3. WATER BUDGET AND STRESS ASSESSMENT

A Water Budget is an understanding and accounting of the movement of water and the uses of water over time. The Assessment Report Technical Rules (MOE, 2009), outline four phases or levels of water budget studies, starting with the least complex and potentially advancing to the Tier 3 Water Budget (which is the most detailed and complex type of study).

Phase 1 - Water Budget Conceptual Understanding (Conceptual WB)
Phase 2 – Tier 1 Water Budget (Tier 1 WB)
Phase 3 – Tier 2 Water Budget
Phase 4 – Tier 3 Water Budget

Not all phases of water budget studies are required or funded under the Clean Water Act and source protection program. The Niagara Peninsula Conservation Authority (NPCA) is required to prepare a Conceptual Water Budget and a Tier 1 WB to satisfy the Assessment Report Technical Rules, but a Tier 2 and Tier 3 Water Budget are not required in this Source Protection Area since all our municipal drinking water comes from Great Lakes or Great Lakes connecting channel sources.

The Conceptual Water Budget study was completed to provide an initial overview of the flow system (Franz et al, 2007). The Conceptual Water Budget provided a description of the physical setting related to the general movement of water in the watershed using existing studies and information. It built on the Watershed Characterization report (NPCA, 2009b) to develop an integrated understanding of local water resources. Some potential quantity stresses on surface and groundwater were considered.

The purpose of the Tier 1 water budget analysis (Tier 1 WB) was to estimate the hydrologic stress of NPSP Area subwatersheds. Two main components of the Tier 1 WB were supply and demand. Water Availability Studies (WAS) were completed for each of the major subwatersheds in the NPSP Area (AquaResource Inc. and NPCA, 2009a through 2009j). These ten (10) studies were completed to quantify available water supplies (i.e. surface water flow and groundwater recharge) on an average monthly basis for 1991 to 2005. These results were combined with assessment of demand to determine if subwatersheds were water quantity stressed (NPCA and AquaResource Inc., 2009).

This chapter summarizes the results of over twelve studies completed as part of the water budgeting process. Sections are included, but not limited to, discussion of environmental factors to be considered in a water budget (Sections 3.1 to 3.8), the determination of the water supply (Section 3.9), assessment of demands (Sections 3.10 to 3.12) and the calculation of stress levels (Section 3.13 to Section 3.14).

3.1 Climate

Climate is the ultimate driver in any water budget investigation. Understanding how climate varies spatially as well as seasonally is critical to accurately identifying key hydrologic processes. This section will characterize the climate within the NPSP Area.

3.1.1 Climate Stations

Climate monitoring stations are commonly used to collect information on temperature, precipitation (rain and/or snowfall), rate of precipitation and solar radiation. Several government agencies operate climate monitoring stations in the NPSP Area for varying purposes, e.g. Environment Canada (EC), RON (Region of Niagara), OWN (Ontario Water Network) (Figure 3.1, Appendix A-2).

The highest quality long-term datasets are maintained by Meteorological Services of Canada (MSC), a division of Environment Canada. For the Tier 1 WB water availability modelling (Section 3.9), select MSC datasets were improved by Schroeter and Associates (2007) f in data gaps in daily and hourly records using a relational procedure and existing Environment Canada stations. This was to improve station density and address missing values as continuous record was required. However only five (5) MSC stations are still in operation (Hamilton Airport, Welland, Port Colborne, Fort Erie and Grimsby Mountain) leaving much of the NPSP Area without long-term climate stations operated to a national standard.

3.1.2 Climate Conditions

The climate of Southern Ontario is characterized as having warm summers, mild winters, a long growing season, and usually reliable rainfall. The climate within southern Ontario differs somewhat from one location to another and from one year to the next. Spatial variations are generally caused by the topography and varying exposure to the prevailing winds in relation to the Great Lakes (Schroeter et al, 1998).

Spatial variations in average annual precipitation (rain plus snow), and temperature were prepared from MSC stations for 1991-2005 (Figures 3.2,3.3 and 3.4). This time period was chosen to best suit available datasets and meet the World Meteorological Organization climate normal criterion of fifteen years.

3.1.2.1 Precipitation

Precipitation is one of the primary components of the hydrologic cycle and is critical to the understanding of any water budget. Average annual precipitation (rain plus snow) mapping (Figure 3.2) indicates the least amounts of precipitation are received along the shore of Lake Ontario (less than 850 mm). The most precipitation (more than 1,000 mm) is received in the Fort Erie area on the shore of Lake Erie. This is due to lake-effect precipitation; as the winds pass over Lake Erie during late fall and early winter, they pick up water and then deposit it as rain or snow when they reach land. This difference across the NPSP Area shows a high level of variability over a short distance. However the uniform distribution of precipitation in the western portion may be as a result of a lack of climate stations.

3.1.2.2 Snowfall

Throughout Ontario it is recognized that snowfall represents a significant proportion of the total annual precipitation, and plays a dominant role in producing the variability as seen in streamflow. Average annual snow water equivalent mapping (Figure 3.3) shows large differences within the NPSP Area: greater than 175 mm in the Fort Erie and Grimsby areas and less than 125 mm in the NOTL and Haldimand/Pelham areas. Snow water equivalent is the amount of water contained within a snow pack (i.e. the depth of water that would result if a snowpack was melted instantaneously).

3.1.2.3 Air Temperature

Air temperature provides an indication of the potential variability in conditions for evapotranspiration. Air temperature is more regional in nature than precipitation, with much less local variability. Average annual temperature (Figure 3.4) ranges from 8^{o}C at Hamilton Airport to 9.5^{o}C at Vineland and Port Dalhousie. Average temperatures are generally warmer moving from the west towards the central area and lower elevations. Generally the NPSP Area is warmer than in-land areas to the west due to the proximity of Lakes Ontario and Erie which moderate/buffer temperatures.

3.1.2.4 General Observations

General observations from the 1991-2005 dataset include:

- The driest and warmest calendar year was 1998 and had generally the lowest values for both precipitation and snow;
- The wettest calendar year was 1996;
- 14-17% of precipitation was generally snow;
- Lowest monthly precipitation was measured in February; and
- The wettest month was generally September.

3.1.3 Evapotranspiration

Evapotranspiration (ET) is a process whereby water contained on the landscape either in soil or in ground surface depressions is released into the air through evaporation or transpiration" through vegetation, or vapourized into the air. It is an essential element of the water cycle and a critical component of the Water Budget, often presented as the largest part. Unfortunately, it is often the least understood component since it cannot be accurately measured with conventional monitoring techniques. Instead, conditions are extrapolated from non-ideal measurement devices, which are sparsely distributed throughout Ontario.

ET was calculated as part of the water availability studies. Areas of low ET (<200 mm/year) largely correspond with urban areas and high ET (>600 mm/year) with agriculture, wetland and forest land cover (Figure 3.5).

3.1.4 Long Term Temperature, Precipitation Trends and Climate Change

Historical climate trends, groundwater levels, and stream flow records were not analyzed to identify future meteorological trends for the watershed. This may be completed in the future to identify climatic trends affecting water resources where sufficient data is available and where warranted. However, the source protection staff has reviewed reports and discussion papers on this topic, and the findings are presented below.

J.P. Hamilton and G.S. Whitelaw (Climate Change Trends Along the Niagara Escarpment, Niagara Escarpment Commission 1999) examined long-term climate trends from stations along or near the Niagara Escarpment. Stations within the Niagara

Peninsula included Niagara Falls, St. Catharines and Welland. These stations (at the time of the analyses) had records of 93, 94 and 103 years, respectively.

Observations included:

- Long-term increases in mean annual temperature of 0.6^{o}C at St. Catharines and 0.7^{o}C at Welland. Generally these increases were highest in winter and spring and lower in summer and fall. Most of the increase in mean temperature was due to rising minimum values and as a result daily temperature ranges declined about 1.0^{o}C.
- At Welland observations included increases in annual rainfall and a decline in annual snowfall. The highest seasonal increase in precipitation was in the fall with stable or declining precipitation in the winter and spring periods. The increasing trend in annual precipitation was noted over the period 1950-1998.

Another article titled "Impacts of Recent Climate Trends on Agriculture in Southwestern Ontario by Tan and Reynolds" (2003), describes the climate as generally drier in the last decade, but agrees that temperature is on the rise. It is acknowledged that increasing temperature will affect precipitation amounts; with the majority in agreement that Canada will see an increase in precipitation.

The Niagara Water Quality Protection Strategy (NWQPS) (MacViro et al, 2003b) referenced Bruce (2002) with respect to predicted future climate change effects for the study area:

- Increased flash flooding as patterns shift from longer low intensity storms to shorter more severe ones and subsequent increased erosion from the intense storms;
- Increased snowmelt floods as shortened lake ice seasons encourage more lake-effect snow deposition;
- Potential for a shorter snow cover season;
- Decreased soil moisture levels through higher evaporation and faster runoff;
- Lower groundwater levels; and
- Lower Lake Levels; it is expected that by 2050 average levels in Lake Erie will be reduced 0.8 m and in Lake Ontario by 0.5 m. This may have the effect of increasing the profile of water quality issues such as rotting algae and exotic species contamination.

According to the NWQPS (MacViro et al, 2003b):
"*The impacts on natural areas will include more severe stress in floodplains and marshes, both from extra sediment and from extra scour. On tablelands, the changing soil moisture regimes could combine with the warming temperatures to impose so much stress that whole ecosystems could be altered. In general the shifts would be towards drier, more southern communities but will require many decades of stressed transition phases before more stable, mature southern communities are established.*"

Natural Resources Canada also published an overview of climate change in Canada in an article called "From Impacts to Adaption: Canada in a Changing Climate (2007)". The key findings include:

- Climate has an influence over the social, economic, and cultural health in Ontario.
- Ecosystems, human health, water quantity and quality, physical infrastructure, and remote/resource-based communities are sensitive to climate.
- Water shortages will become more frequent especially in the southern regions.
- Increased mortality from air pollution, and spread of vector-borne diseases, in addition to increased E.coli outbreaks in heavy precipitation events.
- Impacts to remote and resource-based communities include droughts, ice-jam flooding, forest-fires, and warmer winter temperatures leading to evacuations, disrupted transportation links and stressed forestry-based economies.
- Stress on ecosystems, particularly wetlands, which are declining in number and are also seeing changes in the relative abundance of fish.
- Ontario has a strong capacity to adapt to climate change, but this capacity is not uniform across the Province. Opportunities exist for decision-making regarding climate change, such as infrastructure renewal programs and growth strategies.

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3.2 Subwatersheds

Tier 1 WB subwatershed boundaries were chosen to align with established NPCA watershed planning area (WSPA) boundaries. These fourteen (WSPAs), and two urban areas, range in size from 21 to 478 square kilometres (km^2) (Figure 3.6):

BDSC – Beaverdams and Shriners Creek	LIN – Lincoln
BFC – Big Forks Creek	LWR – Lower Welland River
CWR – Central Welland River	NOTL – Niagara-on-the-Lake
FEC – Fort Erie Creeks	SNF – South Niagara Falls
FSEM – Fifteen, Sixteen and Eighteen Mile	TWEL – Twelve Mile Creek
GR – Grimsby	TWEN – Twenty Mile Creek
LENS – Lake Erie North Shore	UWR – Upper Welland River
NFU – Niagara Falls Urban	SCU – St.Catharines Urban

Topographic features, such as the Niagara Escarpment, have influenced the drainage boundaries such that most of these subwatersheds are headwater areas adjacent Great Lakes shores. Also most of the WSPAs do not have single outlets because of small areas which discharge to the Great Lakes. Of the major drainage systems, the two largest are the Welland River (UWR, CWR and LWR) and Twenty Mile Creek (TWEN).

3.3 Surface Water

3.3.1 Surface Water Hydrology and Gauges

As discussed in section 2.1, the surface water hydrology in the NPSP Area is divided into three main drainage areas. They consist of Lake Ontario, the Niagara River, and Lake Erie, and each drainage area consists of networks of creeks and river watersheds (Figure 2.2).

Within these watersheds, the highest flows occur during the spring snowmelt (Franz et al, 2007); while low flows generally occur in the summer months of July and August. Through the analysis of streamflow data, it appears that the NPSP Area watersheds are dominated by runoff processes. Baseflow in a stream is the portion of the stream flow due to storm water that is not runoff and is the primary source of water in a stream during dry weather. The area is characterized by no or very low baseflows in the summer months, with significant streamflows resulting only during precipitation events. The NPSP Area watersheds are therefore considered to have flashy stream flow characteristics of high flows during storms and very low flows otherwise.

Surface water flows and levels can be monitored through the installation of surface water gauges and maintenance of stage-discharge curves. A summary of surface water gauges in the NPSP Area is presented in Appendix A-3 and Figure 3.7. There are twelve (12) stations set up which are operated by Environment Canada (EC) or by the NPCA under a joint agreement between EC, MNR, and NPCA. The NPCA operates an additional five (5) surface water gauges independent from the agreement. There are twelve (12) historical EC stations that are no longer in operation, but data exists in ranges of two to fifteen years. In the eastern portion of the NPSP Area there are a number of subwatersheds which are not monitored (Figure 3.7).

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3.3.2 Surface Water Control Structures

The NPCA has overseen the construction of numerous water control structures in the watershed. There are approximately 36 structures throughout the jurisdiction (Figure 3.8, Appendix A-4). The structures significantly control the movement of water over land surfaces, providing seasonal flood control and continuous flows during the drier months. These control works were implemented for various water management functions, but primarily to protect life and property from the risk of flood and erosion. Some of the larger dam and reservoir structures were built to enhance the natural flow regime of creeks and rivers, while also providing flood control benefits and irrigation supplies. Such structures include the Binbrook Dam and the Virgil Dams (NPCA, 2009c).
Figure 3.8 shows the locations of dam structures and they are listed in more detail in Appendix A-4.

