Source Water Protection Planning
North Bay – Mattawa Source Protection Area
Conceptual Water Budget

Prepared for

North Bay – Mattawa Conservation Authority

Submitted by

Gartner Lee Limited

April 7, 2008

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Executive Summary

The Ontario government has introduced legislation to protect drinking water at the source, as part of an overall commitment to protect human health. A key focus of the legislation is the production of locally developed, science-based source water assessment reports and protection plans. The North Bay – Mattawa Conservation Authority (NBMCA) is participating in this initiative.

The Water Budget is one of a series of Technical Guidance Modules that were mandated to help watershed communities develop an Assessment Report for the planning area. Developing a water budget is a process that identifies how much water is available in the watershed, and illustrates how water moves through the watershed (lakes, streams, and groundwater). The water budget takes into account the activities that require water, both for the needs of people and of the environment. It also accounts for anticipated future water needs.

The NBMCA has prepared this water budget 'conceptual understanding' on a watershed basis. The conceptual understanding provides an overview of how the groundwater and surface water interact and move through the watershed. This understanding will enable the NBMCA to determine the need for, and level of, water budget assessment through numeric modelling.

The Mattawa and South Rivers are the two major watersheds comprising the North Bay-Mattawa Source Protection Area (North Bay-Mattawa SP Area). North Bay is the major urban centre with a population of about 53,000. At the eastern end of the region where the Mattawa River flows into the Ottawa River is the Town of Mattawa (population ~2,300). Powassan, Callander, and the Village of South River are all small communities lying along the north-south Highway 11 corridor and together host about 7,400 people.

The area considered within the North Bay-Mattawa SP Area is estimated to be 3,963 km^2, with 2,295 km^2 (58%) draining to the Mattawa River, and 930 km^2 (23%) draining to South River. The remaining smaller watersheds comprise 738 km^2 (19%). These watersheds, along with the South River, drain to Lake Nipissing. Only the Mattawa River and its contributing watersheds drain to the Ottawa River.

These watersheds are characterized largely by shallow soils over bedrock particularly in the southern and eastern parts of the region. The overburden is mostly sand and gravel, which readily accepts infiltration of precipitation. The underlying Precambrian bedrock is comparatively impermeable and locally deflects groundwater flow laterally to the streams, wetlands and lakes. South of North Bay, there is an area of deeper soils lying in a geologic basin where the bedrock is lower due to prehistoric faulting. These deeper soils host the most extensive agricultural area in the SP Area and have many private wells. The thickest overburden has been reported on the north and south side of Mattawa River in Olrig Township and Boyd Township, respectively. In Mattawa and Powassan, there are limited sand and gravel aquifers that supply water to these villages.

In the north end of the SP Area, the City of North Bay obtains all of its drinking water from Trout Lake. This is important because treated wastewater is discharged to Lake Nipissing, effectively transferring water from one watershed to another (i.e., inter-basin transfer). Mattawa and Powassan obtain their drinking water from two municipal groundwater wells at each location. The well configuration consists of one active well and one standby well in each town.

For this report, the water balance has been calculated based on historical data from 13 meteorological stations within the vicinity of the SP Area. The analysis considered water surplus, soils, topography and vegetation. The results were verified against the average annual streamflow of four gauging stations within the SP Area from 1971 to 2000, when the meteorological records were most coincident with existing streamflow records. Measured meteorological data and related calculations (i.e., actual evapotranspiration) were interpolated for the SP Area from values measured (or calculated) at the 13 meteorological stations. Individual monthly and annual interpolations were made using ordinary Kriging techniques.

The interpolated average annual precipitation for the study area during this period was 972 mm/yr. The interpolated actual evapotranspiration was estimated to be 535 mm/yr, leaving a surplus of 437 mm/yr. This surplus is available for runoff and groundwater recharge. The average recharge for the area was 208 mm/yr and average runoff was 229 mm/yr. Since the recharge ultimately reaches the watercourses in this shallow flow system, it generates baseflow. The combination of runoff and baseflow compares well with measured streamflow at selected sub-watersheds over the 30 years of record, with a difference of just 11%. This is considered to be in very close agreement, given the variability of the supporting information, and provides some independent assurance of the final conclusions.

When considering water volumes for the entire SP Area, annual consumptive surface and groundwater takings equal 33.6 and 1.5 million cubic metres, respectively, for a total of 35.1 million cubic metres per year. When compared with the available annual surplus, which is about 1,732 million cubic metres, there appear to be ample drinking water supplies within the SP Area, and on a basin-wide basis there is no apparent water quantity issue. However, further study, at a Tier 1 level, is warranted in order to resolve possible source water stresses on a local scale for the centres of North Bay, Mattawa, Powassan and South River.

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1. Introduction

A water budget analysis measures and characterizes the contribution of each component of the hydrologic system. A water budget should provide both a quantitative measure of the various components of the hydrologic cycle such as precipitation, evapotranspiration, runoff and recharge and an understanding of the pathways that water takes through a watershed. (The introduction to Section 4 of this report provides a brief description of these components and how they interact. Section 5 provides the detailed analysis.) The Conceptual Water budget carried out for North Bay-Mattawa Source Protection Area (hereafter referred to as North Bay – Mattawa SP Area or simply SP Area) is intended to address drinking water sources. This Conceptual Water Budget is a stand-alone document. However, it is complemented by, and may be read in concert with, the Watershed Characterization Report for North Bay-Mattawa (NBMCA, 2006).

1.1 Water Budgets and Source Water Protection

Water budgets are the component of the Assessment Report where water supply and demand are quantified and water movement within the watershed is understood. The level of water budgeting required in any specific watershed will depend on a number of factors, in particular water-taking or water-quantity stresses. Further risk assessment components (e.g., Water Quantity Stress Assessment) will be strongly linked to water budgeting, and will loop back to additional higher level water budget investigations if necessary. The objective of a water budget analysis is to provide a technically sound methodology for managing the quantity of existing and future sources of drinking water.

1.2 Water Budget Requirements

A water budget is an understanding and accounting of the movement of water and the uses of water over time, on, through, and below the surface of the earth. Each analysis will address some or all of the following four main questions:

1. Where is the water? (i.e., where are the surface and groundwater reservoirs located?)
2. How does the water move between those reservoirs? (i.e., what are the pathways through which the water travels?).
3. What and where are the stresses on the water? (i.e., where are the takings and assimilative needs?)
4. What are the trends? (i.e., are water levels declining, increasing, or remaining constant over time?)

The water budget developed in each watershed will accommodate some or all of the following considerations:

a) the amount of water within the various reservoirs of the hydrologic cycle, including precipitation, evapotranspiration, runoff, groundwater inflow and outflow, surface water inflow and outflow, change in storage, water withdrawals and water returns.

b) a description of groundwater and surface water flow pathways, and temporal, seasonal and annual changes in water quantities within each reservoir.

c) identification of:

  - areas of key hydrologic processes (e.g., recharge and discharge areas); and
  - the availability of potential water sources (aquifers and unused surface water sources).

d) support for predicted changes in the hydrologic cycle due to trends in land use and additional takings.

1.3 The North Bay – Mattawa SP Area Watersheds

A water budget study is conducted on a watershed basis. There are six independent watersheds in the North Bay-Mattawa SP Area, as shown on Figure 1.1.

a) Mattawa River watershed – the largest watershed within the jurisdiction of North Bay – Mattawa SP Area. It is composed of seven sub watersheds including North River, Kaibuskong River, Sharpes Creek, Amable du Fond River, Pautois Creek, Boom Creek and Upper South-Upper Amable du Fond Rivers.

b) Duchesnay River watershed.

c) La Vase River watershed.

d) Wistiwasing River watershed (referred to locally as the Wasi River).

e) Bear-Boileau Creeks watershed.

f) South River watershed, including Reserve-Beatty and Wolf Creeks.

The last five watersheds discharge flow westward into Lake Nipissing separately. Therefore, they are considered as five independent watersheds for the purpose of hydrologic analysis. The drainage area of each watershed is presented in Table 1.1.

Figure 1.1 The North Bay – Mattawa SP Area Watersheds

Table 1.1 North Bay – Mattawa SP Area Watersheds with Corresponding Drainage Areas

Name of the Watershed	Drainage Area (km^2)
Mattawa River watershed	2,295
Duchesnay River Watershed	144
La Vase River Watershed	182
Wistiwasing River Watershed	234
Bear-Boileau Creeks Watershed	178
South River Watershed	930
Total	**3,963 km^2**

The Mattawa and South Rivers are the two major watercourses within the North Bay-Mattawa SP Area (see the location map on Figure 1.1). The Mattawa River is a major tributary within the Ottawa River watershed. South River flows directly into Lake Nipissing, which ultimately drains to Lake Huron. North Bay is the major urban centre with a population of about 53,000. At the eastern end of the region where the Mattawa River flows into the Ottawa River is the Town of Mattawa (population approximately 2,300). Powassan, Callander Bay, and the Village of South River are all communities lying along the north-south Highway 11 corridor and together host about 7,400 people.

The area considered within the North Bay-Mattawa SP Area has been estimated at 3,963 km^2, of which 2,295 km^2 (58%) belongs to the Mattawa River drainage area, whereas 930 km^2 (23%) is contributed by South River. There are numerous smaller named tributaries within the Mattawa and South River systems.

The North Bay-Mattawa SP Area is characterized largely by bedrock outcrop with isolated deposits of shallow soils. Where present, the overburden is mostly sand and gravel, which readily accepts precipitation. The thickness of overburden may vary from 0 to over 100 m. The underlying Precambrian bedrock is comparatively impermeable that deflects groundwater flow laterally to the streams, wetlands and lakes. Four municipal wells (two in Powassan and two in Mattawa) in the SP Area draw water from sand and gravel overburden aquifers. In the north end of the SP Area, North Bay relies for its drinking water supply on surface water from Trout Lake.

The Ministry of Environment (MOE) Interim Water Budget Technical Direction document (MOE, 2007) suggests up to 27 different maps that could be used to present the results of the water budget exercise. The North Bay – Mattawa SP Area is straightforward from an analytical point of view, having a relatively uniform terrain. This, coupled with the spread-out nature of the data stations in comparison to other watersheds, means that the proposed maps have been consolidated to 15, presented in Appendix B. In this way the reader can conveniently reference the maps as they proceed through the report. Appendix B also includes a summary of information on each map, and how the original suggested list was consolidated.

The water level profile for the Mattawa and South Rivers are presented in Figures 1.2 and 1.3, respectively. The figures show the locations of each component of the river system, including lakes, reservoirs, bays and rivers. Beginning at the headwater Trout Lake, the Mattawa River system drops approximately 50 m in elevation over a distance of almost 70 km, before flowing into the Ottawa River. This represents an average slope of approximately 0.7 m/km. The South River system drops approximately 190 m over an approximate distance of 105 km, prior to discharging into Lake Nipissing. The average slope of South River is approximately 1.8 m/km.

Figure 1.2 Water Level Profile for the Mattawa River System

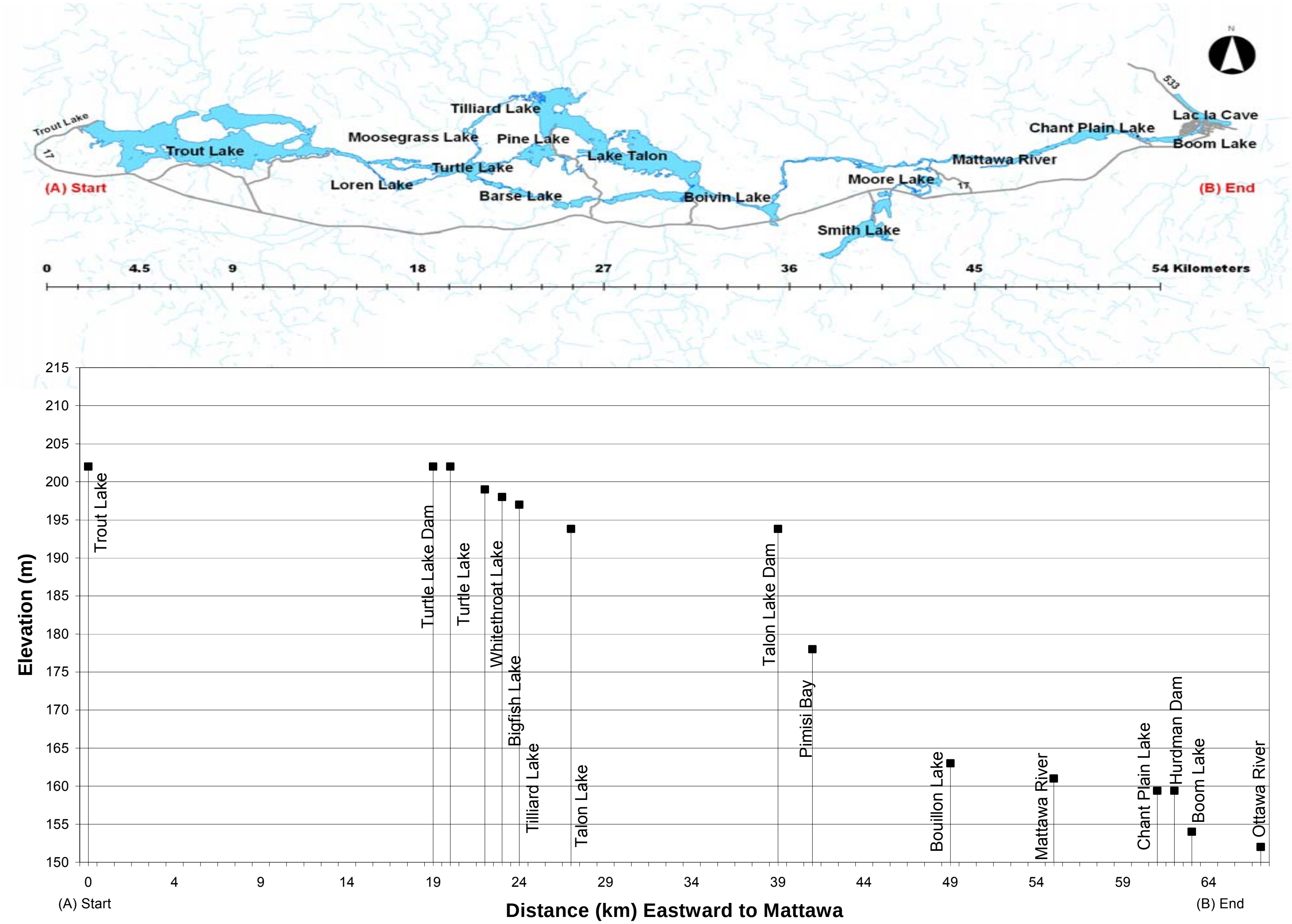
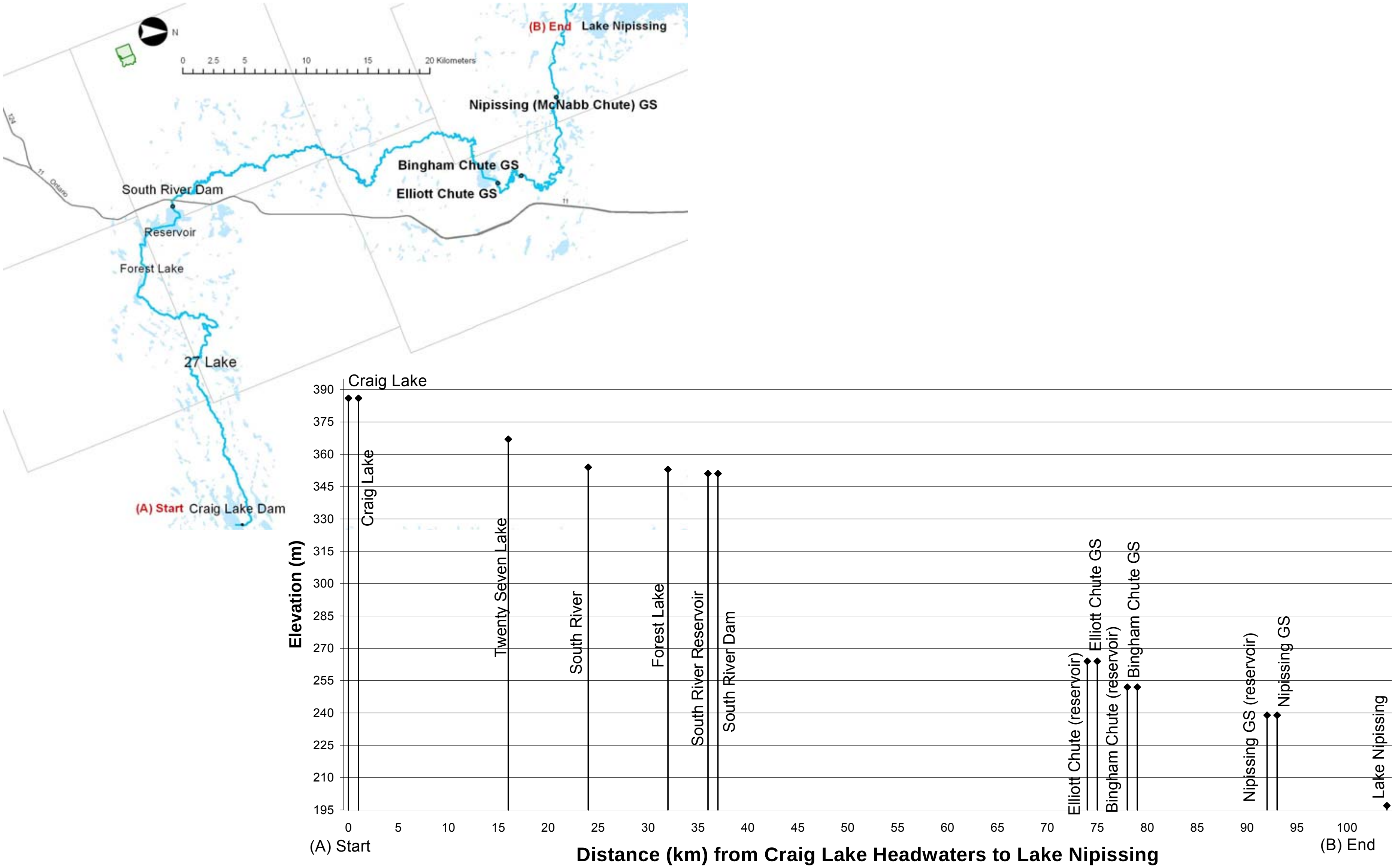


Figure 1.3 Water Level Profile for South River System



2. Objectives of SWP Planning for the North Bay – Mattawa SP Area

Once completed, water budgets prepared for North Bay – Mattawa SP Area will be used for the following purposes in watershed planning:

a) to set quantitative hydrological targets (e.g., water allocation, recharge rates, etc.) within the context of (sub) watershed plans.

b) as a decision-making tool to evaluate, relative to established targets, the implications of existing and proposed land and water uses within (sub) watersheds.

c) to evaluate the cumulative effects of land and water uses within (sub) watersheds.

d) to provide a (sub) watershed-scale framework within which site-scale studies (e.g., hydrological evaluations, sewage treatment plans, water supply plans) can be undertaken.

e) to help make informed decisions regarding the design of environmental monitoring programs.

f) to assist in setting targets for water conservation.

g) to assist in establishing long-term water supply plans.

h) for SWP, these objectives will answer the four main questions in the Watershed, namely:

    - where is the water? (i.e., where are the reservoirs located?);
    - how does the water move between those reservoirs? (i.e., what are the pathways through which the water travels?);
    - what and where are the stresses on the water? (i.e., where are the takings?);
    - what are the trends? (i.e., are levels steadily declining over time?); and

i) to identify data and knowledge gaps.

3. Conceptual Understanding of the Water Balance

This section gives a general overview of the components in the hydrologic water balance in a watershed in order to provide the reader with a basic understanding of the physical processes that characterize the available water resources within the SP Area. For a more complete understanding of the processes involved in the water balance of a watershed, please refer to some of the key textbooks on this subject (e.g., Chow, 1964; Viessman and Lewis, 1996; Linsley *et al.*, 1982).

Figure 3.1 displays a conceptual diagram of the major components of the hydrologic cycle (or water balance) within a watershed. The hydrologic cycle describes the movement of water through atmosphere-land-surface-groundwater system. Water vapour accumulates in the atmosphere by evaporation from open water and land surfaces and transpiration from plants. When it condenses, it falls to the land surface as precipitation (P, comprised of rain and snow). Part of this is returned to the atmosphere by evaporation and plant uptake (ET, that is, evapotranspiration). Part of the remaining precipitation soaks into the ground and recharges (R) the groundwater table. The rest runs off (RO) and is stored on the surface (e.g., lakes, ponds and marshes). From there it is evaporated back to the atmosphere to complete the cycle. The following paragraphs provide further detail[1].

The hydrologic cycle begins with precipitation falling on the ground. The amount and rate of precipitation that actually arrives at the ground surface is controlled by the prevailing weather system that generated the precipitation on a regional scale. At the more localized scale, topography and land cover influence the movement of the precipitation amounts once upon the ground surface.

This water (as rain or snowmelt) can follow three pathways. In liquid form water either runs off across the ground surface directly to a surface watercourse, or infiltrates into the ground to recharge groundwater storage, or goes back to the atmosphere by evaporation or through plant transpiration[2].

Water entering the ground is termed infiltration. The portion of the infiltration that reaches the water table is termed recharge, the difference being lost to plant uptake (transpiration) from the rooting zone. The amount of water that actually infiltrates the ground surface is controlled by the rate of precipitation (rainfall or snowmelt), soil type (i.e., clay, silt, sand or gravel), presence and depth to bedrock, ground surface conditions (e.g., topographic slope, seasonally frozen or desiccated soils) and vegetative cover (e.g., urban, agricultural or forested). In some areas (e.g., hummocky ground), the surface topography has created large depressions, which creates ponding before overland flow occurs. Consequently, water in these depressions either infiltrates downward and contributes to groundwater and subsurface storage or evaporates back to the atmosphere. Flow of groundwater is governed by the porosity and permeability of the soil or rock, the driving head, and the geometry of the pathways.

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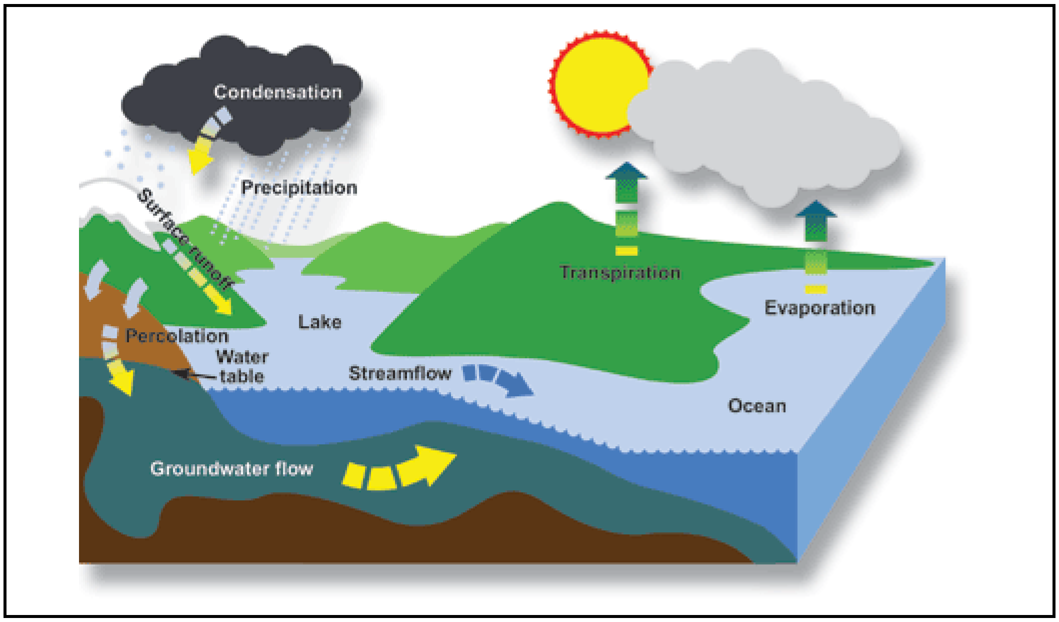
1. *The detailed water balance components are described mathematically at the beginning of Section 5.1.3.*
2. *Henceforth we use the term "evapotranspiration" to couple the processes of evaporation and transpiration (plant uptake). Keep in mind that transpirative losses include temporary storage in the rooting zone and then in the plant body and then subsequent release to the air.*



Source: *Environment Canada. "The Hydrologic Cycle." The Green Lane™. 2004-07-19. Environment Canada. 2008-02-04. www.ec.gc.ca/Water/en/info/pubs/lntwfg/e_chap1b.htm*

Figure 3.1 Conceptual Representation of the Hydrologic Cycle in a Watershed

Runoff water collects in stream channels that lead to larger channels or discharge to ponds, wetlands or lakes. While in these ponds or lakes, part of this water may return to the atmosphere by evaporation, it may infiltrate into the ground, or it may spill into downstream channels. The travel time of flow in these stream channels is governed by the length, slope, roughness and cross-sectional shape of these channels. If the flow is high and fast enough, water may overtop the channel banks, flooding the adjacent land area, resulting in further evaporation or recharge.

