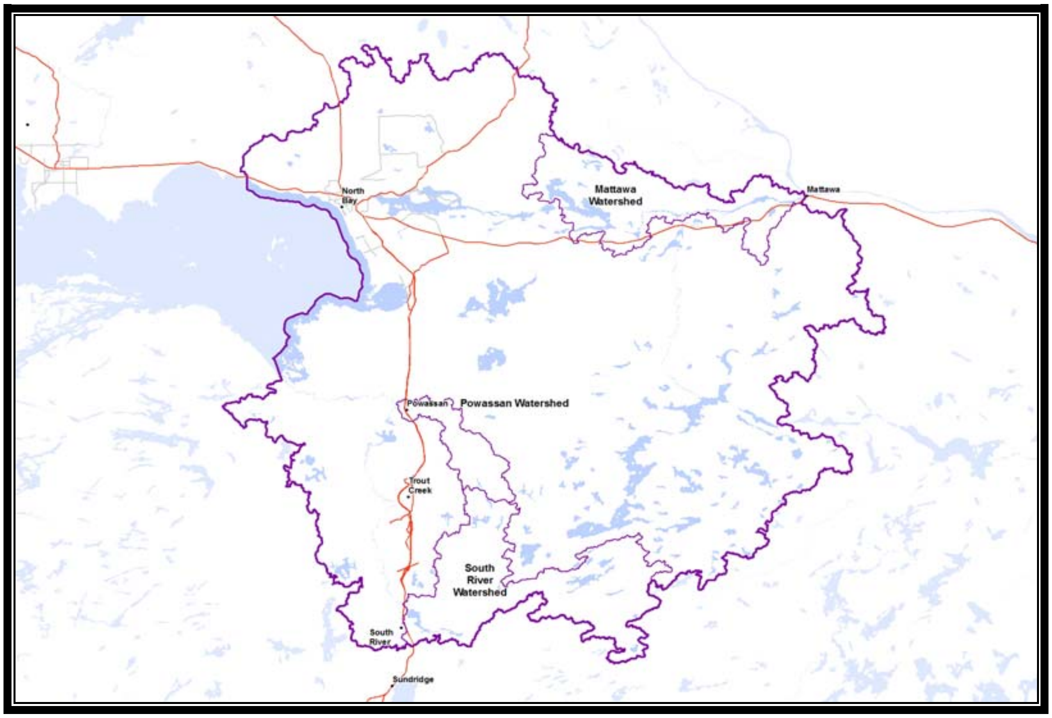

TIER 1 WATER BUDGET AND STRESS ASSESSMENT FOR THE SOUTH RIVER, POWASSAN AND MATTAWA MUNICIPAL WATER SUPPLIES

REVISED FINAL REPORT

Prepared for:

North Bay-Mattawa Conservation Authority
15 Janey Avenue
North Bay, ON P1C 1N1

June 2010

NORTH BAY-MATTAWA CONSERVATION AUTHORITY

WESA
A Better Environment For Business

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1.0 INTRODUCTION

1.1. Background

In October of 2006, the *Clean Water Act* was promulgated by the Government of Ontario. Implementation of this Act will reduce the risk to drinking water at its source from contamination and overuse. In July, 2007 the Act and five regulations came into effect. Source protection planning is to be completed on a watershed basis by the province's Conservation Authorities. For this work, the Conservation Authorities have been grouped into nineteen Source Protection Regions. Each region is required to complete a Technical Assessment Report and a Source Protection Plan. The province has provided funding to establish the Source Water Protection (SWP) Plans for all of Ontario's watersheds in support of this initiative.

In December, 2008, the Province released the *Technical Rules: Assessment Report, December 12, 2008* (herein after referred to as the "Technical Rules"). Proposed amendments were released on August 24, 2009 with the most recent version posted to the Environmental Registry on November 16, 2009 (MOE, 2009). The Technical Rules now provide instruction on the elements required for the preparation of Assessment Reports for each Source Protection Region. In the event of a conflict between the former MOE guidance models and the Assessment Report Technical Rules, the rules have precedence in accordance with *Ontario Regulation 287/07*.

The information presented in this report has been prepared to comply with the Technical Rules and has been structured for ease of migration into the North Bay Mattawa Source Protection Area Assessment Report.

The Water Budget process was introduced under the *Clean Water Act*, 2006, and can be divided into three levels of complexity; Tier 1 Water Budget and Stress Assessment, Tier 2 Complex Water Budget and Stress Assessment, and Tier 3 Water Budget and Water Quantity Risk Assessment, as described in Draft Guidance Module 7 of the MOE Source Water Protection Assessment Report (MOE, 2007). The tiered water budget and water quantity risk assessment is designed to allow a scope of work to be developed based on the hydrologic stress of a watershed. Watersheds that are more highly stressed require further detailed analysis, which necessitates increasingly sophisticated data and analysis techniques. As a result, each successive tier results in further refinement of the water budget. The Tier 1 Water Budget follows the Conceptual Water Budget and aims to estimate the hydrologic stress of watersheds, while screening out regions that are unstressed from a water quantity perspective. Watersheds identified as being under stress can be subject to further investigation at the Tier 2 and Tier 3 level. Watersheds that experience moderate/significant stress and have a potential drinking water risk proceed to the Tier 2 Water Budget. Watersheds that experience moderate/significant stress at the Tier 2 level and require more information proceed to the Tier 3 level.

1.2. The Hydrologic Cycle and Water Budget Elements

MOE (2007) states that the goal of the Tier 1 analysis is to "use simplified, yet structured means to estimate water flow volumes and compare that to consumptive demand" (p. 26). This requires an estimate of the percentage of the water supply that is consumed by use (*% Water Demand*) and quantifying surface and groundwater flow through the watershed by estimating the various water budget fluxes. The water budget can be broken down into the following hydrologic components:

- Precipitation (P)
- Storage (S)
- Evapotranspiration (ET)
- Groundwater recharge (R)
- Baseflow (Q_G)
- Runoff (RO)
- Streamflow (Q_S)
- Anthropogenic output ($Anth_{OUT}$)
- Anthropogenic input ($Anth_{IN}$)

ET occurs at its potential rate (potential evapotranspiration, PET) when water supply is unlimited and the evaporating airmass is stable. The actual evapotranspiration (AET) is restricted by energy, available water and the receiving atmosphere. The balance between inputs and output, or water budget, can be described by the following equation, where all terms for the Tier One water budget can be integrated over a catchment area and reported as equivalent water depths (mm), volumes (m^3), or water fluxes (m^3/s):

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

where ΔS is change in storage, P is precipitation, Q_{SIN} is surface water input, Q_{GIN} is groundwater input, $Anth_{IN}$ is anthropogenic input, ET is evapotranspiration, Q_{SOUT} is surface water output, Q_{GOUT} is groundwater output, and $Anth_{OUT}$ is anthropogenic output. In this equation, direct evaporation from water bodies is incorporated into the ET term.

Withdrawal is the gross taking of water from the watershed, that is, all groundwater and surface water taken for any purpose. Consumption is the removal of water from the watershed. For example, the Municipality of Powassan obtains municipal water from two groundwater supply wells within the community. However, the wastewater treatment lagoons and discharge point are located outside the watershed from which the water is consumed, and therefore, the water is considered consumed. Water return is water taken within the watershed and released to groundwater or surface water within the same watershed. Return is the difference between withdrawal and consumption.

1.3. OBJECTIVES

The study described in this report involves completion of a Tier 1 Water Budget and Stress Assessment for three municipal drinking water systems within the North Bay-Mattawa Source Protection Area (SPA):

- Town of Mattawa Groundwater Supply
- Municipality of Powassan Groundwater Supply
- Village of South River Surface Water Supply

The results of the Tier 1 Water Budget and Stress Assessment will provide an assessment of the cumulative impact of water use on the regional water budget.

1.4. LIMITATIONS

Limited data are available about actual water use in the region. The data that are available for the study area are variable in terms of their reliability, accuracy, spatial coverage and when they were last updated. As a result, water use was estimated indirectly by combining and manipulating datasets and using various assumptions.

Despite the limitations inherent to the available data, this study presents a valuable preliminary analysis and evaluation of water use within the region, and in particular consumptive water use and water returns to the principal hydrologic systems (surface water, shallow groundwater or deep groundwater).

2.0 STUDY AREA

2.1. BACKGROUND

The North Bay-Mattawa Source Water Protection (SWP) Region is located in northeastern Ontario (Figure 1). It encompasses an area of approximately 4,000 km^2 and includes 14 Quaternary watersheds. (Quaternary watersheds are the smallest watershed subdivisions in the top-down watershed delineation methodology in the MNR Provincial Watershed Project (MNR, 2002). They are subdivisions of Tertiary watersheds that show divisions of large rivers and streams into tributary streams.) The Town of Mattawa, Municipality of Powassan, and Village of South River are included within the boundaries of the SWP Region. The region is characterized by rugged highlands in the north and south and a low–lying area across the centre. Elevation ranges from approximately 120 metres above sea level (masl) in the centre of the SWP Region to greater than 500 masl in the south (WHI and TCL, 2006).

2.2. Bedrock and Surficial Geology

The North Bay-Mattawa SWP Region is located on the Canadian Shield, which is characterized by Precambrian bedrock more than 2.5 billion years old. In general, the ground surface is a reflection of the bedrock topography, indicating that the bedrock itself is low-lying and undulating (Gartner Lee Ltd., 2007). The overburden in most of the SWP area is unconsolidated sediment and organic material of varying thicknesses (Gartner Lee Ltd., 2007). It is generally thin but gets thicker in low-lying areas, ranging from less than 5 m around Lake Nipissing to greater than 100 m along the Mattawa River (WHI and TCL, 2006). Figure 2 presents surficial geology.

Numerous glacial deposits are found within the SWP Region, including till, glaciolacustrine deposits, and glaciofluvial deposits (Harrison, 1972). There are well developed eskers in the SWP Region, which trend in a southerly direction in the Mattawa area (Gartner Lee Ltd., 2007).

There are several faults that exist in the SWP Region, including the Ottawa-Bonnechere and Nipissing Faults. The Ottawa-Bonnechere Fault (or Mattawa River Fault) extends east-west along the northern portion of the SWP Region and contains the Mattawa River. The Nipissing Fault extends east-west along the southern portion of the region, through the Town of Powassan. It is suggested that Genesee Creek flows along this fault (WHI and TCL, 2006).

Approximately 90% of the drilled wells in the NBMCA area are screened in bedrock (WHI and TCL, 2006). However, the two municipally-serviced groundwater supplies in the area (Town of Mattawa and Municipality of Powassan) utilize overburden aquifers as these regions have thicker sand and gravel units relative to the rest of the NBMCA area (WHI and TCL, 2006). As well, dug wells and owner-constructed wells are under-represented in the water well database.

2.3. Climate

The SWP Region is located in Northern Ontario at an approximate latitude of 46°N, causing it to have four distinct seasons with a total variation in temperature of 32°C. Canadian Climate Normal data for the SWP Region indicate that the mean annual air temperature is 3.8°C to 4.2°C, based on the North Bay Airport and Powassan Climate Stations, respectively (Figure 3). Mean daily temperatures at both stations range from -13°C in January to 19°C in July and a slight warming trend can be identified over time.

Mean annual precipitation ranges from 936 mm (Powassan Station) to 1008 mm (North Bay Airport Station) at higher elevations (Figure 4), with approximately 75% falling as rain (Environment Canada, 2004). There was an upward trend in mean annual precipitation from 1975 through 2005 (AquaResource, 2010).

2.4. Land Cover

Table 1 summarizes the major land cover types and the percentage of the SWP Region that they comprise. It should be noted that 89% of the SWP Region is natural vegetation. Figure 5 presents land cover.

Table 1: Land Cover in the North Bay-Mattawa SWP Region (Gartner Lee Ltd., 2007)

Land Cover Type	Area (km^2)	% of SWP Region
Water	281.44	7.1
Settlement/Infrastructure	79.93	2.0
Bedrock	5.74	0.1
Cutovers	10.84	0.3
Burns	0.39	0.0
Sparse Forest	170.31	4.3
Deciduous Forest	1134.17	28.6
Mixed Forest	1478.60	37.3
Coniferous Forest	378.24	9.5
Treed Fen	3.35	0.1
Open Bog	3.59	0.1
Treed Bog	92.91	2.3
Pasture	251.66	6.3
Unknown	72.00	1.8
Total	3963.17	100

2.5. Population

The major population centres in the SWP Region are within the central and western low-lying areas. According to 2006 census data, there are approximately 72,800 people living in municipalities completely within the SWP Region. There are another 5,700 people living in municipalities only partially contained within the region. A population decrease of 1.5% occurred between 1996 and 2001, while the population increased by 1.6% between 2001 and

2006. This resulted in an approximately stable population over the 10-year census period. The City of North Bay is the largest urban centre with the Municipality of Callander, Town of Mattawa and Municipality of Powassan comprising the other main population centres (Statistics Canada, 2002a). While the population of the Municipality of Powassan has remained nearly unchanged over the 10-year census period (-0.1%), the Village of South River experienced a decrease of 2.6 %. The Town of Mattawa has experienced the greatest population change, with a decrease of 12.2%, occurring primarily in the 2001-2006 period (-11.8%; Statistics Canada, 2007).

2.6. Tier One Watersheds

The Tier 1 Water Budget concentrates on subwatersheds that provide municipal supply. There are five municipal drinking water systems in the SWP Region that service approximately 80% of the population. The supplies are located in Callander, Mattawa, North Bay, Powassan, and South River. This study will focus on the Town of Mattawa, Municipality of Powassan, and the Village of South River. While Mattawa and Powassan rely on groundwater sources, South River draws from surface water sources.

The subwatersheds contributing to the municipal water supplies were delineated using the Quaternary Watersheds as the maximum extents. The Mattawa River Quaternary Watershed (2JE-02) was split into two at a point on the Mattawa River between Turtle Lake and Talon Lake. The watershed was split because the City of North Bay Municipal water intake is on Trout Lake. AquaResource (2010) addresses the water budget for the Trout Lake/Turtle Lake watershed. The eastern (downstream) watershed includes the Town of Mattawa Municipal supply and has an area of 239.8 km^2. The subwatersheds contributing to the water supplies for the Municipality of Powassan and the Village of South River are contained within the South River Quaternary Watershed (2DD-23), and have areas of 70.1 and 322.6 km^2, respectively. For purposes of this study, the Village of South River subwatershed includes all areas from which surface water flows into the South River as far downstream as the South River Dam. The Powassan subwatershed includes all areas from which surface water flows into Genesee Creek up to the point where it discharges into the South River. Figure 1 illustrates these subwatersheds.

3.0 METHODOLOGY

3.1. Water Budget Model

A spreadsheet model was used in conjunction with ArcMap Spatial Analyst. The computer GIS platform was used to determine average monthly potential evapotranspiration values (PET), which were then incorporated into the spreadsheet model. The spreadsheet model estimated the remaining parameters for monthly and annual water budgets using a soil moisture balance based on the methodology described in Thornthwaite and Mather (1957). It should be noted that the water budget presents average conditions over a watershed but does not account for spatial heterogeneity. This technique was considered sufficient for the present Tier 1 level of assessment.

3.1.1. *General Model Procedure*

The water budget model follows the general procedure outlined below:

- Apply temperature and precipitation to watershed on a daily basis and determine average monthly values, using GIS platform
- Determine monthly PET following the Thornthwaite method (Thornthwaite and Mather, 1957), using GIS platform
- If P>PET, water surplus calculated as P-PET
- If P<PET, water is removed from soil as AET, such that AET<PET
- Estimate soil water holding capacity
- Determine if water surplus is predicted
- If water surplus was predicted when P-AET-RO>0, water first used to fill in soil water storage
- If soil water holding capacity is at a max, remaining water is available for runoff and recharge
- Partition the remaining surplus between the runoff and recharge components

3.1.2. *Precipitation*

A precipitation surface with a 200-m cell size was interpolated using ArcGIS Spatial Analyst to create monthly and annual records covering the Tier 1 subwatersheds. The kriging method used to create the surfaces had a total of 13 meteorological stations to cover the complete geographical area of the SPA. The stations include North Bay and Powassan within the SPA. The remaining 11 stations are in Ontario and Quebec as far west as Sudbury, south to Muskoka, east to Chalk River and north to Earlton. From the resulting surfaces, geographically derived minimums, maximums and means were extracted for each of the subwatersheds. Long-term precipitation (P) data were obtained from Environment Canada climate stations near the study areas (Environment Canada, 2004a). Appendix A includes the detailed methodology.

This method was also used to create a temperature surface (Appendix A).

3.1.3. *Evapotranspiration (ET)*

Potential evapotranspiration (PET) was determined using a GIS platform and following the Thornthwaite Heat Index analysis (Thornthwaite and Mather, 1957). Appendix A includes the detailed methodology. ET occurs at the PET rate when soil is saturated and at the actual evapotranspiration (AET) rate when the soil is unsaturated, where AET is the sum of the precipitation and the change in soil moisture storage (dSW).

3.1.4. *Water Surplus (S)*

Water surplus (S) is defined when the soil moisture storage (SW) exceeds the water holding capacity (WHC), such that any excess precipitation is counted as surplus. WHC was estimated to be 100 mm, based on Gartner Lee Ltd. (2007). If $P>PET$ and $SW \geq WHC$, water surplus (S) is calculated as P-PET.

The availability of the surplus for runoff and recharge is dependent on other factors such as temperature. When temperatures are less than -1°C, excess precipitation is stored above ground as snow and no surplus is available (Thornthwaite and Mather, 1957). Total surplus was subdivided into surplus from rain that was available for direct runoff and the surplus from snow storage that was available for snow melt runoff.

Direct runoff and recharge from rain may occur when the temperature (T) is greater than or equal to -1°C and the soil moisture storage is greater than or equal to the WHC. As suggested in Thornthwaite and Mather (1957), 50% of the available surplus was made available for runoff and recharge, while the remainder is detained for the following month.

Snow melt begins when temperatures exceed -1°C. Snow melt was set to 10% of the available snow storage surplus the first month that temperatures exceed -1°C, and 50% for each subsequent month as recommended in Thornthwaite and Mather (1957).

3.1.5. *Groundwater Recharge (R)*

The fraction of surplus available for recharge was determined based on a partitioning coefficient, which was determined by Gartner Lee Ltd. (2007). The partitioning coefficient divides total surplus (rain and snow melt) between runoff and recharge.

3.1.6. *Surface Runoff (RO)*

Runoff was calculated as the difference between recharge and total surplus ($RO = R - S$).

3.2. Water Supply, Demand, Reserve and Stress Assessment

3.2.1. *Water Supply*

Surface Water Supply

The available drinking water supply from surface water is limited by the instantaneous flow rate. Seasonal variability was taken into account by using monthly values. The estimated monthly water supply from surface sources is calculated as monthly median (Q_{P50}) streamflow if good data are available. MOE (2007) states that the monthly median streamflow can be an approximation of the typical long-term monthly baseflow or low-flow value. Surface water supply was determined for the Village of South River municipal supply subwatershed using the Water Survey of Canada stream flow gauge 02DD009 (South River at South River).

Groundwater Supply

Water available for groundwater users was estimated as equal to groundwater recharge. Lateral groundwater flow was assumed to be negligible and aquifer storage was not considered, therefore, water supply terms are assumed constant on an average annual basis. Estimated monthly water supply from groundwater sources is calculated as annual recharge from the soil moisture balance, divided evenly over 12 months (MOE, 2007).

3.2.2. *Water Reserve*

Water reserve protects a portion of water from being considered within the stress calculations and provides extra conservatism. The water reserve supports other uses within the watershed (ecosystem needs, other human uses, etc).

Surface Water Reserve

Surface water reserve was calculated as the 10^{th} percentile of streamflow, or discharge that was exceeded 90% of the time (Q_{P90}) that continuous streamflow data are available. The difference between surface water supply (Q_{P50}) and surface water reserve (Q_{P90}) is the available surface water for anthropogenic demands (MOE, 2007).

Groundwater Reserve

Groundwater reserve was calculated as 10% of the monthly calculated groundwater recharge (R). For a Tier 1 stress assessment, recharge is assumed to be equal throughout the year; therefore, groundwater reserve will be constant between months. The difference between recharge and groundwater reserve is the available groundwater to serve anthropogenic demands (MOE, 2007).

3.2.3. Water Demand

Consumptive water demand is characterized as water removed to satisfy anthropogenic needs that are not locally returned to the same source in a reasonable period of time. Consumptive demand depends on scale, with respect to the source, sub-basin, and watershed. The percent demand was calculated under average annual and monthly conditions, where applicable (MOE, 2007).

Municipal Surface and Groundwater Demand

Municipal surface water demand may include Water and Wastewater Treatment plants and industry. Municipal groundwater demand may include drinking water and industry. The latest available actual use data were used in demand calculations rather than permitted values. The latest available data ranged from 1997 to 2007 depending on the municipal system. Actual use data for Mattawa, Powassan and South River were available between 1997 and 2007, 2003 and 2007, and 2002 and 2007, respectively. Average actual water use was determined and applied to the 2006 population estimates and 2004 Municipal Water and Wastewater Survey to estimate average water takings, consumption, and returns.

Permitted Water Use

The MOE Permit to Take Water (PTTW) database was reviewed and filters were applied to retain only valid permits for the analysis. The latest version of the database is up to date as of June 2006. Permits were excluded from the water use analysis if they met at least one of the following criteria: (a) Expired for more than five years; (2) Revoked; (3) Transient (i.e., short duration (< 7 days), pipeline testing, hydrogeological testing, construction dewatering); (4) For in-stream uses (diversions); (5) Missing (some takings are blank); or (6) If more up-to-date information was available (e.g., wells taken off line).

As specified in AquaResource (2005), permits for in-stream uses are considered diversions rather than consumptive demand. Consequently, the following types of permits were excluded from the analysis on the basis of their “Specific Type” (number of corresponding records in PTTW database shown in brackets): Power Production (0), Dams and Reservoirs (1), Wildlife Conservation (53), Other-recreational (1) and Wetlands (1).

Agricultural permits contained in the PTTW database were reviewed and none are located within the watersheds of interest in this study.

The PTTW database was used to determine permitted amounts of water and description of use for users of >50,000 L/day. These rates represent the maximum taking, and likely overestimate the actual taking. Methods described by AquaResource (2005) and GRCA (2005) were used to scale permitted amounts to estimated consumed amount when actual data were not available.

AGRICULTURAL USE

Methodology described by de Loe (2002) has been used to estimate annual amounts of water removed. Weighting described by GRCA (2005) was used to convert annual amounts to monthly values. AquaResource (2005) presents consumption factors that allow for seasonal water removals.

Statistics Canada Census of Agriculture data (Statistics Canada, 2007) were reviewed to extract farm data compiled by CCS in the study area (number of farms reporting by farm type, total acreage or number of animals). A conservative approach was taken when utilizing Census data, such that the entire CCS was considered to be within the subwatershed of interest even if it is only partially included. Some census data are suppressed in the data reported by Statistics Canada to meet the confidentiality requirements of the Statistics Act.

Typical water use coefficients (water used per unit area irrigated) were derived from Ontario best management practices (BMP) for irrigation management (OMAF, 2004). Similarly, typical water requirements for livestock were estimated using information published by the British Columbia Ministry of Agriculture and Lands (BCMAL, 2006).

Irrigation water use is climate dependent and was assumed to be seasonal (July and August only as suggested in the MOE guidance document). Conversely, livestock water takings were assumed to be constant throughout the year. All agricultural water use was assumed to be from groundwater sources. Water used for livestock watering was assumed to be 100% consumed and a consumptive factor of 1.0 was used, while a consumptive factor of 0.8 was applied for crop irrigation water use, as specified in the MOE guidance document. The non-consumed portion of the water taken for irrigation (20%) was assumed to return to shallow groundwater through infiltration.

NON-PERMITTED AND RURAL USE

Non permitted rural domestic water use was estimated based on the population density extracted from census data for each CCS within the study area, combined with the proportion of the population relying on private supply wells reported in the 2004 Municipal Water Use ("MUD") survey. Non-serviced residents were estimated to use 175 L/d/capita, but this use can typically be assumed as negligible at the watershed scale as this water is likely returned to the groundwater system through septic beds and tile drains in a reasonable period of time. Rural use can include livestock, irrigation, and rural domestic uses. Where significant, methodologies described in de Loe (2002) were followed.

CROSS-CATCHMENT TRANSFER

Cross-catchment transfer is water removed from one watershed to service residents or industry in another watershed. This was not applicable for the subwatersheds of interest.

APPLICATION OF SEASONAL ADJUSTMENTS AND CONSUMPTIVE FACTORS

Certain types of permit holders only use water seasonally (e.g., golf course irrigation, campgrounds), while other takings are used all year (e.g., municipal and communal water supplies, industrial cooling water). To account for seasonality, the default monthly demand adjustments from Table 15 of Appendix D of the MOE guidance document (MOE, 2007) were applied to each permitted water taking, as appropriate for each permit's specific purpose (e.g., golf course irrigation, aggregate washing, campgrounds, etc).

Similarly, the default consumptive use factors with respect to the source from Table 16 of Appendix D of the MOE guidance document (MOE, 2007) were used to estimate consumptive water use for each water taking, and the balance of the water returned. These factors result in a reduced demand by accounting for water returns.

WATER RETURNS: SURFACE WATER OR SHALLOW GROUNDWATER

The difference between gross water takings and consumed water is returned to surface water or to shallow groundwater. Returns for golf course irrigation, pits and quarries dewatering, aggregate washing and campgrounds were all assumed to return to shallow groundwater through infiltration from ditches, ponds or septic beds. Other permitted takings were attributed to surface water if the respective areas were serviced by municipal sewers or based on comments contained in the PTTW database. Note that some water takings can be located some distance away from the population they service, and professional judgement was used in determining whether the population served by the water taking was also serviced by sewers (i.e., returns to surface water). Otherwise, the default was to assume returns are to shallow groundwater via septic beds.

3.2.4. *Stress Assessment*

A subwatershed stress assessment is designed to screen subwatersheds and highlight those where the degree of stress warrants refined water budget efforts for risk characterization. It evaluates water quantity stress by calculating the ratio of consumptive demand to water supply minus water reserves, as described by the equation below, modified from MOE (2007).

$$\%WaterDemand = \frac{Q_{CONSUMPTIVEDEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} * 100\%$$

Supply and reserve are calculated as described in Sections 3.2.1 and 3.2.2, respectively.