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3.3.3 Aquatic Habitat Dependent upon Water Depth, Flow, and Temperature

Aquatic species and aquatic habitat are water dependent. Type I (critical) habitats, or any other habitat identified as having species that are on the Species at Risk List in Ontario, should be prioritized, protected, and carefully managed especially in drought conditions. Such systems include Welland River, Twelve mile Creek, and Twenty Mile Creek (Figure 2.8). See also Sections 2.2.8 to 2.2.10 for more information.

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3.4 Physiography

The NPSP Area contains a number of key physiographic areas (Figure 3.9), including the Iroquois Plain, Niagara Escarpment, and Haldimand Clay Plain. Other landforms and physiographic features found within the Niagara Peninsula include moraines, eskers, drumlins, sand plains, the Fonthill Kame-Delta Complex, and the Onondaga Escarpment (Chapman & Putman, 1984). The main physiographic areas and features are described below.

The Iroquois Plain is located between the Niagara Escarpment and Lake Ontario, and consists of lacustrine deposits of sand, silt, and clay associated with the glacial Lake Iroquois (Figure 3.9). The Iroquois Plain deposits overlie Halton Till.

The Niagara Escarpment extends east-west across the Niagara Peninsula, and rises up to 120 m above ground surface of the Iroquois Plain, which is located north of the escarpment. The escarpment contains a relatively hard dolostone bedrock cap, which is underlain by softer shales and sandstones of the Clinton, Cataract and Queenston bedrock groups. The escarpment was formed by erosion of the softer bedrock materials below the dolostone cap. The escarpment has a significant impact on the local climate and ecosystems, and as a key topographical feature in the Niagara Peninsula, it influences drainage patterns, as well as wildlife (for example. waterfalls along the escarpment create fish barriers). The escarpment contains a number of ANSIs.

The relatively flat lands of the Haldimand Clay Plain are located above the Niagara Escarpment in the central part of the peninsula. The Haldimand Clay Plain covers the major portion of the NPSP Area and includes within it the Welland River watershed.

Key physiographic features located in the Haldimand Clay Plain include the Onondaga Escarpment, Fonthill Kame-Delta Complex, and several moraines. The Onondaga Escarpment is of relatively low topographical relief, and rises only a few metres above the surrounding lands. Overburden soils overlie portions of the Onondaga Escarpment near the NPSP Area’s western boundary. It is east-west trending, and is located just north of Lake Erie.

The Fonthill Kame-Delta Complex rises 80 m above the surrounding land and covers an area approximately 6 km in diameter (Waterloo Hydrogeologic Inc., 2005). Groundwater from the Fonthill Kame-Delta Complex discharges to the north and into Twelve Mile

Creek, to produce one of the only cold water streams and cold water fish habitats in Niagara Peninsula.

A number of end moraines were also formed on the Haldimand Clay Plain (WHI, 2005). They include the Fort Erie, Wainfleet, Vinemount, Crystal Beach, and Niagara Falls moraines. These moraines form watershed boundaries in most cases. For example, the Fort Erie Moraine and the Niagara Falls Moraine define boundaries of the upper watershed of twenty Mile Creek above the Niagara Escarpment. Additional details about these moraines, shown on Figure 3.9, are provided in Table 3.1.

Table 3.1 Moraines in the Niagara Peninsula

Moraine Name	Core Sediments of Moraine	Cap Sediments of Moraine	Approximate Dimensions of Moraine
Wainfleet Moraine	Halton Till	Gravel, sand, and silt	2.5 km long, by 0.5 km wide, and 8 m high
Vinemount Moraine	Halton Till	Halton till, clay, silt, and sand	7 km long, by 1 km wide, and up to 15 m high
Niagara Falls Moraine	Halton Till	Sand, gravel, and silt	8 km long, by 2 km wide, and up to 30 m high
Fort Erie Moraine	Halton Till	Halton till, clay and silt	6.5 km long, by 1.5 km wide, and up to 7 m high
Table References: 1. MacViro Consultants Inc. et al., 2003b 2. WHI, 2005 3. Chapman and Putman, 1984			

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3.5 Geology

3.5.1 Bedrock Geology

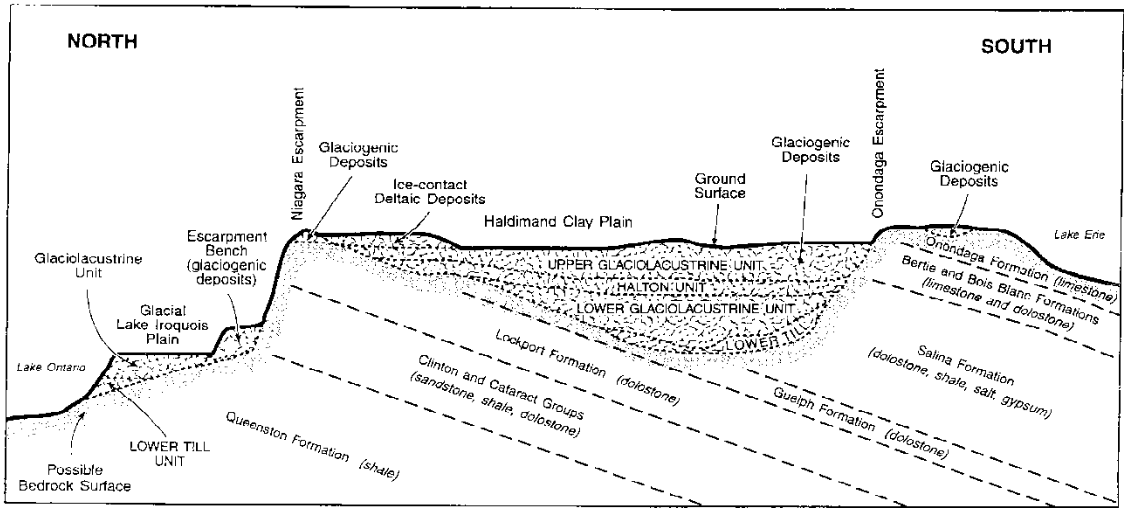
Paleozoic Era bedrock, associated with Appalachian Basin marine sediments, underlies the study area. This sedimentary bedrock consists mainly of interbedded limestone and dolostone carbonate materials, and shale. Bedrock units of the Devonian Period (newest) to the Ordovician Period (oldest) are present. The bedrock contains a slight dip to the south (to southwest) of about 4 to 6 m/km (i.e. <1degree). The bedrock units in the Niagara Peninsula are east-west trending with the oldest bedrock units found along Lake Ontario (i.e. Queenston Formation), and the youngest units found in the south along Lake Erie (i.e. Onondaga Formation) (Figure 3.10). Bedrock outcrops are found in various areas of the NPSP Area (Figure 3.11), but most significantly along the Niagara Escarpment, and on the Onondaga Escarpment which is located north of the Lake Erie shoreline. Table 3.2 provides a chronological summary from youngest to oldest of the Paleozoic bedrock geology found in the Niagara Peninsula.

Table 3.2 Paleozoic Bedrock Geology in the Niagara Peninsula

Age	Group	Formation	Description	Thickness
Middle Devonian		Onondaga	Variably cherty limestone. Grey moderately cherty dolostone, some shale	up to 15 m
Lower Devonian		Bois Blanc	Cherty, brown, limestone, minor shale and dolostone, with sandstone interbeds	3 - 4 m
Upper Silurian		Bertie	Brown dolostone. Brown & cream mottled dolostone	10 m
		Salina	Brown dolomite & grey calcareous shale, with gypsum and anhydrite	90 m
Middle Silurian	Lockport	Guelph	Tan or brown, crystalline, thickly bedded dolostone	10 - 40 m
		Lockport	<u>Eramosa Member</u>-Dark grey to black, finely crystalline, laminated dolostone, with gypsum filled vugs, and black chert	3 - 10 m
			<u>Goat Island Member</u> -Grey medium grained dolostone, with medium to thick bedded white chert	5 - 8 m
			<u>Gasport Member</u> -Pink medium to fine grained dolostone & limestone	14 m
	Clinton	DeCew	Grey, finely crystalline, thin to medium bedded dolostone. Cross-bedded in lower part.	4 m
		Rochester	Dark bluish to brownish grey calcareous shale, with limestone interbeds	14 m
		Irondequoit	Grey to tan, fine to medium crystalline limestone	3 m
		Reynales	Grey blue, thin to massive bedded dolostone	4 - 6 m
		Thorold	Green, thinly bedded sandstone, with shale partings	2 - 3 m
Lower Silurian	Cataract	Grimsby	Red sandstone, some green and yellow mottling. Red shale interbeds primarily in lower portion of the unit.	12 - 16 m
		Cabot Head (Power Glen)	Grey laminated shales with sandstone interbeds, and occasional limestone interbeds	11 m
		Whirlpool	Grey to light brown weathered sandstone, with shale partings	up to 7 m
Upper Ordovician		Queenston	Red shale, occasionally with interbeds of siltstone, sandstone, and limestone.	>100 m

References:1.MacViro Consultants Inc. et al,2003b,2.WHI, 2005,3.Chapman& Putman, 1984

<u>Cross-section of the geology along the Welland Canal. (Menizes and Taylor, 1988)</u>



The insert above shows a generalized cross-section of the sub-surface geology from north to south along the Welland Canal (Menzies and Taylor, 1988). Additional cross-sectional conceptual models of the sub-surface geology for the Niagara Peninsula were completed in the NPCA Groundwater Study and are shown in the Appendix A-5.

A description of major bedrock units in the NPSP Area is presented below:

The Bertie, Bois Blanc, and Onondaga Formations overlie the Salina unit. The <u>Bertie Formation</u> (the oldest of these three formations) consists of a grey and brown dolostone. The <u>Bois Blanc</u> bedrock overlies the Bertie Formation and consists of mostly limestone, and forms the cap of the Onondaga Escarpment while the <u>Onondaga Formation</u> is found between the Onondaga Escarpment and Lake Erie shoreline.

The <u>Salina Formation</u> overlies the Lockport formations, and consists of evaporates (salts, gypsum), shales, and carbonates (dolostone). Groundwater associated with this formation is generally poor in quality due to the salts/sulphur content. The Salina Formation underlies much of the clay plains in the central portion of the peninsula, south of the Niagara Escarpment, but does not extend north of the Niagara Escarpment.

The <u>Lockport Group</u> overlies the Clinton Group, consisting of the Guelph-Lockport Bedrock Formations, which are comprised mostly of limestone and dolostone. The Lockport Group Formations are located on the top of the Niagara Escarpment, and are much harder than the underlying shales and sandstones of the Cataract and Clinton groups. The Niagara Escarpment was formed by the gradual erosion of the softer exposed surfaces of the shales and sandstones that were underlying the relatively hard Lockport Group bedrock.

Terra-Dynamics Consulting Inc. (2006) completed an initial assessment of potential karst topography areas within the NPSP Area (Terra-Dynamics Consulting Inc., 2006). It was determined karst features within the NPSP Area are primarily associated with the Eramosa Formation of the Lockport Formation. Notable karst areas identified included:

(i) The Stoney Creek "Mountain" Area, (ii) The Smithville Area and (iii) Gavora Drain and Balls Falls, Vineland. High karst areas are shown Figure 3.12.

The Clinton Group overlies the Cataract Group consisting mainly of interbedded shale and dolostone. It contains a number of formations including the DeCew, Rochester, Irondequiot, Reynales, and Thorold Formations. These formations below the Rochester Formation are not considered to be a significant groundwater source for drinking water. The Cataract and Clinton bedrock is exposed along the face of the Niagara Escarpment.

The Cataract Group overlies the Queenston Formation which consists primarily of shale, and sandstone (MacViro Consultants Inc. et al, 2003b). This group is not considered to be a significant groundwater source for drinking water as it is buried under thick layers of younger bedrock and has naturally poor water quality (MOE, 2003a).

The Queenston Formation is the oldest of the Paleozoic bedrock formations in Niagara and is generally not considered a significant source of groundwater. The top three to five metres of the formation are weathered and may yield enough water for domestic wells but not for municipal supplies. This formation typically has naturally poor water quality. It consists of shale interbedded with limestone and siltstone, and ranges in thickness from 45 m to 335 m. It is commonly known as the Queenston Shale. Outcropping of this formation is present in the northern extent of the NPSP Area along Lake Ontario.

Main bedrock geological areas of interest in the Niagara Peninsula are described below.

Niagara Escarpment: As outlined previously, the Niagara Escarpment trends east-west across the peninsula and reaches up to 120 m above the adjacent Iroquois Plain to the north. The escarpment results from the differential erosion between the harder bedrock cap, and the softer underlying bedrock units.

Onondaga Escarpment: The Onondaga Escarpment runs along the north side of Lake Erie and only rises a few metres above the surrounding landscape. It is also the result of differential erosion between the harder bedrock cap, and the softer underlying bedrock to the north.

Erigan Channel: The main channel runs from the village of Lowbanks, located on the Lake Erie shoreline, through the Village of Fonthill, and beyond to the Niagara Escarpment. The bedrock channel is estimated to be 400 m wide and up to 50 m deep, and is in-filled with sediment (Figure 3.11)

St. Davids Buried Gorge: This bedrock valley runs from the Whirlpool area of the Niagara River northwest to the Village of St. Davids at the base of the Niagara Escarpment, and is estimated to be up to 130 m deep and 630 m wide. It is infilled with fine sands interbedded with thin clay and silt layers. It is believed to be the former path of the Niagara River.

