guidance for water budget initiatives, the Source Protection Committee decided to use the existing stream gauging network, noting that there may be some data gaps and uncertainty in the water budget projects. Figure 3.1-12 displays the location of the streamflow stations within the study area.

Method Used to Estimate Missing Streamflow Data

A modified drainage-area ratio method, a maintenance of variance extension type 1 (MOVE.1) method, and a multiple linear regression method were used in this study to estimate streamflow for ungauged sites and for gauged sites that had missing data. Correlation between the base (index) station and the site of interest was tested before applying the MOVE.1 method. Since log-transformed estimates are superior to linear estimates for the assessment of streamflow (Hirsch, 1979), the streamflow data used to estimate the missing data for this study were log transformed prior to applying the equation. Streamflow values of zero were treated as missing values. For a detailed explanation of the methods used to estimate the missing streamflow data the reader is referred to the 2007 SGBLS CWB Section 5.5.2.

Mean Annual Streamflow

The mean annual streamflow is defined as the average of the series of annual average streamflow values. The monthly mean streamflows according to the Canadian Climate Normals for the stations of each watershed are given in Appendix WB-3A. As mentioned above, there are data gaps in the monitoring network. The missing data and/or short records make the mean annual flows estimated for those stations not representative. The mean annual flow should be determined from long-term streamflow data to reduce any bias; summer discharges in particular may be biased high.

The flow measured at the Coldwater River is not severely regulated to affect the flow measured at the gauge. Furthermore, the flows recorded at gauges in the other subwatersheds show a very good (generally > 70%) moving (monthly) correlation with this gauge. The results should be acceptable at this level of the investigation to provide mean annual flows based on long term records. Table 3.1 - 2 shows the mean annual streamflows at the gauging stations.

Table 3.1 - 2: Mean Annual Streamflows for the Severn Sound subwatersheds.

Subwatershed	Gauge Location	Mean Annual Streamflow Gauge (m^3/s)	Mean Annual Streamflow Mouth (m^3/s)
Coldwater River	At Coldwater	2.3	2.65
Hog Creek	Near Victoria Harbour	0.49	0.88
Copeland Creek	Penetanguishene	0.16	0.38
North River	At Falls	3.02	4.42
Sturgeon River	Sturgeon Bay	1.29	1.81
Wye River	At Wye Bridge	1.32	3.1

Baseflow

Baseflow is considered to be the groundwater contribution to streamflow, and is important in Source Water Protection studies for:

- The management of water quality through the regulation of watershed discharges to receiving waters. Low flows during summer months allow the stream to heat up rapidly in warm weather while in the fall and winter temperatures may plummet rapidly. Low flow conditions are less conducive to oxygenation. When water temperature is high, dissolved oxygen levels can become critically low. Furthermore, the ability of streams to assimilate additional loading from wastewater discharges is reduced by the low flow condition.
- Estimating surface water availability for domestic, agricultural, industrial and recreational purposes. The estimate provides an indication of the adequacy of natural flow to meet a given demand.

Estimates of the amount of baseflow can be derived from streamflow records. These estimates are critical in the assessment of low flow characteristics of streams.

Baseflow estimation is obtained by hydrograph separation, which has traditionally been done manually. Two commonly used methods are baseflow recession and curve fitting (Linsley et al. 1975). However, different hydrologists using the same manual hydrograph separation method commonly produce different baseflow estimates. The use of a computer program removes the inconsistencies inherent in manual methods and substantially reduces the time required for hydrograph separation. The automated baseflow separation technique described in Arnold et al. (1995), using a digital filter was used in this study.

Daily streamflow data from HYDAT were used and the annual mean baseflows were obtained by calculating the arithmetic mean for each year of record. The results are included below in Table 3.1 - 3 .

Table 3.1 - 3: Mean Annual Baseflows for the Severn-Sound subwatersheds.

Subwatershed	Gauge Location	Mean Annual Baseflow (m^3/s)	Mean Annual Baseflow (mm/yr)
Coldwater River	At Coldwater	1.41	232.318
Hog Creek	Near Victoria Harbour	0.22	115.622
Copeland Creek	Penetanguishene	0.11	147.239
North River	At Falls	1.49	147.421
Sturgeon River	Sturgeon Bay	0.82	263.094
Wye River	At Wye Bridge	0.97	146.961

Surface Water Control Structures

It is important to consider surface water control structures when creating a water budget, as they disrupt the natural flow of water throughout a watershed. The surface water control structures present in the watershed include lock gates, dams and beaver dams. The structures are depicted on (Figure 3.1-13) and are based on the 2006 MNR LIO database. Surface water control structures exist, among other reasons, to:

- Control flooding;
- Irrigate crops;
- Produce electricity; and
- Create transportation pathways;

Lock gate structures transport boats between bodies of water at different elevations. A lock gate structure works by controlling the volume of water within the lock. When water levels are raised the vessel can move to a watercourse at higher elevations, and lower elevations when the water level is lowered. Lock 45 of the Trent Severn Waterway is the only lock gate structure present within the Severn Sound watershed. It is the last lock in the canal system before entering Georgian Bay. The Trent Severn Waterway is owned and operated by Parks Canada, information pertaining to the operation of the waterway can be found at www.pc.gc.ca.

Beaver Dams represent the majority of surface water control structures present within the watershed; these dams impede the natural flow of water. Other small control structures are found the watershed[2]; are operated and maintained by private owners. These structures are therefore exempt from creating operation plans.

Surface Water Takings

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[2] Some structures may be historic and not in operation; however, there presence in a watercourse may still alter the natural flow.

Associated with land use is the extraction of water from groundwater or surface water sources for a variety of reasons. The MOE[3] is the agency responsible for regulating water withdrawals within the study area through their Permit to Take Water Program (PTTW). Active water taking permits are in place for a number of land use activities including but not limited to potable water supply, industrial use, pit and quarry use, golf course operations, and agriculture use.

Withdrawal of water for municipal supply and irrigation (which includes both agricultural and golf course users) accounts for the majority of overall demand in the watershed. The permitted and non-permitted surface water takings are summarized in Appendix WB-2.

3.1.3 Groundwater

In this Source Protection Area, groundwater is used for municipal water supply, agricultural and industrial use, golf course irrigation and private water supplies. Figure 3.1-14 illustrates municipal surface and groundwater takings and Figure 3.1-15 illustrates non-municipal water takings across the region.

Hydrogeologic Setting

A regional hydrostratigraphic framework was developed for the Severn Sound watershed by Golder Associates (2004a) as part of the regional-scale North Simcoe Municipal Groundwater Study. This study was largely completed through the use of local-scale hydrogeologic investigations completed by Lotowater Geoscience Consultants (2004) and EnviroChex Associates Inc., 2001. As a result of the investigation, four regional aquifer units (A1 to A4) and five aquitard units (C0 to C4) overlying bedrock were identified (Golder Associates, 2004a). The aquifer units (A1 to A4) are described by Golder Associates and AquaResources (2009) as follows. The extent of the aquifers present in the Severn Sound watershed is shown in a series of figures (3.1-16 to 3.1-19).

A1- The A1 aquifer is typically found at an elevation of 250 mASL; however, it has been mapped as low as 220 metres above sea level (mASL) in lowland areas, and as high as 350 mASL in some regions. This aquifer exists mainly as an unconfined surficial aquifer; however, it can be locally confined. It is composed of coarse-grained glacial and interglacial sediments. A1 has a unit thickness ranging from 10-50 m. Overall; this aquifer is considered to be a recharge unit. Within the study area this unit is thickest in the uplands of the Oro-Moraine, and thinnest is the Orillia-Coldwater area. In Tiny Township this aquifer is directly connected to the A2 aquifer.

A2- The A2 aquifer is typically found at elevations between 180- 250 mASL; however, it has been mapped as low as 150 mASL in some lowland areas. This aquifer can be absent (Orillia-Coldwater area) or very thin valleys, or very thick in upland areas (Horseshoe Valley- Hillsdale area). Within the study area the A2 aquifer is used as a municipal drinking water supply to the communities in Horseshoe Valley.

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[3] Now, the MECP (Ministry of the Environment, Conservation and Parks)

A3- The A3 aquifer is typically found at elevations between 130-210 mASL. It is composed of medium to coarse grained sediments, with some gravel and silt layers. It exists as a 70 m thick unit north of the Oro Moraine in Coldwater, it is found as a 35 m thick unit more often. This aquifer also supplies drinking water to the communities in Horseshoe Valley.

A4- The A4 aquifer is typically found at elevations below 150 mASL. It is composed of medium to coarse-grained sand and gravel. When defined as a regional unit the aquifer is composed of fine to medium grained sand with some minor gravel in areas. This aquifer is not continuous across the watershed, and ranges in thickness from 3-30 m. This aquifer is most prevalent in the Tiny Township area.

Groundwater Flow

According to Singer *et al*., (1999), the configuration of the potentiometric surface in the bedrock aquifer is a subdued reflection of its surface topography. Groundwater divides coincide closely with the major basin topographic divides and local divides. In general, groundwater appears to flow mainly towards the valleys of rivers and creeks and these valleys act as the main groundwater discharge zones within the watershed.

According to Golder Associates (2004a), groundwater gradients within the shallow groundwater regime typically range from 4 m/km to 6 m/km; however, gradients of up to 19 m/km have been measured on the flanks of the Oro Moraine.

It is not uncommon to have groundwater divides that do not coincide with surface water divides resulting in inter-basin transfers of groundwater. Differences in surface water divides and groundwater divides can also be influenced by groundwater extraction (i.e. municipal water supply wells or irrigation wells) near a watershed boundary.

Figure 3.1-20 illustrates the shallow water table elevation of the Severn Sound watershed. Figure 3.1-21 illustrates the shallow groundwater flow of the Severn Sound watershed. Based on the figure, numerous cross-boundary groundwater fluxes occur across both subwatershed and primary watershed boundaries through the watershed region. Detailed groundwater flow information regarding Midland, Orillia, Oro-Medonte, Penetanguishene, Severn, Springwater, Tay and Tiny is available in the individual Well Head Protection Area (WHPA) reports completed by Golder Associates (2004a) as part of the North Simcoe Municipal Groundwater Study.

Groundwater Takings

The Ontario Water Resources Act Regulation 387 (Water Taking and Transfer) states that any user extracting more than 50,000 L/day is required to have a permit to take water (PTTW). Each permit will have a maximum extraction rate assigned to it based on the user's individual needs. It should be noted that permitted extraction rarely reaches the maximum extraction rates. However, permitted extraction is frequently far greater than the average use because, the provincial system requires that the permit reflect the maximum potential extraction on any one day, regardless of how frequently that extraction rate is achieved. This is due to seasonal variances in water demands.

There exist a number of non-permitted water takings related to agriculture use, construction (dust control), and other uses that do not require permits, either because they use less than 50,00 L/day or are for the purpose of livestock watering. While uses of less than 50,000 L/day will not be explicitly considered for water budget estimates livestock watering extraction will be estimated in future water budget efforts using the University of Guelph work (DeLoe, 2005). Differentiation between surface water and groundwater supplies for these non-permitted uses will be based upon proximity of the land parcel to surface water supplies.

For the purpose of water budgeting, it is also important to understand what proportion of the water that is taken is lost from the watershed versus that proportion that is returned locally. Consumptive use guidelines have been provided by the province to address the issue of 'net extraction', which will be considered for future water budget refinement and stress assessment efforts. However, the entire volume of extraction should be considered for groundwater uses from confined municipal aquifers as these withdrawals, although often returned to the surface water system or shallow aquifer locally, represent a complete loss from the unit supplying the municipality.

There are 290 individual municipal wells within the Source Protection Region which have been addressed to determine Wellhead Protection Areas (WHPA). Good records of the actual water takings from these wells have been obtained for water budget efforts. The permitted and non-permitted groundwater takings are summarized in Appendix WB-2.

3.1.4 Interactions between Groundwater and Surface Water

Recharge

Figure 3.1-22 represents potential recharge areas across the watershed region as a function of geology (permeable materials) and hydraulic gradient (downward gradients from the water well records). This map was considered preliminary and has been refined in further water budget efforts documented in Sections 3.2.2 and 3.4.2.

Major potential recharge areas were defined by Golder Associates (2004a) in the North Simcoe Municipal Groundwater Study and included the highlands of old Medonte Township, areas northwest of Orillia (near Bass Lake), areas west of Midland and Penetanguishene in the northern portion of Severn Township. Within the Severn Sound watershed, the main recharge area is the Oro Moraine located in Oro-Medonte. This complex is comprised of sands and gravels of glaciofluvial and glaciolacustrine origin (Singer *et al.*, 1999).

Discharge

According to Singer *et al*. (1999), river and creek valleys constitute the main discharge zones within the watershed. Stream flow analysis conducted by Singer *et al*. (1999) indicated that a large percentage of the streamflows originate from groundwater sources and only a small amount of groundwater discharges directly to Georgian Bay. Potential discharge areas are presented in Figure 3.1-22.

Aquatic Habitat

Both cold and warm water aquatic habitats are found within the Severn Sound watershed. A detailed description of the habitats can be found in Section 2.1.1.1, along with a table listing the species found within each.

Aquatic habitats can be a key indicator of groundwater discharge in a region. A cold water habitat indicates the presence of baseflow. Baseflow is often cool in temperature as it is supplied to the stream from groundwater flow, therefore indicating groundwater discharge is occurring. Warm water habitats indicate the absence of groundwater discharge.

3.1.5 Land Use and Land Cover in the Source Protection Area

The current land use and land cover conditions of the watershed are described in section 2.4.2. Land cover and land use practices can affect the components of a water budget in different ways. Land cover in this watershed is predominately Rural Cropland and Pasture and Forested areas. Although this watershed is not experiencing the same level of development stress as the areas to the south, considerations should be made as development is proposed to ensure that a water balance is maintained.

3.1.6 Climate and Climate Change

Climate

The climate of southern Ontario is characterized by moderate winters, warm summers, and a long growing season with usually reliable precipitation. It is influenced by the proximity to Georgian Bay and Lake Simcoe. The local differences in climate reflect variations in topography, proximity to large water bodies and prevailing winds. The annual variations are dependent on the nature and frequency of weather systems that cross the area.

According to Brown et al. (1980), the Source Protection study area contains two climatic regions. These include the Simcoe and Kawartha Lakes, and Muskoka Climatic regions. The southern and south-western parts of the Severn-Sound watershed are contained within the Simcoe and Kawartha Lakes climatic region. The northern and north-western parts of the Seven-Sound watershed are in the Muskoka climatic region.

Climate Stations

Climate data including precipitation data are collected by Environment Canada (EC) at twelve active meteorological stations located in the SWP study area. In addition to the EC stations, the Ministry of the Environment, the Severn Sound Environmental Association, the Lake Simcoe

Region and Nottawasaga Valley Conservation Authorities maintain and operate precipitation stations within the Source Protection Region.

In addition to the above mentioned data sources, historic data collected from active and inactive stations within and adjacent to the Severn Sound Source Protection Area was compiled for analysis and used to supplement the existing precipitation database. Information regarding station name, location, and period of record is presented below in Table 3.1 - 4. Additional details regarding climate normals and the precipitation gauge network are presented in Appendix WB-1.

Table 3.1 - 4: Environment Canada: Climate Monitoring Stations in the Lake Simcoe Watershed.

Watershed	ID	Station Name	Start Year	End Year	Period (Years)	Status	Latitude - North	Longitude - West	Elevation m(asl)
Black-Severn River	6115525	Muskoka A*	1953	2000	48	Inactive	44 ° 58’	78 ° 18’	281.9
Black-Severn River	6115524	Muskoka AWO*	2000	2006	7	Active	44 ° 58’	78 ° 18’	281.9
Black-Severn River	6112072	Dorset MOE[1]*	1976	2002	47	Inactive	45 ° 13’	78 ° 55’	323.1
Black-Severn River	6115820	Orillia Brain	1992	2006	51	Active	44 ° 36’	79 ° 26’	250
Lake Simcoe	6110557	Barrie WPCC	1977	2006	30	Active	44 ° 22’	79 ° 41’	221
Lake Simcoe	6116902	Ravenshoe	1971	1992	22	Inactive	44 ° 13’	79 ° 24’	251
Lake Simcoe	6117684	Shanty Bay	1973	2006	34	Active	44 ° 24’	79 ° 37’	252
Lake Simcoe	6119055	Udora	1989	2006	18	Active	44 ° 15’	79 ° 9’	262
Lake Simcoe	6150863	Bradford Muck Res.	1974	1998	25	Inactive	44 ° 1’	79 ° 36’	221
Lake Simcoe	6151750	Cold Creek*	1971	1991	21	Inactive	43 ° 55’	79 ° 42’	251
Lake Simcoe	6154130	King Smoke Tree*	1974	2003	30	Inactive	44 ° 1’	79 ° 31’	352
Lake Simcoe	6155807	Sharon*	1971	1999	29	Inactive	44 ° 6’	79 ° 25’	262
Lake Simcoe	6158082	Stouffville WPCP*	1971	1992	22	Inactive	43 ° 58’	79 ° 15’	267
Nottawasaga Valley	6111859	Cookstown	1972	2006	35	Active	44 ° 12’	79 ° 41’	244
Nottawasaga Valley	6112340	Essa Ont. Hydro	1971	2000	30	Inactive	44 ° 21’	79 ° 49’	216
Nottawasaga Valley	6115099	Midhurst	1971	1996	23	Inactive	44 ° 45’	79 ° 46’	226
Nottawasaga Valley	6142991	Grand Valley WPCP*	1974	1994	21	Inactive	43 ° 52’	80 ° 19’	465
Nottawasaga Valley	6146939	Ruskview	1986	2006	21	Active	44 ° 14’	80 ° 08’	472

Watershed	ID	Station Name	Start Year	End Year	Period (Years)	Status	Latitude - North	Longitude - West	Elevation m(asl)
Nottawasaga Valley	6150100	Albion*	1971	2000	30	Inactive	43 ° 56’	79 ° 50’	274
Nottawasaga Valley	6150103	Albion field Centre*	1971	2000	30	Inactive	43 ° 92’	79 ° 50’	282
Nottawasaga Valley	6151080	Glen Haffy Mono Mills*	1971	2000	30	Inactive	43 ° 56’	79 ° 57’	434
Nottawasaga Valley	6155788	Orangeville MOE*	1971	2006	36	Active	43 ° 55’	80 ° 05’	412
Nottawasaga Valley	611B002	Borden AWOS	1996	2006	11	Active	44° 16’	79 ° 54’	222.5
Nottawasaga Valley	6110218	Alliston	1973	2006	34	Active	44° 9’	79 ° 52’	221
Nottawasaga Valley	6111792	Collingwood	1974	2006	33	Active	44° 30’	80 ° 13’	179.8
Nottawasaga Valley	6.11E+03	Egbert CS	2000	2006	7	Active	44° 15’	79° 46’	251
Severn Sound	6113490	Honey HBR Beausoleil*	1974	2000	27	Active	44 ° 51’	79 ° 52’	183
Severn Sound	6115127	Midland WPCP	1974	2000	27	Active			
Severn Sound	6111769	Coldwater Warminister	1971	2000	30	Active	44° 38’	79° 32’	285

*Station is located outside of the Sourcewater Protection Study Area.

Precipitation

Several methods are commonly used to calculate basin average rainfall from an assumption of aerial (i.e., spatial) distribution using point rainfall from the gauge network. Precipitation depths were interpolated between measured points within and immediately surrounding the watershed region using spherical Kriging, and values for each subwatershed were estimated from geostatistical analyses. Spatial gaps in the data used in the interpolation resulted in what are assumed to be anomalies (bulls-eyes in the interpolated surface). These areas will be re-examined following the receipt of the in-filled data from the provincial climate assessment. Climate normals have been included in Appendix WB-3A.

Analysis of the annual average precipitation for the study area was completed using data collected from EC stations. Periods of data (i.e. months or years) are absent from the EC database at all stations from 1971 to 2000. The methodology used to compensate for these data gaps is discussed below. The~~It is recognized that the MNR~~ MNR ~~has~~ completed a study in 2008 to infill temporal and spatial gaps in climatological data across the province. The results of this study were incorporated into future iterations of water budget estimates.

Annual average precipitation calculated from short records of data may not reflect long-term variations in precipitation within a watershed or the mean may be biased caused by an extreme event that occurred during the short period of data. The technique of infilling missing data or extending the historic record at a precipitation gauging station through a correlation between that station and a longer-term reference station is used to improve statistical measures of precipitation at the short-term station by reducing error and bias. The reference station is derived from a larger study of many stations for which a common reference period of analysis is required. The correlation is used to estimate precipitation at the short-term station from the known precipitation at the index station. The linear regression calculation used in this study is described by Allen et al. (1998) and will not be discussed further.

Evaporation

Evaporation from surface water bodies including lakes and reservoirs were estimated using the unit area evaporation calculated in the Lake Simcoe Environmental Management Strategy LSEMS A.6 (2006) report for Lake Simcoe. The LSEMS reported values derived from a climate model that incorporates elevation, latitude, longitude, temperature, relative humidity, solar radiation, vapour pressure and dew point temperature data, all of which are measured at two locations in the Source Protection Region (Bradford and Ramara). The areal extent of surface water bodies, as determined from GIS layers, was then multiplied by the annual evaporation depth estimated for Lake Simcoe in the above-noted report to obtain the volume of water lost (Table 3.1-5).

Table 3.1 - 5: Water Losses through Evaporation.

Watershed	Land Use	Area (km^2)	Annual Evaporation (mm/m^2)	Annual Evaporation (mm^3)
Severn Sound	Water	18.85	672	12.67
	Wetlands	33.34	-	-
	Vegetation	1111	-	-
	Urban	215.81	-	-

Evapotranspiration

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration. Evapotranspiration is the water lost to the atmosphere by two processes, evaporation and transpiration. Evaporation is the loss from open bodies of water, such as lakes and reservoirs, wetlands, bare soil, and snow cover; transpiration is the loss from living-plant surfaces. Several factors other than the physical characteristics of the water, soil, snow, and plant surface also affect the evapotranspiration process.

The seasonal trend of evapotranspiration within a given climatic region follows the seasonal trend of solar radiation and air temperature. Minimum evapotranspiration rates generally occur during the coldest months of the year; maximum rates, which generally coincide with the summer season, when water may be in short supply, also depend on the availability of soil moisture and plant maturity. However, the seasonal maximum evapotranspiration actually may precede or follow the seasonal maximum solar radiation and air temperature by several weeks. Daily fluctuations in evapotranspiration also occur. On clear days, the rate of transpiration increases rapidly in the morning and reaches a maximum usually in early afternoon or mid afternoon. The midday warmth can cause closure of plant stomata, which results in a decrease in transpiration.

A complete cover by a green crop is considered to return water to the atmosphere by transpiration, and evaporation from the soil, at a peak or 'reference or potential' rate when the water supply is unlimited; the water used is referred to as 'reference or potential evapotranspiration'. In general, watersheds are not entirely covered by well-watered short-green crops. Actual evapotranspiration is the amount or rate of ET occurring in the watershed and it is the value we want to estimate. In practice, actual evapotranspiration (AET) is obtained from first calculating the reference crop evapotranspiration and then multiplying by suitable crop coefficients to estimate the actual crop evapotranspiration.

Determining Evapotranspiration

A large number of empirical methods have been developed over the last fifty years by numerous scientists and specialists worldwide to estimate evapotranspiration from different meteorological variables, these include Blaney-Criddle (1977), Lincare (1967), Priestley-Taylor (1972), Pennman-Montieth (1998), Kohler–Parmale (1967) and Hamon PET (1961). The modified Penman method is considered to offer the best results with minimum possible error in relation to a living grass reference crop. The method has not been used here because of insufficient meteorological data. For this study, the method used was the Hamon reference ET method since air temperature data is available at all the climate stations in the study area. The Hamon method is shown in the text box below.

Hamon Reference Evapotranspiration

Hamon Equation

$$ET_{Hamon} = 13.97dD2Wt$$

Where :ET_{Hamon} is Hamon reference evapotranspiration in mm per month,
d is the number of days in a month,
D is the mean monthly hours of daylight in units of 12 h, and
Wt is a saturated water vapour density term calculated by

$$Wt = (4.95\ e^{0.062T})/100$$

Where: T is the monthly mean temperature in °C.

The ET derived from the reference crop using the WDMUtil software is not reflective of the watershed. As it assumes the entire watershed is covered in grass with specific characteristics and a constant supply of water. To make it more reflective of the actual evapotranspiration occurring in the watershed ET was multiplied by the crop coefficient (K_c). The characteristics that distinguish field crops from grass are integrated into the crop coefficient.

As the crop develops, the ground cover, crop height and the leaf area change. Due to differences in evapotranspiration during the various growth stages, the K_c for a given crop will vary over the growing period. The growing period can be divided into four distinct growth stages: initial, crop development, mid-season and late season. Local K_c values were not available; however, an average K_c value was estimated at 0.96 based upon reported regional climate study results, and the measured difference between local reference and actual ET (Brown et. al., 1980). The results are shown in Table 3.1 - 6. The results are similar to the values reported for by MNR (1984, page 23) for the region of this study.

Table 3.1 - 6: Watershed Mean Monthly Annual Reference ET and Actual ET.

Watershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (mm) - Ref. ET	Annual Total (mm) - Actual ET
SSEA	9.78	12.64	23.16	42.95	73.02	96.44	116.11	92.23	57.00	31.94	17.42	11.53	584.22	560.85

Potential Impacts of Climate Change

The potential impacts of climate change, as well as current climate trends within the Source Protection Region will be discussed in Chapter 14: The Assessment Report in Context.

Figure 3.1- 1: Physiographic Regions.

Figure 3.1-2: Ground Surface Topography.

Figure 3.1-3: Hummocky Topography.

Figure 3.1-4: Bedrock Geology.

Figure 3.1-5: Bedrock Topography.

Figure 3.1-6: Surficial Geology.

Figure 3.1-7: Overburden Thickness.

Figure 3.1-8: North-South Cross Section.

Figure 3.1-9: East-West Cross Section.

Figure 3.1-10: Soils of the Watershed.

Figure 3.1-11: Bathymetry of Severn Sound.

Figure 3.1-12: Streamflow Gauging Stations.

Figure 3.1-13: Surface Water Control Structures.

Figure 3.1-14: Municipal Surface and Groundwater Taking Locations.

Figure 3.1-15: Non-municipal surface and groundwater takings.

Figure 3.1-16: A1 Aquifer Extent.

Figure 3.1-17: A2 Aquifer Extent.

Figure 3.1-18: A3 Aquifer Extent.

Figure 3.1-19: A4 Aquifer Extent.

Figure 3.1-20: Shallow Water Table Elevation.

Figure 3.1-21: Shallow Groundwater Flow Direction.

Figure 3.1-22: Potential Groundwater Recharge and Discharge Areas.

3.2 Tier One Water Budget And Water Quantity Stress Assessment

The Tier One Water Budget and Water Quantity Stress Assessment is the second step in the water budget process. This step is a high level screening that provides an understanding of the available groundwater and surface water resources on an annual and monthly basis within the subwatershed and provides a standard approach for evaluating the level of stress for each subwatershed.

Similarly, water demand is estimated on an annual and monthly basis within each subwatershed. These estimates of supply and demand provide insights into potential stress on existing and future municipal water supplies. Where demand for water exceeds a prescribed threshold of supply and municipal water supplies exist or are planned, more detailed analyses (Tier Two water budgets) are deemed appropriate to ensure an adequate understanding of the system and potential stresses to water quantity. In turn, areas that are not stressed from a water quantity perspective, or do not contain municipal drinking water supplies, are excluded from further study in this planning cycle within the Source Water Protection program.

The Tier One Water Budget and Water Quantity Stress Assessment of the Severn Sound Source Protection Area (Earthfx, 2010) was completed per the MOE Technical Rules (2008a) and is the guiding document for the following section. The document can be referred to for more detailed information.

3.2.1 Study Area and Physical Setting

For the purposes of the Tier One assessment the Severn Sound watershed has been divided into 19 subwatersheds or hydrological units, each drained by one or more tributaries, as outline in Section 2.2. The subwatersheds range in size from tens to hundreds of square kilometers and also cross political boundaries. The largest unit is the Wye River subwatershed at 208 km^2. It is found within one regional and eight lower tier municipalities.

As previously mentioned, the total area of the Severn Sound watershed is approximately 1380km^2 of this 59.53km^2 is made up by islands within the Severn Sound watershed, which have not been included in this study.

It is recognized that, in some portions of the study area, subwatershed boundaries differ from groundwater divides, resulting in groundwater movement between subwatersheds. The difference between surface water divides and groundwater divides can also be influenced by groundwater takings (i.e. municipal water supply wells or irrigation wells) near a watershed boundary. These differences; however, are generally not significant based upon comparison of subwatershed boundaries and groundwater divides inferred from water table elevations.

As a result, it was deemed appropriated to use surface water divides for this assessment, and assume that groundwater inflows to a subwatershed are equivalent to groundwater outflows. The difference between surface water and groundwater divides and associated groundwater movement between subwatersheds, among other things, will be included in Tier Two and Three studies, where they are required.

Four separate analyses were required in this report; groundwater existing conditions, surface water existing conditions, groundwater future conditions and surface water future conditions. The groundwater evaluations are based on both average annual and average monthly conditions from climate and streamflow data (methods described below). In general, the following databases were used for this evaluation: precipitation data from 1950 to 2005; temperature data from 1970 to 2000; and streamflow data from 1985 to 2005[4]. Surface water evaluations are monthly summations and statistics (median monthly and annual) on daily measured stream flow (or estimated flows as described in subsequent sections).

3.2.2 Water Supply

The following sections outline the components of a water budget and the methods used to derive each. More detail on the methods and assumptions used in the Tier One Water Budget and Water Quantity Stress Assessment of the Severn Sound watershed; herein referred to as the Tier One can be found within the report (Earthfx, 2010).

As noted above, the objective of this assessment is to identify those subwatersheds that may experience water quantity stress as a result of existing or forecast water taking. The steps to assessing potential water quantity stress involve quantifying supply and demand.

For surface water resources, available supply is considered to be a proportion of streamflow, which is monitored at a number of stations across the Severn Sound basin. Assessing surface water supply involved the interpolation of gauge data to the outlets of subwatersheds in gauged systems and the interpolation of streamflow data from similar subwatersheds for ungauged systems (described in later sections of the report).

For groundwater resources, the available supply for a subwatershed is considered to be recharge. Recharge is a difficult parameter to measure as there is significant variability as a function of land use and cover (e.g. vegetation), slope, geology and hydraulic gradient. In order to estimate recharge across large subwatershed areas in the absence of site specific investigation, the following relationships between readily available data were relied upon;

P-ET = Rech + Roff *or* Rech = P-ET-Roff (1)

SWO = Roff + BF *or* Roff = SWO-BF(2)

Substituting Equation 2 into Equation 1 yields;

Rech = P - ET - SWO + BF (3)

where:

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[4] A preliminary check of the data showed no significant difference in the 20 year versus 55 year streamflow data sets.

P = Precipitation

ET = Evapotranspiration

SWO = Total Streamflow out of a subwatershed

BF = Baseflow or groundwater discharge component of streamflow

Rech = Groundwater Recharge

Roff = Runoff

The following figure outlines the relationship of the above variables. The variables outlined in red are losses to the watershed, green are gains and yellow are internal movement of water which remain within the subwatershed and are accounted for as such.

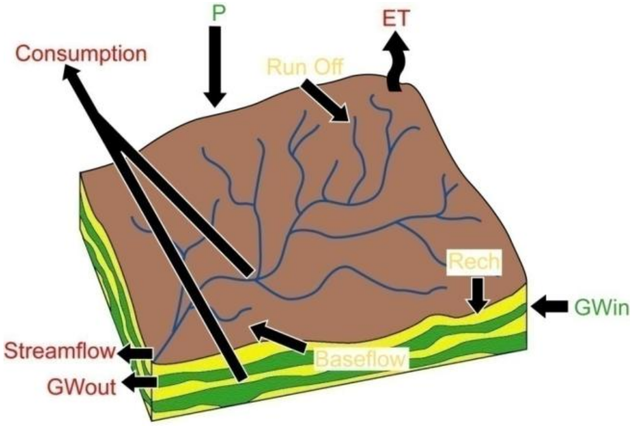

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Figure 3.3.2-a Water supply diagram

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Equation 3 was utilized in the South Simcoe Groundwater Studies (Golder, 2004) to estimate recharge, and was selected for this analysis. It should be noted that, where the surface water and groundwater divides coincide and no consumption of groundwater occurs, recharge should equal baseflow. Where groundwater movement to or from a subwatershed, or where consumption removes groundwater, baseflow may be more or less than recharge. Thus, although groundwater gains and losses and consumptive water takings are not explicitly considered in the calculation, Equation 3 will reflect some of those gains and losses.

The following sections outline the components of the Water Budget required to estimate recharge per Equation 3, and surface water supplies along with the specific methods used to derive each.

Water Budget Elements

The water budget supply elements consist of precipitation, evaporation, stream flow and baseflow. This section is a summary of the methods used to estimate the supply elements used in the Tier One Water Budget and Water Quantity Stress Assessment (SGBLS, 2009).

Precipitation

Precipitation is monitored at two climate stations with the Severn Sound watershed and at 79 stations within the SWP region. This network provides a reasonable coverage across the Severn Sound basin, although some temporal gaps exist in various records.

The Meteorological data used in this report were collected by Environment Canada and modified based on the methodology for filling gaps in Meteorological data sets outlined by Schroeter *et al.* (2000). Schroeter *et al.* (2000) describes practical techniques for estimating missing values in daily climate records, and in hourly rainfall depths. The daily climate data 'fill-in' procedure uses the relationship between monthly climate normals for a surrogate station, and the station under consideration. The data was infilled to reflect a period of record from 1950 to 2005.

