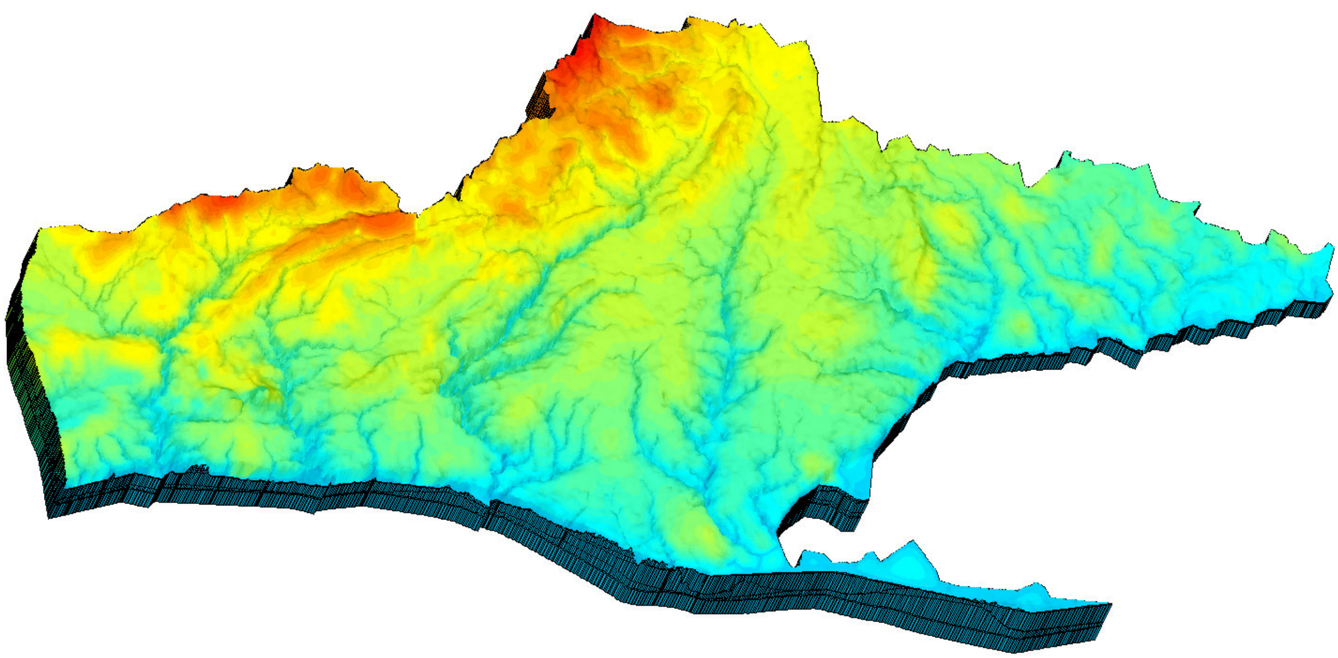
Long Point Region, Catfish Creek and Kettle Creek
Tier 2 Water Quantity Stress Assessment

Final Report

May 2009



Prepared by

AquaResource Inc.

Integrity · Technology · Solutions

Executive Summary

The Clean Water Act (2006) was introduced by the Province of Ontario in its First Reading on December 5, 2005 and it received Royal Assent on October 19, 2006. On July 3, 2007, the Act and its five regulations came into effect. The intent of this Legislation is to ensure communities are able to protect their municipal drinking water supplies through the development of collaborative, locally driven, science-based Source Water Protection plans. Communities are in the process of identifying potential water quality and quantity risks to local sources and will take action to reduce or eliminate these risks. Municipalities, Conservation Authorities, property owners, farmers, industry, community groups, and the public are working together to meet these common goals.

For the purposes of Source Water Protection, the Grand River, Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities have formed the Lake Erie Source Protection Region. The area included within the Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities is approximately 3,900 km^2, and is home to approximately 165,000 people. A number of water resource studies are currently being completed within the Lake Erie Source Protection Region in support of the Clean Water Act. These include vulnerable area delineation, threats identification/classification, and subwatershed-based water budgets.

As part of the water budget assessment process, the Clean Water Act (2006) requires the completion of a Water Quantity Stress Assessment to determine potential subwatershed stress. The Water Quantity Stress Assessment estimates the level of potential stress placed on each subwatershed. This assessment estimates a Percent Water Demand for each subwatershed by comparing the water *demands* to the available surface water and groundwater *supply* for that subwatershed. The Stress Assessment is a tiered process whereby subwatershed areas identified to have higher Percent Water Demands are studied in greater detail than those subwatersheds that have lower Percent Water Demand. This report documents the Tier 2 Water Quantity Stress Assessment for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities.

A Draft Integrated Water Budget and Water Quantity Stress Assessment Report (AquaResource, 2008) was released by the Lake Erie Source Protection Region. This 2008 report documented the tools applied to calculate water budget components, quantified key components of the hydrologic cycle, and documented an initial Water Quantity Stress Assessment. The 2008 Integrated Water Budget Report has been updated and divided into this Water Quantity Stress Assessment Report and a companion Integrated Water Budget Report (AquaResource, 2009a). Similar reports have been completed for the Grand River Conservation Authority (AquaResource, 2009b,c) covering the remainder of the source protection region.

The methodology followed in this report is consistent with the Technical Rules prepared by the Ministry of Environment (MOE, 2008) for the preparation of Assessment Reports under the Clean Water Act. The relevant section in the Technical Rules can be found in *Part III.4 – Subwatershed Stress Levels – Tier Two Water Budgets*. In addition, the Province (MOE, 2007) developed the Provincial Guidance Module 7 Water Budget and Water Quantity Risk Assessment (Guidance Document) which provides further instruction on how to complete a Subwatershed Stress Assessment. As outlined in the Guidance Document, the Stress Assessment determines the potential for stress in each subwatershed by using the Percent Water Demand calculations and the established stress thresholds for both surface water and groundwater.

The Stress Assessment calculations performed for both surface water and groundwater were completed using numerical modeling tools that simulate flows for both the surface water and groundwater systems. These modeling tools are calibrated in a coupled fashion to observed water level and flow conditions within the watershed. Once calibrated, the modeling tools were used to quantify flows and evaluate the potential for stress within subwatersheds of the Long Point, Catfish and Kettle Creek Conservation

Authorities. This process was used to identify subwatersheds with a **Low**, **Moderate** or **Significant** potential for stress. In areas with a higher potential for stress, there is a higher potential that local conditions at a municipal well system may result in higher risks. As a result, municipal water supplies located within subwatersheds classified as having a Moderate or a Significant potential for stress meet the conditions required to proceed to a Tier 3 Water Quantity Risk Assessment, which is a more-detailed evaluation of local conditions. The objective of a Tier 3 Assessment would be to evaluate the risk that a municipal water supply would not be able to meet its planned pumping rates. Where the supply is not able to meet its planned pumping rates, the municipality would identify and make plans to deal with significant threats to water quantity.

To determine potential for stress there are three tests, or scenarios, applied to each subwatershed. To be classified as having a Moderate or Significant potential for Stress, the subwatershed must satisfy one of the following:

1. Recorded historical conditions show a municipal well or surface water intake ceasing pumping due to low water levels / flows under normal pumping conditions, or
2. Percent Water Demand for current, planned, and future water demand exceeds thresholds for Moderate or Significant potential for stress as defined by the Province (MOE, 2008), or
3. Assessment of drought conditions indicates water levels or flows at a municipal well or intake would be insufficient to sustain pumping at normal operation rates.

Should any of the three conditions be met for a subwatershed, any municipal systems within that subwatershed meet the requirements to proceed with a Tier 3 Risk Assessment, as defined in the Technical Rules (MOE, 2008).

The following table lists the subwatersheds located within the Long Point Region, Catfish and Kettle Creek Conservation Authorities that are classified as having a Moderate or Significant potential for stress for surface water resources:

Conservation Authority	Subwatershed	Municipal Water Supply
Catfish Creek	Catfish Creek Above Aylmer	None
	Lower Catfish Creek	None
	Silver Creek	None
Long Point Region	South Otter Creek	None
	Big Creek Above Cement Road	None
	Big Creek Above Delhi	None
	North Creek	Delhi Lehman Reservoir Intake
	Venison Creek	None
	Dedrick Creek	None
	Young/Hay Creeks	None
	Lynn River	None
	Upper Nanticoke Creek	None
	Stoney Creek	None

As listed above, the Delhi Lehman Reservoir Intake is the only municipal surface water supply located in a subwatershed classified with a Moderate or High potential for stress. For this intake, conditions meet the requirements to proceed with a Tier 3 Water Quantity Risk Assessment.

The following table lists the subwatersheds within Long Point Region, Catfish and Kettle Creek Conservation Authorities that are classified as having a Moderate or Significant potential for stress for groundwater resources:

Conservation Authority	Subwatershed	Municipal Water Supply
Long Point Region	Otter Creek at Tillsonburg	Tillsonburg
	Big Creek Above Kelvin Gauge	None
	Big Creek Above Delhi	None
	North Creek	None
	Big Creek Above Minnow Creek	Delhi
	Lynn River	Simcoe
	Upper Nanticoke Creek	Waterford

There are four municipal systems that are located within subwatersheds that have been identified as having a Moderate or Significant potential for stress for groundwater resources. Delhi, Simcoe and Waterford are all municipal systems within Norfolk County which exceeded the stress threshold under existing conditions. Tillsonburg was identified as having a Moderate or Significant potential for stress under future municipal demand. These four municipal systems meet the requirements to proceed with a Tier 3 Water Quantity Risk Assessment. Assessment of historic observations and drought conditions did not identify any additional municipal systems.

It should be noted that subwatersheds identified as having a Moderate or Significant potential for stress are not necessarily experiencing acute hydrologic or ecologic stress. This classification however indicates that additional information is required to understand the local stresses and the cumulative impacts of water withdrawals. Further, such a classification does not indicate that more water is being withdrawn than is replenished, a condition commonly referred to as “mining”. Mining would only occur when the calculated Percent Water Demand exceed 100%; this condition was not observed anywhere within the study area.

In addition to the Subwatershed Stress Assessment, the delineation of Significant Groundwater Recharge Areas (SGRAs) was also completed as part of this project. As per the Source Protection Technical Rules (MOE, 2008), SGRAs will be overlain with intrinsic susceptibility mapping to score groundwater vulnerability across the broader landscape and evaluate potential water quality threats. Beyond Source Protection, these areas may also be used in future municipal / county planning initiatives to protect areas that feed significant hydrologic processes as guided by the Provincial Policy Statement (PPS). In addition to those municipal initiatives, the Source Protection Committee may consider adopting a uniform approach to water quantity protection measures within mapped SGRAs.

Table of Contents

Appendixes (Provided on CD-ROM)

List of Tables

List of Figures

List of Maps

1.0 Water Quantity Stress Assessment

This document describes the Long Point Region, Catfish and Kettle Creek Tier 2 Water Quantity Stress Assessment (Stress Assessment) prepared to meet the requirements of the Province of Ontario's Clean Water Act (2006). In addition to this report, the Long Point Region, Catfish Creek and Kettle Creek Integrated Water Budget Report (AquaResource, 2009a) has been prepared as a separate companion report. The companion report contains information relating to the water budget for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities, including consumptive water demand estimates, watershed characterization, and surface water and groundwater model development/application. The water budget reporting contains critical background information that this Water Quantity Stress Assessment report builds upon; as a result, the two reports should be reviewed in concert.

Under Ontario's Clean Water Act, Source Protection Regions are required to work through the Water Budget and Water Quantity Stress Assessment framework to help managers identify drinking water sources that may not be able to meet current or future water demands. The three-tiered process is designed to focus detailed studies on municipal water supplies that are located within subwatersheds having a higher potential for stress. Each successive tier increases in complexity, requiring a higher level of detail and understanding as summarized below:

- Tier 1 – Water Budget and Subwatershed Stress Assessment. The goal of this assessment is to estimate a subwatershed's potential for stress using preliminary estimates of water demand and water supply to calculate the percentage of water supply used in a subwatershed. This percentage is referred to as Percent Water Demand. Subwatersheds where the estimated Percent Water Demand is above a specified threshold value are identified as having a Moderate or Significant potential for stress and are subject to additional study. Subwatersheds calculated as having a low Percent Water Demand are identified as having a Low potential for stress and do not require more refined water budget evaluation.
- Tier 2 – Water Budget and Subwatershed Stress Assessment. The Tier 2 Assessment is completed similar to the Tier 1 Stress Assessment using refined water demand estimates and more advanced water budget tools. In general, Tier 2 Assessments are required in watersheds with a higher demand for municipal drinking water. The Percent Water Demand calculations are the same as those used in Tier 1. Municipal water supplies located within subwatershed areas confirmed to have a Moderate or Significant potential for stress proceed to a locally-focused, Tier 3 Water Quantity Risk Assessment.
- Tier 3 – Water Quantity Risk Assessment. The objective of the Tier 3 assessment is to estimate the risk that a municipality may not be able to meet current or future water demands. The assessment is carried out for all municipal water supplies located in subwatersheds classified with a Moderate or a Significant potential for stress in the Tier 2 Assessment.

As with the Grand River Conservation Authority (GRCA), the Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities began with a Tier 2 Subwatershed Stress Assessment. With the approval of the Ministry of Natural Resources, a complete Tier 1 Assessment was not required due to the availability of existing surface water and groundwater flow models and the high demands for water in the Conservation Authorities. This approval was in accordance with Technical Rule 24 (MOE, 2008) which allows a Source Protection Area to move directly to a Tier 2 Water Budget if preliminary water budgets already exist for subwatersheds in the area. The Integrated Water Budget Report was originally released in draft in 2008 (AquaResource, 2008), with a revised version (AquaResource, 2009a) released with this report as a supporting companion document.

The Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities are part of the same Source Protection Area as the GRCA, and the Tier 2 Water Quantity Stress Assessments for both areas have been completed by the same consultant and predominantly the same Peer Review Team. As the assessments for both areas were completed concurrently, the Stress Assessment analysis format of this Report follows that of the GRCA Stress Assessment Report (AquaResource, 2009c) very closely. Assumptions made for many analyses are the same between both reports as well as portions of text that relate to both the GRCA and the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities.

1.1 WATERSHED DESCRIPTIONS

The Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities are part of the Lake Erie Watershed Region and Source Protection Region. Shown on Map 1 are the Conservation Authority boundaries as well as major urban centres throughout the region. Each Conservation Authority has distinct physiographic features along with their individual urban centres and major water courses, which will be described briefly in this section. Detailed characterization of the Conservation Authorities is given in the companion Integrated Water Budget Report (AquaResource, 2009a). Map 2 displays the 31 subwatersheds that make up the entire area and form the areas for the Stress Assessment calculations in this report.

1.1.1 LPRCA

The subwatersheds included within the Long Point Region Conservation Authority (LPRCA) cover an area of approximately 2,900 km^2 in southern Ontario. The Conservation Authority is approximately 100 km wide at its widest point, and approximately 60 km from Lake Erie in the south, to the headwaters of the region in the north. The LPRCA also contains approximately 225 km of Lake Erie shoreline, including the Long Point sand spit.

The western portion of the Conservation Authority is mainly comprised of the Norfolk Sand Plain, a silty sand and gravelly sand feature of low relief. The eastern portion of the Conservation Authority is part of the Haldimand Clay Plain, a region of low-relief comprised primarily of lacustrine clay. Map 3 shows the physiography of the Long Point Region Conservation Authority. The streams and rivers in the Conservation Authority are characterized by the material they flow through. In the Eastern clay plain, the hydrogeologic permeability is much lower, with a higher percentage of precipitation travelling as overland flow to surface water features instead of infiltrating to groundwater. This being the case, the clay plains are riddled with many tributaries and streams, referred to as the Eastern Tributaries. The Norfolk Sand Plain has much higher permeability and recharge occurs at a higher rate with significantly less precipitation runoff as overland flow. Fewer water courses are thus found in the sand plains. In the northern part of the Conservation Authority, the Galt and Paris Moraines cross the boundary between the Grand River Watershed and the LPRCA, oriented in a north-south direction. Other moraines in the western part of the Conservation Authority include the Tillsonburg Moraine, Courtland Moraine and the Mabee Moraine, as well as the St. Thomas Moraine and Norwich Moraine, which help define the north-western boundary of the Conservation Authority.

The main urban areas within the Long Point Region Conservation Authority include the communities of Delhi, Courtland, Waterford, Simcoe, Norwich, Otterville, Tillsonburg, Straffordville, Vienna, Port Burwell, Port Rowan, Port Dover, Jarvis, and Hagersville. The LPRCA encompasses most of Norfolk County and portions of Haldimand, Brant, Oxford and Elgin Counties. Delhi has a surface water municipal intake at the Lehman Reservoir, located on North Creek. The towns of Port Dover, Port Rowan, Hagersville, Jaris, and Townsend draw from Lake Erie as their municipal water source. Straffordville, Vienna, and Port Burwell are served by the Elgin Primary Water Supply, which draws from Lake Erie. Delhi, Courtland, Waterford, Simcoe, Norwich, Otterville, and Tillsonburg all use groundwater for their municipal water supplies.

Map 6 shows the main surface water courses that cross the Long Point Region. The combined length of all rivers, streams and tributaries is over 3,700 km. All surface water features within the LPRCA drain into Lake Erie. There are 4 large-scale watersheds within the LPRCA: Big Otter Creek, Big Creek, Lynn River and Nanticoke Creek, as well as numerous small water courses that drain directly into Lake Erie. Many of the smaller water courses have been grouped into the 4 larger watersheds. The tributaries to Lake Erie that are located mainly in the Haldimand Clay Plain have been grouped into their own watershed (Eastern Tributaries). The subwatersheds are listed in Table 1.1 and shown in Map 2.

Table 1.1 - Long Point Conservation Authority Subwatersheds

Watersheds	Subwatersheds	Drainage Area (km^2)
Otter Creek	Otter Above Maple Dell Road	99
	Otter at Otterville	75
	Otter at Tillsonburg	153
	Spittler Creek	116
	Lower Otter	168
	Little Otter	118
	South Otter	120
	Clear Creek	87
Big Creek	Big Above Cement Road	89
	Big Above Kelvin Gauge	64
	Big Above Delhi	154
	North Creek	58
	Big Above Minnow Creek	72
	Big Above Walsingham Gauge	123
	Venison Creek	98
	Lower Big	96
	Dedrick Creek	138
Lynn River	Young/Hay Creek	120
	Lynn River	172
	Black Creek	134
Nanticoke Creek	Upper Nanticoke	114
	Lower Nanticoke	85
Eastern Tributaries	Sandusk Creek	182
	Stoney Creek	186

1.1.2 CCCA

The Catfish Creek Conservation Authority (CCCA) is located in southwestern Ontario between the Long Point Region Conservation to the east, and the Kettle Creek Conservation Authority to the west. Catfish Creek and its tributaries drain an area of approximately 490 km^2 in Elgin and Oxford Counties. The southern boundary of the Conservation Authority borders Lake Erie.

The Norfolk Sand Plain extends into the southern portion of the Catfish Creek Conservation Authority from the adjoining Long Point Region. Courser sands and gravels comprise the Norfolk Sand Plain, resulting in higher rates of precipitation percolating into the ground. The western central portion of the Conservation Authority is comprised of the Ekfrid clay plain, with clay and silt deposits resulting in poor drainage. The St. Thomas Moraine, Norwich Moraine and Tillsonburg Moraine run roughly parallel to the shore of Lake Erie in the northern region of the Conservation Authority. They provide low to moderate relief in surrounding low-relief till plains and are capped mainly with Port Stanley Till. The Sparta Moraine and St. Thomas Moraine define the western boundary of the Conservation Authority from the neighbouring Kettle Creek Conservation Authority. Map 4 displays the physiography of the Catfish Creek Conservation Authority.

The major urban centres in the CCCA include Aylmer, Springfield, Brownsville, and Port Bruce. Aylmer and Port Bruce are serviced by the Elgin Primary Water Supply system which draws from Lake Erie. Brownsville uses groundwater for its municipal needs and the Springfield community is on private well supply.

The main branch of Catfish Creek flows southeast through the community of Aylmer, the Conservation Authority's largest community. The West and East Catfish Creek tributaries drain the northwestern portion of the Conservation Authority. The main branch of Catfish Creek joins with the East and West Catfish Creeks just west of Aylmer, and then flows due south and enters into Lake Erie at Port Bruce. In addition to the lands drained directly by Catfish Creek, there are also several Lake Erie tributaries within the Catfish Creek Conservation Authority. The most notable is Silver Creek, which lies east of the lower reach of Catfish Creek. The main streams in the Conservation Authority are shown on Map 7.

The Catfish Creek Conservation Authority is broken into four subwatersheds, listed in Table 1.2. Boundaries of these subwatersheds are shown on Map 2.

Table 1.2 - Catfish Creek Conservation Authority Subwatersheds

Subwatershed	Drainage Area (km^2)
West Catfish	149
Catfish Above Aylmer	143
Lower Catfish	103
Silver Creek	93

1.1.3 KCCA

The Kettle Creek Conservation Authority (KCCA) is situated on the north shore of Lake Erie, west of the Catfish Creek Conservation Authority. As shown on Map 1, the Conservation Authority is hourglass in shape and drains 520 km^2 of land including the south-central portion of Middlesex County and the City of London, as well as the central portion of Elgin County, including the City of St. Thomas.

The lower portion of the Conservation Authority is comprised of the Norfolk Sand Plain, stretching along the Lake Erie shoreline. Courser sands and gravels characterize the southern sand plain, with higher recharge rates than the remainder of the Conservation Authority area. The central portion of the Conservation Authority is the Ekfrid Clay Plain, also seen in the neighbouring CCCA. It is dominated by low relief clay and silt deposits, providing poor drainage. In the northeastern portion of the Conservation Authority, moderate-relief moraines lie in the till plains. The Westminster Moraine defines the northern boundary of the Conservation Authority. The St. Thomas Moraine and Sparta Moraine help define the eastern boundary of the Kettle Creek Conservation Authority from the Catfish Creek Conservation Authority. Map 5 shows the physiography of the Kettle Creek Conservation Authority.

The main urban centres in the KCCA include the City of St. Thomas, Port Stanley, and Belmont. The City of St. Thomas and Port Stanley are serviced by the Elgin Primary Water Supply. Belmont draws its municipal supplies from groundwater sources.

Kettle Creek has its headwaters in the upper northeast portion of the KCCA. It flows southwest towards the City of St. Thomas, where it is joined by Dodd Creek, and then flows south to empty into Lake Erie. The headwaters of Dodd Creek, a major tributary of Kettle Creek, lie in the northwest quadrant of the Conservation Authority with ground surface elevations ranging from 307 to 250 masl. This relatively flat clay plain has extensive cultivated farmland and only small and isolated wooded areas and wetlands. As a result, baseflow is intermittent and little continuous flow is provided by Dodd Creek to the main branch of Kettle Creek in St. Thomas. The tributaries and main reaches of Kettle Creek are shown on Map 8.

The Conservation Authority is split into 3 subwatersheds, listed in Table 1.3. The boundaries of these subwatersheds are shown on Map 2.

Table 1.3 - Kettle Creek Conservation Authority Subwatersheds

Subwatershed	Drainage Area (km^2)
Upper Kettle	199
Dodd Creek	131
Lower Kettle	190

1.2 SOURCE WATER PROTECTION WATER BUDGETS

The Clean Water Act (2006) was introduced to Ontario Legislature for its First Reading on December 5, 2005, and it received Royal Assent on October 19, 2006. The Act and five regulations came into effect on July 3, 2007. The intent of the legislation is to ensure communities are able to protect their municipal drinking water supplies through the development of collaborative, locally driven, science-based Source Protection Plans. Communities will identify potential risks to local water sources and take action to reduce or eliminate these risks. Municipalities, conservation authorities, property owners, farmers, industry, community groups, and the public will work together to meet these common goals. In addition to understanding threats to water quality, the Clean Water Act requires that communities understand and address the threats to the quantity of water required to sustain the current or the future water supply needs.

The methodology followed in this report is consistent with the Technical Rules prepared by the Ministry of Environment (MOE, 2008) for the preparation of Assessment Reports under the Clean Water Act. The relevant section in the Technical Rules can be found in *Part III.4 – Subwatershed stress levels – Tier Two Water Budgets*. In addition, the Province (MOE, 2007) developed the Provincial Guidance Module 7 Water Budget and Water Quantity Risk Assessment which provides further instructions on how to complete a Stress Assessment. As indicated in the Technical Rules (MOE, 2008), the Stress Assessment determines the level of potential stress in each subwatershed by utilizing the Percent Water Demand calculations, as well as evaluating the impact of drought conditions on the normal operation of a well/intake .

In addition to the Subwatershed Stress Assessment, the Province's Water Budget Framework requires that a Tier 2 Water Budget and Water Quantity Stress Assessment should include the delineation of Significant Groundwater Recharge Areas (SGRAs). The Guidance Module (MOE, 2007) states that SGRAs should be delineated and mapped to identify and protect the drinking water across the broader landscape.

An overview of the tiered studies prescribed within the Guidance Module (MOE, 2007) is provided in the following sections.

1.2.1 Conceptual Water Budget

The Technical Rules and MOE Guidance Module 7 require that a Conceptual Water Budget be developed for each watershed in the Province of Ontario. The Conceptual Water Budget should address baseline data collection, mapping, and an analysis of the compiled information. The conceptual understanding phase of the water budget builds upon the Watershed Characterization completed and should present an initial overview of the functions of the flow systems in the study area (both groundwater and surface water). Four questions are emphasized at this stage:

- Where is the water?
- How does the water move between the various watershed elements (soils, aquifers, lakes, rivers)?
- What and where are the stresses on surface water and groundwater?
- What are the trends?

In addressing the above questions, the Conceptual Water Budget will include an initial understanding of the various watershed hydrologic elements (e.g. soils, aquifers, rivers, lakes) and fluxes in a study area (precipitation, recharge, runoff, evapotranspiration, etc.). It will also require an understanding of the geologic system and a consideration of surficial features, such as wetlands and large impervious areas that would have to be incorporated into any water budget analysis. A preliminary inventory of all water takings would also be undertaken at this stage.

Guidance Module 7 (MOE, 2007) lists the expected deliverables for the Conceptual Water Budget.

1.2.2 Tier 1 Simple Water Budget and Water Quantity Stress Assessment

The goal of the Tier 1 Simple Water Budget and Water Quantity Stress Assessment is to estimate cumulative stresses placed on a subwatershed. The study team undertaking the Tier 1 Assessment will estimate the Percent Water Demand, the percentage of water supply that is demanded by water users. Watersheds where the Percent Water Demand is determined to be above a benchmark threshold value are termed ‘Moderately’ or ‘Significantly stressed’ and require more detailed study (Tier 2). Watersheds calculated as having a low Percent Water Demand are termed ‘Low stress watersheds’ and will not be subject to additional water budget requirements.

Guidance Module 7 (MOE, 2007) lists the expected deliverables for the Tier 1 Water Budget and Subwatershed Stress Assessment.

1.2.3 Tier 2 Complex Water Budget and Subwatershed Stress Assessment

Tier 2 Subwatershed Stress Assessments are completed to verify the results of the Tier 1 Stress Assessment using additional data and numerical water budgeting tools. The Tier 2 Water Budgets are developed at the subwatershed scale, similar to the Tier 1 level, and they require a continuous surface water streamflow model and a calibrated groundwater flow model.

The Long Point, Catfish Creek and Kettle Creek Conservation Authorities proceeded with a Tier 2 Subwatershed Stress Assessment and this document outlines the methodologies and results of this Assessment. The methodologies used throughout this Assessment are consistent with the methodologies outlined in the Province’s Water Quantity Guidance Module 7 (MOE, 2007).

Guidance Module 7 outlines the expected outputs, or deliverables, for the Tier 2 Complex Water Budget and Subwatershed Stress Assessment.

1.2.4 Tier 3 Water Quantity Risk Assessment

The objective of the Tier 3 Water Quantity Risk Assessment is to estimate the likelihood that municipalities will be able to meet planned water quantity requirements. A Tier 3 Risk Assessment is carried out on all municipal water supplies located in subwatersheds that were classified in the Tier 2 Assessment as having a 'Moderate' or 'Significant' potential for stress. The Tier 3 Assessment uses refined surface and/or groundwater flow models, and involves a much more detailed study of the available groundwater or surface water sources.

1.3 TIER 2 REQUIREMENTS

The approach for conducting a Tier 2 Subwatershed Stress Assessment is outlined in the Province's Guidance Module 7 for Water Budget and Water Quantity Risk Assessment (MOE, 2007). This Guidance Document prescribes an approach for estimating a subwatershed's potential for stress based on estimates of water supply, water reserve, and water demand in each subwatershed. The Stress Assessment is performed for both surface water resources and groundwater resources. While estimated values for water supply and water reserve are calculated using the water budget models, the water demand is estimated using the Permits-To-Take-Water and other information. For this study, detailed background information on the models and Permit-To-Take-Water demand is described in the Integrated Water Budget Report (AquaResource, 2009a). A brief summary of the water budget modelling tools developed for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities is included in Section 1.4.

1.3.1 Stress Assessment Methodology

The Technical Rules (MOE, 2008) describes three "tests" or "scenarios" used to determine a subwatershed's potential for stress, as follows:

1. Historical Conditions,
2. Percent Water Demand Scenarios, and
3. Drought Assessment Scenario.

If a subwatershed meets the criteria for having a Moderate or Significant potential for stress under any one of these three tests, the subwatershed is identified as having either a "Moderate" or "Significant" potential for stress. Under the direction of the Technical Rules, when a subwatershed is designated as having a Moderate or Significant potential for stress, municipal systems located in the subwatershed meet the conditions required for moving on to a Tier 3 Water Quantity Risk Assessment Study. The following sections describe each test.

1.3.1.1 Stress Assessment for Historical Conditions

According to the Technical Rules (MOE, 2008) if either of the below conditions have been met in the recorded history of the municipal surface water intake, the subwatershed would be classified as having a Moderate potential for stress:

> *(i) any part of a surface water intake was not below the water's surface during normal operation of the intake, or*

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

For a municipal groundwater well, if either of the below conditions have been met in the recorded history of the municipal well, the subwatershed would be classified as having a Moderate potential for stress:

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

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

1.3.1.2 Stress Assessment for the Percent Water Demand Scenarios

For the Percent Water Demand Scenarios, the following Percent Water Demand calculation is used to determine a subwatershed's potential for stress. The Percent Water Demand is calculated using the following formula, as outlined in the MOE Technical Rules (MOE, 2008):

$$\text{Percent Water Demand} = \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} \times 100\%$$

The terms are defined below:

- Q_{DEMAND} is equal to the consumptive demand calculated as the estimated rate of locally consumptive takings. (Note: demands are grouped into surface and groundwater takings).
- Q_{SUPPLY} is the water supply term, calculated for surface water as the monthly median flow for the area to be assessed, and for groundwater supplies as the estimated annual recharge rate plus the estimated groundwater inflow to a subwatershed.
- $Q_{RESERVE}$ is the water reserve, defined as the specified amount of water that does not contribute to the available water supply. For surface water supplies, reserve is estimated using the 90th percentile monthly median flow, at a minimum (i.e. the flow that is exceeded 90% of the time). Groundwater reserve is calculated as 10% of the total estimated groundwater discharge within a subwatershed.

For surface water systems, the above equation is carried out using monthly estimates. The maximum Percent Water Demand for all months is then used to categorize the surface water quantity potential for stress into one of three levels; Significant, Moderate or Low (see Table 1.4).

Table 1.4 - Surface Water Potential Stress Thresholds

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

For groundwater systems, the Stress Assessment calculation is carried out for the average annual demand conditions and for the monthly maximum demand conditions; groundwater supply is considered constant. The stress level for groundwater systems is also categorized into three levels (Significant, Moderate or Low) according to the thresholds listed in Table 1.5.