Separate stress assessments are conducted on surface water and groundwater systems, depending on which system contains the municipal supply. The percent water demand is evaluated and then the subwatershed stress level is determined based on the criteria contained in the Technical Rules.

If a subwatershed is deemed to have a Low stress level, no further water budget or water quantity stress assessment work is required, but monitoring is recommended. For a Moderate-Significant stress level, a Tier 2 water budget is required if the subwatershed contains municipal drinking water system. The subwatershed will also be highlighted for consideration under PTTW program or DFO regulations if no system exists.

The Tier 1 stress assessment is a screening level calculation to define subwatersheds that may be at risk of failing to provide a sustainable supply of water. This is divided into *current water supply and demand* and *future water supply and demand*, where future supply is assumed to equal current supply, and only municipal demand is estimated for the future (at the Tier 1 level). This is because only municipal demand can be forecast based on Official Plan population scenarios, while the other demands have too much uncertainty involved.

Surface Water Quantity Stress Assessment

Surface water quantity stress were determined monthly and monthly summations and statistics (median monthly and annual) on daily measures streamflow were calculated. Monthly maximum water quantity stress for present and future demand scenarios were assigned to the study subwatersheds based on thresholds as summarized in Table 2.

Table 2: Surface Water Stress Thresholds

Surface Water Quantity Stress Level Assignment	Monthly Maximum % Water Demand
Significant	≥50%
Moderate	>20% and <50%
Low	≤20%

GROUNDWATER QUANTITY STRESS ASSESSMENT

To complete a Tier 1 groundwater stress analysis, average annual recharge, groundwater flow into/out of watershed, groundwater reserve estimates, and groundwater consumptive demand estimates are needed. Like surface water stress, groundwater stress was also calculated monthly. Average annual stress and monthly maximum stress was assessed for current and future demand scenarios and was assigned to the study watersheds based on thresholds as summarized in Table 3.

Table 3: Groundwater Stress Thresholds

Groundwater Water Quantity Stress Level Assignment	Average Annual % Water Demand	Monthly Maximum % Water Demand
Significant	≥25%	≥50%
Moderate	>10% and < 25%	>25% and <50%
Low	≤10%	≤25%

4.0 TOWN OF MATTAWA GROUNDWATER SUPPLY WATERSHED RESULTS AND DISCUSSION

The Town of Mattawa groundwater supply watershed was delineated such that it extends from a point on the Mattawa River between Turtle Lake and Talon Lake east to the Town of Mattawa (Figure 1). Municipal drinking water for the Town of Mattawa is currently serviced by two overburden wells that tap into a gravel aquifer. While the Town of Mattawa has experienced a population decline of 11.8%, between 2001 and 2006 (Statistics Canada, 2007), WHI and TCL (2006) does not anticipate a significant change in population in the upcoming years. As a result, the Tier 1 Water Budget has only been conducted using current population estimates.

4.1. WATER BUDGET ELEMENTS

Water budget elements, including precipitation, AET, surplus, recharge, and runoff were estimated using the methodology described in Section 3.0. Table 4 summarizes these parameters.

The resultant values are very similar (+/-5%) to those estimated in Gartner Lee Ltd. (2007) for the same regions.

Table 4: Estimated Water Budget Elements (Mattawa)

Month	Precipitation (mm)	AET (mm)	Surplus (mm)	Recharge (mm)	Runoff (mm)
January	64.8	0.0	64.8	1.8	2.0
February	49.8	0.0	49.8	0.9	1.0
March	64.7	0.0	64.7	0.5	0.5
April	64.9	20.7	44.2	27.2	29.7
May	81.5	76.2	5.3	80.4	87.8
June	88.4	106.4	0.0	40.2	43.9
July	95.4	117.1	0.0	20.1	21.9
August	94.3	99.9	0.0	10.0	11.0
September	109.5	67.0	0.0	5.0	5.5
October	92.5	29.9	59.7	16.8	18.3
November	92.7	0.0	92.7	8.4	9.2
December	70.7	0.0	70.7	3.6	4.0
Total	**969.1**	**517.2**	**451.9**	**214.9**	**234.6**
Gartner Lee (2007)	966	535	431	206	225

Total annual surplus should theoretically equal stream flow (Gartner Lee Ltd., 2007). Analysis of continuous stream flow data collected at Environment Canada/Water Survey of Canada gauge 02JE020 (Mattawa River below Bouillon Lake; Figure 1) yields a total annual surplus of 452 mm. The total surplus predicted by the Thornthwaite-Mather soil moisture budget conducted by WESA also yielded a total annual surplus of 452 mm. The extremely close agreement between these two methods, as well as the close correlation between results obtained by WESA and Gartner Lee Ltd. (2007), provides a high level of confidence in the water balance.

Total surplus was partitioned into recharge and runoff using a partitioning coefficient. A recharge partitioning coefficient of 0.478 was used based on Gartner Lee Ltd. (2007). This resulted in annual recharge and runoff of 215 and 235 mm, respectively. These values are approximately 4% higher than Gartner Lee Ltd. (2007) due to higher surplus resulting from lower AET. It should be noted that the sum of the recharge and runoff total 450 mm, while the total annual surplus is 452 mm. This discrepancy is due to rounding errors in the spreadsheet model during the calculation of monthly recharge and runoff.

4.2. Water Supply

The groundwater supply is the water available for a subwatershed's groundwater users. Module 7 of the MOE Assessment Report Guidance Documents (MOE, 2007) recommends against using baseflow separation to determine groundwater supply if there are significant streamflow regulation structures in the watershed of interest. The Town of Mattawa municipal supply subwatershed contains three such structures: Turtle Lake Dam, Talon Lake Dam, and the Hurdman Dam. The Turtle Lake and Hurdman Dams are spill dams, and in addition, the Hurdman Dam (located 2 km upstream of the Town of Mattawa) holds back a significant amount of water, forming Chant Plain Lake (Gartner Lee Ltd., 2007). Consequently, groundwater supply was estimated to equal recharge as determined using the soil moisture spreadsheet model described in Section 3.1.

Annual recharge was estimated to be 214.6 mm, which results in an average monthly recharge of 17.9 mm. Considering the area of the subwatershed (239.8412 km^2), the average groundwater supply is 1.632 m^3/s. Lateral groundwater flow was assumed to be negligible.

4.3. Water Reserve

As described in Section 3.2.2, groundwater reserve was estimated as 10% of the recharge, where recharge is assumed equal between months. The average annual water reserve is 21.46 mm and monthly water reserve is 1.79 mm, or 0.16 m^3/s.

4.4. Water Demand

Using the approach and assumptions described in Section 3.0, water use was estimated from the relevant datasets available for the study area. The results, compiled on monthly and annual scales, are reported in the form of figures and tables and discussed in this section.

4.4.1. Municipal and Communal Water Demand

Municipal and communal use was determined using the 2004 Environment Canada Municipal Water and Wastewater Survey (Environment Canada, 2004b) as well as the PTTW database. Municipal and communal water takings include all municipal wells (for which actual water use data are available) and other permitted communal takings contained in the PTTW database, such as campgrounds. The only permitted communal taking is associated with Samuel de Champlain Provincial Park.

Water takings and returns were divided between deep groundwater, shallow groundwater, and surface water. The following assumptions were made:

- Most private wells are completed in bedrock, while municipal wells are completed in the overburden (WHI and TCL, 2006), therefore, it was assumed that takings are from deep groundwater and shallow groundwater, respectively.

- 2004 actual municipal water use values used (753,572 m^3/yr) to be consistent with other values in the Municipal Water and Wastewater Survey and provide a conservative estimate of use (average use between 1997 and 2007 was 703,432 m^3/yr).
- Municipal water consumed includes water from population with sewage haulage.
- Municipal system losses are returned to shallow groundwater through infiltration.
- Communal water returns are to shallow groundwater by infiltration through septic beds and infiltration of surface runoff.
- Environment Canada (2004b) states that 99% of serviced residents are on sewers and 0.8% are on septic. The remaining 0.2% was assumed to return to surface water.

Gross takings for municipal/communal use are approximately 698,765 m^3/yr. Of the gross municipal/communal takings, approximately 80,005 m^3/yr (11%) is consumed, and not returned to the subwatershed. Municipal and communal water takings make up approximately 57% of the total gross water takings in the subwatershed and accounts for approximately 29% of the water consumed.

Municipal and communal water takings comprise groundwater takings from municipal wells for serviced residents (339,107 m^3/yr), groundwater takings from municipal wells that are lost to the system (301,429 m^3/yr), and takings from both groundwater and surface water for communal use (Samuel de Champlain Provincial Park; 58,229 m^3/yr). Table 5 summarizes these results. Groundwater is the source of 95% of municipal and communal takings (698,765 m^3/yr). The municipal and communal water returns are primarily to shallow groundwater (88%).

Table 5: Municipal and Communal Takings (Mattawa)

General Use	Specific Source/Use	Gross Takings (m^3/yr)	Consumed (m^3/yr)	% Consumed
Municipal	Municipal GW to serviced residents	339,107	68,359	9.8
Municipal	System Losses	301,429	0	0.0
Communal	Communal - permitted (groundwater)	25,229	5,046	0.7
Communal	Communal - permitted (surface water)	33,000	6,600	0.9
Total		698,765	80,005	11.4

Note:
The % consumed is the percent of total gross takings that are consumed by each specific source/use.

4.4.2. INDUSTRIAL AND COMMERCIAL WATER USE

Water use results for the industrial and commercial sectors were estimated from the 2004 Environment Canada Municipal Water and Wastewater Survey (Environment Canada, 2004b) and through review of the PTTW database.

The PTTW database yielded one result for the industrial sector (manufacturing; permit number 98-SP-5023). The gross water taking for this permit was 355,875 m^3/yr and 88,969 m^3/yr (25%) is consumed. The Municipal Water and Wastewater Survey stated that 15% of the permitted municipal takings go to the industrial/commercial sector (Environment Canada, 2004b). The gross permitted municipal takings for 2004 were 753,572 m^3. Consequently, it was determined that approximately 113,036 m^3/year is for industrial/commercial use. Since consumption factors for these sectors range from 0.2 to 1.0 and the specific water uses are not known, a conservative consumptive factor of 0.5 was applied to the data to determine the consumptive use of 56,518 m^3/yr. It was assumed that water returns (56,518 m^3/yr) are to surface water.

Total gross industrial/commercial water takings are 468,911 m^3/yr, of which 145,487 m^3/yr are consumed. This is approximately 38% of the total gross water takings in the subwatershed and only 0.1% of the total water consumed.

4.4.3. OTHER PERMITTED WATER USE

There are no additional permits for the Town of Mattawa municipal water supply subwatershed in the PTTW database.

4.4.4. DOMESTIC WATER USE FROM PRIVATE WATER SUPPLIES

Statistics Canada data indicates the population of the Town of Mattawa was 2,003 in 2006. Of this population, 0.1 % are supplied by private wells, with a total gross water taking of 128 m^3/yr. It is assumed that domestic use from outside the Town of Mattawa is negligible. Using a consumptive factor of 0.2, it was estimated that 26 m^3/yr is consumed. It is assumed that the remaining water is returned via septic systems to the shallow groundwater.

4.4.5. AGRICULTURAL WATER USE

Tables 6 and 7 summarize calculations and results for this sector. The following assumptions were made during the analysis of agricultural water use:

- Water use for livestock is constant throughout the year, while water taken for crop irrigation is isolated to July and August (MOE, 2007).
- 100% of the water taken for livestock irrigation is consumed, while 80% of water used for crop irrigation is consumed (MOE, 2007).
- Water taking is from deep groundwater (to be consistent with private domestic wells).
- Water not consumed is assumed to return to shallow groundwater through infiltration.

Gross water takings for agricultural purposes are estimated at 52,517 m^3/yr, where livestock irrigation and crop irrigation are 46,748 and 5,769 m^3/yr, respectively. Total agricultural demand comprises approximately 4% of the total water takings and 18% of the total consumption (consuming 10% of the gross water takings).

Table 6: Statistics Canada Agricultural Census Data and Water Requirements - Crop Irrigation (Mattawa)

Statistics Canada Consolidated Census Subdivision (CCS)	Total Estimated Water Use	Total Estimated Water Consumption	Total vegetables (excluding greenhouse vegetables)			Fruits, Berries and Nuts			Nursery products and Sod			Greenhouse Products		
			822 m³/acre/yr [8 in./yr]			1233 m³/acre/yr [12 in./yr]			1233 m³/acre/yr [12 in./yr]			0.15 m³/m² [6 in./yr]		
	m³/year	m³/year	farms reporting	acres	Water consumption (m³/yr)	farms reporting	acres	Water consumption (m³/yr)	farms reporting	acres	Water consumption (m³/yr)	farms reporting	square metres	Water consumption (m³/yr)
East Ferris - CCS (350548034)	5,756	4,605	4	7	5,756	1	x	x	1	x	x	2	x	x
Calvin - CCS (350548022)	x	x	2	x	x	0	0	x	0	0	x	1	x	x
Bonfield - CCS (350548027)	x	x	1	x	x	1	x	x	1	x	x	1	x	x

Notes:
Other types of crops do not typically require irrigation (Hay and field crops; Christmas trees; Maple trees), and are not listed in this table
x - suppressed to meet the confidentiality requirements of the Statistics Act
Source: Statistics Canada, 2006 Census of Agriculture, Farm Data and Farm Operator Data, catalogue no. 95-629-XWE.
Typical water consumption from OMAFRA Best Management Practices

Table 7: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Mattawa)

Statistics Canada Consolidated Census Subdivision (CCS)	Total cattle and calves			Total pigs			Total sheep and lambs		
	53.9 L/d			5.93 L/d			7.16 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
East Ferris - CCS (350548034)	10	327	17,625	2	x		2	x	
Calvin - CCS (350548022)	25	827	44,575	3	x		2	x	
Bonfield - CCS (350548027)	21	1,073	57,835	2	x		3	x	
Total	56	2,227	120,035	7	x		7	x	

Table 7: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Mattawa), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Total hens and chickens			Horses and ponies			Goats		
		0.226 L/d		32.67 L/d			9.475 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
East Ferris - CCS (350548034)	6	371	84	6	60	1,960	2	x	
Calvin - CCS (350548022)	8	342	77	15	100	3,267	2	x	
Bonfield - CCS (350548027)	9	603	136	10	77	2,516	1	x	
Total	23	1,316	297	31	237	7,743	5	x	

Table 7: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Mattawa), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Wild boars 36.005 L/d			Bison (buffalo) 45.48 L/d			Llamas and alpacas 9.475 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
East Ferris - CCS (350548034)	0	0	0	0	0	0	2	x	
Calvin - CCS (350548022)	0	0	0	x			0	0	0
Bonfield - CCS (350548027)	0	0	0	0	0	0	1	x	
Total	0	0	0	0	0	0	3	0	0

Table 7: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Mattawa), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Deer (excluding wild deer) 9.475 L/d			Elk 22.74 L/d			Estimated Water Consumption - Livestock
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	m^3/year
East Ferris - CCS (350548034)	1	x		0	0	0	7,179
Calvin - CCS (350548022)	1	x		0	0	0	17,491
Bonfield - CCS (350548027)	1	x		0	0	0	22,078
Total	3	x		0	0	0	46,748

Notes:
Agricultural Census data not available for divisions smaller than CD
For a conservative water use estimate, the water use values for each CCS have not been prorated based on the % inclusion in the study watershed. This is due to CCS amalgamation by Statistics Canada.
x - suppressed to meet the confidentiality requirements of the *Statistics Act*

4.4.6. COMBINED WATER USE – ALL SECTORS

The water use results developed for each of the sectors and presented above were amalgamated to estimate the cumulative water use for each of the systems (surface water, shallow groundwater, and deep groundwater). Results from all sectors are summarized on an annual scale in Tables 8a, b and c and graphically on Figure 6.

Of the gross annual water takings within the study area, 97% are from groundwater; 93% from shallow groundwater and 4% from deep groundwater. The remaining 3% of takings are from surface water. Municipal/communal takings account for 57% of gross water takings while industrial/commercial accounts for 38%, and agricultural for 4%.

For total water consumed, 79% comes from shallow groundwater, 19% from deep groundwater and 2% from surface water. Surface water receives 63% of water returns, while shallow groundwater receives 37%, assumed to be primarily through infiltration and septic systems (it is assumed that water lost to the system is lost through leakage and returns to the shallow groundwater through infiltration). This is consistent with the mostly rural nature of the region. Returns to surface water are concentrated in the areas serviced by sewers.

Table 9 compiles net water takings for each of the systems. Positive values indicate that returns exceed takings. This is the case for surface water where an excess of 559,540 m^3 are returned annually. Both the shallow and deep groundwater systems have more water taken than returned: 783,238 and 52,645 m^3/yr, respectively. The net water takings exceed returns by 276,343 m^3/yr.

Table 8a: Annual Water Use Results - Gross Takings (Mattawa)

Reservoir	Gross Annual Takings (m^3)					TOTAL
	Permitted Takings			Non-Permitted		
	Municipal and Communal[a]	Industrial and Commercial[b]	Other Permitted	Private Domestic	Agricultural[c]	
Surface Water	33,000					**33,000**
Shallow Groundwater	665,765	468,911				**1,134,676**
Deep Groundwater				128	52,517	**52,645**
TOTAL	**698,765**	**468,911**	**0**	**128**	**52,517**	**1,220,321**

Table 8b: Annual Water Use Results – Consumption (Mattawa)

Reservoir	Annual Consumed (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal[d]	Industrial and Commercial	Other Permitted	Private Domestic	Agricultural	
Surface Water	6,600					**6,600**
Shallow Groundwater	72,867	145,487				**218,354**
Deep Groundwater				26	51,363	**51,389**
TOTAL	**79,467**	**145,487**	**0**	**26**	**51,363**	**276,343**

Table 8c: Annual Water Use Results – Returns (Mattawa)

Reservoir	Annual Returned (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal	Industrial and Commercial[b]	Other Permitted	Private Domestic[e]	Agricultural	
Surface Water	269,116	323,424				592,540
Shallow Groundwater	350,182			102	1,154	351,438
Deep Groundwater						0
TOTAL	619,298	323,424	0	102	1,154	943,977

Notes:

[a] Includes system losses, which are assumed to return to surface water

[b] Assume industrial and commercial water comes from shallow groundwater and returns to surface water through sewer service

[c] Assume agricultural water comes from deep groundwater, since assuming source is same as private wells, and most private domestic wells are in deep bedrock

[d] Assume remaining 0.2% returns to surface water (99% on sewer and 0.8% on septic)

[e] Assume returns from private domestic wells discharges through septic systems to shallow groundwater

Table 9: Net Water Takings (Mattawa)

Reservoir	Net Water Takings (m³)
Surface Water	559,540
Shallow Groundwater	-783,238
Deep Groundwater	-52,645
TOTAL	-276,343

Note:
Positive values indicate that returns exceed takings

4.4.7. Monthly Water Demand

Monthly water use results, including gross, consumed, and returned water are shown in Tables 10a, b, and c and graphically on Figures 7a, b, and c. Results are compiled for each month and show details for each system (surface water, shallow groundwater, and deep groundwater).

There is not a significant difference in water demand between months as municipal/communal and industrial/commercial water use is consistent throughout the year. There is a slight increase in demand in July and August as a result of water used for crop irrigation.

Table 10a: Monthly Water Use Results - Gross Takings (Mattawa)

Reservoir	Monthly Gross Water Takings (m^3)												Annual Gross Water Takings (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	0	0	0	0	6,820	6,600	6,820	6,820	5,940	0	0	0	33,000
Shallow Groundwater	96,370	87,044	96,370	93,261	96,370	93,261	96,370	96,370	93,261	96,370	93,261	96,370	1,134,675
Deep Groundwater	3,981	3,596	3,981	3,853	3,981	3,853	6,865	6,866	3,853	3,981	3,853	3,981	52,645

Table 10b: Monthly Water Use Results– Consumptive Takings (Mattawa)

Reservoir	Monthly Consumptive Water Takings (m^3)												Annual Consumptive Water Takings (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	0	0	0	0	1,364	1,320	1,364	1,364	1,188	0	0	0	6,600
Shallow Groundwater	18,545	16,750	18,545	17,947	18,545	17,947	18,545	18,545	17,947	18,545	17,947	18,545	218,354
Deep Groundwater	3,973	3,588	3,973	3,844	3,973	3,844	6,280	6,280	3,844	3,973	3,844	3,973	47,927

Table 10c: Monthly Water Use Results– Returns (Mattawa)

Reservoir	Monthly Water Returns (m^3)												Annual Water Returns (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	50,325	45,455	50,325	48,702	50,325	48,702	50,325	50,325	48,702	50,325	48,702	50,325	621,742
Shallow Groundwater	27,508	24,846	27,508	26,621	32,964	31,901	33,541	33,541	31,373	27,508	26,621	27,508	325,697
Deep Groundwater	0	0	0	0	0	0	0	0	0	0	0	0	0

4.5. Groundwater Stress Assessment

Groundwater stress is determined by examining the ratio of water demand (water takings) to water supply, while considering in the reserve water required to maintain ecosystem function (MOE, 2007). The percent water demand is compared to a stress threshold (Table 3) to determine the stress level.

The annual and maximum monthly percent groundwater demand for the Town of Mattawa supply subwatershed are 0.58% and 0.64%, respectively. Table 11 presents the monthly and annual demand, supply and reserve values used to calculate the percent demand.

A subwatershed is considered low stress if the average annual percent demand is less than or equal to 10% and if the maximum monthly percent demand is less than or equal to 25%. As a result, the Town of Mattawa municipal supply subwatershed is considered low stress and does not require a Tier 2 Water Budget.

Table 11: Percent Groundwater Demand (Mattawa)

Month	Consumption	Supply	Reserve	%Demand
January	0.09	17.9	1.79	0.58
February	0.08	17.9	1.79	0.53
March	0.09	17.9	1.79	0.58
April	0.09	17.9	1.79	0.56
May	0.09	17.9	1.79	0.58
June	0.09	17.9	1.79	0.56
July	***0.10***	***17.9***	***1.79***	***0.64***
August	***0.10***	***17.9***	***1.79***	***0.64***
September	0.09	17.9	1.79	0.56
October	0.09	17.9	1.79	0.58
November	0.09	17.9	1.79	0.56
December	0.09	17.9	1.79	0.58
Annual	**1.12**	**215**	**21.5**	**0.58**

Note:
Bold italics indicates months with maximum monthly percent demand.

5.0 MUNICIPALITY OF POWASSAN GROUNDWATER SUPPLY WATERSHED RESULTS AND DISCUSSION

The Municipality of Powassan has an area of approximately 228.8 km^2, of which the majority is designated as rural areas. This includes agriculture, conservation, recreation, tourism, resource harvesting, existing landfill sites, and some housing (NBMCA, 2007). The portion of the South River Watershed that contributes to the groundwater intake for Powassan is approximately 70.1 km^2 in area (Figure 1). Municipal drinking water for the Municipality of Powassan is currently serviced by two overburden wells that tap into a gravel aquifer. The Municipality of Powassan has experienced a population decline of 1.8%, between 2001 and 2006, but had previously experienced an increase of 1.8% between 1996 and 2001, resulting in a stable population over the 10-year period (NBMCA, 2007; Statistics Canada, 2007). In addition, the municipality does not anticipate a significant change in population or in pumping rates in the upcoming years (WHI and TCL, 2006). As a result, the Tier 1 Water Budget has been conducted using current population estimates.

5.1. Water Budget Elements

Water budget elements, including precipitation, AET, surplus, recharge and runoff were estimated using the methodology described in Section 3.0. Table 12 summarizes these parameters. These values are similar to those estimated in Gartner Lee Ltd. (2007) for the same regions.

While total annual surplus should theoretically equal stream flow (Gartner Lee Ltd., 2007), there is no recent stream flow data within the Powassan municipal supply subwatershed. Data from gauge 02DD001, South River at Powassan ends in 1936; therefore, it does not necessarily represent current flow conditions. Environment Canada/Water Survey of Canada gauge 02DD009 (South River at South River) is approximately located at the inlet of the Powassan municipal supply subwatershed; therefore, it is likely a close approximation of the conditions within the Powassan subwatershed. Analysis of continuous stream flow data collected at this gauge yields a total annual surplus of 435 mm. The total surplus predicted by the Thornthwaite-Mather soil moisture budget conducted by WESA on the Powassan subwatershed yielded a total annual surplus of 455 mm. Gartner Lee Ltd. (2007) estimated the surplus in a comparable location to be 430 mm. The primary cause for the difference is that the precipitation predicted by the WESA GIS model was 34 mm greater than that predicted by Gartner Lee Ltd. (2007). All water budget parameters estimated by WESA are within 6% of those estimated by Gartner Lee Ltd. (2007). The close agreement between the results obtained by WESA and Gartner Lee Ltd. (2007) provides a high level of confidence in the water balance.

Total surplus was partitioned into recharge and runoff using a partitioning coefficient of 0.403 was used based on Gartner Lee Ltd. (2007). This resulted in annual recharge and runoff of 183 and 271 mm, respectively. These values are approximately 5% higher than Gartner Lee Ltd. (2007) due to higher predicted precipitation. It should be noted that the sum of the recharge and runoff total 454 mm, while the total annual surplus is 455 mm. This discrepancy is due to rounding errors in the spreadsheet model during the calculation of monthly recharge and runoff.

Table 12: Estimated Water Budget Elements (Powassan)

Month	Precipitation (mm)	AET (mm)	Surplus (mm)	Recharge (mm)	Runoff (mm)
January	64.9	0.0	68.5	1.7	2.5
February	51.9	0.0	53.0	0.8	1.2
March	62.9	0.0	63.4	0.4	0.6
April	66.1	24.9	41.6	22.3	33.1
May	82.8	76.9	6.2	67.5	99.9
June	89.0	106.5	0.0	33.7	50.0
July	99.5	119.6	0.0	16.9	25.0
August	94.6	103.9	0.0	8.4	12.5
September	112.3	68.8	0.8	4.4	6.5
October	95.6	32.0	64.9	15.3	22.6
November	86.7	0.0	89.2	7.6	11.3
December	64.3	0.0	67.3	3.8	5.7
Total	**970.7**	**532.7**	**454.9**	**182.8**	**270.8**
Gartner Lee (2007)	936	539	430	173	257

5.2. Water Supply

The groundwater supply is the water available for a subwatershed's groundwater users. Module 7 of the MOE Assessment Report Guidance Documents (MOE, 2006) recommends against using baseflow separation to determine groundwater supply if there are no significant streamflow regulation structures in the watershed of interest. The Municipality of Powassan municipal supply subwatershed contains two such structures: Elliot Chute, and Bingham Chute. Elliot Chute and Bingham Chute host small hydroelectric generating stations (Gartner Lee Ltd., 2007). It is assumed that groundwater flow into the subwatershed is negligible as the Powassan municipal supply subwatershed is bounded by the South River Reservoir on the downstream side and flow divides on the upstream sides. Groundwater supply has, instead, been estimated to equal recharge as determined using the soil moisture spreadsheet model described in Section 3.1.