Evapotranspiration is a function of multiple factors including temperature, wind, humidity and solar radiation. Potential evapotranspiration (PET) is the amount of water that could be evaporated and transpired if there were an infinite amount of water available in the soil. PET can be calculated indirectly, from other climatic factors, but also depends on the surface type, such as free water (for lakes and oceans), the soil type for bare soil, and the species of vegetation.

Actual evapotranspiration (AET) is the actual amount of water delivered to the atmosphere by evaporation and transpiration under field conditions. AET is either equal to or less than PET. In wet months, when precipitation exceeds PET, AET is equal to PET. In dry months, when PET exceeds precipitation, AET is equal to precipitation plus the absolute value of the change in soil moisture storage (in these cases AET < PET).

4. Water Balance Elements

The purposes of this chapter are twofold; first, to describe the dominant watershed characteristics, features or factors that influence the water balance (or water budget) within the North Bay – Mattawa SP Area, and second, to summarize the available data used to measure or monitor those particular factors, highlighting (where possible) any gaps in the required databases.

Water in a river/stream is the result of precipitation that has fallen on the watershed over time. Water resulting from precipitation gains entry to the creek following three main paths: by directly falling on the creek surface, by running over the land surface to the streams/water bodies (surface runoff) or by infiltrating into the ground and reappearing as groundwater discharge (springs or seeps) along the stream course.

It is important to note that not all of the precipitation that falls on the watershed makes its way to the surface water and groundwater system. A portion of the precipitation that falls returns to the atmosphere by evaporation from open water surfaces (including sublimation in the winter from the snow covered surfaces), or is used by plants through transpiration. A portion of the water infiltrates into the ground and may leave the watershed by discharge to an adjacent watershed.

The path water follows in a watershed will determine to a great extent how the watershed responds to precipitation. The local climate, physiography (surficial geology, topography and land use) are dominant factors that influence how water is delivered to the streams and rivers that form a watershed. In the SP Area, consumptive activities (e.g., drinking water, irrigation, etc.) are locally dominant, but minor in comparison to the overall availability of water. Streamflow is the response to how water is delivered to the streams and creeks forming the drainage network of a watershed. Each of these factors must be considered when describing the water balance within a watershed.

To develop a conceptual understanding for the North Bay – Mattawa SP Area -, the following elements will be considered using available data:

a) Climate
b) Land Cover
c) Geology/Physiography
d) Groundwater
e) Surface Water (including reservoirs and major discharges) and
f) Water Use.

4.1 Climatic Setting

The climate of northeastern Ontario is characterized as having warm wet summers, cold dry winters and a short growing season. Spatial variations are caused by the topography and varying exposure to the prevailing winds in relation to the Great Lakes, which lie to the southwest. The constant influence of several air masses, including moist subtropical air, dry arctic air and dry continental air masses, makes the area susceptible to extreme and rapid variations in weather throughout the year. These variations are especially prevalent during the summer months when warm humid air mixes with dry cool air, resulting in moderate to severe thunderstorms.

The regional climate is described in “The Climate of Northern Ontario” by Chapman and Thomas (1968). The North Bay – Mattawa SP Area lies in the Sudbury-North Bay-Sault Ste. Marie region, between the Northern (Great) Clay Belt and Height of Land climatic regions (Chapman and Thomas, 1968). Given that this region is the southernmost of the Northern Ontario area, it is about 2°C warmer than other northern Ontario regions, with the most frost-free days (112). From a moisture point of view this region has 10 to 30% higher precipitation in comparison to the other regions, and experiences a correspondingly high surplus. These relatively warmer and wetter conditions are understandable given the upwind presence of large water bodies.

Periodically over the past 120 years, climate observations comprising maximum and minimum daily air temperature, and daily precipitation (as rainfall and snowfall) totals have taken place within and surrounding the study area at 40 meteorological stations. However, these measurements have been made over different time periods. Only 13 of these meteorological stations meet the World Meteorological Organization standards. At a few of these locations there are recording rain gauge (e.g., tipping-bucket) measurements, and in others snow depth on the ground. In other places, snow course measurements have been made on a twice monthly schedule during the winter months. For the most part, these climate observations have been carried out by a number of agencies, including: Environment Canada’s Atmospheric Environment Service (AES), the Ontario Ministry of Natural Resources (OMNR), Ontario Power Generation (OPG), various mining companies and local municipalities. A complete list of the climate stations where historical measurements have been made and recorded is given in Appendix A.

Table 4.1 gives a summary of mean annual values for air temperature, rainfall, snowfall and total precipitation at these 13 selected climate stations. (To aid the reader, the station values given in Table 4.1 are deliberately grouped according to geographical weather patterns and then listed in a north to south direction in each group).

Generally speaking, there is a north to south trend in the mean annual air temperatures, with the northern part of the watershed around North Bay being about 0.4°C cooler than Powassan, located approximately 35 km south. To the north, Earlton is 1.5°C colder than North Bay. To the south, Muskoka is 0.7°C warmer than Powassan.

Table 4.1 Climate Summary for Selected Stations at and in the Vicinity of North Bay – Mattawa SP Area (1971-2000 normals)

Climate Station Name		ID	Mean Annual Air Temp. (° C)	Mean Annual Rainfall Depth (mm)	Mean Annual Snowfall Depth (cm)	Mean Annual Total Precipitation Depth (mm)
Stations North of the Study Area	Earlton A (ON)	6072225	2.3	554	247	785
	Remigny (QC)	7086460	1.9	688	228	916
	Belleterre (QC)	7080600	1.9	705	291	996
	Sudbury A (ON)	6068150	3.7	657	274	899
Stations Directly in the Study Area	North Bay Airport	6085700	3.8	775	273	1008
	Powassan (ON)	6116702	4.2	737	199	936
Station Inland to the East of the Study Area	Chalk River (ON)	6101335	5.2	669	195	860
Stations South of the Study Area	Madawaska (ON)	6084770	4.0	655	188	843
	Combermere(ON)	6101820	4.6	662	207	869
	Dunchurch (ON)	6112133	4.5	810	304	1114
	Dwight (ON)	6082178	4.0	851	332	1183
	Muskoka A (ON)	6115525	4.9	809	334	1099
	Minden (ON)	6165195	5.2	797	248	1045

The spatial distribution of mean rainfall and snowfall amounts tends to be related to the distance from Lake Nipissing and Georgian Bay. That is, those stations to the north and east have the lowest totals, while those stations to the south (nearest the water bodies) experience the greatest amount of precipitation (see inset figure in Water Budget (WB) Map 1, Appendix B). The average precipitation for all thirteen stations is 965.6 mm/yr. Map 1 in Appendix B displays the total precipitation across the study area, contoured using ordinary Kriging. These contours range from 1,040 mm/yr in the south, dropping to 950 mm/yr inland past Mattawa. As the inset figure to the right shows, the average precipitation inland to the north and east is less than 900 mm/yr, while that to the south of the study area is just over 1,100 mm/yr.

Given the relatively few meteorological stations in the SP Area and its great spatial extent, total precipitation will vary between stations as well. Variations in climatic data between watershed meteorological stations result from differences in elevation, the orographic and rain shadow effect of topography, the moderating effect of large water bodies (Lake Nipissing and Georgian Bay) and the moderating effect of large urbanized areas. Dominant weather modifiers in the immediate North Bay – Mattawa SP Area include:

a) the modifying effect of Lake Nipissing and Georgian Bay;
b) the orographic effect of the Northern Uplands resulting in a higher precipitation average from cyclonic disturbances in the north through to the northwest;
c) the orographic effect of the Nipissing- Algonquin Highlands resulting in higher precipitation average in the south;
d) the rain shadow and temperature inversions which result in low precipitation occur in the Mattawa lowlands; and,
e) the urban heat island that occurs over urban North Bay.

For discussion purposes, the 30-year mean values of air temperature and precipitation (as rainfall and snowfall) for the North Bay Airport climate station are summarized in Table 4.2. This particular station was selected for discussion because it had the longest period of record and is still in operation. In Table 4.2, we see that the mean annual total precipitation is about 1,008 mm, of which 23% (assuming 273.4 cm snow = 233.4 mm of water) appears as snowfall, and 77% as rainfall (or about 775 mm). The highest average monthly snowfall amounts occur in December and January (61 and 63 cm, respectively). The total precipitation is distributed such that June, July, August, September and October are the wettest months, likely due to the presence of Lake Nipissing. February and March are the two driest months, because ice cover removes Lake Nipissing as a source of moisture. The lowest average monthly precipitation (53 mm) occurs in February, whereas the highest precipitation without snowfall occurs in September (113 mm). Frozen ground conditions are persistent between mid-October and mid-May, yielding high runoff potential for all fine grained soil types.

Table 4.2 Summary of Climate Data for North Bay Airport (1971-2000 normals)

Month	Average Maximum Daily Temp. (°C)	Average Minimum Daily Temp. (° C)	Average Daily Temp. (°C)	Mean Total Rainfall (mm)	Mean Total Snowfall (cm)	Mean Total Precipitation (mm)	Mean Total AET (mm)
JAN	-8.0	-18.0	-13.0	16.9	63.0	67.6	0
FEB	-5.8	-15.9	-10.9	9.6	52.2	52.6	0
MAR	0.2	- 9.8	- 4.8	31.9	38.0	65.4	0
APR	8.4	- 1.8	3.3	51.4	16.2	67.2	21
MAY	16.8	5.5	11.2	85.5	2.1	87.6	77
JUN	21.3	10.5	15.9	95.2	0.0	95.2	108
JUL	23.8	13.3	18.6	100.1	0.0	100.1	123
AUG	22.3	12.3	17.3	100.1	0.0	100.1	106
SEP	16.9	7.4	12.2	113.3	0.2	113.5	68
OCT	10.1	1.7	5.9	92.2	5.5	97.6	30
NOV	2.2	- 4.9	-1.4	58.6	35.0	89.9	0
DEC	-4.7	-13.5	-9.1	19.9	61.3	70.9	0
Annual Mean or Total	**8.6**	**-1.1**	**3.8**	**774.6**	**273.4***	**1008**	**534**

*Note: * assuming 273.4 cm of snowfall is equivalent to 233.4 mm of water*

The daily mean minimum temperature ranges from -13.0°C in January to a mean maximum of 18.6°C in July with an annual mean daily temperature of 3.8°C. Extreme temperatures as high as 40°C can occur in summer and as low as -40°C in winter.

Monthly water balance calculations for AET at the North-Bay Airport meteorological station show that AET is greater than the total precipitation input for June through August (see Table 4.2). Therefore, during the summer period there is a net deficit in the amount of precipitation that falls and is lost to the atmosphere through evapotranspiration. This reduces recharge and subsequently the water table drops during this season. This is seen on Figure A1 in Appendix A, which provides a hydrograph of a representative Provincial groundwater monitor (PGMIS ID: W0000274-1). Figure A1 shows that the low water level period is indeed found in the autumn season each year.

The influence of climate on the region's physical and economic development is significant in that it affects the scope and intensity of certain land use activities either directly or indirectly. A short growing season together with cool temperatures influences the intensity of agricultural activity while long cold winters have a certain impact on out-door recreational patterns. In terms of potential flooding the amount of snowfall, depth and extent of frost and the precipitation levels in the spring all contribute significantly to how the watershed reacts during spring runoff.

In the following sections the North Bay Airport meteorological station is relied upon to discuss trends. For the purposes of the water budget calculations undertaken in Section 4.4, spatially distributed climate data between the 13 meteorological stations within and in the vicinity of the SP Area have been used. Map 1 in Appendix B shows the precipitation distribution, contoured using ordinary Kriging.

4.1.1 Temperature Trends

The temperatures within the SP Area vary with yearly climatic cycles and geographic location. Based on both historical data for the period 1971 to 2000, the highest average daily air temperatures (above 9°C) occur between mid-May and mid-September, and start to decrease significantly in late August, whereas the lowest air temperatures (less than -5°C) occur regularly between November through March. Typically, summer mean monthly high temperatures are 15.9 to 18.6°C. Winter mean monthly temperatures are in the range of -1.4 to -10.9°C (see Table 4.2). Figure 4.1 shows the monthly distribution of average daily, and average maximum and minimum air temperatures at the North Bay Airport climate station.

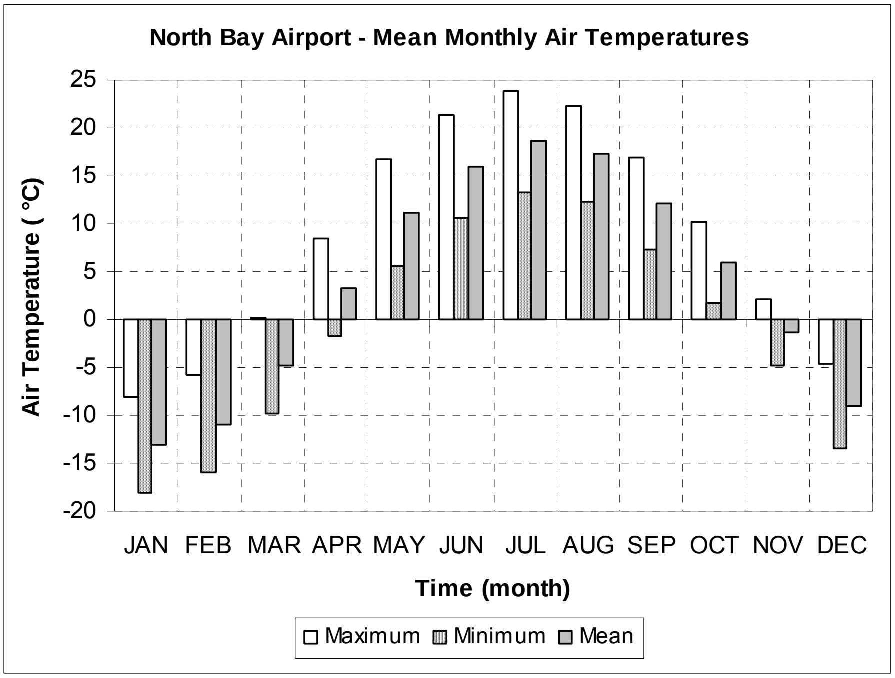


Figure 4.1 Mean Monthly Temperature at North Bay Airport (1971-2000 normals)

The time-series of annual average, minimum and maximum daily air temperatures for the 1971 to 2000 period are plotted on Figure 4.2 along with a five-year moving average trend line for the average daily temperature. It suggests that there has been a mild warming trend over the period from 1971 to 2000. This warming trend has been noticed in most locations throughout Ontario over the same time period, but does not indicate a significant variation from the long-term average. Nonetheless between 1998 and 2002 the average annual air temperature has been above the long term average.

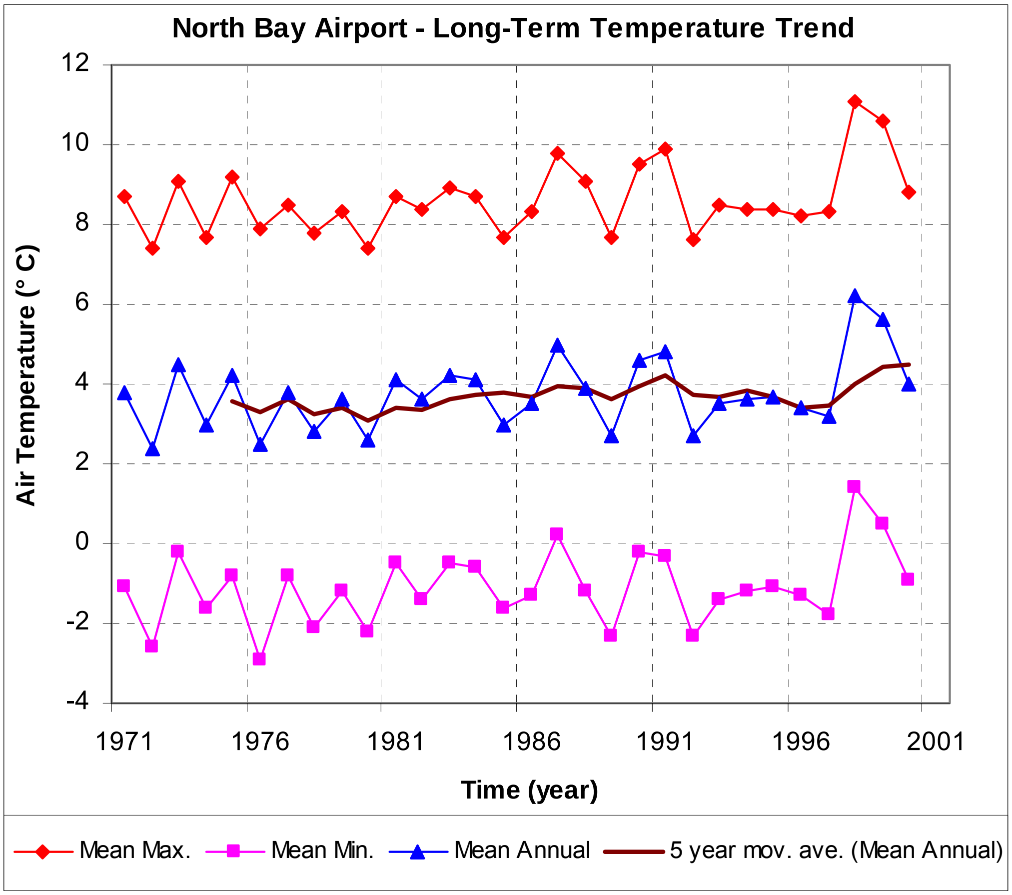


Figure 4.2 Time-Series of Annual Temperatures at North Bay Airport for 1971 to 2000

Of the 30 years shown in Figure 4.2, the year with highest mean daily temperature of 6.2°C occurred in 1998, whereas the year with the lowest mean daily temperature of 2.4°C occurred in 1972. The absolute highest maximum daily temperature of 35.4°C occurred on July 8, 1988, and the lowest minimum daily temperature of -38.4°C happened on January 10, 1982.

4.1.2 Precipitation

Precipitation, like temperature, varies with yearly climatic cycles, geographic location and elevation. Figure 4.3 gives the mean monthly distribution of precipitation occurring at the North Bay Airport climate station for the period 1971 to 2000.

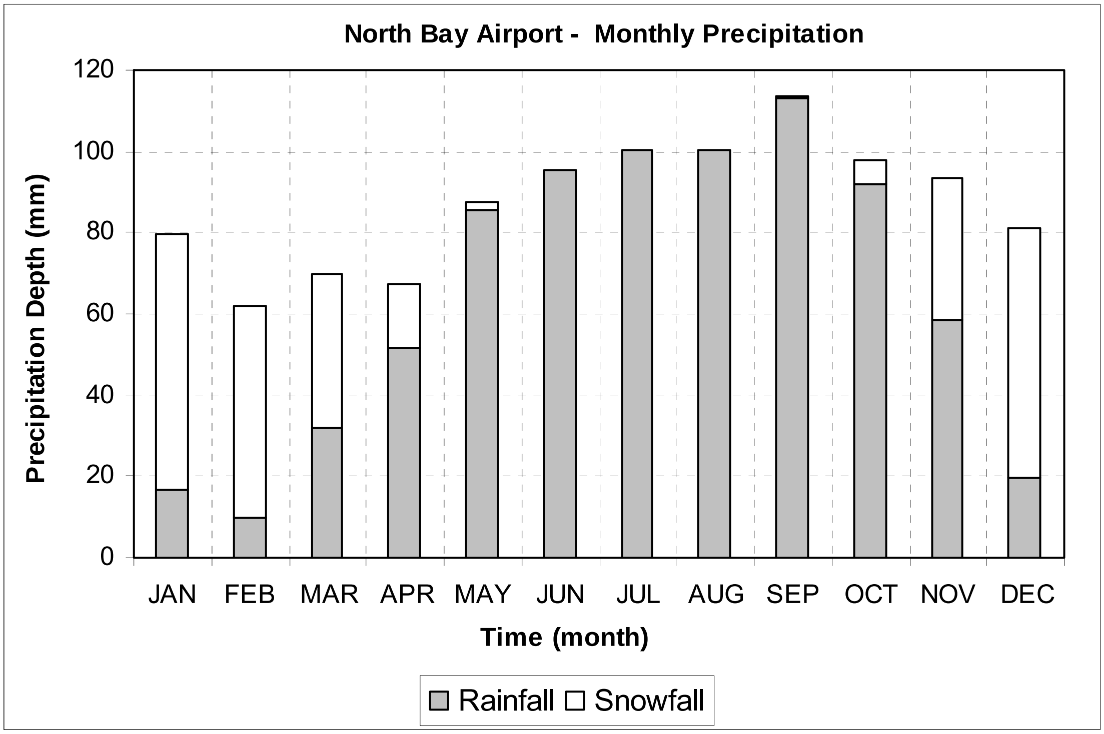


Figure 4.3 Mean Monthly Precipitation at North Bay Airport for 1971 to 2000

Figure 4.3 illustrates the contributions from rainfall and snowfall (snowfall is given in equivalent millimetres of water). From Figure 4.3, we see that the maximum precipitation occurs in the summer months, in the form of rainfall. In winter, most of the total precipitation falls as snowfall in the SP Area, although rainfall can occur. The snowfall can occur as early as mid-September or early-October, and can occur in April to early-May in small quantities.

Figure 4.4 illustrates an annual time-series of total precipitation, rainfall and snowfall occurring at the North Bay Airport from 1971 to 2000. There has been a constant trend in the precipitation totals since the early 1970s; a little rising trend of precipitation is observed after 1995 from the five year moving average of total precipitation (see Figure 4.4). From Figure 4.4, it appears that the wettest period occurred between the late 1990s and early 2000s, whereas the driest period was during the early 1990s. The highest annual precipitation total of 1,216 mm took place in 1999, whereas the lowest total of 812 mm occurred in 1993. In terms of mean annual rainfall totals, the highest total of 1,036 mm also occurred in 1999, whereas the lowest amount of 537 mm happened in 1971. The highest total snowfall of 392 mmew (millimetres equivalent water) occurred in 1972, whereas the lowest total of 175 mmew occurred in 1973.