Table 1.5 - Groundwater Potential Stress Thresholds

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

Percent Water Demand is calculated for three different demand scenarios; 1) Current Water Demand; 2) Planned Water Demand; and 3) Future Demand estimates. Under each scenario, a subwatershed's potential for stress is evaluated by comparing the amount of water consumed (consumptive water demand) with the amount of water available (water supply). These values have previously been quantified as part of the Integrated Water Budget (AquaResource, 2009a). Only those subwatersheds identified as having a Low potential for stress under the Current Demand require assessment for the Planned and Future Demand scenarios.

The Technical Rules (MOE, 2008) require further consideration of subwatersheds that have a Low potential for Stress, but that have a Percent Water Demand close to the thresholds given within Table 1.4 and Table 1.5. Further consideration is required for subwatersheds that meet the following criteria:

- for surface water the maximum monthly Percent Water Demand is between 18% and 20%;
- for groundwater the average annual Percent Water Demand is between 8% and 10%; or
- for groundwater the maximum monthly Percent Water Demand is between 23% and 25%.

For those subwatersheds that meet the above criteria, if the uncertainty associated with the subwatershed classification is classified as 'High' and a sensitivity analysis indicates a possibility for the classification to move up to a "Moderate" potential for stress, the subwatershed will be identified as having a Moderate potential for stress. Further explanation of this is detailed in Section 2.6.

1.3.1.3 Stress Assessment for the Drought Assessment Scenario

Once the Historical Conditions have been reviewed and the Current, Planned, and Future Demand Scenarios have been completed, the subwatersheds still classified as having a Low potential for stress are subject to the Drought Assessment Scenario. The Drought Scenario consists of comparing modelled results of available groundwater or surface water supply for a two-year and ten-year drought period to current demand.

According to the Technical Rules (MOE, 2008), for a municipal surface water intake, if either of the below conditions are met during a modelled two or ten year drought, the subwatershed would be classified as having a Moderate potential for stress:

(i) any part of a surface water intake was not below the water's surface during normal operation of the intake, or

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

For a municipal groundwater intake, if either of the below conditions are met during a modelled two or ten year drought, the subwatershed would be classified as having a Moderate potential for stress:

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

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

Whereas the Percent Water Demand Scenarios were based on subwatershed-wide demand and supply, the Drought Assessment Scenario is based on the available water supply at a specific intake location. If one municipal intake is found to meet the criteria listed above, the entire subwatershed is identified as having Moderate or Significant potential for stress.

1.3.2 Implications of Identification

Subwatersheds are classified as having a 'Significant' or 'Moderate' potential for stress so the subwatersheds with a higher probability of experiencing water quantity-related environmental impacts can be studied in greater detail (Tier 3) than those with a lower probability of impact. Tier 3 studies are more detailed to improve the local understanding of the potential impacts on municipal drinking water sources from various drinking water threats. Subwatersheds identified as having a 'Low' potential for stress are not likely to be affected by water takings under the current water taking regimes, and therefore a more detailed level of study is unnecessary unless increased or additional water takings move the subwatershed into a higher stress category (e.g. 'Moderate' or 'Significant' potential for stress).

Being classified as having a Moderate or Significant potential for stress does not necessarily imply that a subwatershed is experiencing local hydrologic or ecologic stress. This classification indicates where additional information is required to understand local water supply sustainability and potential cumulative impacts of water withdrawals.

1.3.3 Methodology for the Long Point, Catfish and Kettle Creek Regions

While the Technical Rules (MOE, 2008) and the Guidance Module (MOE, 2007) provide a standard approach for carrying out the Stress Assessment, this approach was tailored for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities Tier 2 Study. Specific details relating to the methodology used for the Long Point, Catfish, and Kettle Creek Region are summarized below.

In this study, an iterative water demand estimation approach was completed to reduce the uncertainty associated with water demand estimates. Where the results of the preliminary Stress Assessment highlighted were controlled by a small number of permits and the volume extracted was suspect, additional effort was undertaken to further refine demand estimates. In this manner, a continuous improvement approach was followed in evaluating subwatershed water budgets.

An assessment of Historical Conditions was performed based on a review of available water level and streamflow data and discussions with Conservation Authority staff.

Subwatershed percent water demand was quantified for Current and Future Demands following the process outlined in the Technical Rules and Section 1.3.1.2 above. Water budget parameters were calculated using the GAWSER (Surface Water) and the FEFLOW (Groundwater) models developed for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities (AquaResource, 2009a).

A Drought Assessment was completed for both surface water and groundwater as outlined in the requirements of the Technical Rules (MOE, 2008) and explained in Section 1.3.1.3 above. For groundwater, the Technical Rules suggest that a 2-year drought screening scenario be initially completed follow by a 10-year drought assessment. Since the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities have long-term model results of groundwater recharge predicted from 1960 to 2004, and this period includes both short-term (2-year) and long-term (10-year) drought periods, both scenarios were accomplished within one simulation. This Assessment particularly captures conditions from the significant drought observed during the 1960's.

This report also provides an analysis of the temporal variability of surface water and groundwater supply and demand. While this variability is not incorporated directly into the Stress Assessment calculations, the results of this temporal analysis are useful as a tool to confirm the results of the Stress Assessment calculations. This variability is also an indicator of the degree to which the stress might be observed.

In addition to the Subwatershed Stress Assessment, the Province's Water Budget Framework requires the delineation of Significant Groundwater Recharge Areas (SGRAs). This study follows a straightforward and reproducible procedure for delineating SGRAs as described in the Technical Rules. Using the spatial groundwater recharge rate estimates, the methodology identifies areas with estimated recharge rates equal to or exceeding a threshold rate in each of four main regions in the Conservation Authorities. This initial step identifies many small isolated areas with high groundwater recharge. SGRA delineation is further refined by considering only those areas of high recharge that have a contiguous land area greater than one square kilometer.

1.4 WATER BUDGET MODELLING TOOLS SUMMARY

The LPRCA/CCCA/KCCA Integrated Water Budget (AquaResource, 2009a) was completed using a set of water budget tools (groundwater and surface water numerical models). The water supply results used in this Tier 2 Water Quantity Stress Assessment are based on the output of these numerical water budget tools. This summary offers a brief background on the models and their application. For a complete description of the models, the reader is directed to the Integrated Water Budget Report (AquaResource, 2009a).

1.4.1 Surface Water Continuous Streamflow-Generation Model

To simulate surface water flows and partitioning of precipitation, continuous hydrologic modelling was employed using the available GAWSER continuous streamflow-generation models. A separate GAWSER model was constructed for each of the three Conservation Authorities by Schroeter & Associates (Schroeter & Associates, 2006a, b, c). As part of the Integrated Water Budget Study, these three GAWSER models were modified to better reflect active agricultural water takings, as well as incorporate initial feedback from the groundwater flow model.

The validation exercises completed for the surface water streamflow-generation models focused on processes that could affect the low flow component of the output hydrographs, namely the recession factors for routing the groundwater discharge and the seasonal adjustment factors, which vary water movement through the soil column each month. Particular attention was paid to the seasonal adjustments for the months that act as a transition between cold and warm seasons and are critical for proper representation of recharge. Care was taken to ensure summer median flows were represented accurately.

A full discussion of uncertainty of the model is present in the Integrated Water Budget Report (AquaResource, 2009a). The key areas of uncertainty discussed are: (1) the watershed characterization (especially where observed streamflow data is not available for calibration), (2) the limited climate data available (which may not give a full representation of the spatial climate variability), (3) the errors made in both manual and continuous streamflow data collection, and (4) the limitations of the GAWSER software.

1.4.2 Steady-State Groundwater-Flow Model

To simulate groundwater flows, a regional-scale FEFLOW steady-state groundwater-flow model was developed and calibrated to available water level and baseflow data in the three Conservation Authorities.

The original groundwater flow models (WHI, 2003 & 2007) were built upon in the Integrated Water Budget Report (AquaResource, 2009a) to enhance modelling of key regional-scale features in the study area and to better represent bedrock characteristics. A significant update of the FEFLOW model was to include recharge rates estimated from the surface water model. The FEFLOW model is designed to represent average annual groundwater flow conditions, with particular focus on volumetric flow from one subwatershed to another.

The calibration targets used within the FEFLOW model calibration exercise focused on agreement between observed and simulated water levels, as well as matching baseflow estimates with simulated groundwater discharge estimates. By minimizing differences in simulated and observed values, the model's ability to represent the groundwater flow system was validated. Generally, there was good agreement between both water levels and baseflow estimates throughout the Study Area, although some local areas were identified where additional characterization and calibration would be beneficial.

Although the calibration process is performed to provide a realistic representation of physical conditions and reduce uncertainty, the model results do contain uncertainty which is a reflection of the uncertainty in the model input parameters. The uncertainty factors discussed in detail in the Integrated Water Budget Report (AquaResource, 2009a) include (1) the watershed characterization (a lack of available subsurface data limits the representation of local-scale results), (2) the calibration data (measurement errors in water levels or uncertain observed baseflow estimates), and (3) the FEFLOW modelling approach (which includes inherent numerical approximations).

1.4.3 Modelling Summary

The linking of the GAWSER models and the LPRCA/CCCA/KCCA FEFLOW model via recharge has resulted in a loosely coupled "modelling system". This modelling system includes both a physical representation of the surface water system (streamflow-generation model) and the groundwater system (groundwater flow model).

The modelling system provides the ability to simulate and quantify the relative volume of water moving through the subwatersheds, and is calibrated to two independent data sets; 1) total streamflow / baseflow; and 2) water well levels. When assessing model performance, the use of multiple, but separate datasets increases the confidence that the modelling system is reasonably representing the hydrologic processes. The Integrated Water Budget Report (AquaResource, 2009a) illustrates that the streamflow generation model was reasonably replicating observed streamflow volumes, as well as seasonal and inter-annual variability in streamflow. Recharge rates estimated from the streamflow generation model are used to constrain recharge rates within the groundwater flow model, which has been shown to reasonably replicate both water levels and baseflow estimates. Based on the overall performance of the modelling system in replicating streamflow and water levels, the modelling system is considered to be reasonably representing surface and groundwater flow volumes, and thus is able to provide realistic water budget estimates for the Study Area.

2.0 Surface Water Stress Assessment

This section summarizes the results of the Surface Water Quantity Stress Assessment completed for the Long Point, Catfish Creek, and Kettle Creek Region. This Assessment follows the requirements of the Technical Rules (MOE, 2008) and the Water Budget Guidance Module (MOE, 2007).

2.1 SUBWATERSHEDS

The Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities were further delineated into 9 major watershed areas and a total of 31 smaller subwatersheds listed in Table 1.1, Table 1.2, and Table 1.3 for Long Point Region, Catfish Creek, and Kettle Creek, respectively. All 31 subwatersheds are illustrated on Map 2. These watersheds and subwatersheds were delineated to encompass areas draining to major river systems, municipal water supply systems, and to include areas with similar physiographic features. Whenever possible, a stream gauge is maintained near the outlet of each subwatershed.

2.2 EXISTING CONDITIONS PERCENT WATER DEMAND

2.2.1 Consumptive Surface Water Use

The Long Point Region, Catfish Creek, and Kettle Creek Integrated Water Budget Report (AquaResource, 2009a) summarized the procedure followed to estimate consumptive surface water demand for each subwatershed. The monthly unit consumptive surface water demand estimates are shown in Table 2.1 for each subwatershed. All the surface water Permits-To-Take-Water in the subwatersheds are shown on Map 9. For illustrative purposes, the August unit consumptive water demand is presented on Map 11. The majority of the region is dominated by agricultural water takings; due to the seasonal nature of agricultural pumping, August best represents the month having maximum water demand.

Table 2.1 - Surface Water Unit Consumptive Demands (L/s)

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kettle Creek	Upper Kettle	3	3	3	3	3	5	5	5	5	3	3	3
	Dodd Creek	1	1	1	1	1	1	1	1	1	1	1	1
	Lower Kettle	3	3	3	3	3	31	39	43	35	3	3	3
Catfish Creek	West Catfish	3	3	3	3	3	3	3	3	3	3	3	3
	Catfish Above Aylmer	4	4	4	4	4	17	18	19	18	4	4	4
	Lower Catfish	2	2	2	2	2	66	80	93	80	2	2	2
	Silver Creek	5	5	5	5	5	59	70	80	70	5	5	5
Big Otter	Otter Above Maple Dell Road	3	3	3	3	13	40	40	40	40	13	13	3
	Otter at Otterville	2	2	2	2	2	59	63	66	62	2	2	2
	Otter at Tillsonburg	3	3	3	3	3	143	165	178	160	3	3	3
	Spittler Creek	4	4	4	4	4	14	14	14	14	4	4	4
	Lower Otter	2	2	2	2	2	125	146	167	146	2	2	2
	Little Otter	2	2	2	2	3	61	75	76	65	2	2	2
Lake Erie Tribs	South Otter	1	1	1	1	1	175	228	230	198	1	1	1
	Clear Creek	0	0	0	0	0	40	51	57	46	0	0	0

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Big Creek	Big Above Cement Road	2	2	2	2	2	14	15	17	15	2	2	2
	Big Above Kelvin Gauge	1	1	1	1	1	6	8	10	8	1	1	1
	Big Above Delhi	7	7	7	7	7	197	238	264	223	7	7	7
	North Creek	7	7	7	6	8	83	111	112	88	6	6	6
	Big Above Minnow Creek	1	1	1	1	1	92	108	117	104	1	1	1
	Big Above Walsingham	36	36	36	36	37	212	237	251	230	36	36	36
	Venison Creek	4	4	4	4	4	126	170	142	124	4	4	4
	Lower Big	2	2	2	2	2	57	62	65	60	2	2	2
Lake Erie Tribs	Dedrick Creek	45	45	45	45	45	104	124	113	102	45	45	45
	Young/Hay Creek	15	15	15	17	22	105	131	123	96	19	15	16
Lynn River	Lynn River	3	3	3	3	3	104	124	136	118	3	3	3
	Black Creek	2	2	2	2	2	7	7	7	7	2	2	2
Nanticoke Creek	Nanticoke Upper	2	2	2	2	5	49	58	58	45	2	2	2
	Nanticoke Lower	1	1	1	1	1	1	1	1	1	1	1	1
Eastern Tribs	Sandusk Creek	3	3	3	3	3	3	3	3	3	3	3	3
	Stoney Creek	2	2	2	2	2	8	8	8	8	2	2	2

2.2.2 Surface Water Supply

The monthly Q_{SUPPLY} (Median Flow) and $Q_{RESERVE}$ (90th percentile flow) were calculated using GAWSER-predicted streamflow at the outfall of each subwatershed for the period 1980-2004. This period is consistent with the observed water levels used for the calibration of the groundwater flow model, and was used for Water Budget reporting purposes in AquaResource, 2009a. A longer-term period was not used for averaging as it was felt that the current water demand estimates would not be representative of historical water use.

Several subwatersheds were not completely modelled by GAWSER due to very small areas draining directly to Lake Erie, and had their median and 90th percentile flows prorated, by area, to reflect the non-simulated area.

As was discussed in the Long Point Region, Catfish Creek, and Kettle Creek Integrated Water Budget Report (AquaResource, 2009a), a significant addition to the surface water modelling component of this project was the inclusion of water takings. This approach allows the monthly median and 90th percentile flows to reflect the impact of upstream water takings on the amount of streamflow entering a particular subwatershed. Table 2.2 shows the supply and reserve terms, in addition to their difference, used in the Stress Assessment equation (Q_{SUPPLY}- $Q_{RESERVE}$). The water supply term for the month of August, or "Difference" included in Table 2.2, is illustrated on Map 10.

Table 2.2 - Surface Water Supply Flows (L/s)

Subwatershed		Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kettle Creek	Upper Kettle	Q_{supply}	2,195	2,921	4,290	4,047	2,564	2,213	651	468	537	954	1,888	2,812
		$Q_{reserve}$	256	300	373	809	497	73	66	63	60	124	220	207
		Difference	1,939	2,621	3,918	3,237	2,067	2,139	585	405	477	830	1,668	2,605
	Dodd Creek	Q_{supply}	1,478	2,052	3,156	2,806	1,665	1,428	461	336	370	466	1,168	1,843

Subwatershed		Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		$Q_{reserve}$	156	300	491	664	385	125	79	55	40	34	31	73
		Difference	1,322	1,752	2,666	2,142	1,280	1,303	382	282	330	433	1,137	1,770
	Lower Kettle	Q_{supply}	3,941	3,647	4,799	5,081	4,188	4,019	1,846	1,198	945	1,192	2,085	3,807
		$Q_{reserve}$	1,193	1,543	2,259	3,209	2,753	1,331	810	595	507	657	799	841
		Difference	2,747	2,104	2,540	1,872	1,435	2,687	1,037	603	438	535	1,286	2,966
Catfish Creek	West Catfish	Q_{supply}	939	753	791	913	827	595	86	46	42	43	374	931
		$Q_{reserve}$	259	411	625	764	230	77	36	19	11	8	11	11
		Difference	680	341	165	149	597	517	50	27	31	36	364	920
	Catfish Above Aylmer	Q_{supply}	1,026	901	972	1,346	1,054	756	261	147	120	181	690	1,002
		$Q_{reserve}$	308	477	627	1,069	598	236	114	61	36	61	240	105
		Difference	718	425	345	277	456	520	147	86	84	120	450	897
	Lower Catfish	Q_{supply}	2,909	2,579	2,784	3,450	2,886	2,124	777	406	348	498	1,573	2,784
		$Q_{reserve}$	887	1,325	1,776	2,615	1,598	673	309	150	80	115	338	286
		Difference	2,022	1,254	1,008	835	1,287	1,450	468	256	268	383	1,235	2,498
	Silver Creek	Q_{supply}	931	890	938	1,099	1,026	739	393	234	179	235	450	818
		$Q_{reserve}$	337	392	540	724	669	365	165	93	53	38	66	122
		Difference	594	498	398	375	357	374	228	141	126	197	384	696
Big Otter	Otter Above Maple Dell Road	Q_{supply}	882	790	1,281	1,168	922	959	820	588	465	521	834	1,044
		$Q_{reserve}$	630	571	658	646	682	535	374	266	221	263	295	595
		Difference	252	219	623	522	240	424	446	322	245	259	539	449
	Otter at Otterville	Q_{supply}	1,507	1,347	2,090	1,997	1,567	1,627	1,378	936	746	837	1,414	1,712
		$Q_{reserve}$	1,070	982	1,109	1,122	1,153	854	607	452	376	438	489	942
		Difference	437	365	981	875	415	773	771	485	371	399	925	770
	Otter at Tillsonburg	Q_{supply}	3,720	3,312	5,258	5,346	4,038	4,137	3,747	2,400	1,905	2,507	3,763	4,225
		$Q_{reserve}$	2,704	2,448	2,767	3,035	2,864	2,113	1,311	983	846	1,094	1,273	2,318
		Difference	1,016	864	2,491	2,311	1,174	2,024	2,436	1,417	1,059	1,414	2,490	1,907
	Spittler Creek	Q_{supply}	865	705	1,151	1,360	837	908	721	281	188	310	913	999
		$Q_{reserve}$	617	561	656	720	566	218	133	101	88	99	139	394
		Difference	249	144	494	640	271	689	588	180	100	211	774	605
	Lower Otter	Q_{supply}	7,120	6,536	9,066	9,551	7,774	8,021	6,909	4,795	3,776	4,363	6,404	7,764
		$Q_{reserve}$	4,904	4,576	5,037	5,597	5,545	4,294	2,866	2,148	1,747	2,299	2,587	4,073
		Difference	2,216	1,960	4,029	3,954	2,229	3,727	4,043	2,647	2,030	2,063	3,817	3,691
	Little Otter	Q_{supply}	1,365	1,358	1,527	1,618	1,538	1,525	1,404	1,114	922	872	1,050	1,235
		$Q_{reserve}$	868	854	916	1,011	1,073	1,033	793	639	529	572	588	692
		Difference	496	504	611	606	465	491	611	476	393	300	461	543
Lake Erie Tribs	South Otter	Q_{supply}	1,407	1,495	1,607	1,757	1,706	1,677	1,568	1,308	1,069	1,006	1,137	1,308
		$Q_{reserve}$	936	951	992	1,002	1,116	1,131	937	751	617	626	663	786
		Difference	472	544	615	756	591	546	631	557	452	381	474	521
	Clear Creek	Q_{supply}	986	1,029	1,103	1,203	1,182	1,162	1,088	905	746	691	784	910
		$Q_{reserve}$	641	653	692	684	758	783	641	515	422	421	450	539
		Difference	346	377	412	519	424	379	447	390	324	270	334	371
Big Creek	Big Above	Q_{supply}	513	405	666	781	493	530	360	112	80	138	494	592

Subwatershed		Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Cement Road	$Q_{reserve}$	299	309	384	417	300	100	54	40	36	41	45	154
		Difference	213	96	282	365	193	430	307	72	44	97	449	438
	Big Above Kelvin Gauge	Q_{supply}	1,020	899	1,218	1,388	1,072	1,097	807	472	366	426	874	1,091
		$Q_{reserve}$	588	611	711	801	748	448	313	231	203	228	252	392
		Difference	431	288	507	587	323	649	494	240	163	199	623	699
	Big Above Delhi	Q_{supply}	3,469	3,328	3,884	4,259	3,832	3,854	3,391	2,532	2,067	2,115	2,706	3,206
		$Q_{reserve}$	2,215	2,150	2,325	2,464	2,755	2,428	1,705	1,269	1,073	1,268	1,468	1,833
		Difference	1,254	1,178	1,559	1,796	1,076	1,426	1,687	1,263	995	847	1,238	1,374
	North Creek	Q_{supply}	386	390	420	453	438	442	426	363	303	280	316	349
		$Q_{reserve}$	251	251	262	275	289	304	245	201	166	178	188	216
		Difference	136	139	158	178	149	138	181	161	137	103	129	133
	Big Above Minnow Creek	Q_{supply}	4,742	4,663	5,290	5,768	5,330	5,316	4,677	3,347	2,631	3,011	3,780	4,290
		$Q_{reserve}$	3,063	3,035	3,222	3,420	3,853	3,159	2,003	1,379	1,044	1,687	2,087	2,586
		Difference	1,679	1,628	2,069	2,348	1,477	2,157	2,673	1,969	1,586	1,324	1,694	1,704
	Big Above Walsingham	Q_{supply}	6,455	6,383	7,257	7,835	7,326	7,245	6,535	4,792	3,874	4,231	5,156	5,799
		$Q_{reserve}$	4,204	4,202	4,414	4,644	5,373	4,619	3,012	2,219	1,697	2,548	2,888	3,612
		Difference	2,251	2,181	2,843	3,191	1,953	2,626	3,524	2,573	2,177	1,683	2,268	2,187
	Venison Creek	Q_{supply}	1,169	1,224	1,323	1,439	1,397	1,370	1,293	1,074	882	832	940	1,077
		$Q_{reserve}$	771	778	817	865	929	935	773	619	506	518	544	660
		Difference	399	445	506	574	467	435	520	455	376	314	396	417
	Lower Big	Q_{supply}	8,678	8,592	10,041	10,526	9,724	9,834	8,649	6,087	5,262	6,152	7,200	7,956
		$Q_{reserve}$	5,669	5,548	6,289	6,199	7,115	6,056	3,782	2,585	2,048	3,812	4,263	4,842
		Difference	3,009	3,045	3,753	4,327	2,609	3,778	4,867	3,502	3,214	2,340	2,936	3,114
Lake Erie Tribs	Dedrick Creek	Q_{supply}	1,700	1,677	1,977	2,071	1,937	1,893	1,679	1,342	1,153	1,159	1,346	1,558
		$Q_{reserve}$	1,079	1,059	1,230	1,259	1,325	1,266	985	781	682	765	795	887
		Difference	621	619	748	811	612	627	694	561	471	395	551	671
	Young/Hay Creeks	Q_{supply}	1,524	1,232	1,341	1,400	1,384	1,364	1,272	1,063	878	872	957	1,084
		$Q_{reserve}$	997	1,001	1,027	894	1,148	1,173	968	802	664	692	719	856
		Difference	527	231	314	506	236	190	304	261	214	180	238	229
Lynn River	Lynn River	Q_{supply}	2,020	2,089	2,303	2,427	2,338	2,232	1,941	1,783	1,506	1,535	1,542	1,665
		$Q_{reserve}$	1,273	1,296	1,387	1,491	1,541	1,690	1,283	993	900	989	1,070	1,219
		Difference	747	793	916	937	796	542	658	790	606	547	472	445
	Black Creek	Q_{supply}	998	841	1,230	1,215	975	1,070	1,071	281	226	285	875	1,134
		$Q_{reserve}$	771	660	772	816	798	265	184	138	122	132	175	609
		Difference	227	182	458	399	177	804	887	143	105	153	700	525
Nanticoke Creek	Nanticoke Upper	Q_{supply}	1,401	1,392	1,340	1,356	966	900	535	395	367	1,239	1,194	1,282
		$Q_{reserve}$	503	557	424	399	537	380	248	231	225	275	736	428
		Difference	897	835	916	957	429	520	287	164	142	964	458	853
	Nanticoke Lower	Q_{supply}	2,051	1,958	2,113	2,112	1,494	1,390	663	262	194	1,425	1,616	1,990
		$Q_{reserve}$	720	819	847	783	805	276	58	46	36	162	894	581
		Difference	1,331	1,140	1,266	1,329	689	1,113	605	215	158	1,263	722	1,410

Subwatershed		Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eastern Tribs	Sandusk Creek	Q_{supply}	843	661	1,656	1,658	756	720	191	94	162	156	558	1,038
		$Q_{reserve}$	308	334	630	689	193	55	26	23	101	26	35	104
		Difference	535	327	1,026	969	564	664	165	72	61	129	523	934
	Stoney Creek	Q_{supply}	798	614	1,417	1,164	708	682	157	46	35	83	455	945
		$Q_{reserve}$	283	280	594	605	181	37	9	8	8	8	8	40
		Difference	515	334	823	559	528	645	148	39	28	75	447	905

2.2.3 Percent Water Demand

Monthly Percent Water Demand for surface water is calculated using the Percent Water Demand equation included in Section 1.3.1.2, as well as the values shown in Table 2.1 and Table 2.2.The results of this calculation are included in Table 2.3.

Table 2.3 - Percent Water Demand Estimate (Surface Water)

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
Kettle Creek	Upper Kettle	0%	0%	0%	0%	0%	0%	1%	1%	1%	0%	0%	0%	1%
	Dodd Creek	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Lower Kettle	0%	0%	0%	0%	0%	1%	4%	7%	8%	0%	0%	0%	8%
Catfish Creek	West Catfish	0%	1%	2%	2%	1%	1%	6%	12%	10%	9%	1%	0%	12%
	Catfish Above Aylmer	1%	1%	1%	1%	1%	3%	12%	**22%**	**22%**	3%	1%	0%	**22%**
	Lower Catfish	0%	0%	0%	0%	0%	5%	17%	**36%**	**30%**	1%	0%	0%	**36%**
	Silver Creek	1%	1%	1%	1%	1%	16%	**31%**	**57%**	**56%**	2%	1%	1%	**57%**
Big Otter	Otter Above Maple Dell Road	1%	1%	0%	1%	5%	9%	9%	12%	16%	5%	2%	1%	16%
	Otter at Otterville	1%	1%	0%	0%	1%	8%	8%	14%	17%	1%	0%	0%	17%
	Otter at Tillsonburg	0%	0%	0%	0%	0%	7%	7%	13%	15%	0%	0%	0%	15%
	Spittler Creek	1%	2%	1%	1%	1%	2%	2%	8%	14%	2%	0%	1%	14%
	Lower Otter	0%	0%	0%	0%	0%	3%	4%	6%	7%	0%	0%	0%	7%
	Little Otter	0%	0%	0%	0%	1%	12%	12%	16%	17%	1%	0%	0%	17%
Lake Erie Tribs	South Otter	0%	0%	0%	0%	0%	**32%**	**36%**	**41%**	**44%**	0%	0%	0%	**44%**
	Clear Creek	0%	0%	0%	0%	0%	10%	11%	15%	14%	0%	0%	0%	15%
Big Creek	Big Above Cement Road	1%	2%	1%	0%	1%	3%	5%	**23%**	**35%**	2%	0%	0%	**35%**
	Big Above Kelvin Gauge	0%	0%	0%	0%	0%	1%	2%	4%	5%	1%	0%	0%	5%
	Big Above Delhi	1%	1%	0%	0%	1%	14%	14%	**21%**	**22%**	1%	1%	0%	**22%**
	North Creek	5%	5%	4%	4%	5%	**60%**	**62%**	**69%**	**64%**	6%	4%	4%	**69%**
	Big Above Minnow Creek	0%	0%	0%	0%	0%	4%	4%	6%	7%	0%	0%	0%	7%
	Big Above Walsingham	2%	2%	1%	1%	2%	8%	7%	10%	11%	2%	2%	2%	11%
	Venison Creek	1%	1%	1%	1%	1%	**29%**	**33%**	**31%**	**33%**	1%	1%	1%	**33%**
	Lower Big	0%	0%	0%	0%	0%	1%	1%	2%	2%	0%	0%	0%	2%
Lake Erie Tribs	Dedrick Creek	7%	7%	6%	6%	7%	17%	18%	**20%**	**22%**	11%	8%	7%	**22%**
	Young / Hay Creeks	3%	7%	5%	3%	9%	**55%**	**43%**	**47%**	**45%**	10%	6%	7%	**55%**

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
Lynn River	Lynn River	0%	0%	0%	0%	0%	19%	19%	17%	19%	1%	1%	1%	19%
	Black Creek	1%	1%	1%	1%	1%	1%	1%	5%	6%	2%	0%	0%	6%
Nanticoke Creek	Nanticoke Upper	0%	0%	0%	0%	1%	9%	**20%**	**35%**	**32%**	0%	0%	0%	**35%**
	Nanticoke Lower	0%	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	1%
Eastern Tribs	Sandusk Creek	1%	1%	0%	0%	1%	0%	2%	4%	5%	2%	1%	0%	5%
	Stoney Creek	0%	1%	0%	0%	0%	1%	6%	**22%**	**31%**	3%	0%	0%	**31%**

Note: **Shaded** cells have Percent Water Demand greater than the Moderate Stress Threshold (20%)

The potential for stress classification is determined based on the thresholds presented in Table 1.4. The stress classification for each of the 31 subwatersheds is summarized in Table 2.4.

Table 2.4 - Subwatershed Surface Water Potential for Stress Classification

Subwatershed		Potential Stress Classification	Municipal Water Supply (Surface Water)
Kettle Creek	Upper Kettle	Low	None
	Dodd Creek	Low	None
	Lower Kettle	Low	None
Catfish Creek	West Catfish	Low	None
	Catfish Above Aylmer	Moderate	None
	Lower Catfish	Moderate	None
	Silver Creek	Significant	None
Big Otter	Otter Above Maple Dell Road	Low	None
	Otter at Otterville	Low	None
	Otter at Tillsonburg	Low	None
	Spittler Creek	Low	None
	Lower Otter	Low	None
	Little Otter	Low	None
Lake Erie Tribs	South Otter	Moderate	None
	Clear Creek	Low	None
Big Creek	Big Above Cement Road	Moderate	None
	Big Above Kelvin Gauge	Low	None
	Big Above Delhi	Moderate	None
	North Creek	**Significant**	**Delhi**
	Big Above Minnow Creek	Low	None
	Big Above Walsingham	Low	None
	Venison Creek	Moderate	None
	Lower Big	Low	None
Lake Erie Tribs	Dedrick Creek	Moderate	None
	Young/Hay Creeks	Significant	None
Lynn River	Lynn River	Low	None
	Black Creek	Low	None

Subwatershed		Potential Stress Classification	Municipal Water Supply (Surface Water)
Nanticoke Creek	Nanticoke Upper	Moderate	None
	Nanticoke Lower	Low	None
Eastern Tribs	Sandusk Creek	Low	None
	Stoney Creek	Moderate	None

2.3 PLANNED CONDITION PERCENT WATER DEMAND

No planned systems exist outside of the subwatersheds identified as having a Moderate or Significant potential for stress under the Current Demand Scenario; therefore, the Planned Demand Scenario was not needed for this study.

