DRINKING WATER SOURCE PROTECTION

ACT FOR CLEAN WATER

Thames-Sydenham and Region Source Protection Committee

Upper Thames River Source Protection Area

Amended Proposed

Assessment Report

Revised - August 12, 2011

APPROVED

3.0 Water Budget and Water Quantity Stress Assessment

Made possible through the support of the Government of Ontario

Thames – Sydenham and Region
Upper Thames River Conservation Authority
1424 Clarke Road, London, ON, N5V 5B9

July 4, 2011

Dear reader

Re: **Upper Thames River Amended Proposed Assessment Report posted for comments**

The Thames-Sydenham and Region Source Protection Committee has posted the enclosed report for review and comment by stakeholders. This report includes updates and amendments to the Proposed Assessment Report for the Upper Thames River Source Protection Authority. Comments received through the first posting (draft proposed report) were considered by the Source Protection Committee and the report has been revised. Comments received in response to the second posting were submitted with the Proposed Assessment Report to the Ministry of the Environment (MOE).

Based on directions from the Director of Source Protection Programs Branch, MOE, updates and amendments were made to the Proposed Assessment Report to include further technical work conducted. These include the Tier 2 water budget drought scenario analysis, the delineation, vulnerability assessment and threats assessment of WHPA-E, and threats assessment of sewer line threats. The updates and amendments made are summarized in Appendix 4. This version of the Assessment Report once approved will be used by the Source Protection Committee for the development of the Source Protection Plan which is to be submitted to the MOE in August 2012.

The Amended Proposed Assessment Report for the Upper Thames River Source Protection Area represents a significant milestone in the Source Protection Committee's progress in the completion of the first Source Protection Plans for the Thames-Sydenham and Region. The Source Protection Committee realizes that this report is a "living document" which may be updated as more information becomes available in the future.

We hope that you have had an opportunity to attend previous open houses that were held throughout the region, and plan to attend the open houses to be held in July 2011. More information on this assessment report and the past and current consultation is available on the web site given at the bottom of this letter.

Yours truly,
THAMES-SYDENHAM and REGION

Robert Bedggood, Chair
Source Protection Committee

Table of Contents

Appendices

List of Figures

List of Maps

List of Tables

3.0 Water Budget and Water Quantity Stress Assessment

The Clean Water Act is intended to reduce the threats to the quality and quantity of drinking water sources. In order to do this, threats within *vulnerable areas* are identified and assessed to determine the relative *risk* to the drinking water source. The Clean Water Act and its regulations identify 21 activities which can be drinking water *threats*. These activities include two which are related to the quantity of drinking water. One is an *activity* that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body. The other water quantity threat is an *activity* that reduces the recharge of an aquifer. To determine the risks to drinking water quantity from either of these threats, it is necessary to understand the level of *stress* on a drinking water system's source. The Water Budget is the tool used to understand the level of *stress* on a system or within a *watershed*.

Where there is little potential for *stress*, there are no *threats*. On the other hand, where there is a significant potential for *stress*, activities contributing to the *stress* will be assessed to determine if they constitute significant threats. This is done through the Tier 3 Water Budget in only those areas where the potential for stress warrants this detailed local analysis. The Clean Water Act requires that the *Source Protection Committee* develop a *Source Protection Plan* that reduces the *risk* associated with *significant threats* so that they cease being significant and prevents new *significant threats* from being undertaken in these areas.

The Water Budget looks at the balance of water within an area known as a *watershed*. A Water Budget can be assessed at different scales, but generally this is undertaken on a *watershed* or a part of the *watershed* referred to as a *subwatershed*. It considers inputs or supply to the *watershed* or *subwatershed* which include: precipitation (rain and snow), flow into the watershed from up river, flow into the watershed through groundwater and flow imported into the watershed such as that which is piped water from the Great Lakes. The Water Budget balances these inputs with removals from the *watershed*, or *demand*, which include: discharges into the next *watershed* through stream flow or groundwater, use of water which is consumptive in nature

(and therefore does not return the water to the same source from which it was removed), evaporation and transpiration (use of the water by plants). The water budget considers a balance between supply and *demand* that includes a *reserve* quantity that is removed from the supply in the stress calculation. The components of the water budget are described in detail in the Conceptual Water Budget (attached as Appendix 6), the Tier 1 Water Budget and summarized in the following sections.

The Water Budget is developed in stages referred to as tiers. As they progress, these tiers involve more detailed analysis, refined data and generally reduced study area. In this manner, only those areas with the potential to be stressed require detailed modelling and analysis; those which appear not to be stressed receive a less detailed screening. Each of these tiers is described in the following sections. *The Upper Thames River Source Protection Area* is included with the other Source Protection Areas in the Thames-Sydenham and Region in the Conceptual Water Budget and the Tier 1 Water Budget. Only areas where there is a moderate or significant *potential for stress* on drinking water systems included in the Terms of Reference (only municipal systems in the *UTRSPA*) proceed to a Tier 2 Water Budget. Only those areas which are confirmed to have a significant or moderate stress level in the tier 2 assessment proceed to a Tier 3 Water Budget. It is only through a Tier 3 Water Budget, or Local Area Assessment, that water quantity threats are assessed. As the potential for *stress* on some drinking water sources was determined to be moderate or significant through the Tier 1 and Tier 2 Water Budgets, Tier 3 Local Area Risk Assessments are required for the Upper Thames River Source Protection Area. Work is underway for the completion of the Tier 3 study and the results will be included in future updates to the Assessment Report.

3.1 What is a Water Budget?

A water budget quantifies and compares the components of the hydrologic cycle. Much like a bank account, if more water is leaving than is entering, the water in the *watershed* will be depleted over time. If in balance, the water use is sustainable. Each component of the water budget must be quantified so that the *demand* can be compared to the supply. If the *demand* is greater than the supply, the reserves, like the savings in a bank account, will be depleted. Over time this would result in reduced water levels in water bodies and aquifers. Normal and cyclical fluctuations in water levels make it necessary to look at the components of the water budget

over long periods of time rather than looking at short-term trends in levels. This is especially true in groundwater systems where changes in water levels are more difficult to monitor and analyze.