Annual recharge was estimated to be 183 mm, which results in an average monthly recharge of 15.2 mm. Considering the area of the subwatershed (70.1 km^2), the average groundwater supply is 0.406 m^3/s. Lateral groundwater flow was assumed to be negligible.

5.3. Water Reserve

As described in Section 3.2.2, groundwater reserve was estimated as 10% of the recharge, where recharge is assumed equal between months. Average annual water reserve is 18.3 mm and monthly water reserve is 1.52 mm, or 0.0406 m^3/s.

5.4. Water Demand

Using the approach and assumptions described in Section 3.0, water demand was estimated from the relevant datasets available for the study area. The results, compiled on monthly and annual scales, are reported in the form of figures and tables and discussed in this section.

5.4.1. Municipal and Communal Water Demand

Municipal and communal use was determined using the 2004 Environment Canada Municipal Water and Wastewater Survey (Environment Canada, 2004b) as well as the PTTW database. Municipal and communal water takings include all municipal wells (for which actual water use data are available) and other permitted communal takings contained in the PTTW database, such as campgrounds. There were no permitted communal takings located within the Powassan supply subwatershed.

Water takings and returns were divided between deep groundwater, shallow groundwater, and surface water. The following assumptions were made:

- Most private wells are completed in bedrock, while municipal wells are completed in the overburden (WHI and TCL, 2006), therefore, it was assumed that takings are from deep groundwater and shallow groundwater, respectively
- Municipal water consumed includes water from population with sewage haulage
- Municipal system losses are returned to shallow groundwater through infiltration

Gross takings for municipal/communal use are approximately 164,219 m^3/yr. Of the gross municipal/communal takings, approximately 162,047 m^3/yr (99%) is consumed. The high percentage of consumption is due to the fact that municipal water is returned to a lagoon that discharges to Lake Nipissing, which is not within the Powassan Municipal Intake Watershed, therefore it is considered lost to the watershed in question (i.e., consumed). Municipal and communal water takings make up approximately 68% of the total gross water takings in the subwatershed and 68% of the water consumed.

Municipal and communal water takings comprise groundwater takings from municipal wells for serviced residents (162,047 m^3/yr) and groundwater takings from municipal wells that are lost to the system (2,171 m^3/yr). Table 13 summarizes these results. Groundwater is the source of 100% of municipal and communal takings. Water considered lost to the municipal system is assumed to return to shallow groundwater through infiltration of runoff caused by leakage.

Table 13: Municipal and Communal Takings (Powassan)

General Use	Specific Source/Use	Gross Takings (m^3/yr)	Consumed (m^3/yr)	% Consumed
Municipal	Municipal groundwater to serviced residents	162,047	162,047	98.7
Municipal	System Losses	2,171	0	0.0
Total		164,219	162,047	98.7

Note:
Municipal water (to serviced residents) is consumed with respect to the subwatershed of interest. Water not consumed through the "consumptive factor" is returned to a lagoon that discharges to L. Nipissing, which is not in the Powassan Municipal Intake Watershed, therefore it is considered lost to the watershed in question (i.e., consumed)

5.4.2. Industrial and Commercial Water Use

Water use results for the industrial and commercial sectors were estimated from the 2004 Environment Canada Municipal Water and Wastewater Survey (Environment Canada, 2004b) and through review of the PTTW database.

The PTTW database did not yield any results for the industrial sector. The Municipal Water and Wastewater Survey stated that 0% of the permitted municipal takings go to the industrial/commercial sector (Environment Canada, 2004b).

5.4.3. Other Permitted Water Use

There are no additional permits for the Municipality of Powassan municipal water supply subwatershed in the PTTW database.

5.4.4. Domestic Water Use from Private Water Supplies

Statistics Canada data indicates the population of the Municipality of Powassan was 3,309 in 2006. Of this population, 46 % are supplied by private wells, with a total gross water taking of 97,227 m^3/yr. It is assumed that domestic use from outside the Municipality of Powassan is negligible. Using a consumptive factor of 0.2, it was estimated that 19,445 m^3/yr is consumed. It is assumed that the remaining water is returned via septic systems to the shallow groundwater.

5.4.5. Agricultural Water Use

Tables 14 and 15 summarize calculations and results for this sector. The following assumptions were made during the analysis of agricultural water use:

- Water use for livestock is constant throughout the year, while water taken for crop irrigation is isolated to July and August (MOE, 2007);

- 100% of the water taken for livestock irrigation is consumed, while 80% of water used for crop irrigation is consumed (MOE, 2007);
- Water taking is from deep groundwater (to be consistent with private domestic wells);
- Water not consumed is assumed to return to shallow groundwater through infiltration

Gross water takings for agricultural purposes are utilized entirely for livestock irrigation (as crop data were suppressed to meet confidentiality requirements of the Statistics Act and are therefore assumed negligible) and are estimated at 75,760 m^3/yr. Total agricultural demand comprises approximately 32% of the total water takings and total consumption.

Table 14: Statistics Canada Agricultural Census Data and Water Requirements - Crop Irrigation (Powassan)

Statistics Canada Consolidated Census Subdivision (CCS)	Total Estimated Water Consumption	Total vegetables (excluding greenhouse vegetables)			Fruits, Berries and Nuts			Nursery products and Sod			Greenhouse Products		
		822 m³/acre/yr [8 in./yr]			1233 m³/acre/yr [12 in./yr]			1233 m³/acre/yr [12 in./yr]			0.15 m³/m² [6 in./yr]		
	m³/year	farms reporting	acres	Water consumption (m³/yr)	farms reporting	acres	Water consumption (m³/yr)	farms reporting	acres	Water consumption (m³/yr)	farms reporting	square metres	Water consumption (m³/yr)
Powassan - CCS (350349060)	x	2	x		2	x		0	0	0	0	0	0
Machar - CCS (350349054)	x	0	0	0	1	x		0	0	0	1	x	
Calvin - CCS (350548022)	x	2	x		0	0		0	0		1	x	
Chisholm - CCS (350548031)	x	0	0	0	1	x		0	0		0	0	

Notes:
Other types of crops do not typically require irrigation (Hay and field crops; Christmas trees; Maple trees), and are not listed in this table
x - suppressed to meet the confidentiality requirements of the Statistics Act
Source: Statistics Canada, 2006 Census of Agriculture, Farm Data and Farm Operator Data, catalogue no. 95-629-XWE.
Typical water consumption from OMAFRA Best Management Practices

Table 15: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Powassan)

Statistics Canada Consolidated Census Subdivision (CCS)	Total cattle and calves			Total pigs			Total sheep and lambs		
	53.9 L/d			5.93 L/d			7.16 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
Powassan - CCS (350349060)	32	1,650	88,935	6	x		3	x	
Machar - CCS (350349054)	6	170	9,163	2	x		1	x	
Calvin - CCS (350548022)	25	827	44,575	3	x		2	x	
Chisholm - CCS (350548031)	24	847	45,653	3	x		5	274	1,962
Total	87	3,494	188,327	14	0	0	11	274	1,962

Table 15: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Powassan), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Total hens and chickens			Horses and ponies			Goats		
	0.226 L/d			32.67 L/d			9.475 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
Powassan - CCS (350349060)	12	791	179	20	158	5,162	3	23	218
Machar - CCS (350349054)	4	144	33	7	72	2,352	4	15	142
Calvin - CCS (350548022)	8	342	77	15	100	3,267	2	x	
Chisholm - CCS (350548031)	13	409	92	26	176	5,750	2	x	
Total	37	1,686	381	68	506	16,531	11	38	360

Table 15: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Powassan), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Wild boars 36.005 L/d			Bison (buffalo) 45.48 L/d			Llamas and alpacas 9.475 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
Powassan - CCS (350349060)	0	0	0	x			2	x	
Machar - CCS (350349054)	0	0	0	0	0	0	0	0	0
Calvin - CCS (350548022)	0	0	0	x			0	0	0
Chisholm - CCS (350548031)	0	0	0	0	0	0	1	x	
Total	0	0	0	0	0	0	3	0	0

Table 15: Statistics Canada Agricultural Census Data and Water Requirements - Livestock Irrigation (Powassan), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Deer (excluding wild deer) 9.475 L/d			Elk 22.74 L/d			Estimated Water Consumption - Livestock
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	m^3/year
Powassan - CCS (350349060)	0	0	0	0	0	0	34,490
Machar - CCS (350349054)	0	0	0	0	0	0	4,267
Calvin - CCS (350548022)	1	x		0	0	0	17,491
Chisholm - CCS (350548031)	0	0	0	0	0	0	19,512
Total	1	0	0	0	0	0	75,760

Notes:

Agricultural Census data not available for divisions smaller than CD

For a conservative water use estimate, the water use values for each CCS have not been prorated based on the % inclusion in the study watershed. This is due to CCS amalgamation by Statistics Canada.

x - suppressed to meet the confidentiality requirements of the *Statistics Act*

5.4.6. Combined Water Use – All Sectors

The water use results developed for each of the sectors and presented above were amalgamated to estimate the cumulative water use for each of the systems (surface water, shallow groundwater, and deep groundwater). Results from all sectors are summarized on an annual scale in Table 16a, b and c and graphically on Figure 8.

All of the gross annual water takings within the study area are from groundwater; 49% from shallow groundwater (municipal takings) and 51% from deep groundwater (private domestic and agricultural takings).

Of total water consumed, 63% comes from shallow groundwater and the remaining 37% from deep groundwater. Municipal water to serviced residents is 100% consumed with respect to the subwatershed of interest. Water not consumed through the "consumptive factor" is returned to a lagoon for treatment that discharges to Lake Nipissing, which is not in the Powassan Municipal Intake Watershed; therefore it is considered lost to the watershed in question (i.e., consumed) All water that is not consumed is assumed to be returned to shallow groundwater through infiltration and septic systems (it is assumed that water lost to the system is lost through leakage and returns to the shallow groundwater through infiltration). This is consistent with the mostly rural nature of the region.

Table 17 compiles the net water takings for each of the systems. There is a net taking from groundwater of approximately 257,224 m^3/yr. Both the shallow and deep groundwater systems have more water taken than returned; 84,237 and 172,987 m^3/yr, respectively.

Table 16a: Annual Water Use Results - Gross Takings (Powassan)

Reservoir	Gross Annual Takings (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal[a]	Industrial and Commercial[b]	Other Permitted	Private Domestic	Agricultural[c]	
Surface Water						0
Shallow Groundwater	164,219					164,219
Deep Groundwater				97,227	75,760	172,987
TOTAL	164,219	0	0	97,227	75,760	337,206

Table 16b: Annual Water Use Results - Consumption (Powassan)

Reservoir	Annual Consumed (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal	Industrial and Commercial	Other Permitted	Private Domestic	Agricultural	
Surface Water						0
Shallow Groundwater	162,047					162,047
Deep Groundwater				19,445	75,760	95,205
TOTAL	162,047	0	0	19,445	75,760	257,252

Table 16c: Annual Water Use Results - Returns (Powassan)

Reservoir	Annual Returned (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal[d]	Industrial and Commercial[b]	Other Permitted	Private Domestic[e]	Agricultural	
Surface Water						0
Shallow Groundwater	2,201			77,782		79,983
Deep Groundwater						0
TOTAL	**2,201**	**0**	**0**	**77,782**	**0**	**79,983**

Notes:

[a] Includes system losses, which are assumed to return to surface water

[b] Assume industrial and commercial water comes from shallow groundwater and returns to SW through sewer service

[c] Assume agricultural water comes from deep groundwater, since assuming source is same as private wells, and most private domestic wells are in deep bedrock

[d] Assume remaining 0.2% returns to surface water (99% on sewer and 0.8% on septic)

[e] Assume returns from private domestic wells discharges through septic systems to shallow groundwater

Table 17: Net Water Takings (Powassan)

Reservoir	Net Water Takings (m^3)
Surface Water	0
Shallow Groundwater	-84,236
Deep Groundwater	-172,987
TOTAL	-257,223

Note:

Positive values indicate that returns exceed takings

5.4.7. Monthly Water Demand

Monthly water use was nearly constant between months, since there are no seasonal uses (differing only due to the number of days in each month). Monthly takings from shallow groundwater range from 12,598 to 13,947 m^3, while takings from deep groundwater range from 13,270 to 14,692 m^3. Tables 18a, b and c, and Figures 9a, b and c show monthly water use results, including gross, consumed, and returned water.

Table 18a: Monthly Water Use Results - Gross Takings (Powassan)

Reservoir	Monthly Gross Water Takings (m^3)												Annual Gross Water Takings (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Shallow Groundwater	13,947	12,598	13,947	13,497	13,947	13,497	13,947	13,947	13,497	13,947	13,497	13,947	164,219
Deep Groundwater	14,692	13,270	14,692	14,218	14,692	14,218	14,692	14,692	14,218	14,692	14,218	14,692	172,987

Table 18b: Monthly Water Use Results - Consumption (Powassan)

Reservoir	Monthly Consumptive Water Takings (m^3)												Annual Consumptive Water Takings (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Shallow Groundwater	13,763	12,431	13,763	13,319	13,763	13,319	13,763	13,763	13,319	13,763	13,319	13,763	162,047
Deep Groundwater	8,086	7,303	8,086	7,825	8,086	7,825	8,086	8,086	7,825	8,086	7,825	8,086	95,205

Table 18c: Monthly Water Use Results - Returns (Powassan)

Reservoir	Monthly Water Returns (m^3)												Annual Water Returns (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Shallow Groundwater	6,791	6,133	6,791	6,571	6,791	6,571	6,791	6,791	6,571	6,791	6,571	6,791	79,953
Deep Groundwater	0	0	0	0	0	0	0	0	0	0	0	0	0

5.5. Groundwater Stress Assessment

Groundwater stress is determined by examining the ratio of water demand (water takings) to water supply, while considering in the reserve required to maintain ecosystem function (MOE, 2007). The percent water demand is compared to a stress threshold (Table 3) to determine the stress level.

The annual and maximum monthly percent groundwater demand for the Municipality of Powassan supply subwatershed are 2.23% and 2.27%, respectively. Table 19 presents the monthly and annual demand, supply, and reserve values used to calculate the percent demand.

A subwatershed is considered low stress if the average annual percent demand is between 0 and 10% and if the maximum monthly percent demand is between 0 and 25%. As a result, the Municipality of Powassan municipal supply subwatershed is considered low stress and does not require a Tier 2 Water Budget.

Table 19: Percent Groundwater Demand (Powassan)

Month	Consumption	Supply	Reserve	%Demand
January	***0.312***	***15.2***	***1.52***	***2.27***
February	0.282	15.2	1.52	2.05
March	***0.312***	***15.2***	***1.52***	***2.27***
April	0.302	15.2	1.52	2.20
May	***0.312***	***15.2***	***1.52***	***2.27***
June	0.302	15.2	1.52	2.20
July	***0.312***	***15.2***	***1.52***	***2.27***
August	***0.312***	***15.2***	***1.52***	***2.27***
September	0.302	15.2	1.52	2.20
October	***0.312***	***15.2***	***1.52***	***2.27***
November	0.302	15.2	1.52	2.20
December	***0.312***	***15.2***	***1.52***	***2.27***
Annual	**3.67**	**183**	**18.3**	**2.23**

Note:
Bold italics indicates months with maximum monthly percent demand.

6.0 VILLAGE OF SOUTH RIVER SURFACE WATER SUPPLY WATERSHED RESULTS AND DISCUSSION

The Village of South River surface water supply watershed comprises the South River watershed upstream of the South River Dam (Figure 1). Municipal drinking water for the Village of South River is currently serviced by a surface water intake that draws water from the South River reservoir. The Village of South River has experienced an increase in population of 2.8%, between 2001 and 2006 (Statistics Canada, 2007), but had previously experienced a decline of 5.3% between 1996 and 2001, resulting in a net decline of 2.6% over the 10-year period. As a result, the Tier 1 Water Budget has been conducted using current population estimates.

6.1. Water Budget Elements

Water budget elements, including precipitation, AET, surplus, recharge, and runoff were estimated using the methodology described in Section 3.0. Table 20 summarizes these parameters.

Total annual surplus should theoretically equal stream flow (Gartner Lee Ltd., 2007). Analysis of continuous stream flow data collected at Environment Canada/Water Survey of Canada gauge 02DD009 (South River at South River) yields a total annual surplus of 435 mm. The total surplus predicted by the Thornthwaite-Mather soil moisture budget conducted by WESA on the South River subwatershed yielded a total annual surplus of 482 mm; a difference of approximately 11% compared to EC/WSC stream flow data. The primary cause for the difference is likely that the precipitation predicted by the WESA GIS model was greater than that predicted by Gartner Lee Ltd. (2007), as was the case with the Powassan subwatershed. There is still a high level of confidence in the water balance despite the difference between surplus predicted by WESA and Gartner Lee Ltd. (2007).

Total surplus was partitioned into recharge and runoff using the average partitioning coefficient for the NBMCA Source Protection Region (0.478; Gartner Lee Ltd., 2007). This resulted in annual recharge and runoff of 227 and 250 mm, respectively. It should be noted that the sum of the recharge and runoff total 477 mm, while the total annual surplus is 482 mm. This discrepancy is due to rounding errors in the spreadsheet model during the calculation of monthly recharge and runoff.

Table 20: Estimated Water Budget Elements (South River)

Month	Precipitation (mm)	AET (mm)	Surplus (mm)	Recharge (mm)	Runoff (mm)
January	74.1	0.0	74.1	1.4	1.6
February	54.7	0.0	54.7	0.7	0.8
March	64.5	0.0	64.5	0.4	0.4
April	67.2	20.7	46.5	28.4	31.2
May	83.5	76.2	7.3	84.4	92.9
June	88.2	106.4	0.0	42.2	46.4
July	95.7	117.2	0.0	21.1	23.2
August	92.6	99.1	0.0	10.5	11.6
September	113.1	67.0	0.0	5.3	5.8
October	98.5	29.9	68.5	18.9	20.9
November	93.4	0.0	93.4	9.5	10.4
December	72.8	0.0	72.8	4.1	4.6
Total	**998.3**	**516.4**	**481.9**	**226.9**	**249.8**

6.2. Water Supply

The surface water supply is the water available for a subwatershed's surface water users. The South River water supply was estimated using Environment Canada/Water Survey of Canada HYDAT stream gauge data from gauge 02DD009 (South River at South River). The dataset spans from 1962 through 1991. Parametric statistics (median and Q_{P50}) were calculated for these data as recommended in Module 7 of the MOE Assessment Report Guidance Documents (MOE, 2007). Table 21 presents these results.

The 50th percentile flow (Q_{P50}) ranges from a minimum of 2.3 m^3/s (July through September) to a maximum of 10.5 m^3/s (April). The average total annual water supply based on the streamflow gauge is 435 mm. This is in close agreement with the total surplus predicted using the soil moisture budget spreadsheet (482 mm, Table 21).

Table 21: Surface Water Flow Statistics for HYDAT Station 02DD009

Month	Flow (m^3/s)		
	Median	Supply (Q_{P50})	Reserve (Q_{P90})
Jan	4.1	4.0	3.0
Feb	4.0	3.9	3.1
Mar	4.6	4.7	3.3
Apr	10.9	10.5	5.6
May	6.3	6.5	3.7
Jun	3.6	3.5	2.0
Jul	2.4	2.3	1.4
Aug	2.3	2.3	1.3
Sep	2.4	2.3	1.3
Oct	3.6	3.6	1.7
Nov	4.9	4.8	2.0
Dec	4.9	5.1	2.8

6.3. Water Reserve

As described in Section 3.2.2, surface water reserve was estimated as the Q_{P90} (10^{th} percentile) of the gauged stream flow (MOE, 2007). Average annual water reserve based on continuous stream flow data from EC/WSC gauge 02DD009 is 25.3 mm and monthly water reserve is 2.10 mm, or 2.58 m^3/s (based on a subwatershed area of 322,598,800 m^2). Table 21 presents monthly reserve (Q_{P90}) based on median monthly flows.

6.4. Water Demand

Using the approach and assumptions described in Section 3.0, water use was estimated from the relevant datasets available for the study area. The results, compiled on monthly and annual scales, are reported in the form of figures and tables and discussed in this section.

6.4.1. Municipal and Communal Water Demand

Municipal and communal use was determined using the 2004 Environment Canada Municipal Water and Wastewater Survey (Environment Canada, 2004b) as well as the PTTW database. Municipal and communal water takings include the municipal surface water intake (for which actual water use data are available) and other permitted communal takings contained in the PTTW database, such as campgrounds. There were no permitted takings for communal use in the South River municipal supply subwatershed.

Water takings and returns were divided between deep groundwater, shallow groundwater, and surface water. The following assumptions were made:

- 2004 actual municipal water use values used to be consistent with other values in the Municipal Water and Wastewater Survey
- Municipal water consumed includes water from populations with sewage haulage
- Municipal system losses are returned to shallow groundwater through infiltration

Gross takings for municipal/communal use are approximately 207,316 m^3/yr. Of the gross municipal/communal takings, approximately 37,275 m^3/yr (14%) is consumed. Municipal and communal water takings make up approximately 31% of the total gross water takings in the subwatershed and 10% of the water consumed.

Municipal and communal water takings comprise surface water takings from the municipal intake in the South River Reservoir that reach serviced residents (186,377 m^3/yr) and water that is lost to the system (20,939 m^3/yr). Table 22 summarizes these results. 100% of municipal and communal takings (207,316 m^3/yr) are from surface water. All of the municipal water not consumed is returned to shallow groundwater as 100% of the serviced population uses septic systems for water treatment (Environment Canada, 2004b).

Table 22: Municipal and Communal Takings (South River)

General Use	Specific Source/Use	Gross Takings (m^3/yr)	Consumed (m^3/yr)	% Consumed
Municipal / Communal	Municipal surface water to serviced residents	186,377	37,275	18.0
Municipal	System Losses	20,939	0	0.0
Total		207,316	37,275	18

6.4.2. Industrial and Commercial Water Use

Water use results for the industrial and commercial sectors were estimated from the 2004 Environment Canada Municipal Water and Wastewater Survey (Environment Canada, 2004b) and through review of the PTTW database.

The PTTW database yielded one result for the commercial sector (golf course irrigation; permit number 00-P-5002). The gross water taking for this permit was 396,097 m^3/yr; 354,315 m^3 from surface water and 41,782 m^3 from groundwater. It is assumed that the groundwater takings are from shallow groundwater as the permit information states that water is withdrawn from a dug well. The surface water taking is allowed for 260 days per year (assumed to extend between March 1 through November 15), while the groundwater taking is allowed year-round. The maximum allowable taking for this permit accounts for 60% of the gross water takings, 63% of gross surface water takings, and 100% of the gross takings from shallow groundwater.

A consumptive factor of 0.70 was used to determine consumption (MOE, 2007), which resulted in annual consumption of 248,021 m^3 and 29,247 m^3 from the surface water and groundwater takings, respectively. This accounts for 87% of the consumption from surface water and 100% of the consumption from shallow groundwater. The total consumption of 277,268 m^3 accounts for 74% of total consumption. Commercial water use results in consumption of 42% of gross water takings in the subwatershed. It was assumed that water returns (118,829 m^3/yr) are to shallow groundwater via septic systems and infiltration of irrigation water.

6.4.3. *Other Permitted Water Use*

There are no additional permits for the Village of South River municipal water supply subwatershed in the PTTW database.

6.4.4. *Domestic Water Use from Private Water Supplies*

Statistics Canada data indicates the population of the Village of South River was 1,069 in 2006. Of this population, 1 % are supplied by private wells, with a total gross water taking of 683 m^3/yr. It is assumed that domestic use from outside the Village of South River is negligible. Using a consumptive factor of 0.2, it was estimated that 137 m^3/yr is consumed. It is assumed that the remaining water is returned via septic systems to the shallow groundwater.

6.4.5. *Agricultural Water Use*

Tables 23 and 24 summarize calculations and results for this sector . The following assumptions were made during the analysis of agricultural water use:

- Water use for livestock is constant throughout the year, while water taken for crop irrigation is isolated to July and August (MOE, 2007);
- 100% of the water taken for livestock irrigation is consumed, while 80% of water used for crop irrigation is consumed (MOE, 2007);
- Water taking is from deep groundwater (to be consistent with private domestic wells);
- Water not consumed is assumed to return to shallow groundwater through infiltration

Gross water takings for agricultural purposes are used entirely for livestock irrigation (as crop data was suppressed to meet confidentiality requirements of the Statistics Act and are therefore assumed negligible) and are estimated at 61,778 m^3/yr. Total agricultural demand comprises approximately 9% of the total water takings and 16% of total consumption.