This modified precipitation data set has then been interpolated across the basin to address spatial gaps in monitoring using kriging. This addressed spatial gaps in monitoring and to provide an estimate of the distribution throughout the region (Figure 3.2- 1). Annual means were then determined for each subwatershed. These average data have been used within the stress assessment and are included in (Table 3.2- 1).

Table 3.2- 1: Monthly and Annual Precipitation by Subwatershed (Earthfx, 2010).

Subwatershed	Area (km2)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Coldwater River	191	95	63	59	64	79	81	77	85	93	84	91	94	**965**
Copeland Creek	24	104	68	61	63	77	78	76	83	91	86	93	103	**983**
Hog Creek	60	100	66	60	66	78	79	77	84	92	84	92	99	**974**
North River	319	94	64	61	63	80	81	78	84	95	86	94	95	**978**
Sturgeon River	98	97	64	59	63	78	80	77	85	92	83	91	96	**967**
Wye Rive	208	99	66	60	64	77	79	77	85	91	83	91	98	**967**
Honey Harbour to Port Severn	68	104	68	62	63	79	79	78	83	94	89	97	105	**1000**
Lafontaine Creek	55	103	68	62	63	77	78	76	84	91	86	94	104	**985**
Midland Area	24	105	68	61	63	78	78	77	83	91	86	93	104	**986**
Penetang. Bay W	24	105	68	62	63	77	78	77	83	92	87	95	105	**992**
Penetanguishene and Tay Point	25	106	69	61	63	78	78	77	83	92	87	94	105	**992**
Port Severn and Matchedash Bay N	20	100	66	62	65	79	80	78	83	94	88	95	101	**991**
Tiffin Basin and Port McNicoll Area	16	104	67	61	63	78	79	77	83	92	86	94	103	**986**
Tiny Coastal Area NW	38	103	68	62	63	77	78	76	84	91	86	95	103	**985**
Tiny Coastal Area S	47	98	66	60	62	77	79	77	85	90	83	91	98	**966**
Tiny Coastal Area W Central	21	102	67	61	62	77	78	76	84	91	85	93	102	**977**
Tiny Coastal Area NE	46	105	68	62	63	77	78	77	83	92	88	96	105	**993**
Victoria Harbour Area	17	102	67	61	64	78	79	77	83	93	86	94	101	**984**

Subwatershed	Area (km2)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Waubaushene and Matchedash Bay S	19	100	66	61	64	79	80	78	83	94	87	94	100	**985**

Evapotranspiration

The Thornthwaite method has been used to estimate the potential ET. This method is based on an empirical relationship between potential ET and mean air temperature. While this method has limitations, it provides reasonably accurate estimates of potential ET (Palmer and Havens, 1958).

This method is commonly used because the only input requirements are air temperature and hours of sunshine although it is known that the Thornthwaite method underestimates ET in arid regions while overestimating ET in humid regions (Alkaeed *et al.,* 2006).

The calculated potential evapotranspiration values using monthly data have been included in (Table 3.2- 2). A comparison of these data calculated using the Thornthwaite method to the ET previously calculated with the Conceptual Water Budget (SGBLS, 2007) using the Hamon method, indicates that both methods yield very similar results.

To estimate the actual evapotranspiration a crop coefficients (K_c) was used. Crop coefficients (Kc) are crop specific evapotranspiration values generated by research used with reference evapotranspiration data to estimate the crop evapotranspiration requirement (ET_c). The actual ET for the crop (ET_c) is calculated by multiplying the crop coefficient (K_c) by the reference evapotranspiration value (ET_o).

In the absence of available local values, a K_c value for the watershed was determined using published potential and actual evapotranspiration values for southern Ontario (Brown *et al.*, 1980). An average coefficient of 0.96 was estimated as representative of the watershed. A summary of AET is included in (Table 3.2- 3) and in (Figure 3.2-3). A ratio of 0.96 could be higher than average and during this study a summary of the stations within the SWP area as well as some additional stations were considered and alternate statistical methods were used to calculate AET. The lowest average ratio calculated was 0.84. Due to the conservative approach to this assessment the higher ratio was used, which would be the worst case scenario for evaportranspiration.

Table 3.2- 2: Monthly and Annual Potential Evapotranspiration (Earthfx, 2010).

Subwatershed	Area (km2)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Coldwater River	191	0	0	0	27	78	113	138	122	77	40	9	0	**603**
Copeland Creek	24	0	0	0	27	77	113	139	123	79	42	11	0	**610**
Hog Creek	60	0	0	0	27	77	113	139	123	78	41	10	0	**607**
North River	319	0	0	0	27	77	112	136	120	76	40	8	0	**597**
Sturgeon River	98	0	0	0	27	77	113	138	122	77	41	10	0	**605**
Wye Rive	208	0	0	0	28	77	113	138	123	78	41	10	0	**608**
Honey Harbour to Port Severn	68	0	0	0	27	77	112	137	122	77	41	9	0	**603**
Lafontaine Creek	55	0	0	0	27	76	112	138	123	79	42	11	0	**607**
Midland Area	24	0	0	0	27	77	114	139	124	79	41	11	0	**611**
Penetang. Bay W	24	0	0	0	27	77	113	139	123	78	41	10	0	**608**
Penetanguishene and Tay Point	25	0	0	0	27	77	114	139	124	79	41	11	0	**611**
Port Severn and Matchedash Bay N	20	0	0	0	27	77	112	137	121	77	41	9	0	**601**
Tiffin Basin and Port McNicoll Area	16	0	0	0	27	77	114	139	123	78	41	10	0	**609**
Tiny Coastal Area NW	38	0	0	0	27	76	111	138	123	79	41	11	0	**606**
Tiny Coastal Area S	47	0	0	0	28	77	112	138	122	78	41	10	0	**607**
Tiny Coastal Area W Central	21	0	0	0	27	77	113	138	123	79	42	11	0	**609**
Tiny Coastal Area NE	46	0	0	0	27	76	112	138	123	78	42	10	0	**607**
Victoria Harbour Area	17	0	0	0	27	77	113	138	123	78	41	10	0	**606**

Subwatershed	Area (km2)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Waubaushene and Matchedash Bay S	19	0	0	0	27	77	113	138	123	77	41	9	0	**603**

Table 3.2- 3: Monthly and Annual Actual Evapotranspiration (kc=0.96) (Earthfx, 2010).

Subwatershed	Area (km^2)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Coldwater River	191	0	0	0	26	74	108	132	117	74	39	9	0	**597**
Copeland Creek	24	0	0	0	26	74	108	133	118	75	40	10	0	**585**
Hog Creek	60	0	0	0	26	74	109	133	118	74	39	10	0	583
North River	319	0	0	0	26	74	107	131	115	73	38	8	0	**573**
Sturgeon River	98	0	0	0	26	74	108	133	117	74	39	9	0	**581**
Wye Rive	208	0	0	0	26	74	108	133	118	75	40	10	0	**583**
Honey Harbour to Port Severn	68	0	0	0	26	74	108	132	117	74	39	9	0	**578**
Lafontaine Creek	55	0	0	0	26	73	108	133	118	75	40	10	0	**583**
Midland Area	24	0	0	0	26	74	109	134	119	75	40	10	0	**587**
Penetang. Bay W	24	0	0	0	26	74	108	133	118	75	40	10	0	**584**
Penetanguishene and Tay Point	25	0	0	0	26	74	109	134	119	75	40	10	0	**586**
Port Severn and Matchedash Bay N	20	0	0	0	26	74	108	132	116	74	39	9	0	**577**
Tiffin Basin and Port McNicoll Area	16	0	0	0	26	74	109	133	118	75	39	10	0	**585**
Tiny Coastal Area NW	38	0	0	0	26	73	107	132	118	75	40	10	0	**582**
Tiny Coastal Area S	47	0	0	0	26	74	108	132	118	75	40	10	0	**583**

Subwatershed	Area (km^2)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Nov (mm)	Dec (mm)	Total (mm)
Tiny Coastal Area W Central	21	0	0	0	26	74	108	133	118	75	40	10	0	**584**
Tiny Coastal Area NE	46	0	0	0	26	73	108	133	118	75	40	10	0	**582**
Victoria Harbour Area	17	0	0	0	26	74	109	133	118	74	39	9	0	**582**
Waubaushene and Matchedash Bay S	19	0	0	0	26	74	108	132	117	74	39	9	0	**579**

Aerial Distribution (Precipitation and Evapotranspiration)

Several methods are commonly used to calculate watershed average rainfall from an assumption of aerial (i.e., spatial) distribution using point rainfall from the gauge network. Precipitation depths have been interpolated between measured points within and immediately surrounding the watershed region using kriging, and values for each subwatershed were estimated from geostatistical analyses.

The mean annual precipitation (Figure 3.2- 1) and mean annual AET (Figure 3.2- 2) raster surfaces have been created using ordinary kriging. This method was selected because it is possible to evaluate the suitability of the selected model to the data being interpolated by means of cross validation. Eighty data points, distributed throughout the South Georgian Bay-Lake Simcoe SWP region, were included in the interpolations for precipitation and AET discussed above.

The entire SWP area was kriged so that the maximum number of data points (80 Stations) could be used in the calculations. These surfaces were then scaled down to the watershed areas to create figures for each report.

A circular variogram (i.e., a theoretical curve fit to the graph of variance versus average distance between samples) was used to model the spatial variation of both precipitation and mean annual AET. A circular search neighbourhood was used to determine the nearest data points to be included in the interpolation of the data to each raster cell. The circular search neighbourhood method is considered to more accurately reflect the distribution of the data than an elliptical neighbourhood.

The parameters used in interpolating precipitation and AET were those determined to most effectively capture the spatial variation. A variety of parameter combinations were explored, including using circular, exponential, and Gaussian functions to model variation, as well as simple kriging. A variety of search neighbourhood sizes were investigated as well. The parameters explored were evaluated based on both the prediction error statistics that are generated by the cross-validation, as well as a visual corroboration of the resulting surface.

Annual Stream Flow

Surface water flows are measured at eight sites by the Water Survey of Canada across the Severn Sound watershed (Figure 3.2-3). The streamflow data used in this evaluation was collected from 1965-2008. For the purposes of estimating monthly streamflow statistics to represent surface water supply, streamflow record-extension and regional regression techniques were used to estimate missing temporal data and estimate flow in ungauged streams as discussed below.

Mean and median monthly streamflow values are presented in Table 3.2- 4 and Table 3.2- 5 which includes the results of the infilling of spatial data gaps. It should be noted that all of the subwatersheds outlined above have hydraulic structures upstream of the gauge including stormwater management facilities (dry ponds, extended wet ponds and constructed wetlands) and dams.

A modified drainage-area ratio method was used in this study to estimate mean, median, and baseflow discharge. The drainage- area ratio method is based on the assumption that streamflow for a site of interest can be estimated by multiplying the measured streamflow at the nearby gauged site by the ratio of the drainage area of the site of interest to the drainage-area of a nearby gauged site (Hirsch, 1979). The drainage- area ratio method is given by:

$$Y_i = X_i * \left(\frac{A_y}{A_x} \right)^{\alpha}$$

Where:

Y_i is the estimated streamflow during month i for the site of interest;

X_i is the streamflow during month i for the gauged site (also referred to as the base station);

A_y is the drainage area for the site of interest;

A_x is the drainage area for the gauged site, and

α is the exponent of the drainage-area ratio.

The usual assumption is that the exponent, α, is 1. That may be the best assumption to make if no streamflow data are available for a site of interest. A better estimate for the exponent can be determined by a regression analysis on the log-transformed streamflow data as described in Emerson *et al.* (2005). A mean annual discharge drainage-area ratio exponent of $\alpha = 1.07$ ($r^2=0.97$, n=47 gauge stations) was determined for the South Georgian Bay Lake Simcoe Source Protection Region. Also in accordance with Emerson *et al.* (2005), the drainage-area ratio exponent was varied seasonally. The mean monthly discharge drainage-area ratio exponents used in estimating monthly mean discharge are listed in Table 3.2- 6 below.

Table 3.2- 4: Monthly Mean Streamflow (Earthfx, 2010).

Subwatershed	Guaged or Ungauged (G / UG)	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Coldwater River	G	2.3	2.3	4.3	4.9	2.6	1.9	1.5	1.4	1.6	2	2.7	2.5	**2.5**
Copeland Creek	G	0.2	0.2	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	**0.2**
Hog Creek	G	0.6	0.6	1.2	1.1	0.6	0.3	0.2	0.1	0.2	0.3	0.6	0.5	0.5
North River	G	4.6	4.2	8.1	10.3	4.8	2.5	2.5	0.7	1.3	2.2	4.7	3.9	**4.1**
Sturgeon River	G	1.4	1.1	2	2.5	1.4	1	1	0.7	0.8	1.1	1.6	1.2	**1.3**
Wye Rive	G	2.5	2.3	5.3	5	2.2	1.3	1.3	0.6	1.1	1.5	2.8	2.4	**2.5**
Honey Harbour to Port Severn	UG	0.6	0.6	1.5	1.6	0.6	0.4	0.4	0.2	0.3	0.4	0.7	0.6	**0.7**
Lafontaine Creek	UG	0.5	0.5	1.2	1.3	0.5	0.3	0.3	1	0.2	0.3	0.5	0.5	**0.5**
Midland Area	UG	0.2	0.2	0.6	0.5	0.2	0.1	0.1	0	0.1	0.1	0.2	0.2	**0.2**
Penetang. Bay W	UG	0.2	0.2	0.6	0.5	0.2	0.1	0.1	0	0.1	0.1	0.2	0.2	**0.2**
Penetanguishene and Tay Point	UG	0.2	0.2	0.6	0.6	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	**0.2**
Port Severn and Matchedash Bay N	UG	0.2	0.2	0.5	0.4	0.1	0.1	0.1	0	0.1	0.1	0.2	0.2	**0.2**
Tiffin Basin and Port McNicoll Area	UG	0.1	0.1	0.4	0.3	0.1	0.1	0	0	0.1	0.1	0.1	0.1	**0.1**
Tiny Coastal Area NW	UG	0.3	0.3	0.8	0.9	0.3	0.2	0.1	0.1	0.2	0.2	0.4	0.3	**0.4**
Tiny Coastal Area S	UG	0.4	0.4	1	1.1	0.4	0.2	0.2	0.1	0.3	0.3	0.4	0.4	**0.4**
Tiny Coastal Area W Central	UG	0.2	0.2	0.5	0.5	0.2	0.1	0.1	0	0.1	0.1	0.2	0.2	**0.2**
Tiny Coastal Area NE	UG	0.4	0.4	1	11	0.4	0.2	0.2	0.1	0.3	0.3	0.4	0.4	**0.4**

Subwatershed	Guaged or Ungauged (G / UG)	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Victoria Harbour Area	UG	0.1	0.1	0.4	0.4	0.1	0.1	0.1	0	0.1	0.1	0.2	0.1	**0.1**
Waubaushene and Matchedash Bay S	UG	0.1	0.2	0.4	0.4	0.1	0.1	0.1	0	0.1	0.1	0.2	0.2	**0.2**

Table 3.2- 5: Monthly Median Streamflow (Earthfx, 2010).

Subwatershed	Guaged or Ungauged (G / UG)	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Coldwater River	G	1.8	1.6	2.8	3.6	2.1	1.5	1.3	1.2	1.3	1.7	2.3	2.1	**1.8**
Copeland Creek	G	0.1	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**0.1**
Hog Creek	G	0.4	0.3	0.6	0.7	0.4	0.2	0.1	0.1	0.1	0.3	0.4	0.4	0.3
North River	G	3.3	3	5.2	7.6	3.7	1.9	1	0.8	1	1.6	3.4	3.3	**2.5**
Sturgeon River	G	1.1	0.9	1.3	2.2	1.2	0.8	0.6	0.6	0.7	1	1.3	1.2	**1**
Wye Rive	G	1.5	1.3	3	3.7	1.5	0.7	0.5	0.5	0.6	1	1.7	1.7	**1.3**
Honey Harbour to Port Severn	UG	0.4	0.3	0.8	1.1	0.5	0.2	0.1	0.1	0.2	0.3	0.5	0.4	**0.3**
Lafontaine Creek	UG	0.3	0.3	0.6	0.9	0.4	0.2	0.1	0.1	0.1	0.2	0.4	0.3	**0.3**
Midland Area	UG	0.1	0.1	0.3	0.4	0.1	0.1	0	0	0	0.1	0.1	0.1	**0.1**
Penetang. Bay W	UG	0.1	0.1	0.3	0.4	0.1	0.1	0	0	0	0.1	0.1	0.1	**0.1**
Penetanguishene and Tay Point	UG	0.1	0.1	0.3	0.4	0.1	0.1	0	0	0	0.1	0.2	0.1	**0.1**
Port Severn and Matchedash Bay N	UG	0.1	0.1	0.3	0.3	0.1	0	0	0	0	0.1	0.1	0.1	**0.1**

Subwatershed	**Guaged or Ungauged (G / UG)**	**Jan (m^3/s)**	**Feb (m^3/s)**	**Mar (m^3/s)**	**Apr (m^3/s)**	**May (m^3/s)**	**Jun (m^3/s)**	**Jul (m^3/s)**	**Aug (m^3/s)**	**Sep (m^3/s)**	**Oct (m^3/s)**	**Nov (m^3/s)**	**Dec (m^3/s)**	**Annual Mean (m^3/s)**
Tiffin Basin and Port McNicoll Area	UG	0.1	0.1	0.2	0.2	0.1	0	0	0	0	0.1	0.1	0.1	**0.1**
Tiny Coastal Area NW	UG	0.2	0.2	0.5	0.6	0.2	0.1	0.1	0.1	0.1	0.1	0.2	..2	**0.2**
Tiny Coastal Area S	UG	0.2	0.2	0.4	0.7	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.3	**0.2**
Tiny Coastal Area W Central	UG	0.1	0.1	0.2	0.3	0.1	0	0	0	0	0.1	0.1	0.1	**0.1**
Tiny Coastal Area NE	UG	0.2	0.2	0.5	0.7	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.3	**0.2**
Victoria Harbour Area	UG	0.1	0.1	0.2	0.2	0.1	0	0	0	0	0.1	0.2	0.1	**0.1**
Waubaushene and Matchedash Bay S	UG	0.1	0.1	0.2	0.3	0.1	0	0	0	0	0.1	0.1	0.1	**0.1**

Table 3.2- 6: Drainage-area ratio exponents of 47 gauge stations within the South Georgian Bay-Lake Simcoe Source Protection Region.

Month	α	r^2
Jan	1.07	95.9%
Feb	1.05	97.8%
Mar	0.94	97.1%
Apr	1.05	94.7%
May	1.20	95.2%
Jun	1.19	95.2%
Jul	1.23	94.1%
Aug	1.23	90.4%
Sep	1.15	90.9%
Oct	1.09	92.8%
Nov	1.03	93.9%
Dec	1.07	95.4%

Mean Annual Baseflow

Hydrograph separation techniques were applied to the continuous flow data to split streamflow into two components: (1) overland runoff, and (2) baseflow. Baseflow in the study area is assumed to be primarily composed of groundwater discharge, although discharge from wetlands can also contribute to baseflow. Numerous techniques are available to estimate baseflow including curve processing and statistical techniques. Median streamflow (Q_{50}) is often used as an estimate of annual average baseflow. A range of annual average groundwater contribution to streams in the study area was estimated from long-term streamflow measurements using 12 automatic baseflow separation techniques:

- Four variations (multi-pass min, max, and mean; and the conventional single-pass) of the modified United Kingdom Institute of Hydrology (UKIH) smoothed minima method (FREND, 1989; Piggot et al., 2005);
- The Graham method, also known as the Clarifica method (Clarifica Inc., 2002);
- Three methods from the United States Geological Survey's (USGS) HYSEP program, known as the fixed interval, sliding interval, and local minimum methods (Sloto and Crouse, 1996);
- The USGS PART method (USGS, 1998);
- The Lyne and Hollick digital filter (Lyne and Hollick, 1979; Nathan and McMahon, 1990);
- The Chapman digital filter (Chapman, 1991); and,
- The Chapman and Maxwell (1996) digital filter.

Since the choice of baseflow separation techniques is arbitrary (because many of the variables involved have little to no physical meaning), and due to the heterogeneous physiographic nature of the study catchments, none of the methods listed above was exclusively selected. Instead, all methods were used to provide a range of possibilities, thereby increasing the likelihood of capturing true baseflow discharge. This way the range should cover situations where the amount of groundwater contributing to the storm hydrograph is minimal, such as in cases where tills or deeper lake deposits are at surface and runoff dominates the storm response. The upper range should aid in predicting baseflow from the sand plains where the streams have good hydraulic connection to the surficial aquifer and where the groundwater response is likely to be rapid.

Baseflow estimates for gauges within the study area are provided in Table 3.2- 7 which represents the average result of the above 12 baseflow separation methods. Baseflow estimation produced results that were roughly equivalent to median flows (Q_{bf}:Q_{50} = 1.06 ±0.09); this suggests that the flow regimes within the study area is rather consistent.

Average baseflow values will provide a means of estimating the average rate of groundwater recharge, assuming that overall changes in groundwater storage, pumping rates, and lateral cross-boundary flows are negligible. Also, this assessment assumes that losses for leaky pipes (water, sanitary, and storm and tile drains) are negligible. Baseflow separation results are presented in Table 3.2-8.

Table 3.2- 7: Average separated baseflow for gauges within the study area (m3/s) (Earthfx, 2010).

WSC Station ID	Subwatershed	Begin Year	End Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
02ED007	Coldwater River	1965	2005	1.51	1.50	2.22	2.90	1.72	1.28	1.05	0.98	1.08	1.37	1.72	1.68	1.58
02ED011	Wye River	1973	1986	1.12	1.25	2.35	2.47	1.04	0.68	0.56	0.55	0.73	1.02	1.29	1.35	1.20
02ED013	Wye River	1987	2005	0.96	0.83	1.35	1.63	0.72	0.44	0.31	0.26	0.33	0.54	0.93	0.96	0.77
02ED016	Wye River	1988	1994	0.05	0.04	0.14	0.18	0.05	0.02	0.00	0.00	0.01	0.02	0.06	0.05	0.06
02ED017	Hog Creek	1988	2005	0.34	0.30	0.49	0.64	0.31	0.16	0.10	0.08	0.10	0.20	0.34	0.34	0.28
02ED018	Sturgeon River	1988	1998	0.98	0.87	1.15	1.72	1.04	0.70	0.55	0.51	0.60	0.83	1.10	1.00	0.92
02ED019	Copeland Creek	1988	1999	0.10	0.09	0.13	0.20	0.10	0.07	0.05	0.04	0.05	0.07	0.09	0.09	0.09
02ED024	North River	1988	2005	2.21	2.18	3.42	4.72	2.24	1.20	0.73	0.59	0.69	1.15	2.23	2.16	1.94

Table 3.2-8: Baseflow discharge per catchment interpolated using the modified drainage-area ratio method and baseflow separation techniques (Earthfx, 2010).

Subwatershed	Gauged or Ungauged (G / UG)	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Coldwater River	G	1.6	1.6	2.4	3.1	1.9	1.4	1.2	1.1	1.2	1.5	1.9	1.8	**1.7**
Copeland Creek	G	1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**0.1**
Hog Creek	G	0.3	0.3	0.5	0.6	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.3	**0.3**
North River	G	2.9	2.9	4.4	6.2	3	1	1	0.8	0.9	1.5	2.9	2.9	**2.6**
Sturgeon River	G	1	0.9	1.2	1.7	1	0.6	0.6	0.5	0.6	0.8	1.1	1	**0.9**
Wye Rive	G	1.4	1.4	2.5	3.1	1.3	0.5	0.5	0.4	0.6	0.9	1.4	1.5	**1.4**
Honey Harbour to Port Severn	UG	0.3	0.3	0.5	0.7	0.3	0.2	0.1	0.1	0.1	0.2	0.3	0.3	**0.3**
Lafontaine Creek	UG	0.3	0.3	0.5	0.7	0.3	0.2	0.1	0.1	0.1	0.2	0.3	0.3	**0.3**
Midland Area	UG	0.1	0.1	0.2	0.3	0.1	0.1	0	0	0	0.1	0.1	0.1	**0.1**
Penetang. Bay W	UG	0.1	0.1	0.2	0.3	0.1	0.1	0	0	0	0.1	0.1	0.1	**0.1**
Penetanguishene and Tay Point	UG	0.1	0.1	0.2	0.3	0.1	0.1	0	0	0	0.1	0.1	0.1	**0.1**
Port Severn and Matchedash Bay N	UG	0.1	0.1	0.2	0.3	0.1	0	0	0	0	0.1	0.1	0.1	**0.1**
Tiffin Basin and Port McNicoll Area	UG	0.1	0.1	0.1	0.2	0.1	0	0	0	0	0	0.1	0.1	**0.1**
Tiny Coastal Area NW	UG	0.2	0.2	0.4	0.2	0.2	0.1	0.1	0.1	0	0.1	0.2	0.2	**0.2**
Tiny Coastal Area S	UG	0.2	0.2	0.4	0.5	0.3	0.1	0.1	0.1	0.1	0.2	0.3	0.3	**0.2**
Tiny Coastal Area W Central	UG	0.1	0.1	0.2	0.6	0.1	0.1	0	0	0.1	0.1	0.1	0.1	**0.1**
Tiny Coastal Area NE	UG	0.2	0.2	0.4	0.3	0.3	0.1	0.1	0.1	0	0.2	0.3	0.3	**0.2**
Victoria Harbour Area	UG	0.1	0.1	0.2	0.1	0.1	0	0	0	0	0	0.1	0.1	**0.1**
Waubaushene and Matchedash Bay S	UG	0.1	0.1	0.2	0.1	0.1	0	0	0	0	0.1	0.1	0.1	**0.1**

Water Budget Reserve

Within Technical Rules (MOE, 2008a) water reserve is defined as the water that is required to be “protected” to support other uses within the watershed including ecosystem needs and other human uses such as sewage assimilation, hydroelectric power production and navigation. This reserve value is calculated as 10% of groundwater discharge. For surface water, within subwatersheds that have gauged flow stations, the 10th percentile of stream flow (Q_{90}) was used as the reserve value. For surface water within ungauged subwatersheds the Tessmann (1980) method was used to estimate instream flow.

Surface Water Reserve Estimation

The methods recommended in Guidance Module 7 to estimate the water reserve include 10th percentile streamflow. This is the flow value that is most representative for reserve, as it is the flow value that is exceeded 90 percent of the time. Another option is to employ the Tessmann (1980) method that essentially puts softer targets on what is known as the Tennant (1976) method such that the instream low flow measure is made applicable to a wider range of streams of varying seasonal flow patterns and basing storage capacities.

Tessmann (1980) pointed out that relying on Tennant’s observation that aquatic habitat is sustainable to a flow of at least 30-50% mean annual flow (MAF) could lead to false conclusions; there are many viable streams in which summer low flows can fall below this threshold. Tessmann addressed this with the use of mean monthly flows (MMF) and applying a simple rule: if MMF is less than 40% of MAF the use MMF, otherwise, if MMF is greater than MAF then use 40% of MMF, otherwise, use 40% of MAF (i.e. Tennant method). The first part of the rule handles stream with seasonal low flow conditions, while the second part handles streams with seasonal high flow conditions, otherwise the Tennant method is used. A schematic description is shown below.

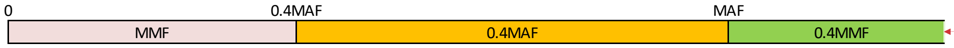

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Figure 3.2.2-a. Streamflow schematic

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As noted in the Guidance Module 7, when using the Tessmann method, the estimated reserve value may be larger than the water supply calculated for summer low flows. To correct for this, a reserve value of 30% of the monthly streamflow was applied in place of the Tessmann equation. This has been done in keeping with Guidance Module 7, which indicates that the reserve value is designed to add a buffer to already conservative percent demand thresholds. Surface water reserve values have been included in Table 3.2-9.

Table 3.2-9: Surface Water Reserve Estimates using Tessmann method (Earthfx, 2010).

Subwatershed	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Coldwater River	1.00	1.00	1.71	1.96	1.05	1.00	1.00	1.00	1.00	1.00	1.09	1.01	**1.15**
Copeland Creek	0.08	0.07	0.12	0.16	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	**0.08**
Hog Creek	0.25	0.24	0.46	0.45	0.20	0.20	0.17	0.14	0.17	0.20	0.23	0.20	**0.25**
North River	1.86	1.68	3.26	4.11	1.93	1.63	1.42	1.09	1.35	1.63	1.90	1.63	**1.96**
Sturgeon River	0.57	0.52	0.78	1.02	0.56	0.52	0.52	0.52	0.52	0.52	0.64	0.52	**0.60**
Wye Rive	1.00	0.98	2.12	2.01	0.98	0.98	0.76	0.61	0.98	0.98	1.11	0.98	**1.12**
Honey Harbour to Port Severn	0.27	0.27	0.58	0.64	0.27	0.27	0.23	0.18	0.25	0.27	0.27	0.27	**0.31**
Lafontaine Creek	0.21	0.21	0.47	0.50	0.21	0.21	0.18	0.13	0.20	0.21	0.21	0.21	**0.25**
Midland Area	0.09	0.09	0.22	0.21	0.09	0.09	0.07	0.05	0.08	0.09	0.09	0.09	**0.10**
Penetang. Bay W	0.09	0.09	0.22	0.21	0.09	0.09	0.07	0.05	0.08	0.09	0.09	0.09	**0.10**
Penetanguishene and Tay Point	0.09	0.09	0.23	0.22	0.09	0.09	0.07	0.05	0.08	0.09	0.09	0.09	**0.11**
Port Severn and Matchedash Bay N	0.07	0.07	0.18	0.17	0.07	0.07	0.05	0.04	0.06	0.07	0.07	0.07	**0.08**
Tiffin Basin and Port McNicoll Area	0.06	0.06	0.15	0.14	0.06	0.06	0.04	0.03	0.05	0.06	0.06	0.06	**0.07**
Tiny Coastal Area NW	0.14	0.14	0.34	0.34	0.14	0.14	0.11	0.09	0.13	0.14	0.14	0.14	**0.17**
Tiny Coastal Area S	0.18	0.18	0.41	0.42	0.18	0.18	0.15	0.11	0.16	0.18	0.18	0.18	**0.21**
Tiny Coastal Area W Central	0.08	0.08	0.20	0.19	0.08	0.08	0.06	0.04	0.07	0.08	0.08	0.08	**0.09**
Tiny Coastal Area NE	0.18	0.18	0.41	0.42	0.18	0.18	0.15	0.11	0.16	0.18	0.18	0.18	**0.21**
Victoria Harbour Area	0.06	0.06	0.15	0.14	0.06	0.06	0.04	0.03	0.05	0.06	0.06	0.06	**0.07**
Waubaushene and Matchedash Bay S	0.07	0.07	0.18	0.17	0.07	0.07	0.05	0.04	0.06	0.07	0.07	0.07	**0.08**

Groundwater Reserve Estimation

Per Technical Rule 1. (2), 10% of the existing groundwater discharge (calculated from a baseflow separation of gauged and simulated stream hydrographs as described in Section 3.1.3.2 has been calculated and used for the groundwater reserve within each subwatershed. These values have been included in Table 3.2-10.

Table 3.2-10: Groundwater Reserve Estimates (Earthfx, 2010).

Subwatershed	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Coldwater River	0.16	0.16	0.24	0.31	0.19	0.14	0.12	0.11	0.12	0.15	0.19	0.18	**0.17**
Copeland Creek	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.01**
Hog Creek	0.03	0.03	0.05	0.06	0.03	0.02	0.01	0.01	0.01	0.02	0.03	0.03	**0.03**
North River	0.29	0.29	0.44	0.62	0.30	0.16	0.10	0.08	0.09	0.15	0.29	0.29	**0.26**
Sturgeon River	0.10	0.09	0.12	0.17	0.10	0.07	0.06	0.05	0.06	0.08	0.11	0.10	**0.09**
Wye Rive	0.14	0.14	0.25	0.31	0.13	0.08	0.05	0.04	0.06	0.09	0.14	0.15	**0.03**
Honey Harbour to Port Severn	0.03	0.03	0.05	0.07	0.03	0.02	0.01	0.01	0.01	0.02	0.03	0.03	**0.03**
Lafontaine Creek	0.03	0.03	0.05	0.07	0.03	0.02	0.01	0.01	0.01	0.02	0.03	0.03	**0.01**
Midland Area	0.01	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	**0.01**
Penetang. Bay W	0.01	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	**0.01**
Penetanguishene and Tay Point	0.01	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	**0.01**
Port Severn and Matchedash Bay N	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	**0.01**
Tiffin Basin and Port McNicoll Area	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	**0.01**
Tiny Coastal Area NW	0.02	0.02	0.04	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	**0.02**
Tiny Coastal Area S	0.02	0.02	0.04	0.06	0.03	0.01	0.01	0.01	0.01	0.02	0.03	0.03	**0.02**
Tiny Coastal Area W Central	0.01	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	**0.01**
Tiny Coastal Area NE	0.02	0.02	0.04	0.06	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.01	**0.02**
Victoria Harbour Area	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.03	**0.01**

Subwatershed	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Annual Mean (m^3/s)
Waubaushene and Matchedash Bay S	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	**0.01**

Uncertainty in Water Supply Estimates

The above sections discuss data interpretation and manipulation that have been completed to estimate the parameters required to complete the supply side of the water quantity stress assessment. The result is an understanding of the flow of water within each subwatershed. All methods discussed above have been derived from published literature, considerably refined in some cases, and the data produced evaluated against previous studies as a check on the validity of results.