2.4 FUTURE CONDITIONS PERCENT WATER DEMAND

The Technical Rules require that a Future Demand Scenario must be completed to estimate the potential effect of projected municipal demands on subwatershed stress classifications. The Future Demand Scenario is applicable only to subwatersheds that have not already been identified as having a Moderate or Significant potential for stress under Current Demand conditions.

As the urban areas within the Study Area are seen as areas of low-growth, future land use changes are expected to have minimal, to no, impact on average subwatershed water budget parameters. As such, water budget parameters for existing land use conditions will be used for the supply and reserve terms.

2.4.1 Municipal Projections

One surface water municipal intake is present in the Long Point Region Conservation Authority, the Lehman Reservoir intake for Delhi, located in the North Creek Subwatershed. The Delhi municipal system relies on both surface and groundwater; it has been assumed that all future demand will be serviced from the groundwater wells. As a result, the future surface water municipal demands equal the current surface water municipal demands, and no additional assessment is required.

Furthermore, North Creek has already been identified as having a Significant potential for stress, which also negates the need to complete a future demand scenario.

2.4.2 Agricultural Projections

The type of crops grown in the Norfolk Sand Plain Region has changed drastically in the past 15 to 20 years. Several important trends in agriculture were documented within a Technical Memo for the Lake Erie Region Source Protection Technical Team (Wong, 2009). A summary of these trends is given in this section.

In the past, the Norfolk Sand Plain was a significant production area for tobacco. In the early 1990's cropland devoted to tobacco was approximately 15% of total land. A variety of factors have recently caused a sharp decline in the demand for tobacco, and has subsequently led to the reduction of tobacco cropland from 17,655 ha in 2001 to 9,886 ha in 2006, a decrease of 44% (Wong, 2009). Tobacco in 2006 comprised approximately 7% of total cropped land, and has likely reduced much further in recent years.

In addition to tobacco, agricultural land devoted to corn production has decreased from 36% of all cropped land in 1991 to 26% in 2006 (Wong, 2009). With the decreases in corn and tobacco crops, other crops have shown an increase in the percentage of crop land they cover.

The most significant increase in crop land coverage from 1991 to 2006 was soybean. From 1991 to 2001, soybean crop land coverage increased from approximately 15% to 25% of total crop land area (Wong, 2009). The 1991-2001 period displayed the greatest growth in soybean cropland. Between 2001 and 2006, the soybean crop land coverage has only increased by approximately 1% (Wong, 2009). This indicates the growth in soybean production has ceased.

Vegetables are another crop that has seen significant growth over recent years. Between 1991 and 2006, the crop land area covered by vegetable agriculture doubled from 3% of cropped land to 6% (Wong, 2009), and as of 2006, is comparable to the amount of land devoted to tobacco production. It is not known if current and future demand can sustain this continued growth in the vegetable sector. Other crops, such as grains, field crops, and berries and grapes, have shown very slight increases in the percentage of crop land they cover according to Agricultural Census data.

Despite the large changes in crop types covering the total agricultural area in the Norfolk Sand Plain, the total irrigated area has not changed significantly since 1991. Shown below in Table 3.6 is the percent of cropped land that was irrigated for each reporting year, along with the precipitation observed for each reporting year. It should be noted that Agricultural Census data is gathered from the year previous to the year of the Census.

Table 2.5 - Historical Irrigated Land

Census / Reporting Year	Irrigated Land (% of Total Cropped Land)	Summer Month Precipitation (% Deviation from 30 Year Average)
1991 / 1990	13.7	~0%
1996 / 1995	16.8	~-30%
2001 / 2000	12.2	~+60%
2006 / 2005	13.2	~+10%

Over the past 15 years, total irrigated land is shown to be stable, at approximately 13%. The driest year, 1995, reported the highest proportion of cropped land as being irrigated. When the percent of irrigated land is compared to precipitation records over the 1990-2005 time period, it seems that any variability in irrigated land is more dependent on precipitation than shifts in the types of crops grown. This suggests that the amount of irrigated land within the Norfolk Sand Plain has been stable and thus may not increase in the future.

While the amount of irrigated land may not increase, it is likely that the irrigation practices (number of irrigation events per year) will change with a shift in crops. For use within the Future Demand Scenario of the Stress Assessment, it is not possible to predict with any certainty what the dominant irrigated crop, or the irrigation practices that are associated with the crop, will be in the future. As a result, for Stress Assessment purposes, existing agricultural demand is assumed to be representative of future agricultural demand.

It is recommended that for broader water management purposes, additional study and consultation with the agricultural sector be undertaken to better understand the future of agriculture and water demand within the Norfolk Sand Plain.

2.5 DROUGHT SCENARIO

The MOE Technical Rules (2008) require that the Stress Assessment be completed under a two-year drought scenario for surface water. This two-year drought period is defined for surface water analysis as "the continuous two year period for which precipitation records exist with the lowest mean annual precipitation" (MOE, 2008). If a municipal surface water intake within a subwatershed has any part of the intake exposed during normal operation of the intake, or if operation of the pump was terminated because of an insufficient quantity of water being supplied to the intake, the subwatershed is classified as having a Moderate potential for stress.

The drought analysis is to be completed only for municipal surface water intakes located in subwatersheds that have not previously been identified as having a Moderate or Significant potential for stress. The only surface water intake in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities is located in North Creek Subwatershed. As the North Creek Subwatershed is the only surface water municipal intake, and has already been identified as having a Significant potential for stress under current conditions, evaluation of a drought scenario is not required.

2.6 UNCERTAINTY IN STRESS CLASSIFICATIONS

The Technical Rules indicate that each subwatershed should be labeled as having a "Low" or "High" uncertainty in regards to the Stress Assessment classification assigned to each subwatershed.

To evaluate whether the uncertainty associated with the Percent Water Demand calculations is sufficient to modify the Stress Assessment classification, a sensitivity analysis was utilized. Where the sensitivity analysis indicates that the classification may change from "Moderate" to "Low" potential, or "Low" to "Moderate" potential, an uncertainty classification of "High" is assigned. For subwatersheds with no such change, an uncertainty classification of "Low" is assigned.

The following sensitivity analysis presents four sensitivity scenarios where maximum monthly demand and supply for each subwatershed are increased and decreased by 25% to estimate Percent Water Demand results under very different surface water demand and supply conditions.

Agricultural water use is the dominant water use within the region, and required a number of assumptions to quantify the associated surface water consumptive demand. Assumptions included:

- Constant Irrigation Season – June through September;
- Number of Irrigation Events in Season – 8;
- Number of Days Pumping per Irrigation Event – 4;
- Percentage of Permitted Rate Pumped – 60%; and
- Consumptive Factor – 100%.

The assumptions, which were used to estimate agricultural demand, are based on average conditions and were verified with reported information (percentage of permitted rate pumped), feedback from the agricultural community, model simulations (average of 8 events per season), or published papers (consumptive factors). The water demand estimates, and hence the underlying assumptions, were also verified when consumptive estimates were incorporated into the GAWSER and FEFLOW models. The ability of the models to reasonably reproduce observed hydrologic conditions, while incorporating water demands, suggests that the underlying water demand assumptions are reasonable.

Despite the validation of the assumptions associated with the estimates of water demand, feedback from the agricultural community indicated that there may be significant variability within the number of days pumping per irrigation event. As a result of this, the focus of the sensitivity analysis was on the number of days pumping per irrigation event. The sensitivity of the final stress classifications to the number of days pumping was estimated by recalculating the Stress Assessment with Low and High estimates of the parameter. While the original assessment assumed 4 days of active pumping for an irrigation event, the sensitivity analysis considers low and high estimates equal to 3 and 5 days, respectively. The analysis effectively places a -25% to +25% range of analysis on the agricultural water use estimates (2 of the 4 scenarios tested). The remainder of water use (non-agricultural) estimates and all reported values were not varied. Therefore, the results of the sensitivity analysis show only how Percent Water Demand would change using different irrigation assumptions.

In addition to the water use sensitivity analysis, additional calculations were carried out by varying the water supply terms upwards and downwards by 25% (2 of the 4 scenarios tested). This is seen as a conservatively large range, as it would be unlikely that water supply volumes, at the scale of the subwatersheds, would vary by more than 25%.

Table 2.6 summarizes the results of the sensitivity analysis for surface water. The Percent Water Demand for maximum monthly demand is presented for the four surface water sensitivity scenarios. Subwatersheds which meet or exceed the Moderate potential stress thresholds are formatted **Bold**.

Table 2.6 - Surface Water Sensitivity Analysis

Subwatershed		Results Under Current Conditions	(1) Agricultural Surface Water Demand x 75%	(2) Agricultural Surface Water Demand x 125%	(3) Supply x 75%	(4) Supply x 125%
		% Water Demand	% Water Demand	% Water Demand	% Water Demand	% Water Demand
		Max Month	Max Month	Max Month	Max Month	Max Month
Kettle Creek	Upper Kettle	1%	1%	1%	2%	1%
	Dodd Creek	0%	0%	0%	0%	0%
	Lower Kettle	8%	7%	9%	11%	6%
Catfish Creek	West Catfish	12%	12%	12%	16%	9%
	Catfish Above Aylmer	**22%**	18%	**27%**	**30%**	18%
	Lower Catfish	**36%**	**27%**	**45%**	**48%**	**29%**
	Silver Creek	**57%**	**44%**	**71%**	**76%**	**46%**
Big Otter	Otter Above Maple Dell Road	16%	13%	19%	**22%**	13%
	Otter at Otterville	17%	13%	**21%**	**22%**	13%
	Otter at Tillsonburg	15%	11%	19%	**20%**	12%
	Spittler Creek	14%	12%	17%	19%	11%
	Lower Otter	7%	5%	9%	10%	6%
	Little Otter	17%	13%	**21%**	**22%**	13%
Lake Erie Tribs	South Otter	**44%**	**33%**	**55%**	**59%**	**35%**
	Clear Creek	15%	11%	18%	19%	12%
Big Creek	Big Above Cement Road	**35%**	**27%**	**43%**	**47%**	**28%**
	Big Above Kelvin Gauge	5%	4%	6%	6%	4%
	Big Above Delhi	**22%**	17%	**28%**	**30%**	18%
	North Creek	**69%**	**53%**	**86%**	**93%**	***56%***

Subwatershed		Results Under Current Conditions	(1) Agricultural Surface Water Demand x 75%	(2) Agricultural Surface Water Demand x 125%	(3) Supply x 75%	(4) Supply x 125%
		% Water Demand	% Water Demand	% Water Demand	% Water Demand	% Water Demand
		Max Month	Max Month	Max Month	Max Month	Max Month
	Big Above Minnow Creek	7%	5%	8%	9%	5%
	Big Above Walsingham	11%	8%	13%	14%	8%
	Venison Creek	**33%**	**25%**	**41%**	**44%**	**26%**
	Lower Big	2%	1%	2%	2%	1%
Lake Erie Tribs	Dedrick Creek	**22%**	19%	**25%**	**29%**	17%
	Young/Hay Creeks	**55%**	**46%**	**64%**	**74%**	**44%**
Lynn River	Lynn River	19%	15%	**24%**	**26%**	16%
	Black Creek	6%	6%	7%	8%	5%
Nanticoke Creek	Nanticoke Upper	**35%**	**27%**	**44%**	**47%**	**28%**
	Nanticoke Lower	1%	1%	1%	1%	1%
Eastern Tribs	Sandusk Creek	5%	5%	5%	7%	4%
	Stoney Creek	**31%**	**31%**	**31%**	**41%**	**24%**

The sensitivity analysis had a minimal impact on the Stress Assessment classifications presented in Table 2.4. For nine of the twelve subwatersheds classified as having a Moderate or Significant potential for stress in Table 2.4 (i.e. Lower Catfish, Silver Creek, South Otter, Big Above Cement Road, North Creek, Venison Creek, Young/Hay Creeks, Nanticoke Upper, and Stoney Creek Subwatersheds), the sensitivity analysis confirmed the Percent Water Demand as being greater than the 20% threshold value for all four sensitivity scenarios. For the remaining three identified subwatersheds (i.e. Dedrick Creek, Big Above Delhi, and Catfish Creek Above Aylmer Subwatersheds), a 25% decrease in demand and a 25% increase in supply resulted in these subwatersheds having a Low potential for stress.

The Lynn River, Little Otter, Otter at Tillsonburg, Otter at Otterville, and Otter Above Maple Dell Road Subwatersheds were classified as having a Low potential for stress in the base scenario. However, the sensitivity analysis shows that a Percent Water Demand greater than 20% is possible by increasing the agricultural water demand or decreasing the water supply parameters by 25%.

Table 2.7 summarizes the results of the sensitivity analysis. Those subwatersheds which were originally identified as having a Moderate or Significant potential for stress and retained that classification for all sensitivity scenarios, were assigned an Uncertainty Classification of “Low”. Likewise, those subwatersheds originally identified as having a Low potential for stress, and retained this classification for all sensitivity scenarios were assigned an Uncertainty Classification of “Low”. An uncertainty classification of “High” was assigned to subwatersheds whose potential for stress changed for at least one of the sensitivity scenarios.

Table 2.7 - Low or High Uncertainty based on Sensitivity Analysis

Subwatershed		Low or High Uncertainty
Kettle Creek	Upper Kettle	Low
	Dodd Creek	Low

Subwatershed		Low or High Uncertainty
	Lower Kettle	Low
Catfish Creek	West Catfish	Low
	Catfish Above Aylmer	**High**
	Lower Catfish	Low
	Silver Creek	Low
Big Otter	Otter Above Maple Dell Road	**High**
	Otter at Otterville	**High**
	Otter at Tillsonburg	**High**
	Spittler Creek	Low
	Lower Otter	Low
	Little Otter	**High**
Lake Erie Tribs	South Otter	Low
	Clear Creek	Low
Big Creek	Big Above Cement Road	Low
	Big Above Kelvin Gauge	Low
	Big Above Delhi	**High**
	North Creek	Low
	Big Above Minnow Creek	Low
	Big Above Walsingham	Low
	Venison Creek	Low
	Lower Big	Low
Lake Erie Tribs	Dedrick Creek	**High**
	Young/Hay Creeks	Low
Lynn River	Lynn River	**High**
	Black Creek	Low
Nanticoke Creek	Nanticoke Upper	Low
	Nanticoke Lower	Low
Eastern Tribs	Sandusk Creek	Low
	Stoney Creek	Low

2.7 UNCERTAINTY ASSESSMENT

As per the Technical Rules (MOE, 2008), subwatersheds that are not identified as being under a Moderate or Significant potential for stress may be assigned a classification of Moderate potential for stress if all the following are true (Technical Rules, Rule #34, 2f):

1. The maximum monthly Percent Water Demand is between 18% and 20%;
2. The uncertainty associated with the Percent Water Demand calculations, when evaluated to be either “Low” or “High” is High; and

3. When an uncertainty analysis using appropriate error bounds suggests that the potential for stress could be Moderate.

As presented in Table 2.3, the only subwatershed that meets the first criteria is Lynn River. The Percent

Water Demand for the Lynn River was found to be 19% under Current Demand and a "High" uncertainty (Table 2.7). Table 2.8 displays the Percent Water Demand results for the four uncertainty scenarios.

Table 2.8 - Lynn River Uncertainty Analysis

Subwatershed	Results Under Current Conditions	(1) Surface Water Demand x 90%	(2) Surface Water Demand x 110%	(3) Supply x 90%	(4) Supply x 110%
	% Water Demand	% Water Demand	% Water Demand	% Water Demand	% Water Demand
	Max Month	Max Month	Max Month	Max Month	Max Month
Lynn River	19%	17%	**21%**	**22%**	18%

As shown in this Table, the Lynn River Subwatershed is shown to have a Moderate potential for stress (> 20% Demand) when either consumptive demand is increased by 10%, or supply is decreased by 10%. Consequently, the Lynn River subwatershed meets all three criteria of the Technical Rules for the uncertainty assessment and is classified as having a Moderate potential for stress.

2.8 TEMPORAL VARIABILITY OF PERCENT WATER DEMAND ESTIMATES

The Stress Assessment, as described so far in this chapter, is based on estimated average water demands and statistical estimates of surface water supply (Q_{SUPPLY}) and reserve flow ($Q_{RESERVE}$). The objective of the assessment has been satisfied; the subwatersheds were identified with potential stress. The assessment, however, does not recognize that hydrologic conditions change from year to year, and as a result, the Percent Water Demand may be higher in some years than in it is in others.

The goal of this temporal analysis is to confirm the above analysis (based on average conditions) by evaluating the frequency that subwatersheds would be classified as having a Percent Water Demand above the prescribed thresholds. This section provides an analysis of Percent Water Demand over a longer term range of hydrologic conditions; the analysis is completed for each month over the 1960 to 2004 period.

2.8.1 Water Demand Variability

The temporal analysis of percent surface water demand does not estimate past Percent Water Demands from 1960 to 2004, but rather estimates what current Percent Water Demand would look like under a range of observed climatic conditions. Water demands are held constant from year to year and are considered to be equal to the current water demand estimates, with the exception of agricultural demands. The only change to demand from year to year in the temporal analysis is the estimated variability of agricultural irrigation demands, as irrigation demands are assumed to change with changing climate annually.

2.8.1.1 Irrigation Event Model and Irrigation Demand

For many subwatersheds, agricultural irrigation is the largest water demand sector and it has the potential to fluctuate significantly from year to year. Lake Erie Source Protection staff solicited feedback from the Canada-Ontario Water Supply Expansion Program (COWSEP) Steering Committee for "Coordinating Crop Irrigation Use Across the Norfolk Sand Plain" regarding typical irrigation months. This committee includes area irrigators, who indicated that most irrigators were typically active from June until September (COWSEP Steering Committee Minutes, July 31st. 2007). From this feedback, it was assumed that all agricultural Permits-To-Take-Water had the potential to be active for these months.

In order to estimate the variability of irrigation water demand due to climate conditions, a model was developed to estimate the number of irrigation events occurring each year from June to September. This model relies on the GAWSER model's prediction of soilwater in typical soil conditions over the 1980-1999 simulation period. The model was first documented in the GRCA Water Use Study (2005) and is further documented in the Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget Report (AquaResource, 2009a). The model assumes that changes in irrigation practices will not occur during the period.

When soilwater content predicted by the GAWSER model reaches approximately 50% of the soilwater storage, or halfway between the field capacity and the wilting point, crops are considered to become "water-stressed". If this threshold is reached during a month of active irrigation, the irrigation model triggers an irrigation event that increases soilwater content by 25 mm. This new water is allowed to evaporate during subsequent timesteps. When the soilwater content again drops below the specified threshold, another irrigation event is triggered, provided at least one week has passed since the previous irrigation event.

Irrigation events in September may occur for different reasons than to simply augment soilwater, which is the main purpose for irrigation from June to August. Irrigation within the month of September may be carried out for crop cooling, wetting of mulch, fertilization, or others purposes. As such, irrigation duration and intensity may be different for this month than for the remainder of the summer months. Since the model assumes that changes in irrigation practices will remain similar throughout the June-September period, irrigation demand associated with the month of September may be conservatively high. Without further details on actual irrigation practices or timing of irrigation in September, the estimate given by the model is suitable for the purpose of varying monthly demand. The sensitivity analysis varying demand by 25% (Section 2.6) is expected to identify where the effects of variable irrigation demand may impact the Stress Assessment classifications.

The result of the irrigation demand model is a time series indicating when soilwater conditions would require an irrigation event to sustain agricultural crops. The model time series estimates the number of irrigation events required each month during the 1960-2004 simulation period. This is a relative indicator of the need for irrigation based on climate and hydrologic conditions.

Table 2.9 summarizes the irrigation event model output including the number of monthly irrigation events, the total annual number of irrigation events, and the average monthly number of irrigation events.

Table 2.9 - Irrigation Event Model Output

Year	Number of Irrigation Events												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1961	0	0	0	0	0	0	1	0	3	0	0	0	4
1962	0	0	0	0	0	4	4	4	3	0	0	0	15
1963	0	0	0	0	0	1	3	1	4	0	0	0	9
1964	0	0	0	0	0	1	3	0	1	0	0	0	5
1965	0	0	0	0	0	1	3	4	3	0	0	0	11
1966	0	0	0	0	0	0	4	4	2	0	0	0	10
1967	0	0	0	0	0	0	0	4	4	0	0	0	8
1968	0	0	0	0	0	0	2	3	1	0	0	0	6

Year	Number of Irrigation Events												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1969	0	0	0	0	0	0	0	4	3	0	0	0	7
1970	0	0	0	0	0	3	1	4	3	0	0	0	11
1971	0	0	0	0	0	1	4	3	4	0	0	0	12
1972	0	0	0	0	0	0	0	2	4	0	0	0	6
1973	0	0	0	0	0	0	3	4	4	0	0	0	11
1974	0	0	0	0	0	0	0	4	4	0	0	0	8
1975	0	0	0	0	0	0	4	3	0	0	0	0	7
1976	0	0	0	0	0	0	0	2	4	0	0	0	6
1977	0	0	0	0	0	2	4	1	0	0	0	0	7
1978	0	0	0	0	0	0	3	3	1	0	0	0	7
1979	0	0	0	0	0	0	3	2	1	0	0	0	6
1980	0	0	0	0	0	0	2	3	0	0	0	0	5
1981	0	0	0	0	0	0	2	3	0	0	0	0	5
1982	0	0	0	0	0	0	0	2	3	0	0	0	5
1983	0	0	0	0	0	0	2	0	0	0	0	0	2
1984	0	0	0	0	0	0	0	2	0	0	0	0	2
1985	0	0	0	0	0	0	1	2	1	0	0	0	4
1986	0	0	0	0	0	0	1	3	2	0	0	0	6
1987	0	0	0	0	0	2	4	3	4	0	0	0	13
1988	0	0	0	0	0	2	2	2	3	0	0	0	9
1989	0	0	0	0	0	0	3	4	2	0	0	0	9
1990	0	0	0	0	0	0	0	3	3	0	0	0	6
1991	0	0	0	0	0	1	3	0	4	0	0	0	8
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	1	4	3	0	0	0	8
1994	0	0	0	0	0	0	0	0	3	0	0	0	3
1995	0	0	0	0	0	1	4	3	4	0	0	0	12
1996	0	0	0	0	0	0	0	3	1	0	0	0	4
1997	0	0	0	0	0	0	0	3	2	0	0	0	5
1998	0	0	0	0	0	3	3	4	4	0	0	0	14
1999	0	0	0	0	0	3	4	3	0	0	0	0	10
2000	0	0	0	0	0	0	0	0	2	0	0	0	2
2001	0	0	0	0	0	0	4	3	3	0	0	0	10
2002	0	0	0	0	0	0	3	4	2	0	0	0	9
2003	0	0	0	0	0	0	2	3	3	0	0	0	8
2004	0	0	0	0	0	0	1	4	3	0	0		8
Monthly Average:	0	0	0	0	0	1	2	3	2	0	0	0	-

Using the agricultural irrigation maximum permitted demands given by the Permits-to-Take-Water database, the total water demand required for one irrigation event was determined for each permit as follows:

- The maximum permitted rate of L/d is a high estimate of irrigation pumping. Actual reported pumping rates were compared with maximum permitted pumping rates in the Norfolk Sand Plain Region; it was found that reported pumping rates were approximately 60% of the permitted maximum pumping rates. The maximum permitted rate for each permit was multiplied by a factor of 60% as an estimate of actual pumping rates;
- The estimated actual pumping rates for surface water have a consumptive factor of 1.0 to represent that the water taken from the water source was not returned to that source in a reasonable amount of time;
- Each irrigation event was assumed to last for 4 days.

The factors given above are explained in more detail in the Integrated Water Budget Report (AquaResource, 2009a). By multiplying the maximum permitted rate for each permit by 60% to represent actual pumping rates, 1.0 to represent consumptive use, and 4 days to represent the length of one irrigation event, a water demand per one irrigation event for each permit was determined.

By summing all the permitted irrigation water demands per irrigation event in each subwatershed, a total irrigation demand per irrigation event was calculated for each subwatershed. These irrigation demands are given in Table 2.10 for each subwatershed.

Table 2.10- Surface Water Demand per Irrigation Event for each Subwatershed

Subwatershed		Irrigation Demand per Event (L/s)
Kettle Creek	Upper Kettle	1
	Dodd Creek	0
	Lower Kettle	12
Catfish Creek	West Catfish	0
	Catfish Above Aylmer	7
	Lower Catfish	39
	Silver Creek	33
Big Otter	Otter Above Maple Dell Road	14
	Otter at Otterville	30
	Otter at Tillsonburg	78
	Spittler Creek	5
	Lower Otter	72
	Little Otter	31
Lake Erie Tribs	South Otter	99
	Clear Creek	22
Big Creek	Big Above Cement Road	7
	Big Above Kelvin Gauge	3
	Big Above Delhi	107
	North Creek	39
	Big Above Minnow Creek	47
	Big Above Walsingham	95
	Venison Creek	58

Subwatershed		Irrigation Demand per Event (L/s)
Lake Erie Tribs	Lower Big	28
	Dedrick Creek	28
	Young/Hay Creeks	37
Lynn River	Lynn River	52
	Black Creek	1
Nanticoke Creek	Nanticoke Upper	19
	Nanticoke Lower	0
Eastern Tribs	Sandusk Creek	0
	Stoney Creek	0

The total irrigation demand for each month was estimated by multiplying the irrigation demand per irrigation event (Table 2.10) by the number of irrigation events each month (Table 2.9). For example, Lynn River has a total irrigation water demand of 52 L/s every time an irrigation event occurs. In 1989, the irrigation demand model predicted that zero (0) irrigation events would occur in June, three would occur in July, four would occur in August, and two would occur in September. The variable agricultural demand in these months would thus be 0 L/s in June, 156 L/s in July, 208 L/s in August, and 104 L/s in September.

These monthly variable agricultural irrigation demands were then summed with all the other surface water demand components (i.e. non-agricultural PTTWs and reported agricultural PTTWs), resulting in a water demand estimate that accounted for the influence of climate on irrigation water demand. These demands were then used in the Percent Water Demand Variability calculations.

2.8.2 Water Supply Variability

Monthly estimates of surface water supply (Q_{SUPPLY}) were determined using the GAWSER model's flow output for each subwatershed for the entire simulation period of 1960 - 2004. The monthly estimates of flow take into account all the upstream water takings, as explained in the Integrated Water Budget Report (AquaResource, 2009a). The previously calculated monthly water reserve ($Q_{RESERVE}$) terms (Table 2.2) are used in this analysis and do not change from year-to-year.

2.8.3 Percent Water Demand Variability

The Percent Water Demand was calculated for each month from January 1961 to November 2004 using variable monthly water demands, variable monthly median flows (Q_{SUPPLY}), and the long term 90th percentile flow ($Q_{RESERVE}$ as given in Table 2.2). The temporal analysis of percent surface water demand does not estimate past Percent Water Demands from 1961 to 2004, but rather estimates what current Percent Water Demand would look like under the range of previously observed climatic conditions.

The monthly Percent Water Demand variability calculation evaluates the frequency that the Percent Water Demand exceeds the stress thresholds used within the Stress Assessment. This evaluation helps to understand and confirm the Stress Assessment. The following sections summarize the results of the Percent Water Demand Variability analysis for the three subwatersheds classified as having a Significant potential for stress under existing conditions. All other results are provided in Appendix A.

2.8.3.1 Silver Creek Subwatershed

The Silver Creek Subwatershed was estimated to have a maximum monthly Percent Water Demand of 57% in the Surface Water Stress Assessment in Section 2.2.3. This Percent Water Demand results in the subwatershed being classified as having a Significant potential for stress. Figure 1 illustrates the results of the temporal analysis, summarizing the monthly Percent Water Demand results for each year.

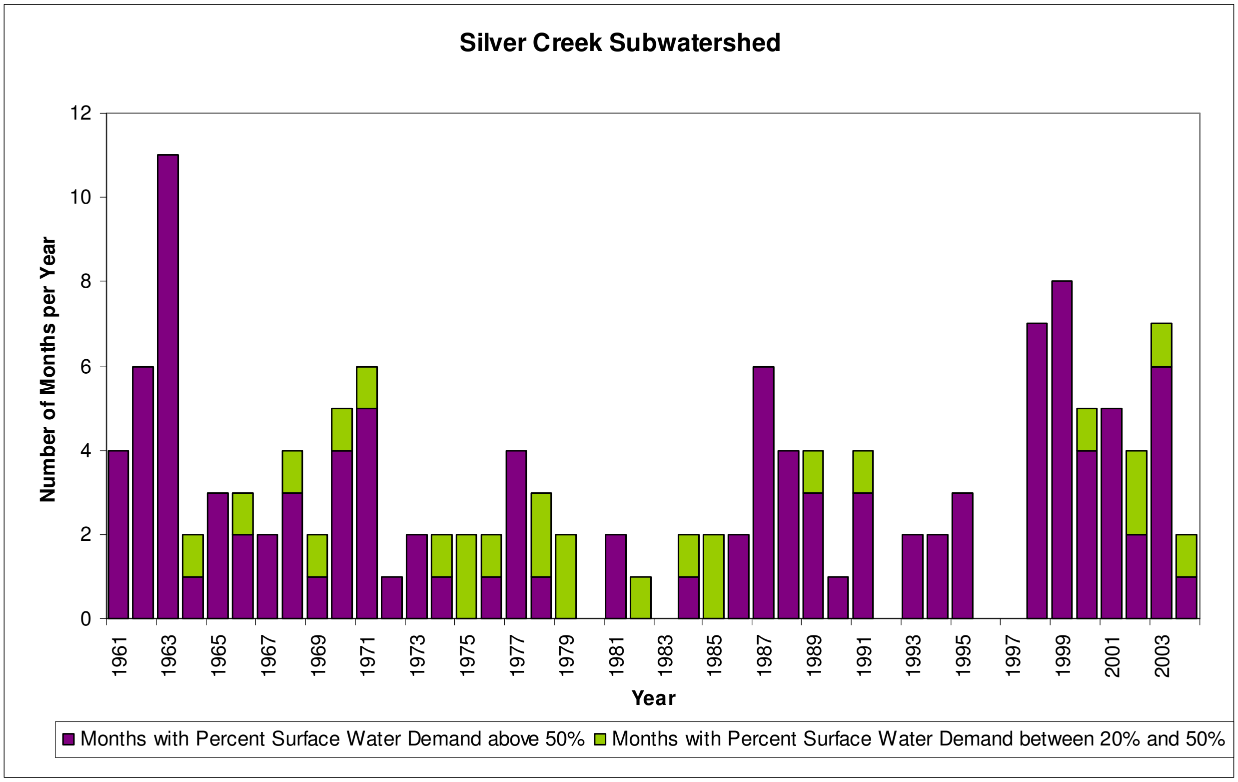


Figure 1 - Silver Creek Subwatershed - Annual Number of Months Potentially Stressed

For each year, Figure 1 summarizes each year based on the monthly Percent Water Demand as follows:

- Months with Percent Water Demand greater than 20% but less than 50%. The Technical Rules identify 20% as the threshold to indicate a Moderate potential for stress.
- Months with Percent Water Demand greater than 50%. The Technical Rules identify 50% as the threshold indicating a Significant potential for stress.

As is shown in Figure 1, the majority of months in the 1961-2004 period have Percent Water Demands less than 20%. Despite this, all years, with the exception of five, have at least one month with a Percent Water Demand greater than 20%. While this Subwatershed does not have a high Percent Water Demand for the majority of months in a particular year, it does have a high Percent Water Demand, for at least one month, for the majority of years. This is characteristic of a subwatershed whose primary water use is tightly focused in one season (agricultural demand).

Figure 1 also illustrates the impact of climate on Percent Water Demand. Years of lower precipitation and surface water supply are seen at the beginning of the 1960s, and between 1998 and 2003, where the number of months that have a Moderate or Significant potential for stress are much higher than other years shown in the analysis.