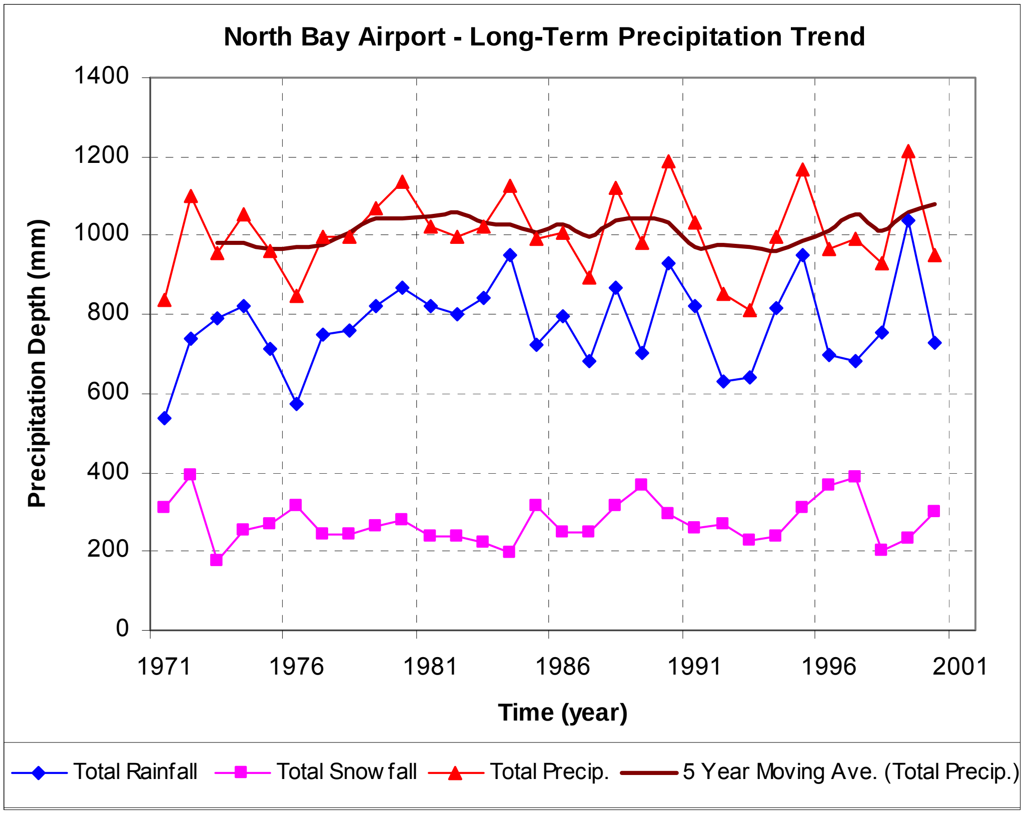


Figure 4.4 Time-Series of Annual Precipitation at North Bay Airport

The greatest 24-hour rainfall total of 93.2 mm occurred on July 30, 1990, and the highest 24-hour snowfall total of 25.2 mmew occurred on January 30, 1978.

4.1.3 Snow Courses

At the present time there is information for three snow course survey locations in the North Bay – Mattawa SP Area. The North Bay Psychiatric Hospital and Corbeil Conservation Area snow courses are monitored by the North Bay Mattawa Conservation Authority. The South River snow course is monitored by Ontario Power Generation. These are shown on Map 1, Appendix B.

Table 4.3 North Bay – Mattawa SP Area Snow Course Data

Station	Data Record Available	Source	Latitude	Longitude
North Bay Psychiatric Hospital	1988-2006	NBMCA	46°24’5” N	79°27’39” W
Corbeil Conservation Area	1987-2006	NBMCA	46°15’48” N	79°18’1” W
South River	1987-2000	OPG	45°54’59” N	79°13’45” W

Note: NBMCA: North Bay Mattawa Conservation Authority, OPG: Ontario Power Generation

The Surface Water Monitoring Centre is run by the OMNR and issues snow cover maps for the Province identifying snow depth, water content, snow density and percent of normal.

Figure 4.5 shows the temporal distribution of snow water equivalent at two snow courses for a high snow winter (2000-2001), when the maximum snow water equivalent tends to occur in mid-March. Conversely, Figure 4.6 gives similar information for a low snow winter (1994-1995), when the maximum snow water equivalent also tends to take place in early to mid-March. During the spring freshet most of the runoff is generated by the melting snowpack because the frozen ground inhibits infiltration, particularly for fine grained soils.

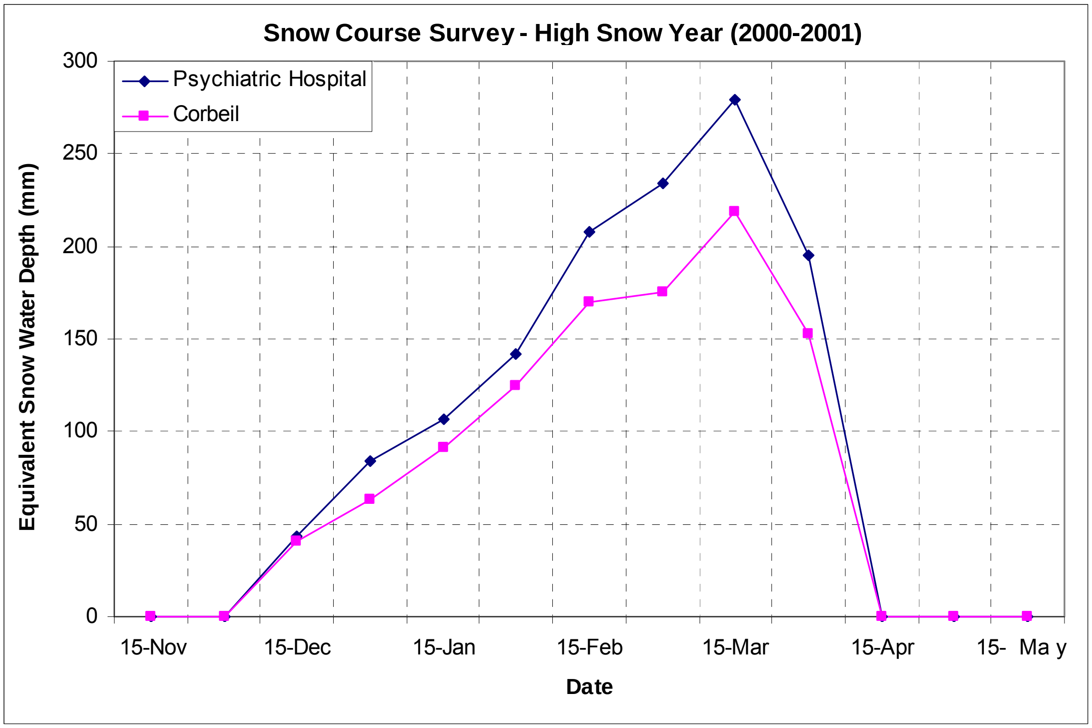


Figure 4.5 Temporal Distribution of Snow Water Equivalent for a High Snow Year (2000-2001)

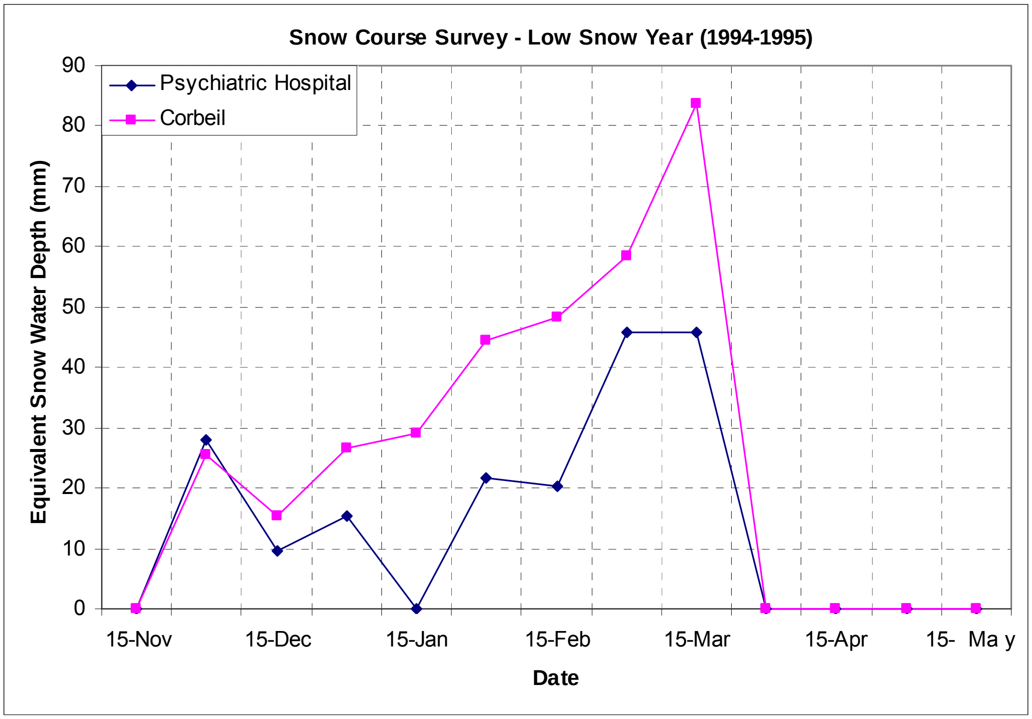


Figure 4.6 Temporal Distribution of Snow Water Equivalent for a Low Snow Year (1994-1995)

4.1.4 Evaporation and Potential Evapotranspiration

None of the climate stations in the general vicinity of the North Bay-Mattawa SP Area, as listed in Appendix A, has been equipped with pan evaporation apparatus to facilitate estimation of PET. Historically, the closest available evaporation measurements have been made in Ottawa, which is about 300 km east of the southeast boundary of the North Bay-Mattawa SP Area. Although these measurements have not occurred within the SP Area, they are sufficiently close to provide an indication of the temporal pattern of evaporation potential that can occur within the study area. Typically, the annual potential (or lake) evaporation total is about 570 to 650 mm. Given the fact that the SP Area is not much further north, one would expect these values to be only marginally lower, because the sun is at a lower angle of incidence throughout the year.

Figure 4.7 shows the distribution of mean monthly potential evaporation for Ottawa CDA, as taken from the 1951-1980 climate normals, including the range of reported values. Potential evaporation is highest in July and generally exceeds precipitation in May June, July and August as shown in Table 4.2. In order to satisfy the deficit between the potential evaporation and precipitation totals, water is drawn from soil-water storage below the land surface, if available.

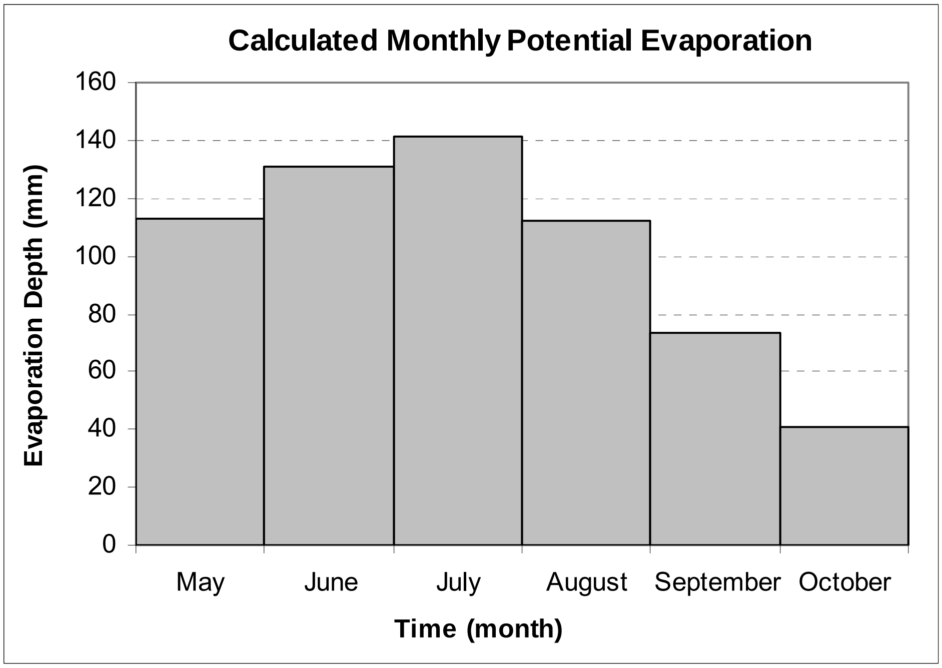


Figure 4.7 Mean Monthly Potential Evaporation at Ottawa CDA (1951-80 Normals)

4.2 Land Cover

By way of introduction, the North Bay – Mattawa SP Area includes the City of North Bay, and several smaller communities such as Mattawa Powassan, Callander, and the Village of South River. Settlement and infrastructure are concentrated in these areas. Census data taken from the Statistics Canada's website showed the population of the area at 75,660 in their 2002 report (Table 4.10, in Section 4.6). Human land use can affect the water balance by changing the physical characteristics of natural land cover.

Since land cover influences the distribution of surface runoff and infiltration to the subsurface, it is necessary to understand the land use distribution. Land cover throughout the SP Area is presented in Map 8 (Appendix B). Information to produce this map was completed using the 2000 Edition of the Ontario Land Cover Database (Spectral Analysis Inc., 2004), the second edition of this provincial land cover classification. The coverage is derived wholly from Landsat-7 Thematic Mapper (TM) satellite data frames recoded between 1999 and 2002, with most from 2000 onward.

As Map 8 shows, the vast majority of the SP Area is covered by woodland (about 80%). Lakes and rivers/streams are densely distributed within this area. These water bodies compose just over 7% of the land surface. There are several Provincial Parks within the study area as well, including parts of Algonquin Park which covers a large area of land in the southern portion of the area.

Up to 1,000 different species of plants grow annually without cultivation within the SP Area. Dominant species in the watershed include Red Pine, Eastern White Pine, Eastern Hemlock, Yellow Birch, and varieties of Oak and Maple.

A considerable amount of land is used for agricultural purposes, primarily on land south of the Mattawa River and on lands in the Wasi River and South River watersheds. Other agricultural areas are sporadically distributed throughout the entire SP Area.

Available information shows that physical and biological features of the SP Area are altered by human land use from pre-development conditions. Pre-development conditions are not fully documented, nonetheless significant alterations can be identified that affect water resources, including populated areas, forestry and mine sites.

Generally, the watershed region has an extensive forest, wetland or water cover (about 90%) with the rest under some form of land use. Of interest, human settlement is about 2% of the 3,963 km^2 area. Projections of land cover and its type within the total watershed area are listed Table 4.4.

Table 4.4 Land Cover Types and Percentages in the North Bay – Mattawa SP Area

Land Cover and Type	GRIDCODE	Area (km^2)	% of Total SP Area
Water – Deep or Clear	1	281	7.1
Settlement/Infrastructure	3	80	2.0
Bedrock Outcrop	5	6	0.1
Cutovers	7	11	0.3
Burns	8	0	<1.0
Sparse Forest	10	170	4.3
Deciduous Forest	11	1134	28.6
Mixed Forest	12	1479	37.3
Coniferous Forest	13	378	9.5
Treed Fen	21	3	0.1
Open Bog	22	4	0.1
Treed Bog	23	93	2.3
Pasture	25	252	6.3
Other		72	1.8
Total		3963	100

Note: The land cover classification was produced by the digital analysis of spectral reflectance data recorded in Landsat-7 satellite images. For Details see Spectranalysis Inc. 2004.

4.3 Geology

Many scientific descriptions of geology of the study area exist. This section is intended to provide a less technical description that sets the local environment for the water budget exercise. Some of the description comes from the companion Watershed Characterization Report as well as the various groundwater studies done for the NBMCA by others. The following sections describe the physiography, bedrock and overburden geology of the study area.

4.3.1 Topography and Physiography

Surficial topographic relief in the SP Area is divided into three distinct regions; the Algonquin Highlands, the Northern Uplands, and the Nipissing – Mattawa Lowland. For convenience these are labelled on Map 3 in Appendix B (Bedrock Geology), however they manifest themselves in the topography, physiography, bedrock topography, surficial and bedrock geology maps as well. Local topographic relief in the study area is largely the result of glacial deposition (moraines, eskers) and bedrock erosion (river valleys) during the Quaternary Period. During the preglacial period, faulting activities produced a dramatic topographic relief in an east-west trending direction across the study area. Map 7a (Appendix B) is a map of ground surface elevation generated using the Digital Elevation Model (DEM) provided by the Ministry of Natural Resources.

The **Algonquin Highlands** in the southern portion of the study area are a topographically variable area with relief up to 260 m and elevations in excess of 520 mASL. Hills are thinly mantled with glacial till, while the low relief areas are occupied by swamps or lakes (Harrison, 1972). The **Northern Uplands** are bounded by a scarp to the south and have a moderate relief of approximately 100 m and elevations ranging from approximately 400 mASL to 490 mASL. The higher elevations in the upland area also have a thin till cover, and Precambrian bedrock outcrops in many areas (Harrison, 1972). The **Nipissing – Mattawa Lowland** is an area that lies at elevations less than 325 mASL and this area is associated with extensive lake sediments around and between bedrock outcrops. The lake sediments consist chiefly of varved clays with some rhythmically banded sands (Harrison, 1972). Minor ridges and several large end moraine segments, drumlins, and eskers are important elements of the surface topography (Harrison, 1972).

Surface elevations (Map 7a) are lowest along the Mattawa River (Nipissing – Mattawa Lowland), which cuts through the central portion of the study area, and rise significantly north or south of the River. The higher elevation areas to the north correspond to the Northern Uplands and the upland areas in the southern portions of the study area correspond to the Algonquin Highlands.

From a physiographic perspective, the North Bay Mattawa SP Area is characterized by numerous lakes, rivers and flat terrain in the west central portion, and the more rugged Precambrian Shield landscape to the southeast and north. The study area is generally composed of rocks of the great Precambrian Shield region. In places within the watersheds, extensive deposits of unconsolidated mineral soils, referred to as overburden or drift, locally obscure much of the bedrock geology. Therefore, a great deal of the present knowledge of the region is based on the interpretation of bedrock outcrops, mineral exploration, drilling and geophysical data as well as water well records.

The Precambrian bedrock consists of metamorphosed rock subsequently altered by prolonged volcanic activity. As the volcanic activity subsided, the land mass started to form and undergo intermittent submergence. During its last stage of development, the region continued in its shallow submergence to form a low topographic relief. Therefore rock knob terrain dominates the bulk of the study area. North of the Mattawa River the local relief is high with bedrock hills often exceeding 60 m in height (Gartner and VanDine, 1980). Similar Scarps are seen in North Bay and west of

Powassan. The vast majority of the area has drift of less than 5 m in thickness. Till thickness reaches 5 to 10 m locally in several areas. Sand and gravel deposits can be locally deep but are in general not extensive. Organic terrain commonly occurs between the bedrock hills and in low-lying areas coupled with a high water table.

4.3.2 Bedrock Geology

Understanding of the bedrock geology is a key component to understanding groundwater movement within the study area. Information on the bedrock geology is compiled from numerous sources, including Ontario Geological Survey mapping, geological reports on Palaeozoic geology from various authors, and a review of well records. Map 3 is found in Appendix B and shows the bedrock geology of the area.

The Canadian Shield is comprised mainly of igneous bedrock in this area. Finely crystalline felsic igneous rocks dominate the surface across the central portion of the study area. To the north and south are areas of primarily gneissic rocks, which are more coarsely grained. From a geologic perspective, the bedrock geology of the North Bay – Mattawa SP Area is part of the Central Gneissic Belt of the Grenville Province of the Canadian Shield. Much of the study area consists of 1.8 to 1.6 billion year old gneisses that have been intruded by 1.4 to 1.5 billion year old granitic and monzonnitic plutons (Thurston, 1991), but also includes metamorphosed mudstones (Metagreywacke), sandstones (quartzite), and limestone (crystalline limestone/marble).

From a hydrogeologic perspective, these rocks are very hard and erosion resistant. However, continental tectonic forces have caused faulting, fracturing and jointing, providing minor pathways for groundwater movement. On the whole, the bedrock surface represents a relatively impermeable surface. Therefore, groundwater preferentially flows through the overlying materials.

The North Bay – Mattawa SP Area has highland areas and lowland areas that have been created by faulting zones. The Northern Uplands and the Algonquin Highlands have been raised or tilted along the fault lines to form escarpments that often exceed 200 m in vertical elevation. The lowland area, known as the Ottawa-Bonnechere Graben, has been prehistorically important in the formation of the Great Lakes. These structural features trend in a predominantly east-west direction within the study area and include faults of the Ottawa – Bonnechere Graben system (OGS, 1991), as seen on Map 3 in Appendix B. The Mattawa River flows along one such fault (the Mattawa River Fault). Similarly, the Nipissing Fault is interpreted to cut through Powassan and appears to follow Genesee Creek through the town itself (Lumbers, 1971).

Three major batholiths (large igneous intrusive formations of granite) have been delineated in the North Bay – Mattawa SP Area:

a) Mulock Batholith (northern part of the SP Area);
b) Bonfield Batholith (east of North Bay); and
c) Powassan Batholith (southeast of Lake Nipissing).

These batholiths are composed predominantly of pink and grey granites and gneisses of variable composition (Lumbers, 1971). Between the batholiths are paragneisses (metamorphosed granites) and some instances of marble (Thurston, 1991).

Much of the bedrock terrain is low-lying and undulating, but becomes more rugged, steep, and complex east of Lake Nipissing. Hosting only thin drift materials, the bedrock surface in the SP Area normally follows the ground surface. These facts, coupled with information from the MOE Water Well Information System (WWIS) database for wells in the study area, were used to interpret the position of the bedrock surface within the area. This information was then contoured in Map 5 (Appendix B), which shows the interpreted topography of the bedrock surface beneath the study area. The bedrock surface has a maximum elevation of approximately 405 mASL in the northwest regions of the study area north of North Bay and in areas of the Algonquin Uplands east of Trout Creek. The bedrock surface dips to an elevation of approximately 125 mASL in the central portion of the study area along the Mattawa River.

Bedrock surface elevations are lowest along the Mattawa River (Nipissing – Mattawa Lowland), which cuts through the central portion of the study area, and rise significantly north or south of the River. As previously identified in Section 4.3.1, the higher elevation areas to the north correspond to the Northern Uplands and the upland areas in the southern portions of the study area correspond to the Algonquin Highlands.

4.3.3 Surficial Geology

Overlying most of the bedrock of the watershed are unconsolidated Quaternary age sediments and organic materials of varying depth deposited during a complex sequence of glacial advances and retreats that have occurred over the past million years. The last glacial advance, known as the Laurentide ice sheet, occurred during the Wisconsin age approximately 100,000 years ago and deposited sand till on the bedrock surface. The most common materials resulting from this glaciation are till, glaciofluvial material deposited by flowing meltwater, and finer grained glaciolacustrine sediments deposited within glacial lakes. Map 6 in Appendix B shows the distribution of these quaternary deposits.

As warming climactic conditions set in, about 12,000 years ago, deglaciation commenced and the ice sheet margin retreated northward. It was during this time that the watershed was reshaped by melt waters and residual soil materials into a number of varying landforms and soil types.

The term “overburden” is used to group the unconsolidated soil deposits lying on the competent bedrock. The SP Area has substantial areas where there is less than a metre of overburden. However it also includes localized areas with more than 100 m of overburden overlying the bedrock. WWIS data for wells in the study area was used to interpret the position of the bedrock surface within the SP Area. This information was then contoured and is presented on Map 4, which shows the interpreted distribution of overburden thickness across the study area.

Overburden is thickest within the Ottawa-Bonnechere Graben and along the Mattawa River. This is because the lower bedrock surface in this area has been infilled with sediment. Overburden is thinnest (<5 m) in the Algonquin Highlands and Northern Uplands, as well as to the southeast of North Bay. There are few minor glacial moraines located within the study area and these are identified on Map 6. They generally correspond to areas of thicker overburden in comparison to the surrounding area. However, their surface expression may be subdued due to the limited amount of data (i.e., few water wells). These moraines include the Rutherglen Moraine and the Gennessee Moraine, which are discussed in the analysis of quaternary geology below.