As an additional check, the components of the hydrologic cycle used in the estimates of recharge for the stress assessment have been used to solve a simple water balance equation.

The tabulated water balance results indicate that the methods used are quite reasonable, with water surplus not exceeding 12% of precipitation. While the uncertainty associated with ungauged systems is acknowledged, the conservatism in the component parts of the stress assessment adequately balances the uncertainty. The following discusses the uncertainty of each method.

Areal Distribution

Using several gauges over a large land area generalizes the results making them possibly bias high or low- the calculated Precipitation and AET have been compared to other published work in an attempt to reduce uncertainty.

Ungauged Stream Flow

The method used is considered the best available in situations where no gauged data is available; however use of this method introduced uncertainty for the ungauged basins but less when used as a data infill or data extension technique.

3.2.3 Water Demand

The following sections outline the methods used to estimate various water demands. The demand estimates for the existing use scenario have been outlined on Table 3.2-11. In addition, future use has also been estimated, using various methods to calculate the demand increase into the future. These estimates have been included in Table 3.2-12.

Surface water taking has also been assessed, as there are no municipal surface water treatment facilities which are to be considered within this report and all un-serviced domestic use is assumed to be private wells, only agricultural and permitted use has been assessed. The agricultural demand has been calculated based on de Loe’s 2005 methodology, and the permit to take water database has been assessed as per the following section. A summary of the existing surface water use estimates are included in Table 3.2-13.

Table 3.2-11: Existing Groundwater Consumption (Earthfx, 2010).

Subwatershed	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Coldwater River	646,000	137,000	36,000	145,000	965,000
Copeland Creek	33,000	13,000	-	22,000	68,000
Hog Creek	-	67,000	-	30,000	97,000
North River	806,000	166,000	146,000	157,000	127,400
Sturgeon River	336,000	81,000	-	74,000	492,000
Wye Rive	236,100	148,000	108,000	166,000	278,200
Honey Harbour to Port Severn	-	7,000	-	-	7,000
Lafontaine Creek	4,000	30,000	-	52,000	86,000
Midland Area	1,692,000	4,000	38,000	11,000	1,744,000
Penetang. Bay W	52,000	14,000	-	21,000	87,000
Penetanguishene and Tay Point	1,772,000	16,000	203,000	9,000	2,000,000
Port Severn and Matchedash Bay N	-	14,000	717,000	8,000	739,000
Tiffin Basin and Port McNicoll Area	-	21,000	1,000	6,000	27,000
Tiny Coastal Area NW	238,000	21,000	324,000	36,000	619,000
Tiny Coastal Area S	14,100	26,000	12,000	44,000	224,000
Tiny Coastal Area W Central	68,000	12,000	-	2,000	100,000
Tiny Coastal Area NE	253,000	25,000	-	44,000	323,000
Victoria Harbour Area	-	25,000	-	6,000	27,000
Waubaushene and Matchedash Bay S	-	25,000	-	7,000	27,000

Table 3.2-12: Future Groundwater Consumption (Earthfx, 2010).

Subwatershed	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Coldwater River	3,328,000	186,000	36,000	145,000	3,695,000
Copeland Creek	43,000	18,000	-	22,000	83,000
Hog Creek	-	91,000	-	30,000	121,000
North River	1,543,000	224,000	146,000	157,000	2,070,000
Sturgeon River	430,000	110,000	-	74,000	614,000
Wye River	5,141,000	200,000	108,000	166,000	5,615,000
Honey Harbour to Port Severn	-	9,000	-	-	9,000
Lafontaine Creek	54,000	41,000	-	52,000	147,000
Midland Area	2,487,000	5,000	38,000	11,000	2,541,000
Penetang. Bay W	40,000	19,000	-	21,000	80,000
Penetanguishene and Tay Point	2,790,000	22,000	203,000	9,000	3,024,000
Port Severn and Matchedash Bay N	-	19,000	717,000	8,000	744,000
Tiffin Basin and Port McNicoll Area	-	28,000	1,000	6,000	35,000
Tiny Coastal Area NW	1,088,000	28,000	324,000	36,000	1,476,000
Tiny Coastal Area S	617,000	35,000	12,000	44,000	708,000
Tiny Coastal Area W Central	114,000	16,000	-	20,000	150,000
Tiny Coastal Area NE	394,000	34,000	-	44,000	472,000
Victoria Harbour Area	-	29,000	-	6,000	35,000
Waubaushene and Matchedash Bay S	-	27,000	-	7,000	34,000

*all values in cubic meters per second

Table 3.2-13: Existing Surface Water Consumption (Earthfx, 2010).

Subwatershed	Municipal	Domestic	PTTW	Agricultural	Total Consumption
Coldwater River	-	-	302,000	145,000	447,000
Copeland Creek	-	-	-	22,000	22,000
Hog Creek	-	-	-	30,000	30,000
North River	-	-	1,733,000	157,000	1,890,000
Sturgeon River	-	-	-	74,000	74,000
Wye River	-	-	81,000	166,000	247,000
Honey Harbour to Port Severn	-	-	-	-	-
Lafontaine Creek	-	-	-	52,000	52,000
Midland Area	-	-	-	11,000	11,000
Penetang. Bay W	-	-	-	21,000	21,000
Penetanguishene and Tay Point	-	-	-	9,000	9,000
Port Severn and Matchedash Bay N	-	-	-	8,000	8,000
Tiffin Basin and Port McNicoll Area	-	-	-	6,000	6,000
Tiny Coastal Area NW	-	-	-	36,000	36,000
Tiny Coastal Area S	-	-	-	44,000	44,000
Tiny Coastal Area W Central	-	-	-	20,000	20,000
Tiny Coastal Area NE	-	-	-	44,000	44,000
Victoria Harbour Area	-	-	-	6,000	6,000
Waubaushene and Matchedash Bay S	-	-	-	7,000	7,000

*all units in cubic meters per second

Permits to Take Water

The MOE (now, MECP) PTTW database is a valuable tool for water use estimates. Several versions of the database have been provided; a version provided to SWP staff by the MNR (now, MNRF) has been deemed the most appropriate to maintain and improve for the purpose of this report. This 'copy' of the database is current to July 2006. As part of this assessment, the database has been modified to improve the accuracy of information based upon field investigations. The modifications include removing any permits within the database that are known to have been revoked or replaced. Expired permits have been considered on a case-by-case basis and removed if it was likely that the permit was no longer being used; this included specific use (i.e. temporary construction or pumping tests were considered to be short term permits and removed). Location searches were also completed and when several permits with the same location were found the most recent was retained and the others were considered to have been revoked and replaced.

Within permits where multiple sources may have been included and prescribed only one pumping rate was utilized and this rate has been divided by the number of sources; for example if there are two wells and one pumping rate of 500L/day a pumping rate of 250L/day would be applied to each well. Also where it could be identified that well water was being pumped to a pond or reservoir to be held for later use, this was considered groundwater taking so that it was not considered twice.

The permitted water taking in the PTTW database is generally presented as a maximum taking over a permitted period of time. This value is often much higher than the actual taking. Due to the present lack of reported actual use data, several attempts were made to acquire values that are more reflective of actual taking.

The MNR ~~has~~ provided a consumption assessment tool with the database discussed above, which provides estimates of the water usage based on each permit. These values have been adjusted using seasonal and consumptive demand modifiers. Although this tool is a more reasonable approach than using the maximum allowable taking per permit, the value is calculated based on the only value currently available, which is maximum taking.

Every attempt has been made to use the most conservative measures and consistently apply the techniques described above. However, it is known that until a database is produced based on the actual water taking data collected by the MOE (as a requirement of Regulation 450/07) this variable of the Water Use Estimate will be the source of high uncertainty. A summary of the permits deemed to be in use has been included as Appendix WB-2 and are depicted in Figure 3.2-4 and Figure 3.2-5.

Municipal Water Use

Municipal Water taking data were obtained from the North Simcoe Groundwater Study (Golder, 2005), the MOE PTTW database, municipal staff, and various other wellhead protection reports from across the Source Protection Region. Well locations, in UTM coordinates, and reported pumping rates as documented within these studies are outlined in Appendix WB-2.

Non-Permitted Water Use

Agriculture Consumption

Under the Ontario Water Resources Act (Revised Statutes of Ontario 1990, Chapter 0.40), farmers using 50,000 litres or less per day, and farmers who are taking water for livestock watering but not storing the water, do not require a PTTW and are therefore "non-permitted' agricultural consumers. To estimate agricultural consumption, Guidance Module 7 has suggested using water use coefficients documented by de Loe (2002, 2005). The 2001 data compiled by de Loe have been allocated to subwatersheds using area weighting to estimate subwatershed water use as per the following process.

Census data calculated based on municipalities has been used to derive the area within a subwatershed which is agricultural. Area-weighting was then used to determine how to allocate the above calculated areas to subwatersheds. For example, if 50% of Township A is in subwatershed X, then the assumption is that 50% of the water use in Township A occurs within subwatershed X. Since most subwatersheds cross municipal boundaries, the above calculations have been completed for all subwatersheds and all townships and the totals have been compiled for each subwatershed. This differs from the recommended methodology outlined by de Loe (2002), in that area weighting assumes that the agricultural area is evenly distributed within each subwatershed.

The coefficients derived by de Loe (2005) have then been applied to each type of agricultural use, to provide a total seasonal and total annual average for each subwatershed. Although this method provides an estimate of water consumption, there is no method to differentiate what is taken from groundwater versus surface water. For the purposes of this report, estimated agricultural taking was considered in both the surface water and groundwater stress assessments to yield the most conservative estimate. Refinement of the agricultural taking through subwatershed-specific census Canada data will be undertaken in the Tier Two for those parts of the region that are identified as having moderate to significant water quantity stress.

Unserviced Domestic Water Use

For the purposes of this report an assumption has been made that all households in the study area not serviced by municipal water are obtaining water from a private well. To derive an estimate of the average groundwater used for domestic purposes the 2006 Statistics Canada Census data were used to determine the 'un-serviced" population within each subwatershed relying on private wells. This un-serviced population was then multiplied by 335 L/day, based on the recommendation within Guidance Module 7 (MOE, 2007). A relatively low factor (0.2) has been used to calculate water consumption, as residences on private wells most often utilize a private septic system, which returns the majority of water used to the local subsurface. It should be noted that the amount of domestic consumption is a relatively small proportion of the overall subwatershed demand, and, therefore, uncertainty in estimating household use is not likely to affect the outcome of the stress assessment.

Future Water Use Estimates

Forecasting a future water balance calculation includes many assumptions, such as land use, water use, population growth, changes to municipal servicing and implementation of water conservation Best Management Practices to name a few. In accordance with the Technical Rules (MOE, 2008a), the methodology to calculate the future demand within the Tier One assessment includes an estimate of increased human consumption.

Population growth forecasts have been applied to domestic use calculations and municipal pumping has been increased by the forecasts outlined within previously mentioned groundwater studies.

There are no municipal surface water treatment and supply facilities taking from rivers within the study subwatersheds. All municipal surface water taking is directly from Georgian Bay. In addition, all private domestic use is assumed to be groundwater and therefore, the current surface water supply estimate was not increased in future forecasts.

Consumptive Water Use Methodology

The above section outlined the methods used to determine the water takings from each subwatershed. It should be recognized that not all of the water being extracted is removed from the hydrologic system. To develop more conservative and accurate representation, water consumption has been estimated using consumptive use factors outlined in Table 3.2-14.

Estimating consumptive water demand requires consideration of the hydrologic regime as well as water use type and discharge location. Some water taking, such as construction dewatering, removes water from a shallow unconfined aquifer and discharges it in close proximity allowing re-infiltration. In this example, only a small percentage of the water is lost. In contrast, water used in a water-bottling plant would be a very high loss, as most of the water is being physically removed from the watershed with no opportunity to return to the system it has been taken from.

Within this assessment specific water uses have been reviewed and consumptive factors have been applied as deemed appropriate. This includes 100% consumption when water is removed and not returned to the source that it is being taken from; and a lesser consumption factor when a portion of this water is being returned to the same source.

For example, consumptive with respect to the source is defined within MOE Guidance Module 7 (MOE, 2007) as; “Water taken from a source and not returned to that same source, this taking is assumed to be 100% consumptive with respect to the source. Groundwater taking from deep aquifers returned to surface water features fall into this category”.

It is important to note that municipal groundwater taking within the Severn Sound watershed is from confined to semi-confined aquifer settings. Municipal water taken from deep aquifer and subsequently discharged via sewage treatment is not being returned to the same groundwater source and possibly not the same subwatershed. Therefore, municipal takings have been considered to be completely consumptive within this stress assessment. Consumptive factors assigned to all other non-municipal water takings have not considered deep aquifer system removal (Appendix WB-2).

Table 3.2-14: Consumptive Use Factors.

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Agrucultural	Field and Pasture	0.8	Industrial	Manufacturing	0.25
Agrucultural	Fruit orchards	0.8	Industrial	Other - Industrial	0.25
Agrucultural	Market Gardens	0.9	Industrial	pipeline Testing	0.25
Agrucultural	Nursery	0.9	Industrial	Power Production	0.1
Agrucultural	Other - Agriculture	0.8	Institutional	Hospitals	0.25
Agrucultural	Sod Farm	0.9	Institutional	Other - Instituitional	0.25
Agrucultural	Tender Fruit	0.8	Institutional	Schools	0.1
Agrucultural	Tobacco	0.9	Miscellaneous	Dams and Reservoirs	0.1
Commercial	Aquaculture	0.1	Miscellaneous	Heat Pumps	1
Commercial	Bottled Water	1	Miscellaneous	Other - Miscellaneous	0.1
Commercial	Golf Course	0.7	Miscellaneous	Pumping Test	0.1
Commercial	Mall / Business	0.25	Miscellaneous	Wildlife Conservation	0.25
Commercial	Other - Commerical	1	Recreational	Aesthetics	0.25
Commercial	Snowmaking	0.5	Recreational	Fish Ponds	0.25
Construction	Other - Construction	0.75	Recreational	Other - Recreational	0.1
Construction	Road Building	0.75	Recreational	Wetlands	0.1
Dewatering	Construction	0.25	Remediation	Groundwater	0.5
Dewatering	Other - Dewatering	0.25	Remediation	Other - Remediation	0.25
Dewatering	Pits & Quarries	0.25	Water Supply	Campgrounds	0.2
Industrial	Aggregate	0.25	Water Supply	Communal	0.2
Industrial	Brewing Soft Drinks	1	Water Supply	Municipal	0.2
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.2
Industrial	Food Processing	1	-	-	-

Table 3.2-15: Monthly Water Consumption Adjustments.

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural	Field and Pasture	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Fruit Orchards	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Market Garden/Flowers	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Nursery	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Sod Farm	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tender Fruit	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Tobacco	0	0	0	0	0	0	1	1	0	0	0	0
Agricultural	Other - Agriculture	0	0	0	0	0	0	1	1	0	0	0	0
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Mall/Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Snowmaking	1	1	0	0	0	0	0	0	0	0	0	1
Commercial	Power Production	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Fish Ponds	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other - Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Road builsing	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Other - Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Pipeline Testing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Institutional	Hospital	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Schools	1	1	1	1	1	1	0	0	1	1	1	1
Institutional	Other - Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Dams and Reservoirs	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Heat Pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Pumping Test	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Wildlife Conservation	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other - Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Aesthetics	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Wetlands	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Other - Recreational	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Groundwater	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Other - Remediation	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Municipal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Other - Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

*Note: 1 indicates that water is consumed during the indicated month

Monthly Usage Factors

Monthly estimates of water use and supply are required to evaluate the seasonal stress level within a subwatershed. Knowledge of the available water and water use requirements allow for optimizing water management at different times of the year. In the study area, low surface water flow, decreased recharge, and high water demand occur during summer months.

The monthly use table, provided in Guidance Module 7 (MOE, 2007), was used when the actual months of water taking was otherwise not known. This table (Table 3.2-15) is a list of coefficients that have been applied to each PTTW based on the specific purpose listed. An assumption has also been made that during these times, water is being taken every day during that month. For the “non-permitted agricultural” consumption, an equivalent taking over a twelve month period was estimated for this assessment.

A summary of groundwater and surface water consumption based on the previous sections and usage factors have been included as Table 3.2-16 and Table 3.2-17, respectively. The values in Table 3.2-16 are a summary of the monthly PTTW calculations derived using the above mentioned assumptions (Table 3.2-15), and calculated monthly domestic, municipal and agricultural use. The surface water demand is a monthly summary of the PTTW and agricultural calculations. The methods used to determine these values have been discussed within Section 3.2.3.

Table 3.2-16: Existing Monthly Groundwater Consumption (Earthfx, 2010).

Subwatershed	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Total (m^3/s)
Coldwater River	79,000	72,000	79,000	76,000	84,000	81,000	84,000	84,000	81,000	84,000	81,000	79,000	**965,000**
Copeland Creek	6,000	5,000	6,000	6,000	6,000	600	6,000	6,000	6,000	6,000	6,000	6,000	**68,000**
Hog Creek	8,000	8,000	8,000	8,000	8,000	800	8,000	8,000	8,000	8,000	8,000	8,000	**97,000**
North River	96,000	87,000	96,000	93,000	113,000	11,300	117,000	117,000	113,000	117,000	113,000	96,000	**1,274,000**
Sturgeon River	42,000	38,000	42,000	40,000	40,000	40,000	42,000	42,000	40,000	42,000	40,000	42,000	**492,000**
Wye River	236,000	215,000	236,000	229,000	23,600	229,000	236,000	236,000	229,000	236,000	229,000	236,000	**2,782,000**
Honey Harbour to Port Severn	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**7,000**
Lafontaine Creek	7,000	7,000	7,000	70,000	700	7,000	70,000	7,000	7,000	7,000	7,000	7,000	**86,000**
Midland Area	148,000	135,000	148,000	143,000	148,000	143,000	148,000	148,000	143,000	148,000	143,000	148,000	**1,744,000**
Penetang. Bay W	7,000	7,000	7,000	70,000	700	7,000	7,000	7,000	7,000	7,000	7,000	7,000	**87,000**
Penetanguishene and Tay Point	159,000	145,000	159,000	154,000	159,000	154,000	223,000	223,000	154,000	159,000	154,000	159,000	**2,000,000**
Port Severn and Matchedash Bay N	630,000	57,000	63,000	61,000	63,000	61,000	63,000	63,000	61,000	63,000	61,000	63,000	**739,000**
Tiffin Basin and Port McNicoll Area	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	**27,000**
Tiny Coastal Area NW	25,000	23,000	25,000	24,000	25,000	24,000	187,000	187,000	24,000	25,000	25,000	25,000	**619,000**
Tiny Coastal Area S	18,000	1,600	18,000	17,000	20,000	20,000	20,000	20,000	20,000	18,000	18,000	18,000	**224,000**
Tiny Coastal Area W Central	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	**100,000**
Tiny Coastal Area NE	27,000	25,000	270,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	**323,000**
Victoria Harbour Area	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	**27,000**
Waubaushene and Matchedash Bay S	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	**27,000**

Table 3.2-17: Existing Monthly Surface water Consumption (Earthfx, 2010).

Subwatershed	Jan (m^3/s)	Feb (m^3/s)	Mar (m^3/s)	Apr (m^3/s)	May (m^3/s)	Jun (m^3/s)	Jul (m^3/s)	Aug (m^3/s)	Sep (m^3/s)	Oct (m^3/s)	Nov (m^3/s)	Dec (m^3/s)	Total (m^3/s)
Coldwater River	12,000	11,000	12,000	12,000	12,000	86,000	89,000	89,000	86,000	12,000	12,000	12,000	**447,000**
Copeland Creek	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	**22,000**
Hog Creek	3,000	2,000	3,000	2,000	300	2,000	3,000	3,000	2,000	3,000	2,000	3,000	**30,000**
North River	147,000	1,340,000	147,000	142,000	147,000	181,000	187,000	187,000	181,000	147,000	142,000	147,000	**1,890,000**
Sturgeon River	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	**74,000**
Wye River	14,000	13,000	14,000	14,000	14,000	14,000	55,000	55,000	14,000	14,000	14,000	14,000	**247,000**
Honey Harbour to Port Severn	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Lafontaine Creek	4,400	4,000	4,400	4,300	4,400	4,300	4,400	4,400	4,300	4,400	4,300	4,400	**52,000**
Midland Area	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**11,000**
Penetang. Bay W	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	**21,000**
Penetanguishene and Tay Point	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**9,000**
Port Severn and Matchedash Bay N	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**8,000**
Tiffin Basin and Port McNicoll Area	-	-	-	-	-	-	-	-	-	-	-	-	**6,000**
Tiny Coastal Area NW	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	**36,000**
Tiny Coastal Area S	4,000	3,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	**44,000**
Tiny Coastal Area W Central	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	**20,000**
Tiny Coastal Area NE	4,000	3,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	**44,000**
Victoria Harbour Area	-	-	-	-	-	-	-	-	-	-	-	-	**6,000**
Waubaushene and Matchedash Bay S	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	**7,000**

Uncertainty

Water demand estimates are subject to various levels of uncertainty. The methods used to develop an understanding of the total amount of water demand within each subwatershed have been discussed within the previous sections. In applying these methods, attempts have been made to be both consistent and conservative, in order to produce a stress assessment as accurately as possible. In accordance with that, the limitations and assumptions of each data source should be recognized.

Attempts to verify water use within subwatersheds have made the PTTW database more accurate; however, it is known that the maximum permitted taking values used are exaggerating the actual taking. This 'as high as possible' value has been used to ensure that all possibly stressed subwatershed are identified within the Tier One.

Now all municipal drinking water facilities are required to keep and report records of water takings. This information has been obtained directly from the municipalities, and is considered accurate and complete. The level of certainty within this data is a benefit as municipal wells are often the most significant water takers within a subwatershed.

The simple method of applying a consumptive usage fact to population data has been used to estimate non-municipal domestic water use, as suggested in Guidance Module 7 (MOE, 2007). This method is effective for this level of assessment; however, there is uncertainty as individual water use will vary significantly between households.

Non-permitted agricultural demand has been calculated based on coefficients and Statistics Canada census data, as it is a general calculation uncertainty is inherent. A modified version of methodology outline by deLoe (2001, 2005) to estimate water use based on agricultural land use has been used. This method is a general estimate of water use and, although the uncertainty of these calculations is higher than other water demand estimates, they are considered adequate for the purposes of this Tier One screening level stress assessment.

3.2.4 Water Quantity Stress Assessment

The Tier One stress assessment is designed to efficiently screen subwatersheds and highlight those where the degree of stress warrants refined water budget efforts for risk characterization. The stress assessment evaluates the ratio of the consumptive water demand for permitted and non-permitted users to available water supplies, minus water reserves within a subwatershed.

At the Tier One level two scenarios are evaluated for each subwatershed: 1) existing conditions; and 2) future demand. The goal of the existing conditions scenario is to identify subwatersheds that are under stress as a result of existing water takings. Whereas the goal of the future demand scenario is to identify additional subwatersheds that may become stressed as a result of additional drinking water requirements.

The percent water demand has been evaluated independently for both groundwater and surface water. The subwatershed stress level was then determined for both the groundwater and surface water systems. The individual stress levels within the surface water and groundwater systems indicated whether further water budget requirements were needed. For example, only areas identified as having a moderate or significant groundwater stress were advanced to more detailed groundwater modelling assessment (Tier Two).

Table 3.2-18 presents the list of scenarios for groundwater and surface water supplies. As this table indicates, groundwater systems are evaluated for both average annual and monthly conditions, whereas surface water conditions are evaluated monthly. An annual average surface water flow would not be appropriate for a stress assessment, as stream flow changes rapidly based on variables such as precipitation, spring freshet, and summer drought. The prescribed approach for determining the surface water quantity stress takes into consideration seasonal variability and is therefore evaluated using an estimate of expected monthly values. Conversely, an evaluation of the average annual conditions for groundwater is useful for evaluating potential long-term stress conditions. The water demand is calculated for each month, and the largest monthly stress is selected for comparison against the threshold criteria.

Table 3.2-18: Tier One Stress Assessment Scenarios.

Time Period	Average Annual % Water Demand	Highest Monthly % Water Demand
Existing Conditions	Groundwater Sources	Groundwater & Surface Water Sources
Future Conditions	Groundwater Sources	Groundwater & Surface Water Sources

Based on the percent water demand equation below, each subwatershed was assigned a stress level for groundwater and for surface water. Those subwatersheds receiving a low level of stress will require no further water budgeting or water quantity risk assessment work.

Those areas identified as having a moderate to significant level of stress will be subject to further water budget evaluation under Tier Two, provided that the subwatershed contains a municipal water supply system.

$$(\%)WaterDemand = \frac{Q_{Demand}}{Q_{Supply} - Q_{\mathrm{Re}serve}} \qquad (4)$$

Where;

Q_{Demand} = the amount of water (surface water or groundwater) consumed as described in Section 3.2.2.

Q_{Supply} = recharge for groundwater uses assuming any subwatershed groundwater inflow is balanced by groundwater outflow and median monthly streamflow for surface water takings as described in Section 3.2.2.;

$Q_{Reserve}$ = the proportion of available surface water or groundwater that is to be maintained for other needs such as navigation, assimilative capacity, ecosystem health etc. (to be estimated as a proportion of baseflow and a low-flow statistic for groundwater and surface water, respectively) as described in Section 3.2.2.

Table 3.2-19: Stress Assessment Thresholds.

Quantity Stress Assignment	Surface Water - Maximum Monthly % Water Demand	Groundwater - Average Annual % Water Demand	Groundwater - Maximum Monthly % Water Demand
Significant	>50%	>25%	>50%
Moderate	20 -50%	>10%	>25%
Low	<20%	0-10%	0-25%

The monthly maximum conditions for the groundwater stress thresholds are higher than average annual thresholds because groundwater supplies can typically tolerate short-term water demands that may not be sustainable over the entire year. Therefore, the groundwater stress level assignment is the maximum of the existing and future assessment values for both conditions.

It should be noted that these thresholds are intended to be conservative to ensure that areas potentially under hydrologic stress will be identified for additional study.

Tier One Stress Assessment

Municipal groundwater takings within the Severn Sound watershed are from confined or semi-confined aquifers. Municipal water taken from deep aquifers and subsequently discharged via sewage treatment is not being returned to the same groundwater source and possibly not the same subwatershed. Therefore municipal takings have been considered to be completely consumptive within this stress assessment.

It should be noted that in some cases the amount of stress identified within a subwatershed is greater than 100%. A stress greater than 100% is a result of the amount of water being taken is larger than the amount that has been identified as being available. Although this is not physically possible, it does indicate that if the entire permitted water taking within a subwatershed was considered as cumulative and maximum takings were needed, there would not likely be enough water to supply all users. This is also a result of many of permitted water users taking during the same time of year (summer months), instead of being spread over the entire year, which coincides with non-permitted takings (e.g. agricultural uses) during the same time of year. The stresses greater than 100% identified within this report are a result of conservative water demand estimates that are known to be the worst case scenario.

Percent Annual Water Demand-Existing Conditions

Groundwater

Based on the results of the groundwater stress assessment discussed above, under existing conditions the Port Severn to Matchedash Bay North subwatershed exceeds the threshold for potential moderate water quantity stress, and the Penetanguishene and Tay Point and Midland Area subwatersheds exceed the threshold for potential significant water quantity stress (Table 3.2-22 and Figure 3.2-6). Water demand within the Port Severn to Matchedash Bay North subwatershed is primarily for pits and quarry operations, while municipal supply accounts for the primary supply within the Penetanguishene and Tay Point and Midland Area subwatersheds.

Surface Water

No subwatersheds within the Severn Sound watershed have advanced to a Tier 2 assessment for surface water stress[5].

All of the municipal surface water systems within the watershed take water from Georgian Bay. Technical Rule 4 (MOE, 2008a) has prescribed that subwatersheds that take from large lakes, such as Lake Simcoe or the Great Lakes, should not be included in the stress assessment.

Percent Monthly Water Demand-Existing Conditions

Groundwater

In addition to the above mentioned existing annual stress, as outlined within Table 3.2-22 below, and summarized on Table 3.2-20. Moderate and monthly occurrences of groundwater stress have been identified for Penetanguishene and Tay Point, and the Midland Area subwatersheds.

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[5] With respect to municipal drinking water supply per Clean Water Act guidance (MOE, 2007)

Table 3.2-20: Existing Monthly Stress Assessment Summary-Groundwater (Earthfx, 2010).

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coldwater River	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Copeland Creek	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Hog Creek	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
North River	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Sturgeon River	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Wye River	7%	6%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
Honey Harbour to Port Severn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lafontaine Creek	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Midland Area	**30%**	**27%**	**30%**	**28%**	**30%**	**29%**	**30%**	**30%**	**29%**	**30%**	**29%**	**30%**
Penetang. Bay W	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Penetanguishene and Tay Point	**30%**	**27%**	**30%**	**29%**	**30%**	**29%**	**42%**	**42%**	**29%**	**30%**	**29%**	**30%**
Port Severn and Matchedash Bay N	14%	13%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
Tiffin Basin and Port McNicoll Area	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Tiny Coastal Area NW	3%	3%	3%	3%	3%	3%	23%	23%	3%	3%	3%	3%
Tiny Coastal Area S	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Tiny Coastal Area W Central	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Tiny Coastal Area NE	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Victoria Harbour Area	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Waubaushene and Matchedash Bay S	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Surface Water

Within the summer months, surface water stress assessments indicate elevated stress values within several subwatersheds summarized on Table 3.2-21 and Figure 3.2-7. Detailed monthly surface water stress assessments are located in Appendix WB-3A. These elevated values are attributed to low available supply values calculated using the Tessmann method. It can also be seen that this available supply affords very little taking before it is considered stressed. The Tiny Coastal Area North West subwatershed is particularly stressed in month of October at 280%. This is a result of the available supply and reserve being almost equal to each other.

Table 3.2-21: Existing Monthly Stress Assessment Summary- Surface water (Earthfx, 2010).

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coldwater River	1%	1%	0%	0%	0%	6%	12%	14%	10%	1%	0%	0%
Copeland Creek	1%	1%	1%	1%	1%	3%	**34%**	2%	**24%**	3%	1%	1%
Hog Creek	1%	1%	1%	0%	1%	1%	2%	2%	1%	2%	0%	1%
North River	4%	4%	3%	2%	3%	**23%**	12%	14%	11%	6%	4%	3%
Sturgeon River	0%	1%	0%	0%	0%	1%	2%	3%	1%	0%	0%	0%
Wye River	1%	2%	1%	0%	1%	2%	7%	7%	2%	12%	1%	1%
Honey Harbour to Port Severn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lafontaine Creek	2%	3%	1%	0%	1%	2%	3%	3%	3%	**41%**	1%	1%
Midland Area	1%	3%	1%	0%	1%	2%	2%	2%	2%	1%	1%	1%
Penetang. Bay W	3%	5%	1%	1%	2%	3%	4%	4%	4%	2%	1%	1%
Penetanguishene and Tay Point	1%	3%	1%	0%	1%	1%	2%	2%	2%	1%	1%	1%
Port Severn and Matchedash Bay N	2%	4%	1%	0%	1%	2%	3%	2%	3%	1%	1%	1%
Tiffin Basin and Port McNicoll Area	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tiny Coastal Area NW	2%	4%	1%	0%	1%	2%	3%	3%	3%	***280%***	1%	1%
Tiny Coastal Area S	2%	3%	1%	0%	1%	2%	3%	3%	3%	***57%***	1%	1%
Tiny Coastal Area W Central	3%	7%	2%	1%	2%	4%	5%	4%	5%	2%	2%	2%
Tiny Coastal Area NE	2%	3%	1%	0%	1%	2%	3%	3%	3%	***57%***	1%	1%
Victoria Harbour Area	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Waubaushene and Matchedash Bay S	2%	4%	1%	0%	1%	2%	3%	2%	3%	1%	1%	1%

Table 3.2-22: Existing Annual Groundwater Stress Assessment (Earthfx, 2010).