Figure 2 illustrates a ranked curve of monthly Percent Surface Water Demand for the Silver Creek Subwatershed. The threshold for Moderate potential stress is included at 20%. This figure shows that the Percent Water Demand is greater than the 20% threshold for approximately 27% of the months simulated. When viewing this figure it should be noted that the primary water use sector (agricultural irrigation) is only active 4 months per year, or 33% of the time. This short duration water use is the primary cause of the Percent Water Demand being below the 20% threshold approximately 70% of the time.

Additionally, it is estimated that the Percent Water Demand is greater than 100% for more than 15% of the months. Having a Percent Water Demand greater than 100% is possible when the monthly water demand is greater than the difference between Q_{SUPPLY} and $Q_{RESERVE}$ and does not necessarily imply that the water demand is greater than the streamflow during that month. While this condition would be observed when water demand is high, it would also occur when the median monthly flow (Q_{SUPPLY}) for a particular time step is less than the long-term water reserve estimate; this is often a result of naturally occurring low flow conditions.

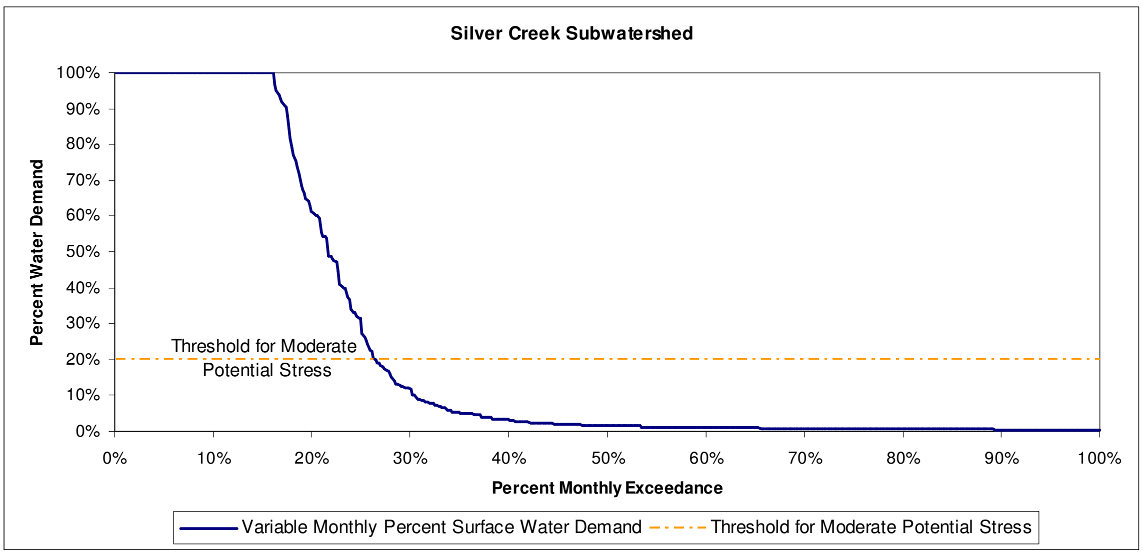


Figure 2 - Silver Creek Subwatershed - Ranked Monthly Percent Water Demand

2.8.3.2 North Creek Subwatershed

The North Creek Subwatershed area was estimated to have a maximum monthly Percent Water Demand equal to 69% in the Surface Water Stress Assessment in Section 2.2.3, resulting in a Significant subwatershed stress classification. Figure 3 shows the results of the variability analysis on this Subwatershed. All years, except 1992, have at least one month with a Percent Surface Water Demand greater than 20%. Compared to the Silver Creek Subwatershed, there are more years showing potentially stressed conditions as well as more months per year showing Moderate and Significant potential for stress. Both subwatersheds show a response to the annual climate conditions, with higher numbers of months that show potential stress in the drier climate years.

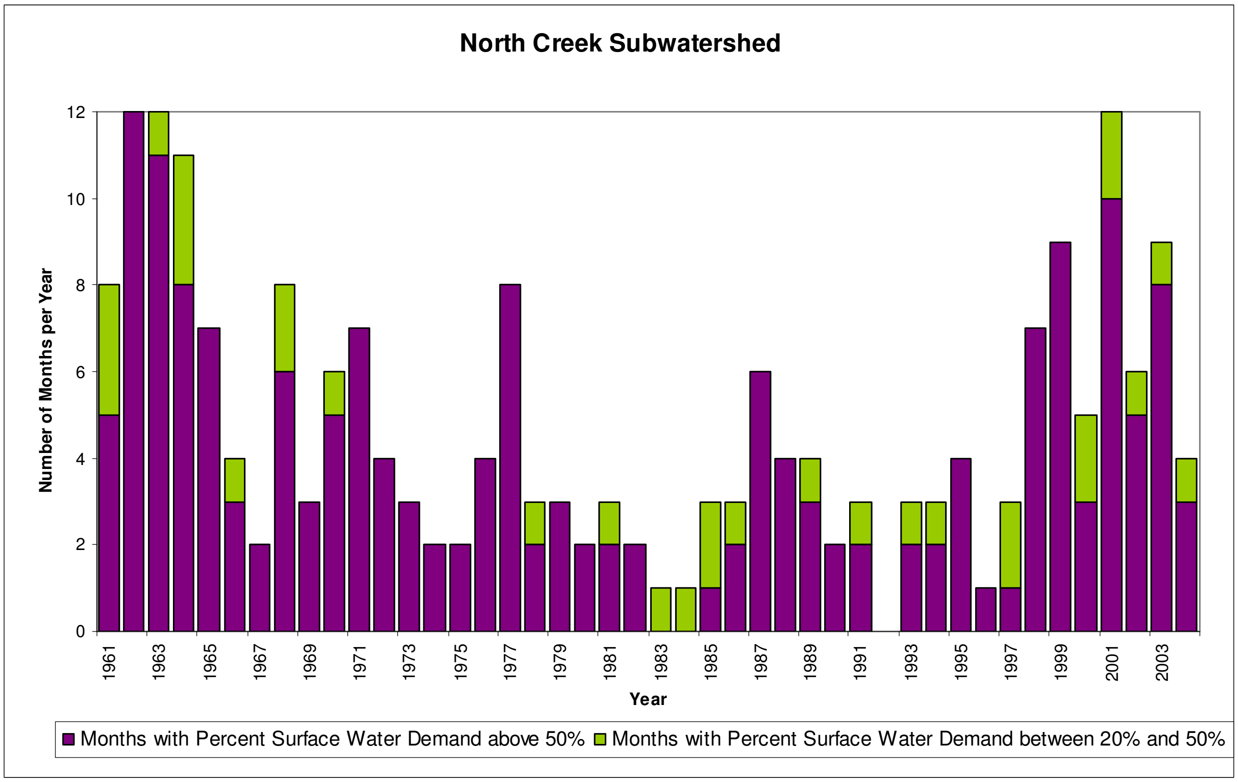


Figure 3 - North Creek Subwatershed - Annual Number of Months Potentially Stressed

Figure 4 shows a ranked curve of monthly percent surface water demands for the North Creek Subwatershed. This figure shows that approximately 40% of the months during the 1961-2004 simulation period have a Percent Water Demand greater than 20%. As with most subwatersheds within the Norfolk Sand Plain, agricultural takings are the dominant surface water use. Due to the short-term intensity of agricultural takings, only a few months each year have a high Percent Water Demand.

Approximately 30% of the months in the 1961-2004 period have a Percent Water Demand of 100%. A Percent Water Demand of 100 % indicates that either the consumptive demand is greater than the available supply $(Q_{median} - Q_{reserve})$ or that the median flow for a particular month is below the long term average reserve flow (90th percentile).

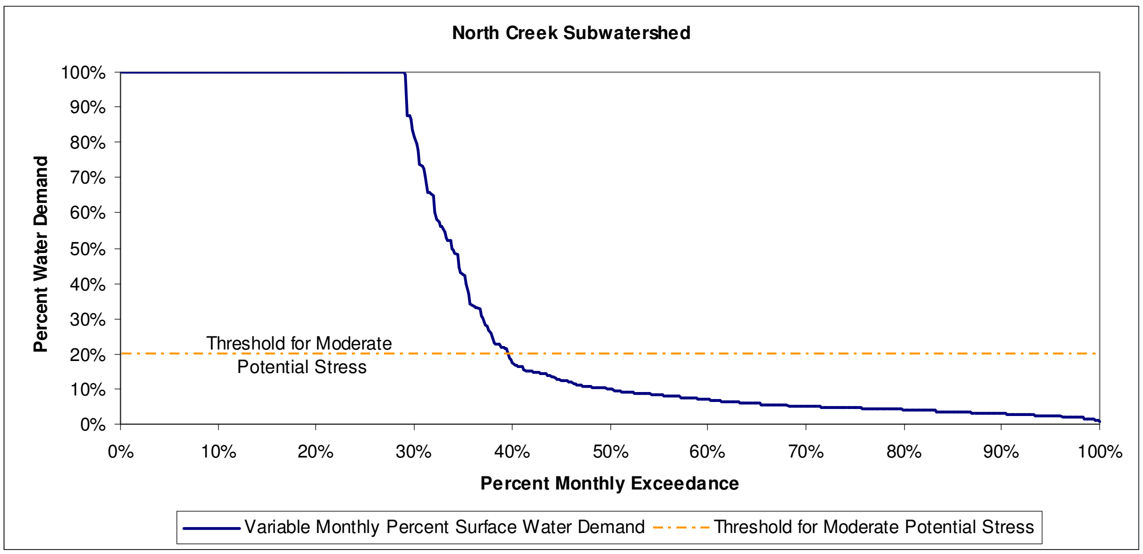


Figure 4 - North Creek Subwatershed - Ranked Monthly Percent Water Demand

2.8.3.3 Young/Hay Creeks Subwatersheds

Young/Hay Creeks Subwatershed was estimated to have a maximum Percent Water Demand of 55% in the Surface Water Stress Assessment in Section 2.2.3, resulting in a Significant potential for stress subwatershed classification. Figure 5 shows the number of months each year that are classified as having a potential for Moderate or Significant potential for stress in the Young/Hay Creeks Subwatershed.

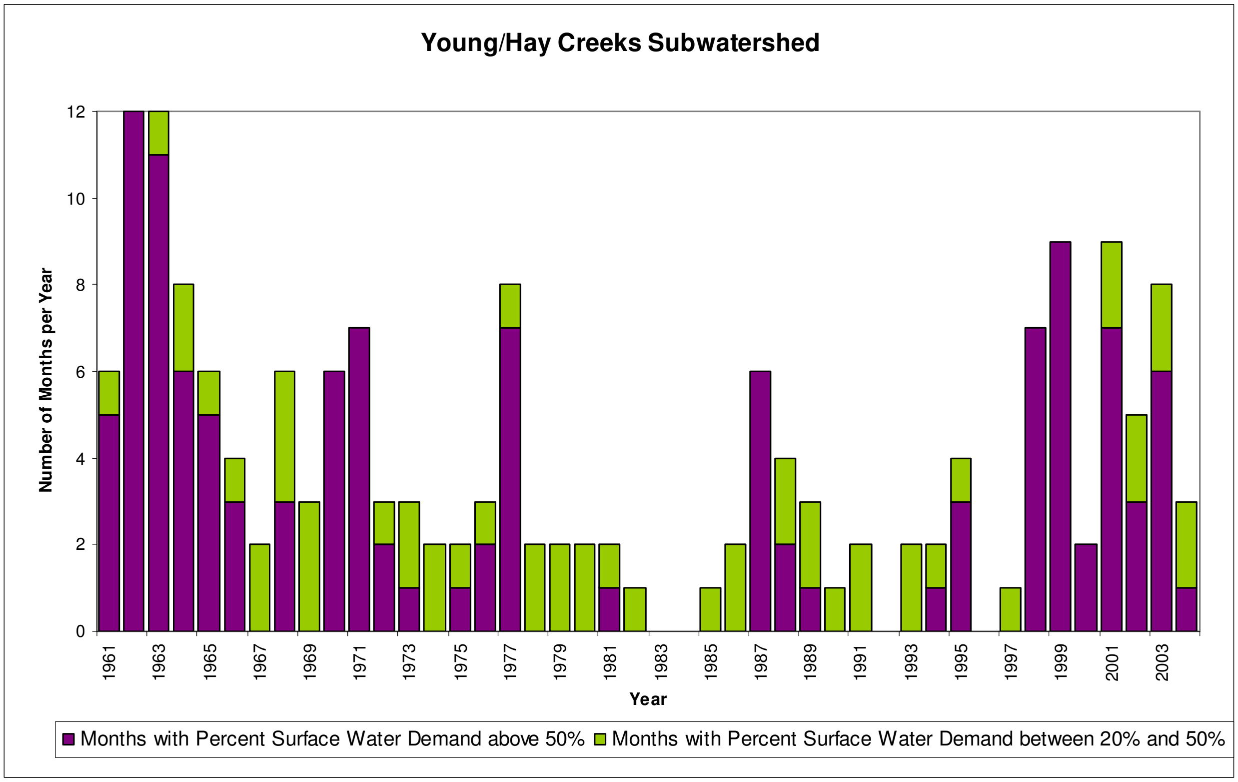


Figure 5 - Young/Hay Creeks Subwatershed - Annual Number of Months Potentially Stressed

The results of the Percent Water Demand Variability analysis for the Young/Hay Creeks Subwatershed indicate that all years, with the exception of four, have a Percent Water Demand greater than 20%. Similar to the North Creek and Silver Creek subwatershed results, a reflection of climate conditions are easily seen in the results of the analysis, with a high number of months showing a relatively high potential for stress in the early 1960s and between 1998 and 2003.

Figure 6 presents a ranked curve of monthly Percent Surface Water Demands for the Young/Hay Creeks Subwatershed. This figure shows that approximately 33% of the months during the 1961-2004 simulation period have a Percent Water Demand greater than 20%. Nearly 20% of the months show a Percent Water Demand equal to or greater than 100 %. A Percent Water Demand of 100 % occurs when the demand surpasses the available supply $(Q_{median} - Q_{reserve})$ or when the median flow for that month is below the long term average reserve flow (90th percentile). Agricultural water use is the most significant sector water use in the Subwatershed. As with the North Creek and Silver Creek Subwatersheds, agricultural water demand is restricted to the growing season, which results in low Percent Water Demand for most months of the year.

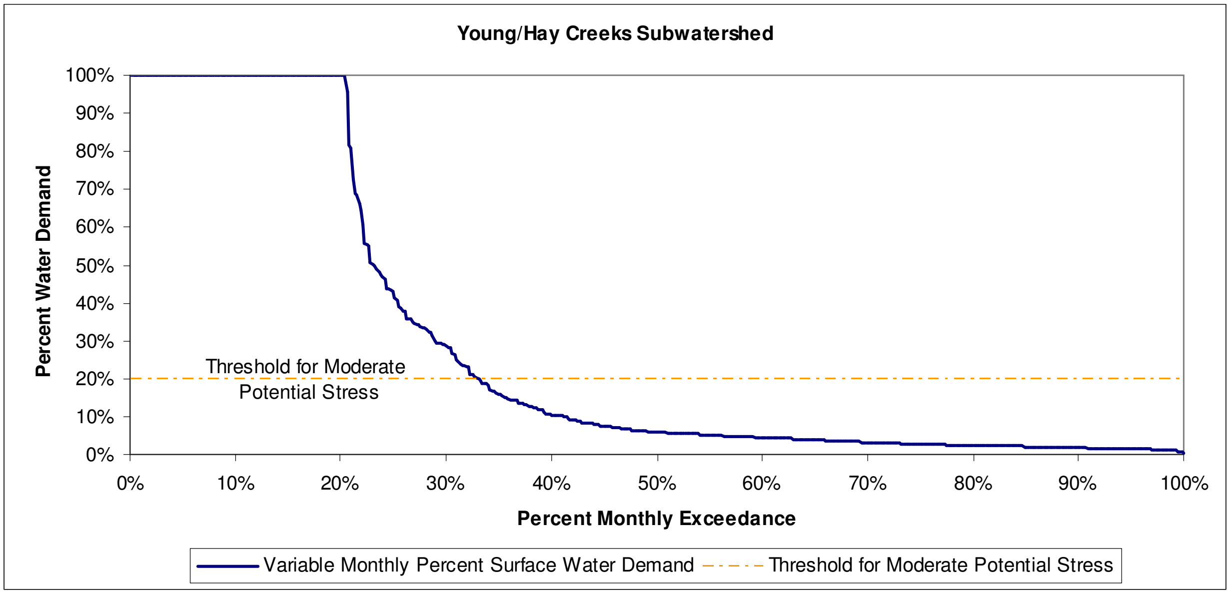


Figure 6 - Young/Hay Creeks Subwatershed - Ranked Monthly Percent Water Demand

2.9 SURFACE WATER STRESS ASSESSMENT RESULTS

Based on the Percent Water Demand calculations for current and future demand conditions, and the results of the Drought Scenario, the surface water stress classifications are included in Table 2.12 below. The potential stress thresholds that are used to identify subwatersheds as having a Moderate or Significant potential for stress are once again presented in Table 2.11 (repeated from Table 1.4). Percent Water Demand for surface water supplies is evaluated based on the maximum monthly Percent Water Demand. If a subwatershed is classified as having a Moderate or Significant potential for stress under monthly maximum conditions, municipal supplies located within the subwatershed meet the Technical Rules requirements for a Tier 3 Water Quantity Risk Assessment.

Table 2.11 - Surface Water Potential Stress Thresholds

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

Table 2.12 - Subwatershed Surface Water Potential for Stress Classification

Subwatershed		Potential Stress Classification	Municipal Water Supply (Surface Water)
Kettle Creek	Upper Kettle	Low	None
	Dodd Creek	Low	None
	Lower Kettle	Low	None
Catfish Creek	West Catfish	Low	None
	Catfish Above Aylmer	Moderate	None
	Lower Catfish	Moderate	None
	Silver Creek	Significant	None
Big Otter	Otter Above Maple Dell Road	Low	None
	Otter at Otterville	Low	None
	Otter at Tillsonburg	Low	None
	Spittler Creek	Low	None
	Lower Otter	Low	None
	Little Otter	Low	None
Lake Erie Tribs	South Otter	Moderate	None
	Clear Creek	Low	None
Big Creek	Big Above Cement Road	Moderate	None
	Big Above Kelvin Gauge	Low	None
	Big Above Delhi	Moderate	None
	North Creek	**Significant**	**Delhi**
	Big Above Minnow Creek	Low	None
	Big Above Walsingham	Low	None
	Venison Creek	Moderate	None
	Lower Big	Low	None
Lake Erie Tribs	Dedrick Creek	Moderate	None
	Young/Hay Creeks	Significant	None
Lynn River	Lynn River	Moderate	None
	Black Creek	Low	None
Nanticoke Creek	Nanticoke Upper	Moderate	None
	Nanticoke Lower	Low	None
Eastern Tribs	Sandusk Creek	Low	None
	Stoney Creek	Moderate	None

The Surface Water Subwatershed Stress Assessment described in this chapter classifies the following subwatersheds as having a Moderate potential for stress:

- Catfish Above Aylmer Subwatershed;
- Lower Catfish Subwatershed;
- South Otter Subwatershed;
- Big Above Cement Road Subwatershed;
- Big Above Delhi Subwatershed;

- Venison Creek Subwatershed;
- Dedrick Creek Subwatershed;
- Lynn River Subwatershed;
- Nanticoke Upper Subwatershed; and
- Stoney Creek Subwatershed.

The Surface Water Stress Assessment classifies the following subwatersheds as having a Significant potential for stress:

- Silver Creek Subwatershed;
- North Creek Subwatershed; and
- Young/Hay Creeks Subwatershed.

All other subwatersheds in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities are classified as having a Low potential for surface water stress, as defined within the Technical Rules (MOE, 2008). The results of the Tier 2 Surface Water Stress Assessment are illustrated on Map 12.

It should be noted that the sensitivity analysis in Section 2.6 also identified a number of subwatersheds that may have Percent Water Demands that exceed 20%, given 25% variations in either supply or consumptive demand. These subwatersheds are not identified under the Provincial Stress Assessment framework; they are identified below for information purposes.

- Otter Creek at Above Maple Dell Road Subwatershed;
- Otter Creek at Otterville Subwatershed;
- Otter Creek at Tillsonburg Subwatershed; and
- Little Otter Creek Subwatershed.

While these subwatersheds are classified as having a Low potential for stress under the Technical Rules (MOE, 2008), the sensitivity surrounding that classification should be considered for watershed management initiatives beyond Source Protection. Shifts in water use practices, particularly within the agricultural sector, have the ability to increase the Percent Water Demand beyond the Moderate potential for stress threshold. For considerations beyond Source Protection, additional investigations may be warranted to better evaluate water management needs.

2.9.1 Discussion

The following sections summarize the subwatersheds which were classified as having a Moderate or Significant potential for surface water stress. The principle hydrologic factors for the identification are discussed, and municipal supplies located within the subwatershed are identified.

2.9.1.1 Catfish Creek Above Aylmer

The Catfish Creek Above Aylmer Subwatershed has been identified as having a **Moderate** potential for stress in terms of surface water. There are a total of 15 takings located within the Subwatershed, and all are for agricultural purposes. The Percent Water Demand is minimal for most of the year; however, it reaches the Moderate threshold for potential stress in the months of August and September, when the Percent Water Demand reaches 22% for the Subwatershed. Demand is evenly distributed between the takings, with no single taking being responsible for a significant proportion of demand. None of the takings have reported pumping rates associated with them.

There are no municipal surface water takings within this Subwatershed.

2.9.1.2 Lower Catfish Creek Subwatershed

The results of the Stress Assessment analysis suggest that the Lower Catfish Subwatershed has a **Moderate** potential for stress in terms of surface water. There are 43 surface water takings within the Subwatershed, which are all assigned for agricultural purposes, with the exception of a single Wildlife Conservation taking. The Percent Water Demand is close to zero for most months; however, the seasonally variable agricultural takings cause the Percent Water Demand to rise to 36% and 30% in the months of August and September, respectively. Water demand is well distributed between all the takings, with no single taking being responsible for the majority of the demand. Only one taking has reported actual pumping rates available.

There are no municipal surface water intakes within the Lower Catfish Subwatershed.

2.9.1.3 Silver Creek Subwatershed

Based on the Stress Assessment analysis, the Silver Creek Subwatershed has a **Significant** potential for stress. There are 39 takings within Silver Creek, of which 36 are for agricultural purposes and 3 assigned for Wildlife Conservation. Like the Lower Catfish Creek Subwatershed, the Silver Creek Subwatershed has a Percent Water Demand that is close to zero for most months, but rises to 31%, 57%, and 56% for the months of July, August, and September. Water demand is well distributed throughout the takings, with no single taking being responsible for more than 10% of the total demand. There are no reported rates available for the water takings associated with this Subwatershed.

There are no municipal surface water intakes within Silver Creek.

2.9.1.4 South Otter Creek Subwatershed

The South Otter Creek Subwatershed has been assigned a **Moderate** potential for stress, based on the surface water Stress Assessment. There are 107 active surface water takings located within the Subwatershed, of which all are for agricultural purposes. With no takings for non-agricultural purposes, the Percent Water Demand for non-irrigated months is minimal. For the months of June-September, the Percent Water Demand is 32%, 36%, 41%, and 44%. Sixteen of the water takings have reported pumping rates associated with them. No single taking is influencing this classification, as there are no individual takings having greater than 10% of the total demand.

There are no municipal surface water intakes found within South Otter.

2.9.1.5 Big Creek Above Cement Road Subwatershed

The headwaters of Big Creek, Big Creek Above Cement Road Subwatershed, has been identified as having a **Moderate** potential for stress. This Subwatershed has limited portions within the Sand Plain, and is predominately located within the Till Plains. As a result, the Subwatershed only has 9 active takings, which are all agricultural, with the exception of a single Wildlife Conservation taking. Percent Water Demand is close to zero for most months, including the months of June and July. In the month of August, the Percent Water Demand rises to 23%, and in September rises to 35% which are both above the surface water stress threshold of 20%.

Water demand throughout the summer months remains fairly steady , from 14 to 17 L/s; however the surface water supply declines from 430 L/s in June to 44 L/s in September. The uncertainty with the GAWSER model in predicting such low flows is considerably higher than with more substantial flows, and therefore may be impacting the Stress Assessment at this location. None of the water takings have reported rates associated with them, and no single permit is responsible for the majority of the demand.

There are no municipal surface water intakes found within the Big Creek Above Cement Road Subwatershed.

2.9.1.6 Big Creek Above Delhi

Based on the Stress Assessment analysis, the Big Creek Above Delhi Subwatershed has been identified as having a **Moderate** potential for stress. There are 94 active takings within the Subwatershed, and all are for agricultural purposes, with the exception of a single wildlife conservation taking. Percent Water Demand is minimal for non-summer months (~1%), but increases to 21% and 22% in the month of August and September, respectively. There are 14 takings which have reported water taking rates associated with them. Given the proximity of the calculated Percent Water Demand to the Moderate threshold, additional characterization of the other 80 takings may reduce the Percent Water Demand below the 20% threshold.

There are no municipal surface water intakes located within the Big Creek Above Delhi Subwatershed.

2.9.1.7 North Creek Subwatershed

The North Creek Subwatershed has been classified as having a **Significant** potential for stress on the basis of this Stress Assessment. Due to no streamflow gauge being located on North Creek, this classification is not able to be confirmed with observed data. However, in 1998 and 1999, concern with North Creek streamflow and the short-term sustainability of Delhi's municipal intake from Lehman reservoir, led to the formation of the Province's first Irrigation Advisory Committee. The primary objective of this Committee is to mediate water related disputes between irrigators, to reduce the impact of water taking operations on watercourses. This local response to dry conditions confirms the current potential for stress identification.

There are 56 active surface water takings located within the Subwatershed. 53 of the permits are for agricultural purposes, with additional takings for Dams & Reservoirs, Wetlands, and a Municipal Water Supply. Percent Water Demand is minimal for the non-irrigated months (~5%); however, it increases to approximately 65% for the months of June-September. Thirteen of the takings have reported pumping rates associated with them, including the water supply taking. Total demand is well distributed throughout all the takings, with no single taking being responsible for more than 10% of demand.

Delhi's surface water intake at Lehman's reservoir is located within this Subwatershed. For the Delhi surface water intake, conditions meet the requirements for a Tier 3 Water Quantity Risk Assessment.

2.9.1.8 Venison Creek Subwatershed

The results of the analysis suggest that Venison Creek has a **Moderate** potential for stress in terms of surface water. There are approximately 79 surface water takings within the Subwatershed, 76 of which are for agricultural purposes, with 2 wetland takings and a single aquaculture taking. Like many subwatersheds, the Percent Water Demand is minimal for non-irrigated months, but increases considerably for the months of June-September to approximately 30%. Approximately 27 water takings have reported rates associated with them, which is a high proportion in comparison to other subwatersheds. No single taking is responsible for more than 10% of the total monthly demand.

There are no municipal surface water intakes located within Venison Creek Subwatershed.

2.9.1.9 Dedrick Creek Subwatershed

The Dedrick Creek Subwatershed has been identified as having a **Moderate** potential for stress in terms of surface water. There are a total of 42 takings located within the Subwatershed. Two takings are for wetlands, another for golf course irrigation, and one for wildlife conservation, with the remainder being agricultural purposes. There is approximately 10% Percent Water Demand for most non-summer months, and increases to 17, 18%, and 20% for the months of June, July, and August, respectively. The Percent Water Demand for the month of September reaches 22%, which is responsible for the **Moderate** classification. Due to proximity of the calculated Percent Water Demand to the Moderate threshold, increased characterization of water taking operations may remove this classification. There are 9 takings with reported pumping rates associated with them.

There are no municipal surface water takings within this Subwatershed.

2.9.1.10 Young/Hay Creeks Subwatershed

The Subwatershed contributing to Young and Hay Creeks is classified with a **Significant** potential for surface water stress. This Subwatershed has 50 takings, of which 46 are for agricultural purposes, 2 are for Dams and Reservoirs, one Wildlife Conservation taking and one Golf Course taking. Percent Water Demand is low for most months, but increases to 55% for June, and approximately 45% for the months of July-September. There are 12 takings with reported pumping rates associated with them. One taking is responsible for more than 15% of the monthly demand; however, reported rates are available for this taking, which reduces the uncertainty associated with it.

There are no municipal surface water intakes located within the Young/Hay Creeks Subwatershed.

2.9.1.11 Lynn River Subwatershed

Under the existing conditions for the Surface Water Stress Assessment Lynn River was found to have a Percent Water Demand of 19%, and was subsequently not identified as having a Moderate or Significant potential for stress. Due to an uncertainty analysis required for subwatersheds with Percent Water Demands within 2% of the threshold, the Lynn River Subwatershed was identified as having a **Moderate** for potential stress.

This Subwatershed has 58 takings, of which 56 are for agricultural purposes and 2 are for golf course irrigation. Percent Water Demand is low for most months (~1%), but increases to 19% for the months of June-September. There are 6 takings with reported pumping rates associated with them. No takings are responsible for more than 10% of the monthly demand.

There are no municipal surface water intakes located within the Lynn River Subwatershed. However, it should be noted that municipal groundwater supplies within this Subwatershed are derived from wells that rely on induced infiltration from the Lynn River at Simcoe. As municipal demands are highest during the same time period as the agricultural demands, maintaining surface water flow in this subwatershed is important for Source Protection.

2.9.1.12 Upper Nanticoke Creek Subwatershed

The Upper Nanticoke Creek Subwatershed has been classified as having a **Moderate** potential for surface water stress. There are 24 agricultural water takings within this Subwatershed. Percent Water Demand is minimal for most non-summer months, but reaches 35% and 32% during August and September, respectively. Approximately half of all the water takings (13) within this Subwatershed have reported water takings associated with them. There are a number of takings each representing more than 10% of the total demand. Takings associated with permits 03-P-2289, 00-P-2168 and 8074-6FKK8N constitutes more than 40% of the demand from this Subwatershed, and obtaining reported rates from these takings may lower the Percent Water Demand below the 20% threshold.

There are no municipal surface water intakes located within the Upper Nanticoke Creek Subwatershed. However, it should be noted that municipal groundwater supplies within this Subwatershed are derived from wells that are suspected to induce infiltration from surface ponds, known as the Waterford Ponds. As municipal demands are highest during the same time period as the agricultural demands, maintaining surface water flow in this subwatershed is important for Source Protection.

2.9.1.13 Stoney Creek

The easternmost subwatershed in the study area, Stoney Creek Subwatershed, has been identified as having a **Moderate** potential for stress. This Subwatershed is almost exclusively located within the Haldimand Clay Plain. As a result, the Subwatershed only has 2 active takings, both of which are for golf course irrigation. Percent Water Demand is 0% for most months, and is minimal for the months of June and July. In the month of August, the Percent Water Demand rises to 22%, and in September rises to 31% which are both above the surface water stress threshold of 20%. Water demand throughout the summer months remains steady at 8 L/s, however the surface water supply declines from 645 L/s in June to 28 L/s in September. The uncertainty with the GAWSER model in predicting very low flows is considerably higher than with more substantial flows, and therefore may be impacting the Stress Assessment at this location. There are no reported rates available for the takings within this Subwatershed, however increased water use characterization may lower the Percent Water Demand below the threshold.

There are no municipal surface water intakes found within Stoney Creek.

3.0 Groundwater Stress Assessment

This chapter contains the Tier 2 Water Quantity Stress Assessment for groundwater supplies in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities. The goal of the Water Quantity Stress Assessment is to identify municipal drinking water supplies that are located in subwatersheds having a Moderate or Significant potential for stress. The subwatershed-wide Percent Water Demand Scenarios are estimated by comparing the ratio of current and future water demand to water supply. A Drought Scenario identifies any municipal drinking water systems that are susceptible to drought conditions at a specific point in the subwatershed. Under the Technical Rules (MOE, 2008), developed for the Clean Water Act (2006), any municipalities identified to be in an area having a Moderate or Significant potential for stress meet the requirements to complete a Tier 3 Water Quantity Risk Assessment.