Table 23: Statistics Canada Agricultural Census Data and Water Requirements - Crop Irrigation (South River)

Statistics Canada Consolidated Census Subdivision (CCS)	Total vegetables (excluding greenhouse vegetables)			Fruits, Berries and Nuts			Nursery products and Sod			Greenhouse Products			Total Estimated Water Use	Total Estimated Water Consumption
	822 m³/acre/yr [8 in./yr]			1233 m³/acre/yr [12 in./yr]			1233 m³/acre/yr [12 in./yr]			0.15 m³/m² [6 in./yr]				
	farms reporting	acres	Water consumption (m³/yr)	farms reporting	acres	Water consumption (m³/yr)	farms reporting	acres	Water consumption (m³/yr)	farms reporting	square metres	Water consumption (m³/yr)	m³/year	m³/year
Powassan - CCS (350349060)	2	x		2	x		0	0	0	0	0	0	x	x
Machar - CCS (350349054)	0	0	0	1	x		0	0	0	1	x		x	x
Calvin - CCS (350548022)	2	x		0	0		0	0		1	x		x	x

Notes:
Other types of crops do not typically require irrigation (Hay and field crops; Christmas trees; Maple trees), and are not listed in this table
x - suppressed to meet the confidentiality requirements of the Statistics Act
Source: Statistics Canada, 2006 Census of Agriculture, Farm Data and Farm Operator Data, catalogue no. 95-629-XWE.
Typical water consumption from OMAFRA Best Management Practices

Table 24: Statistics Canada Agricultural Census Data and Water Requirements - Livestock (South River)

Statistics Canada Consolidated Census Subdivision (CCS)	Total cattle and calves			Total pigs			Total sheep and lambs		
	53.9 L/d			5.93 L/d			7.16 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
Powassan - CCS (350349060)	32	1,650	88,935	6	x		3	x	
Machar - CCS (350349054)	6	170	9,163	2	x		1	x	
Strong - CCS (350349046)	15	206	11,103	4	34	202	5	179	1,282
Calvin - CCS (350548022)	25	827	44,575	3	x		2	x	
Total	78	2,853	153,777	15	34	202	11	179	1,282

Table 24: Canada Agricultural Census Data and Water Requirements - Livestock (South River), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Total hens and chickens			Horses and ponies			Goats		
		0.226 L/d		32.67 L/d			9.475 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
Powassan - CCS (350349060)	12	791	179	20	158	5,162	3	23	218
Machar - CCS (350349054)	4	144	33	7	72	2,352	4	15	142
Strong - CCS (350349046)	5	221	50	19	77	2,516	2	x	
Calvin - CCS (350548022)	8	342	77	15	100	3,267	2	x	
Total	29	1,498	339	61	407	13,297	11	38	360

Table 24: Canada Agricultural Census Data and Water Requirements - Livestock (South River), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Wild boars 36.005 L/d			Bison (buffalo) 45.48 L/d			Llamas and alpacas 9.475 L/d		
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)
Powassan - CCS (350349060)	0	0	0	x			2	x	
Machar - CCS (350349054)	0	0	0	0	0	0	0	0	0
Strong - CCS (350349046)	0	0	0	0	0	0	2	x	
Calvin - CCS (350548022)	0	0	0	x			0	0	0
Total	0	0	0	0	0	0	4	0	0

Table 24: Canada Agricultural Census Data and Water Requirements - Livestock (South River), cont'd

Statistics Canada Consolidated Census Subdivision (CCS)	Deer (excluding wild deer) 9.475 L/d			Elk 22.74 L/d			Estimated Water Consumption - Livestock
	farms reporting	number of animals	Water consumption (L/d)	farms reporting	number of animals	Water consumption (L/d)	m^3/year
Powassan - CCS (350349060)	0	0	0	0	0	0	34,490
Machar - CCS (350349054)	0	0	0	0	0	0	4,267
Strong - CCS (350349046)	0	0	0	0	0	0	5,531
Calvin - CCS (350548022)	1	x		0	0	0	17,491
Total	1	0	0	0	0	0	56,248

Notes:

Agricultural Census data not available for divisions smaller than CD

For a conservative water use estimate, the water use values for each CCS have not been prorated based on the % inclusion in the study watershed. This is due to CCS amalgamation by Statistics Canada.

x - suppressed to meet the confidentiality requirements of the *Statistics Act*

6.4.6. COMBINED WATER USE – ALL SECTORS

The water use results developed for each of the sectors and presented above were amalgamated to estimate the cumulative water use for each of the systems (surface water, shallow groundwater, and deep groundwater). Results from all sectors are summarized on an annual scale in Tables 25a, b and c and graphically on Figure 10.

Of the gross annual water takings within the study area, 84% are from surface water, 6% from shallow groundwater and 9% from deep groundwater.

Of the gross water takings, 57% are consumed, where 76% of water consumed comes from surface water, 8% from shallow groundwater and 16% from deep groundwater. All water that is not consumed is assumed to be returned to shallow groundwater through infiltration and septic systems. Since 100% of serviced residents use septic systems for treatment (Environment Canada, 2004b), it is assumed that returns from other users are also treated via septic systems. It is assumed that water lost to the system is lost through leakage and returns to the shallow groundwater through infiltration).

Table 26 summarizes net water takings for each of the systems. Positive values indicate that returns exceed takings. This is the case for shallow groundwater where an excess of 247,634 m^3 are returned annually. Both the surface water and deep groundwater systems have more water taken than returned; 561,631 and 62,461 m^3/yr, respectively. The net water takings exceed returns by 376,458 m^3/yr.

Table 25a: Annual Water Use Results - Gross Takings (South River)

Reservoir	Gross Annual Takings (m^3)					TOTAL
	Permitted Takings			Non-Permitted		
	Municipal and Communal[a]	Industrial and Commercial[b]	Other Permitted	Private Domestic	Agricultural[c]	
Surface Water	207,316	354,315				**561,631**
Shallow Groundwater		41,782				**41,782**
Deep Groundwater				683	61,778	**62,461**
TOTAL	**207,316**	**396,097**	**0**	**683**	**61,778**	**665,874**

Table 25b: Annual Water Use Results - Consumption (South River)

Reservoir	Annual Consumed (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal	Industrial and Commercial	Other Permitted	Private Domestic	Agricultural	
Surface Water	37,275	248,021				**285,296**
Shallow Groundwater		29,247				**29,247**
Deep Groundwater				137	61,778	**61,915**
TOTAL	**37,275**	**277,268**	**0**	**137**	**61,778**	**376,458**

Table 25c: Annual Water Use Results - Returns (South River)

Reservoir	Annual Returned (m^3)					
	Permitted Takings			Non-Permitted		TOTAL
	Municipal and Communal[d]	Industrial and Commercial[b]	Other Permitted	Private Domestic[e]	Agricultural	
Surface Water						0
Shallow Groundwater	170,040	118,829		546		**289,416**
Deep Groundwater						0
TOTAL	**170,040**	**118,829**	**0**	**546**	**0**	**289,416**

Notes:

[a] Includes system losses, which are assumed to return to surface water

[b] Assume industrial and commercial water comes from shallow groundwater and returns to SW through sewer service

[c] Assume agricultural water comes from deep groundwater, since assuming source is same as private wells, and most private domestic wells are in deep bedrock

[d] Assume remaining 0.2% returns to surface water (99% on sewer and 0.8% on septic)

[e] Assume returns from private domestic wells discharges through septic systems to shallow groundwater

Table 26: Net Water Takings (South River)

Reservoir	Net Water Takings (m3)
Surface Water	-561,631
Shallow Groundwater	247,634
Deep Groundwater	-62,461
TOTAL	-376,458

Note:

Positive values indicate that returns exceed takings

6.4.7. Monthly Water Demand

Monthly takings from surface water range from 15,904 to 59,853 m^3. The large range is due to the seasonal water takings used for golf course irrigation, which occur between March 1 and November 15. Takings from shallow groundwater range between 3,205 and 3,549 m^3, while takings from deep groundwater range from 4,792 to 5,305 m^3. Tables 27a, b and c present monthly water use results, including gross, consumed, and returned water. Monthly water use is presented in Figures 11a, b and c.

Table 27a: Monthly Water Use Results - Gross Takings (South River)

Reservoir	Monthly Gross Water Takings (m^3)												Annual Gross Water Takings (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	17,608	15,904	59,853	57,922	59,853	59,853	57,922	59,853	57,922	59,853	37,481	17,608	561,631
Shallow Groundwater	3,549	3,205	3,549	3,434	3,549	3,434	3,549	3,549	3,434	3,549	3,434	3,549	41,782
Deep Groundwater	5,305	4,792	5,305	5,134	5,305	5,136	5,303	5,305	5,134	5,305	5,134	5,305	62,461

Table 27b: Monthly Water Use Results - Consumption (South River)

Reservoir	Monthly Consumptive Water Takings (m^3)												Annual Consumptive Water Takings (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	3,166	2,859	32,738	31,681	32,738	32,738	31,681	32,738	31,681	32,738	17,373	3,166	285,296
Shallow Groundwater	2,484	2,244	2,484	2,404	2,484	2,404	2,484	2,484	2,404	2,484	2,404	2,484	29,247
Deep Groundwater	5,259	4,750	5,259	5,089	5,259	5,089	5,258	5,259	5,089	5,259	5,089	5,259	61,915

Table 27c: Monthly Water Use Results - Returns (South River)

Reservoir	Monthly Water Returns (m^3)												Annual Water Returns (m^3/yr)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Surface Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Shallow Groundwater	15,553	14,048	28,226	27,316	28,226	28,192	27,350	28,226	27,316	28,226	21,183	15,553	289,416
Deep Groundwater	0	0	0	0	0	0	0	0	0	0	0	0	0

6.5. Surface Water Stress Assessment

Surface water stress is determined by examining the ratio of water demand (water takings) to water supply, while considering in the reserve required to maintain ecosystem function (MOE, 2007). The percent water demand is compared to a stress threshold (Table 2) to determine the stress level.

The maximum monthly percent surface water demand for the Village of South River municipal supply subwatershed is 1.2 %. Table 28 presents the demand, supply, and reserve values used to calculate the percent demand.

A subwatershed is considered low stress if the maximum monthly percent demand is less than 20%. As a result, the Village of South River municipal supply subwatershed is considered low stress and does not require a Tier 2 Water Budget.

Table 28: Percent Water Demand (South River)

Month	Consumption	Supply	Reserve	%Demand
January	0.010	33.2	24.91	0.118
February	0.009	29.2	23.25	0.148
March	0.101	39.0	27.40	0.873
April	0.098	84.4	44.99	0.249
May	0.101	54.0	30.72	0.437
June	0.101	28.1	16.07	0.842
July	0.098	19.1	11.62	1.314
August	***0.101***	***19.1***	***10.79***	***1.222***
September	***0.098***	***18.5***	***10.45***	***1.222***
October	0.101	29.9	14.11	0.643
November	0.054	38.6	16.07	0.239
December	0.02	42.3	23.25	0.126
Annual	**0.90**	**435**	**253.6**	**0.494**

Note:
Bold italics indicates months with maximum monthly percent demand.

7.0 UNCERTAINTY

We have provided an uncertainty analysis of this Tier 1 Water Budget even though the Technical Rules do not require it. The uncertainty analysis completes the understanding of the data on which the Water Budget is based.

The limitations inherent to each dataset individually, combined with the discrepancies between datasets in terms of geographic unit of analysis (different scales) and time of acquisition (different dates), all introduce various levels of uncertainty, which are ultimately compounded into the results. They include the following:

- Spatial scale: because this study is conducted at the regional scale, results must be interpreted in their context and will require confirmation and refinement through further investigation at the local scale. Some data can be georeferenced with varying degrees of accuracy (e.g., municipal and other permitted takings, private water supply wells), while other datasets are only available for large areas (e.g., Statistics Canada census data are aggregated by Consolidated Census Subdivisions (CCS), which correspond approximately to former townships, or for entire municipalities). Conservative estimates were made by not pro-rating data based on percent inclusion of CCSs in the subwatershed of interest;

- Temporal scale: the various datasets used in the analysis are a 'snapshot in time'. Population census is current as of 2006, while municipal water use data is current as of 2004. 2004 actual water use data was used to maintain consistency between the Municipal Water and Wastewater Survey and actual water use data. Obtaining contemporary, more up to date data would reduce the error associated with the combination of datasets from varying dates;

- Provincial Permits to Take Water (PTTW): the greatest source of uncertainty in estimating water use comes from the PTTW database. In particular:

    - Permit validity determined from information contained in the database (e.g., expiry date, whether a permit has been revoked, etc) is challenging because the information included for specific permits is often conflicting and raises questions that would require review of individual permits to increase confidence in the data they contain;

    - The database currently only contains information on maximum allowable withdrawals (actual takings are unknown, with the exception of municipal water supply systems). Despite the fact that some users are required (since 2005) to report actual water takings, the PTTW database available for this study did not contain any such information. The uncertainty associated from this limitation was reduced in part by applying the monthly and consumptive use factors specified in the provincial guidance document (MOE, 2007) and AquaResource (2005);

  - While the database contains some basic information regarding from which system the takings originate (i.e., surface water vs. groundwater), some permits are assigned to both systems with no information on relative proportions;

  - Only the larger water takings (greater than 50,000 L/d) are included in the PTTW database and the water requirements from smaller users is unknown. In addition, water taking for livestock is exempt from the permitting requirements, regardless of the volume taken;

- Statistics Canada census data (population and agriculture):

  - Results are averaged over large areas (CCS)

  - Data excluded from census reporting for confidentiality reasons precludes estimation of water use for a number of crop types and animal categories (this is likely a relatively minor source of uncertainty);

- Environment Canada (EC) Municipal Water Use ("MUD") and Industrial Water Use surveys: details on the provenance of the water within a municipality are unspecified, and all user types (urban/rural/etc) are amalgamated;

- Other sources of uncertainty:

  - Very little information is available for some sectors, for instance there may be a number of smaller industrial and commercial users that are not accounted for. Similarly, no information is available for recreational or ecological users;

  - The evaluation of returns is entirely based on assumptions for their magnitude (derived from the consumptive factor from MOE (2006)), and also which system water is returned to (surface water vs. shallow groundwater).

Considering the significant sources of uncertainty, the uncertainty associated with the Tier 1 Water Budget and Stress Assessment is considered high. However as discussed in Sections 4.5., 5.5 and 6.5, the percent demand (maximum monthly or annual, as appropriate) for each system is well below the defined thresholds. Therefore, WESA recommends that no additional work is required to address the uncertainty.

8.0 CLOSING

WESA is pleased to submit this final report. Please contact the undersigned if you have any questions or comments.

Sincerely,

PROFESSIONAL GEOSCIENTIST
RICHARD TOMAS SCHMIDT
PRACTISING MEMBER
0724
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June 3, 2010

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Figure 10: South River Annual Water Use

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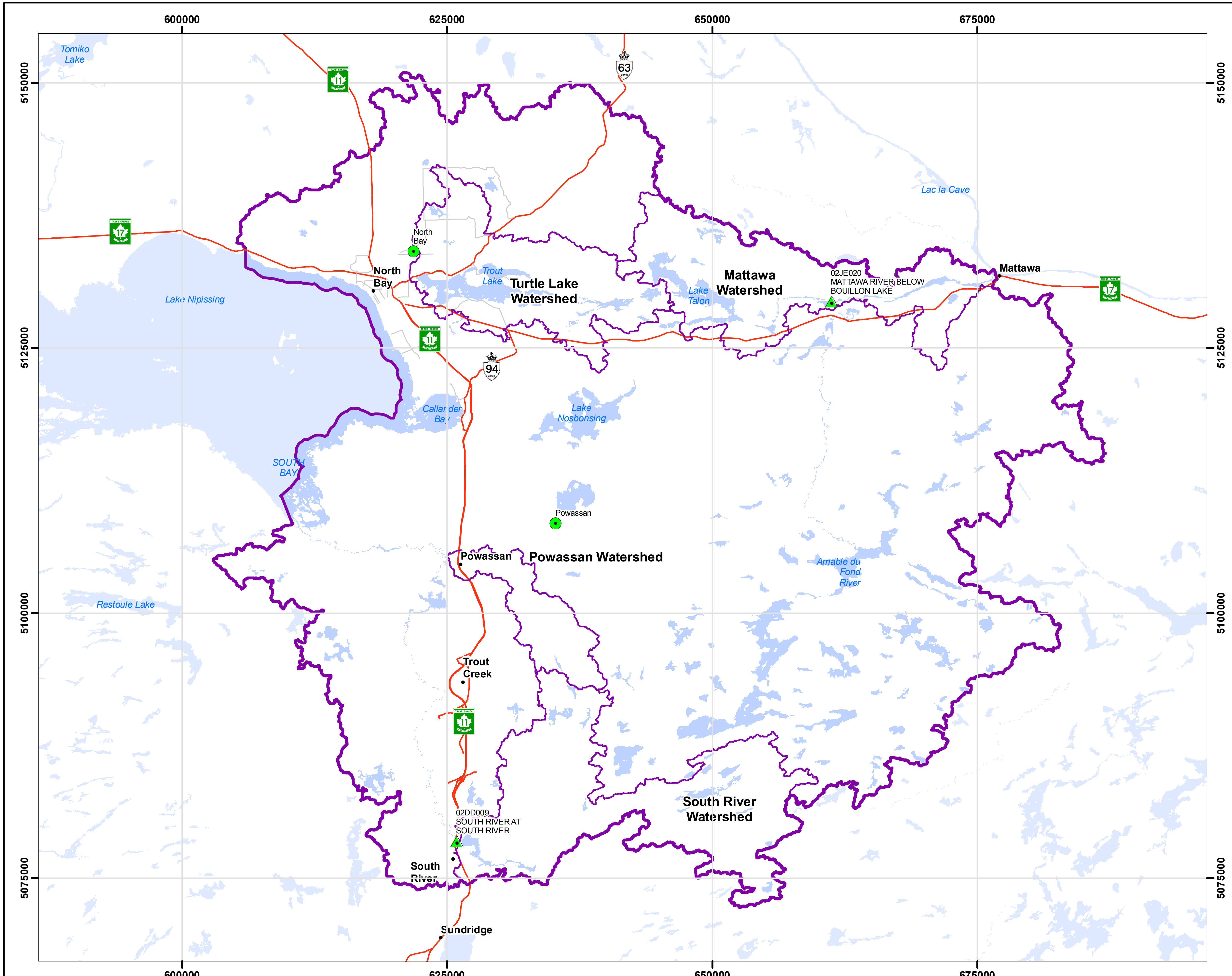
Figure 11b: South River Monthly Water Use – Consumption

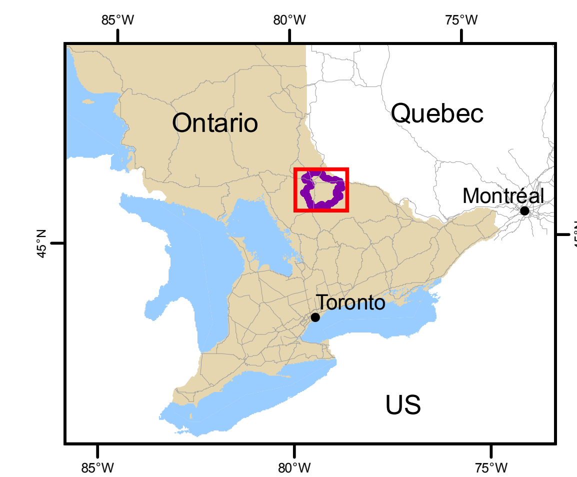
Figure 11c: South River Monthly Water Use – Returns



LEGEND

- Climate Station
- HYDAT Station
- Tier I Water Budget Watersheds
- Source Water Protection Region Boundary

KEY MAP



REFERENCE

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PROJECT
SOURCE WATER PROTECTION
NORTH BAY-MATTAWA CONSERVATION

TITLE
TIER 1 WATER BUDGET
SITE LOCATION

WESA
A Better Environment For Business

PROJECT No. S-B6720-00			SCALE AS SHOWN	REV.0
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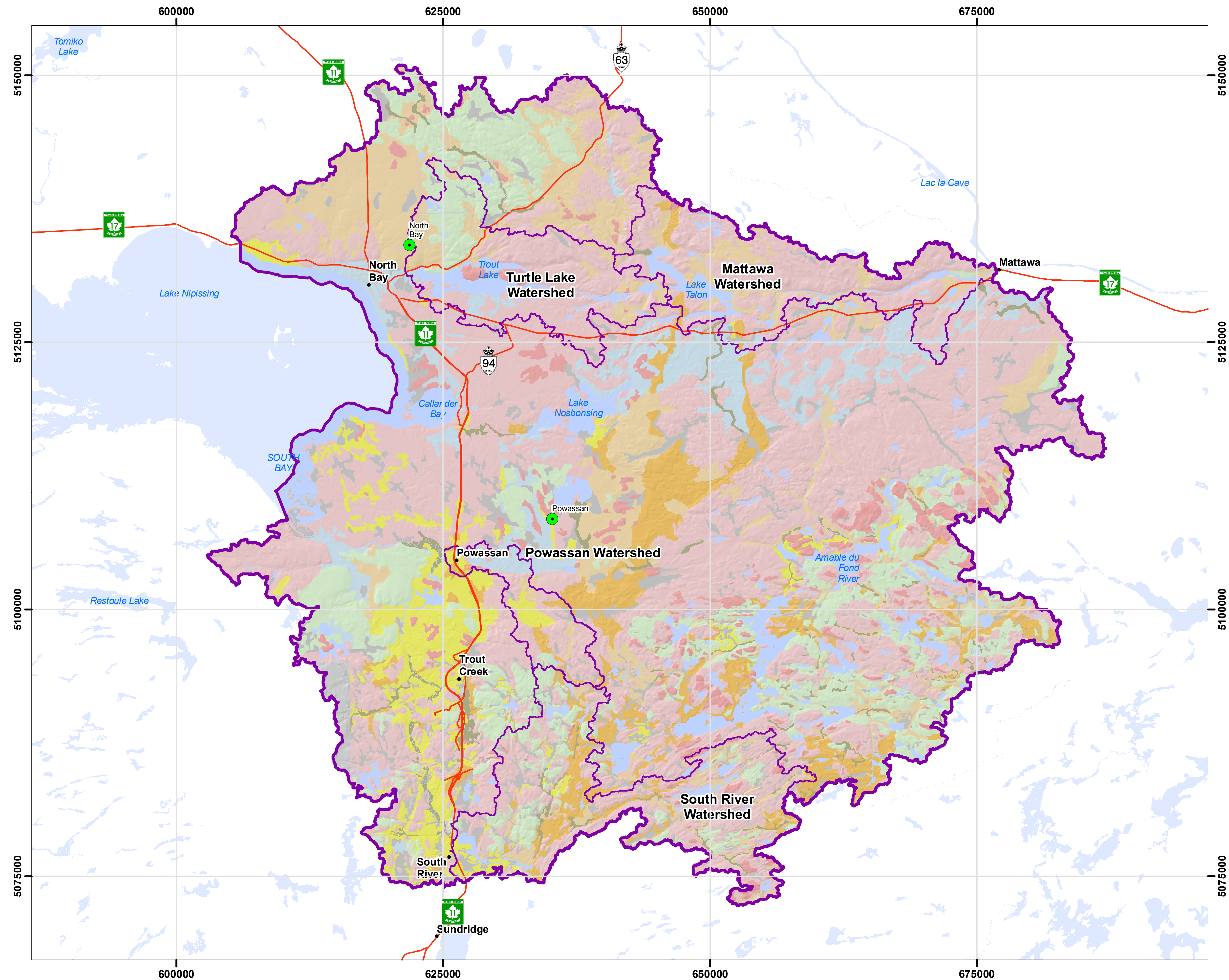
GIS	JFD	12/02/2010		
CHECK	RS			
REVIEW				



LEGEND

- Tier I Water Budget Watersheds
- Source Water Protection Region Boundary
- 1: Precambrian bedrock
- 2: Precambrian bedrock-drift complex
- 2a: Mainly till veneer
- 2b: Mainly stratified veneer
- 5a: Shield-derived silty to sandy till
- 6: Ice-contact stratified deposits
- 6b: In subaquatic fans
- 7: Glaciofluvial deposits
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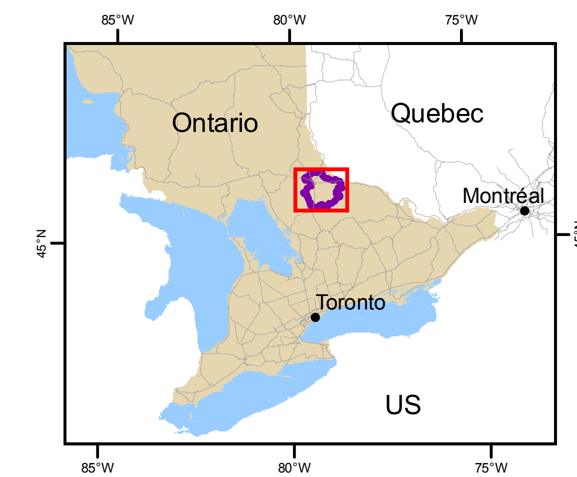
KEY MAP



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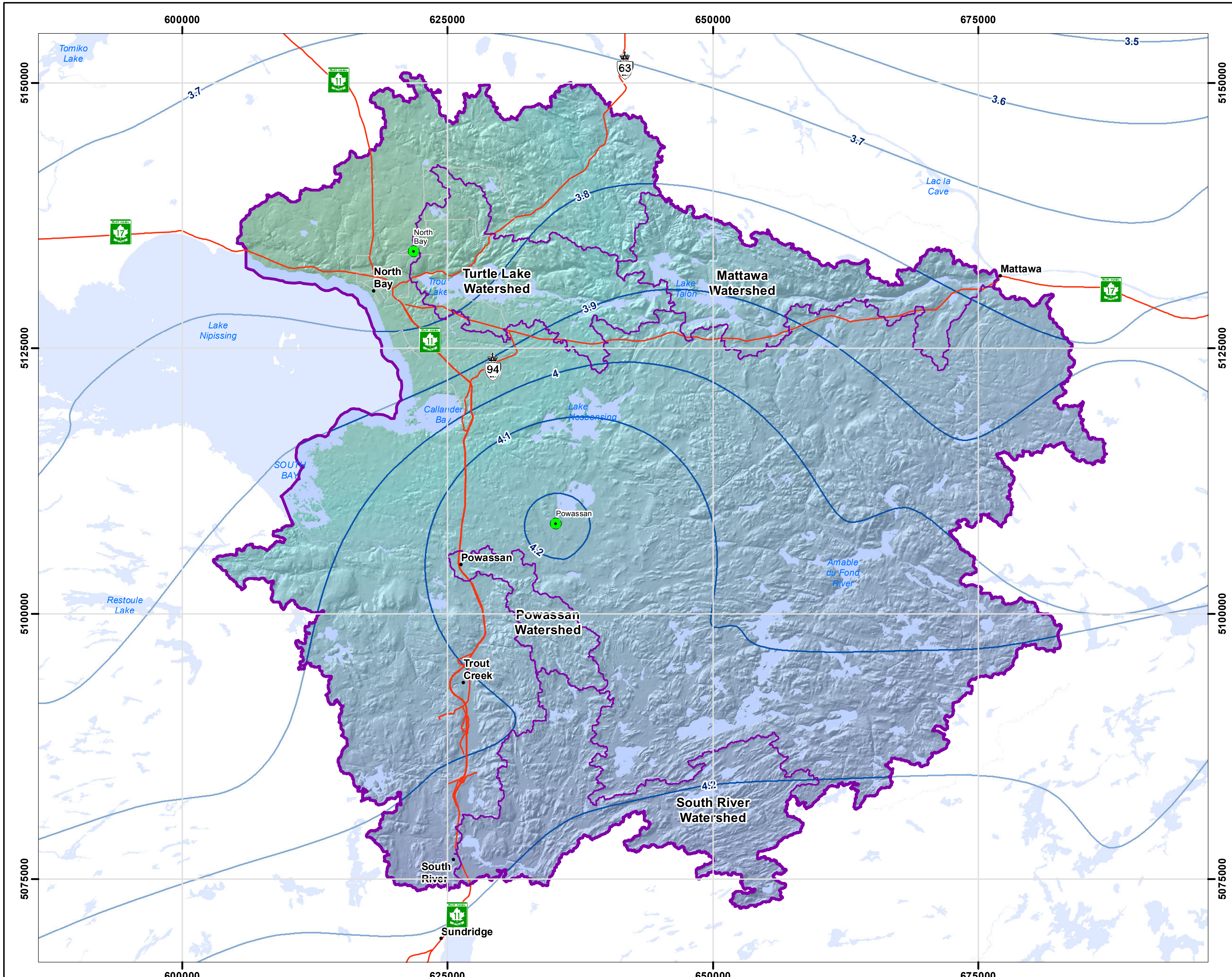
PROJECT
SOURCE WATER PROTECTION
NORTH BAY-MATTAWA CONSERVATION