3.2 Components of the Water Budget

3.2.1 Precipitation

Precipitation, or rain and snow, is the primary component of the supply component of the water budget. Long-term precipitation was analyzed from various meteorological stations around the region. Map 3-2 illustrates the precipitation stations used in the water budget and the spatial variation of the average annual precipitation over the region. Annual average precipitation decreases moving North to South along the UTRSPA from about 1060 millimetres per annum (mm/a) in the north (Stratford) to about 990 mm/a in the south (London) and 950 mm/a in Woodstock. On average, the Upper Thames River Source Protection Area receives about 1000 mm per year of precipitation.

3.2.2 Evapotranspiration

Evapotranspiration (or ET) is the precipitation which either evaporates into the atmosphere or is used by the plants. Water used by plants is also given back to the atmosphere through a process known as transpiration. Together the evaporation and transpiration are known as Evapotranspiration. There is little variation across the region other than as a result of the variation in precipitation. Map 3-3 shows the evapotranspiration across the region. Water which evaporates or is used by the plants is not available as supply and is therefore subtracted from the precipitation in the supply calculations. ET accounts for more than half of the precipitation in the region.

Irrigation, although also used by plants and lost back to the atmosphere through evaporation and transpiration, is considered in the *demand* part of the water budget. Irrigation water is removed from a groundwater or surface water source, and is consumptive to that source. ET, on the other hand, is loss from the precipitation component of the water budget. Another important distinction is that irrigation occurs only in very localized areas where it is required by a crop. ET is directly related to precipitation and temperature and is fairly uniformly distributed across the watershed.

3.2.3 Surface Runoff

Precipitation which falls in the watershed and does not evaporate or get absorbed into the plants either infiltrates into the ground or runs off into streams and rivers. The runoff from the watershed is not available for the supply as it leaves the watershed quickly. Although some of the water which infiltrates into the ground also leaves the watershed relatively quickly, most of the water which seeps deeper into the ground is said to recharge the aquifers, which is discussed in the following section.

3.2.4 Recharge

Recharge is the water from precipitation which soaks into the ground and recharges the aquifers in the ground. This is the water which maintains stream flow during periods between runoff events and is referred to as base flow. The water budget assumes that over time the recharge is equivalent to the base flow discharge from the watershed. This relationship is considered more closely in Tier 2 and 3 of the water budget work where calibrated surface and groundwater models are used to describe the components of the water budget including recharge.

In the Tier 2 Water Budget for the Upper Thames River Source Protection Area, recharge was estimated based on a combination of surficial geology and land use. The landscape is examined using Geographic Information System (GIS) software, and all possible combinations of land use and surficial geology are considered and combined to form one of nine different hydrologic response units (HRU). Each of these response units is then associated with recharge value for a particular climate zone, which has been calibrated for these HRUs throughout southwestern Ontario using a surface water model (GAWSER), and further refined for the *UTRSPA*.

3.2.5 Water Use (Demand)

Water use in the water balance and stress calculations is referred to as *Demand*. While *demand* would be the simplest of the terms to monitor, records of water use are not required, except where permits for the use are required. Water use of more than 50,000 L/day, other than domestic and livestock watering, requires a Permit to Take Water, however until recently, records of water used were not required to be recorded and submitted. Even where the records are required as part of the permit process, they have only been required for the past few years. This recent record keeping is undertaken by the permit holder with little or no quality control on

the data entered. This information is submitted by the permit holder and has only become available to the water budget team near the completion of much of this water budget work. In future revisions to the water budget the actual use records will provide a better estimate of the *demand*. For the Tier 1 and Tier 2 Water Budget work, estimations of actual use were based on adjusted maximum permitted values, or other sources of estimation in some cases. Large water users were polled to provide a better estimate of water *demand*.

Estimates of water use not requiring a permit to take water (often referred to as *non-permitted* water use) were also included in the calculations of *demand*. While municipal systems require a permit to take water and records of this *demand* is well established through municipal pumping records, an estimate of the water used from private water systems is also required. Generally, this *demand* is minor; however, it is important that it not be neglected in the water budget and stress assessment. Non-municipal system domestic *demand* is estimated based on per capita consumption estimations multiplied by population reported in census data.

Livestock watering also does not require a permit. This *demand* was estimated in a similar manner using livestock census data and typical water use by livestock type (Kreutzwiser & de Loë, 1999).

Both of these non-permitted uses are assumed to be distributed evenly across groundwater and surface water sources.

The Permit to Take Water information was analyzed to determine the *demand* in each *subwatershed* and combined with the *non-permitted demand* discussed above. Water use was considered separately for surface water and groundwater as required by the *Technical Rules: Assessment Reports*. Consumptive factors were applied to the surface water *demand* based on the use of the water taken. These factors were recommended by the province in the water budget guidance. The consumptive factors applied to water use are shown in the Tier 1 and Tier 2 Water Budgets. Consumptive factors were generally not applied to groundwater use as water removed from aquifers is generally not returned to the same aquifers. Groundwater is usually returned to surface water bodies after it is used, resulting in the use being completely consumptive. Water taken for aggregate washing and wildlife conservation are exceptions

where consumptive factors were applied. In these cases, permits allow for large quantities to initially fill ponds, but then only a small amount is taken to compensate for evaporation and/or water removed in product in the case of aggregate extraction.

Irrigation *demand* is estimated based on permitted values. As discussed in the section on evapotranspiration, most of the water applied to crops is used by the crops or evaporates back into the atmosphere. This is even truer for irrigation where the amount of water applied is intended to saturate the root zone and not result in any significant runoff or recharge. As such, the consumptive factors for irrigation reflect that little, if any, water is returned to the source from which it was taken.