The bedrock surface topography is shown on Figure 3.11 and Figure 3.12 presents the overburden thickness in the NPSP Area. The overburden thickness was determined by calculating the difference between the bedrock surface and ground surface elevations (WHI, 2005). However, the bedrock topographic surface is now considered a work-in-progress, as previous investigations, highlighting features such as the Erigan Channel (e.g. Flint and Locama, 1988) remain to be more fully incorporated into the dataset. Relief within the bedrock topography is focused along the Niagara Escarpment, and along the Erigan Channel and the St. Davids Buried Gorge. There is also a bedrock depression associated with the sub-crop of the Salina Formation, which was historically more-easily eroded. Corresponding to this, a low area within the bedrock topography is located north-west of the Wainfleet Bog (see Figure 3.11). This area also shows up as one of the thickest areas of overburden in Figure 3.12.

3.5.2 Overburden Geology

Most of the Niagara Peninsula is covered by up to 30 m of unconsolidated sediment. These overburden sediments mainly resulted from glacial advances and retreats that occurred during the last glaciation period in southern Ontario. The glacial movements were responsible for eroding bedrock and creating moraines and till deposits, as well as glaciolacustrine deposits. The last glaciation period is estimated to have created the following four primary overburden units that are found in the NPSP Area (as shown in cross-section in Section 3.5.1):

- Lower Till
- Deeper water glaciolacustrine unit
- Halton Unit
- Upper glaciolacustrine unit

Other noteworthy units include the (i) St. Davids Gorge infill, which is considered to contain some of the oldest soils in the Niagara Peninsula; and (ii) post-glacial deposits of the Recent Age (such as coastal dunes and modern floodplains). Man-made deposits include excavation materials from the construction of the Welland Canal. A description of the main quaternary units from oldest to youngest is provided below.

The Lower Till is a gravelly, sandy silt till, that occasionally contains sand and gravel derived from the underlying Silurian and Devonian bedrock (MacViro Consultants et al, 2003b).

The deeper water glaciolacustrine unit consists of clay and silt overlying the Wentworth Till. This unit covers the Niagara Peninsula extensively.

The Halton Unit is a clayey silt till which ranges up to 30 m thick in bedrock valleys and is visible at ground surface in areas north of the Niagara Escarpment and near Lake Erie. In some areas, the Halton Till directly overlies the Wentworth Till, but in other areas it overlies the clays and silts of the deeper water glaciolacustrine unit.

The upper glaciolacustrine unit includes deposits such as the Haldimand Clay Plain and the Fonthill Kame-Delta Complex.

3.5.3 Surficial Geology

The surficial geology is shown on Figure 2.33 may correlate with the above mentioned upper glaciolacustrine unit. The surficial geology of the NPSP Area is largely silt and clay, matching the overlying clayey soils, e.g. Welland River and Twenty Mile Creek watersheds. Also above the Niagara Escarpment, is the stratified clay, silt and sand to gravel associated with the Fonthill Kame-Delta Complex, e.g. Twelve Mile Creek and Fifteen Mile Creek headwaters. The Fonthill Kame-Delta Complex is a thick deposit consisting mainly of permeable sand and gravel which provides a significant groundwater flow system within the surrounding clay plain. (Blackport et al, 2005).

Bedrock outcrops are located on both the Niagara Escarpment, the Onondaga Escarpment and adjacent the Iroquois shoreline. Between the base of the Escarpment and the Iroquois shore there is also a broad sloping bench which is covered by several feet of boulder clay (Chapman and Putnam, 1984). The Halton Till (silty to clayey till) which is shown as an east-west band across the NPSP Area, as a band is gradually located more to the north going east. While below the Niagara Escarpment close to Lake Ontario, the surficial geology becomes more sand and silt associated with the Iroquois shoreline. However to the southeast are the sands and silts of the Dunnville Sand Plain. And a large portion of the surficial geology adjacent the Welland Canal consists of man-made deposits consisting of overburden excavated for the construction of the canal.

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3.6 Groundwater

Throughout Ontario, groundwater systems are often the dominant water resource available for municipal and agricultural water supply (MOE, 2003a). However, the NPSP Area has a unique location, with an abundance of surface water sources available for municipal and in some cases agricultural supply.

Private water supplies serve over 77,000 people in the NPSP Area (NPCA and AquaResource Inc., 2009b). The number serviced by drilled wells in aquifers, versus dug wells and cisterns is unknown, as only 6,600 wells are on file with the MOE classified as for human consumption in the NPSP Area. MOE water well information system records indicate approximately 80% of wells are installed in bedrock (Figure 3.13), however NPSP Area bedrock aquifers are generally part of a “Contact-zone” aquifer (see Section 3.6.1) covered by sand and gravel.

3.6.1 Aquifer Units

The primary NPSP Area aquifers can be generalized as four (4) main types: surficial overburden, the Guelph/Lockport Formations, the Onondaga/Bois Blanc Formations and the “Contact-zone” aquifer.

The surficial overburden aquifers consist of the Fonthill Kame-Delta Complex, the Dunnville Sand Plain and the Iroquois Sand Plain (Figure 3.14). These are unconfined aquifers consisting of coarse-grained deposits and may be accessed through dug in addition to drilled wells.

The Guelph/Lockport Formation is a bedrock aquifer the width of the Niagara Peninsula (Figure 3.15). This aquifer consists mostly of dolostone with some limestone. It may be unconfined to confined depending upon the presence/absence/condition of overlying material. It is expected to be unconfined where the formations are exposed along the Niagara Escarpment (Figure 3.9, 3.11), semi-confined beneath fractured/weathered overburden and confined where overlain by greater than 5 m of overburden (Figure 3.12).

The Onondaga/Bois Blanc Formation is another bedrock aquifer the width of the Niagara Peninsula (Figure 3.15). This aquifer consists mostly of dolostone and limestone. It may be unconfined to confined depending upon the presence/absence/condition of overlying material. It is expected to be unconfined where the formations are exposed along the Onondaga Escarpment (Figure 3.9), semi-confined beneath fractured/weathered overburden and confined where overlain by greater than 5 m of overburden (Figure 3.12).

The “Contact-zone” aquifer is an overburden/bedrock aquifer that covers over 60% of the NPSP Area (Figure 3.15). The term “Contact-zone” refers to bedrock-overburden contact where granular overburden is overlying fracture bedrock and all this is covered by clay. This regionally significant aquifer is generally considered confined.

Other potential sources of groundwater supplies exist but are generally not suitable as a water supply due to quality or quantity limitations. The Salina Formation (Figure 3.10) has good water yielding capacity but is mineralized and sulphurous. The Queenston Formation can provide marginal supplies but may also have naturally occurring poor water quality.

These units are also shown in regional cross-sections in Appendix A-5.

3.6.2 Aquitards

Aquitards can protect aquifers from sources of contamination. A large portion of the NPSP Area is covered with fine-texture glaciolacustrine deposits (clay and silt) associated with the Haldimand Clay Plain (Figures 3.9 and 2.4). These deposits form an aquitard layer above the bedrock that restricts the vertical movement of groundwater down into the bedrock aquifer. However the upper zone may be intensely fractured to a depth of 5 m making the underlying aquifer vulnerable (NPCA, 2009a).

Another important aquitard is the Rochester Formation, an upper formation of the Clinton Group (Appendix A-4) which consists of shale and limestone. It acts as a barrier to vertical groundwater flow below the Guelph-Lockport Formation aquifer.

3.6.3 Water Table

Shallow groundwater flow, or the water table, generally follows the ground surface topography (Figure 2.3). The regional water table was mapped by Waterloo Hydrogeologic Inc. (2005) from MOE WWIS static water levels observed in overburden and bedrock completed at depths less than 15 m (Figure 3.16). The water table represents primarily flow data from bedrock wells. Due to limited information, especially in the central and southwest portions, the ground surface was used to constrain the map.

The water table system includes the Onondaga Escarpment, the upper portion of the Fonthill Kame-Delta Complex, part of the Niagara Escarpment and at times, the contact-zone aquifer (Appendix A-5). The shallow regional groundwater flow is generally expected to be directed towards either Lake Ontario with an elevation of approximately 75 metres above sea level (masl), Lake Erie (about 176 masl) or the Niagara River (Figure 3.17).

3.6.4 Potentiometric surface

For the NPSP Area, the potentiometric surface is an imaginary surface representing the static head of groundwater and defined by the level to which water will rise in wells completed greater than 15 metres below ground surface. A regional potentiometric surface map was constructed based on static water levels by WHI (2005) (Figure 3.18). The potentiometric surface represents primarily flow data from bedrock wells.

The potentiometric system may include portions of the contact-zone aquifer, the Fonthill Kame-Delta Complex, the Lockport Formation and other bedrock formations with MOE WWIS records (Appendix A-5). The potentiometric surface flow patterns suggest groundwater flow to Lake Ontario, Lake Erie and the Niagara River but also a large area of Twenty Mile Creek and Upper Welland River to the west into the neighbouring Grand River Conservation Authority (Figure 3.19).

3.6.5 Recharge Areas

Potential groundwater recharge areas have been historically delineated where the regional groundwater table is below the ground surface, and sand and gravel are mapped at surface (Figure 3.20). As part of the water availability studies (Section 3.9) for the Tier 1 WB, values of groundwater recharge were determined through modelling for individual catchments (Figure 3.21).

3.6.6 Groundwater Discharge

Discharge areas are typically located where the water table meets the ground surface (Figure 3.22). Discharge areas tend to be situated in wetlands, and low lying areas such as valleys, and at the base of the Niagara Escarpment. Other discharge areas include the base of the Fonthill Kame-Delta Complex, part of the Twelve Mile Creek headwaters, and the area south of Pelham where the sands of the Fonthill Kame-Delta Complex meet the Welland River. Artesian (or flowing) wells are reported in the St Davids area near the base of the Niagara Escarpment, south of the Onondaga Escarpment, and northwest of Fonthill (and the Kame-Delta's highpoint) (WHI, 2005).

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3.7 Interactions between Groundwater and Surface Water

The near-surface soils of the Haldimand Clay Plain limit the interactions between surface water and groundwater in much of the NPSP Area. However interactions between surface water and groundwater does occur in areas such as the Niagara Escarpment (particularly in karst locations), along the escarpment face as diffuse seeps, and as discharge to numerous creeks and streams originating at the foot of the escarpment (both seasonal and perennial). Significant groundwater discharge, on a local scale, occurs where various streams and creeks cut into more permeable overburden and fractured shallow bedrock. Twelve Mile Creek is a significant coldwater stream being fed primarily by the Fonthill Kame-Delta Complex. Groundwater discharge is also known to occur in large quantities in the vicinity of the St. David's Buried Gorge.

A seasonally wet source of groundwater discharge can be lateral groundwater flow and discharge to low lying depressions through the shallow fractured clay, (i.e. slough ponds). An example of this is the Red Maple Swamp in the Chippawa Creek Conservation Area on the Haldimand Clay Plain.

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3.8 Tier 1 Water Budget and Stress Assessment Summary

The Tier 1 Water Budget and Stress Assessment is a structured means of evaluating the degree of potential water quantity stress throughout an area by comparing the volume of water demand to that which is practically available for use.

The Stress Assessment for average conditions (Rule 33) was completed using a set of water budget tools. To simulate surface water flows and partitioning of precipitation, continuous hydrologic modelling was employed using the HEC-HMS models constructed for each watershed planning area. To simulate groundwater flows, a Darcy flow approach across watershed planning area boundaries was developed. This volumetric flow is intended to represent average groundwater flow conditions. Together these modelling tools provide a physical means of quantifying surface water and groundwater flows through the system for use in the stress assessment calculations.

To complete the stress assessment, efforts were undertaken to quantify and characterize the consumptive water demand throughout the study area. The water demand characterization completed in this study included efforts to verify permit-to-take-water (PTTW) information, gathering limited "actual use" data, estimating agricultural demand based on detailed agricultural statistics, calculating private well use from detailed population statistics and a limited gathering of relevant information contained within Ministry of the Environment PTTW files. The improved understanding of water demand provides a reasonable characterization of the degree of stress throughout the study area. Since Niagara municipal water supplies come from Great Lakes sources they are not included as they cannot receive "stress levels".

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3.9 Water Supply and Reserve

Water Availability Studies (WAS) were completed for each subwatershed by analyzing the inflows and outflows using HEC-HMS (Hydrologic Engineering Centre-Hydrologic Modelling System) computer models. The HEC-HMS surface water models were run in continuous mode at hourly intervals and calibrated to stream gauges where available.

The purpose of the studies was to determine the availability for surface water flow, groundwater recharge and evapotranspiration on a monthly basis for the time period 1991-2005. This time period was chosen to best suit available datasets and meet the minimum World Meteorologic Organization climate normal criterion of 15 years. The WAS reports include information on the watershed characteristics (climate, topography, geology, physiology, land cover, soils, streamflow) watershed modelling, and results.