Deposits formed by, or in connection with, continental glaciers are of particular hydrogeologic importance in the North Bay-Mattawa region. Continental scale glaciers repeatedly advanced over the study area in recent geologic history, first scraping the rock then leaving behind a variety of glacial, glaciofluvial, and glaciolacustrine sediments. The following paragraphs identify these surficial geologic deposits in the context of their hydrogeologic properties.

Fine Grained Deposits

With the exception of steep bedrock outcrop exposures and rock knob features, the North Bay-Mattawa region is predominately overlain by subglacial till deposited during the last glacial ice advance (albeit thin in most places). Glacial till is a heterogeneous mixture of fine grained and coarse grained soils, and basically represents what is left after the glacial ice melted. The till matrix varies in texture from fine grained silts to sands with clasts, ranging from small grains to large boulders. The till forms a thin, discontinuous veneer over the bedrock surface and thickens considerably in the valleys. As such, it represents an impediment but not a barrier to groundwater flow. End and medial moraines are scattered throughout the Nipissing– Mattawa lowland area east of Lake Nipissing. These moraines[3] consist of bouldery silty sand till, and they occur as subordinate landforms in the rock knob terrain throughout most of the area (Gartner and VanDine, 1980).

Glaciolacustrine sediments consist of well-stratified fine sand, silt and clay and are deposited in glacial lakes when melt water is trapped between the front of a glacier and a moraine or rock wall that prevents drainage. These deposits are present in a number of localities in the North Bay area and are especially concentrated along the north shore of Lake Nipissing. East of Bonfield Township the glaciolacustrine sediments range in texture from silty sand to silt and clay, and usually overlie bedrock or the till where present (Gartner and VanDine, 1980). These materials exhibit a relatively low permeability, but are flat lying and can contribute to high water table conditions. Glaciolacustrine deposits near Powassan consist of marginally more permeable sand and silt with minor clay (generally where rock knobs are less prominent) (Gartner and VanDine, 1980). In the region of Mattawa, the glaciolacustrine plains consist of clayey silt and lie at elevations of 260 to 275 m, immediately south of the Mattawa and Ottawa Rivers (Gartner and VanDine, 1980).

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[3] *Moraines are deposits of material left by melting ice. Medial and end moraines lie along the margin of ice sheets, whereas ground moraine is left in the footprint of the ice after melting. Moraines can either be lower permeability materials like silty sands, or sandy silts, or they can be comprised of sand and gravel and be highly permeable, depending on the material originally entrained in the ice.*

Organic deposits are found throughout the region and have collected in low-lying areas, covering sand and gravel outwash plains, glaciolacustrine deposits, and Precambrian bedrock. Although highly permeable, they are mostly in areas of groundwater discharge and do not contribute significantly to recharge of the groundwater table other than in the summer months.

Coarse Grained Deposits

Most coarse-grained deposits in the region are comprised of sand, gravel and boulders associated with kames, eskers, and moraines. Well-rounded, and well-sorted fluvial sands and gravels form large flat areas or terraces west of the Mattawa and Ottawa valleys (Harrison, 1972). Beach sands are also well sorted and well-rounded and form raised beaches or scarps (Harrison, 1972). These are all high permeability deposits and serve regionally as groundwater recharge zones.

The Rutherglen moraine (south of Rutherglen) and the Genesee moraine (15 km east of Powassan) are the two major moraines formed during the last ice recession (Harrison, 1972). They formed when ice flowed from the east through the Mattawa Valley lowland. The Rutherglen Moraine extends approximately 11 km from the Mattawa River southward towards Algonquin Park. The moraine, which many consider to be an esker, consists of five segments each with unique composition ranging from sand and gravel, to till and clay (Harrison, 1972). The Genessee Moraine is a large end moraine that lies parallel to the Algonquin Highlands. This moraine is more than 8 km long and up to 3 km wide in some places, and is composed primarily of sand and gravel (Harrison, 1972).

Glacial outwash is widespread throughout the region. Immediately north of North Bay a large area of sandy gravel, gravely sand, or sand, blankets the Precambrian bedrock. In some places the overburden is over 30 m thick, but it is generally 3 to 5 m thick over the bedrock (Gartner and VanDine, 1980). Therefore, these areas can serve as local or regional aquifers, if saturated, as well as groundwater recharge features. Immediately north of the Mattawa River, outwash deposits are found along Highway 533 from the Town of Mattawa northwest into Antoine Township (Gartner and VanDine, 1980). The Town of Mattawa is underlain by a large east-west trending ground moraine on the western edge of town, and a sand and gravel outwash plain upon which most of the town is built. Larger and deeper outwash deposits have good potential for groundwater supplies (Harrison, 1972). The larger portion of the Town of Powassan is underlain by a confined sand and gravel aquifer which is used by the municipal well system. The silty clay confining layer varies in thickness, and ranges from 5 m to 6 m in the immediate vicinity of the town’s two municipal wells. The confining layer may not be continuous and, in some localized areas, the confining layer is interpreted to be absent.

Eskers are sand and gravel deposits that are formed from melt-water channels within or below a glacier. These long ridges of sand and gravel are well developed in the study area. In the Mattawa region, the eskers trend in a southerly direction, with the largest located north of the Town of Mattawa (Gartner and VanDine, 1980). One esker located in the Bonfield Township forms a single ridge and in most places rises 10 to 15 m above the surrounding landscape (Harrison, 1972). While these are groundwater recharge features, eskers can also be the source of small streams at their base.

Kames are ice-contact deposits that are typically laid down at the front of melting glaciers, and they are also a common landform on the rock knob terrain of the study area (Harrison, 1972). Many kames extend from Lake Talon to the southern margin of the North Bay area, a distance of approximately 35 km (Gartner and VanDine, 1980). Kames are common in the Powassan area and southeast of Mattawa (Gartner and VanDine, 1980). Kames are recharge features and serve as local aquifers if extensive enough.

Mineralization and organic resources

There are metallic and non-metallic deposits within the SP Area, however, current mining activity is limited to sand and gravel extraction. Historically other mining activities have taken place in the watershed, but only by relatively small operations that were involved in the extraction of surficial deposits. During the 1920s, feldspar was mined in the Mattawa area. More recently mica has been mined at several locations in the lower Mattawa valley including the Purdy Mica Mine in Mattawa Township. There are extensive aggregate extraction activities in the watershed, mainly within glaciofluvial deposits. A highly productive sand and gravel area is located north of the escarpment in North Bay.

4.4 Groundwater

From 2004 to 2006, a groundwater study report was prepared for the NBMCA by Waterloo Hydrogeologic, Inc. in association with Tunnock Consulting Ltd. (Waterloo Hydrogeologic, 2006). The study was completed in two phases. The first was conducted in 2004 and covered the City of North Bay, Town of Mattawa and Municipality of Powassan, but not the Village of South River. In 2006 another supplementary analysis was undertaken to conform to the Conservation Authority's Source Water Protection Boundary. Overall the above groundwater study provides a useful overview of groundwater conditions in the study area by compiling regional geologic and hydrogeologic data sets and information from previous hydrogeologic studies. In addition, information from many data sources, including the MOE, MNR, Ministry of Northern Development and Mines, Geologic Survey of Canada, Water Survey of Canada and the NBMCA was incorporated into a project database and GIS layers.

The North Bay – Mattawa SP Area is characterized largely by shallow soils over bedrock particularly in the south, north and eastern parts of the study area. In these areas, the overburden is mostly sand and gravel that readily accept precipitation. The underlying Precambrian bedrock is comparatively impermeable and therefore deflects groundwater flow laterally to the streams, wetlands and lakes. In the central portion of the study area, overlying the Ottawa-Bonnechere Graben, overburden is deeper (up to 60 m in depth) and is comprised of both permeable sand and gravel as well as glacial till soils. Due to the more gentle terrain this area is more extensively farmed and as a result there are relatively more private wells compared to the rock knob terrain experienced elsewhere.

Groundwater recharge occurs through all surficial geology units, with the coarse-grained esker and outwash materials having the highest recharge rates. Groundwater discharge occurs mainly along the numerous lakes and streams of the region. In general, groundwater recharge from direct infiltration of precipitation through the till and glaciolacustrine surficial deposits is slower than that of the coarser deposits. However, given the large surface exposure of the till and glaciolacustrine deposits, the volume of water supplied to the regional groundwater regime is significant.

Regional aquifers in the overburden are difficult to characterize as the majority of the overburden aquifers within the study area are associated with glacial or periglacial landforms. These aquifers, including the fluvial sand deposits in Mattawa and the sand plains in Powassan, are discontinuous and highly variable, often interrupted by the uneven bedrock topography (Waterloo Hydrogeologic, 2006). More than 90 percent of all the well records reported for the SP Area indicate wells that are constructed in bedrock, which suggests that the bedrock is an important local aquifer despite its low bulk permeability. (The reader should be aware that there may be a higher proportion of bedrock wells due also in part to local economic factors, such as the practices of and equipment available to drillers servicing the area.)

The municipal wells in Powassan are drilled into the sand plain, while most of the residential wells are completed in bedrock. Wells completed in the overburden are scattered across the SP Area and generally do not show any trends in that specific layers are not identifiable. Harrison (1972) suggests that the largest source of untapped groundwater in the SP Area is in the Town of Mattawa, due to the deeply incised valley carved into the bedrock adjacent to, and beneath, the Mattawa River.

4.4.1 Water Table

A water table elevation map is presented in Map 13. WWIS data provided the depth to water for wells within the SP Area. At each well, the static water level recorded when the well was drilled was used to interpolate groundwater levels throughout the study area. Although static water levels may change over time, groundwater extractions have not changed dramatically, and therefore the static water levels are considered acceptable for the purpose of mapping regional water table elevations. All wells completed to less than 15 m depth were considered in this analysis. This was done to limit the misleading effects of deeper wells that may not measure the groundwater table, but actually a potentiometric head.[4]

WWIS data are sparse in both the northern and southern portions of the study area. In these areas, additional control points were added along surface water bodies where it was assumed that the water table would coincide with such features.

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[4] *In short, a deeper well in a recharge area will have a measured static level lower than the water table. The converse is true in a discharge area where the measured level will be higher than the actual water table.*

Generally, the water table follows the surface topography. The shallow groundwater flow system is entirely local, largely due to the presence of the many streams and lakes. Precipitation that is not taken up by evapotranspiration will either runoff to the local watercourses, or recharge the water table. Because of the low permeability of the bedrock, much of this recharge is deflected laterally through the relatively more permeable overburden. It discharges as baseflow in the local watercourses which then flows out of the highlands in the north and south, draining to different rivers (such as the Mattawa River System, South River, La Vase River etc.) and eventually to either the Ottawa River (Mattawa River System) or Lake Nipissing (South River, La Vase River etc.) Water level elevations range from 404 m in the north and south, to 120 m near Lake Nipissing, and the Mattawa and Ottawa Rivers. Lateral groundwater movement will also occur in the shallow bedrock where fractures exist. There are no appreciable deep groundwater flow systems on the regional scale, although some pathways are longer where the overburden is deepest.

4.4.2 Quantification of Groundwater Recharge

Groundwater recharge can be defined as the supplementation of the groundwater by the infiltration of meteoric water such as rainfall and snowmelt. This provides the driving force that causes groundwater to flow, and ultimately discharge as baseflow to wetlands, watercourses and lakes. As described in Section 3, recharge of the water table is accomplished by the infiltration of precipitation and snowmelt that is not taken up again by plants or evaporation. In 1995, the Ministry of Environment and Energy of Ontario (MOEE) established a method (MOEE, 1995) to estimate recharge based on topography, soils and plant cover. This method relied on applying a partitioning coefficient (F) to the annual surplus (S) to separate it into runoff (RO) and recharge (R) by the following relationships: since F = R/S, then R = F x S and RO = (1-F) x S (i.e., RO = S – R).

Evapotranspiration is a large component of the water balance. This is a function of the vegetative cover as well as soil and climatic conditions. Evapotranspiration includes the amount of moisture lost to the atmosphere through transpiration by plants and evaporation from the soil, tree canopy and other surfaces. Evapotranspiration can be affected by the removal of vegetation, which will result in a reduction of evapotranspiration losses, higher runoff and a smaller loss of soil moisture. The net result will favour the retention of groundwater. The difference between mean precipitation and evapotranspiration is referred to as the mean annual water surplus.

The first step is to prepare a water budget for existing conditions from the meteorological data at each meteorological station. The average annual precipitation for the period 1971 to 2000 was selected, as it can be directly compared to the available period of streamflow record. Using the method of Thornthwaite and Mather (1957) the actual evapotranspiration (AET) was calculated for each station. This method uses precipitation, temperature, site latitude, surficial geology and vegetation cover to calculate the AET. The surplus is determined by subtracting this from the average annual precipitation. Soil moisture storage, which is defined as the amount of water that is stored in the soil within the plant's root zone and used to buffer evapotranspirative losses, was assumed to be 100 mm based on the generally sandy soil type. The results of this analysis are presented in Table 4.5.

Table 4.5 Summary of Water Balance for Selected Meteorological Stations (1971-2000)

	Meteorological Station	Precipitation (mm/yr)	AET (mm/yr)	Water Surplus (mm/yr)
Stations North of the Study Area	Earlton A (ON)	785	482	303
	Remigny (QUE)	916	507	409
	Belleterre (QUE)	996	513	483
	Sudbury A (ON)	899	507	392
Stations Directly in the Study Area	**North Bay Airport**	**1008**	**534**	**474**
	Powassan (ON)	**936**	**539**	**397**
Stations Inland of the East of the Study Area	Chalk River (ON)	860	542	318
	Madawaska (ON)	843	512	331
	Combermere (ON)	869	511	358
Stations South of the Study Area	Dunchurch (ON)	1114	523	591
	Dwight (ON)	1183	526	657
	Muskoka A (ON)	1099	533	566
	Minden (ON)	1045	533	512

As discussed in Section 4.1, the precipitation values are shown on Map 1, Appendix B. Evapotranspiration is shown the same way on Map 2. The AET ranges over a very narrow band of 530 to 539 mm/yr across the study area, a much more narrow variation in comparison to precipitation which was a variance of 100 mm. The difference between the precipitation and the AET is termed the surplus, which is available for runoff and recharge. The surplus is shown on Map 14c, (Appendix B), and ranges between 400 and 500 mm/yr, being greatest in the south where the greatest precipitation occurs.

The next step in determining recharge is to partition the surplus, using the following methodology. The partitioning of the water surplus between runoff and recharge depends on four main factors: 1) topography; 2) soil texture, 3) cover type, and 4) available water. The MOEE method relies on calculating “Infiltration Factors” composed of the first three factors that are applied to the fourth factor, average annual water surplus. These factors are tabulated in Table 2 of the MOEE manual on pages 4-62, and are reproduced here as Table 4.6 for the reader’s convenience.

For this study, topographic factors were calculated based on actual slopes derived from the digital elevation model using a grid-based GIS method. Application of the generalized Infiltration Factors recommended by MOE, was refined by developing a relationship between Infiltration Factor and degrees of slope. For the categories where slope ranges were given, the appropriate slope (in degrees) was calculated for the mid-point of the range. The resulting relationship is shown in Figure 4.8.

Table 4.6 Infiltration Factors Used for Estimating Runoff and Recharge

Table 2: Infiltration Factors

Description of Area/Development Site	Value of Infiltration Factor
TOPOGRAPHY	
• Flat and average slope not exceeding 0.6 m per km	0.30
• Rolling land, average slope of 2.8 m to 3.8 m per km	0.20
• Hilly land, average slope of 28 m to 47 m per km	0.10
SOIL	
• Tight impervious clay	0.10
• Medium combinations of clay and loam	0.20
• Open sandy loam	0.40
COVER	
• Cultivated lands	0.10
• Woodlands	0.20

Reproduced from MOEE (1995), Technical Guidelines for the Preparation of Hydrogeological Studies for Land Development Applications

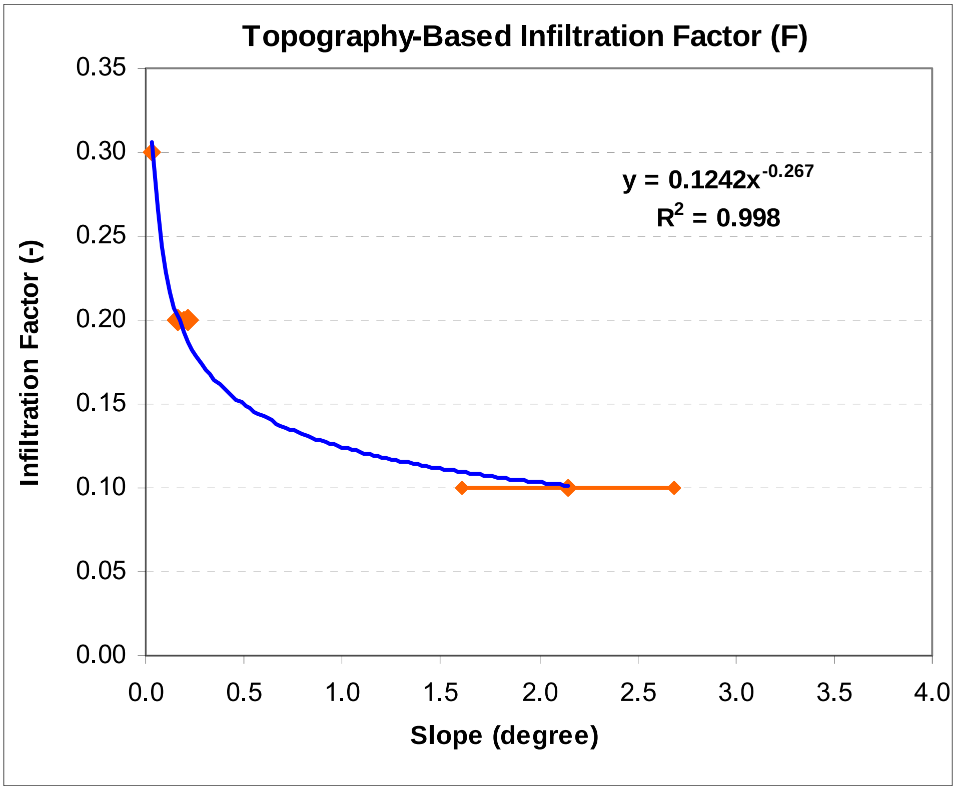

Figure 4.8 Relationship Between Infiltration Factor (F) and Slope

The MOEE method is based on the principle that water will recharge more easily through:

a) sands compared to clays;
b) on flat slopes compared to steep slopes; and
c) through vegetated soils compared to areas that do not intercept runoff.

(An Infiltration Factor, for example, of 0.4 means that 40% of the water surplus will recharge the ground while the remaining 60% will become runoff.) The method is applied on a long-term basis (annually) and is not related to individual precipitation events.

The horizontal range bars in Figure 4.8 show the range of slope associated with the guidelines in the MOE report. The points were best described by a power fit (the equation is shown on Figure 4.8). This relationship was used to derive an Infiltration Factor based on slope. For slopes less than 0.03°, the Infiltration Factor was assigned to 0.3. Slope factors ranged from 0.1 to 0.3 with the higher values in the flat lying areas.

The soil factor is based on the geologic mapping for the area. Factors of between 0.1 for tight impervious soils or bedrock, to 0.4 for permeable aeolian sands were selected, and applied to the digital geologic map in a GIS platform. Bedrock was assumed to be very tight, and was assigned an Infiltration Factor of 0.1. Some rock is marginally more weatherable than others and was given an Infiltration Factor of 0.2. Table B1 in Appendix B lists the Soil Infiltration Factors based on the geologic mapping for the area.

The final factor in the MOE methodology is based on land cover. In this case, there are two factors applied, based on whether or not the area is wooded or cultivated. Wooded areas were assigned an Infiltration Factor of 0.2, and cultivated areas (including lawns) were given an Infiltration Factor of 0.1. To estimate this factor, a grid of the study area was constructed in the GIS platform based on the vegetation coverage obtained from OMNR[5]. That vegetation coverage is based on interpretation of air photos during the development of the Ontario Base Mapping series. For all open water, the Infiltration Factor was set to 0, as all this water contributes to runoff. The folded drawing in Appendix B contains a summary figure showing how each factor was distributed, as well as the total Infiltration Factor calculated.

The method is best described by a sample calculation. For a given 20 m square polygon in the GIS platform, the slope is calculated. In this example the slope is 2 degrees. The factor may be calculated by the equation on Figure 4.8:

$$\begin{aligned} Y &= 0.124 \times (2^{\circ})^{-0.267} \\ &= 0.103 \end{aligned}$$

The slope factor is therefore 0.103, which is reasonable since it is relatively steep and the runoff is increased, meaning there is less to infiltrate. Assuming that the bedrock is near the surface, and of the more weathered variety, a factor of 0.2 is used. This indicates that relatively more water will be

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[5] *Other investigators have used the land cover information, such as is found on Map 8. The difference between the two approaches was not deemed to be significant for the purpose of this conceptual water budget.*

captured by open fractures, thereby contributing to recharge. Finally, there is little vegetation except grasses and mosses on the slope, so retention of runoff is minimal and therefore a factor of 0.1 is selected. These are summed together to determine the partitioning coefficient of 0.103 + 0.2 + 0.1 = 0.403 for this example polygon.

The final step is to apply the partitioning coefficient to the surplus. In this example, we have assumed the polygon is just southwest of Powassan. The surplus from Map 14c is 430 mm. Therefore, recharge equals 0.403 X 430 mm = 173 mm/yr. This groundwater recharge is shown on Map 14a. The remaining water (257 mm/yr in this case) is runoff, (the difference between the surplus and the recharge). Map 14b shows the average annual runoff for the watershed. In this example, the runoff is greater than the recharge, which would be expected for a slope of 2 degrees or more.

It is useful to examine the water budget on a watershed scale. Here we report the water budget as an example for the Mattawa River watershed covering an area of 951.5 km^2 (see also Table 4.7. The following average values were obtained from the GIS platform after interpolation, and were derived by multiplying their cell values by the cell areas, summed as a total volume, and then divided by the total area. For example, for the calculation of precipitation (mm/yr) for a respective watershed in mm/yr the above calculation procedure can be expressed as:

$$Precipitation\ (Watershed) = \frac{\sum Precipitation\ at\ each\ cell\ area * Cell\ area}{Total\ cell\ area}$$

The average precipitation for the Mattawa watershed is 966 mm/yr; AET is 535 mm/yr and the surplus is 431 mm/yr. This surplus has been partitioned into runoff and recharge with a value of 225 mm/yr and 206 mm/yr, respectively. By way of comparison, the streamflow gauge on the Mattawa River below Bouillon Lake estimates a total flow (including both runoff and baseflow[6]) of 452 mm/yr, which is very close to surplus value of 431 mm/yr. The close agreement (+/-5% difference) of these two independent methods provides a measure of certainty in the water balance.

4.4.3 Baseflow Separation

As the watershed region is composed of numerous rivers, lakes and wetlands, and is mostly of silt, sand and gravel soils, there is a significant interaction between surface and groundwater in terms of baseflow contribution to the streams. Baseflow is defined as that portion of the total streamflow that occurs when there is no contribution from rainfall or runoff. In addition, any precipitation that does not runoff and infiltrates into the ground, and later returns to the watercourse, would be referred to as 'baseflow'. Generally, infiltrated water that returns to the stream rapidly (say in less than 24 hours) is referred to as 'subsurface flow' and sometimes as 'interflow', and is usually considered as part of the 'storm flow'. In agricultural watersheds that are drained by subsurface

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6. Since it can be assumed that groundwater storage changes are negligible over the 30 years of record, the total infiltration should equal the baseflow into the river and its' tributaries. Therefore the total stream flow should theoretically be equal to the surplus.

tiles, the flow in the tiles (hence, 'tile flow') is considered part of the 'rapid subsurface flow' (or the 'slow' storm flow). Water that infiltrates deeper into the ground, and returns to the stream much later would be considered as the 'baseflow'.