Tables 3-1 (groundwater) and 3-2 (surface water) summarize the water *demand* in the area by type and source. Note that Table 3-1 data (except for the Thames River between the Forks and Dutton subwatershed), is derived from the Tier 2 Water Budget, and Tables 3-2 is derived from Tier 1. Surface water use was not specifically re-evaluated in the Tier 2 catchments and so is reported based upon Tier 1. It is important to realize that water use by industry and institutions supplied by municipal systems does not require a separate permit and is therefore included in the permitted values for the municipal system. Demands are only considered if they are taken from within the subwatershed under examination. Water taken from the Great Lakes for municipal supply is not included in Table 3-1 as a demand as it is withdrawn from outside the subwatershed being analyzed. Lake water discharged to the surface water through sewage treatment effluent is however considered as part of the supply for surface water.

A complete listing of all surface water permits for each Tier 1 subwatershed is included in the Appendix A of the Tier 1 water budget. A complete listing of all groundwater permits for the Tier 2 subwatersheds is included in the Appendix D of the Tier 2 water budget. The Tier 1 and Tier 2 Water Budget Reports are available at the Thames-Sydenham and Region website: http://www.sourcewaterprotection.on.ca/resources_publications_links.html

Table 3-1 Groundwater use in the UTRSPA (m^3/day)

Ground-water Use	Agricultural	Commercial	Construction	Dewatering	Industrial	Institutional	Miscellaneous	Recreational	Remediation	Water Supply	Non-Permitted	**Total**
Black Ck/ Avon R	0	0	0	0	0	0	0	0	0	147	1249	**1396**
Cedar Ck	0	0	0	0	0	0	953	0	0	22243	315	**23511**
Flat Ck	0	0	0	0	0	0	0	0	0	0	352	**352**
Middle Thames R	114.8	3241.1	0	2882	5130.4	0	0	0	0	518.1	1576	**13462**
North Thames R/ Medway R	117	563.2	0	0	5328.8	0	4255	0	0	257.9	1,838	**12360**
North Thames R/Whirl Ck	150.7	0	0	78.5	0	0	0	0	0	2335	1,592	**4156**
Reynolds Ck	28.7	840.6	0	0	0	0	0	0	0	240.8	741	**1851**
Thames R Above Ingersoll	0	224.3	0	60559.1	3084	0	0	0	194.5	6846.8	898	**71807**
Thames R Above Pittock Reservior	395.4	1277.7	0	0	0	0	0	0	0	2307	1,606	**5586**
Trout Ck/North Thames R	30.2	1405.9	0	8182	12977.8	0	0	0	0	3231.9	1,175	**27003**
Upper Avon R	0	0	16.4	0	94.7	500	0	0	0	12149.4	774	**13535**
Waubuno Ck/Thames R Tribs	292.9	1084.2	0	0	4319.3	0	872.8	235.3	0	2000.4	1,678	**10483**
Thames R. btwn Forks and Dutton*	3439	2423	0	0	720	0	0	0	0	1755	2002	**10339**
Total	**4569**	**11060**	**16**	**71702**	**31655**	**500**	**6081**	**235**	**195**	**54032**	**15796**	**195841**

* Subwatershed Thames R. between the Forks and Dutton crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed. This subwatershed was not evaluated in Tier 2, and numbers are taken from the Tier 1 water budget. All other data from Tier 2 water budget.

Table 3-2 Surface Water use in the UTRSPA (m^3/day)†

Surface Water Use	SW Code	Agricultural	Commercial	Construction	Industrial	Miscellaneous	Recreational	Water Supply	Non-Permitted	**Total**
North Thames River/Whirl Cr.	01T	0	215	0	0	0	0	0	907	**1122**
Flat Cr./North Thames Tributaries	02T	0	0	0	0	0	0	0	240	**240**
Black Cr./Avon River	03T	10	199	0	0	0	0	0	930	**1139**
Trout Cr.	04T	0	31	0	0	0	16	0	584	**631**
N. Thames/Medway R.	05T	0	4050	0	4248	0	0	0	952	**9250**
Thames R. above Pittock Reservoir	06T	256	0	0	818	331	0	0	860	**2265**
Cedar Cr.	07T	0	532	0	0	0	0	0	195	**727**
Reynolds Cr./Thames R. above Ingersoll	08T	158	86	0	3125	267	0	0	833	**4469**
Middle Thames R.	09T	200	88	0	115	0	0	0	959	**1362**
Waubuno Cr./Thames R. Tributaries	10T	1325	540	0	0	13998	41	0	371	**16275**
Thames R. between the Forks and Dutton*	11T*	3633	2708	0	0	183	44	0	430	**6998**
Total		**5582**	**8449**	**0**	**8306**	**14779**	**101**	**0**	**7261**	**44478**

* Subwatershed 11T crosses over the Upper and Lower Thames boundary, and as such numbers reported are for both source protection authorities in this subwatershed
† Data from Tier 1 Water Budget.