TITLE
TIER 1 WATER BUDGET
SURFICIAL GEOLOGY

WESA
A Better Environment For Business

PROJECT No. S-B6720-00			SCALE AS SHOWN	REV.0
DESIGN	JFD			
GIS	JFD	12/02/2010		
CHECK	RS			
REVIEW				

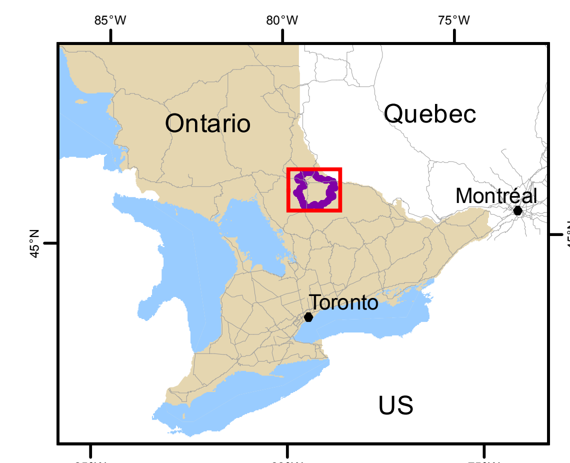
FIGURE 2



LEGEND

- Climate Station
- Mean Annual Temperature (°C)
- Tier I Water Budget Watersheds
- Source Water Protection Region Boundary

KEY MAP



REFERENCE

-The base data is known to be the best available information provided through the Ontario Geospatial Data Exchange and by Ontario Ministry of Natural Resources, Ontario Ministry of the Environment, Conservation Ontario, North Bay-Mattawa Conservation and local Municipalities.
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4 2 0 4 8 12
Kilometres
1:350,000

PROJECT

SOURCE WATER PROTECTION
NORTH BAY-MATTAWA CONSERVATION

TITLE

TIER 1 WATER BUDGET
MEAN ANNUAL TEMPERATURE (°C)

WESA
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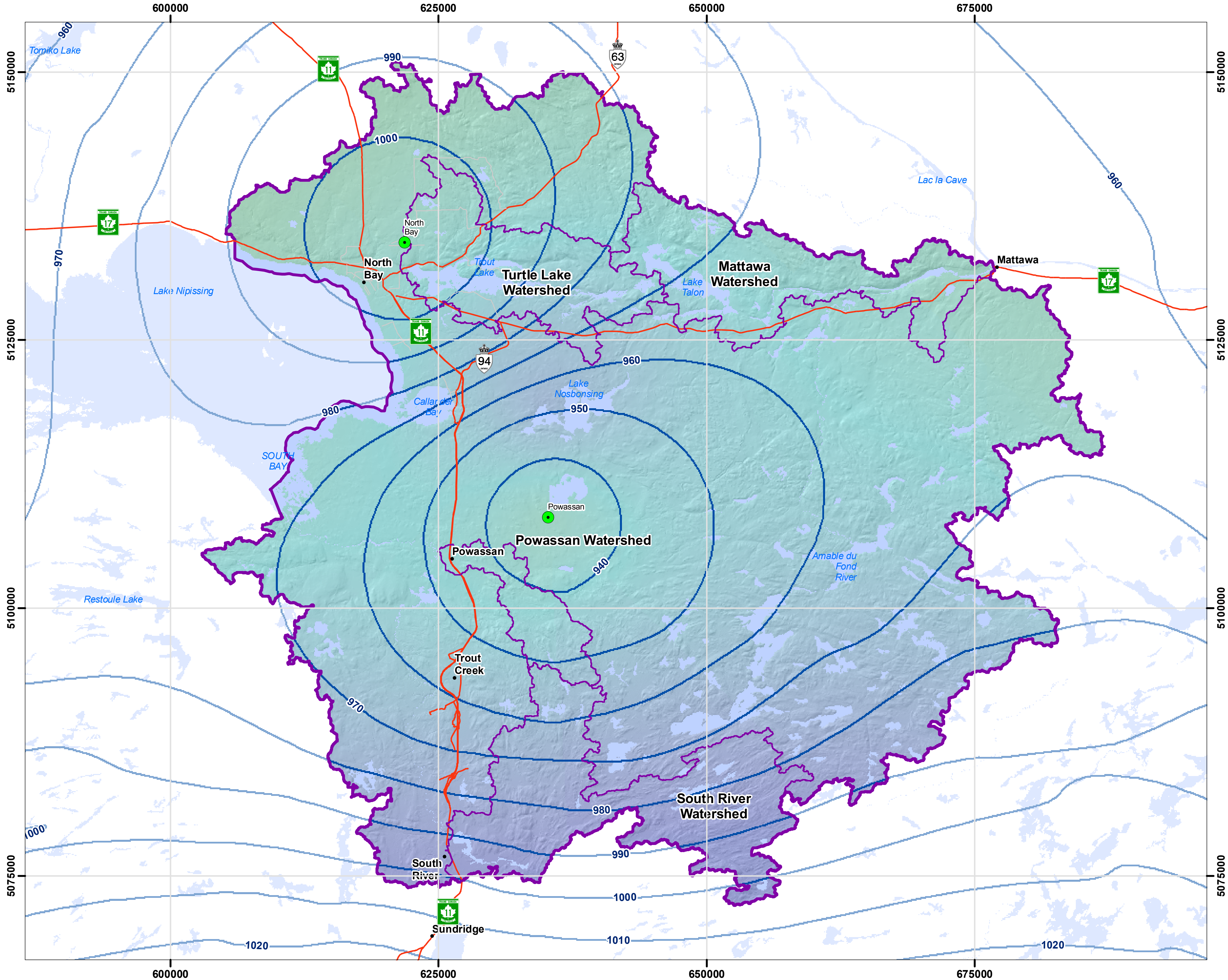
PROJECT No. S-B6720-00			SCALE AS SHOWN	REV.0
DESIGN	JFD			
GIS	JFD	12/02/2010		
CHECK	RS			
REVIEW				

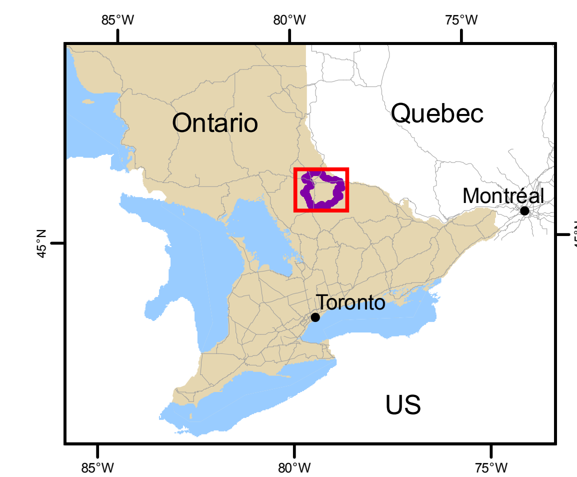
FIGURE 3



LEGEND

- Climate Station
- Mean Annual Precipitation (mm)
- Tier I Water Budget Watersheds
- Source Water Protection Region Boundary

KEY MAP



REFERENCE

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4 2 0 4 8 12
Kilometres
1:350,000

PROJECT

SOURCE WATER PROTECTION
NORTH BAY-MATTAWA CONSERVATION

TITLE

TIER 1 WATER BUDGET
MEAN ANNUAL PRECIPITATION (mm)

WESA
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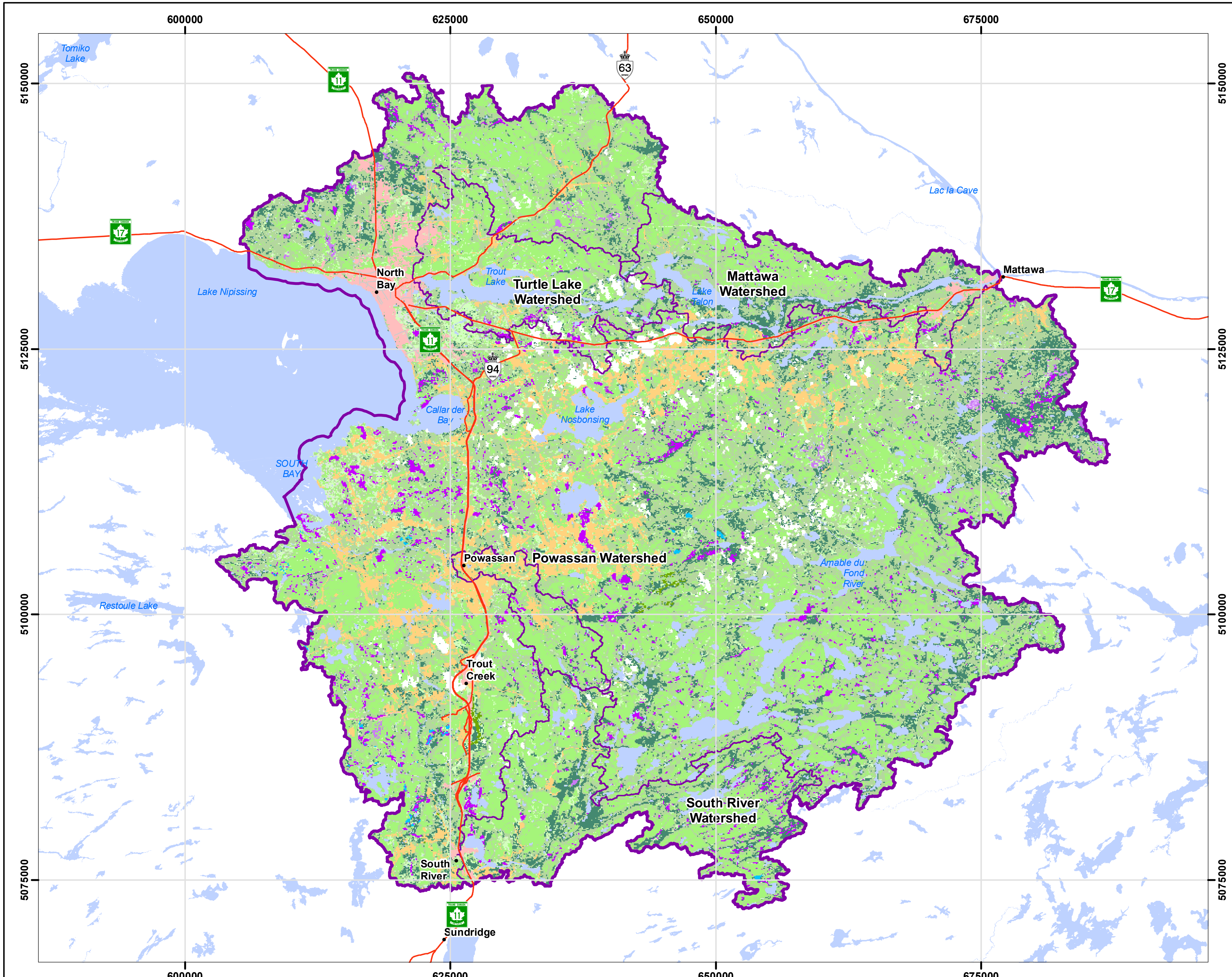
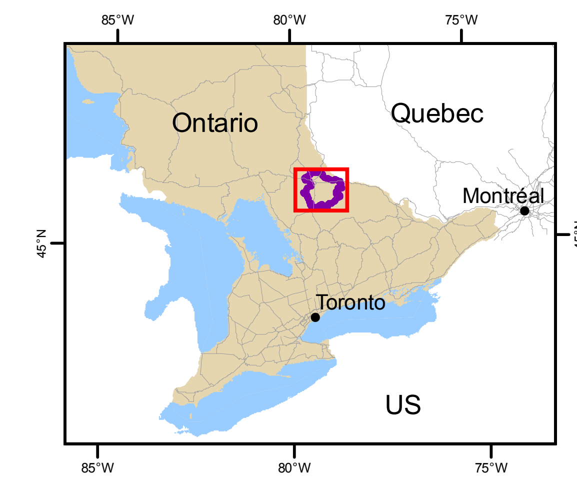
PROJECT No. S-B6720-00			SCALE AS SHOWN	REV.0
DESIGN	JFD			
GIS	JFD	12/02/2010		
CHECK	RS		**FIGURE 4**	
REVIEW				



LEGEND

- Tier I Water Budget Watersheds
- Source Water Protection Region Boundary
- Water - Deep or Clear
- Settlement/Infrastructure
- Bedrock
- Cutovers
- Burns
- Sparse Forest
- Deciduous Forest
- Mixed Forest
- Coniferous Forest
- Treed Fen
- Open Bog
- Treed Bog
- Pasture
- Cloud and Shadow (no data)

KEY MAP



REFERENCE

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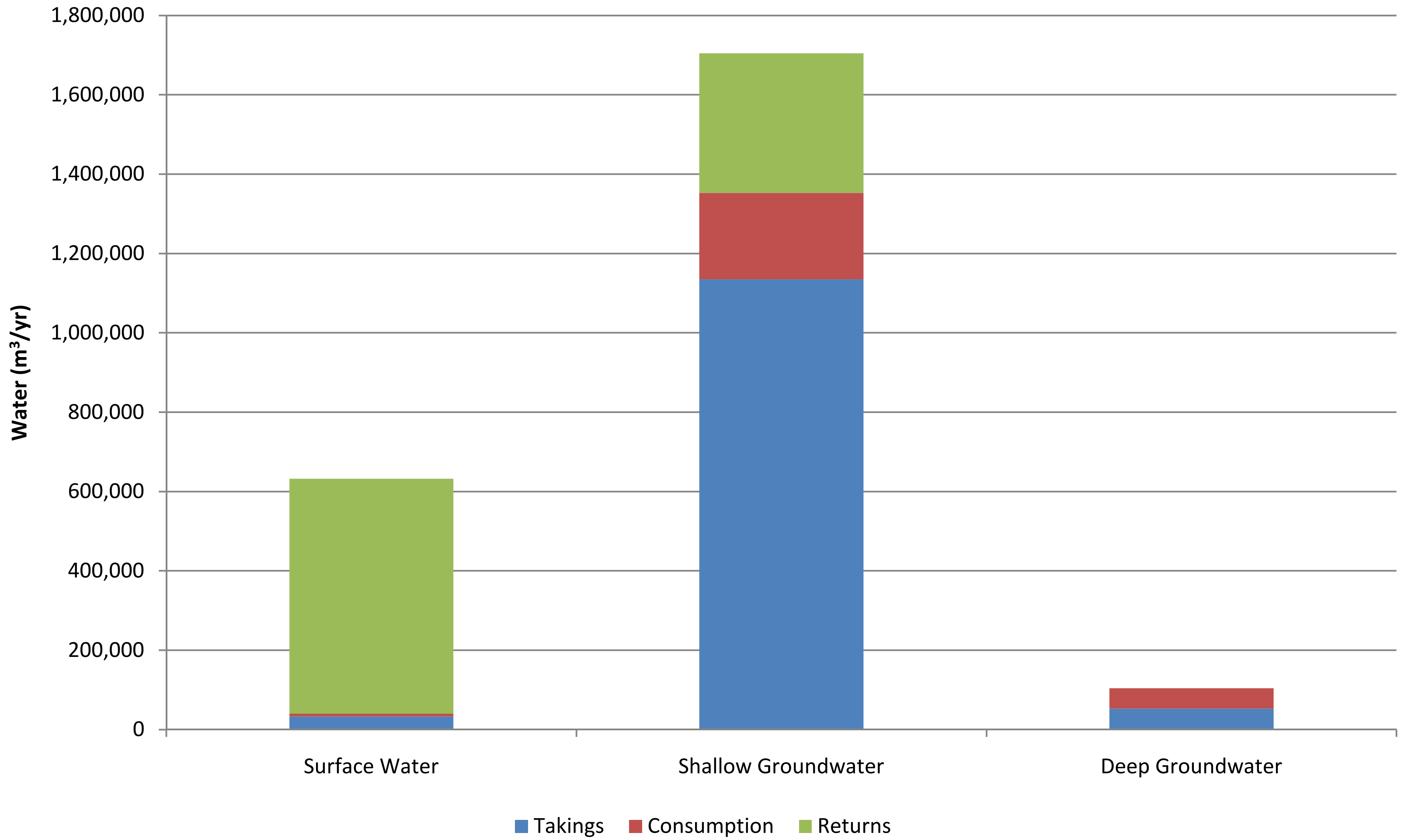
4 2 0 4 8 12
Kilometres
1:350,000

PROJECT
SOURCE WATER PROTECTION
NORTH BAY-MATTAWA CONSERVATION

TITLE
TIER 1 WATER BUDGET
LAND COVER

WESA
A Better Environment For Business

PROJECT No. S-B6720-00			SCALE AS SHOWN	REV.0
DESIGN	JFD			
GIS	JFD	12/02/2010	FIGURE 5	
CHECK	RS			
REVIEW				



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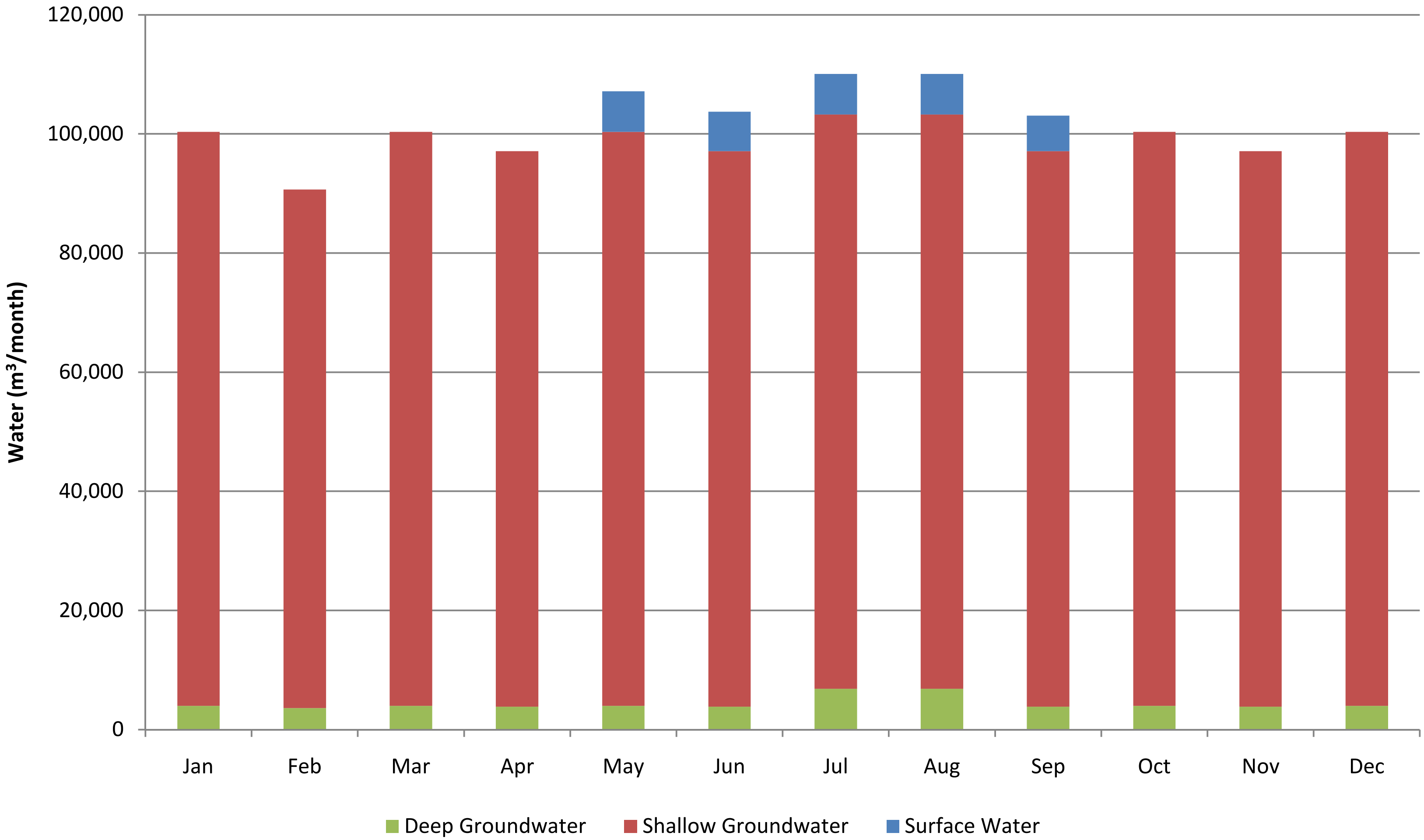
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Mattawa Annual Water Use	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 6**	



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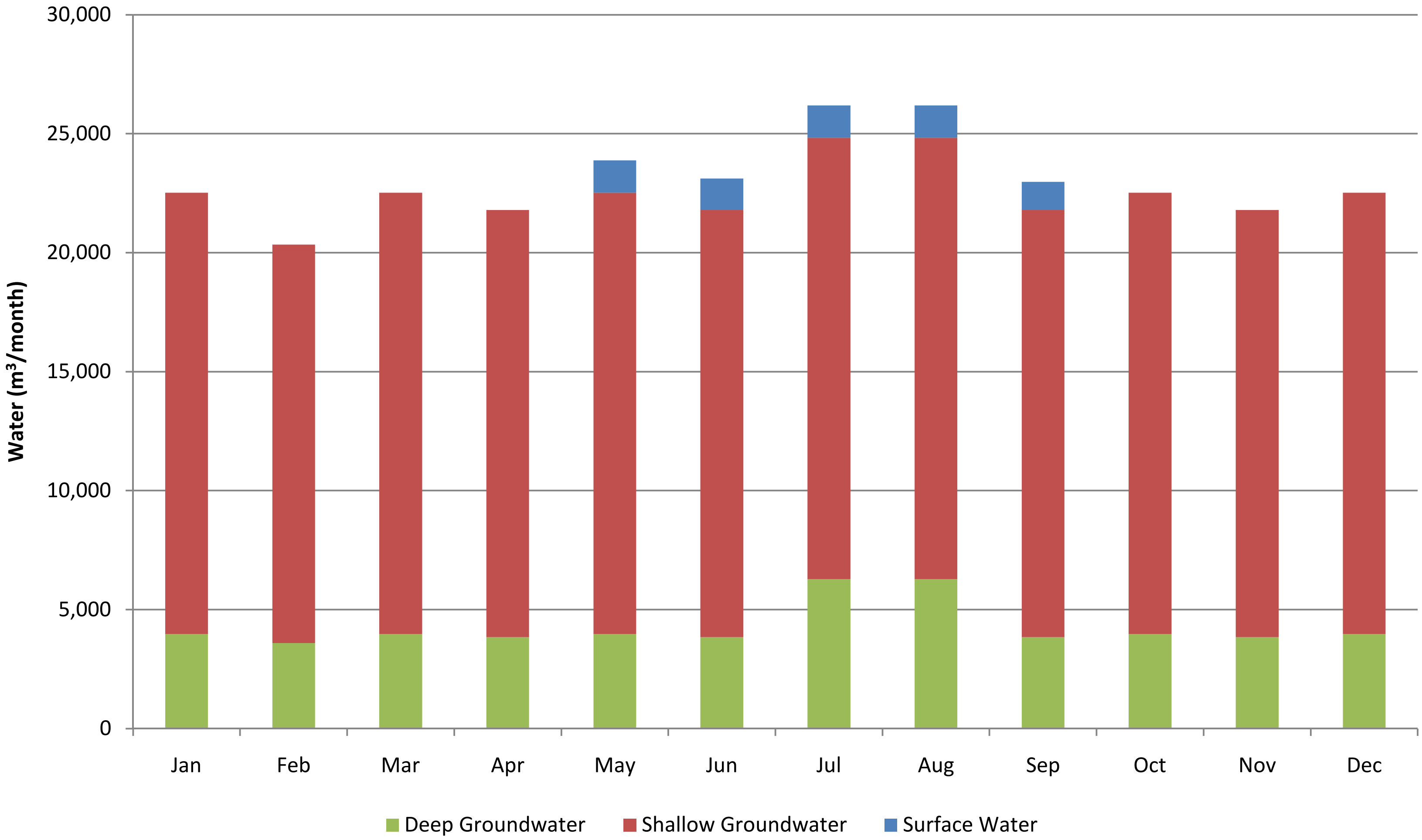
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Mattawa Monthly Water Use - Gross Takings	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 7a**	