Subwatershed	Coldwater River	Copeland Creek	Hog Creek	North River	Sturgeon River	Wye River	Honey Harbour to Port Severn	Lafontaine Creek	Midland Area	Penetang. Bay W
Area (km2)	191	24	60	319	98	208	68	55	24	24
Precipitation (mm/a)	965	983	974	978	967	967	1000	985	986	992
Evapotranspiration (mm/a)	579	585	583	573	581	583	578	583	587	584
Surplus Water (mm/a)	386	398	391	405	386	383	422	402	399	408
Annual Mean Flow (m3/s)	2.5	0.2	0.5	4.1	1.3	2.5	0.7	0.5	0.2	0.2
Annual Mean Flow (mm/a)	413	220	269	402	417	372	310	301	288	288
Baseflow (m3/s)	1.7	0.1	0.3	2.6	0.9	1.4	0.3	0.3	0.1	0.1
Baselfow (mm/a)	285	141	147	255	296	210	136	169	153	153
Available Groundwater Supply (mm/a)	258	319	269	258	264	221	248	269	264	273
Available Groundwater Supply (mm/a)	1.6	0.2	0.5	2.6	0.8	1.5	0.5	0.5	0.2	0.2
Available Surface Water Supply (mm/a)	296	146	154	249	325	191	159	152	135	135
Available Surface Water Supply (m3/s)	1.8	0.1	0.3	2.5	1.0	1.3	0.3	0.3	0.1	0.1
Groundwater Reserve (mm/a)	29	14	15	26	30	20	13	17	15	15
Groundwater Reserve (m3/s)	0.17	0.01	0.03	0.26	0.09	0.13	0.03	0.03	0.01	0.01
Surface Water Reserve (mm/a)	190	106	129	193	193	171	145	141	136	136
Surface Water Reserve (m3/a)	1.2	0.1	0.2	2.0	0.6	1.1	0.3	0.2	0.1	0.1
Groundwater Consumption (m3/s)	965,000	68,000	97,000	1,274,000	492,000	2,782,000	7,000	86,000	1,744,000	87,000
Groundwater Consuumption (mm/a)	5.1	2.8	1.6	4.0	5.0	13.4	0.1	1.6	72.7	3.6
Groundwater Stress (%)	2%	1%	1%	2%	2%	7%	0%	1%	**29%**	1%

Subwatershed	Penetanguishene and Tay Point	Port Severn and Matchedash Bay N	Tiffin Basin and Port McNicoll Area	Tiny Coastal Area NW	Tiny Coastal Area S	Tiny Coastal Area W Central	Tiny Coastal Area NE	Victoria Harbour Area	Waubaushene and Matchedash Bay S	-
Area (km2)	25	20	16	38	47	21	46	17	19	-
Precipitation (mm/a)	922	991	986	985	966	977	993	984	985	-
Evapotranspiration (mm/a)	586	577	585	582	583	584	582	582	579	-
Surplus Water (mm/a)	406	414	401	403	383	393	411	402	406	-
Annual Mean Flow (m3/s)	0.2	0.2	0.1	0.4	4	0.2	0.4	0.1	0.2	-
Annual Mean Flow (mm/a)	287	278	280	294	296	292	303	271	282	-
Baseflow (m3/s)	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	-
~~Baselfow~~Baseflow (mm/a)	151	145	144	160	164	152	167	139	146	-
Available Groundwater Supply (mm/a)	271	281	265	269	251	253	276	270	269	-

Available Groundwater Supply (mm/a)	0.2	0.2	0.1	0.3	0.4	0.2	0.4	0.1	0.2	-
Available Surface Water Supply (mm/a)	135	128	126	144	147	135	150	123	130	-
Available Surface Water Supply (m3/s)	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	-
Groundwater Reserve (mm/a)	15	15	14	16	16	15	17	14	15	-
Groundwater Reserve (m3/s)	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	-
Surface Water Reserve (mm/a)	135	131	133	138	139	137	142	128	134	-
Surface Water Reserve (m3/a)	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	-
Groundwater Consumption (m3/s)	2,000,000	739,000	27,000	619,000	224,000	100,000	323,000	27,000	27,000	-
Groundwater ~~Consuumption~~Consumption (mm/a)	80.0	37.0	1.7	16.3	4.8	4.8	7.0	1.6	1.4	-
Groundwater Stress (%)	**31%**	**14%**	1%	6%	2%	2%	3%	1%	1%	-

Table 3.2-23: Future Annual Groundwater Stress Assessment (Earthfx, 2010).

Subwatershed	Coldwater River	Copeland Creek	Hog Creek	North River	Sturgeon River	Wye River	Honey Harbour to Port Severn	Lafontaine Creek	Midland Area	Penetang. Bay W
Area (km2)	191	24	60	319	98	208	68	55	24	24
Precipitation (mm/a)	965	983	974	978	967	697	1000	985	986	992
Evapotranspiration (mm/a)	579	585	583	573	581	583	578	583	587	584
Surplus Water (mm/a)	386	698	91	405	386	383	422	402	399	408
Annual Mean Flow (m3/s)	2.5	0.2	0.5	4.1	1.3	2.5	0.7	0.5	0.2	0.2
Annual Mean Flow (mm/a)	413	220	269	402	417	372	310	301	288	288
Baseflow (m3/s)	1.7	0.1	0.3	2.6	0.9	1.4	0.3	0.3	0.1	0.1
~~Baselfow~~Baseflow (mm/a)	285	141.0	147	255	296	210	136	169	153	153
Available Groundwater Supply (mm/a)	258	319	269	258	264	221	248	269	264	273
Available Groundwater Supply (mm/a)	1.6	0.2	0.5	2.6	0.8	1.5	0.5	0.5	0.2	0.2
Available Surface Water Supply (mm/a)	296	146.0	154	249	325	191	159	152	135	135
Available Surface Water Supply (m3/s)	1.8	0.1	0.3	2.5	1.0	1.3	0.3	0.3	0.1	0.1
Groundwater Reserve (mm/a)	29	14.0	15	26	30	20	13	17	15	15
Groundwater Reserve (m3/s)	0.17	0.01	0.03	0.26	0.09	0.13	0.03	0.03	0.01	0.01
Surface Water Reserve (mm/a)	190	106.00	129	193	193	171	145	141	136	136
Surface Water Reserve (m3/a)	1.2	0.1	0.2	2.0	0.6	1.1	0.3	0.2	0.1	0.1

Groundwater Consumption (m3/s)	3,695,000	83,000	121,000	2,070,000	614,000	5,615,000	9,000	147,000	2,541,000	
Groundwater ~~Consuumption~~Consumption (mm/a)	19.3	3.5	2.0	6.5	6.3	27.0	0.1	2.7	105.9	
Groundwater Stress (%)	8%	1%	1%	3%	3%	13%	0%	1%	**43%**	1%

Subwatershed	**Penetanguishene and Tay Point**	**Port Severn and Matchedash Bay N**	**Tiffin Basin and Port McNicoll Area**	**Tiny Coastal Area NW**	**Tiny Coastal Area S**	**Tiny Coastal Area W Central**	**Tiny Coastal Area NE**	**Victoria Harbour Area**	**Waubaushene and Matchedash Bay S**	-
Area (km2)	25	20	16	38	47	21	46	17	19	-
Precipitation (mm/a)	992	991	986	985	966	977	993	984	985	-
Evapotranspiration (mm/a)	586	577	585	582	583	584	582	582	579	-
Surplus Water (mm/a)	406	414	401	403	383	393	411	402	406	-
Annual Mean Flow (m3/s)	0.2	0.2	0.1	0.4	0.4	0.2	0.4	0.1	0.2	-
Annual Mean Flow (mm/a)	287	278	280	294	296	292	303	271	282	-
Baseflow (m3/s)	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	-
~~Baselfow~~Baseflow (mm/a)	151	145	144	160	164	152	167	139	146	-
Available Groundwater Supply (mm/a)	271	281	265	269	251	253	276	270	269	-
Available Groundwater Supply (mm/a)	0.2	0.2	0.1	0.3	0.4	0.2	0.4	0.1	0.2	-
Available Surface Water Supply (mm/a)	135	128	126	144	147	153	150	123	130	-
Available Surface Water Supply (m3/s)	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	-
Groundwater Reserve (mm/a)	15	15	14	16	16	15	17	14	15	-
Groundwater Reserve (m3/s)	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	-
Surface Water Reserve (mm/a)	135	131	133	138	139	137	142	128	134	-
Surface Water Reserve (m3/a)	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	-
Groundwater Consumption (m3/s)	3,024,000	744,000	35,000	1,476,000	708,000	15,000	472,000	35,000	34,000	-
Groundwater ~~Consuumption~~Consumption (mm/a)	121.0	37.2	2.2	38.8	15.1	7.1	10.3	2.1	1.8	-
Groundwater Stress (%)	**47%**	**14%**	1%	15%	6%	3%	4%	1%	1%	-

Percent Annual Water Demand-Future Conditions

Groundwater

As previously discussed, estimates of groundwater takings have been increased based on population growth to forecast future demand and estimate future stress. The results of this estimated future stress assessment indicate that in addition to the existing stresses, the Wye

River and Tiny Coastal Area North West subwatersheds are likely to become moderately stressed (Table 3.2-23).

Sensitivity Analysis

A sensitivity analysis was completed for those subwatersheds that reached a percent water demand of 8% but were still below the 10% threshold. It is recognized that variations in some variations in some parameter estimates could alter the stress assessment sufficiently such that the subwatershed stress level could exceed the 10% threshold. The future stress assessment resulted in the Coldwater River subwatershed falling between the 8-10% threshold range, the subwatershed is; therefore, required to undergo a sensitivity analysis.

A means of assessing the sensitivity of the stress assessment is to increase the percent water demand on choice sources of groundwater extraction. For the Coldwater River subwatershed, the only reasonable place to do this would be to increase the consumptive factor for agricultural demand. As actual water taking for three of the permitted groundwater takings and five of twelve municipal wells was unavailable and maximum permitted rates were used in place of actual rates, the Coldwater River stress assessment is likely to be conservative as is.

By increasing the agricultural consumptive factor from 0.8 to 1.0, the future stress level for the Coldwater River increased from 8 to 9%. Considering the conservatism of the scenario, and the fact that the subwatershed still remains less than moderately stressed the Coldwater River subwatershed should not proceed to a Tier Two analysis.

Percent Monthly Water Demand-Future Conditions

Groundwater

In addition to the above mentioned future annual stress, as outlined within Table 3.2-23 above, monthly occurrences of groundwater stress have been identified for Penetanguishene and Tay Point, and the Midland Area subwatersheds. The future monthly stress assessments are located within Appendix WB-3 and summarized within Table 3.2- 24 below.

Table 3.2- 24: Future Monthly Groundwater Stress Assessment Summary.

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coldwater River	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Copeland Creek	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Hog Creek	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
North River	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Sturgeon River	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Wye River	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%
Lafontaine Creek	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Midland Area	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**	**43%**
Penetang. Bay W	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Penetanguishene and Tay Point	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**	**47%**
Port Severn and Matchedash Bay N	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
Tiffin Basin and Port McNicoll Area	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Tiny Coastal Area NW	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Tiny Coastal Area S	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Tiny Coastal Area W Central	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Tiny Coastal Area NE	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Victoria Harbour Area	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Waubaushene and Matchedash Bay S	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

Surface Water

Future surface water monthly stress assessments were not evaluated, as there is no anticipated increase in municipal surface water demand. In addition to no anticipated demand increase, the municipal intakes within the Severn Sound watershed are located in Georgian Bay and are; therefore, exempt from further evaluation per Technical Rule 4 [6](MOE, 2008a).

Tier One Stress Assessment Summary

Table 3.2- 24 summarizes the results of the Tier One Stress Assessment. Subwatersheds which currently exceed the moderate and significant thresholds for potential stress are also projected to exceed the thresholds in the future. All subwatersheds identified as having the potential to be moderately or significantly stressed under existing conditions remain at the stress level under future pumping conditions. Tiny Coastal Area North West and the Wye River increase from a low potential of stress under existing conditions to a moderate potential stress under future conditions. Even though the Port Severn and Matchedash Bay North subwatershed is flagged as having the potential to be moderately stressed, it is not recommended for a Tier Two assessment as it contains no municipal drinking water systems.

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[6] Technical Rule 4: An area represented by a conceptual water budget or water budget prepared in accordance with rule 3 shall not include any part of a surface water body that is a Great Lake, a connecting channel, Lake Simcoe, Lake Nipissing, Lake St.Clair or the Ottawa River.

Table 3.2-25: Stress Assessment Summary.

Subwatershed	Current Annual Groundwater Conditions	Future Annual Groundwater Conditions	Current Monthly Conditions - Groundwater	Current Monthly Conditions - Surface Water	Future Monthly Conditions - Groundwater	Municipal System - Groundwater	Municipal System - Surface Water*	Tier 2 Recommended - Groundwater	Tier 2 Recommended - Surface Water
Coldwater River	2%	9%	none	June	none	Yes	No	Yes	No
Copeland Creek	1%	2%	none	none	none	Yes	No	No	No
Hog Creek	1%	1%	none	none	none	No	No	No	No
North River	2%	2%	none	June & Oct	none	Yes	No	No	No
Sturgeon River	2%	3%	none	none	none	Yes	No	No	No
Wye River	5%	**12%**	none	none	none	Yes	No	Yes	No
Lafontaine Creek	1%	1%	none	none	none	Yes	No	No	No
Midland Area	**31%**	**46%**	all year	none	all year	Yes	No	Yes	No
Penetang. Bay W	1%	2%	none	none	none	Yes	No	No	No
Penetanguishene and Tay Point	**33%**	**51%**	all year	none	all year	Yes	No	Yes	No
Port Severn and Matchedash Bay N	**15%**	**15%**	none	none	none	No	No	No	No
Tiffin Basin and Port McNicoll Area	1%	1%	none	none	none	No	No	No	No
Tiny Coastal Area NW	7%	**13%**	none	none	none	Yes	No	Yes	No
Tiny Coastal Area S	2%	5%	none	none	none	Yes	No	No	No
Tiny Coastal Area W Central	2%	3%	none	none	none	Yes	No	No	No
Tiny Coastal Area NE	2%	3%	none	none	none	Yes	No	No	No
Victoria Harbour Area	1%	1%	none	none	none	No	No	No	No
Waubaushene and Matchedash Bay S	1%	1%	none	none	none	No	No	No	No

*At the time of study. Some communities have implemented surface water intakes since the Tier 1 study was completed.

3.2.5 Uncertainty

In applying these methods, attempts have been made to be both consistent and conservative, in order to produce stress assessments as accurately as possible. In accordance with that, the limitations and assumptions of each data source should be recognized. The assumptions made that reduce the certainty of the estimations include; in-filling long term precipitation data, estimating the areal distribution, calculating streamflow within ungauged watercourses, and errors inherent in automated baseflow separation techniques. These methods are widely used and have been deemed appropriate for the broad purposes of the assessment report. Further study to refine these methods will be completed within the Tier Two assessment, where necessary, based upon estimated water quantity stresses.

The Tier One screening assessments are intended to be conservative such that all areas of potentially moderate to significant stress are captured and moved forward for further study. As a result of this conservative approach, a high level of confidence can be placed on the identification of potentially stressed subwatersheds. All methods discussed in this report have been derived from published literature, considerably refined in some cases, and the data produced evaluated against previous studies as a check on the validity of results.

As an additional check, the components of the hydrologic cycle used in the estimates of recharge for the stress assessment have been used to solve a simple water balance equation

The objective of the Tier One is to be conservative to ensure that all possible stress is identified. The further more refined Tier Two is intended to confirm or negate this stress. Throughout the report methods which have inherent uncertainty have been identified, these methods and the rational have been discussed above in the methods section.

<u>Areal Distribution</u>

Using several gauges over a large land area generalizes the results making them possibly bias high or low. The calculated Precipitation and AET have been compared to other published work in an attempt to reduce uncertainty.

<u>Ungauged Stream Flow</u>

The method used is considered the best available in situations where no gauged data is available; however use of this method introduced uncertainty for the ungauged basins but less when used as a data infill or data extension technique.

<u>Water Demand Estimates</u>

Attempts to verify water use within subwatersheds have made the PTTW database more accurate; however, it is known that the maximum permitted taking values used are exaggerating the actual taking. This ‘as high as possible’ value has been used to ensure that all possibly stressed subwatersheds are identified within the Tier One.

Non-permitted agricultural demand has been calculated based on coefficients and Canadian census data, as it is a general calculation uncertainty is inherent.

Domestic Use has been determined based on an average number and population data. Variation between household and changes in population introduce uncertainty to this method.

Monthly Demand Adjustments

These are general values based on industry averages and could change significantly from year to year based on changes within industry and climate conditions.

Consumptive Demand Factors

These are general factors based water use averages and could change significantly depending on climate, costs, and conservation measures.

In all of the above methods the most conservative approach has been used, in order to ensure all possibly stressed subwatersheds are identified.

3.2.6 Data and Knowledge Gaps

One of the most difficult variables of the Water Budget to quantify is water demand. The methods used within this report are the best available and provide reasonable results. However, the variables included in these methods introduce uncertainty which should be reduced in more complex assessments. Some of these refinements could include the actual water taking data currently being collected by MOE under Regulation 387/04, a more complete understanding of agricultural use based on actual farming practices, and improved seasonal water taking for certain land uses.

For the purposes of this assessment, quantification of groundwater movement into and out of subwatersheds has been excluded, as has movement between aquifer units within a subwatershed which is important when considering pumping from deep confined aquifers. To quantify stresses upon confined groundwater supplies, an understanding of not only groundwater recharge, but aquifer recharge and discharge is required.

3.2.7 Conclusions and Recommendations

The objective of this report was to identify, through a recommended screening process, subwatersheds which are and are not under stress as a result of water use. The conservative methods used and data obtained as described in the report are adequate to identify these stressed and unstressed subwatersheds. As a result, additional study is required on less than half the study area. The reduction of the spatial scale provides a narrower scope for the Tier Two projects, allowing resources to be focused and results to be refined.

As a result of the findings presented in this report and summarized in Table 3.2- 24, it is recommended that the Wye River, Midland Area, Penetanguishene and Tay Point, and Tiny Coastal Area North West subwatersheds should be further studied in a Tier Two assessment as a grouped investigation (Figure 3.2-8).

Figure 3.2- 1: Mean Annual Precipitation Distribution.

Figure 3.2- 2: Actual Evapotranspiration Distribution.

Figure 3.2-3: Surface Water Monitoring Locations.

Figure 3.2-4: Permitted Groundwater Takings.

Figure 3.2-5: Permitted Surface Water Takings.

Figure 3.2-6: Tier One Groundwater Stress Levels.

Figure 3.2-7: Tier One Surface Water Stress Levels.

Figure 3.2-8: Subwatersheds Identified for Tier Two Assessment.

3.3 Tier Two Water Budget Summary And Methods

Tier Two Water Budgets and Stress Assessments have been undertaken in those subwatersheds that were determined to have a moderate or significant potential for stress in the Tier One Water Budget and Water Quantity Stress Assessment. The goal of the Tier Two Water Budget and Stress Assessment is to confirm or negate the stress assignment completed in the Tier One using a more detailed approach that includes detailed and complex modelling tools to estimate water flow volumes to compare to consumptive demand estimates (MOE, 2006). The role of the Tier Two is to refine the estimation of water budget components to facilitate a more reliable stress assessment and allow subwatersheds with marginal stress levels to avoid the detailed local assessments required in the Tier Three. Should the elevated stress levels be confirmed in the Tier Two assessment, an even more detailed Tier Three Water Budget and Water Quantity Risk assessment is required. How the Tier Two Water Budget and Water Quantity Stress Assessment fit into the over all Water Budget and Risk Assessment Process is illustrated in the flow chart below.

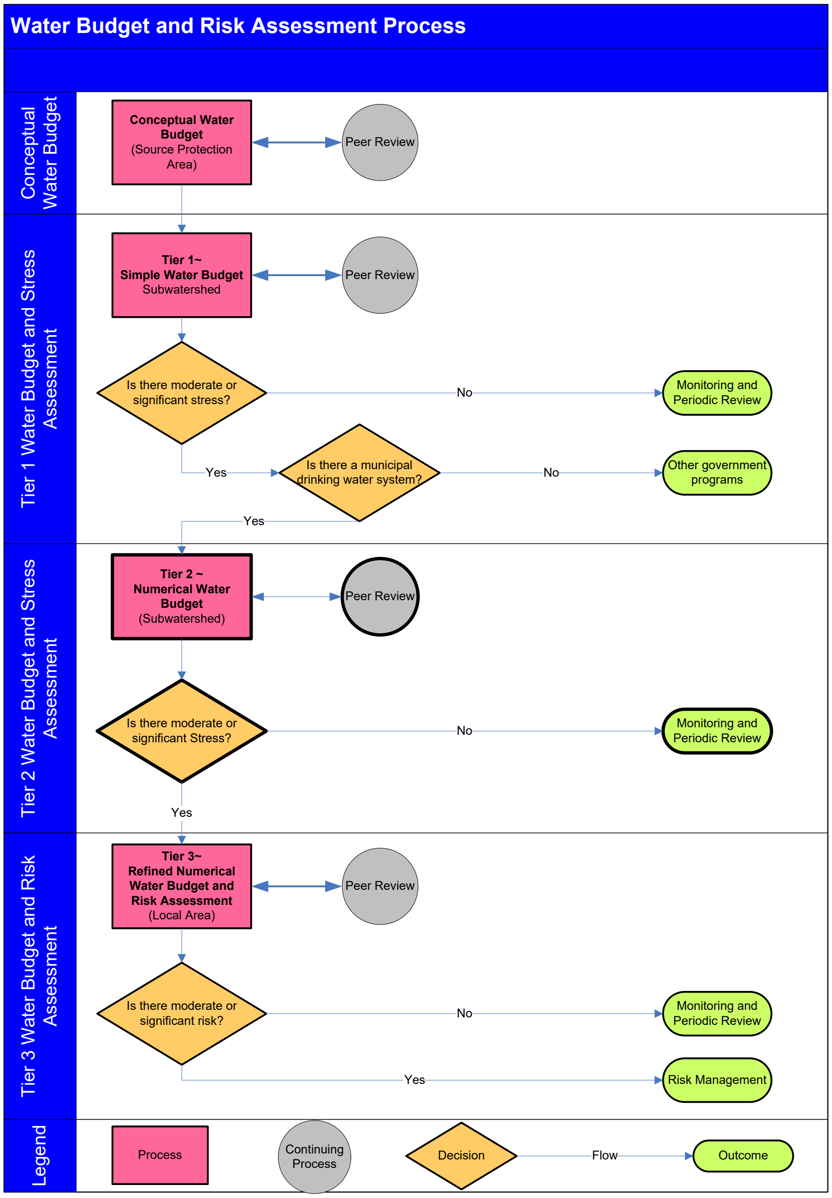


Figure 3.3- 1: Water Budget and Risk Assessment Process (How the Tier Two fits in).

3.3.1 Tier Two Stress Assessment Methodology

The Technical Rules (MOE, 2008a) describe three scenarios used to determine a subwatersheds potential for stress as indicated below. Based on these scenarios each subwatershed is classified as having a low, moderate, or significant potential for stress. Under the direction of the Technical Rules, when a subwatershed is designated as having a moderate or significant potential for stress under any one of the three scenarios, municipal systems located in the subwatershed meet the conditions required for moving on to a Tier Three Water Quantity Risk Assessment Study.

Existing, Planned and Future Percent Water Demand Scenarios

The percent water demand for the existing, planned and future scenarios will be calculated using the same formula and methods that were used in the Tier One Stress Assessment (Section 3.2.4). As outlined in the Technical Rules (MOE, 2008a) and the Guidance Module for Water Budgets (MOE, 2007), the Percent Water Demand is calculated using the following formula:

$$\text{Percent Water Demand} = \frac{Q_{Demand}}{Q_{Supply} - Q_{\mathrm{Re}\,serve}} \times 100\%$$

Where;

Q_{Demand} is equal to the consumptive demand calculated as the estimated rate of locally consumptive takings;

Q_{Supply} is the water supply term, calculated for groundwater supplies as the estimated annual recharge rate plus the estimated groundwater inflow to a subwatershed.

$Q_{Reserve}$ is the water reserve, defined as the specified amount of water that does not contribute to the available water supply. Groundwater reserve is calculated as 10% of the total estimated groundwater discharge within a subwatershed.

For groundwater systems the stress assessment is conducted using the average annual demand conditions and the monthly maximum demand conditions. The groundwater supply will be considered constant for the conditions as per the Technical Rules. The potential groundwater stress thresholds are outlined in Table 3.3- 1.

Table 3.3- 1: Potential Groundwater Stress Thresholds.

Groundwater Potential Stress Level	Average Annual Percent Water Demand	Monthly Maximum Percent Water Demand
Significant	>25%	>50%
Moderate	>10%	>25%
Low	0-10%	0-25%

The Technical Rules (MOE, 2008a) require further evaluation for subwatersheds found to have stress levels close to the moderate stress (i.e. between 8-9% for average annual demand, or between 23-24% for maximum monthly demand), and have high level of uncertainty associated with them. These subwatersheds undergo a sensitivity analysis that allows the percent water demand to be elevated to a moderate potential for stress.

The planned system scenario is conducted in areas where a municipal water system is planned. To meet the technical requirements for a planned scenario, a planned municipal water supply system must have undergone an Environmental Assessment and is intended to be used in the immediate future.

The future water demand scenario considers the evaluation future consumptive water demand estimates for a future population throughout each municipality's planning horizon. In general, this planning horizon is intended to extend to the year 2031; however, in some cases the municipal planning horizons do not extend that far. In this case, the best available information is utilized.

Historic Conditions

According to the Technical Rules (MOE, 2008a) if either of the following two conditions have been met in the recorded history of the municipal groundwater well, the subwatershed would be classified as having a moderate potential for stress:

i. the groundwater level in the vicinity of a well was not at a level sufficient for the normal operation of the well; or

ii. the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

Drought Scenario

One of the scenarios to assess for the subwatershed stress assessment will be the hydrologic stress that may be expected to occur within a long period of drought. The Technical Rules identify the need for both a two year and ten-year drought scenario (Rule 35.2.f/g). These scenarios are designed to capture probable periods of drought conditions; both short and long duration droughts.

The most reliable way to evaluate the effects of a drought is to simulate the time-varying recharge conditions, which result in a drought followed by the long-term recovery once recharge conditions have recovered to normal levels. Where this time varying (transient simulation) approach was required, it was applied. The minimum monthly flow conditions simulated would then be used to represent the worst-case flows expected during drought conditions (MOE, 2006). The methodology and results of this scenario are further discussed in Section 3.4.

3.3.2 Water Demand

Monthly Usage Factors

Monthly estimates of water use are required to represent the seasonal changes in total water use across a subwatershed. All water demand reported in the Tier Two Stress Assessments have been adjusted per Table 3.2.2, where 1 designates the permit is active and 0 designates it is inactive. This facilitates the estimate of actual water used in a subwatershed, as it recognizes that many types of water taking operations only take water during a specific time period for each year (e.g., snow making generally is active December, January and February).

Table 3.3-2: Monthly Demand Adjustments based on Active Months of Takings (Source: MOE, 2006).

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural	Field and Pasture Crops	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Fruit Orchards	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Market Gardens / Flowers	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Nursery	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Other - Agricultural	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Sod Farm	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tender Fruit	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tobacco	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Bottled Water	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Mall / Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other - Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Snowmaking	1	1	0	0	0	0	0	0	0	0	0	1
Construction	Other - Construction	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Road Building	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Pipeline testing	1	1	1	1	1	1	1	1	1	1	1	1

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Instituitional	Other - Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Instituitional	Schools	1	1	1	1	1	1	0	0	1	1	1	1
Miscellaneous	Dams and Reservoirs	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Heat pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other - Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Pumping Test	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Wildlife Conservation	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Other - Recreational	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Wetlands	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Ground Water	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Other - Remediation	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Municipal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Other - Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

*1 indicates water is used that month

Consumptive Use Factors

As discussed in detail in Appendix D of the Water Budget and Water Quantity Risk Assessment Draft Guidance Module (MOE, 2007), water consumption refers to the amount of water removed from a hydrological system and not returned back to the same system in a reasonable time period. To assess the portion of pumped water that is being removed from the hydrologic system, estimates of water demand must consider consumptive use, as opposed to the total amount of water that may be pumped from a system (AquaResource and Golder, 2010).

Estimating consumptive water demand requires a proper consideration of scale as well as the physical water taking operation. Some water takers may have large extraction volumes associated with their permits while actually consuming very little of that water. As an example, aggregate washing operations are permitted to pump large volumes of water between washing and settling ponds, and a relatively small percentage is lost to evaporation, or is removed offsite within the washed material. Another example is a dewatering activity where groundwater that is pumped to lower the water table is discharged to a nearby creek. At the scale of a subwatershed very little of this water is actually consumed; however, this water taking would be fully consumptive with respect to the pumped aquifer (AquaResource and Golder, 2010).

The percent water demand calculation requires the estimate of water which is consumed and not returned to the original source within a reasonable amount of time. Therefore, for a groundwater assessment, if water is removed from the groundwater system and not returned to the groundwater system, the taking is assumed to be 100% consumptive. Groundwater takings are typically 100% consumptive, since wastewater is seldom returned to the groundwater system, but rather discharged to surface water systems. Exceptions would include irrigation, where a portion of the applied irrigation water would saturate surficial soils and percolate beneath the evaporative root zone, returning to the groundwater system. Table 3.3-3 provides a list of consumptive use factors (MOE, 2007) that are used for water takings where water is returned to the same source from which it is taken. These values correspond to the ‘Specific Purpose’ assigned by the MOE to each permit. Where water was not returned to the same source, a consumptive factor of 1 is used.

Table 3.3-3: Consumptive Use Factors (Source: MOE, 2007).

Category	Specific Purpose	Consumptive Factor	Category	Specific Purpose	Consumptive Factor
Agricultural	Field and Pasture	0.8	Industrial	Manufacturing	0.25
Agricultural	Fruit orchards	0.8	Industrial	Other - Industrial	0.25
Agricultural	Market Gardens	0.9	Industrial	pipeline Testing	0.25
Agricultural	Nursery	0.9	Industrial	Power Production	0.1
Agricultural	Other - Agriculture	0.8	Institutional	Hospitals	0.25
Agricultural	Sod Farm	0.9	Institutional	Other - Institutional	0.25
Agricultural	Tender Fruit	0.8	Institutional	Schools	0.1
Agricultural	Tobacco	0.9	Miscellaneous	Dams and Reservoirs	0.1
Commercial	Aquaculture	0.1	Miscellaneous	Heat Pumps	1
Commercial	Bottled Water	1	Miscellaneous	Other - Miscellaneous	0.1
Commercial	Golf Course	0.7	Miscellaneous	Pumping Test	0.1
Commercial	Mall / Business	0.25	Miscellaneous	Wildlife Conservation	0.25
Commercial	Other - Commercial	1	Recreational	Aesthetics	0.25
Commercial	Snowmaking	0.5	Recreational	Fishponds	0.25
Construction	Other - Construction	0.75	Recreational	Other - Recreational	0.1
Construction	Road Building	0.75	Recreational	Wetlands	0.1
Dewatering	Construction	0.25	Remediation	Groundwater	0.5
Dewatering	Other - Dewatering	0.25	Remediation	Other - Remediation	0.25
Dewatering	Pits & Quarries	0.25	Water Supply	Campgrounds	0.2
Industrial	Aggregate	0.25	Water Supply	Communal	0.2
Industrial	Brewing Soft Drinks	1	Water Supply	Municipal	0.2
Industrial	Cooling Water	0.25	Water Supply	Other - Water Supply	0.2
Industrial	Food Processing	1	-	-	-

3.3.3 Severn Sound Source Protection Area Tier Two Summary

As noted in the Tier One Water Budget and Stress Assessment: Severn Sound (Earthfx, 2010) the Wye River, Midland Area, Penetanguishene and Tay Point and Tiny Coastal Area North West are moderately to significantly stressed and should be evaluated at a Tier Two assessment level. It should be noted that the Tier One Stress Assessment (Section 3.2) determined only municipal systems using groundwater sources to be potentially stressed; therefore the Tier Two Stress Assessment was only carried out for groundwater not surface water systems.

The Tier two studies for these subwatersheds have been completed as one project. This project expands the Severn Sound and Nottawasaga Valley Source Protection Areas in their entirety, and captures the western extent of the Lake Simcoe Source Protection Area. An overview of the municipal drinking water systems that underwent a Tier Two evaluation in the Severn Sound Source Protection Area are summarized in Table 3.3-4 below.

Table 3.3-4: Summary of Municipal Drinking Water Systems that underwent a Tier Two Evaluation in the Severn Sound Source Protection Area.

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed
Simcoe County	Town of Midland	Midland Well Supply	Midland Area; Wye River; Penetanguishene and Tay Point
Simcoe County	Town of Penetanguishene	Payette (Penetanguishene) Well Supply	Penetanguishene and Tay Point
Simcoe County	Township of Springwater	Elmvale Well Supply	Wye River
Simcoe County	Township of Tiny	Wyevale Well Supply	Wye River
Simcoe County	Township of Tiny	Perkinsfield Well Supply	Wye River
Simcoe County	Township of Tiny	Georgian Highlands Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Georgian Sands Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Pennorth Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Sandcastle Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Thunder Bay Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Tiny Cover Estates	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Vanier Woods Well Supply	Tiny Coastal Area NW

3.4 Tier Two Water Budget and Water Quantity Stress Assessment- Penetanguishene and Tay Point, Midland Area, Wye River, and Tiny Coastal North West

The Tier One Stress Assessment identified several subwatersheds as having a moderate or significant potential for stress (shown in Figure 3.2-7) and as a result, Tier Two Stress Assessments were completed for these subwatersheds. This section provides an overview of the Penetanguishene and Tay Point, Midland Area, Wye River and Tiny Coastal Area North West Tier Two Water Budget and Quantity Stress Assessment, which was completed as part of the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResources and Golder, 2010).

The work described herein is a summary of the conceptual geologic and hydrostratigraphic modeling (AquaResource and Golder, 2009) and the water budget tool developed for the South Georgian Bay West Lake Simcoe Tier Two Study Area (AquaResource and Golder, 2010) that was completed in compliance with the Technical Rules prepared by the Ministry of the Environment (MOE, 2008a) for the preparation of Assessment Reports under the Clean Water Act and provincial guidance (MOE, 2007). It is recommended that the above two reports be referred to for additional detail.

3.4.1 Study Area and Physical Setting

Location

The study area within the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResources and Golder, 2010) encompasses the Nottawasaga Valley, Severn Sound and a portion of the Lake Simcoe Source Protection Areas (Figure 3.4- 1). This section of the assessment report will focus on the study area located within the Severn Sound Source Protection Area and the Penetanguishene and Tay Point, Midland Area, Wye River and Tiny Coastal Area North West subwatersheds in particular. The Nottawasaga Valley and Lake Simcoe subwatersheds will be discussed in their respective assessment reports.

The Severn Sound watershed covers an area of 1,320 km^2 and extends through the northern portion of Simcoe County. The watershed discharges to Severn Sound within Georgian Bay.