3.2.6 Water Budget Summary

Each *subwatershed* in the region is examined in terms of the water budget components for both surface and ground water systems on an annual average basis. Components include:

Q_P, precipitation,
$Q_{SW\text{-}in}$, surface water flows in,
$Q_{GW\text{-}in}$, groundwater flows in, (assumed zero in Tier 1)
Q_{ET}, Evapotranspiration,
$Q_{SW\text{-}out}$, surface water flows out,
$Q_{GW\text{-}out}$, groundwater flows out, (assumed zero in Tier 1)
$Q_{GW\text{-}C}$, consumptive groundwater use,
$Q_{SW\text{-}C}$, consumptive surface water use, and
ΔS, change in storage (assumed zero in Tier 1)

The water budget equation can be summarized as:

$$Q_P + Q_{SW-in} + Q_{GW-in} = Q_{ET} + Q_{SW-out} + Q_{GW-out} + Q_{GW-C} + Q_{SW-C} + \Delta S$$

Table 3-3 summarizes the annual water budget in units of annual average m^3/day, from the Tier 2 water budget analysis. In Tier 2 the $Q_{SW\text{-}C}$ term is not included, as it was not evaluated for the Tier 2 subwatersheds. However, this is not a significant factor as the amount of annual average surface water demand, in terms of the average annual supply, is negligible. For example, in the Whirl Creek/North Mitchell subwatershed there is an average annual surface water demand of 1123 m^3/day (from previous Tier 1 analysis), compared to a supply of 820,561 m^3/day, or 0.14%; a similar relationship holds true for all subwatersheds. The surface water demand is significant on a monthly basis, but not when considered annually. Note that in the last row of Table 3-3, the Thames R. between the Forks and Dutton subwatershed was not evaluated in Tier 2, and so results from Tier 1 are presented. No groundwater modeling was conducted for Tier 1, and so the $Q_{GW\text{-}out}$ and $Q_{GW\text{-}in}$ terms are absent for this subwatershed.

Table 3-3 Tier 2 water budget summary (m^3/day)

Sub-watershed	Q_{ET}	Q_P	$Q_{sw\text{-}out}$	$Q_{sw\text{-}in}$	$Q_{gw\text{-}out}$	$Q_{gw\text{-}in}$	$Q_{gw\text{-}c}$
Black Creek/Lower Avon River	321458	587618	836929	571377	29030	13133	173
Upper Avon River	202505	365341	162080	0	26957	2246	12787
Trout Creek/North Thames River above St Marys	412700	740400	1265692	939029	96077	40435	18317
Medway Creek/North Thames river above London	875592	1542140	1929678	1265692	184723	82339	10454
Cedar Cr.	138789	231627	92317	0	32054	41299	23155
Reynolds Cr	247516	417016	168107	0	49162	19008	1123
Thames R. above Ingersoll	296796	517286	497000	336989	46181	64541	70762
Middle Thames R.	483021	798152	312437	0	96768	45274	9158
Thames River above Pittock	354842	600867	244672	0	87782	25056	3974
Waubuno Creek/Dorchester	439767	820562	1416685	1036733	129514	61862	8813
Whirl Creek/North Mitchell	473232	835064	360969	0	30067	538358	2419
Flat Creek/Glengowan	193512	344411	511397	360969	15120	19094	0
Thames R. between the Forks and Dutton*	1167292	1998777	4224578	3402509	-	-	10337

* The subwatershed Thames R. between the Forks and Dutton crosses over the Upper and Lower Thames boundary and, as such, numbers reported are for both source protection authorities in this subwatershed. Numbers from this subwatershed derived from Tier 1 analysis

3.3 Phases of Water Budget Work

3.3.1 Conceptual Water Budget

The Conceptual Water Budget, or conceptual understanding, is the first phase of the water budget development. In this stage, background information is collected on the components of the water budget. The information is analyzed to determine the various components of the water budget based on historical and readily available data on a coarse scale. The conceptual Water Budget was completed for the entire region. The region was divided into 6

subwatersheds for the purposes of this analysis. The Conceptual Water Budget is included as Appendix 6 of the Assessment Report.

3.3.2 Tier 1 Water Budget

The Tier 1 Water Budget utilizes the information collected and analyzed in the Conceptual Water Budget. In Tier 1, the potential for stress is assessed in *subwatersheds* within the region. As with the Conceptual Water Budget, the Tier 1 Water Budget was documented in one report for the entire Thames-Sydenham and Region. For the purposes of the Tier 1 Water Budget, the region was subdivided into 32 *subwatersheds*, as shown in Map 3-1. Of these 32 *subwatersheds*, ten are fully within the *UTRSPA* while one subwatershed is partially within the *UTRSPA* and partially within the *LTVSPA*. A water budget and stress assessment were completed for each of these 32 *subwatersheds*, and were used to determine if any *subwatersheds* required a Tier 2 analysis. The Stress assessment is discussed further in Section 3.4.

The Thames River is comprised of a south branch and north branch which meet at the forks of the Thames in London. Upstream of London, the North Thames River flows southerly from Mitchell and St. Marys to the forks in London.The south branch flows from Tavistock through Woodstock and westerly through Ingersoll to the forks in London. The south branch is commonly referred to as the South Thames River and is labeled as such in the maps of this report (such as Map 3-1). However, federal and provincial references to the south branch of the Thames River identify this part of the river as the Thames River. As a result, in some places in this section of the report and the Water Budget reports, the south branch may be referred to as the Thames River (such as Thames River above Pittock, or Thames River above Ingersoll). This refers to the part of the Thames River which is labeled in maps and referred to elsewhere in this report as the South Thames River.

Tier 1 considers a future demand scenario, where municipal takings are increased according to the municipalities' Official Plans, and the stress assessment was recalculated with the increased demand. This is discussed in greater detail later in this document.

3.3.3 Tier 2 Water Budget

During the process of conducting the Tier 1 water budget, five *subwatersheds* containing groundwater-based municipal drinking water systems:

- Black Cr./Avon River (03T)
- N. Thames/Medway R. (05T)
- Cedar Cr. (07T)
- Reynolds Cr./S. Thames R. above Ingersoll (08T)
- Middle Thames R. (09T)

within the UTRSPA were found to exhibit a moderate or significant potential for stress. A Tier 2 investigation was undertaken for those *subwatersheds*, however the model domains included all of the *subwatersheds* in the UTRSPA upstream of the forks of the Thames River in London. This accounts for flow into the *subwatersheds* of interest. Information derived from the Tier 2 study is presented in this Assessment Report for groundwater systems in the UTRSPA. The delineation of the *subwatersheds* used for the stress assessment are slightly altered from those examined in the Tier 1 phase, to focus on the municipal systems being investigated. This resulted in a total of eight *subwatersheds* being analyzed in Tier 2:

- Black Cr. (405)
- Avon River (404)
- Trout Cr./North Thames River (406, 407, 408, 410)
- N. Thames/Medway R. (409, 411, 412, 413)
- Cedar Cr. (301, 302)
- S. Thames R. above Ingersoll (304, 305)
- Reynolds Cr. (306)
- Middle Thames R. (307)

Through these revisions it was important to delineate *subwatersheds* which contained all of the wells of a single system with the area contributing to the supply for the wells. These revised *subwatersheds* are illustrated in Map 3-6, which also shows the results of the stress assessment on groundwater systems based on Tier 2 work.