The hydrogeological parameters required to support the groundwater Stress Assessment include: groundwater recharge, groundwater flow-in from adjacent subwatersheds, groundwater reserve, and average and maximum monthly demand. These parameters are presented for each of the subwatersheds in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities in the following section. Groundwater supply is calculated as the annual amount of recharge plus the amount of total groundwater flow-in expressed in flow rate units of L/s. Similarly, the groundwater reserve component, which is calculated as 10% of the estimated groundwater discharge, is expressed in a flow rate of L/s. The sole purpose of the groundwater reserve is to introduce a measure of conservativeness into the Percent Water Demand equation. It is not meant to represent the portion of groundwater discharge that is needed to sustain ecological function. Utilizing 10% of groundwater discharge for the reserve is suggested in the Technical Guidance Module 7 (MOE, 2007) for completing the Stress Assessment. Average and monthly maximum unit consumptive water demands were previously estimated in the Long Point Region, Catfish Creek, and Kettle Creek Integrated Water Budget Report, and the Percent Water Demand is calculated using the Percent Water Demand equation given in Section 1.3.1.2. Average demand estimates included in Table 3.1 are illustrated on Map 15 of this report. Groundwater supply is illustrated thematically on Map 14.

3.1 EXISTING CONDITIONS PERCENT WATER DEMAND

3.1.1 Groundwater Consumptive Water Use

Map 13 shows the locations of all permitted groundwater users in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities. The Integrated Water Budget Report (AquaResource, 2009a) describes the procedure used to estimate consumptive groundwater demands for these groundwater users across the Conservation Authorities. Table 3.1 contains the monthly estimates of unit consumptive groundwater demands calculated for each subwatershed. The average and maximum monthly demands are shown in the table; they are used to estimate subwatershed potential stress in the groundwater Stress Assessment.

Table 3.1 - Estimated Current Groundwater Unit Consumptive Demands (L/s)

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
Kettle Creek	Upper Kettle	8	9	9	8	10	36	36	34	34	8	8	7	17	36
	Dodd Creek	0	0	0	0	0	1	2	3	2	0	0	0	1	3
	Lower Kettle	0	0	0	0	0	29	41	44	30	0	0	0	12	44

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
Catfish Creek	West Catfish	0	0	0	0	0	1	1	2	1	0	0	0	0	2
	Catfish Above Aylmer	1	1	1	1	1	10	19	28	19	1	1	1	7	28
	Lower Catfish	0	0	0	0	2	50	99	146	98	0	0	0	33	146
	Silver Creek	0	0	0	0	0	31	62	93	62	0	0	0	21	93
Big Otter	Otter Above Maple Dell Road	8	9	9	9	9	33	59	82	56	9	8	9	25	82
	Otter at Otterville	2	1	2	3	4	35	67	95	62	3	3	2	23	95
	Otter at Tillsonburg	88	90	93	90	97	151	199	250	196	90	84	88	126	250
	Spittler Creek	2	3	2	2	3	6	8	11	9	3	2	3	4	11
	Lower Otter	0	0	0	0	0	26	52	79	52	0	0	0	17	79
	Little Otter	27	27	27	27	27	73	120	167	119	27	27	27	58	167
Lake Erie Tribs	South Otter	0	0	0	0	0	48	96	144	96	0	0	0	32	144
	Clear Creek	0	0	0	0	0	61	129	186	124	0	0	0	42	186
Big Creek	Big Above Cement Road	0	0	0	0	0	12	24	36	24	0	0	0	8	36
	Big Above Kelvin Gauge	46	46	46	46	50	141	232	323	232	50	50	46	109	323
	Big Above Delhi	5	5	5	5	5	225	452	668	444	5	5	5	152	668
	North Creek	64	64	64	64	66	109	153	196	153	64	64	64	94	196
	Big Above Minnow Creek	28	28	30	31	35	156	278	400	273	25	27	21	111	400
	Big Above Walsingham	0	0	0	0	0	65	134	194	129	0	0	0	44	194
	Venison Creek	0	0	0	0	0	67	134	197	131	0	0	0	44	197
	Lower Big	0	0	0	0	0	24	55	76	49	0	0	0	17	76
Lake Erie Tribs	Dedrick Creek	0	0	0	0	0	48	96	145	98	0	0	0	32	145
	Young/Hay Creeks	29	34	32	36	25	101	187	235	166	36	30	36	79	235
Lynn River	Lynn River	86	94	90	82	86	268	413	591	423	74	74	70	196	591
	Black Creek	13	13	21	21	21	44	71	86	58	21	21	13	34	86
Nanticoke Creek	Nanticoke Upper	19	17	18	18	23	214	391	539	356	20	21	21	138	539
	Nanticoke Lower	0	0	0	0	0	1	2	2	2	0	0	0	1	2

Subwatershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
Eastern Tribs	Sandusk Ck	3	3	3	3	5	5	5	5	5	5	5	3	4	5
	Stoney Creek	0	0	0	0	0	2	2	2	2	0	0	0	1	2

3.1.2 Groundwater Supply and Reserve

Groundwater supply is calculated as the sum of the average annual recharge and the total amount of groundwater flowing laterally into each subwatershed. The GAWSER modelling results predicted groundwater recharge and the FEFLOW model estimated the groundwater flowing laterally into each subwatershed. The groundwater Flow In for each subwatershed is calculated from the model results as the sum of all positive flow vectors into each area. Both the GAWSER surface water flow model and the FEFLOW groundwater flow model are discussed in the Integrated Water Budget Report (AquaResource, 2009a). The groundwater supply for each subwatershed is illustrated on Map 14.

Groundwater reserve is calculated as 10% of the estimated groundwater discharge to surface water streams in each subwatershed. Groundwater discharge to surface water features was estimated by the FEFLOW groundwater flow model. The groundwater reserve for each subwatershed is given in Table 3.2.

3.1.3 Existing Conditions Percent Water Demand

Percent Water Demand for groundwater is calculated for each subwatershed using estimates of groundwater supply, groundwater reserve, and unit consumptive demand described in Sections 3.1.1 and 3.1.2 within the Percent Water Demand equation presented in Section 1.3.1.2 of this report. The results of the groundwater Stress Assessment are shown in Table 3.2.

Table 3.2 - Groundwater Stress Assessment

Subwatershed		Supply and Demand (L/s)					% Water Demand	
		GW Flow In	Groundwater Recharge	Groundwater Reserve	Average Demand	Maximum Demand	Average Water Demand	Maximum Water Demand
Kettle Creek	Upper Kettle	0	789	46	21	40	3%	5%
	Dodd Creek	45	520	25	2	5	0%	1%
	Lower Kettle	298	1051	55	17	50	1%	4%
Catfish Creek	West Catfish	600	513	39	6	7	1%	1%
	Catfish Above Aylmer	849	613	74	13	34	1%	2%
	Lower Catfish	532	659	113	36	149	3%	14%
	Silver Creek	25	637	45	23	96	4%	16%
Big Otter	Otter Above Maple Dell Road	124	713	56	29	86	4%	11%
	Otter at Otterville	215	497	43	26	98	4%	15%

Subwatershed		**Supply and Demand (L/s)**					**% Water Demand**	
		GW Flow In	**Groundwater Recharge**	**Groundwater Reserve**	**Average Demand**	**Maximum Demand**	**Average Water Demand**	**Maximum Water Demand**
	Otter at Tillsonburg	719	1010	130	130	254	8%	16%
	Spittler Creek	263	625	47	9	15	1%	2%
	Lower Otter	258	1098	107	21	82	2%	7%
	Little Otter	118	1096	98	60	169	5%	15%
Lake Erie Tribs	South Otter	32	1190	85	33	145	3%	13%
	Clear Creek	67	833	51	43	187	5%	22%
Big Creek	Big Above Cement Road	0	535	51	10	38	2%	8%
	Big Above Kelvin Gauge	126	547	29	111	325	**17%**	***<u>50%</u>***
	Big Above Delhi	240	1412	129	156	672	**10%**	**44%**
	North Creek	30	593	39	94	197	**16%**	**34%**
	Big Above Minnow Creek	203	799	80	112	401	**12%**	**44%**
	Big Above Walsingham	140	1149	123	46	196	4%	17%
	Venison Creek	190	974	111	46	199	4%	19%
	Lower Big	23	649	40	19	78	3%	12%
Lake Erie Tribs	Dedrick Creek	310	1199	68	34	147	2%	10%
	Young/Hay Creeks	75	1162	51	80	237	7%	20%
Lynn River	Lynn River	57	1540	112	201	595	**14%**	**40%**
	Black Creek	23	691	49	37	89	6%	13%
Nanticoke Creek	Nanticoke Upper	64	670	52	141	542	**21%**	***<u>79%</u>***
	Nanticoke Lower	67	227	21	3	4	1%	2%
Eastern Tribs	Sandusk Creek	37	392	20	9	9	2%	2%
	Stoney Creek	0	387	9	4	5	1%	1%

Table 3.3 contains the estimated potential for stress under average annual and maximum monthly water demands for each subwatershed. These classifications are based on the Percent Water Demand estimates shown in Table 3.2 and the Province's stress thresholds for groundwater listed in Table 1.5. The table also lists the municipal groundwater supplies in each of the subwatersheds.

Table 3.3 - Groundwater Stress Classification (Current Demand)

Subwatershed		Potential Stress (Average Annual Demand)	Potential Stress (Maximum Monthly Demand)	Municipal Water Supplies
Kettle Creek	Upper Kettle	Low	Low	Belmont GW
	Dodd Creek	Low	Low	None
	Lower Kettle	Low	Low	None
Catfish Creek	West Catfish	Low	Low	None
	Catfish Above Aylmer	Low	Low	Brownsville GW
	Lower Catfish	Low	Low	None
	Silver Creek	Low	Low	None
Big Otter	Otter Above Maple Dell Road	Low	Low	Norwich GW
	Otter at Otterville	Low	Low	Otterville GW
	Otter at Tillsonburg	Low	Low	Tillsonburg GW
	Spittler Creek	Low	Low	Springford, Dereham Center GW
	Lower Otter	Low	Low	None
	Little Otter	Low	Low	None
Lake Erie Tribs	South Otter	Low	Low	None
	Clear Creek	Low	Low	None
Big Creek	Big Above Cement Road	Low	Low	None
	Big Above Kelvin Gauge	**Moderate**	***Significant***	None
	Big Above Delhi	**Moderate**	**Moderate**	None
	North Creek	**Moderate**	**Moderate**	None
	Big Above Minnow Creek	**Moderate**	**Moderate**	Delhi GW
	Big Above Walsingham	Low	Low	None
	Venison Creek	Low	Low	None
	Lower Big	Low	Low	None
Lake Erie Tribs	Dedrick Creek	Low	Low	None
	Young/Hay Creeks	Low	Low	None
Lynn River	Lynn River	**Moderate**	**Moderate**	Simcoe GW
	Black Creek	Low	Low	None
Nanticoke Creek	Nanticoke Upper	**Moderate**	***Significant***	Waterford GW
	Nanticoke Lower	Low	Low	None
Eastern Tribs	Sandusk Creek	Low	Low	None
	Stoney Creek	Low	Low	None

3.2 PLANNED CONDITION PERCENT WATER DEMAND

No planned systems exist outside of the subwatersheds identified as having a Moderate or Significant potential for stress under the Current Demand Scenario; therefore, the Planned Demand Scenario was not required for this study.

3.3 FUTURE CONDITIONS PERCENT WATER DEMAND

Consistent with the Technical Rules, the Percent Water Demand is also calculated using future demand estimates. Those rules specify that future demand should account for projected increases in municipal demand. All other non-municipal water demand is assumed to be equal to current demand.

As the urban areas within the Study Area are seen as areas of low-growth, future land use changes are expected to have minimal, to no, impact on average subwatershed water budget parameters. As such, water budget parameters for existing land use conditions will be used for the supply and reserve terms.

3.3.1 Municipal Projections

Table 3.4 contains estimated future additional water demand requirements for each municipal groundwater supply system in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities.

Municipal future water demand was estimated by applying future population estimates to current average daily per capita water use for each municipal water system. Future population is based on municipal official plans current to 2006, while current water use data was collected from water system owners and operators. In municipalities with Long Term Water Supply Plans, future water demand was taken directly from approved plans. All future water demand is projected to 2031. Further explanation of future water demand calculations is given in the *Status Report on Municipal Long Term Water Supply Strategies* (Shifflett, 2007).

Table 3.4 - Future Groundwater Municipal Demand Increases

Subwatershed		Municipal Water Supply System	Estimated Average Day Increase in Groundwater Demand (m^3/d)	Estimated Average Day Increase in Groundwater Demand (L/s)
Kettle Creek	Upper Kettle	Belmont GW	189	2
Catfish Creek	Catfish Above Aylmer	Brownsville GW	7	0
Big Otter	Otter Above Maple Dell Road	Norwich GW	122	1
	Otter at Otterville	Otterville GW	91	1
	Otter at Tillsonburg	Tillsonburg GW	3,547	41
	Spittler Creek	Springford, Dereham Center GW	68	1
Big Creek	Big Above Minnow Creek	Delhi GW	1,348	16
Lynn River	Lynn River	Simcoe GW	1,924	22
Nanticoke Creek	Nanticoke Upper	Waterford GW	576	7

3.3.2 Agricultural Projections

In the future, the agricultural and irrigation practices in the Norfolk Sand Plain Region are expected to change drastically. Section 2.4.2 describes in detail the trends in crop type changes that are taking place currently in the Region.

As stated in Section 2.4.2, it is not possible to predict with any certainty what the dominant irrigated crop, or the irrigation practices that are associated with the crop, will be in the future, especially for use within the future demand scenario of the Stress Assessment. As such, agricultural demand was not modified for future demand scenarios in this assessment.

For broader water management purposes, additional study and consultation with the agricultural sector needs to be undertaken to better understand the future of agriculture and water demand within the Norfolk Sand Plain.

3.3.3 Percent Water Demand

Groundwater supply and reserve, as described in Section 3.1.2, remained unchanged for the Groundwater Stress Assessment estimated for future conditions. Future average monthly demand and maximum monthly demand were estimated by summing the demands under current conditions with the additional average increase in demand listed in Table 3.4 for future conditions. The results of the Percent Groundwater Demand under future conditions are presented in Table 3.5.

Table 3.5 - Groundwater Stress Assessment Components with Future Demand Estimates

Subwatershed		Supply and Demand (L/s)					% Water Demand	
		GW Flow In	Groundwater Recharge	Groundwater Reserve	Average Demand	Maximum Demand	Average Water Demand	Maximum Water Demand
Kettle Creek	Upper Kettle	0	789	46	23	42	3%	6%
	Dodd Creek	45	520	25	2	5	0%	1%
	Lower Kettle	298	1051	55	17	50	1%	4%
Catfish Creek	West Catfish	600	513	39	6	7	1%	1%
	Catfish Above Aylmer	849	613	74	13	34	1%	2%
	Lower Catfish	532	659	113	36	149	3%	14%
	Silver Creek	25	637	45	23	96	4%	16%
Big Otter	Otter Above Maple Dell Road	124	713	56	30	87	4%	11%
	Otter at Otterville	215	497	43	27	99	4%	15%
	Otter at Tillsonburg	719	1010	130	171	296	**11%**	18%
	Spittler Creek	263	625	47	10	16	1%	2%
	Lower Otter	258	1098	107	21	82	2%	7%
	Little Otter	118	1096	98	60	169	5%	15%
Lake Erie Tribs	South Otter	32	1190	85	33	145	3%	13%
	Clear Creek	67	833	51	43	187	5%	22%
Big Creek	Big Above Cement Road	0	535	51	10	38	2%	8%
	Big Above Kelvin Gauge	126	547	29	111	325	**17%**	<u>***50%***</u>
	Big Above Delhi	240	1412	129	156	672	**10%**	**44%**
	North Creek	30	593	39	94	197	**16%**	**34%**
	Big Above Minnow Creek	203	799	80	128	417	**14%**	**45%**
	Big Above Walsingham	140	1149	123	46	196	4%	17%
	Venison Creek	190	974	111	46	199	4%	19%
	Lower Big	23	649	40	19	78	3%	12%
Lake Erie Tribs	Dedrick Creek	310	1199	68	34	147	2%	10%
	Young/Hay Creeks	75	1162	51	80	237	7%	20%
Lynn River	Lynn River	57	1540	112	223	618	**15%**	**42%**
	Black Creek	23	691	49	37	89	6%	13%
Nanticoke Creek	Nanticoke Upper	64	670	52	147	548	**22%**	<u>***80%***</u>
	Nanticoke Lower	67	227	21	3	4	1%	2%
Eastern Tribs	Sandusk Creek	37	392	20	9	9	2%	2%
	Stoney Creek	0	387	9	4	5	1%	1%

In Table 3.5, subwatersheds which met or exceeded the stress thresholds given in Table 1.5 are formatted **Bold** for Moderate potential for stress, and <u>**Bold and Underlined**</u> for Significant potential for stress.

Otter at Tillsonburg was the lone subwatershed, classified as having a Low potential for stress under existing conditions, which was elevated to having a Moderate potential for stress due to the increase in future municipal demands.

3.4 DROUGHT SCENARIO

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

> (i) the groundwater level in the vicinity of a well was not at a level sufficient for the normal operation of the well; or
>
> (ii) the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

The Technical Rules identify the need for both a two year and a ten year drought scenario (Rule 35.2.f/g). These scenarios are designed to capture probable periods of drought conditions; both short and long term duration droughts. With the surface water simulation producing groundwater recharge estimates for the 1960-2004 time period, the impacts of any drought within this time period can be assessed. Furthermore, the scenarios need to be assessed for both existing and planned systems.

The 1960's represent a recorded period of low precipitation, for which estimated recharge is available from the GAWSER simulations. Since this information is readily available, the two-year and ten-year scenarios were evaluated during the same simulation for this Stress Assessment. Information relating to the planned pumping rates for municipal wells was not available and therefore the drought assessment is only carried out for existing pumping rates.

3.4.1 Methodology

GAWSER simulates daily recharge rates for each hydrologic response unit (HRU) across the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities. These HRUs account for different soil types, land use, and climate zones. For the purposes of the groundwater drought scenario, these estimated recharge rates were temporally and spatially simplified into a time series representing a single recharge adjustment factor for each month of the 1960-2004 simulation period. This adjustment factor represents groundwater recharge for each month as a fraction of average annual groundwater recharge. Having this single factor assumes that monthly variations in groundwater recharge are constant for each HRU across various climate zones. While these variations may not be constant, they are assumed to be representative of relative changes in climate across the Conservation Authorities over the simulation period. Similarly, it is assumed that monthly adjustments to recharge are an appropriate temporal simplification of the daily recharge estimates.

Figure 7 illustrates the monthly recharge adjustment factors estimated from the 1960-2004 simulation. The figure also shows a 12-month moving average of the monthly adjustment factors, which removes monthly variability to highlight more significant trends.

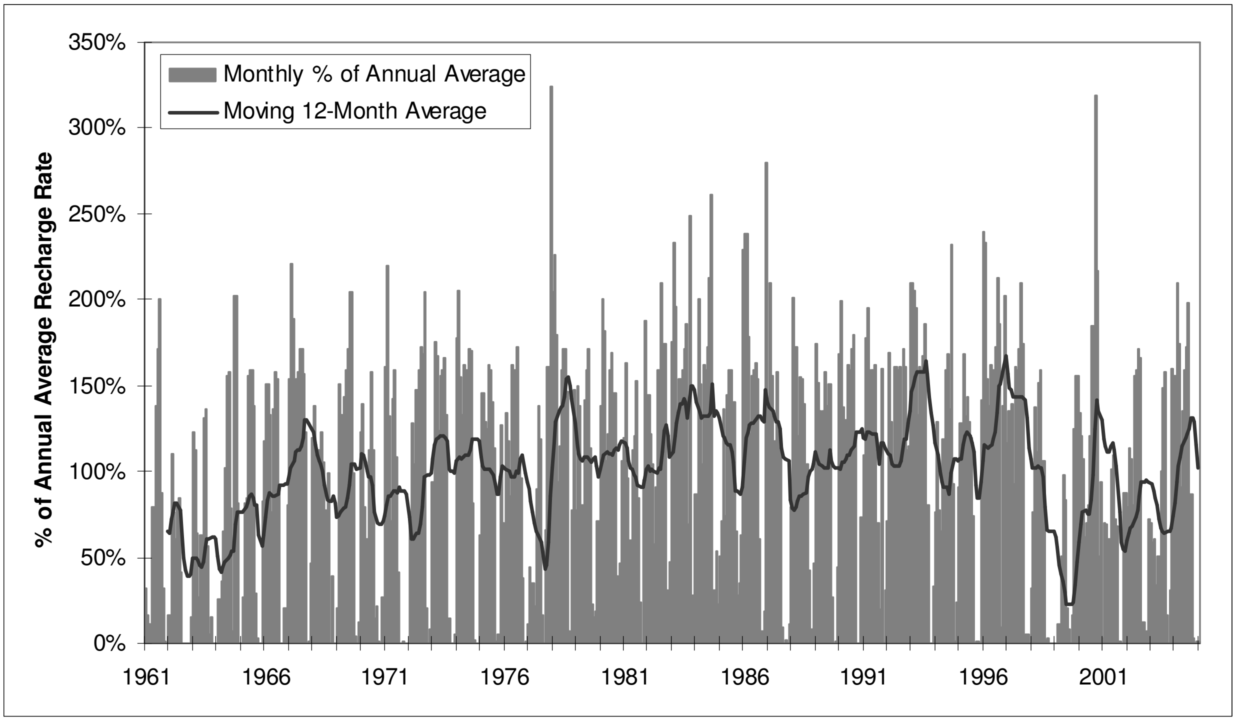


Figure 7 - Monthly Recharge Adjustment Factors

FEFLOW was configured to use the time series of monthly recharge adjustment factors for the complete 1960-2004 simulation. Within each month, FEFLOW adjusts the simulation timestep automatically to achieve a proper numerical solution. FEFLOW was configured to export groundwater levels at each municipal well during the simulation and also save the simulated potentiometric surface at specified times.

Water levels resulting from the steady-state groundwater flow simulation were set as initial conditions for the 1960-2004 transient simulation.

In addition to transient recharge, the pumping rates for agricultural water takings were run both as an average annual pumping rate and as a fluctuating monthly pumping rate to show illustrate differences a fluctuating pumping rate would have on the model results. Monthly pumping rates were modified in the transient run to reflect the number of estimated irrigation events occurring each month in the 1960-2004 period. This was done by utilizing the irrigation demand model, which estimates the number of irrigation events based on soilwater outputs estimated from the GAWSER model. A single time series for varied agricultural irrigation demand was estimated from a central climate zone and then applied to all agricultural takings across the three Conservation Authorities. Inherently, this assumes that relative changes in agricultural demand are constant across different climate zones in the entire modelled area. While these variations may not be constant, they are assumed to be representative of relative changes in climate across the modelled area over the simulation period.

Shown below on Figure 8 is an example of the transient agricultural pumping input and the steady annual average agricultural pumping input used for the Drought Scenario model runs. The difference in irrigation pumping on a monthly basis for the example year of 1989 is given. The Figure shows the percentage of the total annual agricultural pumped volume that is pumped each month based on both the steady and transient methods.

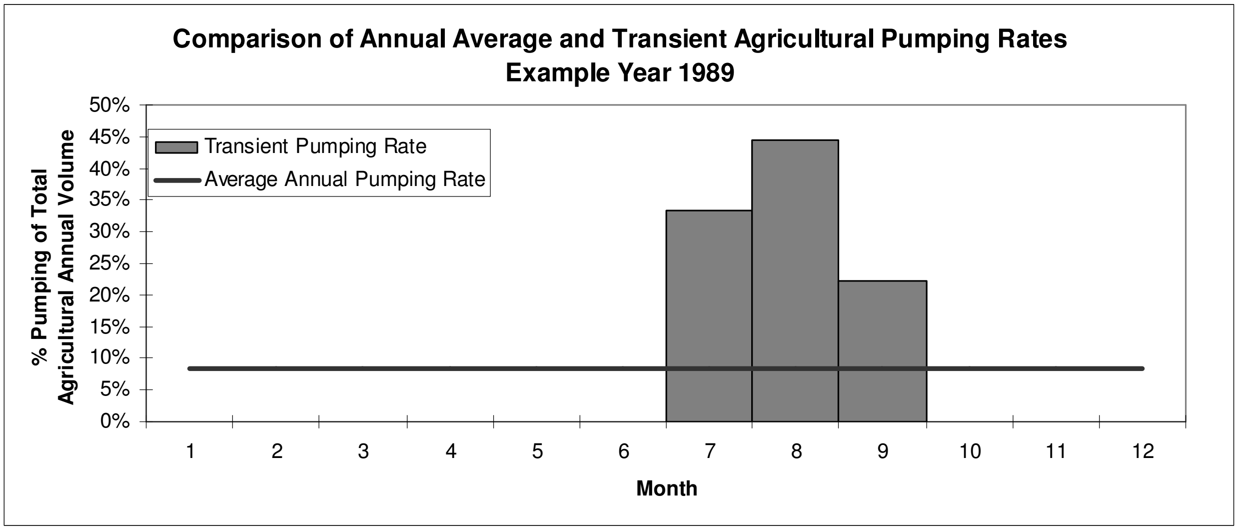


Figure 8 - Comparison of Annual Average and Transient Pumping Rates

During the second run of the model analysis for the Drought Scenario, in which fluctuating monthly irrigation pumping rates were used, FEFLOW was configured to use the time series of monthly agricultural pumping rates for the complete 1960-2004 simulation. Within each month, FEFLOW adjusts the simulation timestep automatically to achieve a proper numerical solution.

The FEFLOW groundwater-flow model is a regional model and is not discretized at the level needed to calculate water levels in the drawdown cone at a well location due to localized pumping. Calibration and validation of the FEFLOW model allows it to show the regional-level changes in water levels during a drought. Shown in the following Section 3.4.2, the results of the FEFLOW analysis of the Drought Scenario were exported at the locations of municipal wells. The exported water levels do not show the impact to well drawdown as a result of pumping, but rather show water level changes as a result of the drought. This is seen as sufficient for the Drought Assessment Scenario at the Tier 2 level of study.

3.4.2 Results of Drought Assessment Scenario

With respect to the Technical Rules, the purpose of the groundwater Drought Scenario is to identify any subwatershed having municipal wells with the potential to be affected by a drought, as described in Section 3.4. Any identified subwatershed is classified as having a Moderate potential for stress. The results of the drought scenario do not change the stress classification of any subwatersheds already classified as having a Moderate or Significant potential for stress. The Big Above Kelvin Gauge, Big Above Delhi, North Creek, Big Above Minnow Creek, Lynn River, Nanticoke Upper, and Otter At Tillsonburg Subwatersheds were each identified as having a Moderate or Significant potential for stress in the groundwater Stress Assessment with existing or future demands and thus their stress classifications would not be affected by the Drought Scenario results.

Figure 9 to Figure 15 illustrate relative groundwater levels simulated at the locations of seven municipal wells throughout the Long Point Region, Catfish Creek, and Kettle Creek Study Area. For information purposes, output from two different transient model runs is shown; 1) with transient agricultural pumping; and 2) with steady average annual agricultural pumping. The selected wells have been chosen for discussion purposes only in this Section. These charts also plot the 12-month moving average of relative recharge to help correlate water level fluctuations with input recharge. The time period shown on the figures is 1960 to 1998, representing both the 1960's drought period and the recovery period following the drought. Water levels are shown relative to the initial conditions used for the simulation.

Figure 9 illustrates the simulated response in water levels at the location of Belmont's Well 2. Belmont is located in the Kettle Creek Conservation Authority and has no agricultural permits close to it. This well is screened in bedrock and due to the depth of the well, seasonal fluctuations in water levels are limited. The overall trend of groundwater levels decreasing during the 1960s drought and increasing in the following recovery period through the 80s and 90s is clear. The total reduction from initial water levels in 1960 is about 0.4m.

Figure 10 shows the relative depth to water at Tillsonburg Well 7. Tillsonburg is located in the Otter at Tillsonburg Subwatershed, located on the northwestern edge of the Norfolk Sand Plain in the Long Point Region Conservation Authority. Tillsonburg Well 7 is an overburden well, and as such, seasonal fluctuations in water levels at the well are significant, with low water levels during the summer months and higher water levels through the winter and spring each year. Overall fluctuations in recharge rates are reflected in the fluctuations of water levels as well. The 1960s drought effects are reflected by low water levels through the 1960s and 1970s with recovery of water levels through the 1980s and 1990s. The maximum water level decrease from initial water levels in 1960 is approximately 1 m.

Figure 11 illustrates the response in water levels at Delhi's Well 2. Groundwater levels were simulated to drop by almost 1.5 m during the 1960 drought, followed by a trend of increasing water levels through the 70s, 80s, and 90s. Delhi Well 2 is an overburden well that is simulated to experience seasonal water level fluctuations, showing lower water levels during the summer months and annual recovery periods through the winter and spring months.

Figure 12 illustrates the simulated response in water levels at the location of the Norwich Well 1, completed in bedrock. The water level reduction at this location, in response to drought conditions, is approximately 2 m. Similar to the Tillsonburg well, Norwich Well 1 is located north of the Norfolk Sand Plain, with very few surrounding agricultural takings. Both the transient agricultural pumping and steady agricultural pumping scenarios produced very similar water level changes. The water levels were simulated to fluctuate substantially between summer months and winter and spring months in this well, with over a metre of fluctuation in many years.