3.9.1 Water Balance

The average (1991-2005) water balance results of the HEC-HMS models are summarized per WSPA in Table 3.3. These results do not include flow diversion amounts which were incorporated under surface water supplies. The water balance terms are defined below:

- Precipitation – Environment Canada records used for precipitation.
- AET – Estimated actual evapotranspiration.
- Interflow – Half of infiltrated water, (except for select Fonthill Kame catchments); infiltrated water which moves laterally through the unsaturated soil horizon.
- Baseflow – Half of infiltrated water, (except for select Fonthill Kame catchments); generally a slow responding groundwater system consisting of water which recharges the saturated soil zone.
- Overland Runoff – Depth of water that does not infiltrate, and reaches the surface water system via overland runoff.
- Total Outflow – Total annual outflow from the catchment; is the sum of Baseflow, Interflow and Runoff.

Table 3.3 - Summary of Water Balance Model Results

WSPA ID	Precipitation (mm)	AET (mm)	Interflow (mm)	Baseflow (mm)	Runoff (mm)	Outflow (mm)
TWEN	**897**	**547**	**39**	**39**	**271**	**350**
UWR	**896**	**575**	**47**	**47**	**224**	**322**
CWR	**934**	**542**	**36**	**36**	**319**	**391**
BFC	**934**	**577**	**48**	**48**	**259**	**356**
BDSC	**887**	**523**	**29**	**29**	**305**	**364**
LENS	**967**	**520**	**51**	**51**	**343**	**446**
FEC	**1041**	**524**	**56**	**56**	**405**	**518**
TWEL	**891**	**446**	**26**	**53**	**363**	**442**
NOTL	**880**	**486**	**49**	**49**	**295**	**394**
LWR	**920**	**509**	**31**	**31**	**348**	**409**
SNF	**972**	**578**	**42**	**42**	**310**	**394**
FSEM	**900**	**564**	**41**	**77**	**218**	**336**
GRM	**923**	**514**	**54**	**54**	**304**	**411**
LIN	**884**	**455**	**64**	**64**	**302**	**430**
NFU	**912**	**395**	**20**	**20**	**475**	**516**
SCU	**890**	**211**	**8**	**8**	**663**	**678**
Overall NPCA	922	531	43	46	301	390
TWEL - Upper	**900**	**592**	**30**	**105**	**172**	**307**

Note: Precipitation may not exactly equal AET+Interflow+Baseflow+Runoff due to rounding errors within HEC-HMS, however they are <0.1% of precipitation

The highest precipitation was in FEC and SNF with the lowest amounts on a number of Lake Ontario catchments in LIN, FSEM and NOTL. Catchments of extremely low AET largely correspond with urban areas, e.g. Welland, Niagara Falls and St.Catharines. Catchments of high AET correlate well to agriculture, wetland and forest land cover. The AET per WSPA results range between 446 and 592 mm/year. The range of AET as a percent of precipitation is from 50 to 70%. Infiltration rates (interflow plus baseflow/recharge) correlate well to typical MOE infiltration rates (1995). The lowest percentage runoff (<20%) correlates well with catchments on the Fonthill Kame-Delta Complex and the highest percentage runoff with urban areas. Most of the NPSP Area is mapped as between 20 to 40 % of precipitation as runoff.

3.9.2 Surface Water Supply

The monthly median and 90th percentile flows were estimated for each WSPA subwatershed (Table 3.4) from the results of the HEC-HMS modelling. These flow estimates include the direct overland runoff calculated from the upstream drainage areas, and the interflow and baseflow components. Monthly median flows are prescribed by the Technical Rules (2009) as the surface water supply for the stress assessment.

The lowest monthly median surface water supply generally corresponded to September or August. The median and 90th percentile flows presented do not include any water added from any of the NOTL municipal diversions, as these are added as part of the PTTW demands.

3.9.3 Groundwater Supply

The groundwater supply was estimated from a sum of groundwater recharge and lateral groundwater flow into a subwatershed (Table 3.5). HEC-HMS results were used to estimate groundwater recharge and lateral groundwater flow was calculated as a flux estimate from groundwater level maps.

The groundwater supply is comprised of 57% recharge from precipitation, 26% shallow groundwater and 17% deep groundwater. At the Tier 1 WB level, all groundwater sources are grouped together, e.g. include overburden and bedrock systems. Aquifer storage was not considered as part of the Tier 1 WB. Also at the Tier 1 WB level no distinction is made for recharge that supplies a specific aquifer unit, and this may result in stress levels being under-estimated for confined aquifers, e.g. contact-zone aquifer below the Haldimand Clay Plain.

TABLE 3.4
SURFACE WATER SUPPLY AND RESERVE
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			(m^3/s)											
BDSC	Beaverdams and Shriners Creeks	Supply	0.25	0.35	0.73	0.46	0.19	0.07	0.04	**0.03**	**0.03**	0.06	0.24	0.27
		Reserve	0.08	0.11	0.15	0.1	0.03	0	0	0	0	0	0.01	0.05
		Difference	0.17	0.24	0.58	0.36	0.16	0.07	0.04	0.03	0.03	0.06	0.23	0.22
BFC	Big Forks Creek	Supply	0.72	0.94	1.68	1.01	0.35	0.12	0.06	0.04	**0.02**	0.05	0.31	0.83
		Reserve	0.25	0.34	0.52	0.33	0.12	0.04	0.01	0	0	0	0.01	0.11
		Difference	0.47	0.60	1.16	0.68	0.23	0.08	0.05	0.04	0.02	0.05	0.30	0.72
CWR	Central Welland River	Supply	4.26	5.52	11.16	8.41	2.48	0.93	0.52	0.43	**0.26**	0.59	2.00	4.65
		Reserve	0.90	1.86	3.35	2.36	0.75	0.21	0.14	0.08	0.05	0.06	0.17	0.43
		Difference	3.36	3.66	7.81	6.05	1.73	0.72	0.38	0.35	0.21	0.53	1.83	4.22
FEC	Fort Erie Creeks	Supply	0.94	1.3	2.58	1.17	0.46	0.21	0.13	**0.07**	0.1	0.23	0.98	1.45
		Reserve	0.38	0.41	0.71	0.35	0.08	0.01	0	0	0	0	0.11	0.50
		Difference	0.56	0.89	1.87	0.82	0.38	0.20	0.13	0.07	0.10	0.23	0.87	0.95
FSEM	Fifteen, Sixteen, Eighteen Mile Creeks	Supply	0.76	0.792	1.389	1.348	0.51	0.188	0.067	**0.034**	0.041	0.065	0.254	0.565
		Reserve	0.105	0.244	0.424	0.352	0.119	0.011	0.002	0	0	0	0.001	0.064
		Difference	0.66	0.55	0.97	1.00	0.39	0.18	0.07	0.03	0.04	0.07	0.25	0.50
GR	Grimsby	Supply	0.493	0.585	0.841	0.598	0.166	0.065	0.015	**0.004**	0.006	0.025	0.159	0.339
		Reserve	0.065	0.208	0.281	0.161	0.036	0.003	0	0	0	0	0.005	0.032
		Difference	0.43	0.38	0.56	0.44	0.13	0.06	0.02	0.00	0.01	0.03	0.15	0.31
LENS	Lake Erie North Shore	Supply	0.69	0.87	1.35	0.71	0.26	0.09	0.04	0.04	**0.03**	0.11	0.56	0.82
		Reserve	0.27	0.28	0.43	0.21	0.05	0.01	0	0	0	0	0.05	0.22
		Difference	0.42	0.59	0.92	0.50	0.21	0.08	0.04	0.04	0.03	0.11	0.51	0.60
LIN	Lincoln	Supply	0.614	0.772	1.127	0.897	0.269	0.128	0.028	**0.011**	0.018	0.051	0.278	0.476
		Reserve	0.146	0.239	0.371	0.232	0.061	0.005	0.001	0	0	0	0.008	0.097
		Difference	0.47	0.53	0.76	0.67	0.21	0.12	0.03	0.01	0.02	0.05	0.27	0.38
LWR	Lower Welland River	Supply	23.78	24.96	30.92	28.34	21.8	20.28	19.83	19.67	**19.56**	19.83	21.27	23.9
		Reserve	20.11	21.16	22.61	21.78	20.09	19.5	19.43	19.37	19.33	19.35	19.46	19.61
		Difference	3.67	3.80	8.31	6.56	1.71	0.78	0.40	0.30	0.23	0.48	1.81	4.29
NOTL	Niagara-on-the-Lake	Supply	0.631	0.777	1.477	1.047	0.431	0.191	0.092	**0.026**	0.042	0.094	0.416	0.617
		Reserve	0.164	0.259	0.446	0.372	0.141	0.028	0.008	0.001	0	0	0.003	0.10
		Difference	0.47	0.52	1.03	0.68	0.29	0.16	0.08	0.03	0.04	0.09	0.41	0.52

TABLE 3.4
SURFACE WATER SUPPLY AND RESERVE
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			(m³/s)											
SNF	South Niagara Falls	Supply	0.73	0.91	1.64	1.04	0.57	0.39	0.34	**0.32**	**0.32**	0.34	0.61	0.82
		Reserve	0.34	0.41	0.47	0.50	0.34	0.30	0.29	0.29	0.29	0.29	0.30	0.24
		Difference	0.39	0.50	1.17	0.54	0.23	0.09	0.05	0.03	0.03	0.05	0.31	0.58
TWEL	Twelve Mile Creek	Supply	214	206	240	245	237	237	236	232	234	228	**205**	225
		Reserve	163	164	195	182	218	179	219	126	125	125	163	146
		Difference	51	42	45	63	19	58	17	106	109	103	42	79
UTWEL	Upper Twelve	Supply	0.359	0.411	0.585	0.637	0.472	0.312	0.221	0.165	0.138	**0.122**	0.167	0.268
		Reserve	0.108	0.16	0.327	0.338	0.244	0.187	0.151	0.12	0.109	0.1	0.098	0.099
		Difference	0.25	0.25	0.26	0.30	0.23	0.13	0.07	0.05	0.03	0.02	0.07	0.17
TWEN	Twenty Mile Creek	Supply	1.87	2.17	4.15	1.28	0.47	0.24	0.14	0.11	**0.07**	0.17	0.61	1.67
		Reserve	0.35	0.57	0.77	0.38	0.09	0.01	0	0	0	0	0.03	0.15
		Difference	1.52	1.60	3.38	0.90	0.38	0.23	0.14	0.11	0.07	0.17	0.58	1.52
UWR	Upper Welland River	Supply	1.97	2.58	5.55	4.43	1.11	0.30	0.21	0.17	**0.11**	0.18	0.50	1.82
		Reserve	0.08	0.76	1.56	1.28	0.35	0.16	0.1	0.07	0.04	0.05	0.06	0.06
		Difference	1.89	1.82	3.99	3.15	0.76	0.14	0.11	0.10	0.07	0.13	0.44	1.76
NFU	Niagara Falls Urban	Supply	0.137	0.174	0.438	0.395	0.237	0.187	0.132	**0.065**	0.106	0.121	0.291	0.31
		Reserve	0.053	0.037	0.066	0.065	0.053	0.009	0.003	0	0	0.002	0.014	0.074
		Difference	0.08	0.14	0.37	0.33	0.18	0.18	0.13	0.07	0.11	0.12	0.28	0.24
SCU	St. Catharines Urban	Supply	0.046	0.086	0.218	0.149	0.051	0.036	0.008	**0.004**	0.01	0.029	0.105	0.098
		Reserve	0.022	0.032	0.020	0.013	0.004	0.001	0.001	0.000	0.000	0.002	0.004	0.013
		Difference	0.02	0.05	0.20	0.14	0.05	0.04	0.01	0.00	0.01	0.03	0.10	0.09

Note: Bolded/shaded value corresponds to the lowest monthly median

TABLE 3.5
GROUNDWATER SUPPLY RESULTS
NPSPA ASSESSMENT REPORT

WSPA	Name	Area (km^2)	Q_R Annual Recharge (mm/yr)[A]	Q_{IN} WT (m^3/yr)	Q_{IN} WT (mm/yr)	Q_{IN} PS (m^3/yr)	Q_{IN} PS (mm/yr)	Q_{SUPPLY} Groundwater (m^3/yr)	Q_{SUPPLY} Groundwater (mm/year)	$Q_{RESERVE}$ Groundwater (mm/year)
BDSC	Beaverdams and Shriners Creeks	75.8	29	3,232,248	43	1,164,387	15	6,593,838	87	8.7
BFC	Big Forks Creek	167.2	48	1,327,376	8	1,123,796	7	10,477,914	63	6.3
CWR	Central Welland River	296.4	36	7,664,442	26	5,469,172	18	23,804,599	80	8.0
FEC	Fort Erie	182.6	56	885,059	5	248,382	1	11,357,976	62	6.2
FSEM	Fifteen, Sixteen, Eighteen Mile Creeks	134.1	77	2,159,770	16	2,310,055	17	14,792,574	110	11.0
GR	Grimsby	78.4	54	2,595,627	33	1,295,711	17	8,124,153	104	10.4
LENS	Lake Erie North Shore	118.1	51	2,184,358	19	1,684,317	14	9,889,438	84	8.4
LIN	Lincoln	82.0	64	5,267,628	64	2,385,929	29	12,899,666	157	15.7
LWR	Lower Welland River	35.4	31	1,821,004	52	966,363	27	3,883,438	110	11.0
NOTL	Niagara-on-the-Lake	136.7	49	2,913,902	21	2,657,922	19	12,271,302	90	9.0
SNF	South Niagara Falls	136.5	42	1,162,933	9	591,761	4	7,487,673	55	5.5
TWEL	Twelve Mile Creek	131.6	53	3,763,765	29	3,445,982	26	14,200,197	108	10.8
UTWEL	Upper Twelve Mile	47.3	105	3,214,505	68	3,690,465	78	11,871,390	251	25.1
TWEN	Twenty Mile Creek	303.6	39	5,031,788	17	2,677,493	9	19,549,407	64	6.4
UWR	Upper Welland River	478.0	47	10,703,493	22	6,309,025	13	39,478,230	83	8.3
NFU	Niagara Falls Urban	48.2	20	786,697	16	2,222,640	46	3,972,836	82	8.2
SCU	St. Catharines Urban	21.3	8	1,099,130	52	264,329	12	1,534,187	72	7.2

Table Notes:
WSPA - Watershed Planning Area
A - Results from Water Availability Studies (AquaResource Inc., NPCA, 2009)
WT - Water Table (well depths <15 metres below ground surface, Waterloo Hydrogeologic, 2005)
PS - Potentiometric Surface (well depths >15 metres below ground surface, Waterloo Hydrogeologic, 2005)
GW Supply - Sum of Annual Recharge, PS GW In and WT GW In

3.9.4 Water Reserve

Water reserve is the proportion of water that must be sustained to support human, or ecological requirements, (e.g. dilution of sewage treatment plant discharge, or sustaining discharge flows to sensitive fish habitat, respectively). The monthly surface water reserve was calculated as the 90^{th} percentile from the continuous surface water model. This is the streamflow rate that is exceeded 90% of the time on a flow duration curve. The groundwater reserve was calculated as 10% of the estimated annual groundwater supply. Groundwater supply is a combination of the (i) groundwater recharge from the continuous surface water model and (ii) the groundwater in-flux from the Darcy flow analysis.