As there are no surface water based municipal drinking water systems within the UTRSPA, Tier 2 investigation of the surface water system was limited to the assessment of groundwater recharge for input to the groundwater model. Therefore surface water stress assessments included in this report are derived from the Tier 1 work. Furthermore, no Tier 2 work was done in the part of the UTRSPA below the forks of the Thames (11T) in ground or surface water

systems, as there are no municipal supplies in this subwatershed with evidence of potential stress. Any data presented on subwatershed 11T are therefore based on the Tier 1 analysis.

In the Tier 2 analysis, future water use is considered, as in Tier 1, as well as 2 and 10 year drought scenarios. This scenario analysis is discussed in greater detail in Section 3.4.

3.3.4 Tier 3 Water Budget

The Tier 3 Water Budget, or local area risk assessment, is a local water balance undertaken on the scale of a single drinking water supply system and is intended to examine the reliability of that supply, including testing of drought and future demand scenarios. The Tier 2 analysis completed in the Upper Thames River Source Protection Area requires that 6 municipal systems undergo a Tier 3 analysis. These systems are illustrated in Map 3-6, and this analysis has just begun at the time of publication of the Assessment Report.

3.3.5 Peer Review of the Water Budget

Each phase of the water budget is subject to a peer review process. The project team and consultants work closely with the peer reviewers to ensure that the work undertaken is technically sound and meets the requirements of the *technical rules* and relevant provincial guidance. As work on the project progresses, the materials are presented to the peer review committee for their comments. Those comments are considered by the peer review team and consultants and are generally incorporated into the final report. The comments, along with their responses, are also incorporated into a peer review record, which becomes a companion to the water budget report. Following completion of the peer review, the draft water budget document is submitted with the peer review record to the Ministry of Natural Resources for acceptance.

The Conceptual and Tier 1 Water Budgets have both successfully completed the peer review process and the drafts have been accepted by the MNR. Work on the Tier 2 Water Budget has been reviewed at various stages. The comments of the peer reviewers have been considered in revised reports, for all of the various stages of the work, including: model selection, integrated model calibration, SGRA determination and stress assessment for the various scenarios required. Final peer review acceptance of the Tier 2 Water Budget is anticipated to be completed during the posting of this report. The material included in this draft of the Assessment Report is based on final drafts of the Tier 2 analyses submitted to the peer

reviewers for their review and comment and comments received on that material. Peer review of the work included in this Assessment Report is not a requirement of the *technical rules*; however the Source Protection Committee relies on the technical experts on the peer review committee to ensure that the work is suitable for the purposes of developing a Source Protection Plan for the area. The Ministry of Natural Resources also relies on the peer review process as part of its review and acceptance of the water budget work.

Due to the peer reviewers having reviewed much of the material as the work progressed, it is not anticipated that changes resulting from the review will have a substantial effect on the stress assessment, the delineation of SGRAs, or the other information presented in this Assessment Report. It is however, anticipated that the comments will continue to improve the documentation and interpretation of the work undertaken. Minor changes may be incorporated into the report prior to posting the Assessment Report for consultation.

3.4 Water Quantity Stress Assessment

The level of potential for stress is calculated based on the following formula as defined in the *Technical Rules: Assessment Reports*:

$$\%\ \text{Water Demand} = \frac{Demand}{Supply - Reserve} x100$$

Percent Water Demand is calculated separately for groundwater and surface water as are the other terms in the above *percent water demand* equation. Percent Water Demand is calculated at both the Tier 1 and Tier 2 stages and is one of the main criteria in determining if more detailed analysis is required.

For surface water, *Demand* is the monthly estimated average *demand* of all surface water sources, *Supply* is the monthly estimated median daily flow, and *Reserve* is the 90th percentile monthly flow, or the flow that is exceeded 90 percent of the time for the month being analyzed.

For groundwater, supply includes a number of components as discussed in section 3.2 above. For the Tier 1 Water Budget, supply is simplified to include only recharge in the subwatershed.

For the Tier 2 Water Budget, a calibrated groundwater model is used to estimate groundwater flows into the subwatersheds. This quantity, plus the estimated recharge, is used as the supply. Groundwater flow into the watershed can be calculated through the use of a calibrated groundwater model.

Groundwater reserve is 10% of the supply, as required in the *Technical Rules: Assessment Reports*. A water reserve estimate is intended to protect a portion of water from being considered within the stress calculations, adding a conservative element to this calculation. This water is removed from the supply in the stress assessment.

The *Percent Water Demand* is used as an indication of the stress level in the *watershed* or *subwatershed*. This stress level is described in this document as the "potential for stress" as it better describes the situation given the *uncertainty* associated with the calculations. Generally, a Tier 1 and Tier 2 *stress assessment* are understood to have *uncertainty* associated with the *percent water demand* calculations. The uncertainty is reduced in Tier 2 over that in Tier 1, but cannot be eliminated entirely. At the completion of the Tier 1 and Tier 2 Water Budgets, it is important to understand that conclusions drawn from these analyses are indicative of whether more analysis is required but are not an absolute determination that there is *stress*. Given the level of conservatism, as discussed above, this is especially important when considering the *subwatersheds* which are being described as having a significant potential for *stress*. However, for the *subwatersheds* which are described as having a low potential for *stress*, this conservatism clearly indicates that they do not have a significant level of *stress*.