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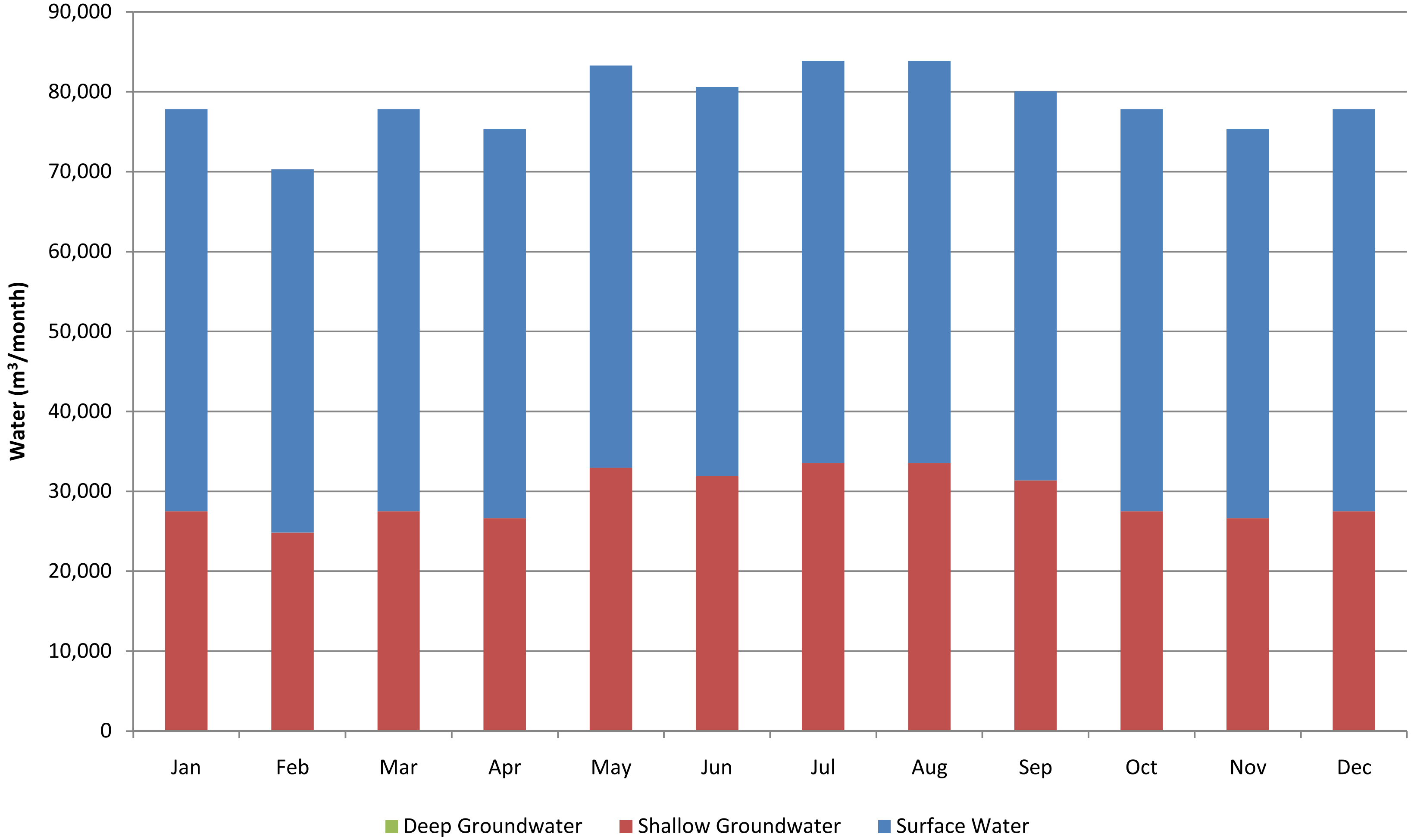
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Mattawa Monthly Water Use - Consumption	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 7b**	



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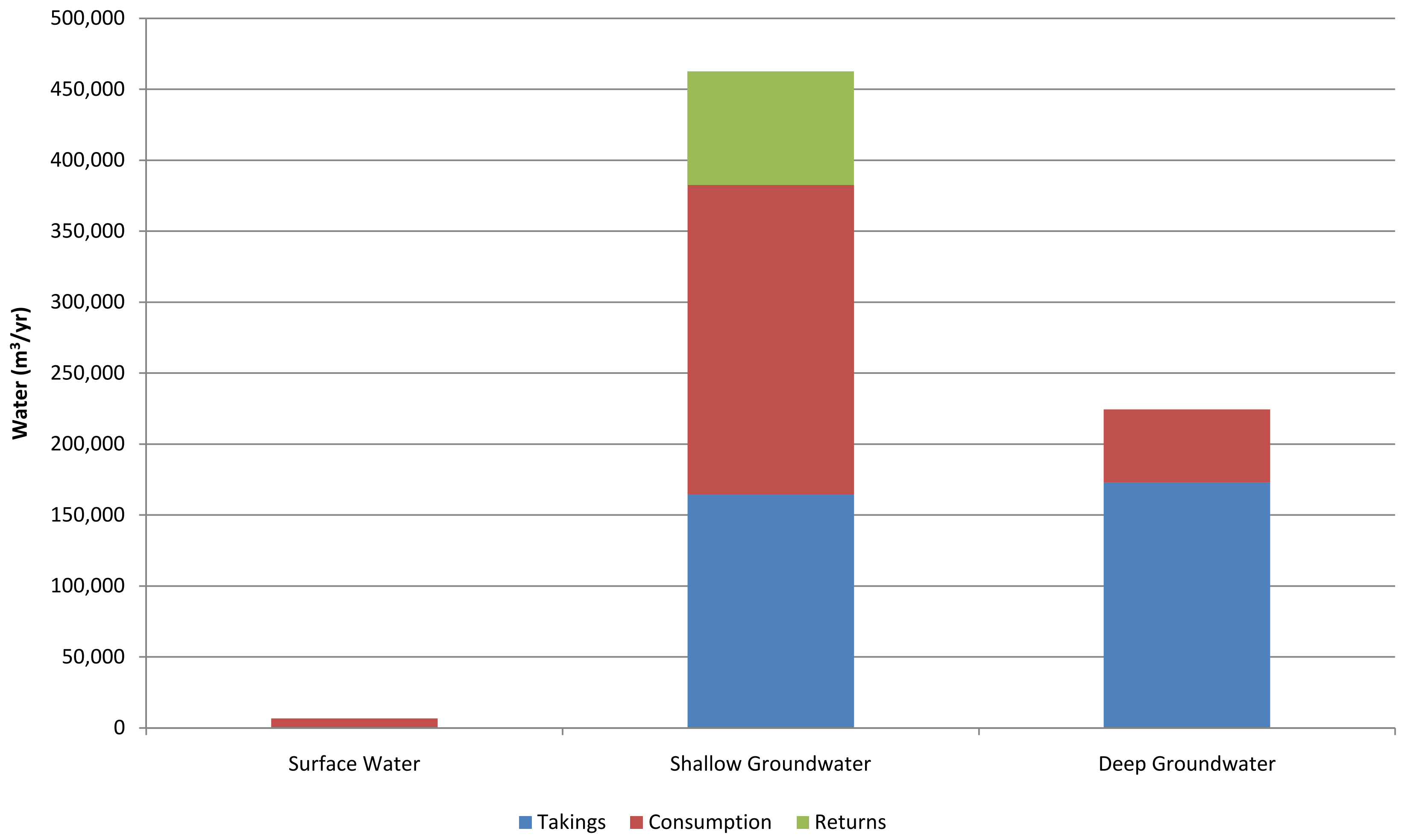
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Mattawa Monthly Water Use - Returns	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 7c**	



WESA
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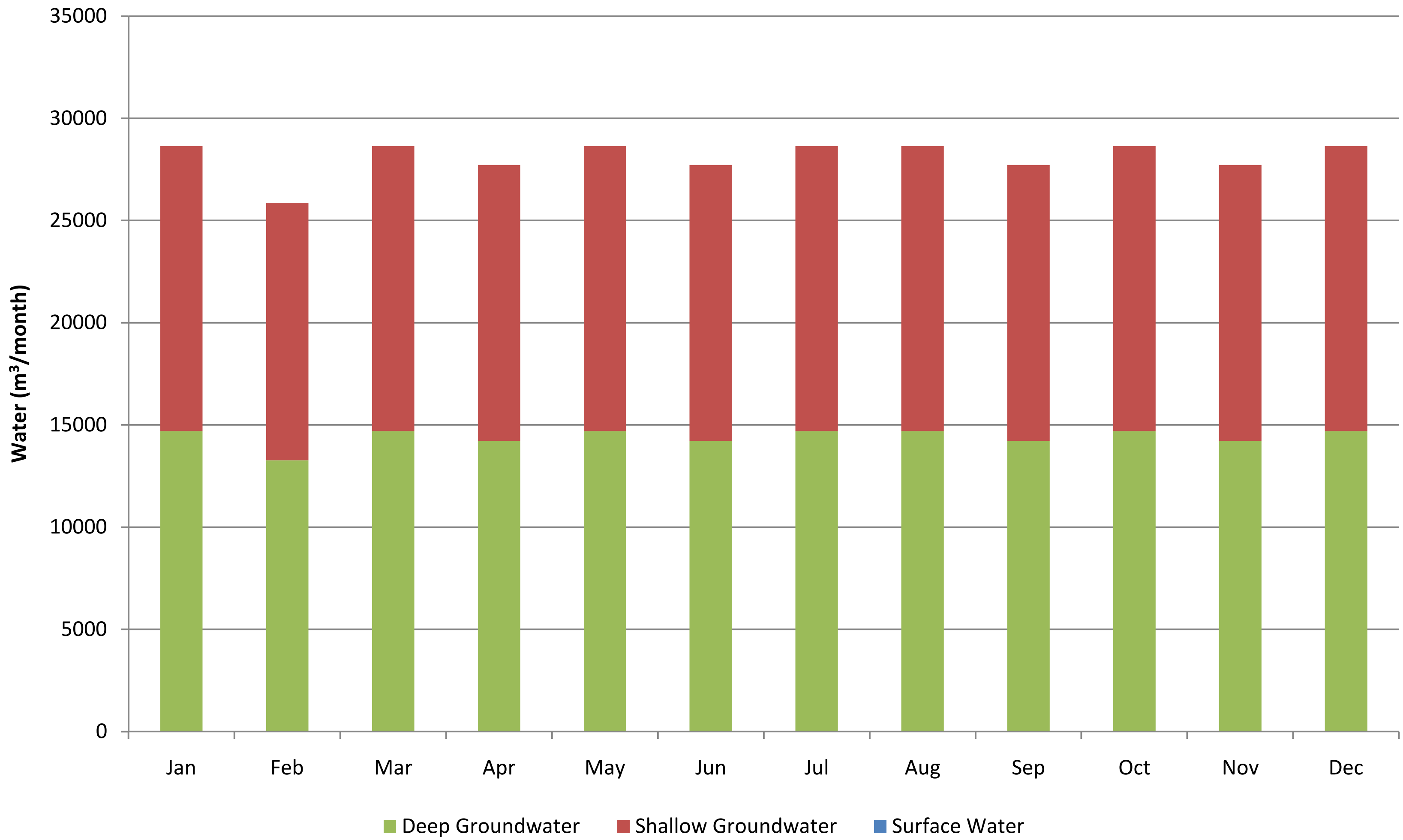
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Powassan Annual Water Use	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 8**	



WESA
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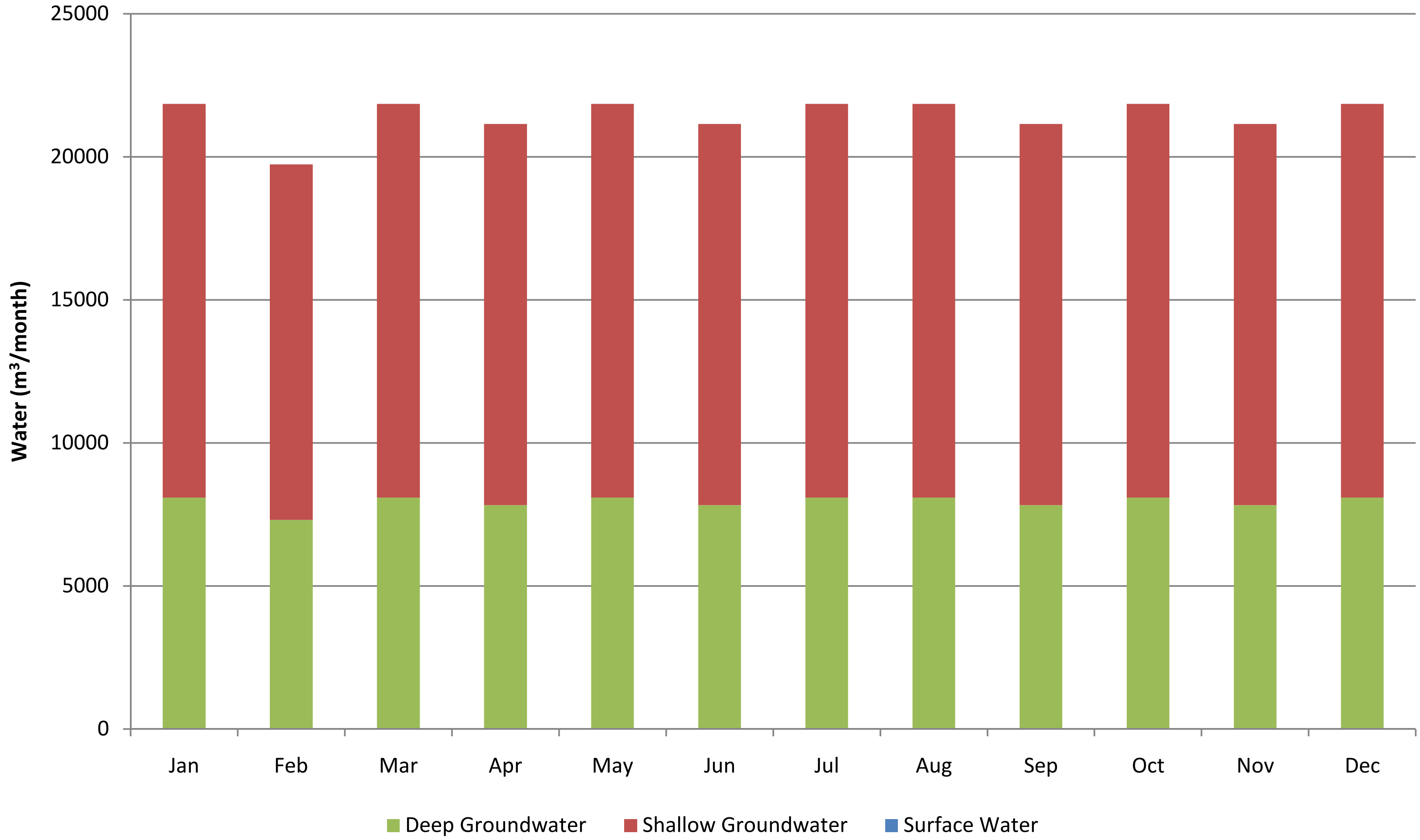
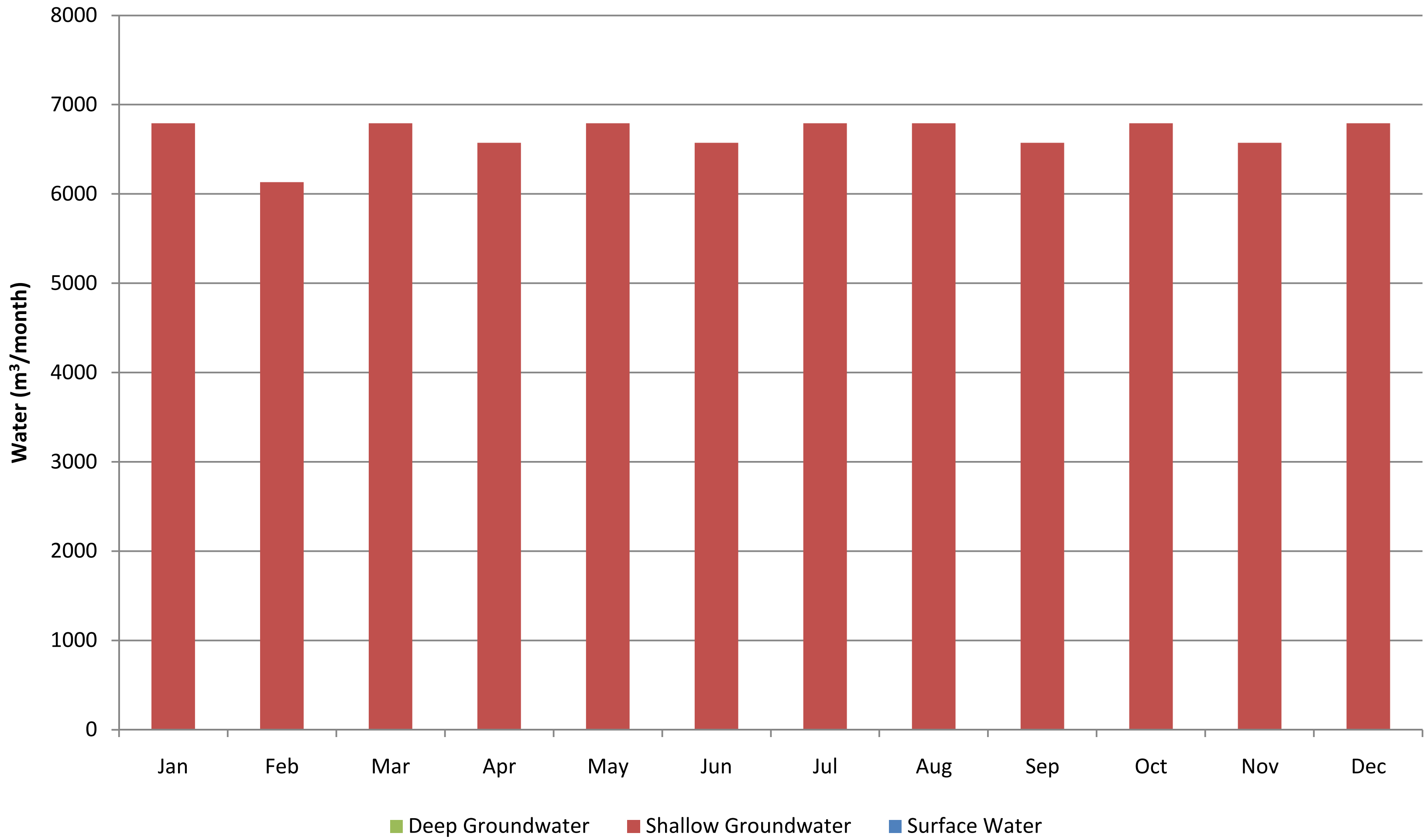
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Powassan Monthly Water Use - Gross Takings	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 9a**	



WESA
A Better Environment For Business

PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.:	S-B6720	DRAWN BY:	SJD
TITLE:	Powassan Monthly Water Use - Consumption	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 9b**	



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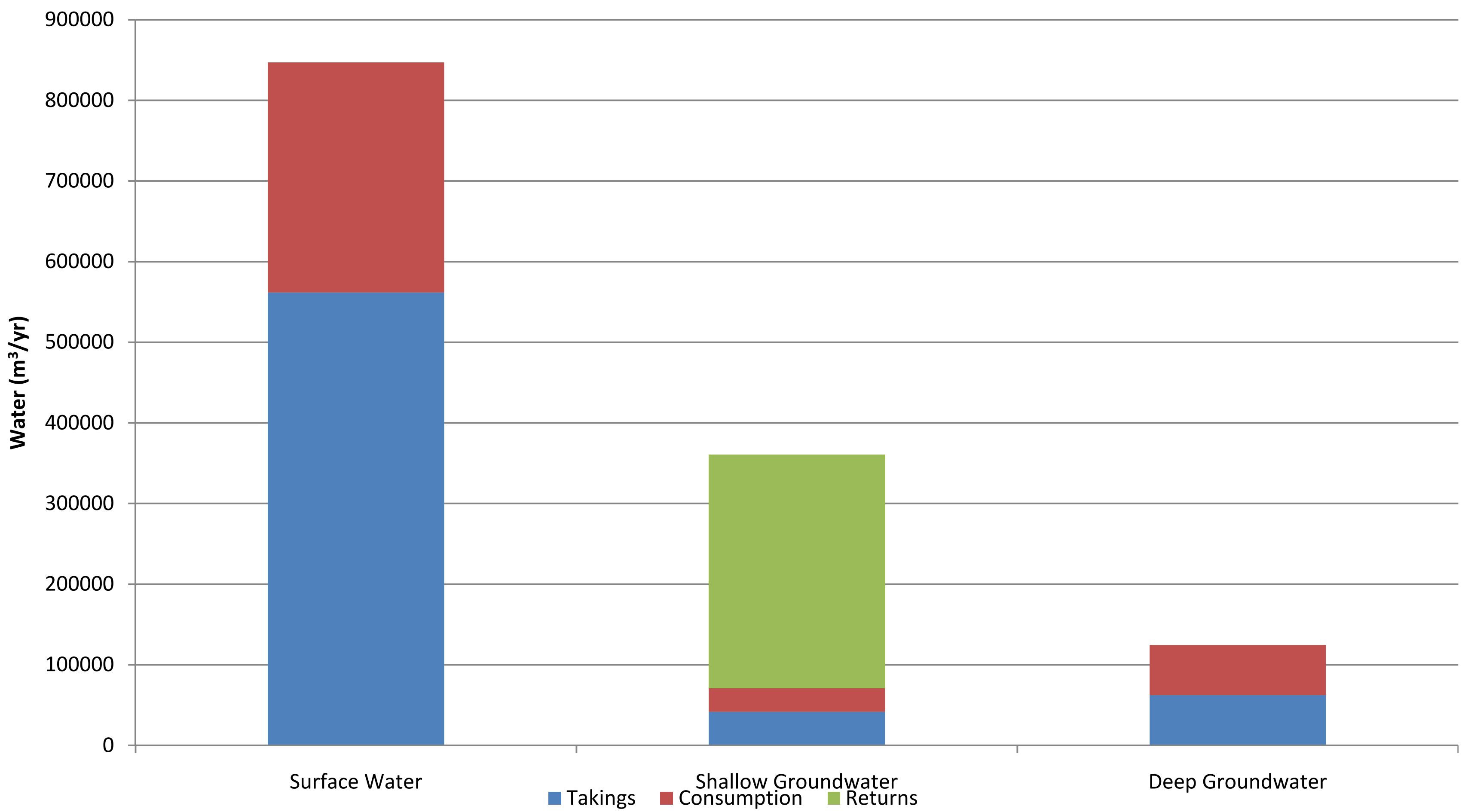
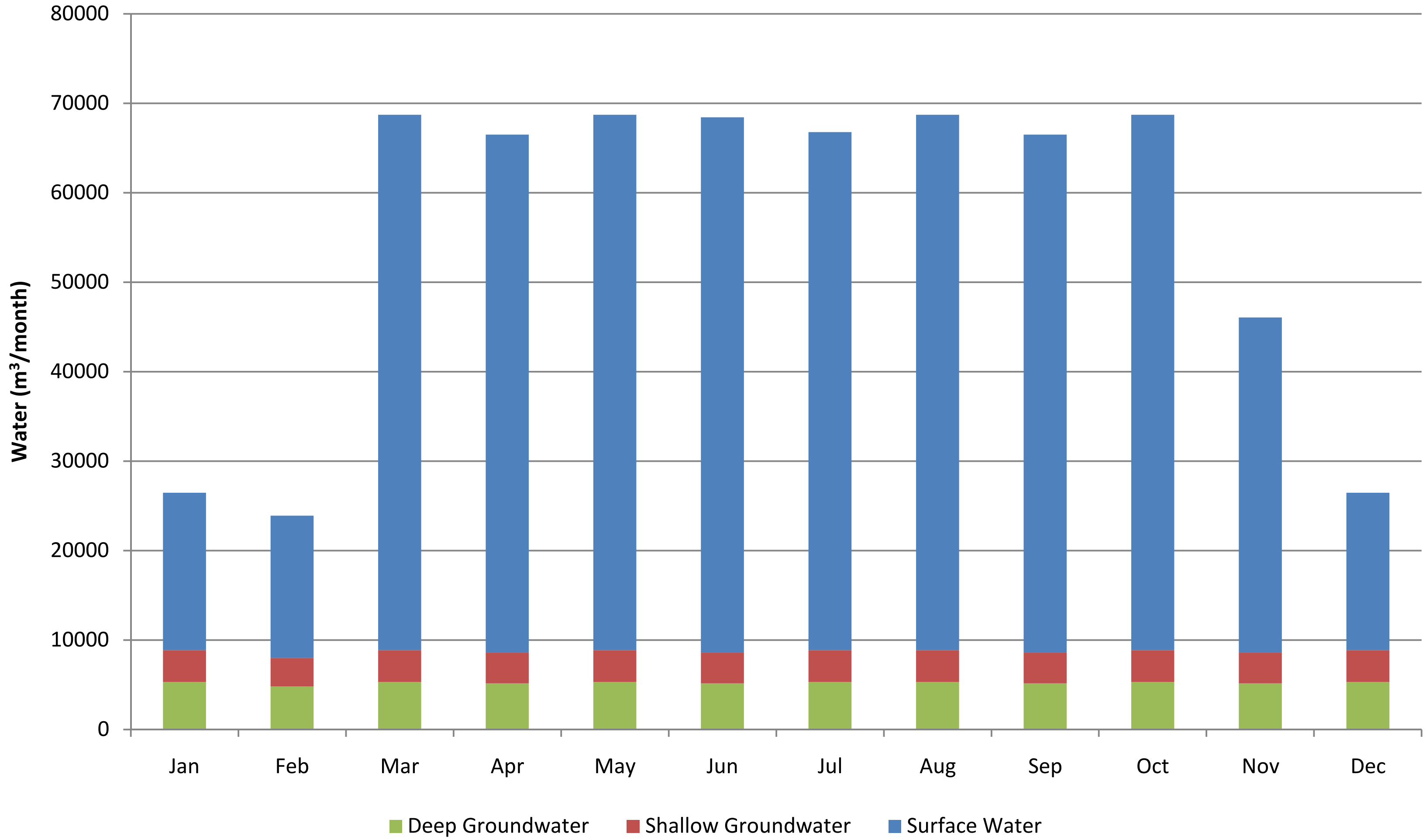
PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	Powassan Monthly Water Use - Returns	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 9c**	