The subwatershed boundaries were modified from those used within the Tier One Stress Assessment as listed in Table 3.4-1(Figure 3.4-2). The size of the Tier One subwatersheds was a concern for the stress assessment process; therefore, the subwatershed boundaries were re-evaluated to be consistent with the Guidance (MOE, 2006). For this study, the larger subwatersheds were subdivided to have areas of roughly 150-200 km^2. The revision of the subwatershed boundaries was also done to facilitate independent stress assessments of municipal systems where neighbouring systems are understood to be hydraulically isolated or to isolate major urban and rural water systems (AquaResource and Golder, 2010).

Table 3.4- 1: Subwatershed Boundary changes for the Severn Sound Tier Two Study Area.

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Tier 2 Subwatershed Name	Tier 1 Subwatershed Name(s)
Simcoe County	Township of Tiny	Cooks Lake	Lafontaine Creek	Tiny Coastal Area NE
Simcoe County	Township of Tiny	Georgian Bay Estates Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Georgian Highlands Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Georgian Sands Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Pennorth Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Sand Castle Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Thunder Bay Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Tiny Cove Estates	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Vanier Woods Well Supply	Lafontaine Creek	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Lafontaine Well Supply	Lafontaine Creek	Lafontaine Creek
Simcoe County	Township of Tiny	Sawlog Bay Well Supply	Lafontaine Creek	Tiny Coastal Area NE
Simcoe County	Township of Tiny	TeePee Point Well Supply	Lafontaine Creek	Penetang. Bay West
Simcoe County	Township of Tiny	Whip-Poor-Will Well Supply	Midland Area	Copeland Creek
Simcoe County	Town of Penetanguishene	Robert Street West Supply Well	Midland Area	Copeland Creek
Simcoe County	Town of Midland	LePage Subdivision (Penetanguishene)	Midland Area	Penetang. Bay West
Simcoe County	Town of Midland	Payette (Penetanguishene) Well Supply	Midland Area	Pentanguishene and Tay Point

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Tier 2 Subwatershed Name	Tier 1 Subwatershed Name(s)
Simcoe County	Town of Midland	Midland Well Supply	Midland Area	Pentanguishene and Tay Point; Midland Area; Wye River
Simcoe County	Township of Springwater	Elmvale Well Supply	Wye River	Wye River
Simcoe County	Township of Tiny	Wyevale Well Supply	Wye River	Wye River; Tiny Coastal Area S
Simcoe County	Township of Tiny	Perkinsfield Well Supply	Wye River	Wye River; Tiny Coastal Area W Central

Conceptual Model

Tier Two Water Budgets and Stress Assessments require that a numerical model be developed to assess the parameters for the percent water demand in the stress calculations. The first step to creating the numerical water budget involves enhancing the conceptual understanding of the study area through the creation of a detailed geological conceptual model. The conceptual model created for the South Georgian Bay West Lake Simcoe Study area builds on various models developed for the North and South Simcoe groundwater studies and geological work completed by the Lake Simcoe Region Conservation Authority (LSRCA). An effort was also made to obtain the information required to conduct water budgeting along the model edge boundaries (AquaResource and Golder, 2009).

An overview of the conceptual model is discussed in this section. A detailed description of the conceptual model can be found in the Nottawasaga Valley Conservation Authority Water Budget Model- Geological/Hydrostratigraphic Model Development Interim Report (AquaResource and Golder, 2009). The goals of the conceptual model were to a) develop a hydrostratigraphic model framework based on the analyses and results of the previous groundwater studies; b) complete bedrock surfaces using sub-regional models and adjacent regional models; c) combine all surfaces and fill gaps with data from bedrock sub-crop maps, NVCA and SSEA data and borehole data; d) develop hydrostratigraphic model layers suitable for numerical model implementation (AquaResource and Golder, 2009).

The understanding of the regional hydrostratigraphy has increased through the creation of the conceptual model. On a regional scale the occurrence of groundwater and groundwater flow within the study area is controlled by precipitation, ground surface topography, water table elevation, surficial geology units, the spatial distribution and connectivity of geologic units.

Precipitation was found to be the main source of groundwater recharge throughout the study area. The groundwater recharge is controlled by the hydraulic conductivity of the surficial geology, the slope of the topography, land use and soil moisture content (AquaResource and Golder, 2009). The updated knowledge of the hydrostratigraphy was key in the development of the layers used in the groundwater model.

The study area contains both overburden and bedrock aquifers that can be used for water supply. The aquifers present in the Nottawasaga Valley study area are generally unconfined. The Barrie-Borden aquifer is situated ideally for water supply. It is confined within a deep tunnel channel valley overlaid by fine-grained deposits. The fine-grained deposits such as the till plains are aquitards impending the vertical movement of water and potential contaminants to the underlying aquifers.

3.4.2 Water Supply

The water supply component of the stress assessment was estimated using a numerical groundwater flow model developed for the South Georgian Bay West Lake Simcoe (SGBWLS) study area. This groundwater model incorporated the enhanced knowledge of the geologic surface and sub-surface gained from the conceptual model discussed in the previous section. The model domain encompasses the Nottawasaga Valley and Severn Sound watersheds in their entirety as well as the western portion of the Lake Simcoe watershed. Additionally, the model was also built to extend to the areas beneath Georgian Bay and Kempenfelt Bay, resulting in a total coverage area of 5416km^2 (Figure 3.4-3) (AquaResources and Golder, 2010).

The FEFLOW modelling code was selected for use because of its ability to simulate physical features, and follow naturally complex boundary conditions. This model runs very efficiently requiring fewer calculation points to achieve the same level of precision as with finite difference model codes. The model elements also have the ability to conform to the pronounced vertical variation of the hydrostratigraphic layers. The stable water table simulation the model performs allows for a more accurate depiction of the shallow subsurface, this allows the modeler to focus on conceptual issues rather than numerical issues. The model is summarized in Appendix WB-4B and described in more detail in the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment (AquaResource and Golder, 2010), which can be referred to for further reasoning on why this model was chosen for the Tier Two assessment.

The water budgets and stress assessment are calculated using the estimated values for groundwater supply and reserve simulated in the numerical FEFLOW model described in Section 3.5.3. Water budgets and stress assessments are conducted to determine a subwatersheds potential stress level, with the ultimate goal of sustaining a water supply.

Recharge

Groundwater recharge in the model was obtained from two surface water models within the study area. Within the Nottawasaga Valley and Severn Sound area a HSP-F surface water model was developed by the Nottawasaga Valley Conservation Authority. In the Lake Simcoe portion of the study area a PRMS model developed by Earth*fx* in 2009 for the Lake Simcoe watershed was used. The surface water models will be discussed in detail in Appendix WB-4. The estimated groundwater recharge used in the stress assessment is illustrated in Figure 3.4-4.

Water Budget Results

The parameters used in the water budget were simulated using the numerical FEFLOW model. This included simulations of groundwater recharge under steady state conditions, consumptive demand estimates determined from recorded pumping rates, groundwater discharge to streams, and the inter-basin transfer of groundwater.

The results of the water budget are shown on Table 3.4-2. The value for groundwater recharge indicates how much recharge the subwatersheds were simulated to receive annually. The negative values for groundwater takings indicate that all subwatersheds are experiencing a net loss of water due to groundwater pumping. A negative value for groundwater discharge to streams indicates that flow is leaving the groundwater system and entering the surface water system. This is observed in all of the Severn Sound subwatersheds undergoing the Tier Two evaluation. A positive value for inter-basin transfer indicates that the subwatershed is experiencing a net in-flux of groundwater. This is observed in the Copeland Creek and Wye River subwatersheds. Conversely a negative net in-flux value indicates that a subwatershed is experiencing a net loss of groundwater flow. This is observed in Laftontaine Creek subwatershed. The values in the water budget form the foundation for the stress assessment calculations.

Table 3.4-2: Water Budget Summary by Subwatershed (AquaResource and Golder, 2010).

ID	Subwatershed	Area (km^2)	Groundwater Recharge (L/s)	Groundwater Takings* (L/s)	Inter-Basin Transfer (L/s)	Cross-Boundary Transfer (L/s)	Total Discharge to Surface Water (L/s)	Discharge to Streams (L/s)	Discharge to Wetlands and Inland Lakes (L/s)	Discharge to Georgian Bay (L/s)
32	Lafontaine Creek and Area	156	1,308	-17	-148	0	-1,144	-11	0	-1,133
34	Midland Area	84	578	-144	34	0	-467	-37	0	-430
31	Wye River	215	1,224	-39	141	0	-1,345	-1,049	-263	-32

**The negative values for groundwater takings indicate that all subwatersheds are experiencing a net loss of water due to groundwater pumping. A negative value for groundwater discharge to surface water indicates that flow is leaving the groundwater system and entering the surface water system.*

Uncertainty Discussion

All models developed to represent natural systems are simplifications of the natural environment and the hydraulic processes within the environment. This simplification results in inherent uncertainty in many of these elements in the groundwater model. As a result of the groundwater model being designed to incorporate the key hydrogeologic features in the study area, the estimation of groundwater flow on a smaller scale may not accurately represent the local area. The scale of the calibration effort was kept consistent with the scale of the model; as such the model was calibrated on a subwatershed level. The water level calibration target only included information provided in the Ministry of the Environment water well database. The expected range of uncertainty associated with these records is 5 m. Since fluctuations in groundwater levels are generally minor, carefully measured water levels were considered to be more certain.

Groundwater discharge is expected to be a component of baseflow in most streams with the remaining baseflow being supplied by other storage mechanisms (i.e. wetlands). Since the proportion of groundwater discharge to wetland is rarely known this is one source of uncertainty. The numerical representation and simulation of groundwater flow systems also contains limitations. Model simulation uncertainty comes from both the approximate solution of the equations using a finite element method, as well as the limitations surrounding finite discretization and assumptions of steady state.

3.4.3 Water Demand

This section provides a summary of the consumptive demands for Lafontaine Creek, Copeland Creek and the Wye River subwatersheds assessed as part of the Tier Two Stress Assessment (AquaResource and Golder, 2010).

Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. aquifer) within a reasonable amount of time. Understanding this type of water demand is critical to the development of a water budget framework. An estimate of the extent and variability of water use throughout the Study Area is required to identify the subwatersheds that may be under the highest degree of potential hydrologic stress, and to guide future efforts to refine water budget tools in those areas (AquaResource and Golder, 2010).

The consumptive groundwater demand was estimated for both permitted (e.g. municipal, industrial and commercial water users) and non-permitted groundwater takings (i.e. domestic water users extracting less than 50,000 L/day and agricultural water users). Figure 3.4-5 shows the locations of all permitted groundwater takings within the Study Area. Only those within the Tier Two Stress Assessment subwatersheds were considered in this assessment. Figure 3.4-6 and Figure 3.4-7 show the average annual and monthly maximum consumptive groundwater demand estimates, respectively, for each Tier Two Stress Assessment subwatershed. These estimates are used to compute the subwatershed potential stress under existing conditions (AquaResource and Golder, 2010).

Actual estimated pumping rates were used to generate the municipal demand, which was a refinement to the estimates used in the Tier One study. While reported pumping rates were used to estimate other permitted water demand by combining the permitted rate with the months of expended active taking. Lastly, non-permitted water demand was estimated by area pro-rating the non-permitted demand estimate from the Tier One stress assessments (SGBLS, 2009). Further refinement to the demand estimates due to the lack of actual water taking data being available at the time of this study. Future consumptive demand was also estimated for the subwatersheds not identified as potentially stressed under existing conditions. After the consumptive demand was estimated a consumptive factor was applied to determine the proportion of groundwater not returned to the original source within a reasonable amount of time. The consumptive factors used are outlined in Table 3.4-3.

There are a number of non-consumptive water users within the study area. However, since they return water to the source from which it was taken they were not considered to be water takers within this Tier Two assessment (AquaResource and Golder, 2010).

Permits to Take Water

Information from the January 2009 permit to take water program database was used to estimate actual water demands. Only permits representing sustained water takings were used in the assessment, temporary permits such as pumping tests were not included. The permit to take water program is now requiring users to report actual pumping rates; however, this updated information was not available for this study. Since the actual pumping rates were unavailable some considerations were taken into account when using the data base.

1) Permit holders often request a volume that exceeds their requirements to be listed on the permit. This is often done to ensure compliance in dry years, or to secure sufficient water for possible future expansion.
2) The permitted volume is often derived from the capacity of the pumping equipment rather than the requirements of the user, which can drastically overestimate the users demand.
3) The database does not maintain a record of whether the permit is just for seasonal use.
4) Multiple sources may be included on a particular permit, and the total refers to all sources associated with the permit. To estimate the total demand, the total permitted rate should be logically divided amongst the active source locations.
5) The spatial location of the water taking sources is not always accurate.
6) The PTTW database is not current with respect to the MOE’s actual permitting activities.
7) Historic water takings may be “grandfathered” and do not require a permit. As a result, there may be some significant water takers not accounted for.

Table 3.4-3: Number of Groundwater Takings by Subwatershed and Water Use Sector (AquaResource and Golder, 2010).

ID	Subwatershed	Agricultural	Commercial	Industrial	Miscellaneous	Recreational	Remediation	Water Supply	Total
32	Lafontaine Creek	4	0	1	0	0	0	29	34
34	Midland Area	0	10	4	0	0	0	22	36
31	Wye River	2	4	1	0	0	0	14	21

Table 3.4-4: Maximum Permitted Takings by Subwatershed (AquaResource and Golder, 2010).

ID	Subwatershed	Area (Km^2)	Maximum Permitted Takings (L/s)	Maximum Permitted Takings (mm/yr)
32	Lafontaine Creek	156	222	45
34	Midland Area	84	510	192
31	Wye River	215	232	34

Municipal Water Demand

Municipal water supplies represent the largest water use within the study area. As such, accurate estimates of municipal water use are a critical component of the consumptive water demand estimate. For the Tier Two Stress Assessment, reported municipal pumping rates were obtained from a variety of sources. Table 3.4-5 lists the municipal systems within the Tier Two Stress Assessment, as well as the source and year of the reported pumping rates. The most recent reported rates were utilized where multiple reported rates were available. Table 3.4-5 summarizes the total municipal groundwater takings by subwatershed for municipal water supply purposes. As seen in these tables, the highest municipal demand for the Nottawasaga Valley watershed is in the Pine River-Borden subwatershed followed by the Willow Creek-Midhurst subwatershed. The communities located within these subwatersheds are currently experiencing growth or are expecting to grow in the near future.

Table 3.4-5: Summary of Municipal Systems (AquaResource and Golder, 2010).

Municipality	Community	Municipal System / Wellfield	Subwatershed(s)	Year of Data	Source of Data	Annual Volume Pumped (L/s)
Midland	Midland	Flume	Midland Area	2007, 2009	SSEA, Golder	11.9
Midland	Midland	Dominion	Midland Area	2007	SSEA	11.1
Midland	Midland	Russell	Midland Area	2007	SSEA	9.9
Midland	Midland	Heritage	Midland Area	2007	SSEA	42
Midland	Midland	Sunnyside	Midland Area	2007, 2009	SSEA, Golder	5.2
Penetanguishene	Penetanguishene	Lepage	Midland Area	2009	Town of Penetanguishene	0.2
Penetanguishene	Penetanguishene	Payette	Midland Area	2009	Town of Penetanguishene	42.8
Penetanguishene	Penetanguishene	Robert St	Midland Area	2006	SSEA	0
Springwater	Elmvale	Elmvale	Wye River	2006	SSEA	8
Tiny	Cooks Lake	Cooks Lake	Lafontaine Creek	2006	SSEA	0.9
Tiny	Georgian Bay Estates	Georgian Bay Estates	Lafontaine Creek	2006	SSEA	1.5
Tiny	Georgian Highlands	Georgian Highlands	Lafontaine Creek	2006	SSEA	0.6
Tiny	Georgian Sands	Georgian Sands	Lafontaine Creek	2002, 2006	Golder, SSEA	8.6
Tiny	Lafontaine	Lafontaine	Lafontaine Creek	2006	SSEA	0.8
Tiny	Pennorth	Pennorth	Lafontaine Creek	2006	SSEA	0.1
Tiny	Perkinsfield	Perkinsfield	Wye River	2006	SSEA	2.2
Tiny	Sand Castle	Sand Castle	Lafontaine Creek	2006	SSEA	0.3
Tiny	Sawlog	Sawlog	Lafontaine Creek	2006	SSEA	0.3
Tiny	TeePee Point	TeePee Point	Lafontaine Creek	2006	SSEA	0.6
Tiny	Thunderbay	Thunderbay	Lafontaine Creek	2006	SSEA	0.2
Tiny	Tiny Cove Estates	Tiny Cove Estates	Lafontaine Creek	2006	SSEA	0
Tiny	Vanier Woods	Vanier Woods	Lafontaine Creek	2006	SSEA	0.3
Tiny	Whip-poor-will	Whip-poor-will	Midland Area	2006	SSEA	1
Tiny	Wyevale	Wyevale	Wye River	2006	SSEA	0.9

Table 3.4-6: Summary of Municipal Groundwater Demands by Subwatershed (AquaResource and Golder, 2010).

ID	Subwatershed	Area (km^2)	Average Municipal Groundwater Demand (L/s)	Average Municipal Groundwater Demand (mm/yr)
32	Lafontaine Creek	156	14	3
34	Midland Area	84	124	47
31	Wye River	215	11	2

Other Permitted Water Demand

Non-municipal permitted water taking types included in the assessment are: agriculture, commercial, dewatering, industrial, miscellaneous, recreational and remediation activities. The other permitted water takings are outlined in Appendix WB-2B and summarized in Table 3.4- 7. It should be noted that the values presented are maximum permitted takings.

Table 3.4- 7: Summary of Non-Municipal Groundwater Demand by Subwatershed (AquaResource and Golder, 2010)

ID	Subwatershed	Area (km^2)	Average Municipal Groundwater Demand (L/s)	Average Municipal Groundwater Demand (mm/yr)
32	Lafontaine Creek	156	222	45
34	Midland Area	84	510	192
31	Wye River	215	232	34

Non-Permitted Water Demand

Non-permitted water demand was estimated by area pro-rating the non-permitted water demand estimated in the Tier One Water Budget and Stress Assessment. The estimated non-permitted water takings in the Severn Sound watershed include agriculture needs and unserviced domestic use. The non-permitted water takings are found in Table 3.4-8.

The non-permitted estimated agriculture water demand includes water used for livestock watering, equipment washing, and any other agriculture water use excluding water used for irrigation. Non-permitted agriculture water demand was estimated as part of the Tier One Water Budget and Stress Assessments. The estimates were area pro-rated to match the boundaries of the Tier Two subwatersheds. It should also be noted that since the non-permitted agriculture demand was based off a census-based estimation technique it is not possible to accurately determine the source of water used. For the Tier Two assessment it was assumed that half of the water would be supplied from a surface source and half would be supplied from a groundwater source. The consumptive nature of non-permitted agriculture water use is also hard to determine, as the water can be used for so many different things. To be on the conservative side all non-permitted agriculture water takings were assumed to be 100% consumptive.

The unserviced domestic water use includes any household water use that is not supplied by a municipal water source. An estimate of the unserviced domestic water use was calculated as part of the Tier One Water Budgets and Stress Assessments. The estimates from the Tier One were also area pro-rated to the boundaries of new subwatersheds. The unserviced domestic water use comes from rural areas, supplied by private wells. Since these takers are generally in rural areas the water taken would be returned to the groundwater system through the septic system and therefore would not be considered 100% consumptive. A consumptive factor of 0.2

was used, which assumes that 20% of water is either consumed or not returned to the same aquifer source (i.e. deeper aquifer system).

Table 3.4-8: Non-permitted Agricultural and Unserviced Domestic Water Use (AquaResource and Golder, 2010).

ID	Subwatershed	Non-Permitted Agricultural Demand (L/s)	Unserviced Domestic Water Use (L/s)	Total Non-Permitted Water Use (L/s)	Total Non-Permitted Water Use (mm/yr)
32	Lafontaine Creek	2.3	2.7	5.0	1.0
34	Midland Area	0.5	0.5	0.9	0.4
31	Wye River	2.6	4.7	7.3	1.1

Monthly Usage and Consumptive Use Factors

Section 3.3.2 summarizes the monthly usage and consumptive use factors that were utilized within the Tier Two assessments. While these factors are generalized, they provide a consistent approach for the initial estimation of consumptive water use. It is recognized that within a specific water use sector the proportion of pumped water consumed may significantly vary between individual operations; the generalized factors, presented in Table 3.3-3, represent a significant source of uncertainty. As, such they were modified as part of a sensitivity analysis to ensure the uncertainty does not affect the stress level assignment (Section 3.4.4).

Table 3.4-9 indicates that the Midland Area subwatershed has a relatively high demand for almost every month, with the highest demands observed in the summer months. Table 3.4-10 outlines the percentage of water demand by sector per subwatershed.

Table 3.4-9: Consumptive Demand by Subwatershed (AquaResource and Golder, 2010).

ID	Subwatershed	Jan (L/s)	Feb (L/s)	Mar (L/s)	Apr (L/s)	May (L/s)	Jun (L/s)	Jul (L/s)	Aug (L/s)	Sep (L/s)	Oct (L/s)	Nov (L/s)	Dec (L/s)	Avg (L/s)	Max (L/s)
32	Lafontaine Creek	17	17	17	20	24	23	28	39	22	20	18	18	22	39
34	Midland Area	124	128	122	133	164	165	166	167	166	152	126	129	145	167
31	Wye River	18	18	18	62	64	71	70	71	70	63	18	18	47	71

Table 3.4-10: Percentage of Consumptive Water Demand by Sector per Subwatershed (AquaResource and Golder, 2010).

Sector	Estimated or Reported?	LaFontaine Creek and Area	Midland Area	Wye River
Agricultural	Estimated	-	-	<1%
Agricultural	Reported	8%	-	<1%
Commercial	Estimated	-	5%	54%
Commercial	Reported	-	<1%	<1%
Industrial	Estimated	3%	3%	4%
Industrial	Reported	-	5%	-
Miscellaneous	Estimated	-	-	-
Recreation	Reported	-	-	-
Remediation	Reported	-	-	-
Private Water Supply	Estimated	1%	-	2%
Private Water Supply	Reported	<1%	-	<1%
Municipal Water Supply	Reported	65%	86%	24%
Livestock and Rural Domestic	Estimated	23%	1%	16%
Total	Estimated	25%	9%	75%
Total	Reported	73%	91%	24%

Uncertainty

Some uncertainty exists with the water demand estimates used in the Tier Two Assessment. Using reported pumping rates for municipal water supply reduces the uncertainty in the municipal water demand. There is still some inherent uncertainty associated with the generated consumptive water demand estimates. The uncertainty associated with the non-municipal permitted water takers will be the highest due to the reliability of the permit to take water database discussed in the proceeding section (Section 3.4.3). Some uncertainty will also exist in the non-permitted water taking estimates. However, since these water users take relatively small rates and with the conservative approach taken with respect to the consumptive nature of these taking types, the impact of this uncertainty is not significant with respect to the stress assessment (AquaResource and Golder, 2010).

3.4.4 Tier Two Stress Assessment

The Tier Two Stress Assessment has only been conducted for groundwater systems since no in-land municipal surface water systems exist within the Source Protection Area. The groundwater systems in the study area that have undergone the stress assessment are shown in Table 3.4-11 and Figure 3.4- 1.

Table 3.4-11: Groundwater Systems in the Study Area.

Upper Tier Municipality	Lower Tier Municipality	Drinking Water System	Subwatershed
Simcoe County	Town of Midland	Midland Well Supply	Midland Area; Wye River; Penetanguishene and Tay Point
Simcoe County	Town of Penetanguishene	Payette (Penetanguishene) Well Supply	Penetanguishene and Tay Point
Simcoe County	Township of Springwater	Elmvale Well Supply	Wye River
Simcoe County	Township of Tiny	Wyevale Well Supply	Wye River
Simcoe County	Township of Tiny	Perkinsfield Well Supply	Wye River
Simcoe County	Township of Tiny	Georgian Highlands Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Georgian Sands Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Pennorth Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Sand Castle Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Thunder Bay Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Tiny Cover Estates	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Vanier Woods Well Supply	Tiny Coastal Area NW
Simcoe County	Township of Tiny	Whip-Poor-Will Well Supply	Copeland Creek

Existing Conditions

The percent water demand was calculated for the Midland, Lafontaine Creek and Wye River subwatersheds using estimates of groundwater supply, reserve and consumptive demand. The water demand used in the stress assessment is discussed above in Section 3.4.3. The estimated consumptive demand for permitted and non-permitted users was used in calculating the subwatersheds potential for stress under existing conditions. The groundwater supply component for the stress assessment was calculated as being the average annual recharge plus the lateral inflow of groundwater to the subwatershed. The groundwater reserve component of the stress assessment was calculated to be 10% of the estimated groundwater discharge to streams. The volume of groundwater discharge on a subwatershed basis was estimated using the FEFLOW numerical model and is illustrated on Figure 3.4-8.

The figure illustrates that a high volume of groundwater discharge is occurring in a portion of the Severn Sound study area over 2,000 L/s on an annual basis for some subwatersheds, when compared to the Lake Simcoe watershed where some subwatersheds discharge less than 500L/s on an annual basis.

The results of the existing conditions stress assessment are shown on Table 3.4-12 and Table 3.4-13. The existing conditions stress assessment indicated that the Midland Area subwatershed has the potential to be moderately stressed. The moderate potential stress classification automatically flags the Midland Area subwatershed for a detailed Tier Three Assessment.

Table 3.4-12: Groundwater Stress Assessment- Existing Conditions (AquaResource and Golder, 2010).

Subwatershed Conditions	Lafontaine Creek	Midland Area	Wye River
Groundwater Supply - Recharge (L/s)	1308	578	1224
Groundwater Supply - Flow In (L/s)	0	94	289
Groundwater Supply - Total Supply (L/s)	1308	672	1513
Groundwater Reserve (L/s)	1	4	105
Consumptive Demand - Annual Average (L/s)	22	145	47
Consumptive Demand - Monthly Maximum (L/s)	39	167	71
Month of Max. Demand	August	August	June
Percent Water Demand - Monthly Maximum (%)	2%	**22%**	3%
Percent Water Demand - Annual Average (%)	3%	**25%**	5%

The cells shaded in orange are above the moderate potential for stress. The cells shaded in orange with bolded underlined text are within 2% of the significant potential for stress threshold, and are required to undergo an uncertainty assessment.

Table 3.4-13: Groundwater Stress Classification-Existing Conditions (AquaResource and Golder, 2010).

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Evaluate Planned Conditions	Municipal Water Supply Systems
32	Lafontaine Creek	Low	Low	**Yes**	Georgian Bay Estates, Georgian Sands, Georgian Highlands, Cooks Lake, Thunderbay, TeePee Point, Lafontaine, Pennorth, Sand Castle, Sawlog, Tiny Cove Estates, Vanier Woods
34	Midland Area	**Moderate**	Low	No	Midland, Penetanguishene, Whip-poor-will
31	Wye River	Low	Low	**Yes**	Elmvale, Wyevale, Perkinsfield

Future Conditions

The future water demand scenario considers the evaluation future consumptive water demand estimates for a future population throughout each municipalities planning horizon. The projected municipal demand was obtained from LSRCA, NVCA, SSEA and the local municipality's. In areas where projections were unavailable future pumping rates were estimated from official growth plans and population estimates (Table 3.4-14).

Future land use conditions were also estimated to determine a future average annual recharge rate to be used as the water supply term in the stress assessment calculations. Any changes to future recharge rates were assumed to be based on the change in urban land use alone (AquaResource and Golder, 2010). The estimated future recharge rates as a function of land use changes are displayed in Table 3.4-15.

The results of the future conditions stress assessment are shown on Table 3.4-16 and Table 3.4-17. The future conditions indicate that all subwatersheds undergoing the Tier Two evaluation located in the Severn Sound watershed remain at a low potential for stress. As a result, both of the subwatersheds are required to undergo the drought assessment scenario.

Table 3.4-14: Future Groundwater Municipal Demand Estimates (AquaResource and Golder, 2010).

Municipality	Community	Wellfield	Subwatershed	Existing Volume Pumped (L/s)	Future Volume Pumped (L/s)	Data Source and Comment on Increase in Future Demand
Midland	Midland	Midland	Midland Area	80.2	102.6	LSRCA, Future max daily pumping is estimated to be the existing system capacity.
Penetanguishene	Penetanguishene	Lepage	Midland Area	0.2	0.4	LSRCA
Penetanguishene	Penetanguishene	Payette	Midland Area	42.8	69.4	LSRCA
Penetanguishene	Penetanguishene	Robert St	Midland Area	0.0	24.6	LSRCA
Springwater	Elmvale	Elmvale	Wye River	8.0	12.4	Based on Residential Development Plans
Tiny	Cooks Lake	Cooks Lake	Lafontaine Creek	0.9	1.9	LSRCA
Tiny	Georgian Bay Estates	Georgian Bay Estates	Lafontaine Creek	1.5	6.5	LSRCA
Tiny	Georgian Highlands	Georgian Highlands	Lafontaine Creek	0.6	2.4	LSRCA
Tiny	Georgian Sands	Georgian Sands	Lafontaine Creek	8.6	17.5	LSRCA
Tiny	Lafontaine	Lafontaine	Lafontaine Creek	0.8	1.7	LSRCA
Tiny	Pennorth	Pennorth	Lafontaine Creek	0.1	0.3	LSRCA
Tiny	Perkinsfield	Perkinsfield	Wye River	2.2	6.6	LSRCA
Tiny	Sand Castle	Sand Castle	Lafontaine Creek	0.3	1.8	LSRCA
Tiny	Sawlog	Sawlog	Lafontaine Creek	0.3	1.3	LSRCA
Tiny	TeePee Point	TeePee Point	Lafontaine Creek	0.6	1.8	LSRCA
Tiny	Thunderbay	Thunderbay	Lafontaine Creek	0.2	0.7	LSRCA
Tiny	Tiny Cove Estates	Tiny Cove Estates	Lafontaine Creek	0.0	0.8	LSRCA, New well

Municipality	Community	Wellfield	Subwatershed	Existing Volume Pumped (L/s)	Future Volume Pumped (L/s)	Data Source and Comment on Increase in Future Demand
Tiny	Vanier Woods	Vanier Woods	Lafontaine Creek	0.3	1.9	LSRCA
Tiny	Whip-poor-will	Whip-poor-will	Midland Area	1.0	1.4	LSRCA
Tiny	Wyevale	Wyevale	Wye River	0.9	2.2	LSRCA

Table 3.4-15: Future Land Use Changes and Recharge Rate Estimates (AquaResource and Golder, 2010).

ID	Subwatershed	Percent Increase in Urban Area (%)	Estimated Existing Average Recharge (L/s)	Estimated Existing Average Recharge (mm/yr)	Estimated Future Average Recharge (L/s)	Estimated Future Average Recharge (mm/yr)	Percent Change in Recharge (%)
32	Lafontaine Creek*	8.4%	1308	265	1253	254	-4
31	Wye River*	8.4%	1224	180	1173	172	-4

*Note: no future land use data available; percent increase in urban area is assumed as the maximum from other subwatersheds.

Table 3.4-16: Groundwater Stress Assessment-Future Conditions (AquaResource and Golder, 2010).

Subwatershed Conditions	Lafontaine Creek (ID 32)	Wye River (31)
Future Groundwater Supply - Recharge (L/s)	1253	1173
Future Groundwater Supply - Flow In (L/s)	0	289
Future Groundwater Supply - Total Supply (L/s)	1253	1462
Groundwater Reserve (L/s)	1	105
Future Consumptive Demand - Annual Average (L/s)	46	57
Future Consumptive Demand - Monthly Maximum (L/s)	70	84
Percent Water Demand - Monthly Maximum (%)	4%	4%
Percent Water Demand - Annual Average (%)	6%	6%

Table 3.4-17: Groundwater Stress Classification- Future Conditions (AquaResource and Golder, 2010).

	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Evaluate Drought Conditions	Major Municipal Water Supply System
32	Lafontaine Creek	Low	Low	**Yes**	Georgian Bay Estates, Georgian Sands, Georgian Highlands, Cooks Lake, Thunderbay, TeePee Point, Lafontaine, Pennorth, Sand Castle, Sawlog, Tiny Cove Estates, Vanier Woods
31	Wye River	Low	Low	**Yes**	Elmvale, Wyevale, Perkinsfield

Planned and Future Conditions

There are four planned wells within the Severn Sound study area. Two wells are planned for the Robert Street well supply and two are planned for the Tiny Cove Estates subdivision (Table 3.4-18).

The percent water demand was calculated using the planned system water demand for each subwatershed and is shown is Table 3.4-19. The water supply and reserve terms are assumed to be the same as existing conditions. The resulting potential stress classifications are listed in Table 3.4-20. Both subwatersheds remained at a low potential for stress under planned conditions and therefore all require further analysis under future conditions.

Table 3.4-18: Summary of Planned Systems.

Municipality	Community	Municipal System	Subwatershed	Source of Data	Annual Volume Pumped (L/s)
Penetanguishene	Penetanguishene	Robert St	Copeland Creek	Golder (2005)	25
Tiny	Tiny Cove Estates	Tiny Cove Estates	Lafontaine Creek	Richardson Foster (2009) (SSEA)	1

Table 3.4-19: Groundwater Stress Assessment-Planned Conditions (AquaResource and Golder, 2010).

Subwatershed Conditions	Lafontaine Creek (ID 32)	Wye River (31)
Groundwater Supply - Recharge (L/s)	1308	1224
Groundwater Supply - Flow In (L/s)	0	289
Groundwater Supply - Total Supply (L/s)	1308	1513
Groundwater Reserve (L/s)	1	105
Consumptive Demand - Annual Average (L/s)	23	47
Consumptive Demand - Monthly Maximum (L/s)	40	71
Percent Water Demand - Monthly Maximum (%)	2%	3%
Percent Water Demand - Annual Average (%)	2%	5%

Table 3.4-20: Groundwater Stress Classification-Planned Conditions (AquaResource and Golder, 2010).