The sensitivity analysis required for *subwatersheds* which are almost moderate gives even more confidence in this conclusion. This sensitivity analysis ensures that all *subwatersheds* with a moderate potential for *stress* also advance to the next stage of analysis, along with those identified with a significant potential for *stress*. At the next stage, additional analysis is required to improve the *water demand estimate* and, in the case of Tier 2, the *stress* level, with a higher level of confidence. If a moderate or significant potential for *stress* is determined to exist in the Tier 1 or Tier 2 analysis and affects a municipal water supply, additional analysis would be undertaken through the Source Protection program. If a *subwatershed* with a municipal system is found to have a moderate or significant potential for stress in Tier 2, it then moves to a Tier 3

local area risk assessment. In Tier 3 new stress assessments are not made; rather, a risk assessment of the reliability of individual systems to be able to meet demand is conducted.

In assessing the potential for *stress*, various scenarios as identified in the *technical rules* must be considered. These scenarios consider current and future municipal *demand* under both average and drought scenarios. Planned systems must also be considered, however there are no planned systems in the Upper Thames River Source Protection Area. Planned wells in existing systems would be included in the future demand for the systems. Drought scenarios are not considered in the Tier 1 Water Budget, but need to be included in the Tier 2 assessment. These scenario analyses are conducted on *subwatersheds* which contain municipal systems, but under average conditions exhibit low potential for stress. If under average conditions a moderate or significant potential for stress is identified, the next tier work is required, and there is no need for the scenario analysis. The intent of scenario analysis is to ensure *subwatersheds* which exhibit a low potential for stress under average conditions will not be pushed to a higher level by increased future municipal demand, or by drought.

The *subwatersheds* in the *UTRSPA* to which this applies contain small communities with no future growth forecasted, and thus the future analysis does not change the stress assessment. Drought scenarios are are described below.

Criteria discussed in Table 3-4 below relate to the current and future municipal *demand* scenarios (respectively). As there are no additional planned systems in the Upper Thames River Source Protection Area, the scenario related to planned systems is not applicable and therefore not included in Table 3-4.

Tables 3-5, 3-6a, 3-6b, 3-7a and 3-7b describe the potential for *stress* based on the *percent water demand* for the applicable scenarios which must be compared to the ranges shown in Table 3-4. Table 3-5 shows the surface water stress assessment from Tier 1 as Tier 2 surface water stress assessment was not required due to the low potential for stress in all UTRSPA subwatersheds. Tables 3-6a, 3-6b, 3-7a and 3-7b report the potential for stress for groundwater from the most advanced level of assessment completed,with sub-tables ‘a’ representing subwatersheds which only attained Tier 1 analysis, and sub-tables ‘b’ present Tier 2 analysis. If

a system was found in Tier 1 to require Tier 2 analysis and a new stress assessment, only the Tier 2 stress assessment is presented to avoid having multiple values for a single area. The full Tier 1 Stress Assessment is available in the Tier 1 study document.

The Table 3-6a and b are for average annual conditions, and Tables 3-7a and b for maximum monthly. Table 3-7b only includes subwatersheds which were not found in the Tier 2 annual average analysis (i.e. Table 3-6a) to have a moderate or significant potential for stress, as an additional check whether they should be included in the Tier 3 work.

Map 3-6 shows the cumulative results of the the most advanced level of analysis completed. As described in section 3.3.2 and 3.3.3 each tier was completed and documented in separate reports. Full results from the Tier 1 and 2 assessments are available in the Tier 1 (Thames-Sydenham and Region, 2010) and Tier 2 (Schlumberger Water Services, 2010) reports.

Additional criteria as described in Rule 32 and 33 are also considered in the stress assessment. If the intake or well was not able to operate due to insufficient quantity of water or a low water level, the potential for *stress* is described as moderate and the *subwatershed* would advance to the next tier.

Table 3-4 Potential for stress based on *percent water demand* under current and future municipal water demand

Potential for Stress	Surface Water % Water Demand	Groundwater % Water Demand	
Based on	Max'm monthly	Max'm monthly	Avg annual
Significant	Greater than or equal to 50%	Greater than or equal to 50%	Greater than or equal to 25%
Moderate	Less than 50% but greater than 20% (or between 18 and 20%, inclusive, but under sensitivity analysis increases to greater than 20%)	Less than 50% but greater than 25%	Less than 25% but greater than10% (or between 8 and 10%, inclusive, but under sensitivity analysis increases to greater than 10%)
Low	Less than or equal to 20% (after sensitivity analysis if between 18 and 20%, inclusive)	Less than or equal to 25%	Less than or equal to 10% (after sensitivity analysis if between 8 and 10%, inclusive)

Table 3-5 Surface water potential for stress based on Tier 1 stress assessment (Month of August)

Subwatershed	Code	Supply (Q_{50}) (m^3/day)	Reserve (Q_{90}) (m^3/day)	Demand (m^3/day)	Percent Water Demand	Potential for stress
North Thames River/Whirl Cr.	01T	8251	907	1466	20%	Low
Flat Cr./North Thames Tributaries	02T	0	0	241	0%	Low
Black Cr./Avon River	03T	36202	20779	1464	9%	Low
Trout Cr.	04T	148349	91584	708	1%	Low
N. Thames/Medway R.	05T	293371	162346	17115	13%	Low
S. Thames R. above Pittock Reservoir	06T	161784	99878	3585	6%	Low
Cedar Cr.	07T	18749	8640	1692	17%	Low
Reynolds Cr./S. Thames R. above Ingersoll	08T	226757	157594	7548	11%	Low
Middle Thames R.	09T	51840	24970	2602	10%	Low
Waubuno Cr./Thames R. Tributaries	10T	396835	258854	23554	17%	Low
Thames R. between the Forks and Dutton*	11T*	933120	606874	29659	9%	Low