3.10 Water Demand

Water demand, or takings, refers to water taken as a result of human activity, e.g. private water well. Five water demands were considered: permits to take water (PTTW), livestock watering, crop irrigation not requiring a PTTW, non-irrigation crop water use (e.g. crop spraying, cooling, equipment washing, etc.) and private water wells.

Assessment of water demand is evaluated separately for groundwater and surface water sources in a Tier 1 WB.

Surface water sources are split between Great Lakes sources and in-land surface water sources. In-land surface water sources, e.g. intake on Four Mile Creek, are consumptive uses, while Great Lakes diversions are considered additions to the surface water system where known, e.g. NOTL municipal irrigation system.

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3.10.1 Water Takings that Require a Permit

A large proportion of water demand can be estimated using the Ministry of the Environment (MOE) Permit to Take Water (PTTW) database. The database tracks and regulates surface and groundwater takings that exceed 50,000 L/day. The most recent PTTW database from the MOE is current to March 31, 2008. The database provides detailed information for each permit such as expiry date, specific purpose, taking type, etc. Figure 3.23 represents the consumptive permits to take water and their sources.

In the NPSP Area, the Tier 1 WB considered 192 PTTW coming from 317 sources, of which 137 are groundwater and 180 are surface water sources (Appendix A-6). The most common PTTWs are for agriculture (50) and golf courses (34). However, 47 PTTW were excluded based upon their taking type and source or because their net contribution is outside the scope of a Tier 1 Water Budget (MOE, 2007). The excluded PTTW were for:

- Great Lakes takings for municipal or communal drinking water systems;
- Great Lakes takings for cooling water and hydroelectric facilities;
- Wetland creation;

- Weirs; and
- Sources not in use (e.g. Fonthill municipal groundwater wells).

The MOE did not provide actual takings amounts. Actual takings amounts were obtained directly from some large PTTW holders, otherwise the maximum taking rates and durations were used for demand calculations.

3.10.2 Water Takings that Do not Require a Permit

The MOEs PTTW program has been in place since the early 1960s. The MOE requires that any person taking more than 50,000 L/day into storage on any given day in a year is required to hold an active PTTW. Exceptions are granted for domestic water use, livestock watering and water taken for firefighting purposes.

Three types of demands that were not captured under the PTTW program but were estimated for the Tier 1 WB included (i) livestock watering, (ii) crop demands not covered under the PTTW program and (iii) private water well use.

3.10.2.1 De Loe Methodology

Livestock demands, and crop demands not covered under the PTTW program, were estimated using Agricultural Census data from 2006 and the de Loe methodology (de Loe, 2001 and 2005). Where crop demands, per subwatershed, exceeded the PTTW amount, these were applied as additional demands and split between groundwater and surface water according to the ratio of existing PTTWs. Livestock demands were split evenly between groundwater and surface water.

Livestock watering was calculated based upon 23 Statistics Canada categories, e.g. turkeys. The greatest livestock demands were identified for the two largest WSPAs, Upper Welland River and Twenty Mile Creek (Figure 3.24).

The greatest crop water demands were identified in Niagara-on-the-Lake, Lincoln, and Fifteen-Sixteen and Eighteen Mile WSPAs at 2.8, 1.7 and 1.6 million m^3/year (Figure 3.25). In the NPSP Area the majority of the demand in 2006 was primarily for greenhouse flowers followed closely by peaches. The de Loe demands were used to account for agricultural water use where there were no agricultural water use PTTWs.

3.10.2.2 Private Wells

It is estimated that in 2006 over 77,000 thousand persons obtained their water supplies from a well or cistern in the NPSP Area (NPCA and AquaResource Inc., 2009b). This is a decrease from over 88,000 persons in 1991. Based upon a rate of 275 L/day/person and the Ministry of Natural Resources required consumptive factor of 0.2, this totaled 4,281 m^3/day in 2006.

The number of cisterns versus wells is not known, however the NPCA Groundwater study estimated most of the rural population uses private wells for domestic water use (WHI, 2005). It is expected that rural residents in areas known for naturally occurring poor groundwater quality are however likely using cisterns, e.g. Salina Formation bedrock in Haldimand County. Municipal water is the usual source for cistern supply (MacViro et al, 2003b).

As part of the Tier 1 WB, the privately serviced population was determined for each of the WSPAs (Table 3.6). The subwatershed with the largest privately serviced population was Upper Welland River (UWR) WSPA with 11,251 'rural' serviced persons.

Table 3.6: NPSP Area Private/Rural Water Supplies (2006)

WSPA	BDSC	BFC	CWR	FEC	FSEM	GR	LENS	LIN
Population	27,194	3,950	62,288	26,898	8,521	14,091	22,979	27,440
'Rural' Serviced/%	210 1%	3,950 100%	8,430 14%	5,722* 21%	5,200 61%	3,955 28%	5,106 22%	7,890 29%
WSPA	**LWR**	**NOTL**	**SNF**	**TWEL**	**TWEN**	**UWR**	**NFU**	**SCU**
Population	3,971	14,874	6,513	92,377	26,776	12,391	51,976	51,245
'Rural' Serviced/%	819 21%	7,445* 50%	3,776 58%	3,169 3%	10,589 40%	11,251 91%	317 0.6%	0 0%

Note: * - Possible over-estimates due to local municipal distribution systems

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3.10.3 Consumptive Water Use

Withdrawal of water differs from consumption. For example, an aggregate resources operator may be permitted to pump water from a pond for aggregate washing, and the permitted pump rate may be very high. However, the operator may be returning all wash water to the same pond, resulting in very little consumptive water demand.

Consumptive water use has been calculated for all water withdrawals using consumptive factors generally provided by the province. Consumptive factors include fully consumptive (e.g. factor of 1 for food processing) to fairly low consumption (e.g. pit and quarry dewatering 0.008).

An amount of water available as additional surface water supply from Great Lakes sources was calculated, based upon the non-consumptive portion of the reported taking.

3.11 Surface Water Demands

Surface water demand (Table 3.7 and Figure 3.26) includes three types of water use:

1. PTTW takings from in-land water sources not related to agricultural use;
2. Takings from in-land water sources to meet crop demands (includes agricultural PTTW where present); and
3. Takings from in-land water sources to meet livestock demands.

The largest in-land surface water demand per WSPA was TWEN at 2.4 million m^3/year. The TWEN surface water demands were mostly for crops (58%), as well as some non-agricultural PTTW (34%) and livestock (8%). WSPA surface water demands were generally dominated by crop demands (over 75% of total surface water demand for BFC, FSEM, GR, LIN and NOTL) or non-agricultural PTTW (over 70% of total surface water demand for BDSC, CWR, FEC, LENS, LWR, SNF and TWEL WSPAs) primarily for golf courses.

Additions to surface water systems from Great Lakes sources and groundwater dewatering will be included as additional supply amounts in the stress assessment.

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3.12 Groundwater Demands

Groundwater demands (Table 3.7 and Figures 3.27 and 3.28) considered four types of water use:

1. PTTW takings from groundwater sources not related to agricultural use;
2. Takings from groundwater sources to meet crop demands (includes agricultural PTTW where present);
3. Takings groundwater sources to meet livestock demands; and
4. Private well demands.

The largest annual groundwater demand per WSPA was LENS at 5.1 million m^3/year. The LENS groundwater demands were mostly for non-agricultural PTTW (97%) related to aggregate production. WSPA groundwater crop demands were the dominant groundwater taking for BFC, CWR, FSEM, GR, LWR, TWEL and UWR, at over 44%. While non-agricultural PTTW demands were the dominant taking, at over 37% for BDSC, FEC, FSEM, LENS, NOTL, SNF and TWEN. The dominant groundwater non-agricultural takings varied from aggregates to golf courses to groundwater remediation. August was commonly the highest demand month per WSPA (Table 3.6) and is shown on Figure 3.28.

Private well demand as a percentage of total groundwater demand, for most WSPAs was between 20 and 32 % (BFC, CWR, GR, LWR, NOTL, SNF, TWEN and UWR).

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TABLE 3.7
WSPA WATER COMPONENTS (m^3)
TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

IN-LAND SURFACE WATER TAKINGS

WSPA	Name	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BDSC	Beaverdams and Shriners Creeks	non-Ag PTTW	0	5,645	34,998	33,869	120,279	116,399	120,279	120,279	116,399	120,279	33,869	18,063
		Crops	4,854	4,854	4,854	4,854	4,854	4,854	7,076	7,076	4,854	4,854	4,854	4,854
		Livestock	317	317	317	317	317	317	317	317	317	317	317	317
		TOTAL	5,170	10,815	40,168	39,039	125,449	121,569	127,671	127,671	121,569	125,449	39,039	23,234
BFC	Big Forks Creek	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	0	0	0	0	38,205	101,453	106,683	106,683	76,410	38,205	0	0
		Livestock	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364
		TOTAL	5,364	5,364	5,364	5,364	43,569	106,817	112,047	112,047	81,774	43,569	5,364	5,364
CWR	Central Welland River	non-Ag PTTW	0	0	0	6,720	74,168	128,331	132,609	132,609	128,331	74,168	6,720	0
		Crops	1,361	1,361	6,101	7,544	8,981	8,775	24,454	33,736	7,544	7,750	7,544	1,979
		Livestock	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542
		TOTAL	11,903	11,903	16,644	24,806	93,692	147,649	167,605	176,887	146,417	92,460	24,806	12,522
FEC	Fort Erie Creeks	non-Ag PTTW	0	0	0	0	69,245	67,011	69,245	69,245	67,011	69,245	0	0
		Crops	733	733	733	733	1,100	1,100	3,638	3,638	733	733	733	733
		Livestock	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541
		TOTAL	2,274	2,274	2,274	2,274	71,885	69,651	74,423	74,423	69,285	71,518	2,274	2,274
FSEM	Fifteen, Sixteen, Eighteen Mile Creeks	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	14,706	15,235	15,500	16,355	25,496	29,926	64,541	152,204	23,388	22,033	16,355	15,500
		Livestock	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093
		TOTAL	24,800	25,329	25,594	26,449	35,589	40,019	74,634	162,298	33,481	32,127	26,449	25,594
GR	Grimsby	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	10,250	10,250	10,250	10,250	11,984	11,984	14,447	14,447	10,250	10,250	10,250	10,250
		Livestock	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270
		TOTAL	12,520	12,520	12,520	12,520	14,253	14,253	16,716	16,716	12,520	12,520	12,520	12,520
LENS	Lake Erie North Shore	non-Ag PTTW	69,354	59,344	65,860	77,102	47,427	20,509	2,436	5,044	14,062	21,642	43,466	58,785
		Crops	1,633	1,633	1,633	1,633	1,902	1,902	15,397	15,397	1,633	1,633	1,633	1,633
		Livestock	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072
		TOTAL	72,060	62,049	68,565	79,807	50,400	23,482	18,905	21,513	16,768	24,347	46,171	61,490
LIN	Lincoln	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	5,262	5,262	5,262	5,262	7,297	7,297	47,738	96,988	5,262	5,262	5,262	5,262
		Livestock	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887
		TOTAL	7,149	7,149	7,149	7,149	9,184	9,184	49,625	98,875	7,149	7,149	7,149	7,149
LWR	Lower Welland River	non-Ag PTTW	58,323	79,462	94,897	133,413	137,860	133,413	152,821	153,853	133,413	137,860	107,328	90,294
		Crops	1,079	1,079	1,079	1,079	1,295	1,295	25,421	25,421	1,079	1,079	1,079	1,079
		Livestock	210	210	210	210	210	210	210	210	210	210	210	210
		TOTAL	59,613	80,752	96,186	134,702	139,366	134,919	178,452	179,484	134,702	139,149	108,618	91,583