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Evaluate Future Conditions	Major Municipal Water Supply System
32	Lafontaine Creek	Low	Low	**<u>Yes</u>**	Georgian Bay Estates, Georgian Sands, Georgian Highlands, Cooks Lake, Thunderbay, TeePee Point, Lafontaine, Pennorth, Sand Castle, Sawlog, Tiny Cove Estates, Vanier Woods
31	Wye River	Low	Low	**<u>Yes</u>**	Elmvale, Wyevale, Perkinsfield

Historical Conditions

There are no known historical conditions as defined by the Technical Rules (MOE, 2008a), where pumping at municipal wells was affected by low groundwater levels in any of the subwatersheds. As a result, no subwatersheds would be classified as moderately stressed due to historical conditions, in the Severn Sound portion of the study area.

Drought Scenario

According to the Technical Rules (MOE, 2008a), a subwatershed can also be identified as having a potential for moderate stress if either of the following circumstances occurs within the subwatershed during either observed or simulated drought conditions (Rule 35.2e).

(i) the groundwater level in the vicinity of a well was not at a level sufficient for the normal operation of the well; or

(ii) the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

The Technical Rules identify the need for both a two year and a ten year drought scenario (Rule 35.2.f). These scenarios are designed to capture probable periods of drought conditions; both short- and long- duration droughts. With the surface water simulation producing groundwater recharge estimates for the 1970-2005 time period, the impacts of short and long duration drought within this time period can be assessed. Furthermore, the scenarios need to be assessed for both existing and planned systems.

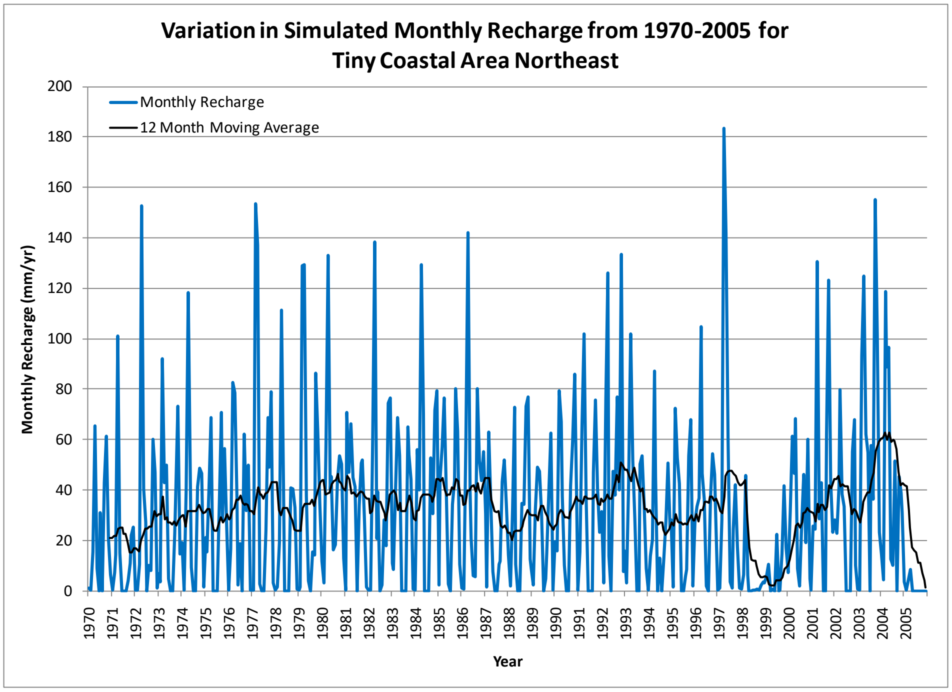
The years of 1998-1999 represent a recorded period of low precipitation, for which estimated recharge is available from the HSP-F and PRMS simulations. Since this information is readily available, the two-year and ten-year scenarios were evaluated simultaneously.

Methodology

To complete the drought assessment, simulated continuous groundwater recharge from the HSP-F and PRMS streamflow generation models is used as transient recharge input to the FEFLOW groundwater flow model. Groundwater recharge is simulated based on units of similar hydrologic response (i.e. areas with similar soil type, land use and climate) for both models. For the purposes of the groundwater drought scenario, the most dominant response unit was used as a representative hydrologic response over the study area, namely forested areas over coarser soils (FORa).

In addition to average annual recharge, a time series of monthly simulated recharge rates for the 1970-2005 period was available from the HSP-F continuous streamflow-generation model across the NVCA and SSEA. Annual average recharge was preserved across the Study Area when completing this exercise. Thus, a monthly time series was generated across the Study Area for each HSP-F model catchment in the NVCA and SSEA watersheds. Utilizing monthly average recharge rates assumes that recharge is constant throughout the month. While in reality, the rates are not constant, they do reflect the relative changes in stress occurring throughout a 2-year or 10-year drought period.

Graph 3.4-1 illustrates the typical variability in monthly recharge estimated from the 1970-2005 simulation for a sample area called Tiny Coastal Area Northeast. This sample area includes the municipal systems of Sawlog, Georgian Bay Estates and Cooks Lake. The figure below also shows a 12-month moving average of the monthly recharge, which removes monthly variability to highlight more significant trends. The 1998-1999 drought is clearly evident in this figure, as is the relatively low recharge conditions that occurred throughout the 1970s.



Graph 3.4-1: Typical Monthly Recharge Variability over the 1970-2005 Simulation Period.

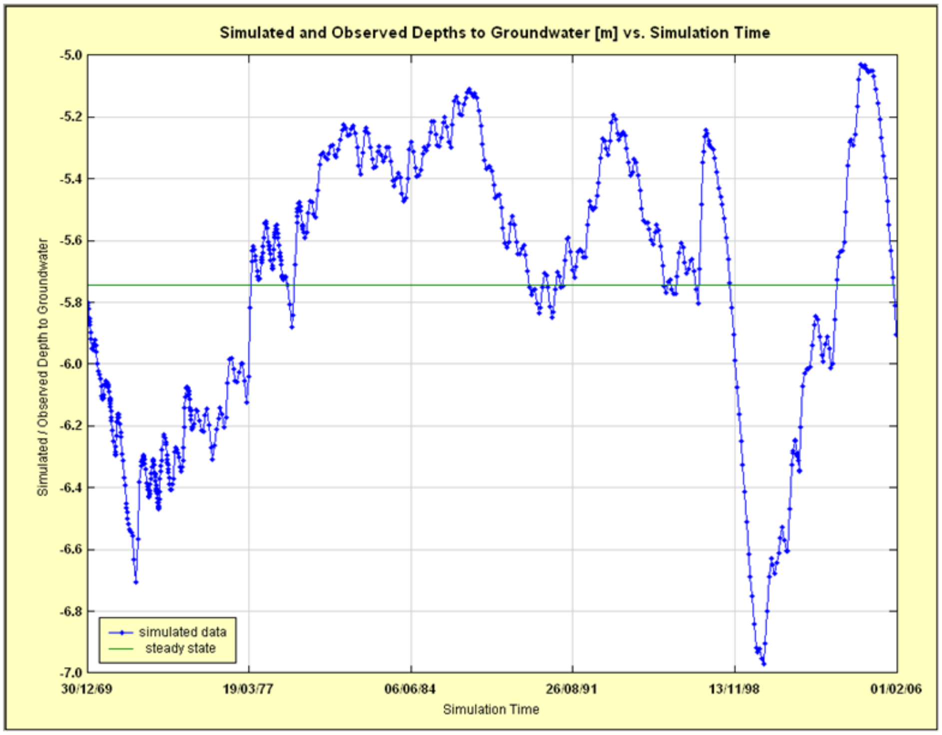
The FEFLOW steady-state groundwater-flow model was configured to use the time series of monthly recharge for the complete 1970-2005 simulation. Water levels resulting from the steady-state groundwater flow simulation were set as initial conditions for the 1970-2005 transient simulation. Within each month, the FEFLOW groundwater-flow model adjusts the simulation time step automatically to achieve a proper numerical solution. The groundwater-flow model was configured to export the minimum simulated groundwater level at each municipal well during the simulation. For discussion purposes, the simulated well response for the entire period for a sample well, namely Sawlog Well 16-2, was also exported (see Graph 3.4-2). This can be generated for any well within the Study Area.

Results

With respect to the Technical Rules, the purpose of the drought scenario is to identify any subwatershed having municipal wells with the potential to be affected by a drought. If such is the case, the subwatershed is classified as having a moderate potential for stress. Subwatersheds already classified as having a moderate or significant potential for stress cannot be affected by the results of the drought scenario.

Graph 3.4-2 illustrates groundwater levels simulated at the sample municipal well of Sawlog. This well was chosen for discussion purposes only. The chart also shows the average water level computed for this pumping well under steady state recharge conditions (green line). The time period shown on the figure is 1970 to 2005, which includes the 1998-1999 drought period. The simulation also assumes constant pumping from each of the wells and therefore the estimated water level fluctuations do not include the impact of variations in pumping rates.

From this figure, the impact of lower recharge throughout the 1970s as well as during the 1998-1999 drought are quite relevant. There is a clear drop in water levels during the drought in 1998-1999 (by approximately 1 m), with climbing water levels during the recovery in the early 2000s. Similarly, the water levels throughout the 1970s were simulated to be below the long term steady-state conditions by about 1m and slowly recover throughout the decade.



Graph 3.4-2: Simulated Well Response from 1970 to 2005 at Sawlog Well 16-2.

As noted above, the drought assessment is performed using transient recharge rates coupled with both existing and planned pumping rates for the municipal wells within subwatersheds listed in Table 3.4-21. The results of the drought assessment are shown in Table 3.4-21, where planned systems are shown in bold. In this table, the estimated available drawdown and the maximum simulated drawdown over the 1970-2005 period are shown for each municipal well. The available drawdown was estimated based on the assumption that the pump intake is located 2 m above the top of the screened interval (as reported in the WWIS or estimated from available information). If the maximum drawdown is greater than the available drawdown, the well is interpreted to be susceptible to drought conditions and could potentially experience climatic conditions that would deplete its ability to pump at the specified rate. As seen in Table 3.4-21, there are no municipal wells susceptible to drought conditions under existing or planned pumping conditions; no wells are predicted to experience drawdown that would exceed their estimated available drawdown. As such, the drought assessment does not affect the overall stress level assignment and all subwatersheds listed below remain at a low potential for stress.

Table 3.4-21: Results of Groundwater Drought Scenario-Maximum Drawdown.

Subwatershed	Municipality	Municipal System	Community	Well Name	Existing Pumping - Available Drawdown (m)	Existing Pumping - Maximum Drawdown (m)	Planned Pumping – Available Drawdown (m)	Planned Pumping – Maximum Drawdown (m)	Drought Concern
Lafontaine Creek	Tiny	Cooks Lake	Cooks Lake	Well 12-1	31	17	31	17	N
Lafontaine Creek	Tiny	Cooks Lake	Cooks Lake	Well 12-2	32	17	32	17	N
Lafontaine Creek	Tiny	Georgian Bay Estates	Georgian Bay Estates	Well 19-1	5	<1	5	<1	N
Lafontaine Creek	Tiny	Georgian Bay Estates	Georgian Bay Estates	Well 19-4	5	<1	5	<1	N
Lafontaine Creek	Tiny	Georgian Bay Estates	Georgian Bay Estates	Well 19-5	5	<1	5	<1	N
Lafontaine Creek	Tiny	Georgian Highlands	Georgian Highlands	Well 1	18	<1	<18	<1	N
Lafontaine Creek	Tiny	Georgian Sands	Georgian Sands	Well 1-1	22	<1	22	<1	N
Lafontaine Creek	Tiny	Georgian Sands	Georgian Sands	Well 14-1	12	2	12	2	N
Lafontaine Creek	Tiny	Georgian Sands	Georgian Sands	Well 2-1	15	1	15	1	N
Lafontaine Creek	Tiny	Georgian Sands	Georgian Sands	Well 2-2	15	3	15	3	N
Lafontaine Creek	Tiny	Georgian Sands	Georgian Sands	Well 5-1	27	2	27	2	N
Lafontaine Creek	Tiny	Lafontaine	Lafontaine	Well 23-1	11	3	11	3	N
Lafontaine Creek	Tiny	Lafontaine	Lafontaine	Well 23-4	9	3	9	3	N
Lafontaine Creek	Tiny	Pennorth	Pennorth	Well 7-1	9	1	9	1	N
Lafontaine Creek	Tiny	Sand Castle	Sand Castle	Well 13-1 Standby	12	1	12	1	N
Lafontaine Creek	Tiny	Sand Castle	Sand Castle	Well 13-2	11	1	11	1	N
Lafontaine Creek	Tiny	Sawlog	Sawlog	Well 16-2	5	3	5	3	N
Lafontaine Creek	Tiny	Sawlog	Sawlog	Well 16-3	5	3	5	3	N

Subwatershed	Municipality	Municipal System	Community	Well Name	Existing Pumping - Available Drawdown (m)	Existing Pumping - Maximum Drawdown (m)	Planned Pumping – Available Drawdown (m)	Planned Pumping – Maximum Drawdown (m)	Drought Concern
Lafontaine Creek	Tiny	TeePee Point	TeePee Point	Well 9-1	5	<1	5	<1	N
Lafontaine Creek	Tiny	TeePee Point	TeePee Point	Well 9-2	6	<1	6	<1	N
Lafontaine Creek	Tiny	Thunderbay	Thunderbay	Well 20-1	8	<1	8	<1	N
Lafontaine Creek	Tiny	Thunderbay	Thunderbay	Well 20-2	8	<1	8	<1	N
Lafontaine Creek	Tiny	Tiny Cove Estates	Tiny Cove Estates	Well 30-1	31	1	31	1	N
Lafontaine Creek	Tiny	Tiny Cove Estates	Tiny Cove Estates	Well 30-2	31	1	31	1	N
Lafontaine Creek	Tiny	Vanier Woods	Vanier Woods	Well 15-1	12	1	12	1	N
Lafontaine Creek	Tiny	Vanier Woods	Vanier Woods	Well 15-2	13	1	13	1	N
Wye River	Springwater	Elmvale	Elmvale	Well 1	37	2	37	2	N
Wye River	Springwater	Elmvale	Elmvale	Well 2 Standby	37	3	37	3	N
Wye River	Tiny	Perkinsfield	Perkinsfield	Well 4	13	4	13	4	N
Wye River	Tiny	Perkinsfield	Perkinsfield	Well 5	22	3	22	3	N
Wye River	Tiny	Wyevale	Wyevale	Well 29-1	20	<1	20	<1	N
Wye River	Tiny	Wyevale	Wyevale	Well 29-2	20	<1	20	<1	N

Uncertainty in Groundwater Stress Classification

A sensitivity analysis was conducted to evaluate the uncertainty associated with the water demand or supply components associated with the percent demand calculations. The sensitivity analysis will determine if the uncertainty associated with the stress assessment components is enough to modify the assigned stress level. Each subwatershed will be assigned a low or high uncertainty level as per the Technical Rules.

Where the sensitivity analysis indicates that the classification may change from moderate to low potential, or low to moderate potential, an uncertainty classification of high is assigned. For subwatersheds that do not change stress levels within the sensitivity analysis, an uncertainty classification of low is assigned (Aqua Resource and Golder, 2010).

While the consumptive use factors (Table 3.3-3) allow for a more realistic estimate of actual amounts of water which are not returned to the same source, these factors do represent a source of uncertainty. Within the study area, groundwater takings for agricultural irrigation purposes are assigned a consumptive factor of 80-90%. It is possible that in reality, none of the irrigation water is returned to the groundwater system, for example, due to tile drainage systems collecting water and discharging it to surface water systems. As such, the following sensitivity analysis presents the percent water demand whereby the average annual and monthly maximum consumptive demands were estimated assuming agricultural takings were 100% consumptive (AquaResource and Golder, 2010).

A second source of uncertainty is the recharge simulated by the surface water models. To ensure the potential stress level for each subwatershed is not sensitive to small changes in recharge, for the second sensitivity scenario, groundwater recharge for each subwatershed was decreased by 10%. This represents a reasonable level of variation in recharge that could be due to differences in characterization, calibration and model capabilities between the HSP-F and PRMS models (AquaResource and Golder, 2010).

The sensitivity scenarios were completed for both the annual and maximum monthly existing demand conditions and are shown in Table 3.4-22. For each subwatershed, the stress classification under the two sensitivity analysis scenarios did not differ from the stress classification current conditions. The sensitivity analysis shows that the stress assessment results are not sensitive to uncertainty associated with water demand and groundwater recharge estimates. This confirmation of the stress classification provides additional confidence in the Tier Two Stress Assessment (AquaResource and Golder, 2010).

Table 3.4-22: Groundwater Sensitivity Analysis-Existing Conditions (AquaResource and Golder, 2010).

Conditions	% Water Demand	Lafontaine Creek	Midland Area	Wye River
Existing Conditions	Average Annual	2%	22%	3%
Existing Conditions	Max. Month	3%	25%	5%
Ground Water Agricultural Demand 100% Consumptive	Average Annual	2%	22%	3%
Ground Water Agricultural Demand 100% Consumptive	Max. Month	3%	25%	5%
10% Less Recharge	Average Annual	2%	24%	4%
10% Less Recharge	Max. Month	3%	27%	5%
Result	**Sensitivity Level**	**Low**	**Low**	**Low**

Stress Assessment Results

Lafontaine Creek

The Lafontaine Creek subwatershed contains the municipal groundwater systems for the communities of Georgian Bay Estates, Georgian Sands, Georgian Highlands, Cooks Lake, Thunder Bay, TeePee Point, Lafontaine, Pennorth, Sand Castle, Sawlog, Tiny Cove Estates and Vanier Woods. The subwatershed has a low potential for stress under all stress assessment scenarios.

The largest groundwater takings within the Lafontaine Creek subwatershed are for municipal water supplies at approximately 65%. The next largest takers are for agricultural and domestic purposes comprising approximately 31% of the available supply and the remaining 4% is divided between private and industrial water supplies.

Under the requirements of the Clean Water Act, the Lafontaine Creek subwatershed is not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

Midland Area

The Midland Area subwatershed contains the municipal groundwater systems for the Town of Midland, the Town of Penetanguishene and the Whip-poor-will (in Tiny Township) subdivision. The subwatershed has a percent water demand of 22% under average demand conditions and 25% under maximum monthly conditions, which results in its classification of a moderate potential for stress.

Within this subwatershed, the municipal water supplies for the Towns of Midland and Pentanguishene including the Whip-poor-will subdivision make up approximately 86% of the total groundwater takings. Additional takings are for industrial purposes, such as golf course irrigation (~5%), and non-permitted demand (~1%). There is low uncertainty associated with the stress classification for this subwatershed.

Under the requirements of the Clean Water Act, the Midland, Penetanguishene and Whip-Poor-Will municipal systems are subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

Wye River

The Wye River subwatershed contains the municipal groundwater systems for the communities of Elmvale, Wyevale and Perkinsfield. The subwatershed has a low potential for stress under all stress assessment scenarios.

The largest groundwater takings within the Wye River subwatershed are for commercial purposes at approximately 54%. The municipal supplies for the subwatershed comprise approximately 24% of the groundwater takings, and the demand is distributed between agricultural and domestic needs.

Under the requirements of the Clean Water Act, the Wye River subwatershed is not subject to completion of a Tier Three Water Quantity Risk Assessment for groundwater.

Table 3.4-23: Summary of subwatershed groundwater stress classification (AquaResource and Golder, 2010).

ID	Subwatershed	Potential Stress (Average Demand)	Potential Stress (Maximum Demand)	Municipal Water Supply Systems
32	Lafontaine Creek	Low	Low	Georgian Bay Estates, Georgian Sands, Georgian Highlands, Cooks Lake, Thunderbay, TeePee Point, Lafontaine, Pennorth, Sand Castle, Sawlog, Tiny Cove Estates, Vanier Woods
34	**Midland Area**	**Moderate**	**Moderate**	**Midland, Penetanguishene, Whip-poor-will**
31	Wye River	Low	Low	Elmvale, Wyevale, Perkinsfield

3.4.5 Conclusions and Recommendations

This Tier Two Water Quantity Stress Assessment, which has been prepared to meet the requirements of the Province of Ontario's Clean Water Act (2006) contains information relating to the water budget and stress assessment for the Severn Sound Source Protection Area, including:

- Physical description of the watershed;
- Consumptive water demand estimates;
- Groundwater model description; and
- Subwatershed-scale stress assessment.

The subwatershed stress assessment presented in this section provides the required evaluation to determine those areas where a Tier Three Risk Assessment is warranted. This Tier Two Stress Assessment was focused entirely on groundwater resources, as no surface water intakes were required to be evaluated.

All of the above conditions were considered in determining the stress classification for each subwatershed. Any one of the conditions that determines the subwatershed to be at a moderate or significant degree of stress is sufficient to identify that subwatershed as requiring a Tier Three Risk Assessment. An uncertainty assessment was also performed to evaluate the realistic potential change in the classification, given the uncertainty in the primary input data (i.e., groundwater recharge and demand estimates).

The groundwater water budget tool developed for the Study Area provides a physical means of evaluating groundwater flows throughout the watershed. As such, its potential applications extend beyond Ontario's Source Protection initiatives and include long-term water management throughout the watershed. Herein the groundwater model is applied to meet the requirements of the Tier Two Stress Assessment through the calculation of inter-basin flows and groundwater discharge rates to surface water resources. Groundwater demand included in the model is consistent with the demand estimates described in Section 3 of this report. Recharge to the groundwater model was derived from a concurrent surface water modelling study as described in NVCA (2009). The estimates of groundwater demand (based on permitted and non-permitted takings), supply (based on recharge and inter-basin flows), and reserve (based on simulated groundwater discharge) provide the subwatershed scale components required to complete the stress assessment (AquaResource and Golder, 2010).

The Midland subwatershed was classified as having a percent water demand of 22% for existing annual demand conditions and 25% under existing monthly maximum demand conditions. These analyses are primarily driven by local municipal demand, but also include substantial industrial and commercial demand beyond the municipal system. As a result, the subwatershed was classified as having a moderate potential for stress and there is need for the Penetanguishene (including the Whip-Poor-Will subdivision in Tiny Township) and Midland municipal systems to proceed with a Tier Three Water Quantity Risk Assessment.

Figure 3.4- 1: Study Area.

Figure 3.4-2: Subwatershed Boundaries.

Figure 3.4-3: Numerical Model Domain.

Figure 3.4-4: Model Recharge per Hydrologic Response Unit.

Figure 3.4-5: Permitted Groundwater Takings.

Figure 3.4-6: Average Groundwater Consumptive Demand.

Figure 3.4-7: Maximum Groundwater Consumptive Demand.

Figure 3.4-8: Groundwater Discharge along streams.

Figure 3.4-9: Subwatershed Groundwater Stress Assessment Results.

Figure 3.4-10: Subwatersheds Recommended for Tier Three Analysis.

3.5 Tier Three Water Budget and Local Area Assessment - Midland, Penetanguishene, and Whip-Poor-Will

The 'Midland Area' subwatershed was identified as having a moderate potential for hydrologic stress in the South Georgian Bay West Lake Simcoe Tier Two Water Budget and Stress Assessment completed by AquaResources and Golder, 2010.Stress level classifications assigned to subwatersheds were based on average annual and monthly maximum water demand conditions determined during the Tier Two analysis. The moderate stress level designation assigned to the Midland Area subwatershed, triggered the need for a more rigorous Tier Three Water Budget and Local Area Risk Assessment for the systems in the Midland Area. The municipal systems within the Midland Area subwatershed include those in the Town of Midland, Town of Penetanguishene, and the Whip- Poor- Will well system in the Township of Tiny.

A Tier Three Water Budget and Local Area Risk Assessment evaluates the long term reliability of a municipality's drinking water sources by determining whether the municipality is able to meet its current and planned water quantity requirements, while accounting for increased municipal demand, future land development, drought conditions, and impacts to other water uses. The Tier Three Assessment requires the identification of threats to drinking water sources found to be under moderate or significant water quantity risk. While the Tier Two Assessment focused on the subwatershed scale and evaluated the total consumptive water demand and water supply for the subwatershed, Tier Three Water Budgets and Local Area Risk Assessments focus on the area which provides water to the well/intake. For groundwater wells this area includes the lands contributing water to the wells.

The Tier Three Assessment relies on refined numerical models to simulate ground and surface water flows and levels (and the interactions between them) under a variety of conditions and scenarios. The models developed for this Tier Three Assessment represent a comprehensive conceptualization of the hydrology and hydrogeology that influences water supplies in the Town of Midland, Town of Penetanguishene, and Township of Tiny. In comparison to the Tier Two Assessment, the Tier Three Assessment uses more refined models, and represents a much more detailed study of the flow systems within a subwatershed.

This chapter provides an overview of the Tier Three Water Budget and Local Area Risk Assessment carried out for the Midland and Penetanguishene area. The work described herein is a summary of the conceptual and numerical hydrologic and hydrogeologic modeling and water budget tool developed by Golder Associates, 2014. The Assessment was completed in compliance with the Technical Rules for the preparation of Assessment Reports under the Clean Water Act (MOE,2008a), and the Water Budget and Water Quantity Assessment Guide (MNR and MOE, 2011). The full study is documented in the "Midland and Penetanguishene Tier Tree Water Budget and Local Area Risk Assessment" foundation report completed by Golder Associates, 2014. It is recommended that the foundation report be referred to for additional insight.

3.5.1 Study Area and Physical Setting

The Midland and Penetanguishene Tier Three Assessment Study Area is generally confined to a peninsula in the Georgian Bay region of Ontario, and can be divided into 13 subwatersheds encompassing an area of 148 km^2, as illustrated in Figure 3.5- 1 and Figure 3.5- 2. The Study Area was delineated to correspond with natural boundaries, such as groundwater flow divides and subwatershed boundaries, while encompassing the entire source area for each of the municipal wells. The area incorporates the municipal well systems of Midland, Penetanguishene, and the Whip-Poor-Will system of Tiny Township. It should be noted that despite being included in the Tier Three model, other well systems in the Township of Tiny were not evaluated as part of the Tier Three Assessment, due to their location outside of the 'Midland Area" subwatershed, recommended for Tier Three Assessment in the Tier 2 Water Budget (as presented in Section 3.4). The locations of the wells systems addressed in this study are illustrated in Figure 3.5- 1, while the specifics of each well system are presented in Table 3.5- 1, Table 3.5- 2, and Table 3.5- 3. The well systems evaluated in this Tier Three Assessment include the Lepage, Robert Street, and Payette Drive systems in Penetanguishene; the Vindin Street, Heritage Drive, Sunnyside, Russell Street, Fourth Line and Dominion Avenue wells in Midland, and the Whip-Poor-Will system in Tiny Township.

Conceptual Model

Tier Three Water Budgets and Local Area Risk Assessments require that detailed numerical models be developed to assess ground and surface water flows under a number of scenarios. The first step to creating these numerical models involves enhancing the conceptual understanding of the Study Area through the creation of a detailed conceptual model. This section details the refined conceptual model specifically developed for the Towns of Midland and Penetanguishene, and Township of Tiny.

Geology

The surficial geology of the Study Area is largely characterized by shallow and deep water glaciolucstrine deposits that partially mantle till deposits in the uplands, and a variety of other deposits in the lowlands. The upland areas mantled by tills include the north part of Midland and parts of Penetanguishene, as well as areas to the west of Midland near Lalligan Lake. Some evidence of glaciofluvial and ice contact deposits can be found to the south of Midland, while the remainder of the Study Area is characterized by coarse textured glaciolacustrine sand and gravel. Fine grained glaciolacustrine, and organic deposits found in lowlands adjacent to water courses are an exception to this. The surficial geology of the Study Area is mapped in Figure 3.5-3.

After the regression of the Late Wisconsonian Glacier, the lower lake phases and Lake Algonquin covered much of the Tier Three Study Area. Lake Algonquin worked to erode terraces in the existing till deposits described above, and removed fine grained sediments through wave-action, resulting in the formation of the gravel bars and spits that now line the former shoreline. The eroded fine grained slit and clay sediments eroded by wave-action were then deposited in in the deep waters of the valleys and in the present day lake basins(Figure 3.5- 4).

The highlands found in the Simcoe Upland regions and portions of the St. Andrews Lake and Lalligan Lake regions are characterized by silt and sand residual landforms. In the northwest portion of Penetanguishene, and in the southwest Copeland Creek area, glaciolucstrine silts and clays primarily characterize the geology, while organic deposits are primarily associated with Wye Lake and the terminus of Copeland Creek, as well as St. Andrews Lake and Sucker Creek.

Hydrostratigraphy

An understanding of the hydrostratigraphy of the area was essential during the development of the layers used in the numerical groundwater model. The regional hydrostratigraphy of the Study Area is defined based on the Quaternary geologic deposits found in the region.

Municipal wells in the Study Area pump groundwater from highly transmissive geologic units called aquifers. Aquifers are layers of permeable overburden deposits primarily composed of coarse grained sediments; higher transmissivity bedrock units are also referred to as aquifers.

Geologic units that act to impede the flow of groundwater from one aquifer to another are called aquitards. Aquitards are generally composed of lower permeability overburden materials such as clay or fine grained tills, and can also be found in poorly transmissive bedrock units.

The aquifer system in the Study Area is characterized by three major units referred to as A1, A2, and A3. A1 is the shallowest of the aquifers, while A3 is the deepest. Aquifer A3, also referred to as the Lower Aquifer, is variable in composition, and consists of sediments ranging from fine sand to coarse gravel. The Lower Aquifer serves as the major groundwater source for the municipal wells in the area, and is continuous across most of the model Study Area. The aquifer ranges between 15 and 50 m of thickness depending on the location, and is thickest in the area west of Midland, and south of the Payette Drive well field.

The Lower Aquifer (Aquifer A3) is overlain by a confining layer in the areas around Penetanguishene Harbour, Midland Bay, and Georgian Bay. However, in the vicinity of the Payette Drive and Vindin Street wells, the Upper Aquifer (A2) connects with the Lower Aquifer (A3). In upland areas, the Lower Aquifer is generally considered to be unconfined, except under the upland till deposits described above.

Upper Aquifer (A2) is also present almost continuously throughout the Study Area. Thickness of the Upper Aquifer ranges between 20m under Midland, and more than 40 m in other regions of the Study Area. Despite being connected to the Lower Aquifer as discussed above, the Upper Aquifer can be found as a discreet unit in the vicinity of the Robert Street well field, and the central Midland area, as well as the highlands to the west (Golder, 2014). The unit is confined in much of the Study Area, and exhibits flowing artesian conditions in the vicinity of the Robert Street and Sunnyside wells. The Upper Aquifer is unconfined in the vicinity of the Penetanguishene Harbour, Little Lake, and the northeastern part of Midland. The general model hydrostratigraphy is illustrated in Figure 3.5- 5 . A more detailed characterization of the hydrostratigraphy can be found in the Conceptual Understanding Report found in Appendix A of the Midland and Penetanguishene Tier Three Risk Assessment Report completed by Golder Associates, 2014. Table 3.5- 1 lists the municipal wells evaluated as part of this study, and their corresponding supply aquifer.

Table 3.5- 1: Municipal Wells and Supply Aquifers (adopted from Golder, 2014).

Municipality	Well Field	Well	Supply Aquifer
Midland	Vindin	Well 6	A3
Midland	Vindin	Well 11	A3
Midland	Vindin	Well 12	A3
Midland	Vindin	Well 14	A3
Midland	Vindin	Well 16	A3
Midland	Vindin	Well 17	A3
Midland	Heritage	Well 7A	A3
Midland	Heritage	Well 7B	A3
Midland	Dominion	Well 9	A3
Midland	Russell	Well 15	A3
Midland	Fourth	Well 1A	A3
Town of Penetanguishene	Payette	Well 1	A3
Town of Penetanguishene	Payette	Well 2	A3
Town of Penetanguishene	Payette	Well 3	A3
Town of Penetanguishene	Robert	Well 2	A3
Town of Penetanguishene	Robert	Well 3	A3
Town of Penetanguishene	Lepage	Well 1	A2
Town of Penetanguishene	Lepage	Well 2	A2
Whip-Poor-Will (Township of Tiny)	Whip-Poor-Will	21-1	A2/A3
Whip-Poor-Will (Township of Tiny)	Whip-Poor-Will	21-2	A2/A3

Hydrology

An understanding of the hydrologic system in the Study Area is instrumental in determining the dominant flow paths that are key to the development of Tier Three models. The Study Area can be divided into 13 subwatersheds, each consisting of a diversity of surface water features, including lakes, wetlands, marshes, creeks, and streams. The boundaries of the 13 subwatersheds are illustrated in Figure 3.5- 2. Land cover, surficial soils, wetlands, lakes, and other storage reservoirs are all key factors that influence the hydrology of the Study Area. Land cover in the Study Area largely consists of woodland and pastureland, indicating a potential for high evapotranspiration rates. The predominant soil classes in the Study Area were identified as sandy loams and loamy sands with “well drained” characteristics. These soil groups are generally indicative of high infiltration rates, and reduced runoff rates when compared to less pervious soils. Storage for runoff generated in the region is provided by the numerous lakes, marshes, wetlands, and reservoirs found in the Study Area. The combined effect of high infiltration, high potential evapotranspiration, and attenuation of flows in the Study Area is indicative of reduced runoff, more persistent baseflow, and relatively small peak flow rates during storm events in the region (Golder, 2014).