* Subwatershed 11T crosses over the Upper and Lower Thames boundary and, as such, numbers reported are for both source protection authorities in this subwatershed

Table 3-6 Groundwater potential for stress (Average Annual Conditions)
a) Tier 1

Subwatershed	Code	Q_{supply} (m^3/day)	$Q_{reserve}$ (m^3/day)	Q_{demand} (m^3/day)	Percent Water Demand	Potential For Stress
North Thames River/Whirl Cr.	01T	114872	11487	5609	5%	Low
Flat Cr./North Thames Tributaries	02T	38459	3846	352	1%	Low
S. Thames R. above Pittock Reservoir	06T	140934	14093	5757	5%	Low
Waubuno Cr./Thames R. Tributaries	10T	201081	20108	9153	5%	Low
Thames R. between the Forks and Dutton*	11T	445491	44549	10337	3%	Low

* Subwatershed 11T crosses over the Upper and Lower Thames boundary and, as such, numbers reported are for both source protection authorities in this subwatershed

b) Tier 2

Subwatershed	Code	Q_{supply} (m^3/day)		$Q_{reserve}$	Q_{demand}	Percent Water Demand	Potential for stress
		Inflow	Recharge	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)
Black Cr.	405	13133	49334	2938	1382	2%	Low
Avon River	404	2246	37152	2678	13565	37%	Significant
Trout Cr./North Thames River	406, 407, 408, 410	40435	97632	9590	19354	15%	Moderate
N. Thames/Medway R.	409, 411, 412, 413	82339	212026	18490	12269	4%	Low
Cedar Cr.	301, 302	41299	38102	3197	23501	31%	Significant
S. Thames R. above Ingersoll	304, 305	19008	71798	4925	1814	2%	Low
Reynolds Cr.	306	64541	85536	4666	71712	49%	Significant
Middle Thames R.	307	45274	127267	9677	10714	7%	Low

Table 3-7 Groundwater potential for stress (Maximum Monthly Conditions)
a) Tier 1

Subwatershed	T1 Code	Q_{supply} (m^3/day)	$Q_{reserve}$ (m^3/day)	Q_{demand} (m^3/day)	Percent Water Demand	Potential for Stress
North Thames River/Whirl Cr.	01T	114872	11487	7743	7%	Low
Flat Cr./North Thames Tributaries	02T	38459	3846	352	1%	Low
S. Thames R. above Pittock Reservoir	06T	140934	14093	13589	1%	Low
Waubuno Cr./Thames R. Tributaries	10T	201081	20108	12342	1%	Low
Thames R. between the Forks and Dutton*	11T	445491	44549	34032	11%	Low

b) Tier 2

Subwatershed	Code	Q_{supply} (m^3/day)		$Q_{reserve}$	Q_{demand}	Percent Water Demand	Potential for stress
		Inflow	Recharge	(m^3/day)	(m^3/day)	(m^3/day)	(m^3/day)
Black Cr.	405	13133	49334	2938	1382	2%	Low
N. Thames/Medway R.	409, 411, 412, 413	82339	212026	18490	33869	12%	Low
Reynolds Cr.	306	19008	71798	4925	3974	5%	Low
Middle Thames R.	307	45274	127267	9677	12355	8%	Low

Map 3-5 indicates the Tier 1 potential for stress on surface water sources and Map 3-6 illustrates the Tier 1 and Tier 2 potential for stress on groundwater sources.

From the Tier 2 Stress Assessment, municipal systems which are moving to a Tier 3 analysis include:

- Stratford
- St. Marys
- St. Pauls
- Woodstock
- Beachville
- Ingersoll

Tier 3 work has begun for these systems with data being collected as of May 2010. The Tier 3 work is expected to be completed in 2012.

Drought

Consideration of drought scenarios is required for all subwatersheds classified in the Tier 2 water budget analysis as having a low potential for stress based on historic conditions and percent water demand analysis, Subwatersheds included are:

- Black Creek / Lower Avon River
- Medway Creek / North Thames River above London
- Reynolds Creek
- Middle Thames River

The methodology for completing the drought scenarios began by running a 2-year drought scenario, which was accomplished by running the numerical groundwater model in transient mode for 2 years with zero recharge using average annual pumping rates for all municipal wells in the subwatershed. The head in the pumping well was then checked to make sure that the height of water above the pump was sufficient for normal operation of the well. In all cases, the height of water above the pump (depth to pump minus depth to final water level) did not drop below a level considered sufficient for normal operation of the pump.

Based on the 2-year drought scenario analysis, there are no changes to stress categories that were determined in the assessment based on historic conditions or the percent water demand analysis. As the 2 year drought is considered the 'worst case scenario' the 10 year drought was unnecessary to run.

3.4.1 Uncertainty in the Stress Assessment

As the *stress* assessment for the Upper Thames River Source Protection Area was completed as part of the Tier 1 and Tier 2 Water Budgets, some uncertainty in the data and analysis is expected. Tier 2 work reduces uncertainty from what is expected in Tier 1, but does not eliminate it, and thus the requirement to move ahead with Tier 3 in some areas, where uncertainty must be further reduced. It is especially important that the uncertainty associated with the Tier 1 analysis be considered in interpreting the surface water stress assessment. Although this *uncertainty* has no effect on the Source Protection Plan it is of considerable importance in interpreting this analysis for use in other programs such as the Permit to Take Water Program.