WSPA	Units	Annual
BDSC	non-Ag PTTW	840,356
	Crops	62,689
	Livestock	3,798
	SUM	906,844
BFC	non-Ag PTTW	0
	Crops	467,640
	Livestock	64,365
	SUM	532,005
CWR	non-Ag PTTW	683,655
	Crops	117,131
	Livestock	126,509
	SUM	927,296
FEC	non-Ag PTTW	411,001
	Crops	15,339
	Livestock	18,486
	SUM	444,826
FSEM	non-Ag PTTW	0
	Crops	411,240
	Livestock	121,121
	SUM	532,361
GR	non-Ag PTTW	0
	Crops	134,860
	Livestock	27,238
	SUM	162,097
LENS	non-Ag PTTW	485,030
	Crops	47,665
	Livestock	12,861
	SUM	545,556
LIN	non-Ag PTTW	0
	Crops	201,418
	Livestock	22,644
	SUM	224,062
LWR	non-Ag PTTW	1,412,938
	Crops	62,067
	Livestock	2,522
	SUM	1,477,527

TABLE 3.7
WSPA WATER COMPONENTS (m^3)
TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

IN-LAND SURFACE WATER TAKINGS (continued)

WSPA	Name	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NOTL	Niagara-on-the-Lake	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	0	0	0	0	44,751	213,496	253,455	287,981	104,063	29,333	0	0
		Livestock	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169
		TOTAL	2,169	2,169	2,169	2,169	46,919	215,665	255,624	290,150	106,231	31,501	2,169	2,169
SNF	South Niagara Falls	non-Ag PTTW	0	0	15,858	48,771	50,397	48,771	50,397	50,397	48,771	50,397	32,115	0
		Crops	567	567	567	567	945	945	3,711	3,711	567	567	567	567
		Livestock	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343
		TOTAL	1,911	1,911	17,769	50,681	52,685	51,059	55,451	55,451	50,681	52,307	34,026	1,911
TWEL	Twelve Mile Creek	non-Ag PTTW	0	0	11,673	54,617	58,147	57,392	59,305	59,305	57,392	58,147	29,879	0
		Crops	1,063	1,063	1,063	1,063	1,063	1,063	58,003	63,223	1,063	1,063	1,063	1,063
		Livestock	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073
		TOTAL	2,136	2,136	13,809	56,752	60,282	59,527	118,380	123,600	59,527	60,282	32,014	2,136
UTWEL	Upper Twelve	non-Ag PTTW	0	0	0	0	408	720	744	744	720	408	0	0
		Crops	0	0	0	0	0	0	0	0	0	0	0	0
		Livestock	676	676	676	676	676	676	676	676	676	676	676	676
		TOTAL	676	676	676	676	1,084	1,396	1,420	1,420	1,396	1,084	676	676
TWEN	Twenty Mile Creek	non-Ag PTTW	0	9,778	82,195	87,087	89,990	87,087	89,990	89,990	87,087	89,990	84,336	36,666
		Crops	0	0	0	0	134,593	264,773	290,654	330,690	264,773	134,593	0	0
		Livestock	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670
		TOTAL	15,670	25,448	97,866	102,757	240,253	367,530	396,314	436,350	367,530	240,253	100,006	52,336
UWR	Upper Welland River	non-Ag PTTW	14,520	18,480	20,460	20,063	31,165	42,003	43,403	43,403	42,003	31,165	20,063	20,460
		Crops	2,384	2,384	2,384	2,384	2,384	15,641	26,822	26,822	11,222	2,384	2,384	0
		Livestock	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443
		TOTAL	32,347	36,307	38,287	37,889	48,991	73,087	85,668	85,668	68,668	48,991	37,889	35,903
NFU	Niagara Falls Urban	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	69	69	69	69	83	83	1,623	1,623	69	69	69	69
		Livestock	13	13	13	13	13	13	13	13	13	13	13	13
		TOTAL	82	82	82	82	96	96	1,636	1,636	82	82	82	82
SCU	St. Catharines Urban	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	0	0	0	0	0	0	0	0	0	0	0	0
		Livestock	0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL	0	0	0	0	0	0	0	0	0	0	0	0

WSPA	Units	Annual
NOTL	non-Ag PTTW	0
	Crops	933,079
	Livestock	26,023
	SUM	959,103
SNF	non-Ag PTTW	395,872
	Crops	13,849
	Livestock	16,121
	SUM	425,842
TWEL	non-Ag PTTW	445,856
	Crops	131,853
	Livestock	12,874
	SUM	590,583
UTWEL	non-Ag PTTW	3,744
	Crops	0
	Livestock	8,111
	SUM	11,855
TWEN	non-Ag PTTW	834,196
	Crops	1,420,075
	Livestock	188,044
	SUM	2,442,314
UWR	non-Ag PTTW	347,188
	Crops	97,197
	Livestock	185,310
	SUM	629,695
NFU	non-Ag PTTW	0
	Crops	3,962
	Livestock	161
	SUM	4,123
SCU	non-Ag PTTW	0
	Crops	0
	Livestock	0
	SUM	0

TABLE 3.7
WSPA WATER COMPONENTS (m^3)
TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

GROUNDWATER TAKINGS

WSPA	Name	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BDSC	Beaverdams and Shriners Creeks	non-Ag PTTW	7,475	13,574	33,835	33,851	42,720	37,588	38,771	38,781	37,808	37,938	20,311	11,831
		Crops	4,854	4,854	4,854	4,854	4,854	4,854	7,076	7,076	4,854	4,854	4,854	4,854
		Livestock	317	317	317	317	317	317	317	317	317	317	317	317
		Private Wells	319	303	329	329	354	343	390	401	381	380	347	337
		TOTAL	12,964	19,048	39,335	39,350	48,244	43,101	46,554	46,575	43,359	43,488	25,828	17,337
BFC	Big Forks Creek	non-Ag PTTW	576	734	812	786	1,252	1,611	1,665	1,665	1,611	1,252	786	812
		Crops	0	0	0	0	8,258	33,035	78,195	112,563	7,992	8,258	0	0
		Livestock	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364	5,364
		Private Wells	5,994	5,708	6,196	6,192	6,667	6,452	7,341	7,543	7,169	7,139	6,518	6,331
		TOTAL	11,934	11,805	12,372	12,341	21,542	46,462	92,564	127,134	22,136	22,013	12,667	12,507
CWR	Central Welland River	non-Ag PTTW	0	0	0	3,819	24,926	24,798	25,625	25,625	24,798	24,926	3,819	0
		Crops	4,083	4,083	4,083	4,083	47,395	46,117	71,858	90,979	42,423	43,701	4,083	4,083
		Livestock	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542	10,542
		Private Wells	12,792	12,181	13,223	13,214	14,229	13,770	15,667	16,098	15,300	15,236	13,910	13,511
		TOTAL	27,418	26,807	27,849	31,659	97,093	95,228	123,691	143,244	93,064	94,405	32,354	28,136
FEC	Fort Erie Creeks	non-Ag PTTW	12,332	15,678	27,631	111,704	165,649	168,355	173,791	173,739	167,967	139,022	39,264	17,230
		Crops	733	733	733	733	1,100	1,100	3,638	3,638	733	733	733	733
		Livestock	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541
		Private Wells	8,683	8,268	8,976	8,969	9,658	9,347	10,634	10,927	10,385	10,341	9,441	9,171
		TOTAL	23,289	26,220	38,880	122,947	177,948	180,342	189,604	189,844	180,626	151,636	50,978	28,674
FSEM	Fifteen, Sixteen, Eighteen Mile Creeks	non-Ag PTTW	4,024	4,521	5,006	4,844	50,597	103,954	117,121	117,444	103,954	50,597	4,844	5,006
		Crops	22,614	22,979	29,154	39,444	56,832	73,404	95,617	114,750	67,632	51,061	34,541	23,161
		Livestock	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093	10,093
		Private Wells	7,891	7,514	8,157	8,151	8,777	8,494	9,664	9,930	9,438	9,398	8,580	8,334
		TOTAL	44,622	45,107	52,410	62,533	126,300	195,945	232,495	252,217	191,117	121,149	58,059	46,594
GR	Grimsby	non-Ag PTTW	257	98	612	349	243	162	222	303	223	180	207	342
		Crops	10,250	10,250	10,250	10,250	11,984	11,984	14,447	14,447	10,250	10,250	10,250	10,250
		Livestock	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270	2,270
		Private Wells	6,002	5,715	6,204	6,199	6,676	6,460	7,350	7,552	7,178	7,148	6,526	6,339
		TOTAL	18,778	18,333	19,336	19,068	21,173	20,876	24,289	24,572	19,921	19,847	19,252	19,201
LENS	Lake Erie North Shore	non-Ag PTTW	527,321	509,235	468,574	588,103	569,693	336,659	298,577	331,695	363,064	305,251	298,812	290,099
		Crops	1,633	1,633	1,633	1,633	1,902	1,902	15,397	15,397	1,633	1,633	1,633	1,633
		Livestock	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072	1,072
		Private Wells	7,748	7,378	8,009	8,004	8,619	8,341	9,489	9,750	9,267	9,228	8,425	8,183
		TOTAL	537,775	519,318	479,288	598,811	581,285	347,973	324,535	357,915	375,037	317,184	309,942	300,987

WSPA	Units	Annual
BDSC	non-Ag PTTW	354,483
	Crops	62,689
	Livestock	3,798
	Private Wells	4,213
	SUM	425,184
BFC	non-Ag PTTW	13,562
	Crops	248,302
	Livestock	64,365
	Private Wells	79,249
	SUM	405,477
CWR	non-Ag PTTW	158,336
	Crops	366,971
	Livestock	126,509
	Private Wells	169,131
	SUM	820,947
FEC	non-Ag PTTW	1,212,362
	Crops	15,339
	Livestock	18,486
	Private Wells	114,801
	SUM	1,360,988
FSEM	non-Ag PTTW	571,910
	Crops	631,189
	Livestock	121,121
	Private Wells	104,328
	SUM	1,428,549
GR	non-Ag PTTW	3,199
	Crops	134,860
	Livestock	27,238
	Private Wells	79,349
	SUM	244,645
LENS	non-Ag PTTW	4,887,084
	Crops	47,665
	Livestock	12,861
	Private Wells	102,442
	SUM	5,050,052

TABLE 3.7
WSPA WATER COMPONENTS (m^3)
TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

GROUNDWATER TAKINGS (continued)

WSPA	Name	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
LIN	Lincoln	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	1,475	1,475	1,475	1,475	2,046	2,046	2,077	4,037	1,475	1,475	1,475	1,475
		Livestock	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887	1,887
		Private Wells	11,973	11,401	12,376	12,368	13,318	12,888	14,663	15,067	14,320	14,260	13,019	12,645
		TOTAL	15,335	14,763	15,739	15,730	17,251	16,821	18,628	20,991	17,683	17,622	16,381	16,008
LWR	Lower Welland River	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	1,079	1,079	1,079	1,079	1,295	1,295	25,421	25,421	1,079	1,079	1,079	1,079
		Livestock	210	210	210	210	210	210	210	210	210	210	210	210
		Private Wells	1,243	1,183	1,285	1,284	1,382	1,338	1,522	1,564	1,486	1,480	1,351	1,313
		TOTAL	2,532	2,473	2,574	2,573	2,888	2,843	27,153	27,195	2,776	2,770	2,641	2,602
NOTL	Niagara-on-the-Lake	non-Ag PTTW	10,031	12,766	14,134	13,678	42,849	44,611	46,098	46,098	44,611	42,849	13,678	14,134
		Crops	0	0	0	0	0	0	0	11,496	0	0	0	0
		Livestock	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169	2,169
		Private Wells	11,297	10,758	11,678	11,670	12,567	12,161	13,836	14,217	13,513	13,455	12,284	11,932
		TOTAL	23,497	25,693	27,981	27,517	57,585	58,941	62,103	73,980	60,292	58,473	28,131	28,235
SNF	South Niagara Falls	non-Ag PTTW	0	0	0	0	0	33,910	35,040	35,040	33,910	0	0	0
		Crops	567	567	567	567	945	945	3,711	3,711	567	567	567	567
		Livestock	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343	1,343
		Private Wells	5,730	5,456	5,923	5,919	6,374	6,168	7,018	7,211	6,853	6,824	6,230	6,052
		TOTAL	7,640	7,367	7,834	7,829	8,662	42,366	47,112	47,305	42,674	8,735	8,141	7,962
TWEL	Twelve Mile Creek	non-Ag PTTW	0	0	7,946	11,918	19,661	26,456	27,338	27,338	26,456	19,661	11,918	0
		Crops	4,251	4,251	25,236	61,483	63,391	61,483	66,362	66,362	61,483	63,391	44,314	4,251
		Livestock	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073	1,073
		Private Wells	4,809	4,579	4,971	4,967	5,349	5,177	5,889	6,052	5,752	5,727	5,229	5,079
		TOTAL	10,133	9,903	39,226	79,442	89,474	94,189	100,663	100,825	94,764	89,852	62,534	10,403
UTWEL	Upper Twelve	non-Ag PTTW	0	0	6,419	9,629	10,596	10,769	11,128	11,128	10,769	10,596	9,629	0
		Crops	2,657	2,657	23,642	59,889	61,797	59,889	66,084	66,084	59,889	61,797	42,720	2,657
		Livestock	676	676	676	676	676	676	676	676	676	676	676	676
		Private Wells	3,126	2,976	3,231	3,229	3,477	3,365	3,828	3,933	3,739	3,723	3,399	3,301
		TOTAL	6,459	6,309	33,968	73,423	76,546	74,699	81,716	81,822	75,073	76,792	56,423	6,634
TWEN	Twenty Mile Creek	non-Ag PTTW	11,731	12,307	15,671	18,158	12,428	34,375	40,167	47,180	18,243	12,022	11,211	16,221
		Crops	1,080	1,375	1,522	1,473	1,522	3,633	5,242	5,242	1,473	1,522	1,473	1,522
		Livestock	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670	15,670
		Private Wells	16,068	15,301	16,610	16,598	17,874	17,297	19,679	20,221	19,219	19,137	17,472	16,971
		TOTAL	44,549	44,653	49,473	51,899	47,494	70,976	80,759	88,314	54,605	48,351	45,826	50,384