Land Use and Land Use Change

Tier Three modeling must consider the impact of existing and future land use on groundwater recharge in order to identify potential impacts to water quantity. The existing land use and land cover found within the Study Area is illustrated in Figure 3.5- 6, while Figure 3.5- 7 highlights the areas of projected land use change. The areas outlined in black in Figure 3.5- 7 represent areas of projected development. As illustrated on the map, most of the development projected is focused on the central and southern parts of Midland, and Penetanguishene, along with some minor pockets of development along the Georgian Bay shoreline to the west of the Study Area.

The existing land use and land cover mapped in Figure 3.5- 6 is based on information obtained from the Southern Ontario Land Resources Information System (SOLRIS) and Natural Resources and Values Information System (NRVIS) data, as well as agricultural surveys completed by the Severn Sound Environmental Association.

Information regarding areas of land use change in each town was obtained from three main sources. For the Town of Midland, future development lands were identified using the town’s Water Works Maser Plan Update drafted by Aecom, 2013. For the Town of Penetanguishene, the Official Plan was used as the main source of land use change information, while the Development Properties Map was the main reference used for the Township of Tiny.

3.5.2 Numerical Models

An important element of the Tier Three Assessment is a refined evaluation of water budget components at a localized scale. The modeling approach used to complete the Risk Assessment requires the development of detailed numerical models that integrate both surface and ground water components of the local flow system to evaluate the sustainability of municipal water sources under a variety of scenarios. The numerical models developed for the Midland and Penetanguishene Tier Three study are based on the refined conceptual understanding of ground and surface water systems in the Study Area, as discussed in the Section 3.5.1 above.

For this Tier Three Assessment, the numerical modeling approach was designed to:

- Simulate average and drought climates under steady state and transient conditions
- Represent the detailed hydrologic/hydrogeologic conditions of the Study Area
- Integrate the inputs and outputs of the surface water and groundwater models

Numerical modeling was conducted to simulate surface water flows using MIKE SHE software, while groundwater flows were simulated using the FEFLOW code. Both models were calibrated to represent typical flow conditions under average (steady-state), and variable (transient) climate conditions. The representation of a wide variety of climatic conditions is necessary to determine if a municipality's water supply will be able to reliably meet water demand under a range of weather conditions.

The major objective of the MIKE SHE surface water modelling was to estimate recharge rates to the saturated zone in the groundwater model. Appendix C of the Midland and Penetanguishene Tier Three foundation report describes the construction and calibration of the surface water model in greater detail.

As part of the Tier Three Assessment the major objective of the detailed FEFLOW groundwater flow model was to simulate the 3D groundwater flow system within the Study Area. The model is a more refined and localized version of the larger scale NVCA model used in the Tier Two Assessment (developed by AquaResource and Golder, 2010). The refined model was calibrated to both steady state and transient climate conditions, with a focus on matching higher quality water level and stream baseflow targets in the local well field areas (Golder, 2014).

3.5.3 Water Demand

The development of representative Tier Three Models is dependent on accurate estimates of water demand in the Study Area. An estimate of the extent and variability of consumptive water demand is essential for the calculation of water budgets, simulation of various risk scenarios, and the overall identification of aquifers under hydrologic stress. This section provides a summary of the consumptive groundwater demands within the Study Area. Consumptive groundwater demand refers to water that is taken and not returned to its original source (i.e. an aquifer) within a reasonable amount of time. Consumptive water demand was estimated for both permitted and non-permitted water takings within the Study Area. Permitted water takings are generally carried out by large municipal, industrial, and commercial water users, while non-permitted groundwater takings tend to be attributed to domestic and agricultural uses.

In addition to consumptive groundwater takings, there are several non-consumptive water uses that also rely on groundwater supplies within the Midland and Penetanguishene Tier Three Study Area. Such uses may include surface water features that rely on groundwater discharge for sustaining coldwater fisheries (and other similar environmental/ ecological communities), as well as uses associated with recreation. Non-consumptive water uses often rely on ground and surface water systems to maintain minimum flow or water levels. Due to their reliance on ground and surface water flows, non-consumptive water uses are also considered during the Tier Three Risk Assessment.

Municipal Demand

The accurate estimation of existing and future municipal water demand is essential for the simulation of the various risk scenarios required under the Tier Three Assessment. The pumping rates used as inputs for the simulation of these scenarios must reflect current demand conditions (existing demand), and future demand conditions including any additional takings that will be required to meet the needs of an approved settlement area (committed demand), and any additional demand that may be required as a result of projected growth identified within a Master Plan or Class Environmental Assessment (Planned Demand)(MOE,2013). The following section further describes the components of the demand calculations required for this Tier Three Assessment.

Existing demand refers to the average pumping rate during the year the Tier Three Assessment was conducted. For this study, the existing demand calculation was conducted for the years of 2010 and 2011, and was based on municipal pumping rates provided by the municipalities, as well as values taken from the MOE's water taking reporting system (WTRS) database.

Committed demand refers to an amount, greater than the existing demand that is necessary to meet the needs of an approved settlement area identified within an Official Plan. The portion of this amount that is within the current lawful Permit to Take Water is part of the allocated quantity of water; a parameter used as an input during the modelling of the Risk Assessment scenarios. Any amount greater than the current lawful PTTW Taking is considered part of the planned quantity of water (MOE, 2013). For this study, the committed demand for each municipality was within the current lawful Permit to Take Water and therefore no planned quantity of water was identified.

Planned demand refers to a specific amount of water required to meet the projected growth identified within a Master Plan or Class Environmental Assessment, but is not already linked to growth within an Official Plan (MOE, 2013).

The planned quantity of water includes any amount of water that meets the definition of a planned system in Ontario Regulation 287/07 and any amount of water that is needed to meet a Committed Demand above the current lawful Permit to Take Water Taking (MOE, 2013). As described above, the committed demand for the well systems in this study are within the currently permitted taking rates, and therefore there was no planned quantity of water identified.

The allocated quantity of water refers to the combined amount of existing and committed demand up to the current lawful Permit to Take Water Taking. For this study, the allocated quantity of water (existing plus committed demand) was used as an input during the simulation of the Risk Assessment scenarios, to determine how increases in demand would impact water supplies. The allocated quantity of water can often be determined from population growth estimates, official plan data, and planning documents provided by municipalities. The allocated quantity of water used in the model scenarios for this Tier Three Assessment has been assigned using information and planning documents provided by the Towns of Midland, Penetanguishene, and Tiny Township. The following section details the existing and allocated water demand for each of the municipalities.

Town of Midland

The well system for the Town of Midland consists of 11 production wells situated in 5 individual well fields. 10 of the 11 municipal wells are currently operational. The Vindin Street well field consists of 6 operational wells located in the northern part of Midland (Wells 6, 11,12,14,16,and 17). The Heritage Drive well field, located at the southern end of the town, consists of 2 operational wells referred to as wells 7A and 7B. Two single wells, the Dominion Avenue and Russell Street wells are respectively located in the west and central areas of Town.

Despite being included in the Town's system permit, an additional single well referred to as the Fourth Street Well, is currently not in service. Moreover, four former municipal wells, referred to as the Sunnyside Drive wells are located in the northern part of Town. These wells have been decommissioned, and no longer form part of the Midland system. Table 3.5- 2 presents the existing demand and allocated quantity of water for each of the wells mentioned above.

The existing demand for the Town of Midland was determined using the average pumping rates at each well for the years of 2010 and 2011. These 2010/2011 average rates were used as inputs during model calibration and scenario simulations.

Calculations to determine the allocated quantity of water for each well were based on the Town's projected 2031 water demands. Water demands for 2031 were estimated using the Town's Waterworks Master Plan Update (AECOM, 2013). As presented in Table 3.5- 2, 2031 pumping rates represent a total pumping increase of 58%, with the total pumping rate increasing to 9,590 m^3/day. Despite the increase in the total pumping rate, 2031 pumping rates for each well remain below current permitted limits.

To distribute the projected demand rates across the municipal wells for 2031, an optimization exercise was performed in order to allocate the additional 2031 demand. It is important to note that the Midland well system is well integrated and pumping can be easily reallocated between wells; this allows for the optimization of pumping in the distribution system. The first attempt at the optimization exercise distributed incremental increases evenly across the system. Evenly distributing the additional demand across the system put the Vindin Street and Russell Street wells at risk of potentially exceeding safe drawdown levels. As a result, an additional optimization run was completed, during which pumping rates at these wells were kept constant, or in the case of well 15, were slightly reduced. The pumping rates resulting from the final optimization exercise are the rates presented as the allocated quantity of water in Table 3.5- 2 .

Table 3.5- 2: Allocated Quantity of Water - Tier Three Risk Assessment Scenarios -Town of Midland (Golder, 2014).

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)
Vindin	Well 6	5707106	1,642	164	164
Vindin	Well 11	5715187	1,961	393	393
Vindin	Well 12	5716076	656	185	185
Vindin	Well 14	5716078	985	251	518
Vindin	Well 16	5722487	1,313	184	414
Vindin	Well 17	5722489	1,227	249	646
Heritage	Well 7A	5709697	4,925	2,176	2,592
Heritage	Well 7B	-----	4,234	769	2,228
Dominion	Well 9	5714014	1,964	780	1,034
Russell	Well 15	-----	1,309	924	566
Fourth	Well 1A	-----	1,964	0	850
Total Taking	-	-	22,180	6,075	9,590

Town of Penetanguishene

The well system for the Town of Penetanguishene consists of three well fields, two of which are currently active. The three well fields are composed of a total of 7 wells commonly referred to as the Payette Drive (Wells, 1, 2, and 3), Robert Street (Wells 2 and 3), and Lepage wells(Wells 1 and 2).

The Robert Street wells have been non- operational since 1991, due to the identification of TCE and other solvent related compounds present in the well. Tests performed since the shutdown indicate that concentrations at the wellhead are declining but still remain above Ontario Drinking Water Standard (ODWS) limits. Future operation of these wells may be a possible alternative to pumping at the Payette Drive wells when contaminant levels decline to suitable levels.

The existing demand and allocated quantity of water for the Town of Penetanguishene well system are provided in Table 3.5- 3. The existing demand for the Town was calculated as the average pumping rate for each well during the years of 2010 and 2011. In addition to being used for model calibration, these average pumping rates were utilized as inputs during the simulation of risk scenarios detailed in Section 3.5.5.

The allocated quantity of water for the Town of Penetanguishene, was calculated based on the Town's water demands for the year 2031. The Town's 2031 water demands were obtained from an Environmental Assessment report completed by AECOM, 2012 for the Payette Water System Storage Upgrade. Water demands in the EA were estimated from population projections, as well as historical water demands, and per capita water demand information (Golder, 2014).

The 2031 total average demand per day for the Town is estimated to be 5,078m^3/day, compared to the existing 2010/2011 daily taking of 3,567m^3/day. The difference between existing and allocated pumping rates indicates a 42% increase in total pumping. Despite the increase in pumping, allocated pumping rates remain below current Permit to Take Water (PTTW) rate limits.

Although the Robert St. Wells have a valid Permit to Take Water, they will not be able to pump water until the quality terms outlined in the Ontario Drinking Water Standards are met. The 2031 pumping rates presented in Table 3.5- 3 consider a pumping configuration where the Payette Drive wells continue to pump at existing rates, while additional projected demands are met by the Robert Street wells. Table 3.5- 3 also presents an alternate pumping scenario where additional 2031 projected demand is supplied solely by the Payette Drive wells, and no pumping is undertaken at the Robert Street wells. Allocated pumping rates for each well under this alternate scenario also remain below current Permit to Take Water rate limits.

Table 3.5- 3: Allocated Quantity of Water - Tier Three Risk Assessment Scenarios - Town of Penetanguishene (Golder, 2014).

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)	Allocated Quantity of Water[2] 2031 Alternate Rates (m^3/day)
Payette	Well 1	5717696	2,851	703	703	1,000
Payette	Well 2	5732671	4,579	2,374	2,374	3,400
Payette	Well 3	5728347	3,715	472	472	654
Robert	Well 2	5703542	3,273*	0	1,505*	0
Robert	Well 3	5703546	3,273*	0	1,505*	0

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)	Allocated Quantity of Water[2] 2031 Alternate Rates (m^3/day)
Lepage	Well 1	5708732	144	18**	24**	24**
Lepage	Well 2	5712811	288	18**	24**	24**
Total Taking	-	-	14,850	3,567	5,078	5,078

Note: * and ** indicated combined values

Township of Tiny : Whip-Poor-Will System

The Whip-Poor-Will system in the Township of Tiny services a small residential community located south of Penetanguishene and west of Midland. The system consists of two wells (Wells 21-1 and 21-2) in one well field. Due to their construction at the top of Lower Aquifer (A3), the wells have the potential to exceed safe drawdown levels if pumping rates are increased, as discussed in the section above. Existing demand for the system is based on pumping rates recorded by the Township in 2010 and 2011. In addition to being used for model calibration, existing pumping rates, were also utilized as inputs during the simulation of risk scenarios described in section 3.5.5.

Existing demand rates and the allocated quantity of water for the Whip-Poor-Will system are presented in Table 3.5-4 . Allocated pumping rates are based on information provided by the Township, and consider total build out of the associated subdivision that relies on the wells. As presented in Table 3.5-4 , the allocated pumping rates for each well are below current Permit to Take Water limits. 2031 allocated pumping rates were estimated at 78m^3/day, compared to existing pumping rates of 72m^3/day; this represents an 8% increase in total pumping.

Table 3.5-4: Allocated Quantity of Water - Tier Three Risk Assessment Scenarios - Township of Tiny (Whip- Poor-Will System) (Golder, 2014).

Well Field	Wells	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)
Whip-Poor-Will	21-1 & 21-2	5728953	532	72	78

Safe Available Drawdown

The Tier Three Assessment requires the calculation of an analytical parameter called Safe Available Drawdown. Safe Available Drawdown refers to the additional depth that the water level within an aquifer could drop and still maintain the well's allocated pumping rate (Golder,2014). Safe Available Drawdown levels are used as the criteria against which Risk Assessment scenario results are evaluated. Additional drawdown values defined during the simulation of Risk Assessment scenarios are compared against Safe Available Drawdown values. If additional drawdown exceeds *Safe Available Drawdown* at a well, the well is flagged as a potential water quantity threat.

Safe Available Drawdown is calculated as the difference between existing (2010/2011) average water level and the safe water level in a pumping well (Golder, 2014). Safe water level is defined as the lowest water level that the well can be pumped to and is constrained by a number of operational limitations depending on whether the well's operation is limited by in-well conditions, or in-aquifer conditions. In- well constraints include the elevation of the well screen, pump intake, or other operational limitations. If in-aquifer conditions constrain the well's operation, it is necessary to ensure that the dewatering of the aquifer is prevented. Depending on the constraints that limit the well's operation, the safe water level is defined by either the:

- the elevation of the pump intake or well screen or
- the level at the top of the aquifer

Depending on the constraints that limit the well's operation, the Safe Water level in a well is calculated as either:

- the additional available drawdown in the well, determined by the difference between the current operating level in the well and top of the well screen or pump intake or
- the additional available drawdown in the supply aquifer , as determined by the difference between existing aquifer water levels and the top of the aquifer

The criteria that results in the smaller additional available drawdown is used to calculate the Safe Available Drawdown - which is determined as the difference between existing (2010/2011) average water level and the selected safe water level in a pumping well. It should be noted that the average water level for this study was a time-averaged calculation intended to represent the variable nature of municipal pumping in the Study Area. For more details about the approach taken refer to Appendix WB 5.

During the Risk Assessment scenarios (explained in Section 3.5.5), the calculated Safe Available Drawdown is compared to the drawdowns that result under the simulation of the Tier Three Scenarios. If the drawdowns experienced under the scenarios exceed Safe Available Drawdown, the wells are flagged with a moderate or significant risk depending on the circumstance triggered in the Technical Rules (MOE, 2008a), and potential threats are assigned accordingly.

The following text and tables discuss the Safe Available Drawdown levels for the Town of Midland and Penetanguishene, and Township of Tiny.

Safe Available Drawdown – Town of Midland

The Safe Available Drawdown levels for the Town of Midland are presented in Table 3.5- 5. An example of a Safe Available Drawdown calculation for Midland Well 6 is presented in Figure 3.5- 8.

For Well 6, the level of the top of the well screen was the criterion used to determine the Safe Available Drawdown. As illustrated in Figure 3.5- 8, to calculate the Safe Available Drawdown, the elevation of the pump intake (160.4 masl) is subtracted from the average pumped water level in the well (179.6 masl); the resulting difference indicates the amount of safe available drawdown that is available. For Well 6 the Safe Available Drawdown was determined to be 18.2 m. Safe Available Drawdown calculations for each municipal Midland well can be found in the Midland and Penetanguishene Tier Three Risk Assessment foundation report by Golder Associates, 2014 and Appendix WB 5.

As illustrated in Table 3.5- 5 , with the exception of wells 15 and 7a, the majority of the Midland wells have over 15m of Safe Available Drawdown that is accessible under existing operating conditions. As discussed above, due to the susceptible nature of the well 15, the 2031 allocated pumping rates have been reduced from their current existing rate.

Table 3.5- 5: Safe Available Drawdown -Tier Three Risk Assessment - Town of Midland (Golder, 2014).

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Available Drawdown (m)
Vindin	Well 6	182.6	159.9	152.3	160.4	166.1	181.8	14	179.6	161.4	18.2
Vindin	Well 11	185.6	159.1	150.3	158.6	167.6	185.6	17	182.5	160.1	22.4
Vindin	Well 12	184.6	161.7	155.6	---	164.6	183.1	20	179.4	162.7	16.7
Vindin	Well 14	186.2	158.8	153.0	---	173.2	185.4	21	182.8	159.8	23.0
Vindin	Well 16	180.1	152.0	146.0	153.0	167.6	179.4	20	177.1	154.0	23.1
Vindin	Well 17	179.8	159.6	153.9	162.4	171.8	181.1	24	178.9	163.4	15.5
Heritage	Well 7A	215.8	169.8	152.1	169.9	174.7	188.3	50	181.5	170.9	10.6
Heritage	Well 7B	215.2	158.0	150.4	159.9	177.2	187	20	185	160.9	24.1
Dominion	Well 9	245.4	158.3	153.6	157.6	174.4	194.2	56	183.2	159.3	23.9
Russell	Well 15	220.1	179.7	173.2	178.1	181.9	185.1	91	182.2	180.7	1.5

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Available Drawdown (m)
Fourth	Well 1A	184.4	161.8	154.2	N/A	182.1	182.1	0	182.1	162.8	19.3

Safe Available Drawdown – Town of Penetanguishene

The Safe Available Drawdown levels for the Town of Penetanguishene are presented in Table 3.5- 6. Safe Available Drawdown calculations for each of the municipal wells are presented in Appendix WB-5 and in the Midland and Penetanguishene Risk Assessment foundation document completed by Golder, 2014. As presented in Table 3.5- 6 the majority of the Penetanguishene wells have over 15m of Safe Available Drawdown under existing average operating conditions. Exceptions to this include Payette Drive Wells 1 and 2, which respectively have 10.7m and 12m of Safe Available Drawdown.

Table 3.5- 6: Safe Available Drawdown -Tier Three Risk Assessment - Town of Penetanguishene (Golder, 2014).

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Avrg. Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Available Drawdown (m)
Payette	Well 1	238.27	168.7	151.9	173.8	178.5	188.4	29	185.5	174.8	10.7
Payette	Well 2	237.29	161.9	150.8	166.1	172.1	187.2	54	179.1	167.1	12.0
Payette	Well 3	237.74	161.7	149.6	163.1	169.0	187.5	14	185.0	164.1	20.9
Robert	Well 2	181.4	138.1	125.9	N/A	189.0	189.0	0	189.0	139.1	49.9
Robert	Well 3	180.9	141.9	123.6	N/A	189.7	189.7	0	189.7	142.9	46.8
Lepage	Well 1	201.81	168.9	168.0	173.4	187.8	190	7	189.8	174.4	15.4
Lepage	Well 2	202.26	168.3	166.8	173.4	184.3	190.1	5	189.8	174.4	15.4

Safe Available Drawdown – Tiny Township: Whip-Poor-Will System

Whip-Poor-Will wells 21-1 and 21-2 are constructed at the top of the supply aquifer, and consequently have little Safe Available Drawdown. Well 21-2 has 4.6 m of Safe Available Drawdown, while well 21-1 has only 1.0 m, as presented in Table 3.5- 7. Well 21-2 serves as a back-up to well 21-1, and could provide the necessary water supply in the event of a service interruption resulting from declines in operational capacity, this however would mean that no back-up source would be available.

Table 3.5- 7: Safe Additional Available Drawdown -Tier Three Risk Assessment - Tiny Township - Whip-Poor-Will System (Golder,2014).

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Avrg. Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Available Drawdown (m)
Whip-Poor-Will	21-1	311.8	251.2	246.6	252.7	253.6	254.8	6	254.7	253.7	1.0
Whip-Poor-Will	21-2	314.6	246.9	242.6	252.7	256.6	258.6	6	258.6	253.7	4.6

Permitted Non-Municipal Demand

Information regarding other permitted non-municipal water uses in the Study Area was obtained from the Ministry of Environment's Water Taking Reporting System Database, through to the date of March 31st, 2012. Figure 3.5- 9 illustrates the location of both the municipal and non-municipal Permits to Take Water held in the Study Area, while Table 3.5- 8 lists the permits, and details the water use that each of permits address. There are 5 active non-municipal operations with permits in the Study Area. Water takings by these operations are used for industrial and commercial purposes.

Table 3.5- 8: Non-Municipal Permits to Take Water (PTTW)

Permit Number	Category	SOURCE ID	Source	Consumptive Factor	Maximum Permitted Volume (m^3/day)	Average Annual 2010/2011 Well Pumping Rate (m^3/day)	Rate Data Source
5326-74JGUF	Industrial - Aggregate Washing	Main Pond	Ground Water	0.10	1,022	56	WTRS
2311-7EKLNZ	Commercial - Golf Course Irrigation	PW1/MGCC1 (MOE ID 4502)	Ground Water	0.70	1,090	177	WTRS
2311-7EKLNZ	Commercial - Golf Course Irrigation	PW2/MGCC2 (MOE ID 4503)	Ground Water	0.70	818	111	WTRS
2311-7EKLNZ	Commercial - Golf Course Irrigation	PW3/MGCC3 (MOE ID 4501)	Ground Water	0.70	5	0	WTRS
7224-6EBQS8	Industrial	Well # 1	Ground Water	1.0	1,964* combined	0	WTRS
7224-6EBQS8	Industrial	Well # 2	Ground Water	1.0	1,964* combined	533	WTRS
2110-6NQLJ4	Commercial - Golf Course Irrigation	Well #1	Ground Water	0.70	451	12	WTRS
2110-6NQLJ4	Commercial - Golf Course Irrigation	Unnamed Stream	Surface Water	N/A	1,404	N/A	N/A
4426-7C6MPB	Commercial - Golf Course Irrigation	Well BBGC1	Ground Water	0.70	2	0	WTRS
4426-7C6MPB	Commercial - Golf Course Irrigation	Well BBGC2	Ground Water	0.70	8	0	WTRS
4426-7C6MPB	Commercial - Golf Course Irrigation	Well BBGC3	Ground Water	0.70	29	0	WTRS
4426-7C6MPB	Commercial - Golf Course Irrigation	Well BBGC4 (MOE ID 5715544)	Ground Water	0.70	55	1	WTRS
4426-7C6MPB	Commercial - Golf Course Irrigation	Well BBGC5 (MOE ID 5738332)	Ground Water	0.70	360	24	WTRS

Permit Number	Category	SOURCE ID	Source	Consumptive Factor	Maximum Permitted Volume (m^3/day)	Average Annual 2010/2011 Well Pumping Rate (m^3/day)	Rate Data Source
4426-7C6MPB	Commercial - Golf Course Irrigation	Pond 1 (P1) - Copeland Creek	Surface Water	N/A	1,057 ** Combined	N/A	N/A
4426-7C6MPB	Commercial - Golf Course Irrigation	Pond 2 (P2) - Copeland Creek	Surface Water	N/A	1,057 ** Combined	N/A	N/A
4426-7C6MPB	Commercial - Golf Course Irrigation	Pond 5 (P5)	Surface Water	N/A	1,057 ** Combined	N/A	N/A
0205-7GFP76	Industrial - Aggregate Washing	Source Pond	Surface Water	N/A	6,547	N/A	N/A
1566-7C3HRU	Industrial - Manufacturing	Source 1	Surface Water	N/A	3,312*** Combined	N/A	N/A
1566-7C3HRU	Industrial - Manufacturing	Source 2	Surface Water	N/A	3,312*** Combined	N/A	N/A
Total (Groundwater)	-	-	-	-	5,804	914	-

Note: Information was obtained from the March 31st, 2012 version of the Water Taking Reporting System (WTRS) database.

Non-Permitted Water Uses

Non-permitted water use in the Study Area is primarily devoted to meeting the demands of unserviced domestic water users, and other demands that extract less than 50, 000 L/day. Large non-permitted water users were not identified in the Study Area. Consumptive demand from non-permitted domestic water users was not a concern during this Tier Three Assessment, as much of the water taken by these users is likely returned to the groundwater system through septic sewage disposal systems.

Aquatic Habitats

The Tier Three Risk Assessment must also consider whether water demands can be met while maintaining the water needs of aquatic ecosystems in the Study Area. During the Risk Assessment, if a groundwater reduction of 10% or more is predicted at coldwater streams, due to well pumping, the Local Area in which the scenarios are carried out is assigned a moderate Risk Level. Figure 3.5- 10 illustrates the coldwater streams in the Study Area. The coldwater streams highlighted in the figure are important habitats for fish communities, and must therefore be evaluated as part of the Tier Three Local Area Risk Assessment.

Provincially Significant Wetlands

Provincially Significant Wetlands are another water use evaluated during the Tier Three Risk Assessment that should not be significantly impacted by municipal pumping. Impacts to wetland features are determined by evaluating water level changes in the vicinity of the wetland, and the impact of such changes on the function of the wetland. As per the Technical Rules (MOE, 2008a) and the MOE /MNR guidance (MOE and MNR, 2011; MOE 2013). Figure 3.5- 10 illustrates the provincially significant wetlands found in the vicinity of the Study Area. These wetlands include the Wye Marsh, Midland Swamp, Penetanguishene Marsh, Midland Little Lake Wetland, St. Andrew's Wetland, Sucker Creek Wetlands, and the Lalligan Lake Swamp.

3.5.4 Water Budget

In order to refine the understanding of hydrologic and hydrogeologic flow systems within the Study Area, improved estimates of water budget components were made using the MIKESHE and FEFLOW models described in Section 3.5.2. Tier Three Water Budget estimates are considered more reliable than those made under the Tier Two Assessment due to model updates made at the local scale. Although the updated MIKE SHE and FEFLOW models represent two separate modeling approaches, the two models were linked through groundwater recharge and interbasin flow components. Results generated from the combination of the two models create a refined estimate of average annual values for various components of the hydrologic cycle within the Study Area. The groundwater flow budget for the entire model area is presented in Table 3.5- 9 .

The estimation of cross boundary groundwater flow budgets between subwatersheds/catchments is also a key component of refined water budget calculations. To estimate cross boundary flow between catchments in the Study Area, it was necessary to estimate individual water budget component fluctuations within each subwatershed. Flow components included the inflows and outflows within a subwatershed. Major inflows include recharge and cross- boundary flow, while major outflows included discharge to lakes and streams, cross boundary outflows, and discharges to Georgian Bay. Pumping wells, where present, typically represented around 10% or less of the subcatchment water balance (Golder, 2014). Figure 3.5- 11 summarizes the major cross boundary fluxes between Study Area catchments. Combined the catchments shown in Figure 3.5- 11 were determined to have an overall net loss of approximately 36,153m ^{3}/day. Cross boundary flow towards the Wye River accounts for 18,000m^3/day, while an additional 12,000m^3/day leaves primarily through the northern catchments of Sawlog Bay and Picotes Creek. The remaining 6,153m^3 of flow exits west towards Tiny Township.

Table 3.5- 9: Groundwater Model Flow Budget

Source / Sink	Input (m^3/d)	Output (m^3/d)
Recharge	368,128	0
Wells (municipal and non-municipal)	0	11,250
Georgian Bay	0	250,741
Wye River	944	26,880
Wye Marsh	0	7,126
Wye Tributaries	0	23,515
Cooks Lake	1,385	3,275
Little Lake	5,552	0
Copeland Creek	0	10,486
Vindin Creek	0	5,792
Picotes Creek	0	7,944
Other Tributaries	0	29,000
TOTAL	376,009	376,009

3.5.5 Local Area Risk Assessment

An essential part of the Tier Three Assessment is the completion of a Local Area Risk Assessment. As per the Technical Rules (MOE, 2008a), a Local Area Risk Assessment must be completed for all municipal drinking water systems located within subwatersheds assigned a moderate or significant stress level after undergoing a Tier Two Stress Assessment. More specifically, the Local Area Risk Assessment aims to evaluate the possibility of municipalities being unable to meet their existing and allocated pumping rates under scenarios of increased municipal demand, planned land development, and drought conditions, while also considering the impact to other water uses.

Delineation of Vulnerable Areas

In order to carry out the Risk Assessment, it was first necessary to delineate the ‘Local Area’ within which the Risk Assessment scenarios would be evaluated. The term ‘Local Area’ is defined as the area surrounding drinking water wells that must be protected in order to ensure the sustainability of municipal water supplies. The Local Area is delineated using the Tier Three models discussed in Section 3.5.2 . To determine the extent of the Local Area, it is necessary to delineate specific vulnerable areas called Wellhead Protection Areas for Quantity (WHPA- Q1 and WHPA- Q2). The WHPA- Q1 and WHPA- Q2 are delineated for all municipal wells located within significantly or moderately stressed subwatersheds identified during a Tier Two Stress Assessment. For this study, the Local Area is calculated as the WHPA –Q1 plus WHPA- Q2 and consists of the following sub-areas as illustrated in Figure 3.5- 13:

Local Area A – Penetanguishene Payette Drive System and Midland System

Local Area B- Penetanguishene Lepage System

Local Area C- Penetanguishene Robert Street System

Local Area D – Tiny Township Whip-Poor-Will System

As per the Technical Rules (MOE, 2008a), the WHPA-Q1 is delineated as the combined area that is the cone of influence of a well and the whole of the cones of influence of all other wells that intersect that area (MNR and MOE, 2011). The cone of influence for a well is determined through simulations carried out under a scenario that considers existing land use and future (existing plus committed) pumping rates. The cone of influence is estimated by calculating the maximum water level drawdown for the scenario as compared to the aquifer drawdown under non-pumping conditions. The drawdown cone used to delineate the WHPA-Q1 should be based on the allocated (existing plus committed) pumping rates for municipal wells. In addition, the drawdown cone will be intersected with the drawdown cone of all other consumptive water users in the Study Area (MNR and MOE, 2011). The extent of the cone of influence should be determined by selecting an appropriate drawdown threshold. When estimating this threshold, several factors should be considered including: observed seasonal fluctuations of the water level in the aquifer, and any field observations of the extent of the cone of influence based on monitoring (MNR and MOE, 2011). For this study, the appropriate threshold was determined to be 1m of drawdown.

The WHPA- Q1 for the Midland - Penetanguishene area is illustrated in Figure 3.5- 12 . As illustrated in the figure, the WHPA- Q1 area primarily consists of a single area between the pumping centres of Midland and Penetanguishene. Smaller WHPA-Q1 subareas can be seen around the Whip-Poor-Will, Robert Street, and Lepage wells. These smaller subareas were determined by delineating a 100m radius around each well field to represent the WHPA-Q1. This was done because the 1m drawdown threshold was not reached during the simulations ran to delineate the WHPA-Q1. This approach was recommended by the Ministry of Natural Resources (MNR), and accepted by the peer reviewers.

The WHPA- Q2 is delineated as the WHPA- Q1 area plus any area where a future reduction in recharge would significantly impact municipal aquifer levels (Golder,2014). When identifying an area where a future reduction in recharge might occur, reference must be made to a municipality's Official Plan to identify lands designated for new development. The maximum amount of recharge reduction that might result from these developments must also be considered; any influence from stormwater best management practices should not be accounted for (MNR and MOE, 2011). The WHPA- Q2 to for the Midland -Penetanguishene area is presented in Figure 3.5- 13. To delineate the WHPA- Q2, a simulation modelling the effects of reductions in recharge resulting from new development was performed. Simulations indicated that the effects on drawdown at municipal wells due to projected land cover change were generally minimal (0.1 to 0.3m) and would generally be immeasurable; exceptions included the Payette Drive wells in Penetanguishene, and the Heritage Drive, Dominion and Russell St. Wells in Midland. Simulations indicated that these wells experienced 0.5 to 1.0m of drawdown due to recharge reductions.

An additional simulation evaluating only the effects of land use change outside of the WHPA-Q1 on water levels was carried out to determine if such areas should be incorporated into the WHPA- Q2 delineation. Drawdown in the aquifer as a result of the projected development lands was predicted to range between 0.5 -1m in the Heritage Drive and Russell St wells in Midland; indicating that projected land development would potentially have a measureable impact on municipal aquifer levels. As a result, these areas were incorporated into the WHPA- Q2 delineation as shown in Figure 3.5- 13.

The Local Area in which the scenarios are evaluated is delineated to include the cone of influence of the municipal wells (WHPA- Q1) plus the areas where a reduction in recharge would have a measurable impact on cone of influence (WHPA- Q2). For this study, the Local Area is equivalent to the WHPA- Q2 delineation as show in Figure 3.5- 13. As illustrated in WHPA Q2/ Local Area delineation presented in Figure 3.5- 13, the Local Area for this study is made up of 4 smaller local sub areas. As noted earlier, the extent of these smaller local areas around the Whip-Poor-Will, Robert Street, and Lepage Wells, was delineated as a 100m radius around each well field. This was done because the 1m drawdown contour was not expressed during the simulations ran to delineate the WHPA-Q1/Q2. This approach was recommended by the Ministry of Natural Resources (MNR), and accepted by the peer reviewers.