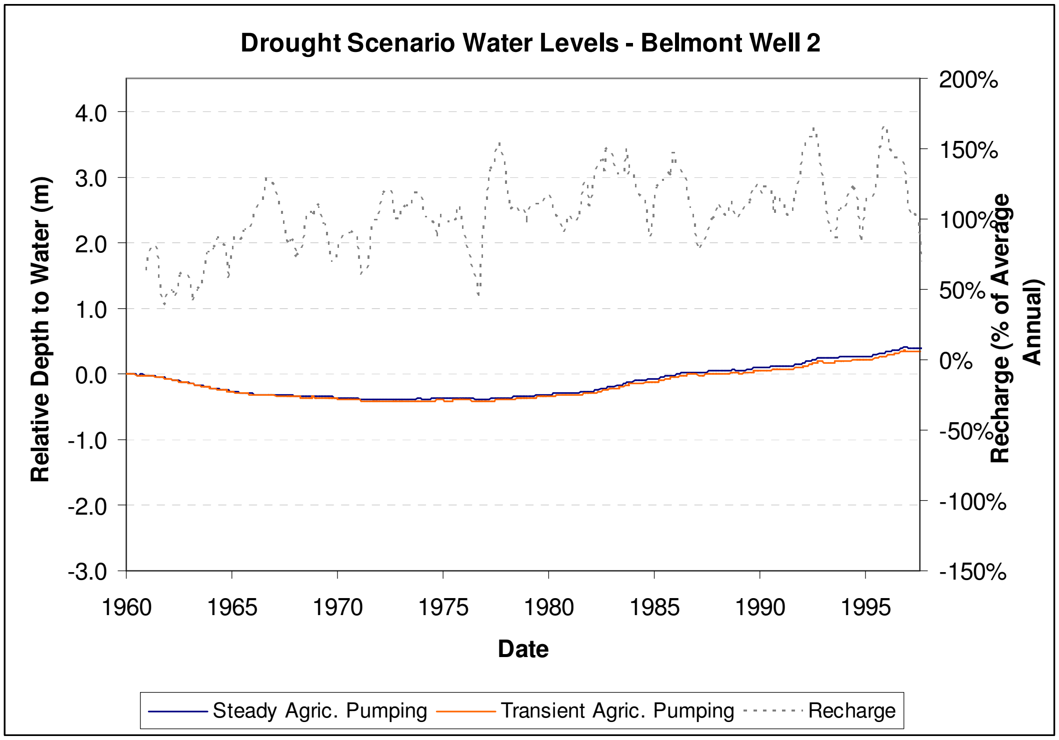


Figure 9 - Drought Scenario Simulated Water Level Changes (Belmont Well 2)

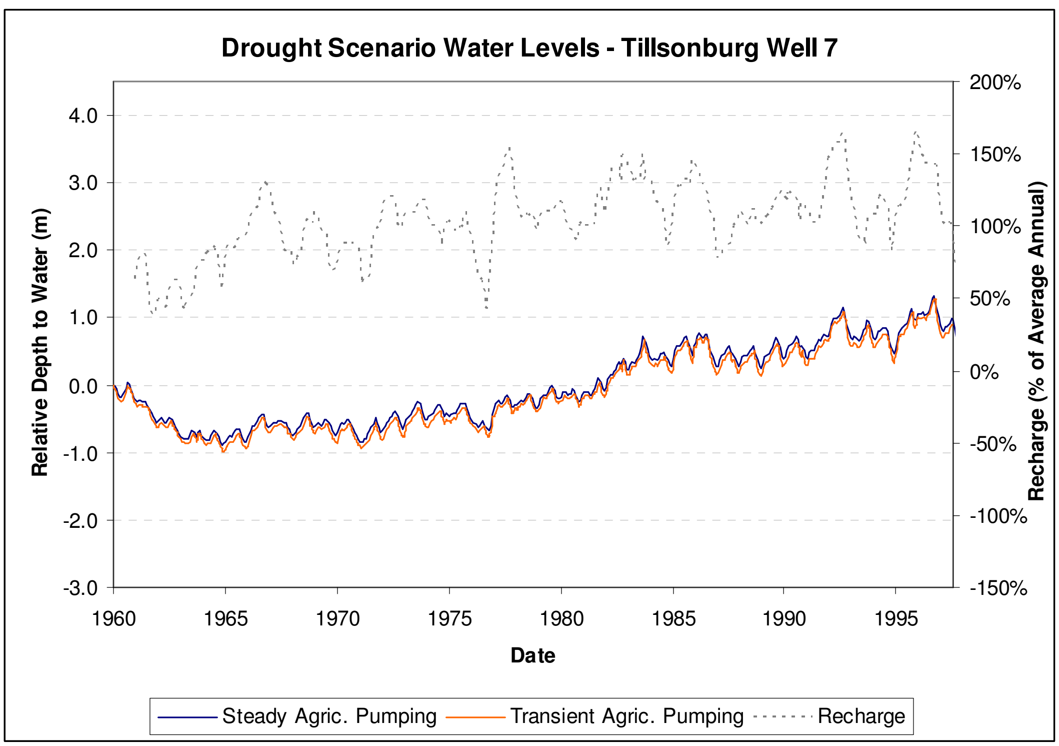


Figure 10 - Drought Scenario Simulated Water Level Changes (Tillsonburg Well 7)

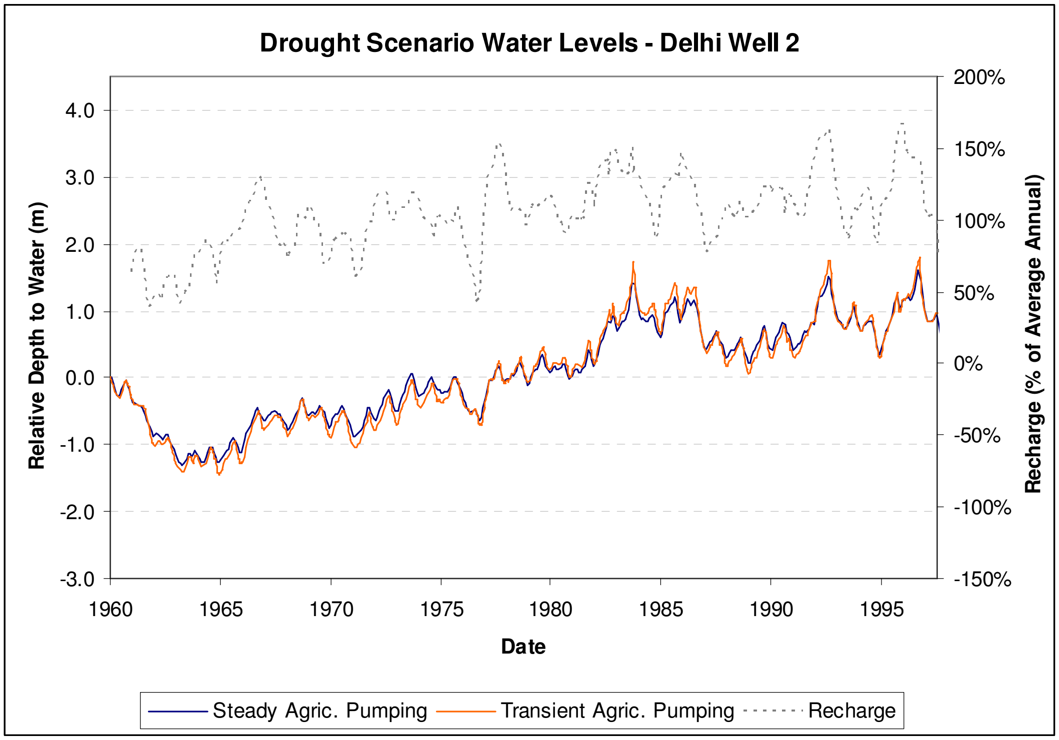


Figure 11 - Drought Scenario Simulated Water Level Changes (Delhi Well 2)

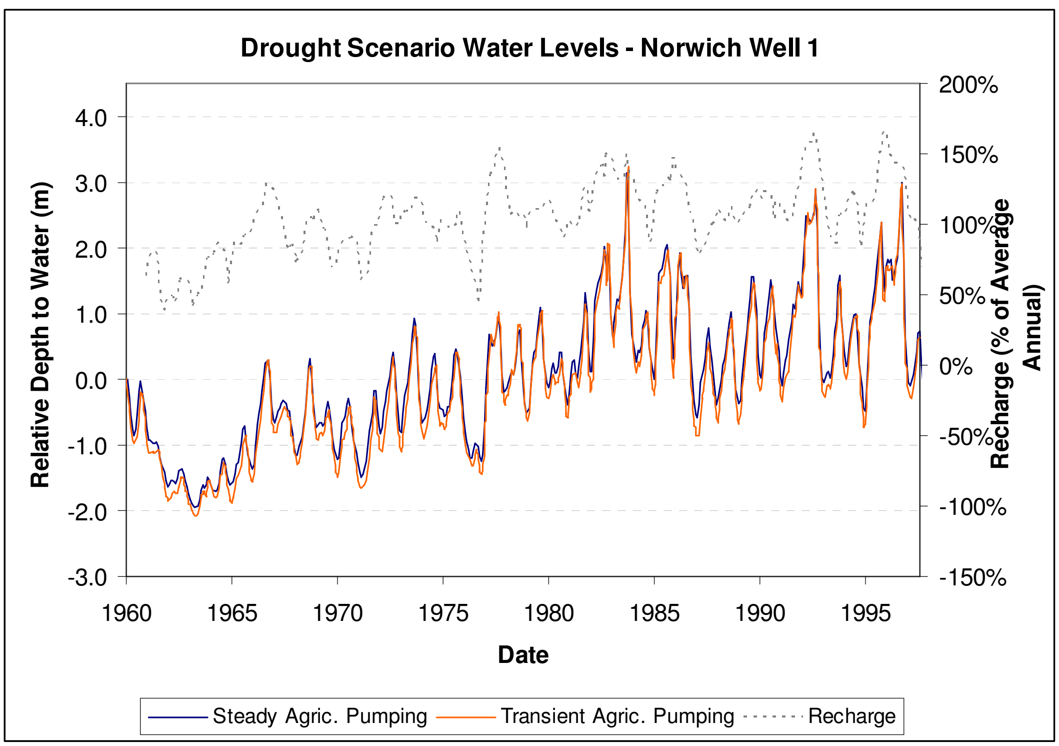


Figure 12 - Drought Scenario Simulated Water Level Changes (Norwich Well 1)

Figure 13 illustrates the simulated response in water levels at the location of the Simcoe NW1 municipal well. This well is an overburden well completed approximately 26 m below ground surface. The maximum reduction in water levels at the well location is simulated to be approximately 0.5 m. Following this period of reduced water levels, water elevations increase slightly over the 1970s to the 1990s. Located in the Norfolk Sand Plain with many surrounding agricultural permits, significant seasonal variability in water levels is simulated to occur.

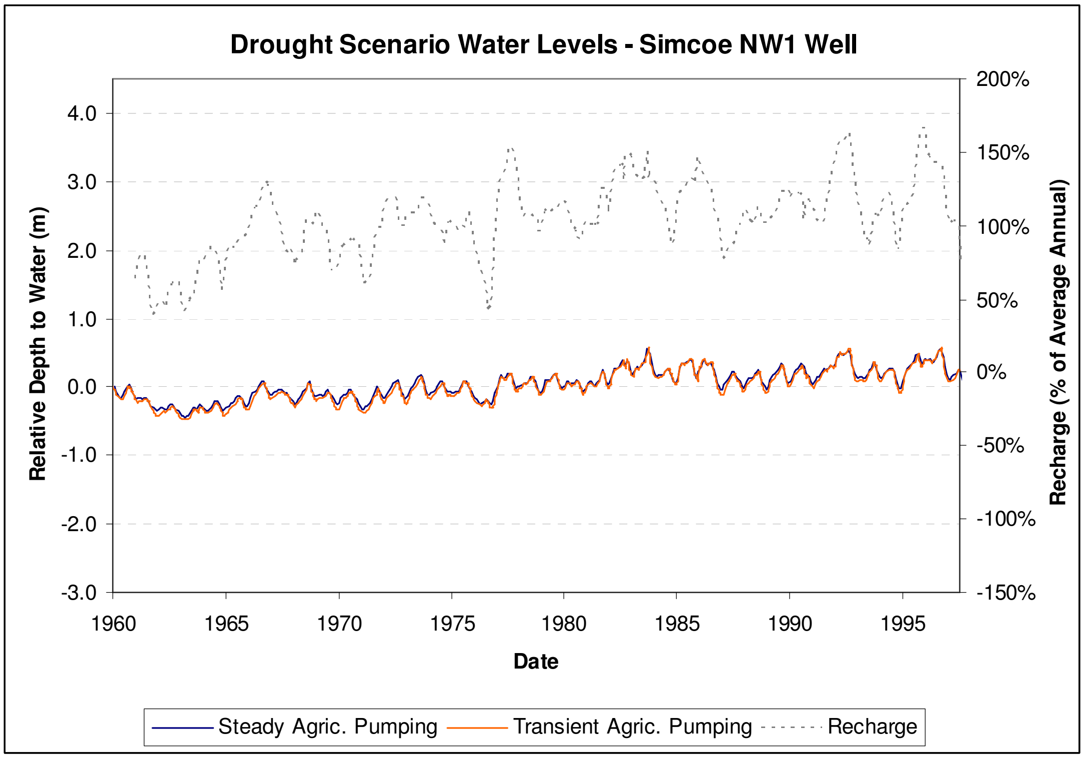


Figure 13 - Drought Scenario Simulated Water Level Changes (Simcoe NW1 Well)

Figure 14 illustrates the simulated response in water levels at the location of the Waterford Well 3 in the north-eastern portion of the Norfolk Sand Plain in the Long Point Region Conservation Authority. The effect of the many agricultural permits around the Waterford well is evident from the results of the modelling, as the transient agricultural pumping results show a much greater decrease of water levels in the summer months than the steady agricultural pumping results. Likewise, in the winter and spring months, the transient agricultural pumping results show higher water levels, with no pumping being simulated during those months in the transient run.

Figure 15 illustrates the simulated water levels at the Otterville Well 3, located in the Otter Creek at Otterville Subwatershed, towards the northern portion of the Norfolk Sand Plain in the Long Point Region Conservation Authority. The maximum decrease from initial water levels at this location is about 1.4 m. This location, completed in sandy overburden, shows annual variability in water levels corresponding to the summer pumping months and winter and spring recovery period.

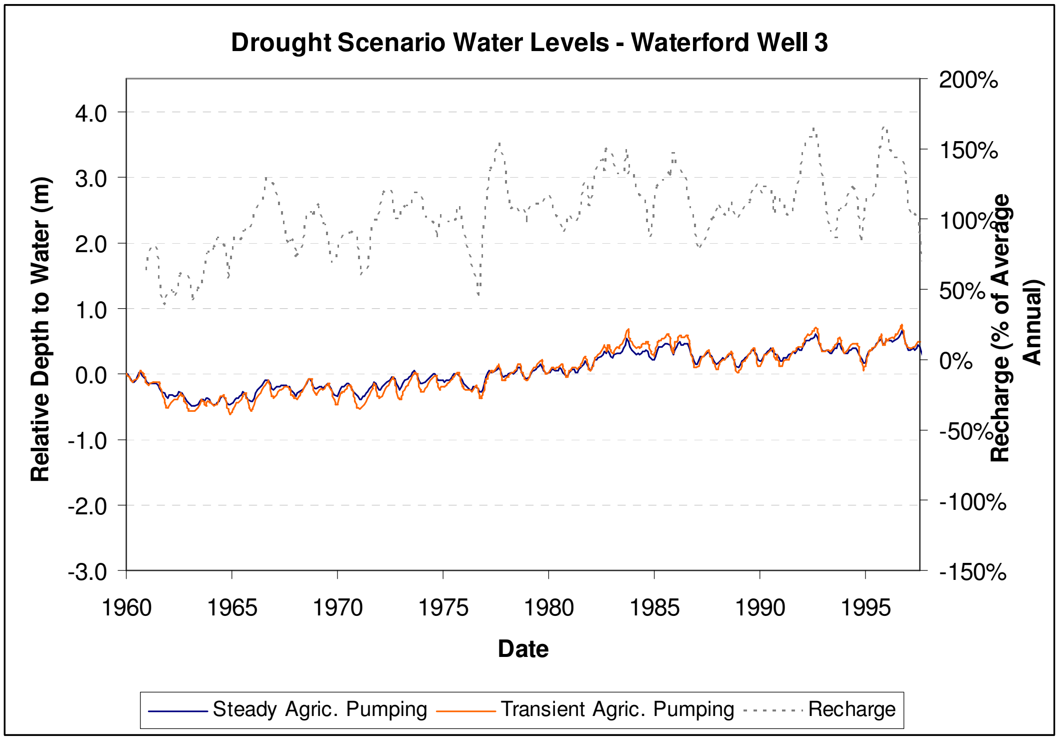


Figure 14 - Drought Scenario Simulated Water Level Changes (Waterford Well 3)

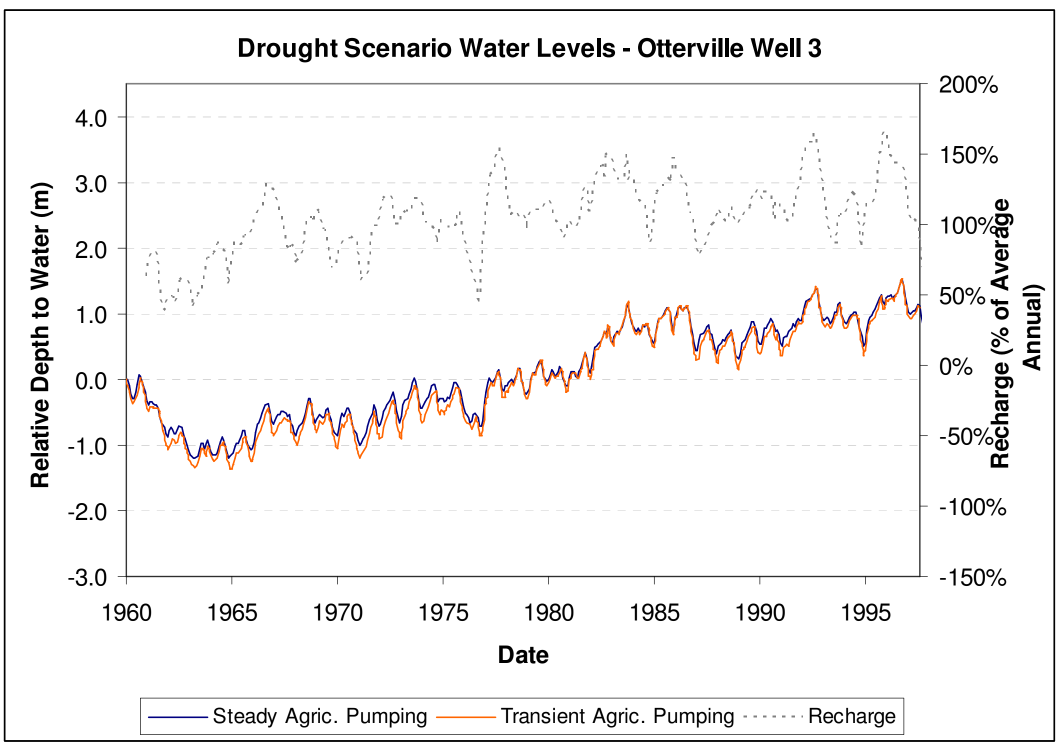


Figure 15 - Drought Scenario Simulated Water Level Changes (Otterville Well 3)

It is clear in Figure 9 to Figure 15 that there was very little difference in simulated water levels at each pumping location whether an annual average irrigation pumping rate or a transient irrigation pumping rate was used. The temporal variability in pumping causes little impact. This indicates that the system has resiliency to higher rates of pumping over a short time period. The groundwater system has a storage buffering capacity, and it is clear from comparing both the average and precise pumping patterns that the variation in groundwater extraction over a year is not a very sensitive parameter.

It is assumed that all municipal wells would be constructed with an available drawdown of approximately 5 metres. This assumption is in keeping with information provided by Norfolk County Staff regarding water level depths at municipal wells. As all municipal wells are shown to have a maximum water level decrease less than this threshold (Table 3.6) it is unlikely that there are instances where a municipal well is unable to pump at normal operating levels due to drought impacts.

Table 3.6 - Results of Groundwater Drought Scenario - Maximum Decrease in Water Levels

Municipality	Municipal System	Subwatershed	Well	Maximum Water Level Decrease (m below initial water level)
Elgin County	Belmont	Upper Kettle	Well_1	-0.26
Elgin County	Belmont	Upper Kettle	Well_2	-0.43
County of Oxford	Brownsville	Catfish Above Aylmer	Well_#5_(Van Gurp)	-0.64
County of Oxford	Brownsville	Catfish Above Aylmer	Well_#6_Park_Well	-0.65
County of Oxford	Norwich	Otter Above Maple Dell Road	Well_#1	-2.08
County of Oxford	Norwich	Otter Above Maple Dell Road	Well_#2	-2.09
County of Oxford	Norwich	Otter Above Maple Dell Road	Well_#4	-2.21
County of Oxford	Otterville	Otter at Otterville	Well_2-A	-1.03
County of Oxford	Otterville	Otter at Otterville	Well_3	-1.37
County of Oxford	Otterville	Otter at Otterville	Well_4	-1.38
County of Oxford	Springford	Spittler Creek	Well_1	-1.39
County of Oxford	Springford	Spittler Creek	Well_2	-1.37
County of Oxford	Springford	Spittler Creek	Well_3	-1.36
County of Oxford	Springford	Spittler Creek	Well_TW1	-1.40
County of Oxford	Springford	Spittler Creek	Well_TW2	-1.37
Norfolk County*	Tillsonburg	Little Otter	Well_13_Vance Site	-2.01
Norfolk County*	Tillsonburg	Little Otter	Well_14_Vance Site	-2.01

*Note: These wells are for an Oxford County system but are located in Norfolk County. Water quality of these wells is not suitable for drinking water purposes.

The Technical Rules stipulate that the drought scenario applies only to municipal wells that have not already been identified as having a Moderate or Significant potential for stress under current and future demand conditions. Table 3.6 shows the maximum water level decreases simulated through the modelling analyses only for municipal wells located outside of the subwatersheds classified with a Moderate or Significant potential for stress. Without further information about static water levels at each of these wells and available drawdown depths, no other subwatershed areas would be classified as having a Moderate potential for stress based on these results.

3.5 UNCERTAINTY IN STRESS CLASSIFICATIONS

As explained in Section 2.6, to evaluate whether the uncertainty associated with the Percent Water Demand calculations is sufficient to modify the Stress Assessment classification, a sensitivity analysis was utilized. Where the sensitivity analysis indicates that the classification may change from “Moderate” to “Low” potential, or “Low” to “Moderate” potential, an uncertainty classification of “High” is assigned. For subwatersheds with no such change, an uncertainty classification of “Low” is assigned.

The following sensitivity analysis presents eight sensitivity scenarios where both the average annual and maximum monthly agricultural demands and recharge for each subwatershed are increased and decreased by 25% to estimate Percent Water Demand under significantly different groundwater demand and recharge conditions. Section 2.6 describes the assumptions used to estimate agricultural demand in the Region and details the justification for using 25% as the sensitivity factor. A 25% change in the recharge volume within a subwatershed is considered a reasonable sensitivity level.

Table 3.7 summarizes the results of the sensitivity analysis for groundwater. The Percent Water Demand for average annual demand and maximum monthly demand is presented for the groundwater sensitivity analysis. Subwatersheds which meet or exceed the stress thresholds are formatted **Bold** to indicate a Moderate or Significant potential for stress.

Table 3.7 - Groundwater Sensitivity Analysis (Current Conditions)

Subwatershed		Current Conditions		(1) Agricultural Groundwater Demand x 75%		(2) Agricultural Groundwater Demand x 125%		(3) Recharge x 75%		(4) Recharge x 125%	
		% Water Demand		% Water Demand		% Water Demand		% Water Demand		% Water Demand	
		Avg Annual	Max Month	Avg Annual	Max Month	Avg Annual	Max Month	Avg Annual	Max Month	Avg Annual	Max Month
Kettle Creek	Upper Kettle	3%	5%	3%	5%	3%	5%	4%	7%	2%	4%
	Dodd Creek	0%	1%	0%	1%	0%	1%	1%	1%	0%	1%
	Lower Kettle	1%	4%	1%	4%	1%	4%	2%	5%	1%	3%
Catfish Creek	West Catfish	1%	1%	1%	1%	1%	1%	1%	1%	0%	1%
	Catfish Above Aylmer	1%	2%	1%	2%	1%	3%	1%	3%	1%	2%
	Lower Catfish	3%	14%	3%	10%	4%	17%	4%	18%	3%	11%
	Silver Creek	4%	16%	3%	12%	5%	19%	5%	21%	3%	12%
Big Otter	Otter Above Maple Dell Road	4%	11%	3%	9%	4%	13%	5%	15%	3%	9%
	Otter at Otterville	4%	15%	3%	11%	5%	18%	5%	20%	3%	12%
	Otter at Tillsonburg	8%	16%	8%	14%	9%	18%	**11%**	21%	7%	13%
	Spittler Creek	1%	2%	1%	1%	1%	2%	1%	2%	1%	1%
	Lower Otter	2%	7%	1%	5%	2%	8%	2%	9%	1%	5%
	Little Otter	5%	15%	5%	12%	6%	18%	7%	20%	4%	12%
Lake Erie Tribs	South Otter	3%	13%	2%	10%	4%	16%	4%	17%	2%	10%
	Clear Creek	5%	22%	4%	17%	6%	**27%**	7%	**29%**	4%	18%
Big Creek	Big Above Cement Road	2%	8%	2%	6%	3%	10%	3%	11%	2%	6%
	Big Above Kelvin Gauge	**17%**	**50%**	**15%**	**40%**	**20%**	**61%**	**23%**	**67%**	**14%**	**40%**
	Big Above Delhi	**10%**	**44%**	8%	**33%**	**13%**	**55%**	**14%**	**59%**	8%	**35%**

Subwatershed		Current Conditions		(1) Agricultural Groundwater Demand x 75%		(2) Agricultural Groundwater Demand x 125%		(3) Recharge x 75%		(4) Recharge x 125%	
		% Water Demand		% Water Demand		% Water Demand		% Water Demand		% Water Demand	
		Avg Annual	Max Month	Avg Annual	Max Month	Avg Annual	Max Month	Avg Annual	Max Month	Avg Annual	Max Month
	North Creek	**16%**	**34%**	**15%**	**28%**	**17%**	**39%**	**22%**	**45%**	**13%**	**27%**
	Big Above Minnow Creek	**12%**	**44%**	**10%**	**34%**	**14%**	**53%**	**16%**	**58%**	**10%**	**35%**
	Big Above Walsingham	4%	17%	3%	13%	5%	21%	5%	22%	3%	13%
	Venison Creek	4%	19%	3%	14%	5%	24%	6%	**25%**	3%	15%
	Lower Big Ck.	3%	12%	2%	9%	4%	15%	4%	16%	2%	10%
Lake Erie Tribs	Dedrick Creek	2%	10%	2%	8%	3%	13%	3%	14%	2%	8%
	Young/Hay Creeks	7%	20%	6%	16%	8%	24%	9%	**27%**	5%	16%
Lynn River	Lynn River	**14%**	**40%**	**12%**	**32%**	**15%**	**48%**	**18%**	**53%**	**11%**	**32%**
	Black Creek	6%	13%	5%	12%	6%	15%	8%	18%	5%	11%
Nanticoke Creek	Nanticoke Upper	**21%**	**79%**	**16%**	**60%**	**25%**	**98%**	**28%**	**106%**	**17%**	**64%**
	Nanticoke Lower	1%	2%	1%	1%	1%	2%	1%	2%	1%	1%
Eastern Tribs	Sandusk Creek	2%	2%	2%	2%	2%	2%	3%	3%	2%	2%
	Stoney Creek	1%	1%	1%	1%	1%	1%	1%	2%	1%	1%

For the groundwater assessment, there are four subwatersheds (Big Otter at Tillsonburg, Clear Creek, Venison Creek, and Young/Hay Creeks) whose classifications were shown to change due to the sensitivity calculations. All of these subwatersheds are classified as having a Low potential for stress under existing conditions. The Big Otter at Tillsonburg Subwatershed was classified as having a Moderate potential for stress under future demand conditions. If recharge decreased by 25% or agricultural demand increased by 25%, these four subwatersheds may move to a Moderate potential for stress classification.

The six subwatersheds identified as having either a Moderate or Significant potential for stress in the Groundwater Stress Assessment in Table 3.3 (i.e. Big Above Kelvin Gauge, Big Above Delhi, North Creek, Big Above Minnow Creek, Lynn River, and Nanticoke Upper Subwatersheds) maintain estimated Percent Water Demands consistent with their original classification for each sensitivity scenario. Despite large changes to demand and supply parameters in the Sensitivity Analysis calculations, all the subwatersheds identified as having a Moderate or Significant potential for stress would still be identified under each scenario. This confirmation of the stress classification provides additional confidence in the classification.

Table 3.8 summarizes the results of the sensitivity analysis. Those subwatersheds which were originally identified as having a Moderate or Significant potential for stress and retained that classification for all sensitivity scenarios, were assigned an Uncertainty Classification of “Low”. Likewise, those subwatersheds originally identified as having a Low potential for stress and retained that identification for all sensitivity scenarios, were assigned an Uncertainty Classification of “Low”. An uncertainty classification of “High” is assigned to subwatersheds whose potential for stress was shown to change for at least one of the sensitivity scenarios.

Table 3.8 - Low or High Uncertainty based on Sensitivity Analysis

Subwatershed		Low or High Uncertainty
Kettle Creek	Upper Kettle	Low
	Dodd Creek	Low
	Lower Kettle	Low
Catfish Creek	West Catfish	Low
	Catfish Above Aylmer	Low
	Lower Catfish	Low
	Silver Creek	Low
Big Otter	Otter Above Maple Dell Road	Low
	Otter at Otterville	Low
	Otter at Tillsonburg	**High**
	Spittler Creek	Low
	Lower Otter	Low
	Little Otter	Low
Lake Erie Tribs	South Otter	Low
	Clear Creek	**High**
Big Creek	Big Above Cement Road	Low
	Big Above Kelvin Gauge	Low
	Big Above Delhi	**High**
	North Creek	Low
	Big Above Minnow Creek	Low
	Big Above Walsingham	Low
	Venison Creek	**High**
	Lower Big	Low
Lake Erie Tribs	Dedrick Creek	Low
	Young/Hay Creeks	**High**
Lynn River	Lynn River	Low
	Black Creek	Low
Nanticoke Creek	Nanticoke Upper	Low
	Nanticoke Lower	Low
Eastern Tribs	Sandusk Creek	Low
	Stoney Creek	Low

3.6 UNCERTAINTY ASSESSMENT

As required by the Technical Rules, any subwatershed with an average monthly Percent Groundwater Demand between 8% and 10% or with a maximum monthly Percent Groundwater Demand between 23% and 25% is required to undergo further evaluation for certainty of the Percent Water Demand results.

While the Otter at Tillsonburg Subwatershed was assigned a Percent Water Demand of 8% for the existing conditions, it was classified as having a Moderate potential for stress under future conditions, with a Percent Water Demand of 11%. As such, the classification for this subwatershed is confirmed and no uncertainty assessment is required for this Subwatershed. No other subwatersheds met the criteria required for an uncertainty assessment.

3.7 PERCENT WATER DEMAND VARIABILITY

Similar to percent surface water demand variability, percent groundwater demand variability was calculated using variable supply and demand from the years 1960 to 2004. The purpose of this assessment was to confirm the potential for stress classification derived through the steady-state (average annual and max-monthly) assessments. The groundwater irrigation demand was estimated using the irrigation event model and groundwater supply was determined based on a time series multiplier for annual recharge.

3.7.1 Water Demand Variability

Similar to surface water demand variability explained in Section 2.8.1, all groundwater demand components remained constant for each year of the temporal variability assessment, with the exception of agricultural demand. Agricultural irrigation demand varies with climate; the method for determining how that demand would change with annual climates experienced from 1960 to 2004 is outlined below.

3.7.1.1 Irrigation Event Model and Irrigation Demand

Section 2.8.1.1 describes the irrigation model used to estimate irrigation frequency of irrigation. This method is applied here for groundwater irrigation permits.

The water demand required for one irrigation event was determined for each permitted groundwater source in the same manner described for surface water permits in Section 2.8.1.1, with the exception of the consumptive factor used. In estimating the surface water irrigation demand, a consumptive factor of 1.0 was used. To estimate the groundwater irrigation demand, a consumptive factor of 0.75 was used. Total irrigation demand per irrigation event was estimated for each subwatershed by summing all the irrigation groundwater demands per irrigation event in the subwatershed. These irrigation demands are given in Table 3.9 for each subwatershed.

Table 3.9 - Groundwater Demand per Irrigation Event for each Subwatershed

Subwatershed		Groundwater Irrigation Demand per Irrigation Event (L/s)
Kettle Creek	Upper Kettle	0
	Dodd Creek	1
	Lower Kettle	4
Catfish Creek	West Catfish	1
	Catfish Above Aylmer	9
	Lower Catfish	48

Subwatershed		Groundwater Irrigation Demand per Irrigation Event (L/s)
	Silver Creek	31
Big Otter	Otter Above Maple Dell Road	24
	Otter at Otterville	29
	Otter at Tillsonburg	46
	Spittler Creek	3
	Lower Otter	26
	Little Otter	46
Lake Erie Tribs	South Otter	48
	Clear Creek	60
Big Creek	Big Above Cement Road	12
	Big Above Kelvin Gauge	91
	Big Above Delhi	219
	North Creek	43
	Big Above Minnow Creek	121
	Big Above Walsingham	64
	Venison Creek	64
	Lower Big	24
Lake Erie Tribs	Dedrick Creek	47
	Young/Hay Creeks	68
Lynn River	Lynn River	160
	Black Creek	15
Nanticoke Creek	Nanticoke Upper	163
	Nanticoke Lower	1
Eastern Tribs	Sandusk Creek	0
	Stoney Creek	0

The above demands are multiplied by the number of irrigation events for each month of the year, as given in Table 2.9. This produces a monthly time series of agricultural water demand from 1960-2004. When summed with the other groundwater demand components for each year, a complete time series of groundwater demands is produced.