While the stress assessment is based on best estimates of consumptive water demand, water supply and water reserve, there is uncertainty associated with these estimates that may affect the classification. Other sources of uncertainty exist in the stress assessment and include, but are not limited to, the data that was used to develop the conceptual model, the numerical models that were used to represent the conceptual model, and the calibration of these models that was based on limited observation data. However, to address uncertainty in the final subwatershed stress classifications, a sensitivity analysis was completed on both the average annual percent water demand and maximum monthly percent water demand analysis to determine how sensitive the subwatershed stress classifications were to changes in recharge and flow. This sensitivity analysis was designed based on the sensitivity analysis completed in the Tier 1 stress assessment, and includes the following scenarios:

- Increase groundwater recharge by 20%;
- Reduce groundwater recharge by 20%;
- Increase groundwater demand by 20%; and,
- Reduce groundwater demand by 20%.
- Reduce groundwater in component to zero

The net result of this analysis was that the associated uncertainty for each subwatershed investigated in Tier 2 remained in the low category for all uncertainty scenarios.

3.5 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (*SGRA*s) are delineated through the water budget work. These areas are determined through the use of the recharge calculated in the Tier 2 Water Budget and discussed in Section 3.2.4 above. Rule 44 allows recharge to be compared with the average recharge of the area, or to the effective precipitation (precipitation less evaporation) of the area to determine if the recharge at that location is significant. Rule 44 identifies the criteria for determining whether a recharge area is significant:

- the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or
- the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

Rule 44(1) was used in the TSR to determine the *SGRA*s, and the entire Upper Thames basin was used as “the whole of the groundwater recharge area” for the purposes of determining average recharge. The average recharge of the entire Upper Thames River is 132 mm/a. According to Rule 44(1), this is multiplied by 1.15 to provide the criteria of *SGRA*. Therefore 151 mm/a is the threshold used to determine the significance of groundwater recharge areas in the Upper Thames River Source Protection Area.

Rule 45 indicates that the area must have "a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system". For the purposes of this rule a drinking water system can be any water well including a single residential water well. Map 34 in the Thames Watershed Characterization Report summary included as Appendix 5 illustrates that wells are located throughout the region. In areas where shallow sandy deposits provide for recharge areas, well installation is simple through the use of sand points driven to a modest depth. These types of water wells are, in most cases, installed without a permit and therefore not included in the water well information system used to produce Map 34. Further, it is not intended by the *technical rules* that the connection be direct or immediate, but rather that there is a "hydrologic connection". This recognizes that water not only flows vertically through

the ground but also flows laterally from areas of higher levels to areas of lower water levels. Thus, it is generally accepted that aquifers are recharged from areas up gradient from the aquifer as well as directly above. Thus, a precautionary and conservative approach is warranted and all areas which meet the criteria for significance are included as *SGRA*.

Rule 46 allows professional judgement in the determination of areas deemed to exhibit significant recharge or not. For example, if an area is known to provide significant recharge on a local scale due to its unique physiography, but does not show up as significant using the methodology described above, it can be changed in the SGRA mapping to be significant. In the modelling done for SGRA determination in the TSR, river valleys and flood plain areas were shown to be SGRAs. In the opinion of some of the Water Budget Peer Review Committee (PRC) members, these areas are more appropriately defined as groundwater discharge rather than recharge areas, due to their low elevations and to the general groundwater hydraulic gradient towards them. However, there is also a body of research which shows that river valley areas can potentially exhibit both types of behaviour, dependent upon the season, and other PRC members felt it was appropriate to consider them as recharge areas. In the end it was agreed that they would be considered discharge areas, and thus removed from the SGRA mapping in Map 4-2-1.

Map 4-2-1 illustrates the *Significant Groundwater Recharge Areas* in the Upper Thames River Source Protection Area. The vulnerability of the *SGRAs* is considered in the Vulnerability Assessment section of the Assessment Report. It is, however, important to point out that the *SGRAs* which are coincident with *Highly Vulnerable Aquifers* (*HVA*), will receive a vulnerability score of 6 which can result in moderate or low threats, while activities in the other *SGRAs* cannot result in water quality *threats* due to the *vulnerability* score being 4 or less.

It is important to note that overlaying the groundwater vulnerability onto the *SGRAs* creates “overlay artifacts” or “sliver polygons”. This occurs where the boundary of a contiguous groundwater vulnerability area falls close to the boundary of the *SGRA*. Since the datasets do not perfectly align to each other, the slight gaps and overlaps between the boundaries create small, uniquely valued polygons. In some cases, these polygons will be assigned a vulnerability

score of 6 (i.e. potential for moderate or low threats) but have areas less than 1 square meter in size. This should be considered in policy development and implementation.

3.6 Data Gaps and Next Steps

Table 3-8 summarizes data gaps identified through the Tier 1 and Tier 2 Water Budgets and Water Quantity Stress Assessments. As the *stress* assessment was completed through a combination of Tier 1 and Tier 2 Water Budgets, it is expected that there would be data gaps. In the case of surface water analysis, if work were to proceed to Tier 2, many of these gaps would need to be addressed at that time. In the case of groundwater analysis, work proceeding to Tier 3 will address many of the data gaps found in Tier 2.

These gaps do not affect the reliability of the analysis for use in the development of the Source Protection Plan.

Table 3-8 Data gaps related to Water Budget and Water Quantity Stress Assessment

Gap	Description
Improved understanding of water use	• Obtain actual water use data from all significant water users through the PTTW reporting system • Requires reassessment after sufficient data has been reported, perhaps when Assessment Report requires future update • Where Tier 3 assessment will be undertaken, updated PTTW will be considered to the extent that the data is available
Completion of the peer review of the T2WB	• Receive and consider comments of the peer reviewers prior to submission of the T2WB report to MNR for acceptance • Finalize the peer review record
Un-gauged Areas	• Surface Water Model to better understand distribution of flows in un-gauged subwatersheds
Climate Change	• Requires an understanding of the local climatic conditions resulting from global climate change which is not yet available • Consider the change in local climatic conditions in the water budget and the stress assessment when that information is available
Refine ET	• Improve calculation of ET to include consideration of soil types and land use at a local level