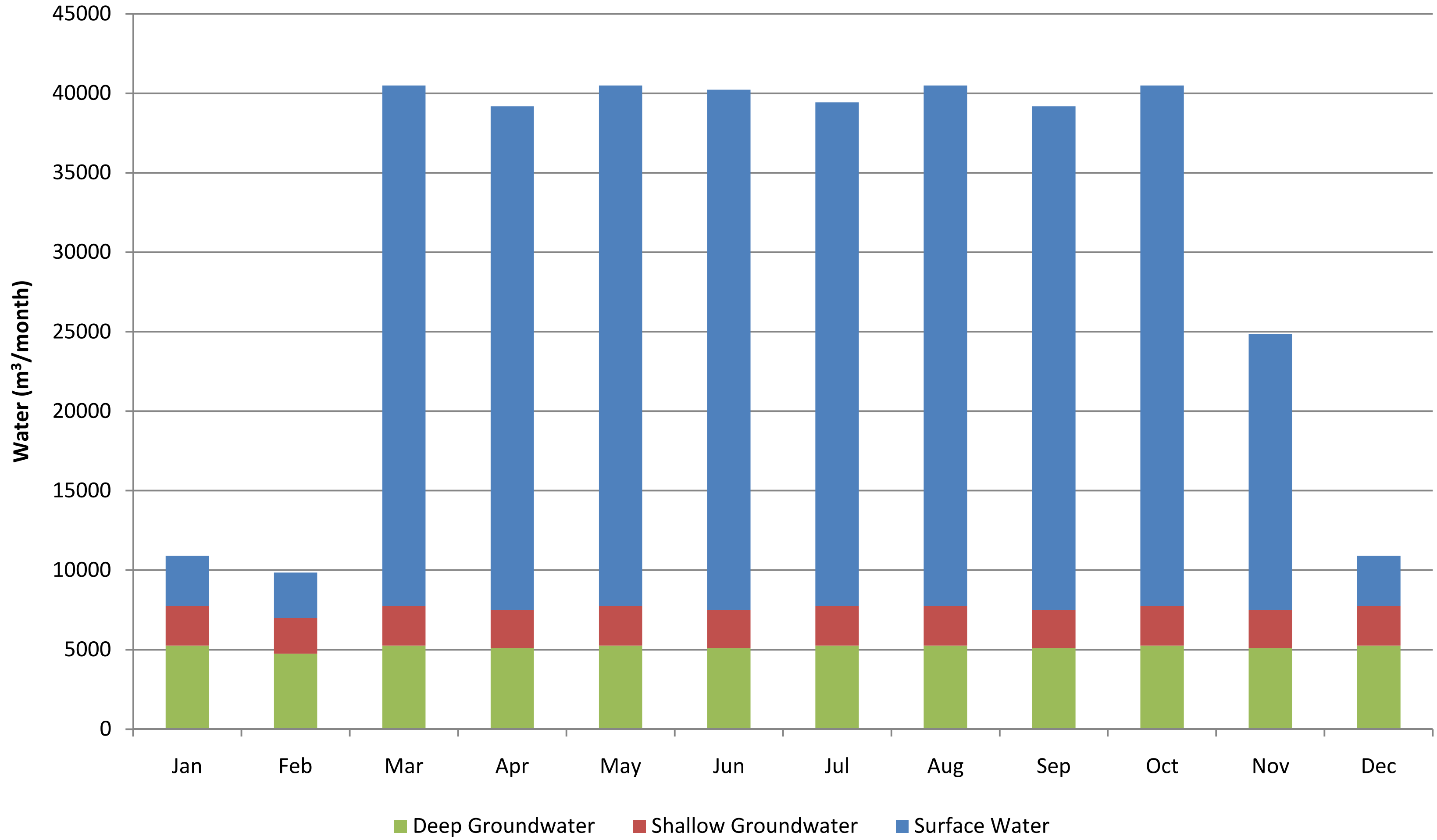


WESA A Better Environment For Business	PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
	PROJECT NO.	S-B6720	DRAWN BY:	SJD
	TITLE:	South River Annual Water Use	CHECKED BY:	RTS
	DATE:	18-Feb-10	**Figure 10**	



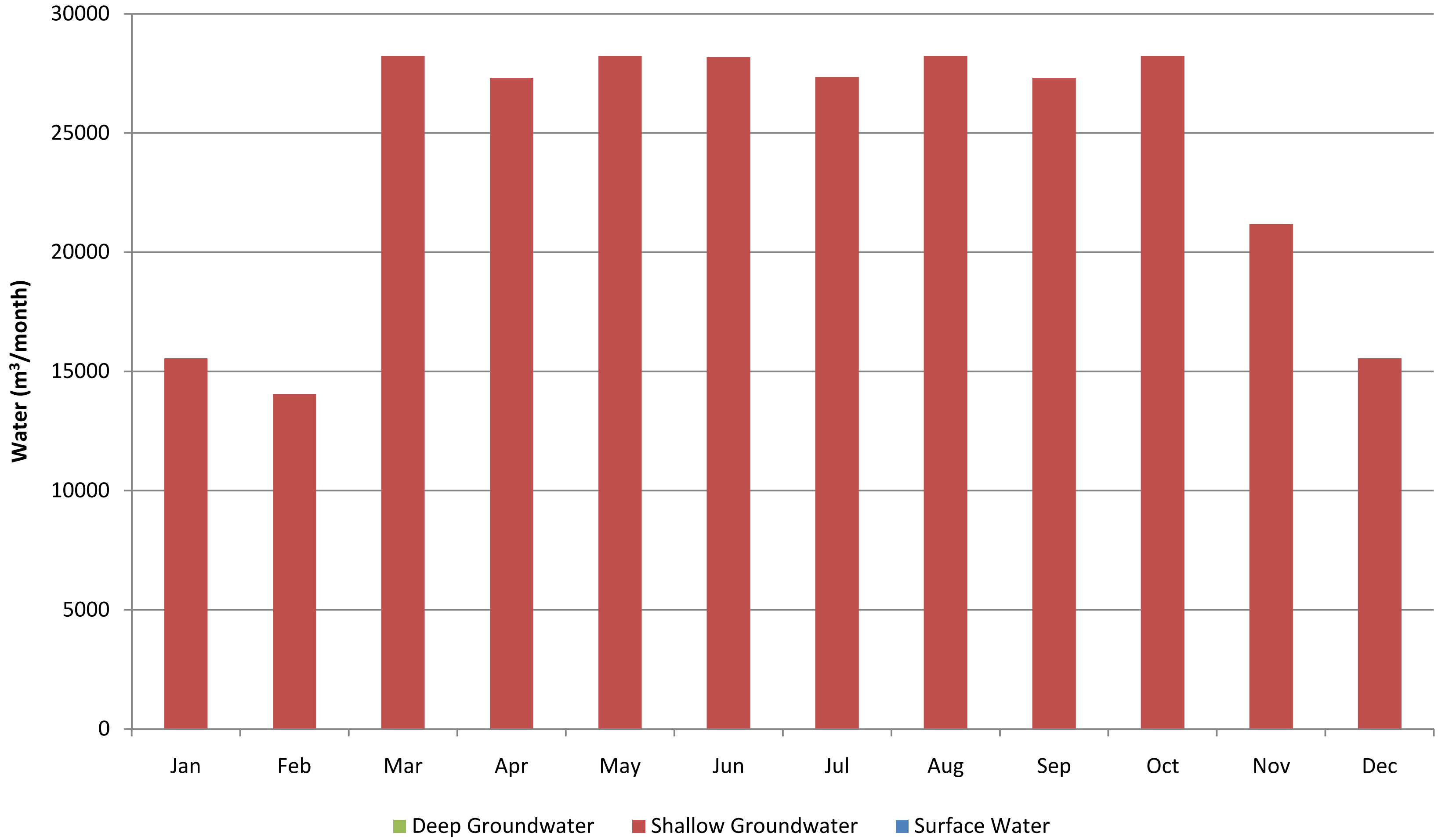
WESA
A Better Environment For Business

PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	South River Monthly Water Use - Gross Takings	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 11a**	



WESA
A Better Environment For Business

PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	South River Monthly Water Use - Consumption	CHECKED BY:	RTS
DATE:	18-Feb-10	**Figure 11b**	



WESA

A Better Environment For Business

PROJECT:	Tier 1 Water Budget and Stress Assessment Mattawa, Powassan, and South River Municipal Water Supplies		
PROJECT NO.	S-B6720	DRAWN BY:	SJD
TITLE:	South River Monthly Water Use - Returns	BY:	RTS
DATE:	18-Feb-10	**Figure 11c**	

Appendix A

GIS Methodology for Estimating Monthly Potential Evapotranspiration

Overview:

This document describes the methodology and specific calculations used by WESA for determining Actual Evapotranspiration (AET) values. This methodology is a modified version of the Mississippi-Rideau Source Protection region work. Mississippi-Rideau also made some minor changes after having the original methodology created by Waterloo Hydrologic for Quinte Conservation. It has been modified to fit the regional data availability of the North Bay-Mattawa Conservation Authority.

Environment:

Software: ESRI ARCMAP V.9.3.1
Tools: SPATIAL ANALYST EXTENSION

Core Datasets:

Temperature: 13 METEOROLOGICAL STATIONS INTERPOLATED WITH KRIGING
ESRI GRID format
UTM, NAD 83 datum.
200m cells.
Kriging done using IDW method

Precipitation: 13 METEOROLOGICAL STATIONS INTERPOLATED WITH KRIGING
ESRI GRID format
UTM, NAD 83 datum.
200m cells.
Kriging done using IDW method

Table A1: Climatic Stations Used

Station Name*	Station ID	Latitude	Longitude	Elevation (m)
North Bay A	6085800	46°21' N	79°25' W	370
Powassan	6116702	46°7' N	79°15' W	274
Chalk River AECL	6101335	43°3' N	72°22' W	122
Combermere	6101820	45°22' N	77°37' W	287
Dunchurch	6112133	45°37' N	79°53' W	268
Dwight	6082178	45°23' N	78°54' W	404
Earlton A	6072225	47°42' N	79°51' W	243
Madawaska	6084770	45°30' N	77°59' W	316
Minden	6165195	44°56' N	78°43' W	274
Muskoka A	6115525	44°58' N	79°18' W	282
Sudbury A	6068150	46°37' N	80°48' W	348
Belleterre	7080600	47°23' N	78°42' W	322
Remigny	7086460	47°43' N	79°14' W	290

Notes:
All stations are located in Ontario except Belleterre and Remigny (Quebec)

<u>Spatial Analyst Settings:</u>

Cell Size initial: **200M**
Cell Size final: **25M**

<u>Detailed Methodology:</u>

- A step-by-step methodology was provided by Waterloo Hydrologic, the consultant used by Quinte Conservation to complete their groundwater modeling. These procedures were used as a guideline for this methodology.

HEAT INDEX CALCULATION

- Using monthly mean temperature GRIDS (ex: [meant_011])
- Reclassify:
  - Where [meant_011] <= 0, [Result A] = 0
  - Where [meant_011] > 0, [Result A] = 1
- Multiply (Spatial Analyst):
  - [Result B] = [Result A] * [meant_011]

- Monthly Heat Index:
  - [meant_011f] = Pow(([Result B]/5),1.514)
- Annual Heat Index:
  - [annheatindex] = [meant_011f] + [meant_021f] + … [meant_121f]

For the months of January, February, March and December, the mean temperatures are below zero. Therefore, when reclassifying according the above calculations, these months do not contribute to the index (their values are = 0).

EXPONENT M CALCULATION

- [exponentm] = 6.75 * 0.0000001 * Pow([annheatindex], 3) – 7.71 * 0.00001 * Pow([annheatindex], 2) + 1.79 * 0.01 * [annheatindex] + 0.492

UNADJUSTED POTENTIAL EVAPOTRANSPIRATION (UPE) CALCULATION

- Using monthly mean temperature GRIDS
- Reclassify:
  - Where all values in a month < 0, reclass entire raster to zero. For the M-R region, these are [meant_011], [meant_021], [meant_031], and [meant_121]
- Where values span 0, then:
  - Where [meant_111] < -0.000001, [Result A] = 0
  - Where [meant_111] > -0.000001, [Result A] = 1
  - [Result B] = [Result A] * [meant_111]
  - [upe_111] = Pow((10 * [Result B] / [annheatindex]),[exponentm]) * 16
- Where all values in a month >= 0 and < 26.5°C, then:
  - [upe_061] = Pow((10 * [meant_061] / [annheatindex]),[exponentm]) * 16
- Repeat for all months. For months where temperatures are < 0, all outputs will be zero (so there is no UPE)

WATER HOLDING CAPACITY

The water holding capacity from Strahler and Strahler (1997) was used to assign values to the MNDM surficial geology dataset (Table A2).

Table A2: Relationship Between Surficial Geology and Water Holding Capacity (Strahler and Strahler, 1997)

Surficial Geology	Water Holding Capacity (mm)
Glaciolacustrine	280
Bedrock and thin till	200
Glaciofluvial	100
Alluvial	100
Organic	50
Morainal till	50
Man made	50

A new WHC raster was created: **[gwhc_new2]**

ADJUSTED POTENTIAL EVAPOTRANSPIRATION (APE) CALCULATION

According to the document "Modeling Your Water Balance.pdf", the unadjusted PET values must be adjusted to accommodate daylight correction values, based on latitude. The North-Bay Mattawa Source Protection Area straddles 45°N latitude, so the adjustments factors were interpolated between 40° and 50° latitudes, as presented in Table A3.

Table A3: Latitude Correction Values

Lat	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Avg
40°	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81	1.03
50°	0.74	0.78	1.02	1.15	1.33	1.36	1.37	1.25	1.06	0.92	0.76	0.7	1.04
45°	***0.79****	***0.81****	***1.03****	***1.13***	***1.29***	***1.31***	***1.32***	***1.22***	***1.05***	***0.94***	***0.80***	***0.76****	***1.03***

**Months of Jan, Feb, Mar and Dec had negative temperatures, resulting in no PET values.*

- Set output cell size to 25m
- [adjpe_0425] = [upe_041] * 1.13
- [adjpe_0525] = [upe_051] * 1.29
- [adjpe_0625] = [upe_061] * 1.31
- [adjpe_0725] = [upe_071] * 1.32

- [adjpe_0825] = [upe_081] * 1.22
- [adjpe_0925] = [upe_091] * 1.05
- [adjpe_1025] = [upe_101] * 0.94
- [adjpe_1125] = [upe_111] * 0.80

ACTUAL EVAPOTRANSPIRATION (AE) CALCULATIONS

For each month, subtract the adjusted evapotranspiration from the mean precipitation. If the resulting GRID ([P_AEP]_<mm>25) has no negative values, then there is enough precipitation to meet the ET needs, so Actual ET = Potential Adjusted PET.

If, however, there are any negative values in the output raster, then there is not enough precipitation to meet the Potental ET needs. Checks need to be performed to see if there is enough Water Holding Capacity (WHC). In the North Bay-Mattawa Source Protection Area, values ranged as illustrated in Table A4.

Table A4: Adjusted Potential Evapotranspiration Values from May through October

Month	Min	Max
[p_ape_0425]	36.694	46.5243
[p_ape_0525]	-0.218445	11.5002
[p_ape_0625]	-20.2821	-12.9066
[p_ape_0725]	-33.4749	-24.8597
[p_ape_0825]	-13.4829	-9.05668
[p_ape_0925]	39.1565	46.2697
[p_ape_1025]	59.7887	67.5912

May contains some negative (deficit) values, and June, July and August values are completely negative. These deficits must be checked against the Water Holding Capacity, and adjusted accordingly.

For the month of May (where the APE values contain some negative values), a storage calculation is performed.

MayStorage = Con([p_ape_0525] < 0, [gwhc_new2] - Abs([p_ape_0525]), [gwhc_new2])

The equation states:

- For those cells where the difference between precipitation and Adjusted Potential ET is negative, subtract the extra ET from the available WHC at that location. The output cell represents storage available at that location after July.
- Because this is the first month where there is more ET than Precipitation, the calculation can use the WHC as is (it has not been tapped into in previous months)
- For cells where there is no deficit, the storage available remains the unadjusted WHC.

The [MayStorage] output above resulted in no negative values, meaning that there is enough storage in the ground to accommodate the estimated ET values. [MayStorage] is then used as the WHC value grid for June Storage calculations. Therefore:

[AET_05] = [adjustpe_0525]

For the month of June, because ALL of the APE values are negative, first a deficit raster is calculated:

JuneDeficit = [MayStorage] – Abs([p_ape_0625])

The deficit raster identifies any areas where there is not enough WHC left in the ground from May to accommodate the PET in June. In this case, all values in [JuneDeficit] are above zero, meaning that the Potential ET does not need to be adjusted, so:

[AET_06] = [adjpe_0625]

The storage calculation for June is then:

JuneStorage = Con([JuneDeficit] > 0, [JuneDeficit], 0)

The storage equation states:

- For those cells where the deficit is greater than zero- that is, where there is enough water in the ground to accommodate the difference between precipitation and PET is positive, set the storage equal to subtract the extra ET from the available WHC at that location. The available WHC is what is left as storage after **BOTH** the July and August PET needs are met. The output cell represents storage available at a given location after August.

- Because this is the second month where there is more ET than P, the calculation uses the remaining storage available after previous months have met their needs (in this case, July).
- For cells where there is no deficit, the storage available remains the value as carried over from the previous month.

For the month of July, the deficit raster is:

JulyDeficit = [JuneStorage] – Abs([p_ape_0725])

The [JulyDeficit] raster contains values below zero, meaning that the Potential ET values must be adjusted down to create the Actual ET. The Actual Potential Evapotranspiration (AET) for **July** is:

[AET_07]= Con([JulyDeficit] >= 0, [adjpe_0725], [adjpe_0725] – Abs([JulyDeficit]))

The equation states:

- For those cells where the July deficit raster is not negative (i.e. where there is enough WHC storage left from June to accommodate the PET values in July), the Actual ET value is equal to the Potential ET value.
- Where the deficit raster is negative, subtract the difference from the Potential ET value (i.e. adjust the potential ET value to meet the ground condition).

The July storage raster is then calculated as:

JulyStorage = Con([JulyDeficit] > 0, [JulyDeficit], 0)

For the month of August, the deficit raster is:

AugDeficit = [JulyStorage] – Abs([p_ape_0825])

The [AugDeficit] raster contains values below zero, meaning that the Potential ET values must be adjusted down to create the Actual ET. The Adjusted Potential Evapotranspiration (AET) for **August** is therefore:

[AET_08]=Con([AugDeficit]>=0, [adjpe_0825], [adjpe_0825] –Abs([AugDeficit]))

The equation states:

- For those cells where the August deficit raster is not negative (i.e. where there is enough WHC storage left from July to accommodate the PET values in August), the Actual ET value is equal to the Potential ET value.
- Where the deficit raster is negative, subtract the difference from the Potential ET value (i.e. adjust the potential ET value to meet the ground condition).

For the remaining months with non-negative temperatures,

Actual Evapotranspiration = Adjusted Potential Evapotranspiration

ANNUAL ACTUAL EVAPOTRANSPIRATION

The Annual Actual Evapotranspiration value is then calculated as:

[MR_Actual_ET] = [adjpe_0425] + [adjpe_0525] + [adjpe_0625] + [AET_07] + [AET_08] + [adjpe_0925] + [adjpe_1025] + [adjpe_1125]

SLOPE – REVISED METHODOLOGY

Using percent slope map for DEMv2, reclassify values according to the criteria presented in Table A5:

Table A5: Slope Reclassification Criteria

Description	% Slope	Value
Flat Land	<1.5%	0.172
Rolling Land	>1.5 to 3%	0.120
Hilly Land	> 3%	0.073

This was completed with the 'Reclassify' tool in Spatial Analyst. The reclassified values are saved in the slope_reclass_new INFO table. The reclassified percent slope raster is **[slope_inflt25]**.

LAND COVER INFILTRATION

The 28 categories contained in the Provincial Land Cover are categorized according to the infiltration values presented in Table A6.

Table A6: Landcover Infiltration Values

Landcover	Infiltration Category	Infiltration Factor
Urban, Aggregate	Low	0.05
Agriculture, Pasture, Abandoned Field, Wetland	Medium	0.1
Forest, Plantation	High	0.2

SURFACE INFILTRATION

The MNDM Surficial Geology was assigned a permeability score based on the Single Primary Material field. These values are presented in Table A7.

Table A7: Permeability Scores

Single Primary Material	Permeability	Infiltration Factor
Clay, Silt	Low	0.1
Till	Low-Medium	0.15
Till	Medium	0.15
Sands	Medium-High	0.3
Gravel, Sands, Organics	High	0.4
Till	Variable, Assumed Medium	0.2
Fill	Variable, Assumed High	0.4
Sand	Variable, Assumed Medium-High	0.35
Bedrock, Precambrian	Low	0.02
Bedrock, Paleozoic	Low	0.05

COMBINED INFILTRATION COEFFICIENT

Infiltration Coefficient is calculated by:

[inflt_coeff] = [lc28_infilt] + [slope_inflt25] + [srfgeo_infilt]

The projection of the grid was set to Geographic Projection. This was completed by exporting the UTM Z18 grid to Geographic Nad83 projection in Spatial Analyst. The output cell size was set to the 25m, resulting in [g_infilt_coeff].

WATER SURPLUS

Water Surplus is the difference between total Annual Precipitation and Actual Evapotranspiration, expressed as:

[h20_surplus] = [annpc25_mr] – [MR_Actual_ET]

Before completing this, however, the NRCan Annual Precipitation raster had to be resampled to match the higher 25m resolution of the Actual ET work, resulting in [annpc25_mr].

RECHARGE VOLUME

The volume is calculated by the multiplication of Water Surplus by the Infiltration Coefficient.

[recharge_vol] = ([annpc25_mr] – [mr_Actual_ET]) * [g_inflt_coeff]

RUNOFF VOLUME

Runoff Volume is calculated by subtracting the Infiltration Volume, as calculated above, from the Water Surplus (precipitation – actual evapotranspiration). The equation used in Spatial Analyst was:

[runoff_vol] = [annpc25_mr] - [MR_Actual_ET] - [infilt_vol]

ZONAL STATISTICS

Zonal statistics were completed with the Spatial Analyst for the annual and monthly precipitation, AET, surplus, recharge and runoff. These statistics are provided in Tables 4 (Mattawa), 12 (Powassan) and 20 (South River) of the main report.

Appendix B

Thornthwaite-Mather Soil Moisture Budget Results

MATTAWA THORTHWAITE-MATHER WATER BUDGET

Available water content (AWC)	from concep. WB =	100.000	mm
Reservoir coefficient f		0.500	
Input data source:			
Monthly precipitation/temp data : JF's model			
Monthly PET data : JF			
Snowmelt runoff coefficient (1st month):		0.100	
Snowmelt runoff coefficient (subsequent months):		0.500	
Recharge coefficient		0.478	

Situation in the Watershed	*SW*	*APWL*	Excess
• Soil is drying: $\Delta P < 0$	$= AWC \exp\left(\frac{APWL_t}{AWC}\right)$	$= APWL_{t-1} + \Delta P$	$= 0$
• Soil is wetting: $\Delta P > 0$ but $SW_{t-1} + \Delta P \leq AWC$	$= SW_{t-1} + \Delta P$	$= AWC \ln\left(\frac{SW_t}{AWC}\right)$	$= 0$
• Soil is wetting above capacity: $\Delta P > 0$ but $SW_{t-1} + \Delta P > AWC$	$= AWC$	$= 0$	$= SW_{t-1} + \Delta P - AWC$

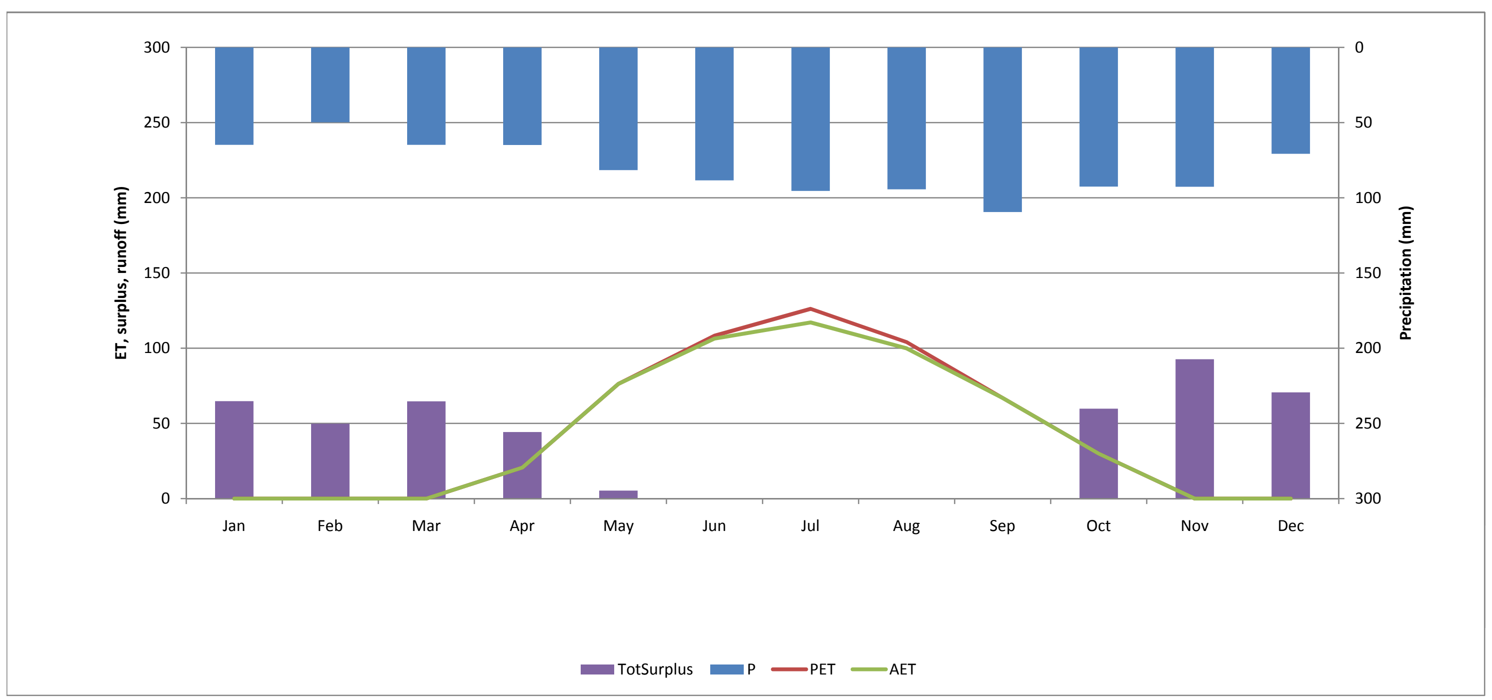
TERM	DEFINITION	RULES AND ASSUMPTIONS
T	Temerature	
P	Precipitation	
PET	Potential Evapotranspiration	T>0
APWL	Accumulated Potential water loss	See box above
SW	Soil Water	See box above
dSW	change in soil water	
AET	Actual Evapotranspiration	When P>PET, AET = PET; when P<PET, AET = dSW + P
Deficit	defined when PET>AET	PET>AET
TotSurplus	Total excess water after ET and recharging soil water	
Surplus	defined when SW>AWC	SW>AWC; T>-1 for surplus to be available
Detention	Water available the following month	
Storage	Water available for current month	
DirRunoff	Direct runoff from rain	
SMSurplus	Snow melt surplus; water available for snowmelt	T_{m+1}>=-1
SMDetention	Snow melt detention; water available for snow melt the following month	
SMStorage	Snow melt storage; water available for snow melt for current month	
SMRO	Snow melt runoff	Occurs when T_m>=-1. 10% available first month when T_m>=-1, 50% available when T_m>=-1 and T_{m-1}>=-1
ROtot	Total water available to partition into runoff and recharge	Sum of direct runoff and snow melt runoff; partitioning coefficient divides ROtot into runoff and recharge
R	Recharge	
RO	Runoff	
DT	Total moisture detention	
f	linear reservoir coefficient (fraction of of surplus available for runoff/recharge each month)	

All units in mm.