3.7.2 Water Supply Variability

The annual variability of groundwater supply was estimated from the GAWSER output of annual recharge for each subwatershed. Figure 16 shows the annual average recharge for each year from 1961 to 2004 for the North Creek Subwatershed. Other components of the groundwater supply term, specifically groundwater inflow and groundwater reserve (10% of discharge) were assumed to remain constant.

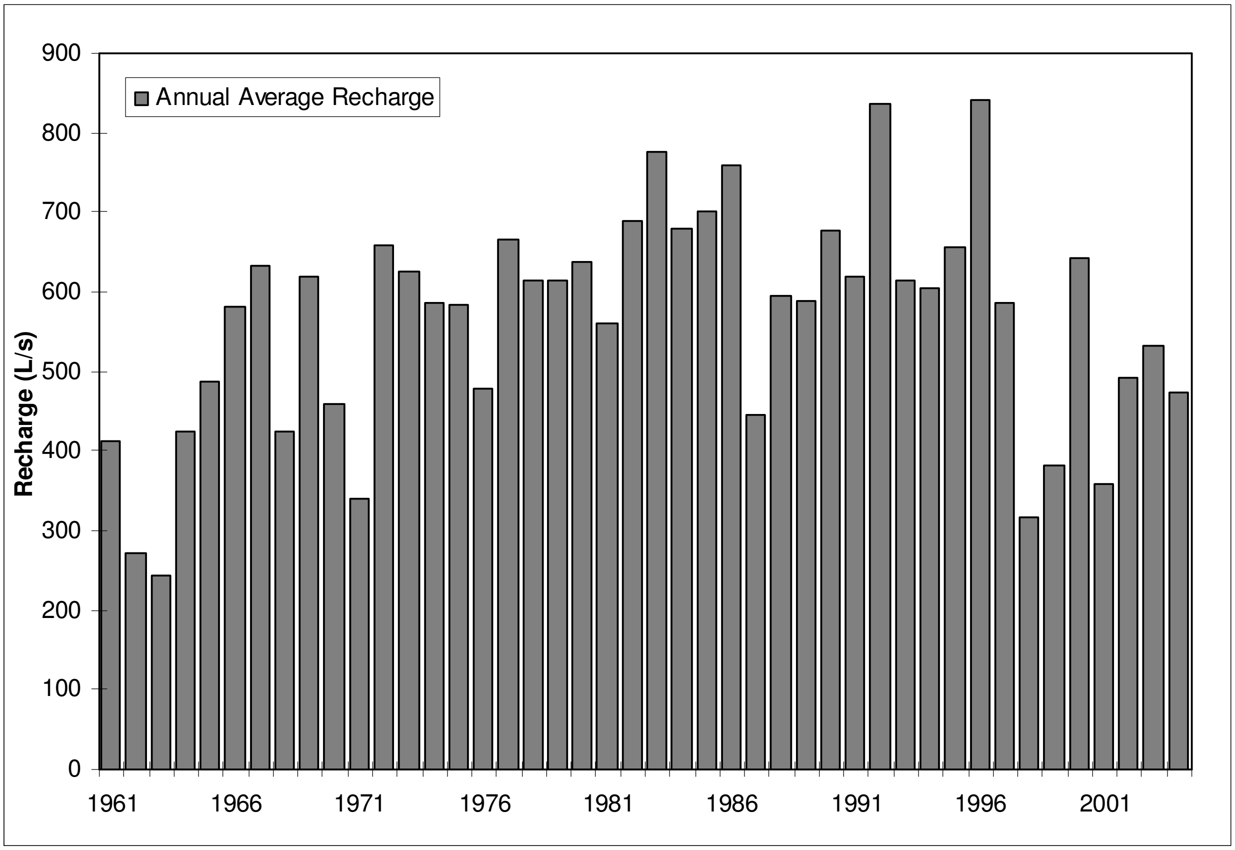


Figure 16 - North Creek Subwatershed Annual Recharge Variability

3.7.3 Percent Water Demand Variability

Percent Water Demand was calculated annually for each subwatershed using the annual recharge rates from 1961 to 2004 shown on Figure 16. Annual water demand estimates were adjusted based on estimated irrigation requirements for that year and used as variable demand parameters each year from 1960 to 2004. The monthly maximum demand scenario was not calculated on an annual basis.

The following discussion focuses on the seven groundwater subwatersheds having a potential stress of Moderate or Significant. The results of the Percent Water Demand Variability analysis are presented as a ranked curve of variable annual percent groundwater demands for each area. Results for all remaining subwatersheds are provided in Appendix B.

As shown on Figure 17, annual Percent Water Demand for Groundwater in the Big Creek Above Delhi Subwatershed varies from 1% to 31% for the period of 1960 to 2004. The threshold for potential stress outlined by the Technical Rules (MOE, 2008) for percent groundwater demand was 10%, indicating that the Big Creek Above Delhi Subwatershed would be classified as having a Moderate potential for stress 45% of the years shown. For 5% of the years, the Subwatershed would be classified as having a Significant potential for stress.

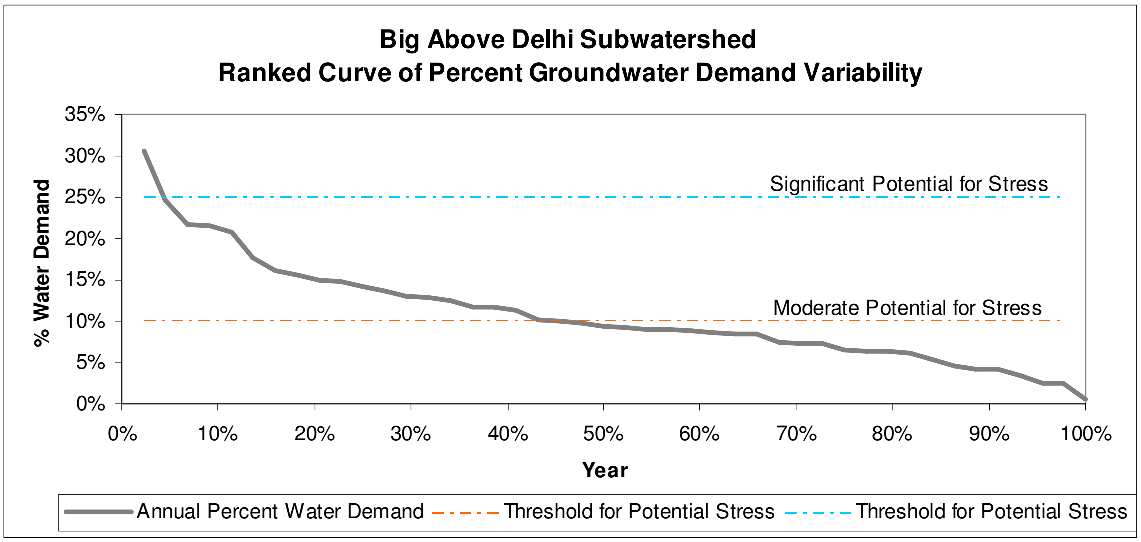


Figure 17 - Big Above Delhi Subwatershed - Ranked Annual Percent Groundwater Demand

As Shown in Figure 18, annual Percent Water Demand for Groundwater in the Big Creek Above Kelvin Gauge Subwatershed varies from 6% to 38% for the period of 1960 to 2004. The Percent Water Demand for this Subwatershed is above the threshold for Moderate potential stress about 86% of the years and above the threshold for Significant potential for stress 14% of the years, confirming the Significant stress level classification for this subwatershed.

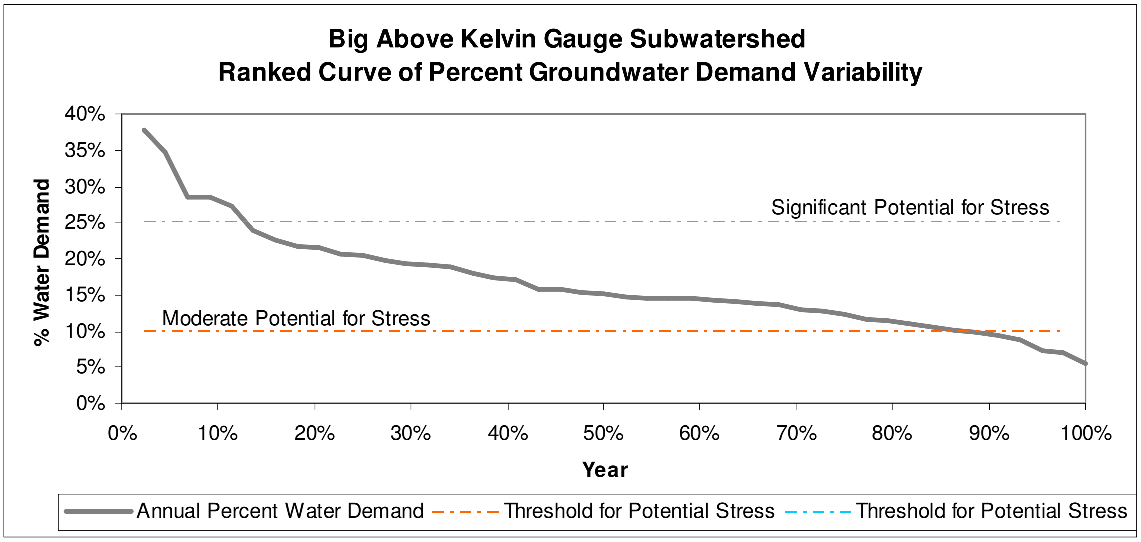


Figure 18 - Big Above Kelvin Gauge Subwatershed - Ranked Annual Percent Groundwater Demand

As shown in Figure 19, annual Percent Water Demand in the North Creek Subwatershed ranges from a low of 8% up to 35%. Percent Water Demand is greater than 10% for approximately 90% of the years in the time period, representing a majority of time when the Subwatershed has a Moderate potential for stress. The threshold for Significant potential for stress was passed 9% of the years.

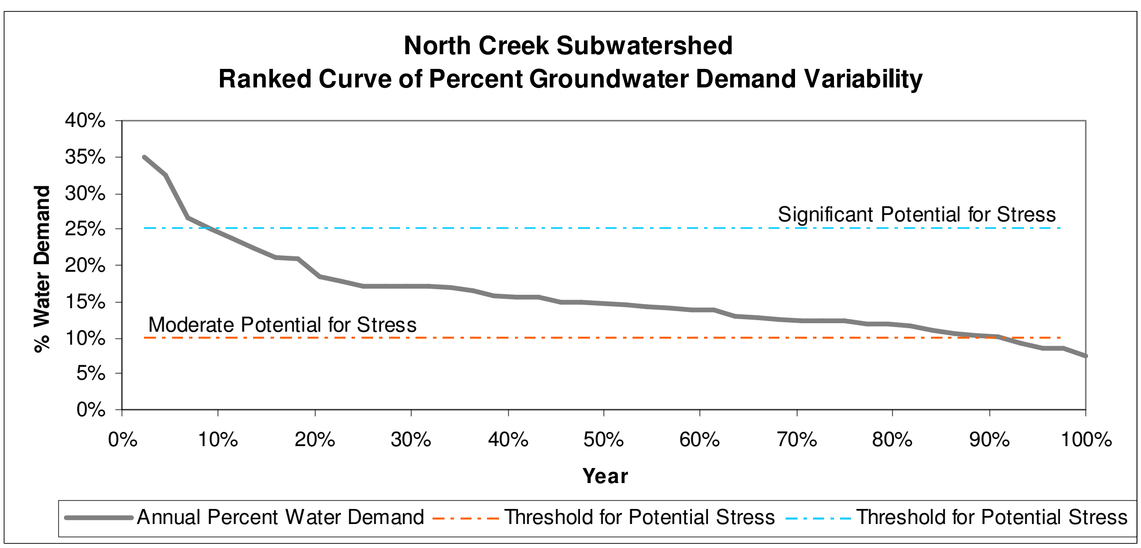


Figure 19 - North Creek Subwatershed - Ranked Annual Percent Groundwater Demand

Shown in Figure 20, annual Percent Water Demand in the Lynn River Subwatershed ranges from 5% up to 27% over the 1960 to 2004 period. Percent Water Demand is greater than 10% approximately 80% of the time, confirming the Moderate stress level classification for this subwatershed. Rarely, only 5% of years, does the Percent Water Demand for Lynn River cross the Significant threshold for potential stress.

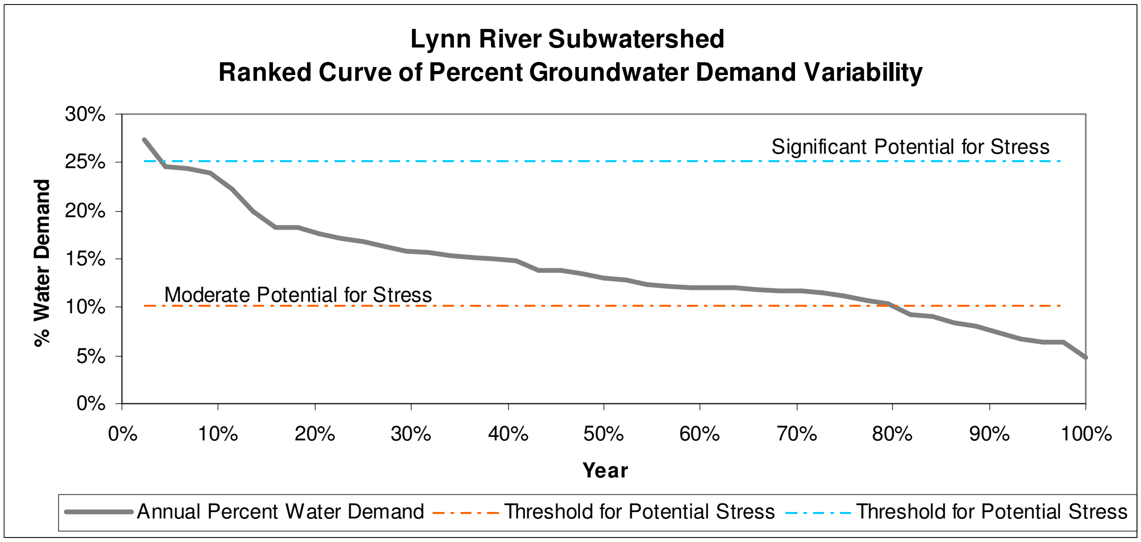


Figure 20 - Lynn River Subwatershed - Ranked Annual Percent Groundwater Demand

As shown on Figure 21, the Percent Water Demand for groundwater in the Nanticoke Upper Subwatershed ranged from 4% to 48%. The results are above the Moderate threshold for stress for approximately 90% of all years. A total of 36% of years fall above the threshold for Significant potential for stress, confirming the Significant stress level classification for this subwatershed.

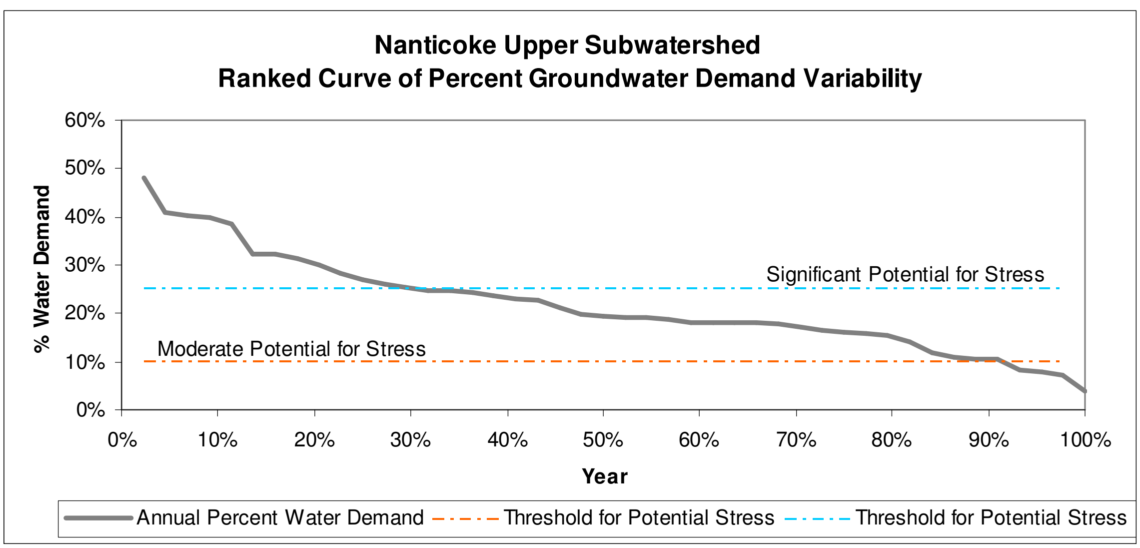


Figure 21 - Nanticoke Upper Subwatershed - Ranked Annual Percent Groundwater Demand

As illustrated on Figure 22, the estimated annual Percent Water Demand ranges from 5% to 13% for the Otter Creek at Tillsonburg Subwatershed. The Percent Water Demand is only above the Moderate threshold 14% of the time and never surpasses the threshold for Significant potential for stress, indicating that the potential for stress, under current demand conditions, is relatively infrequent. The Otter at Tillsonburg Subwatershed was found to have a Moderate potential for stress only under future conditions.

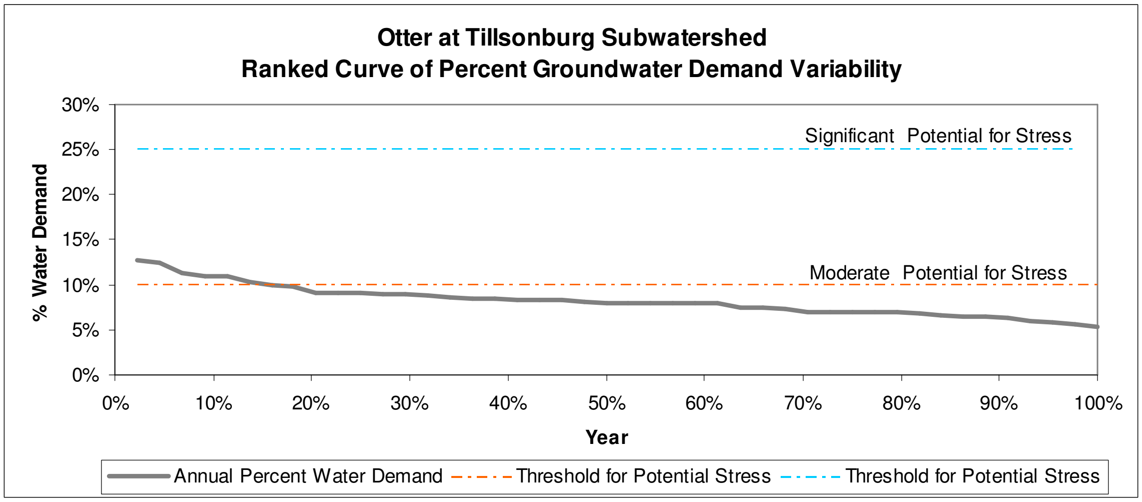


Figure 22 - Otter at Tillsonburg Subwatershed - Ranked Annual Percent Groundwater Demand

As shown on Figure 23, the annual Percent Water Demand for groundwater in the Big Creek Above Minnow Creek Subwatershed varies from 3% to 31% for the period of 1960 to 2004. The threshold for potential stress is surpassed approximately 70% of the years, confirming the Moderate stress level classification for this subwatershed. Only 7% of months surpass the threshold for Significant potential for stress.

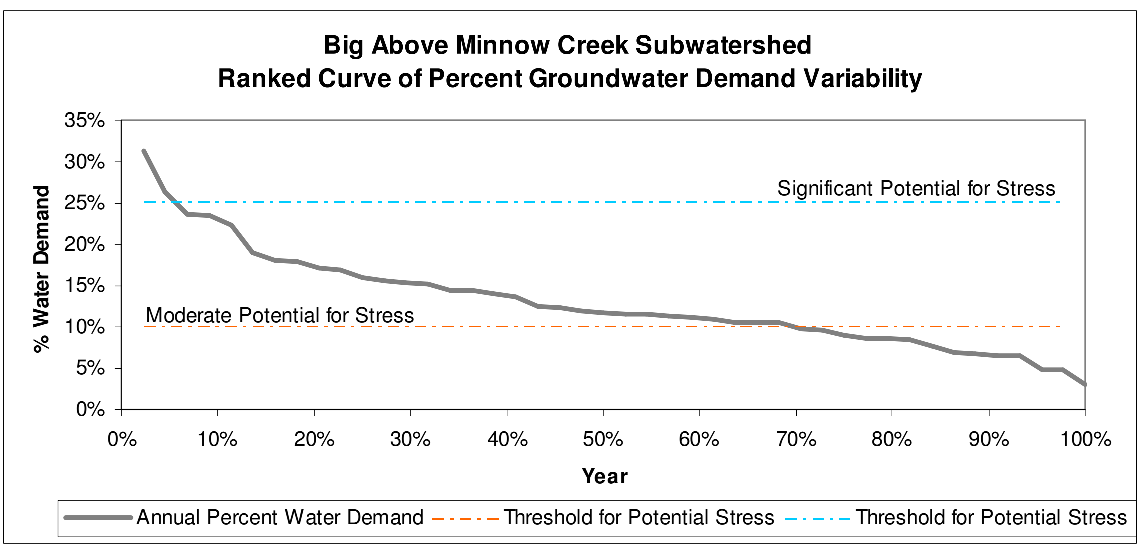


Figure 23 - Big Above Minnow Creek Subwatershed - Ranked Annual Percent Groundwater Demand

3.8 GROUNDWATER STRESS ASSESSMENT RESULTS

Based on the Percent Water Demand calculations for current and future demand conditions, and the results of the Drought Scenario, the groundwater stress classifications are included in Table 3.11 below. The potential stress thresholds that are used to identify subwatersheds as having a Moderate or Significant potential for stress are repeated in Table 3.10 (from Table 1.5). The potential for stress within a subwatershed with respect to groundwater is evaluated based on the Percent Water Demand calculated for annual average demand as well as monthly maximum demand. If conditions within a subwatershed are classified as having a Moderate or Significant potential for stress under either demand condition, municipal supplies located within the subwatershed meet the Technical Rules requirements for a Tier 3 Water Quantity Risk Assessment.

Table 3.10 - Groundwater Potential Stress Thresholds

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

Table 3.11 - Subwatershed Groundwater Stress Classification

Subwatershed		Potential for Stress (Avg Demand)	Potential for Stress (Monthly Max Demand)	Municipal Water Supply
Kettle Creek	Upper Kettle	Low	Low	**Belmont**
	Dodd Creek	Low	Low	None
	Lower Kettle	Low	Low	None
Catfish Creek	West Catfish	Low	Low	None
	Catfish Above Aylmer	Low	Low	**Brownsville**
	Lower Catfish	Low	Low	None
	Silver Creek	Low	Low	None
Big Otter	Otter Above Maple Dell Road	Low	Low	**Norwich**
	Otter at Otterville	Low	Low	**Otterville**
	Otter at Tillsonburg	Moderate	Low	**Tillsonburg**
	Spittler Creek	Low	Low	**Springford, Dereham Center**
	Lower Otter	Low	Low	None
	Little Otter	Low	Low	None
Lake Erie Tribs	South Otter	Low	Low	None
	Clear Creek	Low	Low	None
Big Creek	Big Above Cement Road	Low	Low	None
	Big Above Kelvin Gauge	Moderate	Significant	None
	Big Above Delhi	Moderate	Moderate	None
	North Creek	Moderate	Moderate	None
	Big Above Minnow Creek	Moderate	Moderate	**Delhi**
	Big Above Walsingham	Low	Low	None
	Venison Creek	Low	Low	None
	Lower Big	Low	Low	None
Lake Erie Tribs	Dedrick Creek	Low	Low	None
	Young/Hay Creeks	Low	Low	None

Subwatershed		Potential for Stress (Avg Demand)	Potential for Stress (Monthly Max Demand)	Municipal Water Supply
Lynn River	Lynn River	Moderate	Moderate	**Simcoe**
	Black Creek	Low	Low	None
Nanticoke Creek	Nanticoke Upper	Moderate	Significant	**Waterford**
	Nanticoke Lower	Low	Low	None
Eastern Tribs	Sandusk Creek	Low	Low	None
	Stoney Creek	Low	Low	None

The Groundwater Subwatershed Stress Assessment described in this chapter classifies the following subwatersheds as having a Moderate or Significant potential for stress:

- Otter Creek at Tillsonburg Subwatershed;
- Big Creek Above Kelvin Gauge;
- Big Creek Above Delhi Subwatershed;
- Big Creek Above Minnow Creek Subwatershed;
- North Creek Subwatershed;
- Lynn River Subwatershed; and
- Nanticoke Upper Subwatershed.

These subwatersheds represent the upstream portion of the Big Creek, Lynn River and Nanticoke Creek Watersheds, as well as the most developed portion of the Otter Creek Watershed. All other subwatersheds in the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities are classified as having a Low potential for surface water stress, as defined within the Technical Rules (MOE, 2008). The results of the Tier 2 Groundwater Stress Assessment are illustrated on Map 16.

It should be noted that the following subwatersheds were found to have a Low potential for stress, but assigned a High level of uncertainty:

- Clear Creek Subwatershed;
- Venison Creek Subwatershed; and
- Young / Hay Subwatershed.

The uncertainty classification of High indicates that Percent Water Demand for these subwatersheds could be above the threshold for a Moderate potential for stress, given variations of +-25% in either the water supply or demand terms. While these subwatersheds are classified as having a Low potential for stress under the Technical Rules (MOE, 2008), the sensitivity surrounding that classification should be considered for watershed management initiatives beyond Source Protection.

3.8.1 Discussion

The following sections summarize the subwatersheds classified as having a Moderate or Significant potential for stress under existing and future demand conditions. The hydrologic factors influencing the classification are discussed, and municipal supplies located within the subwatershed are identified.

To facilitate the discussion of the driving factors that result in the relative levels of potential for stress for each subwatershed, Table 3.12 presents a breakdown of the consumptive water demand by sector.

Table 3.12 - Breakdown of Consumptive Groundwater Demand By Sector

Subwatershed		Average Demand (L/s)	Average % Water Demand	Agricultural	Commercial	De-watering	Industrial	Misc.	Recreational	Non-Munic. Water Supply	Livestock and Rural Domestic	Municipal Demand
Kettle Creek	Upper Kettle	21	3%	0%	41%	0%	0%	0%	0%	17%	17%	25%
	Dodd Creek	2	0%	24%	0%	0%	0%	0%	0%	0%	76%	0%
	Lower Kettle	17	1%	20%	49%	0%	0%	0%	0%	0%	31%	0%
Catfish Creek	West Catfish	6	1%	8%	0%	0%	0%	0%	0%	0%	92%	0%
	Catfish Above Aylmer	13	1%	48%	0%	0%	0%	0%	0%	0%	43%	9%
	Lower Catfish	36	3%	90%	0%	0%	0%	0%	0%	3%	8%	0%
	Silver Creek	23	4%	90%	0%	0%	0%	0%	0%	0%	10%	0%
Big Otter	Otter Above Maple Dell Rd	29	4%	56%	0%	0%	0%	0%	0%	0%	13%	32%
	Otter at Otterville	26	4%	77%	0%	0%	0%	0%	0%	0%	11%	12%
	Otter at Tillsonburg	130	8%	23%	18%	0%	0%	0%	0%	0%	3%	56%
	Spittler Creek	9	1%	24%	0%	0%	0%	0%	0%	0%	50%	26%
	Lower Otter	21	2%	83%	0%	0%	0%	0%	0%	0%	17%	0%
	Little Otter	60	5%	52%	44%	0%	0%	0%	0%	0%	4%	0%
Lake Erie Tribs	South Otter	33	3%	96%	0%	0%	0%	0%	0%	0%	4%	0%
	Clear Creek	43	5%	97%	0%	0%	0%	0%	0%	0%	2%	0%
Big Creek	Big Above Cement Road	10	2%	79%	0%	0%	0%	0%	0%	0%	21%	0%
	Big Above Kelvin Gauge	111	17%	55%	28%	0%	16%	0%	0%	0%	1%	0%
	Big Above Delhi	156	10%	94%	0%	0%	0%	0%	3%	0%	2%	0%
	North Creek	94	16%	31%	68%	0%	0%	0%	0%	1%	1%	0%
	Big Above Minnow Creek	112	12%	72%	1%	0%	0%	0%	0%	0%	1%	26%
	Big Above Walsingham	46	4%	95%	0%	0%	0%	0%	0%	0%	5%	0%
	Venison Creek	46	4%	96%	0%	0%	0%	0%	0%	0%	4%	0%
	Lower Big	19	3%	92%	0%	0%	0%	0%	0%	0%	8%	0%
Lake Erie Tribs	Dedrick Creek	34	2%	95%	0%	0%	0%	0%	0%	0%	5%	0%
	Young/Hay Creeks	80	7%	59%	0%	0%	0%	39%	0%	0%	2%	0%
Lynn River	Lynn River	201	14%	54%	3%	0%	2%	0%	0%	0%	2%	39%
	Black Creek	37	6%	28%	11%	52%	0%	0%	0%	0%	10%	0%

Subwatershed		Average Demand (L/s)	Average % Water Demand	Agric-ultural	Com-mercial	De-watering	Ind-ustrial	Misc.	Recre-ational	Non-Munic. Water Supply	Livestock and Rural Domestic	Municipal Demand
Nanticoke Creek	Nanticoke Upper	141	21%	84%	0%	0%	0%	0%	0%	0%	2%	15%
	Nanticoke Lower	3	1%	20%	0%	0%	0%	0%	0%	0%	80%	0%
Eastern Tribs	Sandusk Creek	9	2%	0%	0%	0%	15%	0%	0%	37%	49%	0%
	Stoney Creek	4	1%	0%	16%	0%	0%	0%	0%	0%	84%	0%
TOTAL		1571	-	64%	11%	1%	1%	2%	0%	1%	6%	14%

3.8.1.1 Big Creek Above Kelvin Gauge Subwatershed

The Percent Water Demand for the Big Creek Above Kelvin Gauge Subwatershed is 17% under average demand conditions and 50% under maximum monthly demand conditions. The Subwatershed assigned a **Moderate** potential for stress under average pumping and a **Significant** potential for stress under maximum monthly pumping. The future scenario for the groundwater Stress Assessment does not change the stress classification for this Subwatershed, as no municipal takings are present in the Big Creek Above Kelvin Gauge Subwatershed.

Of the 87 water takings located within this Subwatershed, 83 are for agricultural purposes. Of the remaining 4 water takings, 2 are for industrial water cooling, one is for aggregate washing, and the final permit is for aquaculture purposes. Given in Table 3.12 above, a total of 55% of demand depends on average agricultural pumping, 28% of demand comes from one commercial aquaculture taking, 16% of total groundwater demand depends on industrial takings, and 1% of total demand is estimated as livestock watering and rural domestic demand. Only one agricultural permit in this Subwatershed has reported pumping rates available.

There are no municipal groundwater supplies in this Subwatershed; therefore, the conditions do not meet requirements for a Tier 3 Water Quantity Risk Assessment.

3.8.1.2 Big Creek Above Delhi Subwatershed

The results of this analysis assign the Big Creek Above Delhi Subwatershed a Percent Water Demand of 10% under average demand conditions and 44% for maximum monthly demand conditions. Based on the Stress Assessment thresholds, this Subwatershed has been identified as having a **Moderate** potential for stress under both average and maximum monthly demand conditions. Due to having no groundwater municipal takings within the Big Creek Above Delhi Subwatershed, the percent groundwater demand and stress classifications do not change in the future demand scenario.