WSPA	Units	Annual
LIN	non-Ag PTTW	0
	Crops	22,010
	Livestock	22,644
	Private Wells	158,297
	SUM	202,951
LWR	non-Ag PTTW	0
	Crops	62,067
	Livestock	2,522
	Private Wells	16,432
	SUM	81,021
NOTL	non-Ag PTTW	345,538
	Crops	11,496
	Livestock	26,023
	Private Wells	149,369
	SUM	532,427
SNF	non-Ag PTTW	137,899
	Crops	13,849
	Livestock	16,121
	Private Wells	75,758
	SUM	243,627
TWEL	non-Ag PTTW	178,692
	Crops	526,260
	Livestock	12,874
	Private Wells	63,580
	SUM	781,406
UTWEL	non-Ag PTTW	90,662
	Crops	509,763
	Livestock	8,111
	Private Wells	41,327
	SUM	649,863
TWEN	non-Ag PTTW	249,713
	Crops	27,080
	Livestock	188,044
	Private Wells	212,448
	SUM	677,284

TABLE 3.7
WSPA WATER COMPONENTS (m^3)
TIER 1 WATER BUDGET AND WATER QUANTITY STRESS ASSESSMENT

GROUNDWATER TAKINGS (continued)

WSPA	Name	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
UWR	Upper Welland River	non-Ag PTTW	0	0	0	106	19,766	22,929	23,693	23,693	22,929	19,766	106	0
		Crops	25,501	29,281	31,171	30,541	31,171	30,784	53,525	84,224	30,703	31,171	30,541	19,530
		Livestock	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443	15,443
		Private Wells	17,073	16,258	17,648	17,636	18,991	18,379	20,909	21,485	20,421	20,334	18,564	18,032
		TOTAL	58,016	60,981	64,262	63,725	85,370	87,534	113,570	144,845	89,495	86,713	64,653	53,004
NFU	Niagara Falls Urban	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	69	69	69	69	83	83	1,623	1,623	69	69	69	69
		Livestock	13	13	13	13	13	13	13	13	13	13	13	13
		Private Wells	481	458	497	497	535	518	589	605	575	573	523	508
		TOTAL	563	540	580	579	631	614	2,225	2,241	658	655	605	590
SCU	St. Catharines Urban	non-Ag PTTW	0	0	0	0	0	0	0	0	0	0	0	0
		Crops	0	0	0	0	0	0	0	0	0	0	0	0
		Livestock	0	0	0	0	0	0	0	0	0	0	0	0
		Private Wells	0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL	0	0	0	0	0	0	0	0	0	0	0	0

WSPA	Units	Annual
UWR	non-Ag PTTW	132,987
	Crops	428,142
	Livestock	185,310
	Private Wells	225,729
	SUM	972,169
NFU	non-Ag PTTW	0
	Crops	3,962
	Livestock	161
	Private Wells	6,360
	SUM	10,483
SCU	non-Ag PTTW	0
	Crops	0
	Livestock	0
	Private Wells	0
	SUM	0

3.13 Trends

During the Tier 1 Water Budget and Water Quantity Stress Assessment, several trends in surface and groundwater demand became evident. Using Statistics Canada data for 1991, 1996, 2001, and 2006, the trends were:

- A decrease in the total amount of livestock watering
- An overall increase in crop water use
- A 14% increase in the overall population (396, 575 in 1991 to 453, 484 in 2006)
- An increase in the percent of the population on municipal water (78% in 1991 to 83% in 2006)

TR 19(12)

3.14 Stress Assessment Methodology

Using the calculation outlined in the Assessment Report Rules 31-33, stress levels were estimated for subwatersheds by comparing the amount of water consumed to the amount of water available. Percent Water Demand is calculated using the equation:

$$\%\ \text{Water Demand} = \frac{\text{QDEMAND}}{\text{QSUPPLY-QRESERVE}} \times 100\%$$

Where:

QDEMAND — is consumptive demand, either average annual or monthly consumption as the estimated rate of locally consumptive takings.

QSUPPLY — is water supply for surface and groundwater

QRESERVE — is the amount of water not considered part of the available water supply.

For surface water systems, the Percent Water Demand equation is based on an average monthly basis. The maximum percent water demand for all months is then used to estimate the potential for surface water stress as shown on Table 3.8.

Table 3.8– Potential for Surface Water Stress Thresholds

Surface Water Potential Stress Level Assignment	Maximum Monthly % Water Demand
Significant	> 50%
Moderate	20% - 50%
Low	<20 %

For groundwater systems, the stress assessment calculation is based on average annual demand conditions or the monthly maximum demand conditions. The stress level for groundwater systems is calculated according to the thresholds shown on Table 3.9.

Table 3.9 – Potential for Groundwater Stress Thresholds

Groundwater Potential Stress Level Assignment	Average Annual	Monthly Maximum
Significant	> 25%	> 50%
Moderate	> 10%	> 25%
Low	0 – 10%	0 – 25%

The rational of such an identification process is that subwatersheds with a Significant or Moderate potential for stress have a higher probability of experiencing water quantity related impacts due to water takings. Being classified as potentially stressed does not necessarily imply that a subwatershed is under hydrologic or ecologic stress, or the opposite. It simply indicates where the percent water demand is greater than selective thresholds.

Future water demand scenarios were completed using the same supply and demands as the current scenario. The current scenario uses fifteen year average monthly supply (1991-2005) and the most current available demand estimates (PTTW 2008, agricultural use and private wells 2006). This is because there is no municipal demand from in-land water supplies. Therefore, an increase in the municipally serviced 'urban' population should not affect the conclusions of this report, i.e. the current and future water demand scenarios have the same results as the NPSP Area municipal water supplies are drawn from Great Lakes sources.

Statistics Canada census information (1991-2006) indicates that the non-municipally serviced population has been decreasing in the NPSP Area (Section 5.4.2) and agricultural water demands have been increasing (Section 5.4.1). Regardless of the above, according to the TR a Tier 2 WB is not required because these are not municipal drinking water supplies.

TR 9(3)(b)

3.15 Water Quantity Stress Assessment

The Tier 1 Water Budget and Water Quantity Stress Assessment were completed to fulfill the requirements of the Source Water Protection (SWP) Assessment Report (MOE, 2009b). The purpose of the Tier 1 Water Budget is to assign every subwatershed a surface water stress level. The Tier 1 Water Budget consisted of three (3) estimates:

1. Water Supply
2. Consumptive Demand; and
3. Water Reserve

3.15.1 Surface Water Stress Assessment

Generally WSPAs were classified at moderate or significant surface water stress levels (Table 3.10 at end of chapter, Table 3.11 and Figure 3.29). Moderate stress levels were assigned to CWR, FEC, LENS, LWR, SNF and UWR WSPAs. Significant stress levels were assigned to BDSC, BFC, FSEM, GR, LIN, NOTL and TWEN WSPAs. These were generally for the months of August and/or September. The monthly extent of potentially stressed conditions ranged from six (BDSC) to one month (CWR), but was on average three months. Exceptions to this were TWEL, UTWEL, NFU and SCU which were classified as low stress and had monthly percent water demands below 2%. None of the WSPAs contain in-land municipal water supplies.

Table 3.11 Surface Water Stress Levels

Surface Water Stress Level Assignment	Subwatershed
Significant	BDSC, BFC, FSEM, GR, LIN, NOTL, TWEN
Moderate	CWR, FEC, LENS, LWR, SNF, UWR
Low	TWEL, UTWEL, NFU, SCU

Highest monthly water demands were above 100% for five (5) WPSAs in August: BDSC, FSEM, GR, LIN and TWEN. Percent water demands calculated over 100% are possible because takings may be from storage which were filled earlier in the year. The detailed takings and hydrologic system information that would be needed to account for these water transfers are beyond the scope of the Tier 1 Water Budget.

When considering the moderate surface water stress level classifications for LWR and SNF it should be noted that the extremely high 90th percentile reserves, as a proportion of the total supply, drive the high percentage demand and stress classifications (i.e. there are not necessarily high absolute demands but rather low relative net supplies when the conservative reserves used in the prescribed approach are considered). It is noted that the prescribed percentage demand equation does not lend itself to systems with low variability in monthly supply, and erroneously reports ‘high demand” in these systems with a high, stable base supply.

A number of months could potentially be considered for elevation from low to moderate based upon Assessment Report Technical Rule 32 (2) (c) (i). These include CWR (August), FEC (July), FSEM (October) and GR (October) at monthly stress levels of between 18 and 19%. However a change in these monthly classifications would not change their overall individual stress level classifications. And therefore do not require additional consideration.

3.15.2 Groundwater Stress Assessment

WSPA maximum monthly percent groundwater demand varied from 2 to 81% (Table 3.12 at end of chapter, Table 3.13 and Figure 3.30). The annual percent water demand for WSPAs varied from 2 to 57%. Most WSPAs were assigned low groundwater stress levels given the Section 3.14 threshold criteria. Three (3) WSPAs were assigned significant or moderate groundwater stress levels:

- LENS - Significant monthly (81%) and significant annual (57%), i.e. based on both criteria;
- FEC - Moderate annual (13%) based on the annual criterion only; and
- FSEM - Moderate annual (11%), i.e. based on the annual criterion only.

None of the WSPAs contain municipal water supplies.

Table 3.13 Groundwater Stress Levels	
Groundwater Stress Level Assignment	**Subwatershed**
Significant	LENS
Moderate	FEC, FSEM
Low	BDSC, BFC, CWR, GR, LIN, LWR, NOTL, SNF, TWEL, UTWEL, TWEN, UWR, NFU, SCU

The highest water demand component for LENS was for aggregate operations (76%). Actual takings pumpage information was provided for one of the quarries but was considered fully consumptive, with respect to groundwater, as dewatering discharge is directed off-site to a surface water course. The proportion of water captured by the quarry sump that is from deep groundwater sources or Lake Erie is not known however.

The moderate stress level assignments for FEC and FSEM generally do not include actual PTTW takings. If actual takings amounts compared to permitted taking amounts were included these two (2) may be below the moderate criteria.

TR 21, 32,33

3.16 Discussion of Uncertainty Factors Assigned and Analysis Conducted

All water budget calculations contain inherent uncertainty due to incomplete data, data inaccuracies, and imperfect estimation and simulation tools. It is believed the largest sources of uncertainty are the actual takings for PTTWs compared to their permitted takings and the assignment of agricultural takings to a specific source, i.e. surface water or groundwater.

While any modelling exercise contains inherent uncertainties, it should be noted that the TWEN and UWR HEC-HMS models are acting as excellent to very good predictors of streamflow. Based on the exhibited performance, the constructed HEC-HMS models produce estimates of streamflow and water balance values that far exceed the level of accuracy expected for a Tier 1 WB Water Quantity Stress Assessment.

TR 9(2)(f)

TABLE 3.10
SURFACE WATER QUANTITY STRESS ASSESSMENT
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Stress Classification
			(m^3/s)													
BDSC	Beaverdams and Shriners Creeks	Sup-Res	0.17	0.24	0.58	0.36	0.16	0.07	0.04	0.03	0.03	0.06	0.23	0.22	***150%***	Significant
		Additions	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005	0.005	0.005	0.000	0.000		
		Demand	0.002	0.004	0.015	0.015	0.047	0.047	0.048	0.048	0.047	0.047	0.015	0.009		
		%WD	1%	2%	3%	4%	***29%***	***61%***	***111%***	***150%***	***129%***	***75%***	7%	4%		
BFC	Big Forks Creek	Sup-Res	0.47	0.60	1.16	0.68	0.23	0.08	0.05	0.04	0.02	0.05	0.30	0.72	***77%***	Significant
		Additions	0.000	0.000	0.000	0.000	0.011	0.018	0.018	0.018	0.018	0.011	0.000	0.000		
		Demand	0.002	0.002	0.002	0.002	0.016	0.041	0.042	0.042	0.032	0.016	0.002	0.002		
		%WD	0%	0%	0%	0%	7%	***40%***	***58%***	***71%***	***77%***	***27%***	1%	0%		
CWR	Central Welland River	Sup-Res	3.36	3.66	7.81	6.05	1.73	0.72	0.38	0.35	0.21	0.53	1.83	4.22	***27%***	Moderate
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.004	0.005	0.006	0.010	0.035	0.057	0.063	0.066	0.056	0.035	0.010	0.005		
		%WD	0%	0%	0%	0%	2%	8%	16%	19%	***27%***	7%	1%	0%		
FEC	Fort Erie Creeks	Sup-Res	0.56	0.89	1.87	0.82	0.38	0.20	0.13	0.07	0.10	0.23	0.87	0.95	***30%***	Moderate
		Additions	0.000	0.000	0.001	0.019	0.020	0.022	0.022	0.022	0.022	0.010	0.000	0.000		
		Demand	0.001	0.001	0.001	0.001	0.027	0.027	0.028	0.028	0.027	0.027	0.001	0.001		
		%WD	0%	0%	0%	0%	7%	12%	18%	***30%***	***22%***	11%	0%	0%		
FSEM	Fifteen, Sixteen, Eighteen Mile Creeks	Sup-Res	0.66	0.55	0.97	1.00	0.39	0.18	0.07	0.03	0.04	0.07	0.25	0.50	***143%***	Significant
		Additions	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.008	0.000	0.000	0.000	0.000		
		Demand	0.009	0.010	0.010	0.010	0.013	0.015	0.028	0.061	0.013	0.012	0.010	0.010		
		%WD	1%	2%	1%	1%	3%	9%	***39%***	***143%***	***32%***	18%	4%	2%		
GR	Grimsby	Sup-Res	0.43	0.38	0.56	0.44	0.13	0.06	0.02	0.004	0.01	0.03	0.15	0.31	***156%***	Significant
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.005	0.005	0.005	0.005		
		%WD	1%	1%	1%	1%	4%	9%	***42%***	***156%***	***81%***	19%	3%	2%		
LENS	Lake Erie North Shore	Sup-Res	0.42	0.59	0.92	0.50	0.21	0.08	0.04	0.04	0.03	0.11	0.51	0.60	***22%***	Moderate
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.027	0.025	0.026	0.031	0.019	0.009	0.007	0.008	0.006	0.009	0.018	0.023		
		%WD	6%	4%	3%	6%	9%	11%	18%	***20%***	***22%***	8%	3%	4%		
LIN	Lincoln	Sup-Res	0.47	0.53	0.76	0.67	0.21	0.12	0.03	0.01	0.02	0.05	0.27	0.38	***145%***	Significant
		Additions	0.000	0.001	0.001	0.002	0.004	0.006	0.009	0.015	0.006	0.004	0.001	0.001		
		Demand	0.003	0.003	0.003	0.003	0.003	0.004	0.019	0.037	0.003	0.003	0.003	0.003		
		%WD	1%	1%	0%	0%	2%	3%	***51%***	***145%***	11%	5%	1%	1%		