Local Area Risk Assessment Scenarios

A Local Area Risk Assessment evaluates the impacts on current hydrogeological conditions in response to various water demand, climate, and land use scenarios. These scenarios are simulated using the numerical models described in Section 3.5.2.

The scenarios that must be evaluated as part of the Local Area Risk Assessment are outlined in Table 3.5- 10. Where scenario simulation results indicate that municipal wells may not be able to supply their allocated rates, the Local Area (described above) is assigned a moderate or significant water quantity Risk Level. Consumptive water uses and activities associated with reductions in groundwater recharge within the Local Area are then classified as moderate or significant drinking water threats. Risk scenario simulations also consider the water demand requirements of other water uses in the Local Area, such as the ecological flow requirements of coldwater fish habitats.

Table 3.5- 10: Risk Assessment Scenario Overview (MOE and MNR, 2011).

Scenario	Time Period	Conditions
C	Average Climate: The period for which climate and stream flow data are available for the Local Area.	Scenario reflects current conditions with existing land cover, pumping rates and stead-state, average annual recharge.
D	Ten Year Drought	Reflects existing land cover and pumping rates but reduced recharge due to ten year drought conditions
G	Average Climate: The period for which climate and stream flow data are available for the Local Area.	Multiple versions of the scenario are required to evaluate pumping rates under existing and projected demands with variable land cover conditions (existing and projected based on the Official Plans).
H	Ten Year Drought	Transient drought simulation with multiple scenarios possible with variable pumping rates and land cover conditions.

The Technical Rules (MOE, 2008a) outline whether or not each scenario needs to be run in transient or steady state mode. Steady state models simulate the scenarios using average annual recharge and pumping levels. Transient models simulate scenarios using monthly recharge and pumping levels. Each scenario simulation is also required to evaluate a specific period of time, as indicated in the second column of Table 3.5- 10. The scenarios are evaluated as follows:

- Scenarios C and G are evaluated under average climate conditions and simulated using a steady state approach
- Scenarios D and H represent drought conditions, and make use of transient simulations to represent the drought of the 1960s.

Model Predicted Scenario Results

The results of the scenario simulations are assessed with respect to estimated drawdown levels at each municipal well, and the impact on groundwater discharge to coldwater streams and provincially significant wetlands. Impacts on groundwater discharge were only modeled under steady state scenarios (scenarios C and G). The following section details the results of the scenario simulations conducted using the Tier Three Water Budget models discussed in Section 3.5.2. Where simulations indicated that the scenario drawdown was greater than the Safe Available Drawdown, the wells were flagged as potentially not being able to sustain pumping rates under the given scenario. Where the simulated drawdown was less than the Safe Available Drawdown, wells were classified as low risk based on their ability to sustain allocated pumping rates. Table 3.5- 11 summarizes the predicted maximum drawdown for each municipal well, under each of the Risk Assessment scenarios. The following text discusses the results of each scenario in greater detail.

Table 3.5- 11: Risk Assessment Scenario Results (maximum drawdown in m)(Golder,2014).

Well Details	Safe Available Drawdown	Average Climate - Scenario G(1) Drawdown - Recharged Reduction and Increased Demand (m)	Average Climate - Scenario G(2) Drawdown - Increased Demand (m)	Average Climate - Scenario G(3) Drawdown - Recharged Reduction (m)	Drought - Scenario D - Existing Demand / Recharge	Drought - Scenario H(1) Drawdown - Recharged Reduction and Increased Demand (m)	Drought - Scenario H(2) Drawdown - Increased Demand (m)	Drought - Scenario H(3) Drawdown - Recharged Reduction (m)
Midland - Vindin - Well 6	18.2	2	1.6	0.3	2	4.5	4.3	2.2
Midland - Vindin - Well 11	22.4	1.4	1	0.3	2.4	4	3.7	2.6
Midland - Vindin - Well 12	16.7	1.6	1.2	0.3	2.2	4	3.8	2.4
Midland - Vindin - Well 14	23	2.6	2.3	0.3	2.3	5.7	5.5	2.5
Midland - Vindin - Well 16	23.1	3	2.7	0.3	2	6.1	5.9	2.2
Midland - Vindin - Well 17	15.5	3.5	3.2	0.3	1.9	6.9	6.7	2.1
Midland - ~~Hertitage~~Heritage Wells 7A and 7B	10.6 / 24.1	3.7	2.6	1	1.6	5.5	4.6	2.5
Midland - Dominion - Well 9	23.9	1.7	1.1	0.5	2	3.6	3.2	2.3
Midland - Russell - Well 15	1.5	0.4	-0.5	0.9	1.2	1.2	0.5	1.9
Midland - Fourth - Well 1A	19.3	3.7	3.4	N/A	N/A	6.6	6.5	N/A
Penetanguishene - Payette - Well 1	10.7	1.1	0.1	1	1.5	2.5	1.5	2.4
Penetanguishene - Payette - Well 2	12	1.1	0.1	1	2.3	3.3	2.3	3.2
Penetanguishene - Payette - Well 3	20.9	1.1	0.1	1	2	3	2	2.9
Penetanguishene - Robert - Well 2	49.9	0.9	0.7	N/A	N/A	2.2	2.1	N/A
Penetanguishene - Robert - Well 3	46.8	0.9	0.7	N/A	N/A	2.3	2.2	N/A

Well Details	Safe Available Drawdown	Average Climate - Scenario G(1) Drawdown - Recharged Reduction and Increased Demand (m)	Average Climate - Scenario G(2) Drawdown - Increased Demand (m)	Average Climate - Scenario G(3) Drawdown - Recharged Reduction (m)	Drought - Scenario D - Existing Demand / Recharge	Drought - Scenario H(1) Drawdown - Recharged Reduction and Increased Demand (m)	Drought - Scenario H(2) Drawdown - Increased Demand (m)	Drought - Scenario H(3) Drawdown - Recharged Reduction (m)
Penetanguishene - Lepage - Wells 1 and 2	15.4	0.2	0.1	0.1	1.4	1.6	1.5	1.4
Tiny - Whip-Poor- Will - Wells 21-1 and 21-2	1.0 / 4.6	0.5	0.3	0.2	2.3	2.8	2.6	2.5

Scenario C

Scenario C models existing demand and land cover under average climate conditions and is therefore used as the baseline level for the evaluation of drawdowns and impacts to baseflow resulting from the simulation of other scenarios. Consequently, drawdowns and baseflow reductions under this scenario are equal to zero. Model inputs used to simulate scenario C are also the inputs used in the calibration of the Tier Three models used to simulate the scenarios.

Scenario D

Scenario D evaluates fluxes in water levels due to short and long term drought; more specifically, the purpose of the scenario is to determine whether each municipal well is able to sustain its existing pumping rate during both long and short term drought periods. This scenario was simulated in transient mode, and run over the drought period of 1955 to 1964. The period of 1955 to 1964 was determined to be the worst drought period in the available meteorological record due to lower than average precipitation levels, and was therefore selected for use during modelling. Results of the simulation indicate that water levels at municipal wells under the drought condition are between 1.2 to 2.4 m lower than the average climate modelled levels predicted under Scenario C. Simulation predictions indicate that despite the drops in water level, drawdowns at the majority of the municipal wells under scenario D did not exceed the Safe Available Drawdown in the municipal wells with the exception of Whip- Poor -Will Well 21-1. Under scenario D, Whip- Poor-Will Well 21-1 exceeds Safe Available Drawdown by 1.3 m. This is primarily due to the system's construction at the top of the aquifer, which results in very little Safe Available Drawdown, despite the adequate capacity of the aquifer to meet demand.

Although the Safe Available Drawdown level at Midland well 15 is not exceeded, the drawdown at well 15 (1.2m) closely approaches the Safe Available Drawdown level of 1.5m. In the event of a drought, the Town of Midland has sufficient operational flexibility to pump this well at a lower rate in order to reduce the well's overall sensitivity to drought impacts. The simulated drawdown results for scenario D are presented in Table 3.5- 11.

Scenario G

Scenario G requires the simulation of three model scenarios that make use of the same average climate inputs, but aim to determine the separate and combined effects of projected demand increases and reductions in recharge due to land cover change.

Scenario G1 evaluates changes in water level due to reductions in recharge, and increases in demand (allocated quantity of water), using a steady state model. As presented in Table 3.5- 11 water level changes resulting from an increase in pumping and reduction in recharge, were generally between 0.2 to 3.7m lower than the water levels under baseline scenario C. It is important to note that the amount of resulting drawdown is a consequence of the degree to which pumping is increased at the individual well. For example, 0.2 m of drawdown is experienced at wells where a small increase in pumping is assigned (6m^3/day), while 3.7 m of drawdown occurs at wells with much greater (850 -1875 m^3/day) pumping increases.

Under Scenario G1, drawdown at the municipal wells did not exceed Safe Available Drawdown levels in any of the municipal wells in the Midland and Penetanguishene Study Area.

Scenario G3 evaluates changes in water level due to reductions in recharge resulting from planned land use development. The simulation is carried out in steady state mode, under average climate conditions and considers existing demand (2010/2011). Results of the simulation of this scenario indicated that in general, the effect on water levels at municipal wells would generally be minor, with the exception of the Payette Drive wells in Penetanguishene, and the Heritage Drive, Dominion, and Russell St wells in Midland. Figure 3.5- 17 illustrates the modelled extent of drawdown in supply aquifer A3 relative to baseline conditions (Scenario C). Under Scenario G3, Safe Available Drawdown was not exceeded at any of the municipal wells.

Scenario G2 evaluates the impact of increased municipal pumping (existing plus committed rates) under existing land use conditions and average climate. Figure 3.5- 14, 3.5- 15, and 3.5-16, illustrate the drawdown experienced in aquifers A1, A2, and A3 relative to scenario C, respectively. As indicated in Table 3.5- 11 all drawdown results for this scenario did no exceed Safe Available Drawdown levels. The amount of drawdown experienced at each well is a consequence of the degree to which pumping is increased at a given well. A small portion of the drawdown experienced could also be attributed to the interference from pumping increases at other nearby wells.

For this scenario allocated pumping rates at well 15 were reduced, which resulted in a water level rise of 0.5 m at the well. The remaining municipal wells exhibited drawdown levels ranging between 1.0 to 3.4 m. Allocated pumping levels at the Payette Drive wells were not increased, resulting in very little drawdown (0.1m).

The results of all simulations performed under scenario G (including G 1, 2 and 3) indicate that drawdown at all wells will not exceed the Safe Available Drawdown. If municipal pumping is increased to meet allocated demand (existing plus committed rates), and reductions in recharge associated with planned development take place, all municipal wells will be able to continue to pump sustainably, neglecting the uncertainty associated with model parameters.

Scenario H

Scenario H requires the simulation of three scenarios that aim to determine the isolated and combined effects of increased demand and projected land cover change through a drought period, using a transient model.

Scenario H1 considers the cumulative impact of increased demand and reduced recharge and drought. It is considered the worst case assessment of potential water level declines. As presented in Table 3.5- 11 , Midland's well 15 comes very close to exceeding Safe Available Drawdown under scenario H1. Despite the minimal amount of Safe Available Drawdown at the well, the Town's system has the operational flexibility to reduce the well's sensitivity to drought impacts, by pumping the well at lower rates.

Whip-Poor-Will Well 21-1 exceeds Safe Available Drawdown levels under all of the category H scenarios, indicating that pumping rates could not be sustained under scenario conditions.

Scenarios H2 and H3 are also both evaluated under drought conditions. Scenario H2 evaluates the isolated impact of increased demand, while Scenario H3 evaluates the isolated impact of reductions in recharge due to projected land cover change.

Under scenario H2, Midland well 15 experienced minimal impact due to the lowering of future pumping rates at the well. Under scenario H3 however, well 15 exceeded Safe Available Drawdown levels. This was due to the fact that Scenario H3 does not take into account the reduction in pumping rates assigned to well 15, and is therefore not a reliable reflection of future drought conditions at the well (Golder, 2014).

Alternate Scenario – Penetanguishene

In addition to the scenarios required under the Tier Three Risk Assessment, an additional scenario was run to assess an alternate pumping configuration for the Town of Penetanguishene. The alternate scenario assesses the Town's ability to provide the allocated quantity of water by increasing pumping at the Payette Drive wells alone. The scenario assumes no pumping is undertaken at the Robert Street wells; instead the pumping increase originally applied to the Robert St. wells is solely assigned to the three Payette Drive wells. For more details about the results of this alternate simulation refer to Appendix WB-5.

Impacts to Groundwater Discharge

The Tier Three Assessment requires that impacts on groundwater discharge to streams and provincially significant wetlands be evaluated under scenarios C and G2.Impacts to streams were evaluated by comparing the groundwater discharge simulated under scenario G2 (steady state, projected demand) to groundwater discharge modelled under scenario C baseline conditions (existing conditions). Scenario G2 is the only scenario that isolates the influence of municipal pumping from land development. Since reductions in baseflow resulting from land use development are independent from increased municipal pumping, only the impacts associated with groundwater pumping (e.g. Scenario G2) should be used to assess the impacts to other users such as coldwater streams (aquatic habitats) and wetlands.

The locations of the streams evaluated in this Tier Three Study are presented in Figure 3.5- 10. Modelled impacts to groundwater discharge in the Study Area are presented in Table 3.5- 12.

Under scenario G2, groundwater discharge reductions range between 3% at Copeland Creek to 10% at Vindin Creek, discounting the uncertainty associated with model parameters. It should be noted that there was no reduction in groundwater discharge modelled at Picotes Creek, as this stream is located outside of the municipal well influence zone.

Table 3.5- 12: Baseflow Reductions (Model Scenario G2) (Golder, 2014.)

Station	Observed Baseflow (m^3/d)	Model Scenario C Baseflow (m^3/d)	Model Scenario G2 (m^3/d)	% Reduction
Copeland (gauge)	7,000 to 9,000 (BFLOW) 2,765 to 5,875 (spot flows)	7,470	7,256	3%
Copeland (at harbour)	6,396 to 7,690	10,490	9,951	5%
Lower Wye River Trib.	1,068	1,003	964	4%
Vindin (at Sunnyside)	3,633	4,300	3,887	10%

As noted earlier, impacts to Provincially Significant Wetlands must also be evaluated under scenarios C and G2. Impacts to Provincially Significant Wetlands, were determined by evaluating the drawdowns in the aquifer beneath the wetland. Drawdowns greater than or equal to 1m were considered to have a measurable impact. As presented in Figure 3.5- 14, declines in the shallow water table in response to increased municipal pumping to meet allocated rates are generally limited in extent and are generally less than 1m. The simulated shallow water level declines are largely expected in the built- up area around Midland, outside of Provincially Significant Wetland areas. As a result, impacts to wetlands due to increased municipal pumping are not expected, neglecting the uncertainty associated with model parameters.

3.5.6 Uncertainty Analysis and Gap Assessment

The models constructed for this Tier Three Assessment are generalized representations of complex hydrological and hydrogeological systems and are therefore associated with a level of uncertainty. The section outlines the data gaps and uncertainties encountered during the construction and calibration of both the surface and groundwater models.

Uncertainties associated with the MIKESHE surface water model are presented below.

- Stream flow data used in the construction and calibration of the surface water model was obtained from a single streamflow gauge situated on Copeland Creek. The period of record for the gauge was limited to a 10 year period, during which many instances of missing or suspect data occurred. The lack of continuous streamflow data in the Study Area represents a significant data gap for this study (Golder, 2014).
- Periods of missing data from the Copeland Creek gauge records were removed from the model results in order to allow for comparison between total flows predicted by the model and those observed at the gauge (Golder, 2014). This likely removed most of the potential

for error to be introduced to the calibration comparisons however, during the calibration it was noted that at times, time lag in the model results caused water sourced from precipitation or snowmelt to report in the following days or weeks in the model results (Golder, 2014). Errors associated with the lagged flow from within the missing data periods likely contributed to calibration error and cannot be quantified (Golder, 2014).
- Precipitation data for this study was obtained from two meteorological stations situated in the east central part of the model domain, predominantly on the leeward side of the peninsula. Meteorological station records and corresponding modelled results indicate instances of rainfall events not present in the observed flow data. This observation is indicative of highly convective storm events occurring over the meteorological stations but not affecting significant portions of the Copeland Creek watershed upstream of the stream flow gauge (Golder, 2014). This is indicative of a gap in understanding of precipitation events and their impact on flow systems in the Study Area.
- Potential evapotranspiration is an important component in the Tier Three water budget that is not directly measureable. Predicted evapotranspiration estimates introduce a level of uncertainty into the study. Over and underestimates in evapotranspiration values may have resulted in errors associated with other water budget components such as runoff and recharge (Golder, 2014).
- Surficial soils in the Study Area were predicted to have relatively high infiltration rates due to their sandy classification, while underlying soils in certain parts of the Study Area were conceptualized to have lower hydraulic conductivities. In these areas, mounding of water in the shallow overburden layers was addressed through reduction of the soil hydraulic conductivities in the surface water model, and through the implementation of drain boundaries in the groundwater model. A degree of uncertainty remains with regards to whether this represents runoff (rejected recharge) or interflow (Golder, 2014).
- Representation of the drainage network is varied throughout the Study Area. In areas of interest, small drainage features are well represented, while other areas with similar topography and land use exhibit far fewer small drainage features. The underrepresentation of small drainage features in particular regions the Study Area, represent some uncertainty in the surface water modelling conducted for this study (Golder ,2014).
- Gauge underflow and cross boundary flow to Georgian Bay represents a significant part of the water budget for the Copeland Creek subwatershed. Gauge underflow and cross boundary flow to Georgian Bay is not directly measureable and represents a source of uncertainty. Uncertainty associated with this aspect of the water budget may have an influence on other parts of the water budget (Golder ,2014).

The groundwater flow system of the Midland-Penetanguishene area is a multi-unit, heterogeneous system influenced by a number of groundwater sources and sinks. Due to complex nature of the system, the extent to which the groundwater system can be modelled is limited by the flow processes that are modelled numerically, the quantity and quality of the data available, and the degree to which the additional complexity is judged necessary in order to produce a reasonable calibration and predictive outcome (Golder, 2014).

Although the FEFLOW groundwater model developed to represent this system cannot model the complex reality of this flow system, the model represents a significant enhancement in the hydrogeological characterization of the Midland - Penetanguishene area. To ensure the model reasonably represented the behavior of the flow system, a detailed calibration process was undertaken. Despite enhancements to the characterization of the flow system, several uncertainties remained. Areas of groundwater model uncertainty included:

- The existence or lack of hydraulic connections between deeper aquifer units and Georgian Bay, where water levels suggest highly localized areas of connection
- Hydraulic conductivity inputs for the aquitard units that remain untested
- Properties of the bedrock aquifer, where hydraulic testing data is unavailable
- The role of unsaturated flow processes in directing shallow groundwater flow
- Hydraulic parameters distal to the wellfield, mainly west in the highland areas, where no pumping test data exists (Golder, 2014)

It should be noted that most of the above uncertainties relate to areas outside of the municipal wellfields that were the primary focus of this study. Confidence in the modelling around municipal well fields is high due to the bulk of existing high quality data available in these areas. As a result, a reasonable degree of confidence is placed on model parameterization in the wellfield area, with uncertainty increasing further from the areas of interest for this study (Golder, 2014).

3.5.7 Summary of Local Area Risk Assessment Results

As per the Technical Rules (MOE, 2008a), following the simulation of various risk scenarios, the Local Areas for which the Risk Assessment was conducted must be assigned a water quantity risk level classification. The classification is assigned based on the Local Area's ability to meet peak demand (Tolerance) as well as the results of the scenario simulations described above (Risk Level)(Section 3.5.5).

To determine the Risk level associated with each Local Area, the Technical Rules (MOE,2008a), Technical Bulletin: Part IX Local Area Risk Level (MOE, 2011), and MOE Risk Assignment Memorandum (MOE,2013) list a series of circumstances under which the Local Area is assigned a Significant or Moderate Risk level. If any one of the circumstances are met, the Local Area must be assigned a significant or moderate risk level accordingly. The risk level circumstances are summarized in Table 3.5- 13.

For this study, Local Area D (associated with the Tiny Township Whip-Poor-Will system) was assigned a significant risk level due to the exceedance of Safe Available Drawdown at well 21-1 under drought conditions (Scenarios D, H1, H2, and H3). The system's susceptibility to small water level declines is due to the well's construction at the top of the aquifer. In the event of reduced operational capacity, well 21-2 could provide the required supply; however, no back up supply would be available.

Local Area A was assigned a moderate risk level due to a modelled baseflow reduction of 10% at the Vindin Creek coldwater stream. Local Area A is also the location of Midland Russell St. Well 15. Despite exceeding Safe Available Drawdown levels under Scenario H3, the simulation of other scenarios suggests that Safe Available Drawdown at well 15 would not be exceeded if allocated pumping rates at the well are lowered below existing rates. Scenario H3 does not consider future allocated demand, and is consequently not a reliable reflection of future drought conditions at the well. As a result, despite the exceedence of Safe Available Drawdown at Well 15, Local Area A was not assigned a significant risk level, however the Town of Midland is advised to further shift pumping to other wells with underutilized capacity during future potential drought conditions (Golder,2014).

Local Areas B and C (associated with Penetanguishene's Lepage and Robert Street systems), were both assigned a low risk level due to the fact that the Safe Available Drawdown was not exceeded under any of the simulated scenarios.

For this study, impacts on provincially significant wetlands were predicted to be minimal. Declines in the shallow water table level were limited in extent, and generally measured less than 1 m (Figure 3.5- 14). Such declines were primarily confined to the built up areas of Midland, outside of any provincially significant wetland areas. As a result, no measureable impacts were predicted for wetlands within in the Study Area as a result of the simulation of Risk Assessment scenarios.

As mentioned above, the risk level assigned to the Local Area is also based on the Local Area's ability to meet peak demand (Tolerance). According to the Technical Rules (2008a), if a municipality's system is able to meet existing peak demand, the system's tolerance is considered high; otherwise the tolerance is low. The systems evaluated as part of this Tier Three study were classified as having a high tolerance due to their ability to meet peak demand. The underutilized capacity of the well sources, and existence of storage reservoirs further highlight the systems' tolerance. The underutilized capacity of the systems is evident through the remaining Safe Available Drawdown available for the majority of the wells under the various model scenarios. It should also be noted that the well systems on average only actively pump an average of 25% of the time, further demonstrating the high tolerance of the Midland-Pentanguishene systems.

Table 3.5- 13: Risk Scenarios and Circumstances - Groundwater (MOE, 2011; MOE,2013) .

Significant Risk	**Groundwater**
Scenarios	**Circumstance**
C - Existing – average annual D - Existing – ten year drought	1) the quantity of water that could have been taken from groundwater in the local area would not have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells. 2) the quantity of water that could have been taken from groundwater in the local area would have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells and the tolerance is Low.
G – Planned system or existing system with committed demand – average annual	1) the quantity of water that can be taken from groundwater in the local area would not be sufficient to meet the allocated quantity of water for those municipal groundwater wells.
H – Planned system or existing system with committed demand – ten year drought	1) the quantity of water that can be taken from groundwater in the local area would not be sufficient to meet the allocated quantity of water for those municipal groundwater wells.
Moderate Risk	**Groundwater**
Scenarios	**Circumstance**
G – Planned system or existing system with committed demand – average annual	1) The difference between the Existing Demand and the Allocated Quantity of Water would result in a reduction to flows or levels of water thereby creating a measureable and potentially unacceptable impact 2) The difference between the Existing Demand and the Allocated Quantity of Water would result in a reduction to groundwater discharge to aquatic habitat that is classified as a cold water stream by an amount that is, a. At least 10 percent of the existing estimated stream flow that is exceeded 80 percent of the time (Qp80), or b. At least 10 percent of the existing estimated average monthly baseflow of the stream.

Water Quantity Threats

As outlined in the Technical Rules (MOE, 2008a), drinking water quantity threats that may limit the sustainability of a municipal water supply must be identified in every Local Area classified as having a significant or moderate risk level (Golder ,2014). A drinking water quantity threat is defined as one of the following:

- An activity that takes water from an aquifer without returning the water to the same aquifer or surface water body that the water was originally taken from or
- An activity that reduces the recharge of an aquifer

Consumptive water uses in Local Areas assigned a significant risk level are classified as significant drinking water threats. In Local Areas assigned a moderate risk level, only increased or newly permitted water takings can be classified as significant drinking water threats. For Local Areas assigned a moderate risk level, a significant drinking water threat classification can only be made if (when factored into the risk level assessment), the increased/new permitted water taking increases the Local Area's risk level to significant.

Table 3.5- 14 lists all of the consumptive water uses located in each Local Area identified in the Tier Three study. All consumptive water uses in the Whip-Poor-Will Local Area (Local Area D) are identified as significant drinking water threats, due to the Local Area's significant risk level assignment. The remaining Local Areas were assigned a risk level of moderate or low, indicating that existing permitted consumptive water uses in these areas cannot be classified as significant water quantity threats. However, a future consumptive water use in the moderate risk level area may potentially be identified as a significant threat if a proposed/increased water use escalates the Local Area's risk classification from moderate to significant.

Table 3.5- 14: Consumptive Water Uses in Local Areas

Local Area Risk Level	Permitted Consumptive Demand (Threat)
Moderate- Local Area A	Well 6 (Midland Municipal)
Moderate- Local Area A	Well 11 (Midland Municipal)
Moderate- Local Area A	Well 12 (Midland Municipal)
Moderate- Local Area A	Well 14 (Midland Municipal)
Moderate- Local Area A	Well 16 (Midland Municipal)
Moderate- Local Area A	Well 17 (Midland Municipal)
Moderate- Local Area A	Well 7A (Midland Municipal)
Moderate- Local Area A	Well 7 B (Midland Municipal)
Moderate- Local Area A	Well 9 (Midland Municipal)
Moderate- Local Area A	Well 15 (Midland Municipal)
Moderate- Local Area A	Well 1A (Midland Municipal)
Moderate- Local Area A	Well 1- Payette Drive (Penetanguishene Municipal)
Moderate- Local Area A	Well 2- Payette Drive (Penetanguishene Municipal)
Moderate- Local Area A	Well 3- Payette Drive (Penetanguishene Municipal)

Local Area Risk Level	Permitted Consumptive Demand (Threat)
Low- Local Area B	Well 1- Lepage (Penetanguishene Municipal)
Low- Local Area B	Well 2- Lepage (Penetanguishene Municipal)
Low- Local Area C	Well 1- Robert St. (Penetanguishene Municipal)
Low- Local Area C	Well 2- Robert St. (Penetanguishene Municipal)
Significant- Local Area D	Well 21-1 Whip-Poor-Will (Tiny Township Municipal)
Significant- Local Area D	Well 21-2 Whip-Poor-Will (Tiny Township Municipal)
Moderate- Local Area A	PTTW# 7224-6EBQS8 (2 wells - industrial)

The Technical Rules (MOE, 2008a) also specify when reductions in groundwater recharge could be classified as a significant drinking water threats. According to the Technical Rules (MOE, 2008a), where a risk level of moderate is assigned to a Local Area, any modified or new activity within a WHPA-Q2 that reduces recharge to an aquifer should be listed as a significant drinking water threat, if after factoring the modified/new activity into the risk level assessment, the risk level of the Local Area increases to significant (Golder, 2014).

For this Tier Three Risk Assessment, a moderate risk was assigned to Local Area A, surrounding the Midland and Payette Drive systems in Penetanguishene. The moderate risk was assigned due to a modelled baseflow reduction of 10% at the Vindin Creek coldwater stream. However, due to the Moderate Risk Local Area classification, no existing significant drinking water threats related to reduction in groundwater recharge could be identified.

Conclusions

Simulations performed using modelling tools were carried out to evaluate the sustainability of municipal water supplies under existing and projected demand, projected land use changes, and drought conditions. Modelled drawdown results at municipal well systems and stream baseflow reductions were used to complete the overall Risk Assessment for the Midland and Penetanguishene Tier Three Water Budget and Local Area Risk Assessment study.

Following the delineation of the WHPA-Q1, WHPA-Q2, four separate Local Areas were identified. A low risk level was assigned to the Penetanguishene Robert Street and Lepage Well System Local Areas, whereas the Penetanguishene Payette Drive and Midland Well System Local Area, was assigned a moderate risk level due to the potential for baseflow reductions at Vindin Creek. The Whip-Poor-Will System Local Area was assigned a significant risk based on the potential that Well 21-1 would not meet demand requirements under drought conditions (Golder, 2014).

Projected development areas impacting municipal aquifer water levels, were also delineated in the study, as reflected in the WHPA-Q2 delineation. The delineation of such areas allowed for the identification of wells most susceptible to water level declines, and encouraged the completion of an optimization of pumping strategies that can be used to guide future municipal pumping plans.

Figure 3.5- 1: Study Area Location

Figure 3.5- 2: Study Subwatersheds and Topography

Figure 3.5- 3: Quaternary Geology

Figure 3.5- 4: Upland Till Landforms and Tunnel Channel Aquifers

Figure 3.5- 5: Hydrostratigraphy

Figure 3.5- 6: Existing Land Use

Figure 3.5- 7: Projected Land Use Change

Figure 3.5- 8: Safe Available Drawdown Calculation

Figure 3.5- 9: Permit to Take Water Locations

Figure 3.5- 10: Provincially Significant Wetlands and Aquatic Habitats

Figure 3.5- 11: Subwatershed/Catchment Water Budgets

Figure 3.5- 12: WHPA - Q1 Delineation

Figure 3.5- 13: WHPA-Q2 Delineation

Figure 3.5- 14: Scenario G2 - A1 Aquifer Drawdown (relative to Scenario C)

Figure 3.5- 15: Scenario G2 - A2 Aquifer Drawdown (relative to Scenario C)

Figure 3.5- 16: Scenario G2 - A3 Aquifer Drawdown (relative to Scenario C)

Figure 3.5- 17: Scenario G3 - A3 Aquifer Drawdown (relative to Scenario C)

3.6 Peer Review Process

The water budgets within this document were prepared as indicated in the MOE Technical Rules 19-36 (2008) and the MOE guidance documents. Each of the water budget studies are undergoing or have been subsequently peer reviewed by qualified professionals. The peer review process ensures there is consistency with the expectations of the Technical Rules for completion of the Assessment Report. That appropriate methodologies are utilized, and that the technical assumptions are necessary and reasonable. The process also ensures that the water budgets are scientifically defensible products. Table 3.6- 1 outlines who the peer reviewers were for each water budget, highlights their qualifications to peer review these water budgets. All water budget projects presented within the Assessment Report have undergone at least one round of peer review. Table 3.6-2 outlines if the water budget project has completed the full peer review process.

Table 3.6- 1: Water Budget Peer Reviewers in the Severn Sound Watershed.

Study	Peer Reviewer	Title
Tier One Water Budget and Stress Assessment Summary	Dillon Consulting	Robert Muir, M.A.Sc., P.Eng, (Surface water expert)
Tier One Water Budget and Stress Assessment Summary	Dillon Consulting	Igor Iskra, Ph.D., P.Eng
Tier One Water Budget and Stress Assessment Summary	Richard Gerber	Richard Gerber, Ph.D., Pigeon (Hydrogeological Expert)- CTC SWP Region- Technical Advisor and Senior Hydrogeologist; Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier One Water Budget and Stress Assessment Summary	York Region	Tom Bradley Water Resources Technologist.
Tier One Water Budget and Stress Assessment Summary	York Region	Tammy Silverstone, M.Eng., P.Eng - Program co-ordinator Water Resources and Environmental Services
Tier Two Water Budget (Severn Sound Watershed)	Dillon Consulting	Robert Muir, M.A.Sc., P.Eng, (Surface water expert)
Tier Two Water Budget (Severn Sound Watershed)	Dillon Consulting	Igor Iskra, Ph.D., P.Eng
Tier Two Water Budget (Severn Sound Watershed)	Richard Gerber	Richard Gerber, Ph.D., P.Geo (Hydrogeological Expert)- CTC SWP Region- Technical Advisor and Senior Hydrogeologist; Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier Two Water Budget (Severn Sound Watershed)	York Region	Tom Bradley Water Resources Technologist.
Tier Two Water Budget (Severn Sound Watershed)	York Region	Tammy Silverstone, M.Eng., P.Eng - Program co-ordinator Water Resources and Environmental Services
Tier Three Water Budget and Local Area Risk Assessment (Midland, Penetanguishene, and Whip-Poor-Will)	Stantec Consulting	Igor Iskra, Ph.D., P.Eng
Tier Three Water Budget and Local Area Risk Assessment (Midland, Penetanguishene, and Whip-Poor-Will)	Richard Gerber	Richard Gerber, Ph.D., Pigeon (Hydrogeological Expert)- CTC SWP Region- Technical Advisor and Senior Hydrogeologist; Oak Ridges Moraine Hydrogeology Program (YPDT-CAMC)
Tier Three Water Budget and Local Area Risk Assessment (Midland, Penetanguishene, and Whip-Poor-Will)	S.S. Papadopulos & Associates	Christopher J. Neville, M.Sc., P.Eng.

Table 3.6-2: Peer Review Water Budget Project Status.

Water Budget	Peer Review Status
Tier 1 Water Budget and Stress Assessment Summary	Complete
Tier 2 Water Budget (South Georgian Bay West Lake Simcoe)	Complete
Tier 3 Water Budget (Midland, Penetanguishene, Whip-Poor-Will)	Complete