Therefore, baseflow comprises the accumulated subsurface or groundwater discharge to the watercourses. These are important for the natural function of the ecosystem, providing clean water and sustaining streamflow and wetlands in dry periods. In particular, it supplies the cold water that provides thermal buffering in headwater streams and sustains fish habitat. The accumulation of baseflow throughout the watershed sustains the river system and lakes. From a source water protection aspect, this is an important component of Trout Lake, which is the main source of water for North Bay.

In hydrology, numerous analytical techniques have been developed to separate baseflow from total streamflow hydrograph. Typically baseflow recession is calculated from the point on the hydrograph (streamflow versus time) where it is assumed that all surface flow has ceased as shown on Figure 4.9. However, manual separation of the streamflow hydrograph into surface flow and baseflow is difficult and inexact; often results derived from such manual methods cannot be replicated among investigators (White and Sloto, 1990). Alternatively, computer programs have been developed by many authors (e.g., White and Sloto, 1990) to automate the methods which remove some of the inherent subjectivity and substantially reduce time required for analysis of streamflow records.

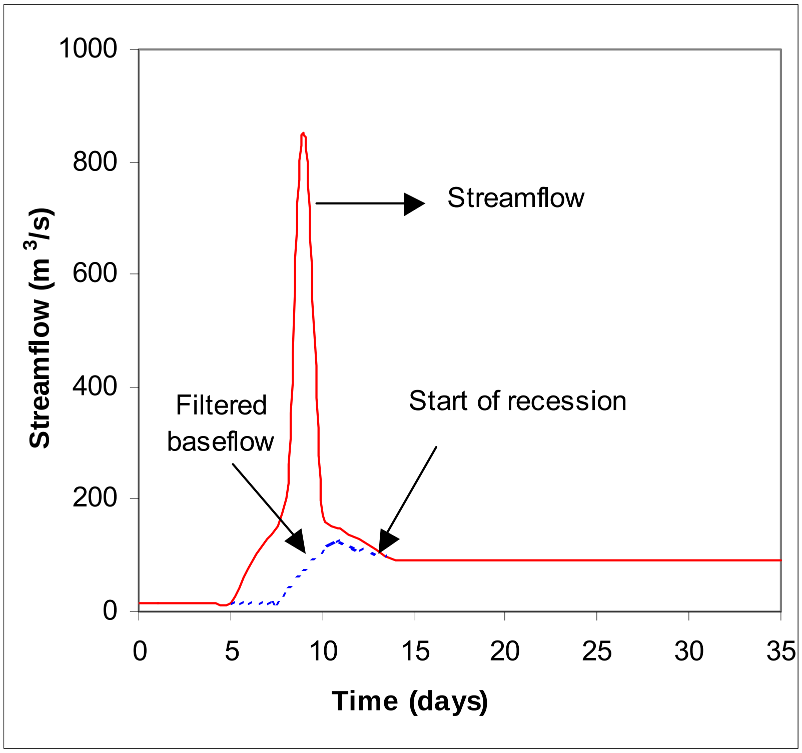

Figure 4.9 Manual Hydrograph Analysis for Baseflow Separation (adapted from Arnold et al., 1995)

To estimate the contribution of baseflow to the total streamflow in the SP Area, an automated baseflow filter program which is available as a component of SWAT (Soil and Water Assessment Tool) has been used here. The baseflow filter estimates baseflow and groundwater recharge from streamflow records using the methodology described by Arnold *et al.* (1995). The streamflow data are passed through the filter program, which calculates and uses the point where the surface rejoins the streamflow record. The program then searches the filtered record and picks out the baseflow segments for a particular period of record.

This filter method has been shown to be comparable to other automated techniques in its ability to reproduce the results produced from graphical separation techniques. This method calculated baseflow ranges between 30 to 55% of the total stream. On the other hand, values of 20 to 30% based upon surficial geology (e.g., soils information) considerations are given in OMNR (1984) and Singer and Cheng (2002). Using the Mattawa watershed example discussed in Section 4.4.2 above, a value of 52% was derived (225 mm / 431 mm = 0.52; recall the equation F = S/R in Section 4.4.2). This would seem to indicate the Arnold *et al.* derivation is more in agreement for this northern watershed.

4.5 Surface Water

There are two major river systems in the SP Area: the Mattawa River system and the South River system. Each of these is discussed separately in the subsections that follow. Approximately 58% of the North Bay – Mattawa SP Area lies within the Ottawa River watershed, with the remaining 42% draining to Georgian Bay via Lake Nipissing and the French River. Of those watersheds draining to Lake Nipissing, the South River represents half the contribution. Table 4.7 summarizes the drainage areas for each contributing watershed.

Table 4.7 Major Rivers and Tributaries within the North Bay – Mattawa SP Area

River/Tributary	Corresponding Quaternary Watershed	Approx. Drainage Area of Watershed (km^2)
Mattawa River	Mattawa River Watershed	450
Amable du Fond River		258
Upper South – Upper Amable du Fond River		706
Pautois Creek		176
Sharpes Creek		137
Kaibuskong River and Depot Creek		182
North River		248
Boom Creek		138
South River	South River Watershed (including Reserve-Beatty Creek)	930
Wistiwasing (Wasi) River	Wistiwasing River Watershed	234
La Vase River	La Vase River Watershed	182
Chippewa Creek		
Bear Creek	Bear-Boileau Creeks Watershed	178
Boulder Creek		
Duchesnay Creek	Duchesnay River Watershed	144

4.5.1 Mattawa River System

The Mattawa River is a natural passage through the Algonquin Highlands between a point above Lake Nipissing to the west and the Ottawa River to the east. The watershed begins just 3.5 km east of Lake Nipissing, and drains east along a geologic fault line (the Mattawa River Fault, see Section 4.3.2) into the Ottawa River. The Mattawa River begins at the east end of Trout Lake at 202 mASL, and drops 50 m over the 43 km distance to the Ottawa River (Table 4.8). Its watershed is 2,295 km^2 and accounts for 1.6 percent of the Ottawa River drainage area. A total of approximately 195 km^2 (or approximately 8.5 percent) of the Mattawa River drainage area is water covered. The Mattawa River system contains numerous lakes, which provide significant storage volumes that attenuate peak runoff flows. The Mattawa River watershed is also characterized by many small creeks, ephemeral streams and lakes. The Mattawa River enters the Ottawa River at an elevation of 152 mASL at the Town of Mattawa.

Table 4.8 Water Levels of the Major River Systems Within the Study Area

Name of River	Lake/Dam	Water Level (mASL)
Mattawa River	Trout Lake	202
	Turtle Lake	202
	Whitethroat Lake	199
	Bigfish Lake	198
	Tilliard Lake	197
	Talon Lake	194
	Pimisi Bay	178
	Bouillon Lake	163
	Mattawa River	161
	Chant Plain Lake at Hurdman Dam	159
	Boom Lake	154
	Ottawa River	152

Name of River	Lake/Dam	Water Level (mASL)
South River	Craig Lake	386
	Twenty Seven Lake	367
	South River	354
	Forest Lake	353
	South River Reservoir	351
	Elliott Chute	264
	South River	263
	Bingham Chute	252
	South River	245
	South River	244
	Nipissing GS	239
	Outlet – Lake Nipissing	197

The primary surface water feature of interest within the Mattawa watershed is Trout Lake in the west, which serves as North Bay's only water supply. The Trout Lake catchment is the headwater of the Mattawa River. Trout Lake empties into Turtle Lake which flows into Lake Talon before it drains via the Mattawa River and ultimately into the Ottawa and St. Lawrence Rivers. The significance of a headwater lake is that its water supply is derived entirely from its own drainage basin. Trout Lake is an oligotrophic lake. It is cold and deep with low nutrient levels and consequently low ecologic productivity, and meets drinking water standards with minimal treatment.

Trout Lake is one of the largest individual water bodies within the SP Area, and it is a focus in terms of drinking water source protection. There are five major sub-basins in Trout Lake such as Delaney Bay, Dugas Bay, 68 Metre Basin, Four Mile Bay and One Mile Bay. The uppermost, Delaney Bay, forms part of the main basin, which contains 80 percent of the total volume of 331 million cubic metres. The remaining 20 percent is made up of all the other sub-basins of the Lake.

There are three water control structures/facilities on the Mattawa River system, shown on Map 9 in Appendix B. One of these facilities is used to generate hydroelectricity, and the other two (see also discussion under Section 4.5.5) serve primarily to maintain water levels at their respective locations.

4.5.2 South River System

The approximate length of the South River is 104 km and drops from an elevation of 386 mASL to 197 mASL, having a gradient of approximately 1.8 m/km (Table 4.8). The drainage area is 930 km^2. The headwater of the South River system is Craig Lake, which is located in the western portion of Algonquin Park, at the southern end of the SP Area. The river then flows southwest through Twenty Seven Lake and Forest Lake before reaching the South River Reservoir near the Village of South River. This reservoir is maintained at a mean water level of approximately 351 mASL. Downstream of the reservoir, the river turns and meanders north towards the Town of Powassan.

Within the Powassan area, the South River includes Elliot Chute and Bingham Chute, both of which host small hydroelectric generating stations, and are maintained at elevations of 264 mASL and 252 mASL, respectively. Northwest of the Town of Powassan, the South River changes direction again and begins to flow west towards Nipissing.

The Beatty-Reserve subwatershed also feeds the South River. Within it, the two main watercourses are Wolf and Beatty-Reserve Creeks. Wolf Creek flows into Beatty-Reserve Creek south of Nipissing, which then discharges into South River northwest of Nipissing. The South River then flows northwest and flows into South Bay of Lake Nipissing.

4.5.3 Streamflow Gauges

Within the North Bay – Mattawa SP Area there are eleven streamflow gauges/hydrometric stations used for measuring streamflow, which have extensive records of flow dating from 1914 until 2003. Water levels in most of the rivers vary depending on the control dams, lakes and reservoirs. The Mattawa River is the largest river within the SP Area followed by the South River. Table 4.9 summarizes the flow gauging stations within the SP Area, in terms of their location, station identification, period of record for available data, and their current operational status.

Table 4.9 Summary of Continuous Streamflow Gauge Stations within the Study Area

Station Name	Station ID	Drainage Area (km^2) [1]	Latitude	Longitude	Period of Records	Number of Years	Max Annual Flow Rate (m^3/S)	Mean Annual Flow Rate (m^3/S)	Min Annual Flow Rate (m^3/S)
Duchesnay River Near North Bay	02DD008	90.4	46°19’53”N	79°30’20”W	(1956-1982)	26	2.32	1.65	0.93
Chippewa Creek at North Bay	**02DD014**	37.3 (32.4)	46°18’42”N	79°26’54”W	(1974-2003)	29	**0.821**	**0.62**	**0.444**
La Vase River Near North Bay	**02DD013**	70.4 (69.2)	46°15’48”N	79°23’42”W	(1974-2003)	29	**1.33**	**0.93**	**0.559**
South River Near Nipissing	02DD005	787	46°05’49”N	79°28’45”W	(1937-1984)	47	17.9	11.8	6.36
South River Near Powassan	**02DD001**	761 (783)	46°5’40”N	79°23’45”W	(1914-1936)	22	**23.2**	**12**	**6.57**
South River Above Truisler Chute	02DD002	420	45°57’48”N	79°24’21”W	(1919-1952)	33	13.3	6.7	3.33
South River at South River Prov-Terr-State	**02DD009**	316 (326.3)	45°50’54”N	79°22’46”W	(1956-1991)	35	**7.33**	**5.34**	**2.93**
Kaibuskong River At Bonfield	02JE008	174	46°14’5”N	79°09’0”W	1915	1	ND	ND	ND
Mattawa River Near Rutherglen	02JE014	2040	46°18’7”N	78°52’51”W	(1962-1971)	9	35.2	25.6	14.4
Amable Du Fond River at Samual Du Champlain Provin	**02JE019**	1130 (1140)	46°18’0”N	78°52’45”W	(1972-1995)	23	**22.6**	**16.1**	**9.05**
Mattawa River Below Bouillon Lake	**02JE020**	909 (951.5)	46°17’56”N	78°54’26”W	(1971-1998)	27	**20.6**	**15.4**	**9.31**

Note: 1. Drainage areas are from Hydat database. Drainage areas in parentheses were calculated using Archydro. ND: No data. Streamflow gauge stations marked with a shaded area were used for water budget analyses as they closely match with climatic stations data (see also discussion in Section 5.2.3).

4.5.4 Streamflow Response

Figure 4.10 shows as an example the time-series of mean annual, minimum and maximum daily flows for the Mattawa River below the Bouillon Lake gauge (02JE020) for the period 1971-2000. Periods of record for the stream flow gauge are from 1971-1998. In order to match the period of record for the meteorological stations, values for the year 1998 through 2000 were calculated on a proportional basis. The calculation first involved determining ratios of streamflow between pairs of adjacent watersheds for periods that data existed. Ratios were found to be nearly constant for each pair. So the missing data for the gauge station in question was then calculated by simply multiplying the available measured data of the nearby gauge station with the ratio. For the period represented by Figure 4.10, the computed mean annual discharge was found to be 15.09 m^3/s, the mean maximum daily flow was 91.13 m^3/s, and the mean minimum daily flow was 1.71 m^3/s. The highest mean annual flow of 20.6 m^3/s occurred in 1990, whereas the lowest value of 9.31 m^3/s took place in 1987.

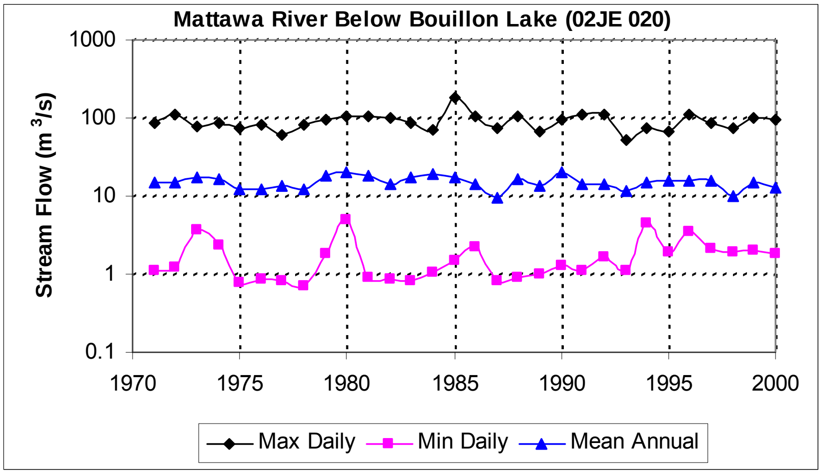

Figure 4.10 Time-Series of Annual Flows on the Mattawa River Below Bouillon Lake (02JE020)

The highest maximum daily flow of 176 m^3/s occurred during April (Figure 4.10) of 1985, whereas the lowest maximum daily flow of 53 m^3/s occurred in 1993. For the record shown, the lowest minimum daily flow value of 0.71 m^3/s occurred in 1978, while the highest minimum daily flow of 4.91 m^3/s took place in 1980. For the past 30 years, the mean annual flow has been quite steady.

The within year variations in the maximum daily, mean daily and minimum daily flows are exhibited in Figure 4.11. Generally speaking, the highest flows occur in the spring freshet months of April to May, whereas the lowest flows occur in the late summer months of August and September.

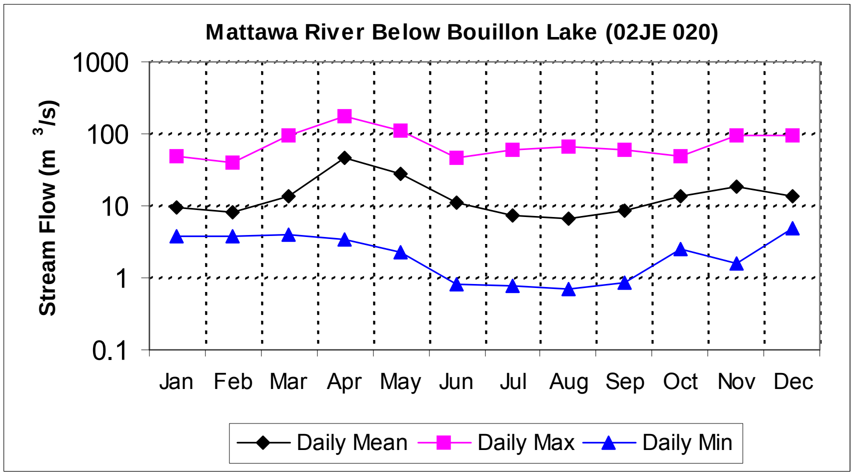

Figure 4.11 Monthly Flow Distribution of the Mattawa River Below Bouilon Lake (02JE020)

4.5.5 Surface Water Nodes (Points of Interest) for Watershed Catchment Delineation

The major surface water nodes on the Mattawa and South River Systems are the dams and generating stations shown on Figures 1.2 and 1.3 and listed in Table 4.8 which regulate the flow of surface water. Water control facilities are shown in Map 9 (streamflow characteristics).

The control structures on the Mattawa River include Turtle Lake, Talon Lake and Hurdman Dams. The Trout Lake control structure is a spill dam located at the outlet of Turtle Lake, at the border of Bonfield and Phelps Townships. The primary purpose of the dam is to control the water level of Trout Lake for recreational and navigational purposes at an elevation of 202.2 mASL.

Talon Lake Dam is located at the outlet of Talon Lake, directly downstream of Boivin Lake on the border of Olrig and Calvin Townships. The water level upstream of the dam is maintained at 193.8 mASL. The dam is owned and operated by the MNR.

Hurdman Dam is a spill dam with the capacity to generate hydroelectric power. This dam is located 3.2 km upstream of the Town of Mattawa and backs water up for approximately 6 km, forming the narrow water body known as Plain Lake. The dam has an associated generating station operated by Algonquin Power Systems, but the dam structure is owned by the MNR.

There are multiple control structures located on South River. Craig, Sausage and Smyth Lake Dams as well as the Nipissing, Elliot Chute and Bingham Chute Generating Stations (GS) are owned and operated by Ontario Power Generation.

The Craig Lake control dam is located approximately 36 km east of the Village of South River, and maintains the upstream water elevation of the headwater lake of South River at 386 mASL. The South River Dam is located at the outlet of the South River Reservoir, adjacent to the Village of South River, and is owned and operated by the MNR. The water level elevation of the reservoir is 354 mASL.

The Truisler Chute GS is located approximately 15 km downstream of the South River Reservoir, and is owned by Trout Creek Power Corporation. Downstream of this dam are the Geisler Chute GS and Corkery Falls GS, which are owned by Rapid'eau Technologies, followed by the Elliot Chute GS (264 mASL) and Bingham Chute GS (263 mASL). The Sausage and Smyth Lake Dams are approximately 5.6 and 9.5 km east of the Village of Trout Creek, respectively. The most downstream control structure on South River is the Nipissing GS, located 3 km east of the Village of Nipissing, with an upstream water elevation of 239 mASL.

There are currently three water control structures in the Amable Du Fond River basin. Recreation spill dams are located on Moore Lake in Champlain Provincial Park, at the outlet of Lake Kioshkokwi in Kiosk and on Club Lake in Algonquin Park.

4.6 Water Use

The NBMCA 2006 Groundwater Study Report identifies the basic water uses within the SP Area. These are summarized here, and where data gaps are identified by that study, estimates have been provided. Potable water is provided by a variety of sources. Population estimates for each municipality are presented in Table 4.10.

Table 4.10 Estimated Population in the Study Area (Source: Statistics Canada 2002)

Municipality/Township	Urban Population	Non-Urban Population	Total Population
North Bay	50,452	2,319	52,771
East Ferris	104	4,187	4,291
Chisholm		1,230	1,230
Mattawa	2,270		2,270
Bonfield		2,064	2,064
Calvin		603	603
Papineau- Cameron	16	981	997
Callander	1,339	1,838	3,177
Powassan	1,177	2,075	3,252
South River	1,040		1,040
Nipissing		1,553	1,553
Parry Sound (Unorganized, Northeast Part)		185	185
Machar	89	760	89.5
Total NBMCA SP Area Population	**56,487**	**19,173**	**75,660**

The Permit To Take Water (PTTW) information from the Ministry of Environment helps generalize surface and groundwater use in the SP Area. Tables 4.11 and 4.12 identify only active surface and groundwater takings in the study area according to PTTW database.

The italicized values in Table 4.11 are non-consumptive surface water uses that include power generation, totalling 293.28 Mm^3/yr, most of which is returned to the source after usage. The total permitted consumptive surface water takings is 35.86 Mm^3/yr, which consists of permitted municipal water takings in the amount of 30.73 Mm^3/yr (Trout Lake: 29.02 Mm^3/yr for the City of North Bay, Callander Bay 1.1 Mm^3/yr and the Village of South River 0.61 Mm^3/yr), plus irrigation volumes of 4.60 Mm^3/yr [7], and permitted industrial volumes of 0.53 Mm^3/yr. Together, these permitted takings account for approximately 11% of the estimated water taking. Total actual water takings are probably lower based on the fact that the MOE PTTW database currently does not report actual takings, only maximum permitted amounts.

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7. The consumptive water takings from this permitted value is probably about 80% of this as over-irrigation infiltrates about 20% to the ground water with the remainder returning to the atmosphere via evapotranspiration.

Table 4.11 Maximum Permitted Surface Water Takings According to PTTW Database

Permit No	Easting	Northing	Water Use	Source (River, Lake, Creek)	Takings * (Mm^3/yr)
03-P-5011	615190	5105850	Agriculture (Field and Pasture Crops)	South River	1.43
03-P-5018	664730	5129230	Campgrounds	Long Lake	0.03
74-P-5011	653900	5125200	Other – Industrial	Pimisi Lake	0.05
8315-6ADM8M	640600	5146150	Aquaculture	Balsam Creek	1.47
81-P-5226	624100	5098800	Agriculture (Field and Pasture Crops)	Unnamed Creek	0.01
89-P-5762	639900	5117300	Other – Commercial	Unnamed Creek	0.02
94-P-5025	626450	5118750	Municipal	Callander Bay	1.10
90-P-5838	622300	5131250	Municipal	Trout Lake	29.02
94-P-5011	622800	5131750	Other – Institutional	Trout Lake	0.08
98-P-5023	668099	5129680	Manufacturing	Mattawa River	0.36
99-P-5010	627650	5077650	Municipal	Forest Lake	0.61
00-P-5052	629536	5133188	Field and Pasture Crops	Four mile Creek	0.02
0251-6ADRGZ	623200	5123800	Golf Course Irrigation	LaVase River	0.12
01-P-5006	673388	5131071	Power Production	Mattawa River	*293.28*
92-P-5988	Not Available	Not Available	Agriculture (Field and Pasture Crops)	Boulder Creek	0.80
00-P-5002	625244	5075778	Golf Course Irrigation	Irrigation Ponds	0.35
01-P-5008	624718	5121441	Golf Course Irrigation	Irrigation Ponds	0.40
Total					**329.15**
Non-consumptive (Power Generation)					***293.28***
Consumptive (Municipal, Irrigation, Other-Industrial, Campgrounds etc.)					**35.86**
Municipal					**30.73**
Irrigation					**4.60**
Other-Industrial, Campgrounds etc)					**0.53**

*Note: * Italicized values represent non-consumptive uses.*

Table 4.12 Maximum Permitted Groundwater Takings According to PTTW Database

Permit No	Easting	Northing	Source Name	Water Use	Takings (Mm^3/yr)
02-P-5059	676210	5131526	Well # 1 (Mattawa)	Municipal	1.67
02-P-5059	676210	5131526	Well # 2 (Mattawa)	Municipal	0.72
04-P-5008	619528	5136736	Leachate Collection System & Pump Station	Groundwater-Remediation	0.44
92-P-5975	617750	5136650	Well Other	Industrial	0.03
04-P-5027	Not available	Not Available	Well #1	Campgrounds	0.03
04-P-5027	622900	5123700	Well #2	Campgrounds	0.001
82-P-5292	625900	5104350	Well #1 (Powassan)	Municipal	0.48
82-P-5292	625900	5104350	Well #2 (Powassan)	Municipal	0.48
93-P-5026	618300	5100550	Springs #1	Bottled Water	0.05
93-P-5026	618300	5100550	Springs #2	Bottled Water	0.07
93-P-5026	618300	5100550	Springs #3	Bottled Water	0.09
00-P-5002	625244	5075778	Dug Well	Golf Course Irrigation	0.04
02-P-5002	631550	5124340	Well #1	Other-Institutional	0.03
02-P-5002	631550	5124340	Well #2	Other-Institutional	0.02
02-P-5002	631550	5124340	Well #3	Other-Institutional	0.01
02-P-5002	631550	5124340	Well #4	Other-Institutional	0.02
03-P-5018	664750	5128520	Well #1	Campgrounds	0.03
Total					**4.20**
Municipal					**3.35**
Irrigation					**0.04**
Other-Industrial, Campgrounds etc.					**0.81**

The largest demand for potable water is in the area of the City of North Bay, where water is drawn from Delaney Bay, at the western end of Trout Lake. Actual annual water takings from Delaney Bay in 2005 were about 13 Mm^3/yr (based on records from the North Bay Water Treatment Plant), an amount which is more than half the volume of the bay (20 million cubic metres), for a population of almost 53,000. This water taking must be considered consumptive in the context of the Mattawa system, because the treated effluent is discharged to Lake Nipissing, constituting an inter-basin water transfer.