TABLE 3.10
SURFACE WATER QUANTITY STRESS ASSESSMENT
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	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)	Max	Stress Classification
LWR	Lower Welland River	Sup-Res	3.67	3.80	8.31	6.56	1.71	0.78	0.40	0.30	0.23	0.48	1.81	4.29	***23%***	Moderate
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.022	0.033	0.036	0.052	0.052	0.052	0.067	0.067	0.052	0.052	0.042	0.034		
		%WD	1%	1%	0%	1%	3%	7%	17%	***22%***	***23%***	11%	2%	1%		
NOTL	Niagara-on-the-Lake	Sup-Res	0.47	0.52	1.03	0.68	0.29	0.16	0.08	0.03	0.04	0.09	0.41	0.52	***61%***	Significant
		Additions	0.000	0.000	0.000	0.000	0.013	0.087	0.148	0.152	0.085	0.008	0.000	0.000		
		Demand	0.001	0.001	0.001	0.001	0.018	0.083	0.095	0.108	0.041	0.012	0.001	0.001		
		%WD	0%	0%	0%	0%	6%	***33%***	***41%***	***61%***	***32%***	12%	0%	0%		
SNF	South Niagara Falls	Sup-Res	0.39	0.50	1.17	0.54	0.23	0.09	0.05	0.03	0.03	0.05	0.31	0.58	***42%***	Moderate
		Additions	0	0	0.0114	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0		
		Demand	0.001	0.001	0.007	0.020	0.020	0.020	0.021	0.021	0.020	0.020	0.013	0.001		
		%WD	0%	0%	1%	3%	8%	18%	***30%***	***42%***	***39%***	***28%***	4%	0%		
TWEL	Twelve Mile Creek	Sup-Res	51	42	45	63	19	58	17	106	109	103	42	79	0%	Low
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.001	0.001	0.005	0.022	0.023	0.023	0.044	0.046	0.023	0.023	0.012	0.001		
		%WD	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		
UTWEL	Upper Twelve	Sup-Res	0.25	0.25	0.26	0.30	0.23	0.13	0.07	0.05	0.03	0.02	0.07	0.17	2%	Low
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000		
		%WD	0%	0%	0%	0%	0%	0%	1%	1%	2%	2%	0%	0%		
TWEN	Twenty Mile Creek	Sup-Res	1.52	1.60	3.38	0.90	0.38	0.23	0.14	0.11	0.07	0.17	0.58	1.52	***203%***	Significant
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.006	0.010	0.037	0.040	0.090	0.142	0.148	0.163	0.142	0.090	0.039	0.020		
		%WD	0%	1%	1%	4%	***24%***	***62%***	***106%***	***148%***	***203%***	***53%***	7%	1%		
UWR	Upper Welland River	Sup-Res	1.89	1.82	3.99	3.15	0.76	0.14	0.11	0.10	0.07	0.13	0.44	1.76	***38%***	Moderate
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0.012	0.015	0.014	0.015	0.018	0.028	0.032	0.032	0.026	0.018	0.015	0.013		
		%WD	1%	1%	0%	0%	2%	***20%***	***29%***	***32%***	***38%***	14%	3%	1%		
NFU	Niagara Falls Urban	Sup-Res	0.08	0.14	0.37	0.33	0.18	0.18	0.13	0.07	0.11	0.12	0.28	0.24	*1%*	Low
		Additions	0	0	0	0.0136	0.0511	0.0554	0.0554	0.0554	0.0544	0.0511	0.0136	0		
		Demand	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000		
		%WD	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%		

TABLE 3.10
SURFACE WATER QUANTITY STRESS ASSESSMENT
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Stress Classification
			(m^3/s)													
SCU	St. Catharines Urban	Sup-Res	0.02	0.05	0.20	0.14	0.05	0.04	0.01	0.00	0.01	0.03	0.10	0.09	*0%*	Low
		Additions	0	0	0	0	0	0	0	0	0	0	0	0		
		Demand	0	0	0	0	0	0	0	0	0	0	0	0		
		%WD	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		

Notes: Sup-Res: Supply minus Reserve, %WD: Percent Water demand, Significant - Bold shaded italics, Moderate - Bold underlined italcs

TABLE 3.12
GROUNDWATER QUANTITY STRESS ASSESSMENT
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max Month	Monthly Stress Classification	Term	Annual (mm/year)	Annual Stress Classification
			(mm/month)																
BDSC	Beaverdams and Shriners Creeks	Supply	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	10%	Low	Supply	87	Low
		Reserve	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7			Reserve	9	
		Demand	0.17	0.25	0.52	0.52	0.64	0.57	0.61	0.61	0.57	0.57	0.34	0.23			Demand	6	
		%WD	3%	4%	8%	8%	10%	9%	9%	9%	9%	9%	5%	4%			%WD	7%	
BFC	Big Forks Creek	Supply	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	16%	Low	Supply	63	Low
		Reserve	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5			Reserve	6	
		Demand	0.07	0.07	0.07	0.07	0.13	0.28	0.55	0.76	0.13	0.13	0.08	0.07			Demand	2	
		%WD	2%	2%	2%	2%	3%	6%	12%	16%	3%	3%	2%	2%			%WD	4%	
CWR	Central Welland River	Supply	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	8%	Low	Supply	80	Low
		Reserve	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7			Reserve	8	
		Demand	0.09	0.09	0.09	0.11	0.33	0.32	0.42	0.48	0.31	0.32	0.11	0.09			Demand	3	
		%WD	2%	2%	2%	2%	5%	5%	7%	8%	5%	5%	2%	2%			%WD	4%	
FEC	Fort Erie Creeks	Supply	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	22%	Low	Supply	62	Moderate
		Reserve	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5			Reserve	6	
		Demand	0.13	0.14	0.21	0.67	0.97	0.99	1.04	1.04	0.99	0.83	0.28	0.16			Demand	7	
		%WD	3%	3%	5%	14%	21%	21%	22%	22%	21%	18%	6%	3%			%WD	***13%***	
FSEM	Fifteen, Sixteen, Eighteen Mile Creeks	Supply	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	23%	Low	Supply	110	Moderate
		Reserve	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9			Reserve	11	
		Demand	0.33	0.34	0.39	0.47	0.94	1.46	1.73	1.88	1.43	0.90	0.43	0.35			Demand	11	
		%WD	4%	4%	5%	6%	11%	18%	21%	23%	17%	11%	5%	4%			%WD	***11%***	
GR	Grimsby	Supply	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	4%	Low	Supply	104	Low
		Reserve	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9			Reserve	10	
		Demand	0.24	0.23	0.25	0.24	0.27	0.27	0.31	0.31	0.25	0.25	0.25	0.24			Demand	3	
		%WD	3%	3%	3%	3%	3%	3%	4%	4%	3%	3%	3%	3%			%WD	3%	
LENS	Lake Erie North Shore	Supply	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	***81%***	Significant	Supply	84	Significant
		Reserve	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7			Reserve	8	
		Demand	4.56	4.40	4.06	5.07	4.92	2.95	2.75	3.03	3.18	2.69	2.63	2.55			Demand	43	
		%WD	***73%***	***70%***	***65%***	***81%***	***78%***	***47%***	***44%***	***48%***	***51%***	***43%***	***42%***	***41%***			%WD	***57%***	
LIN	Lincoln	Supply	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	2%	Low	Supply	157	Low
		Reserve	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3			Reserve	16	
		Demand	0.19	0.18	0.19	0.19	0.21	0.21	0.23	0.26	0.22	0.21	0.20	0.20			Demand	2	
		%WD	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%			%WD	2%	

TABLE 3.12
GROUNDWATER QUANTITY STRESS ASSESSMENT
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Monthly Stress Classification	Term	Annual (mm/year)	Annual Stress Classification
			(mm/month)																
LWR	Lower Welland River	Supply	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9%	Low	Supply	110	Low
		Reserve	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9			Reserve	11	
		Demand	0.07	0.07	0.07	0.07	0.08	0.08	0.77	0.77	0.08	0.08	0.07	0.07			Demand	2	
		%WD	1%	1%	1%	1%	1%	1%	9%	9%	1%	1%	1%	1%			%WD	2%	
NOTL	Niagara-on-the-Lake	Supply	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8%	Low	Supply	90	Low
		Reserve	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7			Reserve	9	
		Demand	0.17	0.19	0.20	0.20	0.42	0.43	0.45	0.54	0.44	0.43	0.21	0.21			Demand	4	
		%WD	3%	3%	3%	3%	6%	6%	7%	8%	7%	6%	3%	3%			%WD	5%	
SNF	South Niagara Falls	Supply	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	8%	Low	Supply	55	Low
		Reserve	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5			Reserve	5	
		Demand	0.06	0.05	0.06	0.06	0.06	0.31	0.35	0.35	0.31	0.06	0.06	0.06			Demand	2	
		%WD	1%	1%	1%	1%	2%	8%	8%	8%	8%	2%	1%	1%			%WD	4%	
TWEL	Twelve Mile Creek	Supply	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9%	Low	Supply	108	Low
		Reserve	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9			Reserve	11	
		Demand	0.08	0.08	0.30	0.60	0.68	0.72	0.76	0.77	0.72	0.68	0.48	0.08			Demand	6	
		%WD	1%	1%	4%	7%	8%	9%	9%	9%	9%	8%	6%	1%			%WD	6%	
UTWEL	Upper Twelve Mile	Supply	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	9%	Low	Supply	251	Low
		Reserve	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1			Reserve	25	
		Demand	0.14	0.13	0.72	1.55	1.62	1.58	1.73	1.73	1.59	1.62	1.19	0.14			Demand	14	
		%WD	1%	1%	4%	8%	9%	8%	9%	9%	8%	9%	6%	1%			%WD	6%	
TWEN	Twenty Mile Creek	Supply	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	6%	Low	Supply	64	Low
		Reserve	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5			Reserve	6	
		Demand	0.15	0.15	0.16	0.17	0.16	0.23	0.27	0.29	0.18	0.16	0.15	0.17			Demand	2	
		%WD	3%	3%	3%	4%	3%	5%	6%	6%	4%	3%	3%	3%			%WD	4%	
UWR	Upper Welland River	Supply	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	5%	Low	Supply	83	Low
		Reserve	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7			Reserve	8	
		Demand	0.12	0.13	0.13	0.13	0.18	0.18	0.24	0.30	0.19	0.18	0.14	0.11			Demand	2	
		%WD	2%	2%	2%	2%	3%	3%	4%	5%	3%	3%	2%	2%			%WD	3%	
NFU	Niagara Falls Urban	Supply	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	1%	Low	Supply	82	Low
		Reserve	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7			Reserve	8	
		Demand	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.05	0.01	0.01	0.01	0.01			Demand	0	
		%WD	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%			%WD	0%	

TABLE 3.12
GROUNDWATER QUANTITY STRESS ASSESSMENT
NPSPA ASSESSMENT REPORT

WSPA	Name	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Monthly Stress Classification
			(mm/month)													
SCU	St. Catharines Urban	Supply	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	0%	Low
		Reserve	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6		
		Demand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
		%WD	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		

Term	Annual (mm/year)	Annual Stress Classification
Supply	72	Low
Reserve	7	
Demand	0	
%WD	0%	

Notes: %WD: Percent Water Demand, Significant - Bold shaded italics, Moderate - Bold underlined italcs

3.17 Technical Advisory Groups and Peer Review

The Technical Advisory Group for the Tier 1 Water Budget and Stress Assessment (and Chapter 4 - SGRAs) consisted of staff from NPCA and Aqua Resource Inc. Peer evaluations of the Tier 1 and SGRA reports were completed by the Ministry of Natural Resources, Terra-Dynamics Limited and Dillon Consulting Limited. The Tier 1 and SGRA reports were revised accepting the recommendations of the peer reviewers. The Tier 1 and SGRA reports were accepted and endorsed by the peer review team.

Niagara Escarpment, Niagara-on-the-Lake