Mattawa	MODEL INPUTS			MODEL CALCULATIONS																			ANNUAL SUMMARY			
month	**T**	**P**	**PET**	**P-PET**	**APWL**	**SW**	**dSW**	**AET**	**Deficit**	**TotSurplus**	**Surplus**	**Detention**	**Storage**	**DirRunoff**	**SMSurplus**	**SMDetention**	**SMStorage**	**SMRO**	**ROtot**	***R***	***RO***	**DT**	**P**	**AET**	**RO**	**R**
Jan	-12.6	64.8	0.0	64.8	0.0	100.0	0.0	0.0	0.0	*65*	0	0	0	0	0	0	0	0	0	*0*	*0*	100.0	969.1	517.2	112.4	103.0
Feb	-10.5	49.8	0.0	49.8	0.0	149.8	0.0	0.0	0.0	*50*	0	0	0	0	0	0	0	0	0	*0*	*0*	149.8				
Mar	-4.3	64.7	0.0	64.7	0.0	214.5	0.0	0.0	0.0	*65*	0	0	0	0	114	114	114	0	0	*0*	*0*	214.5				
Apr	4.1	64.9	20.7	44.2	0.0	100.0	0.0	20.7	0.0	*44*	44	22	44	22	0	103	114	11	34	*16*	*18*	450.9				
May	11.6	81.5	76.2	5.3	0.0	100.0	0.0	76.2	0.0	*5*	5	14	27	14	0	52	103	52	65	*31*	*34*	165.2				
Jun	16.1	88.4	108.3	-19.8	-19.8	82.0	-18.0	106.4	1.8	*0*	0	7	14	7	0	26	52	26	33	*16*	*17*	114.6				
Jul	18.7	95.4	126.2	-30.8	-50.7	60.2	-21.8	117.1	9.1	*0*	0	3	7	3	0	13	26	13	16	*8*	*9*	76.5				
Aug	17.3	94.3	104.1	-9.8	-60.5	54.6	-5.6	99.9	4.2	*0*	0	2	3	2	0	6	13	6	8	*4*	*4*	62.8				
Sep	12.6	109.5	67.0	42.5	-2.9	**97.2**	42.5	67.0	0.0	*0*	0	1	2	1	0	3	6	3	4	*2*	*2*	101.2				
Oct	6.4	92.5	29.9	62.6	0.0	100.0	2.8	29.9	0.0	*60*	60	30	61	30	0	2	3	2	32	*15*	*17*	131.9				
Nov	-0.4	92.7	0.0	92.7	0.0	192.7	0.0	0.0	0.0	*93*	0	15	30	15	0	1	2	1	16	*8*	*8*	208.6				
Dec	-8.5	70.7	0.0	70.7	0.0	263.4	0.0	0.0	0.0	*70.7*	0	8	15	8	0	0	1	0	8	*4*	*4*	270.9				
Jan	-12.6	64.8	0.0	64.8	0.0	328.1	0.0	0.0	0.0	*65*	0	4	8	4	0	0	0	0	4	*2*	*2*	332	969.1	517.2	234.6	214.9
Feb	-10.5	49.8	0.0	49.8	0.0	377.9	0.0	0.0	0.0	*50*	0	2	4	2	0	0	0	0	2	*1*	*1*	379.8				
Mar	-4.3	64.7	0.0	64.7	0.0	442.6	0.0	0.0	0.0	*65*	0	1	2	1	343	343	343	0	1	*0*	*0*	443.6				
Apr	4.1	64.9	20.7	44.2	0.0	100.0	0.0	20.7	0.0	*44*	44	23	45	23	0	308	343	34	57	*27*	*30*	428.5				
May	11.6	81.5	76.2	5.3	0.0	100.0	0.0	76.2	0.0	*5*	5	14	28	14	0	154	308	154	168	*80*	*88*	268.1				
Jun	16.1	88.4	108.3	-19.8	-19.8	82.0	-18.0	106.4	1.8	*0*	0	7	14	7	0	77	154	77	84	*40*	*44*	166.1				
Jul	18.7	95.4	126.2	-30.8	-50.7	60.2	-21.8	117.1	9.1	*0*	0	3	7	3	0	39	77	39	42	*20*	*22*	102.3				
Aug	17.3	94.3	104.1	-9.8	-60.5	54.6	-5.6	99.9	4.2	*0*	0	2	3	2	0	19	39	19	21	*10*	*11*	75.7				
Sep	12.6	109.5	67.0	42.5	-2.9	97.2	42.5	67.0	0.0	*0*	0	1	2	1	0	10	19	10	11	*5*	*5*	107.7				
Oct	6.4	92.5	29.9	62.6	0.0	100.0	2.8	29.9	0.0	*60*	60	30	61	30	0	5	10	5	35	*17*	*18*	135.1				
Nov	-0.4	92.7	0.0	92.7	0.0	192.7	0.0	0.0	0.0	*93*	0	15	30	15	0	2	5	2	18	*8*	*9*	210.2				
Dec	-8.5	70.7	0.0	70.7	0.0	263.4	0.0	0.0	0.0	*71*	0	8	15	8	0	0	2	0	8	*4*	*4*	270.9				
Total		**969.1**	**532.3**	**436.8**	**-133.9**	**2198.7**	**0.0**	**517.2**	**15.1**	**452**	**109.3**	**109.3**	**218.6**	**109.3**	**342.6**	**956.9**	**1299.5**	**340.2**	**449**	**215**	**235**	**2919.9**				

surplus + SMSurplus = tot surplus

R + RO = ROtot, which is the total water from direct runoff and snowmelt that is available for runoff and recharge



POWASSAN THORTHWAITE-MATHER WATER BUDGET

Available water content (AWC)	from concep. WB =	100.000	mm
Reservoir coefficient f		0.500	

Input data source:
Monthly precipitation data : Environment Canada climate normals 1971-2000
Monthly PET data : JF

Snowmelt runoff coefficient (1st month):	0.100
Snowmelt runoff coefficient (subsequent months):	0.500
Recharge coefficient	0.403

Situation in the Watershed	*SW*	*APWL*	Excess
• Soil is drying $\Delta P < 0$	$= AWC \exp\left(\frac{APWL_t}{AWC}\right)$	$= APWL_{t-1} + \Delta P$	$= 0$
• Soil is wetting $\Delta P > 0$ but $SW_{t-1} + \Delta P \leq AWC$	$= SW_{t-1} + \Delta P$	$= AWC \ln\left(\frac{SW_t}{AWC}\right)$	$= 0$
• Soil is wetting above capacity $\Delta P > 0$ but $SW_{t-1} + \Delta P > AWC$	$= AWC$	$= 0$	$= SW_{t-1} + \Delta P - AWC$

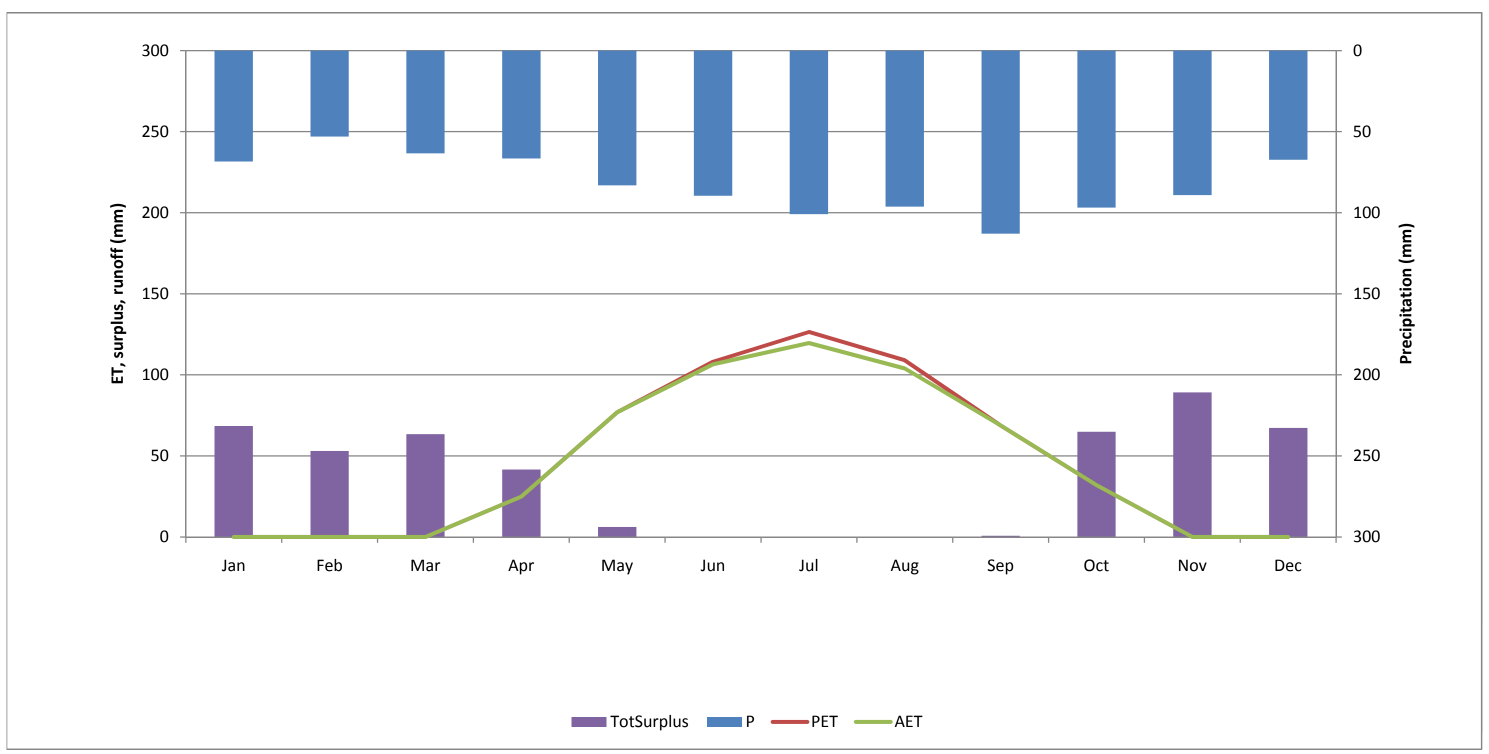
TERM	DEFINITION	RULES AND ASSUMPTIONS
T	Temerature	
P	Precipitation	
PET	Potential Evapotranspiration	T>0
APWL	Accumulated Potential water loss	See box above
SW	Soil Water	See box above
dSW	change in soil water	
AET	Actual Evapotranspiration	When P>PET, AET = PET; when P<PET, AET = dSW + P
Deficit	defined when PET>AET	PET>AET
TotSurplus	Total excess water after ET and recharging soil water	
Surplus	defined when SW>AWC	SW>AWC; T>-1 for surplus to be available
Detention	Water available the following month	
Storage	Water available for current month	
DirRunoff	Direct runoff from rain	
SMSurplus	Snow melt surplus; water available for snowmelt	T_{m+1}>=-1
SMDetention	Snow melt detention; water available for snow melt the following month	
SMStorage	Snow melt storage; water available for snow melt for current month	
SMRO	Snow melt runoff	Occurs when T_m>=-1. 10% available first month when T_m>=-1, 50% available when T_m>=-1 and T_{m-1}>=-1
ROtot	Total water available to partition into runoff and recharge	Sum of direct runoff and snow melt runoff; partitioning coefficient divides ROtot into runoff and recharge
R	Recharge	
RO	Runoff	
DT	Total moisture detention	
f	linear reservoir coefficient (fraction of of surplus available for runoff/recharge each month)	

All units in mm.

Powassan	MODEL INPUTS			MODEL CALCULATIONS																			ANNUAL SUMMARY			
month	**T**	**P**	**PET**	**P-PET**	**APWL**	**SW**	**dSW**	**AET**	**Deficit**	**TotSurplus**	**Surplus**	**Detention**	**Storage**	**DirRunoff**	**SMSurplus**	**SMDetention**	**SMStorage**	**SMRO**	**ROtot**	***R***	***RO***	**DT**	**P**	**AET**	**RO**	**R**
Jan	-12.6	68.5	0.0	68.5	0.0	100.0	0.0	0.0	0.0	*68*	0	0	0	0	0	0	0	0	0	*0*	*0*	100.0	987.5	532.7	131.8	89.0
Feb	-10.5	53.0	0.0	53.0	0.0	153.0	0.0	0.0	0.0	*53*	0	0	0	0	0	0	0	0	0	*0*	*0*	153.0				
Mar	-4.3	63.4	0.0	63.4	0.0	216.5	0.0	0.0	0.0	*63*	0	0	0	0	116	116	116	0	0	*0*	*0*	216.5				
Apr	4.1	66.5	24.9	41.6	0.0	100.0	0.0	24.9	0.0	*42*	42	21	42	21	0	105	116	12	32	*13*	*19*	448.2				
May	11.6	83.1	76.9	6.2	0.0	100.0	0.0	76.9	0.0	*6*	6	13	27	13	0	52	105	52	66	*27*	*39*	165.9				
Jun	16.1	89.6	108.1	-18.5	-18.5	83.1	-16.9	106.5	1.6	*0*	0	7	13	7	0	26	52	26	33	*13*	*20*	116.1				
Jul	18.7	100.9	126.4	-25.6	-44.0	64.4	-18.7	119.6	6.8	*0*	0	3	7	3	0	13	26	13	16	*7*	*10*	80.9				
Aug	17.3	96.3	109.0	-12.7	-56.7	56.7	-7.7	103.9	5.0	*0*	0	2	3	2	0	7	13	7	8	*3*	*5*	65.0				
Sep	12.6	112.9	68.8	44.1	0.0	**100.0**	43.3	68.8	0.0	*1*	1	1	2	1	0	3	7	3	5	*2*	*3*	104.5				
Oct	6.4	96.9	32.0	64.9	0.0	100.0	0.0	32.0	0.0	*65*	65	33	66	33	0	2	3	2	35	*14*	*21*	134.7				
Nov	-0.4	89.2	0.0	89.2	0.0	189.2	0.0	0.0	0.0	*89*	0	17	33	17	0	1	2	1	17	*7*	*10*	206.5				
Dec	-8.5	67.3	0.0	67.3	0.0	256.5	0.0	0.0	0.0	*67*	0	8	17	8	0	0	1	0	8	*3*	*5*	264.7				
Jan	-12.6	68.5	0.0	68.5	0.0	325.0	0.0	0.0	0.0	*68*	0	4	8	4	0	0	0	0	4	*2*	*2*	329	987.5	532.7	270.1	182.3
Feb	-10.5	53.0	0.0	53.0	0.0	378.0	0.0	0.0	0.0	*53*	0	2	4	2	0	0	0	0	2	*1*	*1*	380.1				
Mar	-4.3	63.4	0.0	63.4	0.0	441.4	0.0	0.0	0.0	*63*	0	1	2	1	341	341	341	0	1	*0*	*1*	442.5				
Apr	4.1	66.5	24.9	41.6	0.0	100.0	0.0	24.9	0.0	*42*	42	21	43	21	0	307	341	34	55	*22*	*33*	426.2				
May	11.6	83.1	76.9	6.2	0.0	100.0	0.0	76.9	0.0	*6*	6	14	27	14	0	154	307	154	167	*67*	*100*	267.4				
Jun	16.1	89.6	108.1	-18.5	-18.5	83.1	-16.9	106.5	1.6	*0*	0	7	14	7	0	77	154	77	84	*34*	*50*	166.8				
Jul	18.7	100.9	126.4	-25.6	-44.0	64.4	-18.7	119.6	6.8	*0*	0	3	7	3	0	38	77	38	42	*17*	*25*	106.2				
Aug	17.3	96.3	109.0	-12.7	-56.7	56.7	-7.7	103.9	5.0	*0*	0	2	3	2	0	19	38	19	21	*8*	*12*	77.7				
Sep	12.6	112.9	68.8	44.1	0.0	100.0	43.3	68.8	0.0	*1*	1	1	3	1	0	10	19	10	11	*4*	*6*	110.9				
Oct	6.4	96.9	32.0	64.9	0.0	100.0	0.0	32.0	0.0	*65*	65	33	66	33	0	5	10	5	38	*15*	*23*	137.9				
Nov	-0.4	89.2	0.0	89.2	0.0	189.2	0.0	0.0	0.0	*89*	0	17	33	17	0	2	5	2	19	*8*	*11*	208.1				
Dec	-8.5	67.3	0.0	67.3	0.0	256.5	0.0	0.0	0.0	*67*	0	8	17	8	0	0	2	0	8	*3*	*5*	264.7				
Total		**987.5**	**546.1**	**441.5**	**-119.2**	**2194.3**	**0.0**	**532.7**	**13.4**	**455**	**113.5**	**113.5**	**226.9**	**113.5**	**341.4**	**953.6**	**1295.0**	**339.0**	**452.5**	**182**	**270**	**2917.5**				

surplus + SMSurplus = tot surplus

R + RO = ROtot, which is the total water from direct runoff and snowmelt that is available for runoff and recharge



SOUTH RIVER THORTHWAITE-MATHER WATER BUDGET

Available water content (AWC)	from concep. WB =	100.000	mm
Reservoir coefficient f		0.500	
Input data source:			
Monthly precipitation/temp data : JF's model			
Monthly PET data : JF			
Snowmelt runoff coefficient (1st month):		0.100	
Snowmelt runoff coefficient (subsequent months):		0.500	
Recharge coefficient		0.476	

Situation in the Watershed	SW	APWL	Excess
• Soil is drying $\Delta P < 0$	$= AWC \exp\left(\frac{APWL_t}{AWC}\right)$	$= APWL_{t-1} + \Delta P$	$= 0$
• Soil is wetting $\Delta P > 0$ but $SW_{t-1} + \Delta P \le AWC$	$= SW_{t-1} + \Delta P$	$= AWC \ln\left(\frac{SW_t}{AWC}\right)$	$= 0$
• Soil is wetting above capacity $\Delta P > 0$ but $SW_{t-1} + \Delta P > AWC$	$= AWC$	$= 0$	$= SW_{t-1} + \Delta P - AWC$

TERM	DEFINITION	RULES AND ASSUMPTIONS
T	Temerature	T>0
P	Precipitation	See box above
PET	Potential Evapotranspiration	See box above
APWL	Accumulated Potential water loss	
SW	Soil Water	When P>PET, AET = PET; when P<PET, AET = dSW + P
dSW	change in soil water	PET>AET
AET	Actual Evapotranspiration	
Deficit	defined when PET>AET	SW>AWC; T>-1 for surplus to be available
TotSurplus	Total excess water after ET and recharging soil water	
Surplus	defined when SW>AWC	
Detention	Water available the following month	
Storage	Water available for current month	T_{m+1}>=-1
DirRunoff	Direct runoff from rain	
SMSurplus	Snow melt surplus; water available for snowmelt	
SMDetention	Snow melt detention; water available for snow melt the following month	Occurs when T_m>=-1. 10% available first month when T_m>=-1, 50% available when T_m>=-1 and T_{m-1}>=-1
SMStorage	Snow melt storage; water available for snow melt for current month	Sum of direct runoff and snow melt runoff; partitioning coefficient divides ROtot into runoff and recharge
SMRO	Snow melt runoff	
ROtot	Total water available to partition into runoff and recharge	
R	Recharge	
RO	Runoff	
DT	Total moisture detention	
f	linear reservoir coefficient (fraction of of surplus available for runoff/recharge each month)	

All units in mm.

South River	MODEL INPUTS			MODEL CALCULATIONS																			ANNUAL SUMMARY			
month	**T**	**P**	**PET**	**P-PET**	**APWL**	**SW**	**dSW**	**AET**	**Deficit**	**TotSurplus**	**Surplus**	**Detention**	**Storage**	**DirRunoff**	**SMSurplus**	**SMDetention**	**SMStorage**	**SMRO**	**ROtot**	***R***	***RO***	**DT**	**P**	**AET**	**RO**	**R**
Jan	-12.6	74.1	0.0	74.1	0.0	100.0	0.0	0.0	0.0	*74*	0	0	0	0	0	0	0	0	0	*0*	*0*	100.0	998.3	541.8	109.7	99.6
Feb	-10.5	54.7	0.0	54.7	0.0	154.7	0.0	0.0	0.0	*55*	0	0	0	0	0	0	0	0	0	*0*	*0*	154.7				
Mar	-4.3	64.5	0.0	64.5	0.0	219.2	0.0	0.0	0.0	*64*	0	0	0	0	119	119	119	0	0	*0*	*0*	219.2				
Apr	4.1	67.2	24.6	42.6	0.0	100.0	0.0	24.6	0.0	*43*	43	21	43	21	0	107	119	12	33	*16*	*17*	466.4				
May	11.6	83.5	76.7	6.8	0.0	100.0	0.0	76.7	0.0	*7*	7	14	28	14	0	54	107	54	68	*32*	*35*	167.7				
Jun	16.1	88.2	107.9	-19.7	-19.7	82.1	-17.9	106.1	1.8	*0*	0	7	14	7	0	27	54	27	34	*16*	*18*	115.9				
Jul	18.7	95.7	126.1	-30.5	-50.2	60.5	-21.6	117.2	8.9	*0*	0	4	7	4	0	13	27	13	17	*8*	*9*	77.4				
Aug	17.3	92.6	108.8	-16.1	-66.3	51.5	-9.0	101.7	7.1	*0*	0	2	4	2	0	7	13	7	8	*4*	*4*	60.0				
Sep	12.6	113.1	68.6	44.5	-4.1	**96.0**	44.5	68.6	0.0	*0*	0	1	2	1	0	3	7	3	4	*2*	*2*	100.2				
Oct	6.4	98.5	46.9	51.6	0.0	100.0	4.0	46.9	0.0	*48*	48	24	48	24	0	2	3	2	26	*12*	*14*	125.9				
Nov	-0.4	93.4	0.0	93.4	0.0	193.4	0.0	0.0	0.0	*93*	0	12	24	12	0	1	2	1	13	*6*	*7*	206.3				
Dec	-8.5	72.8	0.0	72.8	0.0	266.2	0.0	0.0	0.0	*72.8*	0	6	12	6	0	0	1	0	6	*3*	*3*	272.3				
Jan	-12.6	74.1	0.0	74.1	0.0	340.4	0.0	0.0	0.0	*74*	0	3	6	3	0	0	0	0	3	*1*	*2*	343	998.3	516.4	249.8	226.9
Feb	-10.5	54.7	0.0	54.7	0.0	395.1	0.0	0.0	0.0	*55*	0	2	3	2	0	0	0	0	2	*1*	*1*	396.6				
Mar	-4.3	64.5	0.0	64.5	0.0	459.5	0.0	0.0	0.0	*64*	0	1	2	1	360	360	360	0	1	*0*	*0*	460.3				
Apr	4.1	67.2	20.7	46.5	0.0	100.0	0.0	20.7	0.0	*47*	47	24	47	24	0	324	360	36	60	*28*	*31*	444.7				
May	11.6	83.5	76.2	7.3	0.0	100.0	0.0	76.2	0.0	*7*	7	15	31	15	0	162	324	162	177	*84*	*93*	277.3				
Jun	16.1	88.2	108.3	-20.1	-20.1	81.8	-18.2	106.4	1.9	*0*	0	8	15	8	0	81	162	81	89	*42*	*46*	170.4				
Jul	18.7	95.7	126.2	-30.5	-50.6	60.3	-21.5	117.2	9.0	*0*	0	4	8	4	0	40	81	40	44	*21*	*23*	104.6				
Aug	17.3	92.6	104.1	-11.4	-62.1	53.8	-6.5	99.1	4.9	*0*	0	2	4	2	0	20	40	20	22	*11*	*12*	75.9				
Sep	12.6	113.1	67.0	46.1	-0.1	99.9	46.1	67.0	0.0	*0*	0	1	2	1	0	10	20	10	11	*5*	*6*	111.0				
Oct	6.4	98.5	29.9	68.6	0.0	100.0	0.1	29.9	0.0	*69*	69	35	69	35	0	5	10	5	40	*19*	*21*	139.8				
Nov	-0.4	93.4	0.0	93.4	0.0	193.4	0.0	0.0	0.0	*93*	0	17	35	17	0	3	5	3	20	*9*	*10*	213.3				
Dec	-8.5	72.8	0.0	72.8	0.0	266.2	0.0	0.0	0.0	*73*	0	9	17	9	0	0	3	0	9	*4*	*5*	274.9				
Total		**998.3**	**532.3**	**466.1**	**-132.9**	**2250.2**	**0.0**	**516.4**	**15.8**	**482**	**122.4**	**119.7**	**239.5**	**119.7**	**359.5**	**1004.1**	**1363.6**	**357.0**	**477**	**227**	**250**	**3012.0**				

surplus + SMSurplus = tot surplus

R + RO = ROtot, which is the total water from direct r
snowmelt that is available for runoff and recharge