The total volume of water entering the bay annually, from the watershed, is approximately 6 million cubic metres. The city withdraws about 13 million cubic metres annually from the bay, resulting in a deficit of about 7 million cubic metres. Due to the depth of the water intake, most water is drawn from the hypolimnion (the bottom layer) of Delaney Bay during the summer stratification period (June to September). This will include both hypolimnion water and water from above, that flows back from the rest of Trout Lake. During the summer months, water taking by the City of North Bay may exceed the entire discharge of Trout Lake. This results in a westward flow[8] of water into Delaney Bay towards the city's municipal water taking system (Miller Environmental Services Inc., 2000). This is consistent with seasonal observations of no flow at the east end of Trout Lake (where the overflow of the Turtle Lake dam ceases. There is nonetheless still flow downstream in the Mattawa River from baseflow and tributaries.

The large volume of water taken from Delaney Bay may have two consequences, particularly during summer, namely that dissolved contaminants may not be flushed out of Delaney Bay, and dissolved contaminants in the main basin could flow westwards into Delaney Bay where the water intake is located. For this reason a detailed understanding of the hydraulics/hydrology of this bay, is warranted, and constitutes a data gap in the present assessment.

Another surface water taking within the SP Area is the South River Reservoir for the supply of municipal water for the Village of South River. The Village of South River has a total population of 1,040 and is permitted to withdraw 0.61 Mm^3/yr of water from the South River Reservoir (Permit no. 99-P-5010)[9].

Maximum allowable groundwater takings, based on the MOE PTTW database are presented on Table 4.12. The Town of Mattawa has a population of 2,270 and is permitted to draw a maximum of 2.39 Mm^3/yr of water from two groundwater wells according to the PTTW database (Table 4.12, Permit # 02-P-5059). Actual use, based on the NBMCA Groundwater Study Report (Waterloo Hydrogeologic, 2006) was 0.153 Mm^3/yr for 1999 to 2003. The Town of Powassan receives its supply of potable water from two groundwater wells (Wells 1 & 2: Permit # 82-P-5292). The permitted water takings from these two wells for the population of 1,177 is approximately

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[8] *The reader should be aware that the rate of movement is not great, given the tremendous volume of the lake, however there will be water movement back to the west to satisfy the City's withdrawals.*

[9] *The Ministry of Environment's Permit To Take Water database for South River's municipal supply indicates that the source of water is Forest Lake, but in fact it is from the South River Reservoir, which is downstream of Forest Lake.*

0.96 Mm^3/yr. Actual use, based on the NBMCA Groundwater Study Report (Waterloo Hydrogeologic, 2006) was 0.176 Mm^3/yr for 1997 to 2000.

A rural population of 19,173 lives in the study area, and most use water from private groundwater wells for domestic supply. Rural groundwater use has therefore been estimated to be approximately 2.34 Mm^3/yr based on an assumed consumption of 335 L/person/day (Environment Canada, 2005).

The agricultural census data (Table 4.13) collected by Statistics Canada represent the best available overview of agricultural activities within the SP Area.[10] The PTTW database was evaluated to estimate the proportion of agricultural water use derived from either surface or groundwater. The current database indicates that there are no groundwater PTTWs for agricultural use, and that all agricultural demand is satisfied with surface water takings.

Table 4.13 Agricultural Water Use (m^3/yr)

Quaternary Watershed	No. of Farms	Livestock	Field	Vegetable	Specialty	Total
North River (2JE-09)	0	0	0	0	0	0
Duchesnay Creek (2DD-19)	0	0	0	0	0	0
La Vase River (2DD-20)	13	3,497	13	4,501	4,209	12,220
Mattawa River (2JE-02)	18	4,612	32	2,000	1,866	8,511
Bear-Boileau Creeks (2DD-21)	13	5,580	27	197	1,996	7,799
Reserve-Beatty Creeks (2DD-25)	10	2,597	13	174	4,491	7,275
South River (2DD-23)	59	26,261	116	633	4,986	31,995
Wistiwasing River (2DD-22)	36	11,301	86	1,113	1,002	13,500
Upper Amable Upper South Rivers (2JE-04)	0	81	1	0	0	82
Amable du Fond River (2JE-03)	19	4,612	34	18	0	4,663
Pautois Creek (2JE-05)	7	1,591	11	7	0	1,609
Sharpes Creek (2JE-06)	11	2,975	28	0	0	3,003
Kaibuskong River and Depot Creek (2JE-07)	19	5,255	40	1,556	1,449	8,300
Boom Creek (2JE-17)	0	0	0	0	0	0
Total	**205**	**68,362**	**401**	**10,199**	**19,998**	**98,957**

These values are based on census data and are clearly lower than the maximum permitted amounts reported in the MOE PTTW database. The reason for this is that not all takings in Table 4.13 are reported by the MOE as they are less than 50 m^3/day, and that not all of the MOE permitted water taking is actually taken. It should be noted that PTTW program does not require permits for livestock watering operations regardless of the amount of water being taken and therefore this has not been captured here.

The volume of actual consumptive surface and groundwater demand from the watershed is summarized by type in Table 4.14. Actual consumptive surface water takings that include water takings for industrial supply, municipal water supply and agricultural use (irrigation, livestock etc.) total

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[10] *It is important to note that the original data is based on Census subdivisions and has been realigned to watershed boundaries. This process is an approximation only, but is deemed acceptable for the purpose of this report.*

about 33.63 Mm^3/yr which is only about 10.2% of the amounts indicated in the PTTW database. Similarly, the actual consumptive groundwater demand from the watershed is approximately 1.49 Mm^3/yr which is approximately 35.5% of the amounts indicated in the PTTW database.

Table 4.14 Consumptive Surface and Groundwater Use/Demand in the SP Area According to the PTTW Database

Water Use		Water Takings (Mm^3/yr)	Consumptive Factor	Consumptive Use
Surface Water				
Total Surface Water Takings according to PTTW		329.15		
Permitted Takings: Power Generation		293.28	0.0	0.0
Permitted Takings: Other- Industrial		0.53	0.25	0.13
Permitted Takings: Municipal Water Supply	*Trout Lake*	29.02	[1]1.0	29.02
	Callander Bay	1.10	0.2	0.22
	South River Reservoir	0.61	0.2	0.12
Permitted Takings: Agriculture (Irrigation)		4.60	0.9	4.14
Total Consumptive Surface Water Use/Demand				**33.63**
Groundwater				
Total Groundwater Takings according to PTTW		4.20		
Permitted Takings: Other- Industrial		0.81	0.25	0.20
Permitted Takings: Municipal Water Supply		3.35[2]	0.20	0.67
Permitted Takings: Agriculture (Irrigation)		0.04	0.90	0.04
Water Takings: Private wells		2.34	0.25	0.58
Total Consumptive Groundwater Use/Demand				**1.49**

Note: 1. A consumptive factor of 1.0 has been used instead of recommend 0.2 as the water taken from the Trout Lake does not return to the Trout Lake after usage, but rather to Lake Nipissing

2. This includes permitted municipal water takings for the Town of Mattawa (2.39 Mm^3/yr) and the Municipality of Powassan (0.96 Mm^3/yr). See also section 4.6 for details

In calculating the actual consumptive water takings provided in Table 4.14, the following assumptions were made[11]:

a) consumptive water loss for power generation is 0% (that is all of the water drawn from the watershed returned to watershed);

b) consumptive water loss for industrial water use is 25% and the rest is returned to the watershed through drains;

c) consumptive water loss for private or municipal water use is 25% (except as noted in Table 4.14) and the rest is returned to the watershed through residential septic tanks or sewage treatment plants; and

d) consumptive water loss for irrigation water use is 90% through evapotranspiration etc. and the rest is returned to the watershed through the drainage system.

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[11] *These initial assumptions are made for this Conceptual Water Budget. Different values may be used for the more detailed analysis of the Tier 1 or 2 Water quantity Stress Assessment (e.g. Table 16, Guidance Module 7, March 2007)*

4.7 Report on Quality and Quantity of Data Available

4.7.1 Climate Data

With respect to the quantity of data, there have been about 45 climate stations operating within 150 km of the SP Area and recording data over the past 100 years. These stations have been identified and are operated by different agencies such as Ontario Power Generation, the Ontario Ministry of Natural Resources, and Environment Canada's Atmospheric Environment Service (AES). Many of these climate stations are no longer active. Historical data that dates as far back as the early 1900s are available through Environment Canada's Canadian Climate Centre website. At present, the only long-term climate stations still collecting data are at the North Bay Airport (#6085700, since 1939) and one located at Powassan, (#6116702, since 1974).

Although more than 40 stations[12] have operated within and in the vicinity of the North Bay-Mattawa SP Area over the years, most of them have only recorded daily precipitation (as rainfall and snowfall depths), with a handful of them including daily maximum and minimum air temperatures as part of their climate observation program. An even smaller number of stations have included recording rainfall (tipping-bucket) data, and some have included relative humidity and wind speed measurements. There have been no pan evaporation measurements in the study area from which to estimate lake evaporation, which constitutes a data gap in the present analysis. Overall, the availability of climate data in the region can be classified as sparse at best. Few stations were in operation for more than 25 years, although a sufficient number have been open long enough to make some general conclusions about the overall climate of the region. As noted above, only two long-term climate stations are still in operation.

Climate averages, means or normals refer to the arithmetic computations based on the observed meteorological values for a given location over a specified time period and are used to describe the climatic characteristics of the location. The averages can be used to describe a "typical" climate pattern for a specific location. Daily meteorological data can be used to describe how unusual or how great is the departure/deviation from the average scenario.

The World Meteorological Organization (WMO) considers thirty years long enough to eliminate year-to-year variations. Thus the WMO climatological standard period for normals calculation are defined as "averages of climatological data computed for a consecutive period of thirty years as follows: 1 January 1901 to 31 December 1930, 1 January 1931 to 31 December 1960, etc." Additionally the WMO established that normals should be arithmetic means calculated for each month of the year from daily data. To qualify, temperature data and evaporation must fit the 3/5 rule: if more than three consecutive daily values are missing or more than five daily values in total in a given month are missing, the monthly mean should not be computed and the year-month mean should be considered missing. For total precipitation, degree-days, and "days with" calculations, no missing days are allowed. Obviously the ideal averages can only be calculated when enough historically recorded data are available.

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[12] *Only 13 of the 40 stations have data quality that meets the WMO standard.*

Once the months that qualified are determined, a similar 3/5 rule is also applied to the number of monthly average or total values in the thirty-year period. For example, to meet this WMO standard, the "normal" value of a monthly element, such as the normal rainfall amount for May, can have no more than three consecutive, or five in total, missing rainfall values in any month of May from 1971 to 2000.

Normals for some elements are derived from less than thirty years record. The minimum number of years used are indicated by a code defined as:

- "A": no more than three consecutive or five total missing years from 1971 to 2000;
- "B": at least 25 years of record from 1971 to 2000;
- "C": at least 20 years of record from 1971 to 2000; and
- "D": at least 15 years of record from 1971 to 2000

In the analysis of water budget for this study, 30 years of monthly average climate data (precipitation including rainfall and snowfall, temperature) were collected from the environment Canada web site (*www.climate.weatherofficve.ec.gc.ca/climate_normals*). A detailed description about how the data are measured and processed is explained in the above site. These 30 years climatic normals data were further processed to calculate other climatic parameters like AET. Thirteen climate stations within and the vicinity of the SP Area were found to follow WMO standards and were therefore selected for further analysis.

4.7.2 Streamflow Data

The availability of streamflow data are much better than climate data, because of the need for operators to use these data for the direct operation of reservoirs and other control structures. Complete annual records of daily flows are available for 10 locations within the watershed, of which seven of these have been in operation for more than 25 years.

Despite the better coverage of streamflow records it was not possible to completely match the period of record for climate data. Where the period of record did not completely match, data were extrapolated by doing a simple pro rata based calculation discussed earlier in section 4.5.4. For the Mattawa watershed as an example this was done on the years 1998 to 2000. This approach was deemed acceptable for the purposes of this report, in order to extend the period of record to match the meteorological period of record.

A Water Quantity Stress Assessment for the specific case of the Trout Lake watershed, which is the source of North Bay's municipal water supply will need to be undertaken at a Tier 1 level of study. Preliminary examination identifies that there is a water deficit to the lake for 5 months of the year in the summer due to the water taking. This cannot be addressed without properly understanding lake outflow and lake levels, and it is recommended that a proper gauge be constructed to measure continuous streamflow, and daily discharge volumes at Turtle Dam.

4.7.3 Groundwater Information

A groundwater study report for the entire North Bay –Mattawa SP Area was prepared by Waterloo Hydrogeologic Inc. in association with Tunnock Consulting Limited in 2006. This report (Waterloo Hydrogeologic, 2006) presents an extensive compilation and evaluation of regional and local water resources information including groundwater and aquifer characterization, intrinsic susceptibility analysis, and groundwater use assessment.

However, it is important to understand that the existing number of available private wells, over a wide and relatively uninhabited area, do not provide complete coverage. While it would not be possible to have enough wells to cover each of the small local groundwater flow systems around each creek and portion of every subwatershed, it is recommended that a few well-placed sentinel wells (unused for pumping), in typical settings, equipped with daily level recorders would suffice to characterize the area. While it is beyond the scope of this report to determine where and how many wells, the typical settings should include bedrock aquifers, local overburden aquifers, and more extensive overburden aquifers from which there is municipal water taking.

The CFB Sage complex is underground near the airport and is kept dry through continual dewatering. This discharge reportedly goes to Lees Creek, which in turn ends up in Delaney Bay of Trout Lake. Information on quantities and seasonal discharge will have to be obtained as part of the anticipated Tier 1 work on Trout Lake.

5. Integrated Conceptual Understanding

5.1 Water Budget on a Watershed Basis

5.1.1 Spatial Scale

The North Bay – Mattawa SP Area consists of two surface water river systems – the Mattawa and South Rivers. Surface water flow in the Mattawa River is from west to east and in South River from south to north. Groundwater flow is localized towards the surface water system. In our study area it is assumed that the surface drainage watershed or subwatershed boundaries largely correspond to the groundwater flow divides. Given the shallow nature of the groundwater system this is a reliable assumption. The SP Area includes a large enough area that cross-boundary groundwater flow is not an issue. The topography is therefore one of the key influences on the groundwater flow system.

Municipal groundwater takings for drinking water consist of two wells supplying the Town of Powassan, and two wells supplying the Town of Mattawa. There are also wells supplying campgrounds in North Bay. There were 4,581 private wells listed in the MOE water well database, spread over the 3,963 km^2 of watershed area. There may also be some unreported wells in the SP

Area, which can number as high as 30% more than the number of reported wells[13]. However, the water takings from these private wells will not induce changes that will extend beyond the surface watershed or subwatershed boundaries.

For the North Bay – Mattawa SP Area, the City of North Bay obtains all of its water supply from Trout Lake, at the headwater of the Mattawa River, in the Ottawa River watershed. Treated wastewater is discharged into Lake Nipissing, which ultimately flows into Lake Huron. This situation means that there is interbasin transfer between the Ottawa Basin and the Great Lakes Basin, albeit a small amount in comparison to the larger scale of the basins. However, it is a significant amount on the local scale. From a regulatory perspective, this situation predates the Water Transfer regulation (285/99 and its successor, 387/04) under the Ontario Water Resources Act (OWRA), and therefore is allowed based on it being pre-existing permit. This is consistent with the revisions to the OWRA in 2007, which simply move this aspect into the legislation itself. For the purpose of clarity during the Conceptual Understanding, the water budget is calculated on the subwatershed scale (see Figure 1.1 in Section 1.3).

5.1.2 Annual Temporal Scale

The hydrologic patterns can be subdivided into four general periods of the year. The actual length of each period can differ between particular locations on an annual basis, depending on climate.
Period 1 occurs from approximately mid-December to the early part of March. Precipitation generally falls in the form of snow (Figure 4.3) with the thickness of the snowpack increasing with time. The temperature is generally below freezing (Figure 4.1). Evaporation from the snowpack is minimal and the recharge to the water table is almost zero, due to the frozen ground. The exception would be for periodic melting events before the ground freezes. Streamflow is primarily composed of groundwater discharge. In the absence of recharge during this time, groundwater storage may deplete.

Period 2 runs from March to May. The rise in temperature to above freezing means that most precipitation is in the form of rain, and with the melting of the snowpack, leads to high streamflow and flooding. This is enhanced by the fact that the ground is still frozen in March and early April, preventing the infiltration of snowmelt. Streamflow runoff is generally the highest in April. Percolating water exceeds the field capacity or wet limit of the soil, as suggested by a rise in the water table. In this period, evapotranspiration is not significant because the temperature is still low and plant growth minimal. This is a period of rapid transition from no groundwater recharge to significant groundwater recharge as the frozen surficial sediments melt.

Period 3 occurs from June to September, and is characterized by high temperatures and evapotranspirative uptake due to plant growth. Precipitation comes in the form of rain, and the majority of it is retained by the surficial soil to satisfy an increasing moisture deficiency created by evapotranspiration. The water only soaks through to the groundwater when the field capacity

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[13] This estimated percentage of unreported wells is based on the experience of Gartner Lee Limited. (S.Usher, Personal Communication, 2007)

(wet limit) of soil is exceeded. Limited groundwater recharge can occur during periods of soil moisture deficit through such features as fractures, and by runoff that collects in ditches (or dry kettles and swales) and may reach the water table. However, the water table is steadily declining, as groundwater discharge to streams is greater than recharge to groundwater.

Period 4 occurs from September to early December. Precipitation comes in the form of rain and occasional snow. The growing season is finished and transpiration is low and evaporation declines as temperatures drop. The soil moisture has returned to field capacity as shown by the water table rise. This is the second major period of the year when groundwater recharge exceeds discharge. The December period more closely resembles Period 1 in the SP Area, as frost sets into the ground.

Water availability within the various components of the hydrologic cycle also varies on longer than seasonal scales. For example, there are periodically 2 to 3 year periods of above average precipitation or below average precipitation. The vertical position of the water table can vary by 1-2 m over a year (see Figure A1 in Appendix A), but can vary by another 2 m from year to year, depending upon availability of recharge from precipitation and the thickness of the aquifer[14]. The climate information used for the SP Area water budgeting purposes has been taken over a 30 year period from 1971 to 2000 to be representative of average conditions. Water management decisions will be more effective if the water budget is considered within a temporal climatic framework, however site-specific water management will have to consider the extremes as well.

5.1.3 Water Budget Approach

In initiating the water budget analyses for the North Bay – Mattawa SP Area, the following approach has been used:

1. Consideration of a long enough period of time, in which storage changes and natural inter-basin flows can be safely assumed to be minimal.
2. Usage of average saturation state conditions, where input data and calibration targets represent average climate conditions, average groundwater levels and average streamflow conditions.
3. Selection of the timeframe 1971 to 2000, because this is the period where nearly complete streamflow and precipitation records are coincident.

For the purposes of this conceptual water balance study, a subwatershed scale was considered large enough to balance the water budget. It is also necessary to understand the saturation state of the study area required for a particular application. As discussed above, streamflow and groundwater levels vary seasonally, but at different rates (streamflow being much more dynamic, and groundwater being attenuated by soil permeability).

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[14] This is a general information and is typical of this type of topography, geology and land cover.

For this reason a long, 30-year period was deemed appropriate. To summarize, the design of water budget investigations must incorporate:

a) climate data representative of the geographic area of concern;
b) an area large enough to balance the water budget (a more regional understanding of the flow system must account for estimates of groundwater transfers); and,
c) data from a period covering a range in saturation states both annually and long-term (drought versus non-drought conditions).

The North Bay – Mattawa SP Area is divided into six subwatersheds; the Mattawa River, South River, Duchesnay River, La Vase River, Wistiwasing (Wasi) River and Bear-Boileau Creeks subwatersheds (see Table 1.1 and Figure 1.1 in Section 1.3). From the surface water supply perspective Trout Lake, South River Reservoir and Callander Bay are the only surface water sources. The North Bay Water Treatment Plant (NBWTP) supplies drinking water to a population of approximately 53,000 people in the City of North Bay. The Village of South River has only one source of municipal water supply for its 1,040 urban population, comprising a surface water taking from the South River Reservoir. The municipality of Callander has one source of municipal water supply for its 1,339 urban population, a surface water taking from Callander Bay. The Town of Mattawa, with a population of approximately 2,270 people, is supplied by two groundwater wells. The Town of Powassan uses two groundwater wells as well to supply drinking water to an urban population of approximately 1,177. A total rural population of about 19,200 people was considered in the calculation as well.

To calculate the simple water balance/budget for the subwatershed, a simple empirical water balance equation was used. The approach is expressed as follows:

$$P + Sw_{in} + Gw_{in} + ANTH_{in} = ET + Sw_{out} + Gw_{out} + ANTH_{out} + \Delta S \qquad \textit{Equation (1)}$$

Where: P = Precipitation
Sw_{in} = Surface water inflow into the system from outside
Gw_{in} = Groundwater inflow into the system from outside
$ANTH_{in}$ = Anthropogenic or human inputs
ET = Evapotranspiration losses
Sw_{out} = Surface water outflow from the system
Gw_{out} = Groundwater outflow from the system
$ANTH_{in}$ = Anthropogenic or human removals
ΔS = Change in storage (both surface and groundwater)

Equation (1) applies to the entire watershed. Internal to the watershed the precipitation follows a more intricate pathway. The evapotranspiration is derived from surface water and groundwater. The groundwater recharge is only a portion of the actual infiltration, some of it being lost to transpiration. Evaporation comes from both open waterways, canopy interception and temporary puddle storage. Streamflow is made up of both runoff and groundwater discharge (called baseflow). The water balance can be simplified, on a local scale and ignoring any change in storage, as:

$$P = AET + S \qquad \textit{Equation (2)}$$

Where: P = Precipitation
AET = Actual Evapotranspiration
S = Surplus

The surplus is further broken down into runoff (RO) and recharge (R) by:

$$S = RO + R \qquad \textit{Equation (3)}$$

Therefore Equation (2) can be restated as:

$$P = AET + RO + R \qquad \textit{Equation (4)}$$

For the preliminary estimation of the water balance components (i.e., actual evapotranspiration, surface runoff and recharge for equation (4) above), the climactic data are used as determined in Section 4.4.2. Environment Canada has generated climate normals for the period (1971-2000) for all stations used.

5.2 SP Area Water Budget Calculations

In calculating the water budget, measured meteorological data and related parameters (like evapotranspiration) were interpolated for the SP Area from values measured (or calculated) at 13 meteorological stations. Individual month and annual interpolations were made using ordinary Kriging. Kriging is a geostatistical interpolation method that uses information about the spatial autocorrelation in the vicinity of each observation point to provide an interpolated surface. The interpolation is dependent on the variation between observed data points. This is an approximation only, and actual values at any location are expected to vary. The success of this technique relies upon the observation that positive and negative discrepancies from actual values in the interpolated space generally cancel. To obtain an “average” value for each measured and derived meteorological variable, the interpolated surface was clipped to the boundary of the SP Area, and the mean value of the resulting grid of values used as the average. In plain language, the water amounts (expressed as depths for each cell in the grid) were multiplied by the area to derive a cell volume. These were summed and then divided by the entire area to obtain an average value for the entire domain.

Kriged surfaces are dependent on the input variables and the difference between them as a function of distance. Because the differences in measured and derived meteorological data among weather stations were different for each month, different fitting functions were used for each monthly data set. The same was true for the annual data. As a result, the average of monthly interpolated data are not the same as the interpolated average annual data.[15]

5.2.1 Precipitation

Section 4.1 noted that climate normals data for thirteen stations within and surrounding the SP Area were available for the period 1971 to 2000 (see Table 4.1). The mean annual precipitation for each of these thirteen stations was computed for that time period to agree with the time frame for streamflow records available in the SP Area.

The point observations of mean annual precipitation for the thirteen climatic stations were entered into the GIS database and mean annual precipitation was interpolated over the entire study area with ordinary Kriging. The interpolated annual precipitation is presented in Map 1 in Appendix B and calculated monthly and annual precipitation for each station is presented in Appendix A. Table 5.1 presents annual average precipitation estimated by this method for the different watersheds (above specific stream gauges) in the SP Area. Among the 13 selected meteorological stations, precipitation ranges from 785 mm/yr to 1,182 mm/yr with an arithmetic average annual precipitation of 965.6 mm/yr and an area weighted interpolated annual average for the entire study area is 972 mm/yr.

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[15] *For example interpolation between stations for the average annual conditions will yield one value. The average of each of the monthly values (which were kriged with different fitting functions) yields a subtly different value. This is because the averaging includes the fitting functions in the second case and not in the first.*

5.2.2 Evapotranspiration

Actual evapotranspiration (AET) losses were calculated using the Thornthwaite and Mather (1957) method, which takes into consideration the average monthly temperature and the hours of daylight, as well as soil moisture storage. This method is very widely used in water balance estimates and was chosen here for its simplicity and its ability to directly utilize the available climate data. This method produces an estimate of the potential evapotranspiration (PET), which are adjusted to yield AET by considering soil moisture storage. Based on the application of this method, AET estimated for the thirteen stations ranges from 481 mm to 542 mm with an arithmetic average of 520.2 mm annually. In Section 4.4.2, an areally-weighted mean annual AET total of 535 mm is derived and used in Table 5.2 (found in Section 5.2.4). [16]

5.2.3 Streamflow

In the North Bay – Mattawa SP Area, there are 11 operating streamflow gauges/hydrometric stations among which 4 stations have periods of record that match closely with the climatic stations. Complete flow records are available at these gauges for the period mentioned in Table 4.9. The annual flow volumes (expressed as depth) for the 4 stations are provided in Table 5.1. The mean annual water balance for the entire SP Area is summarized in Table 5.2 (found in Section 5.2.4).

The mean, maximum and minimum stream flows in this exercise for the entire watershed were calculated on a pro rata basis. For example, the flow rate of each individual sub-watershed was divided by the corresponding sub-watershed area, averaging it out and finally multiplying it with the total area of the watershed.

5.2.4 Summary of the SP Area Water Budget

The sub-watershed based water budget is provided in Table 5.1. Table 5.1 is compiled for the four watersheds with gauges and includes the surficial area (in square kilometres) draining past each gauge.[17] The selection of these watersheds was based on the consistent period of records (1971-2000) between streamflow and climatic data. South River watershed was not analyzed as the length of time for the streamflow records did not correlate with the climate data. (As discussed below, this watershed will require a Tier 1 analysis for water quantity stress assessment, in which case it may be prudent to consider a shorter period of record in order to provide insight into the dynamics of the watershed.)

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16. Areally-weighted mean annual AET values were also reported for different watersheds in the SWP area in Table 5.1.

17. For this reason, the areas do not reconcile with Table 4.7 in Section 4.5.

Table 5.1 Summary of Water Budget on Subwatershed Basis

Catchment Name (Gauge #)	Area (km^2)	Average Annual Precip. (mm)	Average Annual Actual ET (mm	Surplus (mm)	Runoff (mm)	Recharge (mm)	Streamflow (mm)	Baseflow (mm)**
Chippewa Creek (02DD014)	32.4	1005	533	472	193	279	621	256
La Vase River (02DD013)	69.2	967	536	431	265	166	438	127
Amable Du Fond River (02JE019)	1140	961	535	426	235	191	439	215
Mattawa River Below Bouillon Lake (02JE020)	951.5	966	535	431	225	206	500	227

*Note: ** Baseflow was calculated using an automated baseflow separation program described by Arnold and Allen, 1994*

Examination of Table 5.1 yields some interesting observations. The surplus value (comprised of runoff and recharge) theoretically should match the Streamflow value (correspondingly comprised of storm runoff and baseflow). There is excellent agreement for La Vase and Amable Du Fond watersheds at their respective gauges. The Mattawa River is out by only 14%, which is near the accuracy of streamflow measurement. Only Little Chippewa Creek (Map 10) was significantly different (by 31%), which may have more to do with the urbanized character of this smaller watershed.[18]

Table 5.2 below provides a summary of the integrated water budget for the entire SP Area. The description column of the table provides some insight as to assumptions and limitations of the analysis.

To simplify the interpretations of Table 5.2, the following narrative is meant to assist the reader. It is expressed solely in terms of average annual amounts. All values are expressed in terms of a volume of water, expressed in “million cubic metres per year (Mm^3/yr)”.

A total of 3,852 Mm^3/yr falls as precipitation, of which 2,120 Mm^3/yr is returned to the atmosphere by evapotranspiration (or about 55% is lost). This leaves 1,732 Mm^3/yr as a surplus, available for runoff or recharge. By way of comparison the average streamflow out of the watershed is 1,951 Mm^3/yr which is made up of both runoff and baseflow. There is about an 11% difference in these values, with the measured streamflow being higher than the calculated surplus. This difference is considered to be an acceptable margin of error, given the uncertainties in parameter estimation, measurement error and meteoric distribution of precipitation.

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[18] *An urbanized watershed will have less transpiration, shorter water retention times and thus less evaporation. This means that there is a greater surplus, which generally ends up as runoff. Hence the measured Streamflow value is greater than the theoretical surplus.*

Table 5.2 Summary of the Conceptual Water Budget of the SP Area (Total Drainage Area: 3,963 km^2)

Parameters	Annual Depth (mm)	Annual Volume (10^6 m^3)	Description
Precipitation (mm)	972	3,852	Interpolated from an area-averaged annual mean precipitation. Precipitation calculated by arithmetic average of the 13 stations is 965.6 mm
Actual ET (mm)	535	2,120	Interpolated from an area-averaged annual average actual ET. (Arithmetic average of AET calculated using Thornthwaite and Mather (1957) is 520.2 mm)
Surplus (mm)	437	1,732	Spatially distributed average value. (Arithmetic average value is 445.4)
Recharge	208	824	Determined in GIS platform
Runoff	229	908	Determined in GIS platform
Max Streamflow	721.4	2,859	Area weighted maximum annual streamflow
Mean Streamflow	492.4	1,951	Area weighted mean annual streamflow
Min Streamflow	294.4	1,166	Area weighted minimum annual streamflow
Consumptive Surface Water Takings	8.5	33.63	According to PTTW Database provided in Table 4.11. For details see Table 5.3
Non-Consumptive Surface Water Takings	74	293.3	According to PTTW Database Provided in Table 4.11. See also Table 5.3
Consumptive Groundwater Takings	0.38	1.49	According to PTTW database provided in Table 4.12 and include water takings from private wells for about 19,173 people consuming water at a rate of 335 L/day/capita (see also Table 5.4).
Non Consumptive Groundwater Takings	0.76	3.01	According to PTTW Database provided in Table 4.12. See also Table 5.4

The Surplus of 1,732 Mm^3/yr is partitioned between runoff and recharge in the following way. A total of 52.4% of the surplus, or 908 Mm^3/yr directly runs off, while 824 Mm^3/yr goes to recharge the water table (to later appear as baseflow).

Maximum permitted surface and groundwater takings total 333.35 Mm^3/yr according to Table 4.14 in Section 4.6, or about 19.2% of the overall surplus. Of this, approximately 296 Mm^3/yr is comprised of non-consumptive uses[19]. As previously defined, non-consumptive uses involve the use of the water that is returned to the local watershed of origin in a reasonable timeframe. In the context of source water protection water budget, consumptive uses refer to the amount of water removed from a hydrological system and not returned back to the same system in a reasonable time period. The consumptive use, including North Bay's maximum permitted withdrawal from Trout Lake, is about 34.83 Mm^3/yr or about 2.01% of the surplus.

5.3 Consumptive Water Use Percentage

As per the Interim Water Budget Technical Direction document, the percent consumptive use of water in the watershed region was also calculated. Table 5.2 gives the summary of the conceptual

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19. For the purpose of this summary, both ground and surface water sources are considered together.

water budget of the North Bay – Mattawa SP Area. Stream flow volumes are compared to the water use to estimate the "Percent of Consumptive Water Use" for the whole SP Area, and these are presented in Table 5.3.

Table 5.3 Stream Flow Volume Versus Consumptive Water Use Scenarios

Catchment Area	Streamflow	Volume (Mm^3/yr)	Water Use[1] (Mm^3/yr)	% Water Use
SP Area	Mean Streamflow	1,951	33.63	1.72
	Minimum Streamflow	1,166		2.88
	Maximum Streamflow	2,859		1.17

Note: 1. Consumptive surface water use is based on the maximum permitted surface water takings (for details see the Table 4.14)

As Table 5.3 shows, average consumptive surface water demand/use in the entire SP Area is just 1.72% of mean streamflow. In the case of minimum streamflow the demand is still less than 3%. Overall, the water balance summary for the North Bay – Mattawa SP Area illustrates that the flow at the above selected long-term gauge stations appears reasonable with respect to the climate data on an annual basis.

Table 5.4 provides a groundwater use scenario and compares consumptive groundwater demand/use with groundwater recharge for the entire SP Area. Annual groundwater recharge for the entire SP Area is calculated based on the estimated annual average recharge of 208 mm determined in GIS and multiplied with the area where most of the wells are concentrated. This area is estimated to be about 500 km^2. According to PTTW database and based on assumption that approximately 19,173 population use 335 L/day/capita, the total consumptive groundwater demand in the entire North Bay-Mattawa SP Area is approximately 1.5 Mm^3/yr, which represents approximately 1.2% of recharged water in the selected portion of the study area.

Table 5.4 Groundwater Recharge Versus Groundwater Use Scenarios

Catchment Area	Parameters	Amount
SP Area	Recharge Area (km^2)	500
	Recharge Rate (mm/yr)	208
	Total Groundwater Recharge (Mm^3/yr)	125
	Consumptive Groundwater Use (Mm^3/yr)	1.49
	% Consumptive Groundwater Use	1.19

The geology surrounding the municipal wells in Mattawa and Powassan indicates aquifers of potential limited local extent. Therefore, on a SP Area basis, the % consumptive groundwater use value may be misleading, and likely underestimates the stress placed on the local aquifers.

Consequently, further detailed study on the delineation of actual recharge area is required in order to more accurately compare groundwater recharge with the groundwater use, and is recommended for further study at a Tier 1 assessment.

5.4 Summary

In Section 1.2 four questions were asked in defining the requirements of the study. The conceptual understanding is summarized below, followed by a synopsis of how each of the four items were addressed:

1. Surface water plays a vital role in the watershed region. It is the major source of supply for drinking water purposes and most drinking water is supplied from surface water sources. The agricultural area south of North Bay enjoys thicker overburden and groundwater supplies are derived locally.
2. The geologic framework of the area governs the surface and subsurface groundwater pathways. The area is dominated by shallow permeable soils overlying low permeability bedrock. Infiltrating water recharges the local water table, and is deflected by the bedrock to local watercourses, wetlands and streams. Soils deepen in the centre of the watershed.
3. Water movement is dominantly by surface water, flowing northwest (South River) and eastward (Mattawa River) through the watershed.
4. Groundwater Studies were conducted in 2004 and 2006 covering the entire North Bay-Mattawa SP Area. Mattawa and Powassan use strictly groundwater, obtaining it from an overburden sand and gravel aquifer of limited extent. The City of North Bay and the Village of South River rely on surface water for municipal drinking water purposes from Trout Lake and from the South River Reservoir, respectively. Most rural residents rely on residential wells.
5. From a water quantity perspective, municipal takings (North Bay, Mattawa, Powassan and the Village of South River) require additional evaluation at Tier 1. With those exceptions, it appears the amount of water moving through the rest of the watershed greatly outweighs present and future anticipated uses.
6. Given the large watershed and renewable nature of the water supply, there are no serious concerns in water availability. Annual fluctuations are significant enough to cause local stresses, however these generally have been temporary.
7. Water management decisions will be more effective if the water budget is considered within a temporal climatic framework. However site-specific water management will have to consider the extremes as well.

As identified above, four questions have been addressed by this study. Points 1 and 2 address the question of **where the water is found**. Points 2 and 3 summarize **how the water moves**. Points 4 and 5 address **what and where the stresses are** on the water supply. Point 6 deals with the **trends for water** availability.

6. Moving Forward

Based on a conceptual understanding of the water balance conditions, and current Provincial direction regarding the Source Water Protection program, a Tier 1 evaluation of several ground and surface water supplies should be undertaken. This should be done for the City of North Bay, Village of South River (surface water based source for municipal drinking water supply) and for the Town of Mattawa and Municipality of Powassan (groundwater based source for municipal drinking water supply).

The most important data gap that exists for addressing the City of North Bay's water supply at Tier level 1 is the lack of information on the dynamics within and around Trout Lake. In the Trout Lake watershed, there are no hydrometric/gauge stations for measuring stream flow which is essential for determining the water budget for the watershed.

Although water budgets carried out for source water protection are to specifically address drinking water sources, the resulting tools can be applied to many other water management decisions. For example, the results can be used to:

a) improve the understanding and protection of aquatic ecosystems that rely on certain flow regimes within a given watersheds;

b) assess further consumptive water demands (e.g., PTTW applications); and

c) address issues related to the Federal Department of Fisheries and Oceans.

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Appendix A

Summary of Climate Data and Groundwater Level Information

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Summary of Climate Data and Groundwater Level Information

Table A1. Summary of Climatic Stations used for Water Balance Analysis

Station Name		Station ID	Latitude	Longitude	Elevation (m)	Period of Record	Data Period Used in Analysis
Stations located Within the Study Area	North Bay A (ON)	6085700	46° 21’ N	79° 25’ W	370	1953-2007	1971-2000
	Powassan (ON)	6116702	46°7’ N	79° 15’ W	274	1974-2007	1971-2000
Stations Located at the Vicinity of the Study Area	Chalk River AECL (ON)	6101335	43° 3’ N	72° 22’ W	122	1960-2007	1971-2000
	Combermere (ON)	6101820	45° 22’ N	77° 37’ W	287	1956-2006	1971-2000
	Dunchurch (ON)	6112133	45° 37’ N	79° 53’ W	268	1973-2007	1971-2000
	Dwight (ON)	6082178	45° 23’ N	78° 54’ W	404	1973-2005	1971-2000
	Earlton A (ON)	6072225	47° 42’ N	79° 51’ W	243	1953-2007	1971-2000
	Madawaska (ON)	6084770	45° 30’ N	77° 59’ W	316	1915-2000	1971-2000
	Minden (ON)	6165195	44° 56’ N	78° 43’ W	274	1883-2006	1971-2000
	Muskoka A (ON)	6115525	44° 58’ N	79° 18’ W	282	1953-2005	1971-2000
	Sudbury A (ON)	6068150	46°37’ N	80° 48’ W	348	1954-2007	1971-2000
	Belleterre (QUE)	7080600	47°23’ N	78° 42’ W	322	1951-2004	1971-2000
	Remigny (QUE)	7086460	47°43’ N	79° 14’ W	290	1971-2004	1971-2000

Notes: ON: Ontario, QUE: Quebec

Table A2. Average Monthly Precipitation Over the Period 1971-2000

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
North Bay A (ON)	67.6	52.6	65.4	67.2	87.6	95.2	100.1	100.1	113.5	97.6	89.9	70.9	**1007.7**
Powassan (ON)	58.9	44.0	59.1	61.5	77.6	89.1	101.8	97.3	112.1	91.6	83.2	59.5	**935.7**
Chalk River AECL (ON)	56.7	45.3	62.0	60.4	81.6	88.3	86.8	82.1	84.6	79.3	72.3	60.9	**860.2**
Combermere (ON)	62.4	50.4	61.9	70.7	74.9	82.6	78.6	78.9	86.4	80.3	72.9	69.3	**869.2**
Dunchurch (ON)	108.0	68.6	70.4	71.6	91.3	82.6	82.5	91.7	113.5	110.6	117.0	106.3	**1114.2**
Dwight (ON)	108.7	70.8	83.8	77.2	90.6	93.4	96.3	110.3	115.1	108.9	121.5	106.3	**1182.8**
Earlton A (ON)	54.0	39.8	59.1	55.5	67.0	77.1	79.7	80.9	88.7	69.4	60.1	53.9	**785.1**
Madawaska (ON)	61.1	44.3	50.3	58.8	73.0	83.5	83.9	89.7	89.1	79.4	71.3	58.9	**843.2**
Minden (ON)	94.0	63.1	74.2	74.3	92.7	90.3	82.7	87.8	96.0	91.5	102.1	96.0	**1044.7**
Muskoka A (ON)	98.5	62.9	74.1	78.9	91.1	85.5	93.4	87.3	111.3	101.3	112.2	102.3	**1098.6**
Sudbury A (ON)	68.6	50.6	65.9	64.9	77.5	77.8	76.6	90.5	101.3	82.1	76.5	67.1	**899.3**
Belleterre (QUE)	69.1	54.0	67.1	69.2	78.4	94.5	104.8	101.3	104.8	89.7	86.8	76.3	**995.9**
Remigny (QUE)	55.0	42.7	60.4	60.5	83.3	92.0	91.8	101.9	102.7	85.9	76.3	63.4	**915.9**

Table A3. Calculated Actual Evapotranspiration (mm) at the Selected Climatic Stations (Climatic Data used from 1971-2000)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
North Bay A (ON)	0.0	0.0	0.0	21.0	77.3	108.2	123.1	106.1	67.8	30.2	0.0	0.0	**533.7**
Powassan (ON)	0.0	0.0	0.0	25.2	78.6	108.1	121.8	104.3	69.1	32.1	0.0	0.0	**539.2**
Chalk River AECL (ON)	0.0	0.0	0.0	28.2	81.6	113.3	115.8	96.1	72.1	33.7	1.0	0.0	**541.9**
Combermere (ON)	0.0	0.0	0.0	24.4	77.9	107.6	108.6	90.9	69.2	32.4	0.0	0.0	**511.1**
Dunchurch (ON)	0.0	0.0	0.0	25.8	76.6	105.6	110.5	100.7	70.1	33.6	0.5	0.0	**523.3**
Dwight (ON)	0.0	0.0	0.0	22.9	76.3	102.4	118.3	107.5	67.2	31.0	0.0	0.0	**525.7**
Earlton A (ON)	0.0	0.0	0.0	15.6	76.0	102.1	105.7	90.9	64.7	26.7	0.0	0.0	**481.6**
Madawaska (ON)	0.0	0.0	0.0	23.8	76.0	104.5	110.9	97.7	68.0	31.2	0.0	0.0	**512.0**
Minden (ON)	0.0	0.0	0.0	27.2	77.6	107.3	113.7	98.8	71.1	34.8	2.9	0.0	**533.4**
Muskoka A (ON)	0.0	0.0	0.0	27.2	77.1	105.5	115.4	100.3	70.1	34.9	2.7	0.0	**533.2**
Sudbury A (ON)	0.0	0.0	0.0	19.4	77.4	106.8	107.6	98.5	67.9	29.3	0.0	0.0	**506.9**
Belleterre (QUE)	0.0	0.0	0.0	13.7	73.6	106.5	121.8	105.3	64.6	27.6	0.0	0.0	**513.1**
Remigny (QUE)	0.0	0.0	0.0	12.3	73.8	106.0	117.8	104.9	64.7	27.5	0.0	0.0	**507.0**

Table A4. Estimated Water Surplus (mm) at the selected Meteorological Stations (Data Period: 1971-2000; Soil Moisture Content of 100 mm)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
North Bay A (ON)	68	53	65	46	10	0	0	0	4	67	90	71	**474**
Powassan (ON)	59	44	59	36	0	0	0	0	0	56	83	60	**396**
Chalk River AECL (ON)	57	45	62	32	0	0	0	0	0	0	61	61	**318**
Combermere (ON)	62	50	62	46	0	0	0	0	0	0	68	69	**358**
Dunchurch (ON)	108	69	70	46	15	0	0	0	0	60	117	106	**591**
Dwight (ON)	109	71	84	54	17	0	0	0	17	78	122	106	**657**
Earlton A (ON)	54	40	59	40	0	0	0	0	0	0	57	54	**304**
Madawaska (ON)	61	44	50	35	0	0	0	0	0	10	71	59	**331**
Minden (ON)	94	63	74	47	15	0	0	0	0	23	99	96	**511**
Muskoka A (ON)	99	63	74	52	14	0	0	0	0	53	110	102	**566**
Sudbury A (ON)	69	51	66	45	0	0	0	0	0	18	77	67	**393**
Belleterre (QUE)	69	54	67	56	5	0	0	0	7	62	87	76	**483**
Remigny (QUE)	55	43	60	48	10	0	0	0	0	53	76	63	**409**

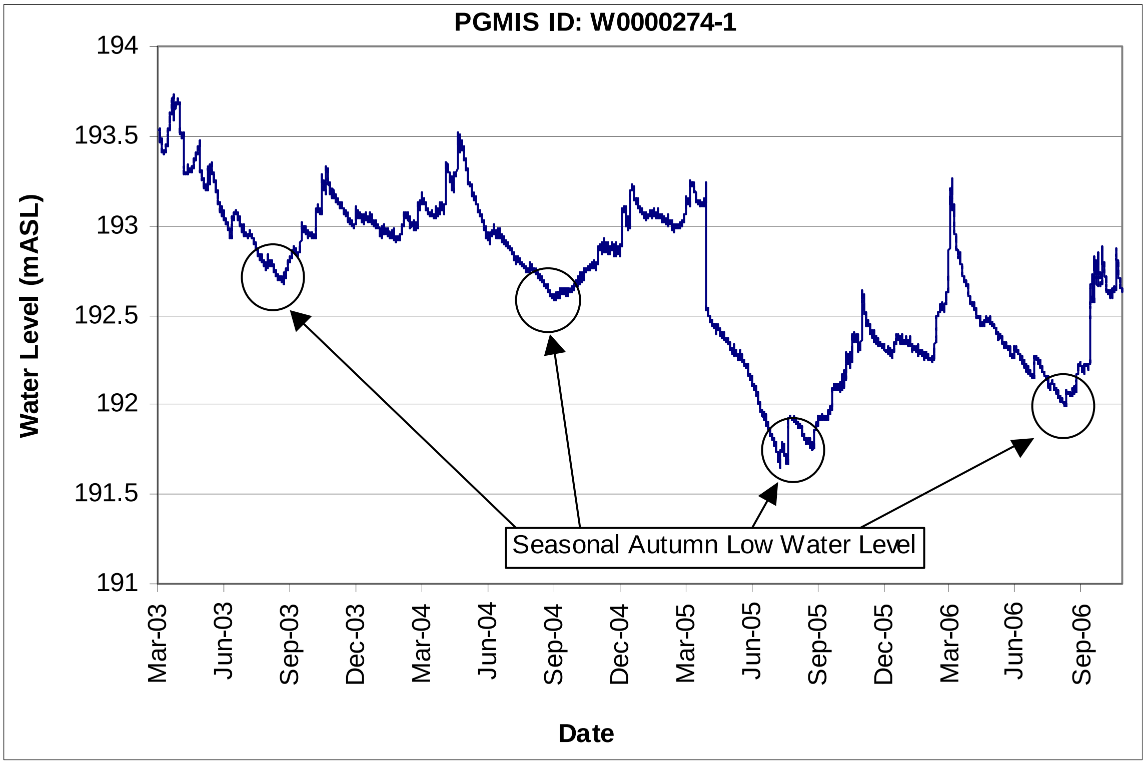

Figure A1. Water Level Fluctuations and Seasonal Autumn Low Water Level

Appendix B

Water Budget Maps and Soil Infiltration Factors

Appendix B

Water Budget Maps

MOE Suggested WB Maps	Mattawa WB Action Maps	Comments
WB Map 1- Climate Stations	**Map 1** Climate	Combined with WB Map 1 and WB Map 2
WB Map 2- Precipitation Distribution		
WB Map 3 – Representative Areas for Climate station (e.g. Theissen Polygons)	Not required	Ordinary Kriging Interpolation Technique Used
WB Map 4 – Meteorological Zones	Not required	Only 1 Meteorological zone exists
WB Map 5 - Evapotranspiration	**Map 2** Actual Evapotranspiration	Actual ET was determined from Thornthwaite and Mather method
WB Map 6 – Bedrock Geology	**Map 3** Bedrock Geology	
WB Map 7 – Sediment Thickness	**Map 4** Overbur. Thickness	
WB Map 8 – Geologic Unit Thickness	Not required	- Shallow Overburden - No discrete aquifer/aquitards,
WB Map 9 – Bedrock Topography (elevation)	**Map 5** Bedrock Topography	
WB Map 10 – Surficial Geology	**Map 6** Surficial Geology	
WB Map - 11 Hummocky Topography		Included in **Map 6**
WB Map 12 – Physiographic Regions	**Map 7** Physiography Map 7a Topography	
WB Map 13 – Ground Surface Topography		
WB Map 14 – Soils Map	Not required	No full coverage. Use of Surficial Geology map and GIS Approach
WB Map 15 – Land Cover Map	**Map 8** Land Cover	
WB Map 16 – Streamflow Gauging Stations	**Map 9** Streamflow Characteristics	Combined with WB Map 16, 18 and 21
WB Map 17 – Flow Distribution	**Map 10** Flow Distribution	
WB Map 18 – Dams, Channel diversions etc.		Included in **Map 9**
WB Map 19 – Fisheries	**Map 11** Fisheries	Very few portions of the watershed covered under this category
WB Map 20 – Surface Water Takings	**Map 12** Surface –and GW takings	Combined with WB Map 25 and WB Map 26
WB Map 21 – Surface Water Nodes		Included in **WB Map 9**
WB Map 22 – Aquifer Extents, GW Flow Directions	**Map 13** Water Table Surface	Combined with WB map 24
WB Map 23 – Recharge and Discharge Zone	**Map 14a** Recharge Distribution	
WB Map 24 – Depth to Water Table		Included in **Map 13**
WB Map 25 – GW Monitoring Network Locations		Included in **Map 12**
WB Map 26 – Groundwater Takings		Included in **Map 12**
WB Map 27 - Stress Assessment Sub-watersheds	**Map 15** Stress Assessment Sub-watersheds	

*Note: * "WB Map" # refers to the suggested mapping from the MOE Interim Water Budget Technical Direction Document (Version 3.0, December 21, 2005)*

Some of the suggested maps have not been used in this report. WB Map 3 for the Theissen polygons was not included because these were not used in the analysis. Rather an Ordinary Kriging interpolation technique was used to avoid the "steps" that cross the watershed when using the Theissen technique. This was particularly important as there were only 2 useable meteorological stations within the SWP area. WB Map 4 on meteorological zones was also not included because the whole watershed lies in one zone due to the similar physiography. WB Map 8 was intended to identify the unit thicknesses. However, given the shallow overburden there are no major aquifer/aquitards or other formations that can be discretely identified.

WB Map 14 was intended to be the pedological soils mapping. Such mapping exists only for a part of the SWP area, however much is based on interpretation of high level aerial photography. Since soil properties (from a groundwater recharge perspective) have been obtained from the surficial quaternary mapping, the soils map was deemed redundant. 2 maps which are not specified by MOE were prepared for the quantification of run-off (Map 14b) surplus (Map 14c) distribution.

Table B1. Soil Infiltration Factors

Map Unit	Geologic Description	Factor
2a	Bedrock-drift complex in Precambrian terrane: Primarily till cover	0.10
1	Precambrian Bedrock	0.10
2	Bedrock-drift complex in Precambrian terrane:	0.10
2b	Bedrock-drift complex in Precambrian terrane: Primarily stratified drift cove	0.10
3	Paleozoic bedrock:	0.20
4	Bedrock-drift complex in Paleozoic terrane:	0.25
4a	Bedrock-drift complex in Paleozoic terrane: Primarily till cover	0.20
4b	Bedrock-drift complex in Paleozoic terrane: Primarily stratified drift cover	0.30
5	Till:	-99.00
5a	Till: Silty sand to sand-textured till on Precambrian terrain	0.30
5b	Till: Stone-poor, sandy silt to silty sand-textured till on Paleozoic terrain	0.20
5c	Till: Stony, sandy silt to silty sand-textured till on Paleozoic terrain	0.20
5d	Till: Clay to silt-textured till (derived from glaciolacustrine deposits or s	0.10
5e	Till: Undifferentiated older tills, may include stratified deposits	0.40
6	Ice-contact stratified deposits: sand and gravel, minor silt, clay and	0.40
6a	Ice-contact stratified deposits: In moraines, eskers, kames and crevasse fill	0.40
6b	Ice-contact stratified deposits:In subaquatic fans	0.40
7	Glaciofluvial deposits: braided river deposits and delta topset facies	0.40
7a	Glaciofluvial deposits: Sandy deposits	0.40
7b	Glaciofluvial deposits:Gravelly deposits	0.40
8	Fine-textured glaciolacustrine deposits: silt and clay, minor sand and gravel	0.10
8a	Fine-textured glaciolacustrine deposits:Massive to well laminated	0.10
8b	Fine-textured glaciolacustrine deposits:Interbedded silt and clay and gritty,	0.10
9	Coarse-textured glaciolacustrine deposits: sand, gravel, minor silt and	0.30
9a	Coarse-textured glaciolacustrine deposits: Deltaic deposits	0.40
9b	Coarse-textured glaciolacustrine deposits:Littoral deposits	0.30
9c	Coarse-textured glaciolacustrine deposits:Foreshore and basinal deposits	0.25
10	Fine-textured glaciomarine deposits: silt and clay, minor sand and gravel	0.10
10a	Fine-textured glaciomarine deposits: Massive to well laminated	0.10
10b	Fine-textured glaciomarine deposits: Interbedded silt and clay and gritty, pe	0.10

Table B1. Soil Infiltration Factors

Map Unit	Geologic Description	Factor
11	Coarse-textured glaciomarine deposits: sand, gravel, minor silt and cla	-99.00
11a	Coarse-textured glaciomarine deposits:Deltaic deposits	0.40
11b	Coarse-textured glaciomarine deposits: Littoral deposits	0.30
11c	Coarse-textured glaciomarine deposits: Foreshore and basinal deposits	0.20
12	Older alluvial deposits: clay, silt, sand, gravel, may contain organic	0.20
13	Fine-textured lacustrine deposits: silt and clay, minor sand and gravel	0.10
14	Coarse-textured lacustrine deposits: sand, gravel, minor silt and clay	-99.00
14a	Coarse-textured lacustrine deposits: Deltaic deposits	0.40
14b	Coarse-textured lacustrine deposits: Littoral deposits	0.30
14c	Coarse-textured lacustrine deposits: Foreshore and basinal deposits	0.20
15	Fine-textured marine deposits: silt and clay, minor sand and gravel	0.10
16	Coarse-textured marine deposits: sand, gravel, minor silt and clay	-99.00
16a	Coarse-textured marine deposits:Deltaic deposits	0.40
16b	Coarse-textured marine deposits:Littoral deposits	0.30
16c	Coarse-textured marine deposits:Foreshore and basinal deposits	0.20
17	Eolian deposits: fine to very fine sand and silt (loess)	0.20
18	Colluvial deposits: boulders, scree, talus, undifferentiated landslide	0.40
19	Modern alluvial deposits: clay, silt, sand, gravel, may contain organic	0.40
20	Organic deposits: peat, muck, marl	0.40
21	Man-made deposits: fill, sewage lagoon, landfill, urban development	0.30

Appendix C

List of Acronyms

Appendix C

List of Acronyms

AES	Atmospheric Environment Service
AET	Actual Evapotranspiration
cm	centimetre
GAWSER	Guelph All-Weather Sequential-Events Runoff Model
GIS	Geographic Information System
GW	Groundwater
IDW	Inverse Distance Weighted interpolation technique
km	kilometre
km^2	square kilometre
m	metre
mASL	metre Above Sea Level
mm	millimetre
mm/yr	millimetre per year
m^3/s	cubic metres per second
NBMCA	North Bay – Mattawa Conservation Authority
Mm^3/yr	Million cubic metres per year
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
MOEE	Ministry of the Environment and Energy
OGS	Ontario Geologic Survey
OMNR	Ontario Ministry of Natural Resources
OPG	Ontario Power Generation
PET	Potential Evapotranspiration
PTTW	Permit To Take Water
SPR	Source Protection Region
SWP	Source Water Protection

Appendix D

Glossary

Appendix D

Glossary

Anthropogenic	Influenced by human activity.
Aquifer	The area in which groundwater is located is called an aquifer. Aquifers store water because the rocks and soils that are made of are porous, that is, characterized by large open spaces; and they transmit or move the water if they are permeable, that is, if these open spaces are large and interconnected.
Baseflow	The sustained flow (amount of water) in a stream that comes from groundwater discharge or seepage. Groundwater flows underground until the water table intersects the land surface and the flowing water becomes surface water in the form of springs, streams/rivers, lakes and wetlands. Baseflow is the continual contribution of groundwater to watercourses and is important for maintaining flow in streams and rivers between rainstorms.
Bedrock	Solid or fractured rock usually underlying unconsolidated geologic materials; bedrock may be exposed at the land surface.
Bog	Bogs are peat-covered areas or peat-filled depressions with a high water table and a surface carpet of mosses, chiefly *Sphagnum*. The water table is at or near the surface in the spring, and slightly below during the remainder of the year. The mosses often form raised hummocks, separated by low, wet interstices. The bog surface is often raised, or, if flat or level with the surrounding wetlands, it is virtually isolated from mineral soil waters. Hence, the surface bog waters and peat are strongly acid and upper peat layers are extremely deficient in mineral nutrients.
Conceptual Water Budget	A written description of the overall flow system dynamics for each watershed in the Source Protection Area taking into consideration surface water and groundwater features, land cover (e.g., proportion of urban vs. rural uses), human-made structures (e.g., dams, channel diversions, water crossings), and water takings.
Confined Aquifer *(artesian aquifer)*	An aquifer holding water under pressure by a layer above it that does not allow water to pass through. Due to pressure, the water level of a well in a confined aquifer will rise above the top of the aquifer.
Confining Layer *(aquitard)*	Geologic material with little or no permeability or hydraulic conductivity. Water does not rapidly pass through this layer or the rate of movement is extremely slow.
Data Gaps	The lack of raw information for a specific geological area and/or specific type of information.

Discharge Area	An area where groundwater emerges at the surface; an area where upward pressure or hydraulic head moves groundwater towards the surface to escape as a spring, seep, or base flow of a stream.
Downgradient	A term used in hydrogeology to describe a point at a lower hydraulic head.
Drainage Basin	The land area from which surface runoff drains into a stream or lake.
Drinking Water Issue	A substantiated condition relating to the quality of quantity of water that interferes or is anticipated to soon interfere with the use of a drinking water source by a municipal residential system or designated system.
Eskers	A long winding ridge of post glacial gravel and other sediment; deposited by meltwater from glaciers or ice sheets
Evaporation	The process by which water or other liquids change from liquids to a gas vapour; evaporation can return infiltrated water to the atmosphere from upper soil layers before it reaches groundwater or surface water, and occur from leaf surfaces (interception), water bodies (lakes, streams, wetlands, oceans), small puddled depressions in the landscape.
Evapotranspiration	The sum of evaporation plus transpiration.
Event	Occurrence of an incident (isolated or frequent) with the potential to promote the introduction of a threat into the environment. An event can be intentional as in the case of licensed discharge or accidental as in the case of a spill.
Exposure	The extent to which a contaminant or pathogen reaches a water resource. Exposure, like a drinking water threat, can be quantified based on the intensity, frequency, duration and scale. The degree of exposure will differ from that of a drinking water threat dependent on the nature of the pathway or barrier between the source (threat) and the target (receptor) and is largely dependent on the vulnerability of the resource.
Fen	Fens are peatlands characterized by surface layers of poorly to moderately decomposed peat, often with well-decomposed peat near the base. The waters and peat in fens are less acid than in bogs, and often are relatively nutrient rich and minerotrophic since they receive water through groundwater discharge from adjacent uplands.
Field Capacity Soil-Water Content	Is the condition whereby the soil voids contain the maximum residual water that can be held by the capillary forces after gravity drainage. It is normally defined at a suction head of 1/3 bar.
Flow System	Groundwater flow from the recharge area to a discharge area; three levels of regional, intermediate, and local. In a regional flow system, the recharge area is at the basin or watershed divide and the discharge area is at a river in the valley bottom. In a local flow system, the recharge area is at a topographical high spot and the discharge area is at a nearby topographical low spot.

Fluvial	Pertaining to rivers and streams or to features produced by the actions of rivers and streams.
Geology	The study of science dealing with the origin, history, materials and structure of the earth, together with the forces and process operating to produce change within and on the earth.
Glaciofluvial	Pertaining to rivers and streams flowing from, on or under melting glacial ice, or to sediments deposited by such rivers and streams.
Glaciolacustrine	A term used to describe fine-grained glacial materials deposited in glacial lake environments.
Great Lakes	The five (large) lakes located in Canada and United States: Lake Ontario, Lake Superior, Lake Huron, Lake Eerie, and Lake Michigan.
Great Lakes Connecting Channels	The large rivers that connect the Great Lakes (e.g., St. Clair River, St. Lawrence River).
Groundwater	The portion of rain and snow that soaks through the earth's surface and moves down through the soil – through the unsaturated zone – to the water table. The water table is the top of the saturated zone: the large underground area in which all the interconnected spaces in the rocks and soil are filled with water.
Groundwater Basin	The underground area from which groundwater drains. The basins could be separated by geologic or hydrologic boundaries.
Hydraulic Conductivity	The term used to describe the rate at which water moves through a medium; a controlling factor on the rate at which water can move through a permeable medium.
Hydraulic Gradient	Rate of change of pressure head per unit of distance of flow at a given point and in a given direction.
Hydraulic Head (Head)	The energy that causes groundwater to flow; the total mechanical energy per unit weight; the sum of the elevation head and the pressure head.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hypolimnion	The hypolimnion is the bottom and most dense layer of water in a thermally-stratified lake. Typically, it is non-circulatory and remains cold throughout the year. Being at depth, it is isolated from surface wind-mixing and does not receive enough incoming irradiance (light) for photosynthesis to occur.
Imminent Threat to Health	A contaminant of concern that can affect human health in a short period of time.
Impermeable	Not allowing water to pass through.

Infiltration	The process of water moving from the ground surface vertically downward into the soil.
Impact	Often considered the consequence or effect, the impact should be measurable and based on an agreed set of parameters. In the case of SWP, the parameters may be and acceptable list of standards which identify a maximum raw water levels of contaminants and pathogens of concern. In the case of water quantity, the levels may relate to a minimum annual flow, piezometric head or lake level.
Knowledge Gaps	Lack of referenced materials or expertise to assess certain characteristics of the specific watershed that can be adequately described without tabular or spatial data.
Land Use	A particular use of space at or near the earth's surface with associated activities substances and events related to the particular land use designation.
Leachate	Materials readily soluble in water and removed and transported in solution to groundwater.
Marsh	Marshes are wet areas periodically inundated with standing or slowly moving water, and/or permanently inundated areas characterized by robust emergents, and to a lesser extent, anchored floating plants and submergents. Surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats.
Monitoring Well	A non-pumping well, generally of small diameter, that is used to measure the elevation of a water table or water quality. A piezometer is one type of monitoring well.
Moraine	An accumulation of earth and stones carried by a glacier and usually deposited into a high point like a ridge.
Municipal Well *(public or community well)*	A pumping well that serves five or more service connections.
Percolation	The actual movement of subsurface water either horizontally or vertically; lateral movement of water in the soil subsurface toward nearby surface drainage feature (e.g., stream) or vertical movement through the soil to groundwater zone.
Permeable	A porous surface in which water passes through quickly.
Pesticides	Chemicals including insecticides, fungicides, and herbicides that are used to kill living organisms.
Physiography	The study of the landforms – form and process.
Porosity	The ratio of the volume of void or air spaces in a rock or sediment to the total volume of the rock or sediment.

Potable	Water that is safe for drinking.
Precipitation	Deposition of rain, snow, hail or sleet.
Risk	The likelihood of a drinking water threat (a) rendering an existing or planned drinking water source impaired, unusable or unsustainable, or (b) compromising the effectiveness of a drinking water treatment process, resulting in the potential for adverse human health effects.
Runoff-Surface *(overland flow)*	Precipitation that cannot be absorbed by the soil because the soil is already saturated with water (soil capacity); precipitation that exceeds infiltration; the portion of rain, snow melt, irrigation water, or other water that moves across the land surface and enters a wetland, stream, or other body of water (overland flow). Overland flow usually occurs in urban settings (pavement, roofs, etc.) or where the soils are very fine textured or heavily compacted.
Runoff-Total	Includes the sum of surface runoff (overland flow), baseflow, and interflow (subsurface storm flow) that moves across or through the land and enters a stream or other body of water.
Soil-Water	Water held in a normally unsaturated zone above a perennial water table; water below this level is considered to be groundwater.
Source Water	Untreated water from lakes, rivers, streams or underground aquifers.
Spring	A natural discharge of groundwater at the land’s surface.
Static Water Level	The water level in a well that is not being pumped or influenced by pumping.
Stratigraphy	A branch of geology which studies of the formation, composition, sequence, and correlation of the stratified rocks as parts of the earth’s crust.
Subwatershed	An area that is drained by an individual tributary into the main watercourse of a watershed.
Surface Water	Water that is present on the earth’s surface and may occur as rivers, lakes, wetlands, ponds, etc.
Swamp	Wooded wetlands with 25% cover or more of trees or tall shrubs. Standing to gently flowing waters occur seasonally or persist for long periods on the surface. Many swamps are characteristically flooded in spring, with dry relict pools apparent later in the season.
Targets	In the context of technical guidance documents, these are detailed goals that are often expressed as numeric goals (e.g., to reduce contaminant X in this aquifer by 10% by 2009).
Thornthwaite Method	A method to estimate soil water budget, based on air temperature, latitude and date.

Threat Assessment – Tier 1	Preliminary examination of a drinking water threat based on readily accessible information.
Tier 1, 2 and 3 Water Budgets	Numerical analysis at the watershed (Tier1), subwatershed (Tier 2) or local (Tier 3) level considering existing and anticipated amounts or water taken from the watershed, as well as quantitative flow between components such as recharge/discharge areas and rates.
Till	Glacier deposits composed primarily of unsorted sand, silt, clay, and boulders laid down directly by the melting ice.
Time of Travel (TOT)	An estimate of the time required for a particle of water to move in the saturated zone from a specific point in an aquifer into the well intake.
Topography	The contour of the land surface; the configuration of the land surface including its relief and the position of its natural and man-made features.
Transpiration	The process by which plants take up water through their roots and then give off water vapour through their leaves (open stomata).
Tributaries	Any stream that contributes water to another water body.
Unconfined Aquifer *(water table aquifer)*	An aquifer with continuous layers of permeable soil and rock that extends from the land surface to the base of the aquifer. The water table forms the upper boundary of the aquifer and is directly affected by atmospheric pressure.
Varve CLay	Varve, also knows as varve clay, is a layer or series of layers of sediment deposited in a body of still water Usually found in glacial lake deposits, varves consist of a coarse-grained, light to dark-colored deposits formed when fine sediment settles out from the water under the ice cover.
Water Cycle *(hydrologic cycle)*	The continuous circulation of water from the atmosphere to the earth and back to the atmosphere including condensation, precipitation, runoff, groundwater, evaporation, and transpiration.
Watershed	Land lying adjacent to water courses and surface water bodies which creates the catchment or drainage area of such water courses and bodies; the watershed boundary is determined by connecting the topographic high point surrounding such catchment or drainage areas.
Water Table	The water surface in an unconfined aquifer; the level below which the pore spaces in the soil or rock are saturated with water; the upper surface of the zone of saturation.
Well	A vertical bore hole in which a pipe-like structure is inserted into the ground in order to discharge (pump) water from an aquifer.

Wetlands	Land such as a swamp, marsh, bog or fen (not including land that is being used for agricultural purposes and no longer exhibits wetland characteristics) that, (a) is seasonally or permanently covered by shallow water or has the water table close to or at the surface, (b) has hydric soils and vegetation dominated by hydrophytic or water-tolerant plants, and (c) has been further identified, by the Ministry of Natural Resources or by any other person, according to evaluation procedures established by the Ministry of Natural Resources, as amended from time to time.

Snow-Related Terms

Snow	Water precipitated in the form of minute ice crystals, and usually falling in irregular agglomerated masses or flakes.
Snowfall	Depth of snow layer produced on the measurement surface by atmospheric precipitation during a given period, measured as accumulated depth above starting plane, at the end of the period.
Snowmelt	Conversion of water from solid (ice) to liquid in the snowpack.
Snowpack	The mass of ice crystals and of liquid water contained within the ice-crystal matrix that is accumulated above the ground surface at a specified place and time.
Snowpack Depth	The vertical distance between the upper surface of a snowpack and the ground surface beneath.
Snow Cover	A general term for the presence of snow on the surface of a watershed. Use of the term should include acknowledgement of the areal and temporal variation of snowpack amounts on the watershed surface.
Snow Layer	A portion of a snowpack with distinct features in terms of grain size, density, and liquid-water content, which is defined by an upper and a lower surface.
Snow Sublimation	Solid to vapour conversion of ice in the snowpack.
Snow Water Equivalent *(also equivalent water content, or total water content)*	Depth of water layer produced, after melting, of snow at a given place.