There are 244 water takings located within this Subwatershed, with 238 takings assigned for agricultural, 4 for Aesthetics and 2 for miscellaneous purposes. Table 3.12 shows that 94% of total groundwater demand is dependent on agricultural pumping, 3% is due to recreational demand, and 2% is attributed to estimated livestock watering and rural domestic demand. Only 11 of the takings have reported pumping rates associated with them. The water demand is well distributed between the 244 takings, with no one taking being responsible for more than 3% of the total demand.

As there are no municipal groundwater supplies within this Subwatershed, conditions do not meet the requirements for a Tier 3 Water Quantity Risk Assessment.

3.8.1.3 Otter at Tillsonburg Subwatershed

The Percent Water Demand for the Otter at Tillsonburg Subwatershed is 8% under current average demand conditions and 16% under maximum monthly demand conditions. For these current conditions, the Subwatershed was given a Low potential for stress. When future average demands were applied to this Subwatershed, the average Percent Water Demand jumped to 11%, above the threshold for Moderate stress, and went to 18% for future maximum demand conditions. Due to future estimated demands, Otter at Tillsonburg is classified as having a **Moderate** potential for stress.

There are 66 groundwater takings located within this Subwatershed, with 48 being attributed to agricultural purposes, 7 for aquaculture takings, 1 golf course irrigation permit, and 10 reported municipal water takings. Three of the aquaculture takings plus the golf course irrigation takings were also reported values. Table 3.12 shows that 23% of total groundwater demand is dependent on agricultural pumping, 18 % is due to the commercial sector, 3% is due to estimated livestock watering and rural domestic demand, and 56% is attributed to the municipal water demands. No one taking is responsible for more than 10% of the total demand in the maximum month of demand.

Municipal supplies within this Subwatershed include the Tillsonburg Supply wells. At Tillsonburg, the conditions meet requirements for a groundwater Tier 3 Water Quantity Risk Assessment.

3.8.1.4 North Creek Subwatershed

The Percent Water Demand for the North Creek Subwatershed is 16% under average demand and 34% for peak monthly demand conditions. The Subwatershed is therefore classified with a **Moderate** potential for stress under both average and peak monthly conditions. Due to having no groundwater takings in this Subwatershed for municipal supplies, the classification for potential stress does not change in the future scenario for the North Creek Subwatershed.

There are 78 takings located within this Subwatershed, of which 68 are for agricultural purposes. Of the remaining takings, 8 are for aquaculture takings and 2 are for a Campground Water Supply. Shown in Table 3.12, 31% of the total groundwater demand is due to agricultural groundwater demand, 68% comes from the commercial sector comprising of aquaculture permits in this Subwatershed, 1% is attributed to non-municipal supply, and 1% is estimated to represent the livestock watering and rural domestic demand in the North Creek Subwatershed. There are no water takings within this Subwatershed with reported pumping rates. The top 3 takings, in terms of estimated demand, are all aquaculture takings, and comprise over 60% of the average annual demand for this Subwatershed. Additional reported information regarding these takings may lower the Percent Water Demand for this Subwatershed.

There are no municipal groundwater supplies located within North Creek, although the Delhi municipal system does take surface water from Lehman Reservoir within the North Creek Subwatershed. Because of the lack of municipal groundwater wells within this Subwatershed, the conditions are not met for requiring a Tier 3 Water Quantity Stress Assessment.

3.8.1.5 Big Creek Above Minnow Creek Subwatershed

The results of the analysis indicate that Big Creek Above Minnow Creek Subwatershed has a Percent Water Demand of 12% under average demand conditions, and 44% under peak monthly demand conditions. Based on the Stress Assessment thresholds, this Subwatershed has been identified as having a **Moderate** potential for stress under both average and peak demand conditions. Including future projected municipal demands in the future groundwater Stress Assessment scenario, Percent Water Demand under average conditions is 14% and under maximum monthly pumping conditions is 45%. This slight increase to the Percent Water Demand does not cause a change in the stress classifications for the Subwatershed.

Big Creek Above Minnow Creek Subwatershed has 129 water takings located within it, with 126 agricultural takings, 2 water supply takings and a single golf course taking. Table 3.12 shows 72% of total groundwater demand attributed to agricultural takings, 26% attributed to municipal water demand, 1% of total demand due to the golf course irrigation and 1% estimated for livestock watering and rural domestic demand. Of the 129 takings, only 8 of the takings have reported pumping rates associated with them. The two water supply takings represent more than 25% of the average annual demand; these takings already have reported rates associated with them and are therefore highly certain. Beyond the two water supply takings, demand is very well distributed, with no single taking being responsible for more than 4% of the average annual demand.

Municipal supplies within this Subwatershed include the Norfolk County Delhi Supply wells. As outlined in the Technical Rules, the conditions at Delhi meet requirements for a groundwater Tier 3 Water Quantity Risk Assessment.

3.8.1.6 Lynn River Subwatershed

The Percent Water Demand for the Lynn River Subwatershed is 14% under average demand conditions and 40% under peak monthly demand conditions. This value classifies the Subwatershed as having a **Moderate** potential for stress under both average and peak demands. Including future municipal demands in the groundwater Stress Assessment, the percent groundwater demand for Lynn River Subwatershed is 15% under average conditions and 42% under maximum monthly demand conditions. These do not change the Subwatershed stress classifications for Lynn River.

There are 186 takings located within this Subwatershed, with 172 takings being for agricultural purposes. The remaining takings are split between golf courses, food processing, aggregate washing and water supply. Only 15 of the takings have reported pumping rates associated with them, including all municipal takings. On average, 54% of water demand comes from agricultural water takings, 39% of demand comes from municipal takings, 3% comes from the commercial sector, 2% comes from industrial takings, and 2% is estimated to come from livestock watering and rural domestic demand. Two water supply takings are each responsible for more than 10% of the total annual demand and have reported rates associated with them, making them more reliable than estimated demands.

Municipal supplies within this Subwatershed include the Norfolk County Simcoe wells. The Simcoe well takings account for 39% of the total demand in Lynn River. The conditions at the Town of Simcoe meet the requirements for a groundwater Tier 3 Water Quantity Risk Assessment.

3.8.1.7 Upper Nanticoke Creek Subwatershed

The Upper Nanticoke Creek Subwatershed has a Percent Water Demand under average demand conditions of 21%, and 79% under maximum monthly demand conditions. Based on the Stress Assessment thresholds, this Subwatershed has been classified as having a **Moderate** potential for stress under average demand conditions, and a **Significant** potential for stress under maximum monthly demand conditions. Considering future projected municipal demands, future percent groundwater demand under average conditions is 22% and under maximum monthly conditions is 80%. This slight increase in Percent Water Demand does not change the Subwatershed potential stress classification.

There are 181 takings located within Upper Nanticoke Creek, of which, 179 are for agricultural purposes. The Waterford municipal supply takings are the 2 remaining takings. As shown in Table 3.12 above, Upper Nanticoke Subwatershed has 84% of its demand from the agricultural sector, 15% from municipal pumping, and 2% from estimated livestock watering and rural domestic demand. There are 30 takings within the Subwatershed having reported pumping rates associated, including the 2 municipal takings. The estimated demand is well distributed between the takings, with no single taking being responsible for more than 10% of the total annual demand.

The municipal supplies within this Subwatershed that depend on groundwater supply include the Norfolk County Waterford wells. These demands account for 15% of the entire consumptive demand in Upper Nanticoke. The conditions at the Waterford wells meet the requirements for a groundwater Tier 3 Water Quantity Risk Assessment.

4.0 Significant Groundwater Recharge Areas

The Technical Rules (MOE, 2008) require the identification of Significant Groundwater Recharge Areas (SGRAs) as a specific type of vulnerable area that will be protected under the Clean Water Act (2006). The role of SGRAs is to support the protection of drinking water across the broader landscape. SGRAs delineated using the water budget tools are further scored as areas of high, moderate, or low groundwater vulnerability based on their mapped intrinsic susceptibility (or alternate vulnerability mapping) as part of the Water Quality Threats Assessment process.

Recharge is the process whereby water moves from the ground surface through the unsaturated zone to the underlying watertable. Groundwater recharge occurs across a watershed at a range of rates depending on soil type, land use, slope, and climate. Within the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities, the GAWSER results provide an estimate of groundwater recharge in Hydrological Response Units (HRUs) designed to reflect surficial geology (soil type) and land cover. The Technical Rules (MOE, 2008) provide a straightforward methodology to delineate SGRAs from the GAWSER simulation results.

4.1 METHODOLOGY

The Technical Rules (MOE, 2008) provide the following instructions for the delineation of SGRAs;

> ***Part V.2 - Delineation of significant groundwater recharge areas***
>
> *44. Subject to rule 45, an area is a significant groundwater recharge area if,*
>
> > *(1) 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*
> >
> > *(2) 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.*
>
> *45. Despite rule 44, an area shall not be delineated as a significant groundwater recharge area unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system.*
>
> *46. The areas described in rule 44 shall be delineated using the models developed for the purposes of Part III of these rules and with consideration of the topography, surficial geology, and how land cover affects groundwater and surface water.*

This Assessment follows rule 44(1) to define the thresholds for SGRAs; these threshold values are further justified through a review of estimated recharge distributions. For each of the Catfish Creek, Kettle Creek and Long Point Region Conservation Authorities, the “related groundwater recharge area” was taken as the entire Conservation Authority area. This is consistent with the guidance which recommends that this assessment is performed at the watershed scale.

After estimating Significant Groundwater Recharge Areas, small, isolated areas (< 1km^2) were removed to create mapping that focuses the delineated SGRAs to larger geologic and physiographic features that are considered more representative of mapped Quaternary geology features. This modification is considered more practical and workable for planning purposes.

4.2 RESULTS

Map 17 illustrates the average annual groundwater recharge rates across the three Conservation Authorities based on the output of the GAWSER surface water model. AquaResource (2009a) describes the modelling process used to estimate the average annual groundwater recharge rates based on Hydrologic Response Units (HRUs). Average annual recharge rates are much lower in the Haldimand Clay Plain (eastern extent of the Long Point Region Conservation Authority), and in Catfish Creek and Kettle Creek Conservation Authorities to the west, than in the central Long Point Region Norfolk Sand Plain. Given these different types of conditions, a lower groundwater recharge rate may be significant in the Catfish Creek or Kettle Creek Conservation Authories than within the Long Point Region Conservation Authority. To account for these different hydrologic processes, SGRAs were delineated separately for each conservation authority (CA).

Table 4.1 lists the Significant Groundwater Recharge Area thresholds calculated for each of the three conservation authorities, using the criteria set out in Rule 44(1). These thresholds are calculated based on the average annual recharge rates estimated for each of the zones, multiplied by 115%.

Table 4.1 - Significant Groundwater Recharge Area Thresholds

Physiographic Region	Average Annual Recharge Rate (AARR) (mm/yr)	Threshold Recharge Rate (AARR *115%) (mm/yr)
Kettle Creek Conservation Authority	143	164
Catfish Creek Conservation Authority	157	180
Long Point Region Conservation Authority	224	257

To evaluate the reasonableness of these threshold recharge values, as is consistent with Technical Rule 46, the distribution of recharge within of the conservation authorities was analyzed. Figures 24 to 26 illustrate the distribution of recharge rates as well as the volume and area exceeding each recharge rate for each of the four regions. The exceedance curves are calculated as follows:

- % Volume Exceeding Recharge Rate = sum of recharge **volume** for all rates equal to or above a threshold value, divided by the total recharge volume;
- % Area Exceeding Recharge Rate = sum of **area** associated with all rates equal to or above a threshold value, divided by the total area;

Using these calculations, these figures illustrate how much volume or area would be identified as exceeding a threshold recharge rate. Inflections in these curves illustrate natural divisions within the distribution and reflect the variation in surficial geologic and land use within each conservation authority.

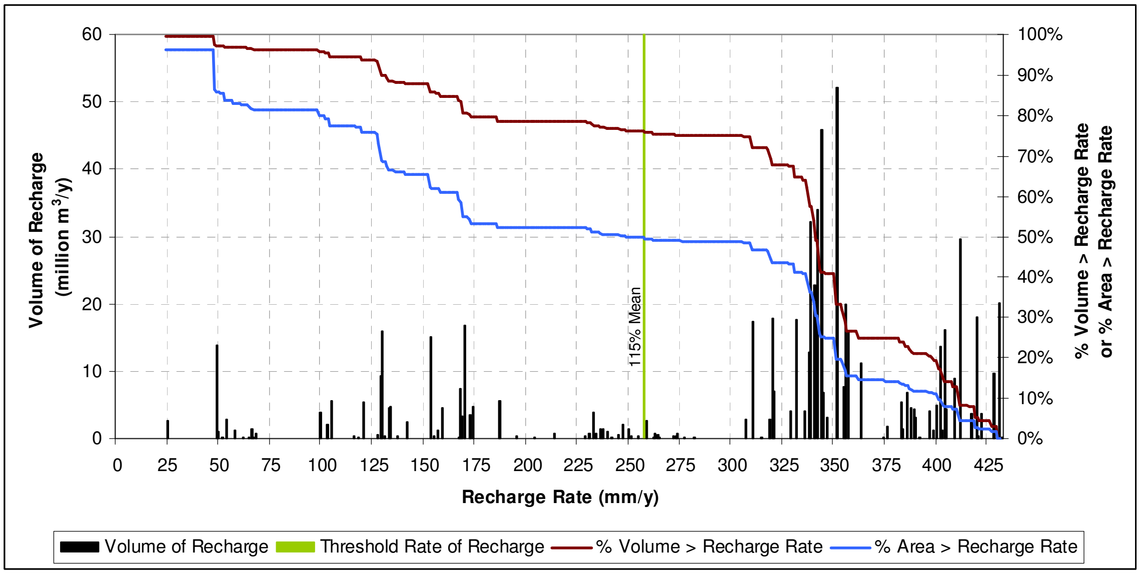


Figure 24 - Cumulative % Recharge Volume and Area in the Long Point Region CA

As illustrated Figure 24, the computed threshold value lies within a plateau of the % volume and % area curves and results in identifying approximately 75% of the recharge volume as significant, which occurs within approximately 50% of the conservation authority area. For this conservation area, it appears that threshold value is reasonable and practical for defining SGRAs since the threshold value encompasses all land within the Sand Plain area (> 300 mm/yr) as well as portions of the Paris and Galt Moraines.

Figure 25 presents the recharge distribution, cumulative volume and area curves for the Kettle Creek Conservation Authority. As illustrated, the computed threshold value lies within a plateau of the % volume and % area curves and identifies approximately 50% of the recharge volume as significant, occurring within approximately 25% of the conservation authority area. For this conservation area, it appears that threshold value is practical for defining SGRAs since the threshold value encompasses all areas with sandy soils.

Figure 26 presents the recharge distribution, cumulative volume and area curves for the Catfish Creek Conservation Authority. As illustrated, the computed threshold value lies within a plateau of the % volume and % area curves and identifies approximately 60% of the recharge volume as significant, occurring within approximately 35% of the conservation authority area. For this conservation area, it appears that threshold value is practical for defining SGRAs as the threshold value encompasses all areas with sandy soils.

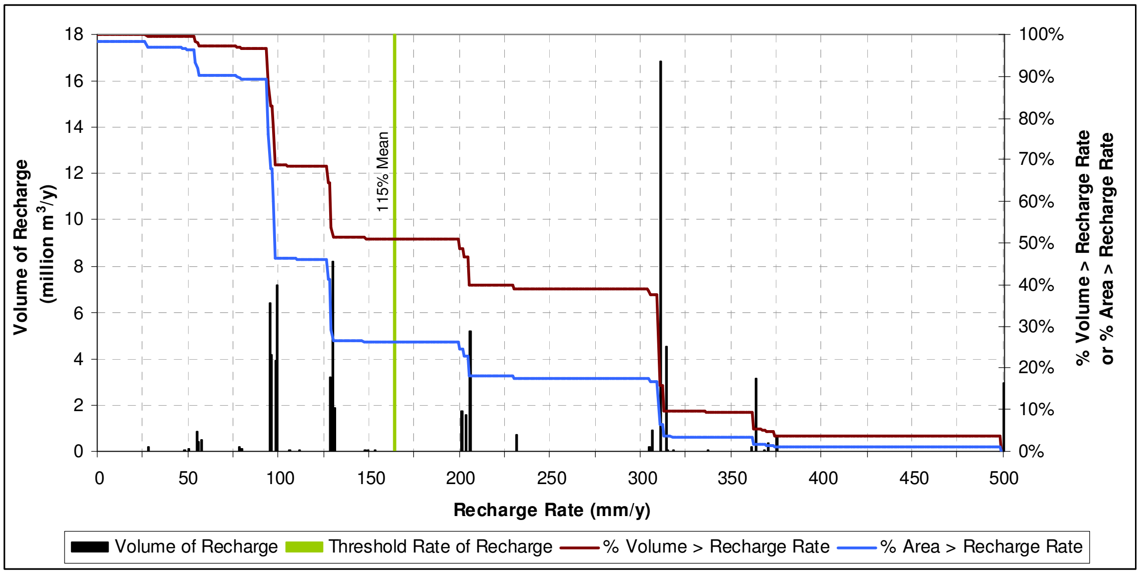


Figure 25 - Cumulative % Recharge Volume and Area in the Kettle Creek CA

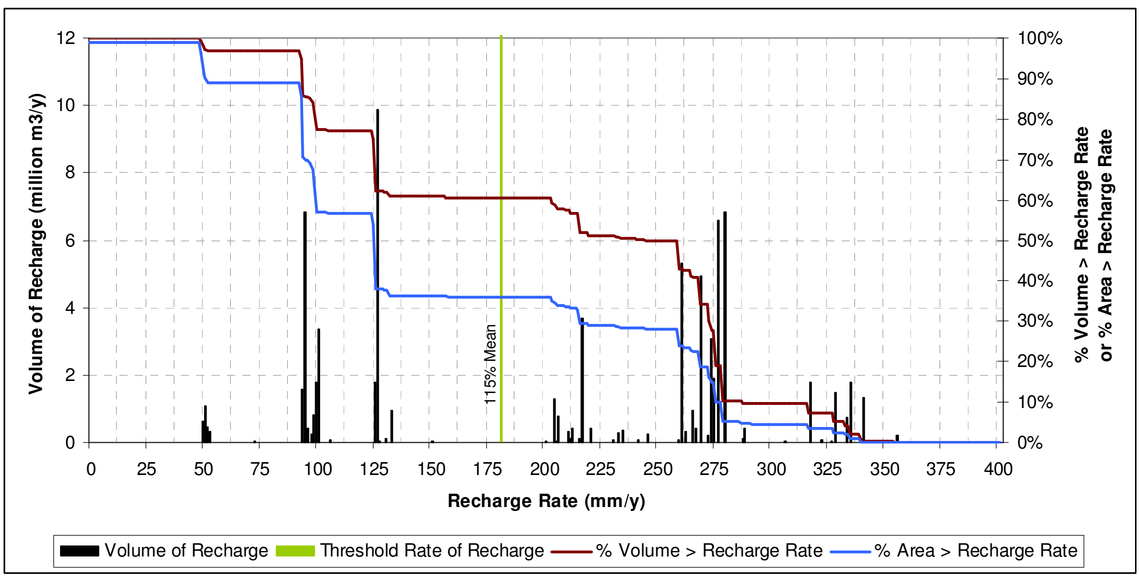


Figure 26 - Cumulative % Recharge Volume and Area in the Catfish Creek CA

Based on this evaluation of the recharge distribution and threshold values, it appears that the established SGRA thresholds provide realistic and practical definition of the Significant Groundwater Recharge Areas.

Map 18 illustrates all areas where the estimated average annual groundwater recharge rates are greater than the threshold rates for the respective conservation areas. As shown in this figure, SGRAs are concentrated within the Long Point Region Conservation Authority. SGRAs within the other regions correspond to surficial soils with relatively higher permeability as well as land cover (e.g., forest) that would tend to increase estimated groundwater recharge rates.

As described in the Long Point Region, Catfish Creek, and Kettle Creek Integrated Water Budget Report (AquaResource, 2009a), the HRUs are delineated across the three Conservation Authorities with a very high level of precision as a reflection of detailed geological and land cover mapping. Consequently, the map of estimated groundwater recharge is very detailed, showing relatively small parcels of land that are above the SGRA threshold. Map 19 illustrates a modification of the SGRA map that removes all isolated polygons with an area less than or equal to 1 km^2, following the methodology described in Section 4.1. The 1 km^2 threshold was selected as it represents the scale of the features reflected in the available Quaternary geology mapping.

To show that all delineated SGRAs are hydrologically connected to groundwater sources used for drinking water purposes, domestic wells and municipal well locations are shown on Maps 20, 21, and 22 for the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities, respectively.

4.3 DISCUSSION

The SGRAs delineated in this chapter reflect those areas within the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities that are considered to be important groundwater recharge areas. These areas include the Norfolk Sand Plain in the western portion of the Long Point Region Conservation Authority extending down into the southern portions of the Catfish Creek and Kettle Creek Conservation Authorities. Other areas identified as SGRAs, especially in the northern portions of Catfish and Kettle Creek Conservation Authorities, indicate more locally significant groundwater recharge areas, where the recharge rates are greater than the threshold for those zones.

When relying on the SGRA map to support water quantity or water quality protection activities there is a need to consider some of the assumptions and limitations associated with the delineated SGRAs. They are as follows:

1. Significant rates and volumes of groundwater recharge occur in areas that are not classified as SGRAs. Estimated groundwater recharge rates in some areas might be high, but just below the SGRA threshold.
2. The GAWSER and FEFLOW models are calibrated to achieve the best overall fit to measured streamflow and baseflow estimates. Within a specific watershed, there is a wide range of estimated groundwater recharge rates depending on local soil type and land cover. While the calibration process addresses the confidence of the hydrologic and hydrogeological simulation within a subwatershed, the water budget parameters for a specific HRU are not calibrated and the results should only be considered as a relative measure of hydrologic processes.

The Province's objectives for incorporating SGRAs into the Water Quality Threats Assessment process are clearly defined within the Technical Rules (MOE, 2008). SGRAs are used in coordination with intrinsic susceptibility mapping to determine a vulnerability score outside of wellhead protection areas. SGRAs are one of the three types of vulnerable areas identified by the Province.

Conversely, the role of protecting SGRAs from a water quantity perspective is not prescribed in the Technical Rules (MOE, 2008). SGRA mapping may be adopted by individual municipality and county planning offices as a "designated vulnerable area" through the Provincial Policy

Statement (PPS), to improve or restore the quality and quantity of water, particularly in areas pertinent to significant hydrologic processes (as per the guidance in section 2.2.1 of the PPS). However, such initiatives are undertaken as each jurisdiction sees fit and may not provide a uniform approach to water quantity protection throughout the watershed, including the potential cumulative impacts of development. The Source Protection Planning Process also provides a good opportunity to address the need to protect groundwater quantity across a watershed / subwatershed basis. A groundwater quantity protection initiative for SGRAs would need to include consideration of the total recharge volume, the hydrologic function of recharge from any given area and also the uncertainty of estimated recharge rates.

5.0 Conclusions

This document describes the Tier 2 Water Quantity Stress Assessment for the Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities, which has been prepared to meet the requirements of the Province of Ontario's Clean Water Act (2006). A companion report, the Long Point Region, Catfish Creek and Kettle Creek Integrated Water Budget Report (AquaResource, 2009a) has also been prepared. This companion report contains information relating to the water budget for the Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities (the Conservation Authorities), including watershed characterization, consumptive water demand estimates, and surface water and groundwater model development. The water budget information provides the technical basis for the Subwatershed Stress Assessment presented in this report.

The methodology followed in this report is consistent with the Technical Rules prepared by the Ministry of Environment (MOE, 2008) for the preparation of Assessment Reports under the Clean Water Act (Province of Ontario, 2006). The relevant section in the Technical Rules can be found in *Part III.4 – Subwatershed Stress Levels – Tier Two Water Budgets*. As outlined in the Technical Rules, the Stress Assessment determines the level of potential stress in each subwatershed by using the Percent Water Demand calculations and the potential stress thresholds for both surface water and groundwater. In addition, Drought Scenarios for both surface water and groundwater are performed, and recorded Historical Conditions of municipal intakes (if available) are used to determine a subwatershed's potential for stress.

The water budget tools developed for the Conservation Authorities and described in the Integrated Water Budget Report (AquaResource, 2009a) were applied to meet the requirements of the Stress Assessment. The results of the Tier 2 Stress Assessment are consistent with expectations. As agricultural takings are the most dominant water use sector in the Conservation Authorities, areas that are classified as having a Moderate or Significant potential for stress correspond to subwatersheds that have many agricultural permits associated with them.

The specific objectives of this Tier 2 Water Quantity Stress Assessment were as follows:

- Evaluate the stress classification for surface water and groundwater demands in subwatersheds within the Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities;
- Complete a surface water and groundwater drought assessment for municipal water supplies;
- Identify municipal water supplies that are located in the subwatersheds that are classified as having a Moderate or Significant potential for stress; and
- Delineate Significant Groundwater Recharge Areas (SGRAs).

5.1 STRESS ASSESSMENT RESULTS

The following table lists the subwatersheds located within the Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities that are classified as having a Moderate or Significant potential for stress for surface water resources:

Table 5.1 - Summary of Surface Water Stress Assessment

Conservation Authority	Subwatershed	Municipal Water Supply
Catfish Creek	Catfish Creek Above Aylmer	None
	Lower Catfish Creek	None
	Silver Creek	None
Long Point Region	South Otter Creek	None
	Big Creek Above Cement Road	None
	Big Creek Above Delhi	None
	North Creek	Delhi Lehman Reservoir Intake
	Venison Creek	None
	Dedrick Creek	None
	Young/Hay Creeks	None
	Lynn River	None
	Upper Nanticoke Creek	None
	Stoney Creek	None

As listed above, the Delhi Lehman Reservoir Intake is the only municipal surface water supply located in a subwatershed classified as having a Moderate or Significant potential for stress. As a result, the conditions for the requirement of a Tier 3 Water Quantity Risk Assessment were met for that intake. During the years of 1998 and 1999, years with very low precipitation, there was concern with the North Creek streamflow and the short-term sustainability of Delhi's municipal intake from the Lehman Reservoir. This led to the formation of the Province's first Irrigation Advisory Committee, which mediates water related disputes between irrigators to reduce the impact of water taking operations on water courses. This local response to dry conditions confirms the current potential for stress identification and the need for the Delhi Intake to move forward with a Tier 3 Water Quantity Risk Assessment.

The following table lists the subwatersheds located within the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities that are classified as having a Moderate or Significant potential for stress for groundwater resources.

Table 5.2 - Summary of Groundwater Stress Assessment

Conservation Authority	Subwatershed	Municipal Water Supply
Long Point Region	Otter Creek at Tillsonburg	Tillsonburg
	Big Creek Above Kelvin Gauge	None
	Big Creek Above Delhi	None
	North Creek	None
	Big Creek Above Minnow Creek	Delhi
	Lynn River	Simcoe
	Upper Nanticoke Creek	Waterford

As listed above, a number of municipal groundwater supplies are contained within subwatersheds classified with a Moderate or Significant potential for stress. It is found that the conditions meet the requirements for a Tier 3 Water Quantity Risk Assessment for these groundwater supplies.

Otter Creek at Tillsonburg was classified as having a Percent Water Demand of 8% for average current conditions. Using 25-year population projections, a Percent Water Demand of 11% under future municipal demand conditions was calculated, resulting in the subwatershed classification to be Moderate potential for stress. Consequently, the conditions meet the requirements for proceeding with a Tier 3 Water Quantity Risk Assessment for Tillsonburg.

Whereas the majority of the groundwater demand associated with the Otter Creek at Tillsonburg subwatershed is for municipal supply, the Upper Nanticoke Creek, Lynn River, and Big Creek above Minnow Creek subwatersheds have groundwater demands that are predominantly from the agricultural sector. Accurately characterizing the timing and required demand volumes for these agricultural takings will be particularly important in a Tier 3 Assessment.

The Technical Rules (MOE, 2008) require that a drought assessment be completed to identify any municipal well or intake that might be adversely impacted by reduced water levels for any subwatershed not identified as having a Moderate or Significant potential for stress under current conditions. For this Assessment, the drought scenario was completed by adjusting monthly average recharge rates across the model to be consistent with those simulated in the GAWSER surface water model for the complete 1960-2004 calibration period. The agricultural demands were also varied in the groundwater flow model for this period to represent variable irrigation events occurring during the summer months of each year, as predicted by the irrigation demand model. Maximum water level decreases, as compared to initial conditions, was recorded at the location of each municipal well as a relative indication of the potential impact of drought at that well. No analysis was required for surface water intakes, as the only municipal intake, Delhi's Lehman Reservoir, was already identified under current conditions. Table 5.3 summarizes the relevant results of the groundwater drought scenario; simulated water level reductions are shown for municipal well locations outside subwatersheds previously identified as having a Moderate or Significant potential for stress.

Table 5.3 - Municipal Wells with Maximum Water Level Decreases during Drought Scenario

Municipality	Municipal System	Subwatershed	Well	Maximum Water Level Decrease (m below initial water level)
Elgin County	Belmont	Upper Kettle	Well_1	-0.26
Elgin County	Belmont	Upper Kettle	Well_2	-0.43
County of Oxford	Brownsville	Catfish Above Aylmer	Well_#5_(Van Gurp)	-0.64
County of Oxford	Brownsville	Catfish Above Aylmer	Well_#6_Park_Well	-0.65
County of Oxford	Norwich	Otter Above Maple Dell Road	Well_#1	-2.08
County of Oxford	Norwich	Otter Above Maple Dell Road	Well_#2	-2.09
County of Oxford	Norwich	Otter Above Maple Dell Road	Well_#4	-2.21
County of Oxford	Otterville	Otter at Otterville	Well_2-A	-1.03
County of Oxford	Otterville	Otter at Otterville	Well_3	-1.37
County of Oxford	Otterville	Otter at Otterville	Well_4	-1.38
County of Oxford	Springford	Spittler Creek	Well_1	-1.39
County of Oxford	Springford	Spittler Creek	Well_2	-1.37
County of Oxford	Springford	Spittler Creek	Well_3	-1.36
County of Oxford	Springford	Spittler Creek	Well_TW1	-1.40
County of Oxford	Springford	Spittler Creek	Well_TW2	-1.37
Norfolk County	Tillsonburg	Little Otter	Well_13_Vance Site	-2.01
Norfolk County	Tillsonburg	Little Otter	Well_14_Vance Site	-2.01

It is assumed that all municipal wells would be completed with approximately 5 metres of available drawdown, in keeping with information provided by Norfolk County Staff. Based on this assumption, it is likely that all municipal wells, located outside previously identified subwatersheds, would not be adversely impacted by historical drought conditions. It should be noted that the water level changes at municipal well locations were estimated through use of a regional groundwater flow model. Without being calibrated to wellfield conditions or having monitoring data to validate model results, there is a significant degree of uncertainty regarding these calculations.

5.2 SIGNIFICANT GROUNDWATER RECHARGE AREAS

In addition to the Subwatershed Stress Assessment, Significant Groundwater Recharge Areas (SGRAs) were delineated as part of this project. SGRAs will be used in Source Protection to identify Highly Vulnerable Areas across the broader landscape and score potential water quality threats; they may also be used in future planning initiatives under the Provincial Policy Statement (PPS). For this study, SGRAs are limited to those areas that have a contiguous land area greater than one square kilometer as this is considered to be the resolution limit of available mapping data.

The SGRAs delineated in this Assessment reflect those areas within the Long Point Region, Catfish Creek, and Kettle Creek Conservation Authorities that are considered to be important groundwater recharge areas. These areas include a large percentage of the Norfolk Sand Plain. Other areas of significant recharge include small pockets of gravel alluvium in the till plains and moraine areas in the northern portion of the Kettle Creek Conservation Authority, and in the northwestern portion of the Long Point Region Conservation Authority.

The Technical Rules (MOE, 2008) highlight the application of the SGRAs to identify Highly Vulnerable Areas, which are used in the Water Quality Threats Assessment scoring. However, the Technical Rules do not provide protection from potential water quantity threats within SRGAs. SGRA mapping may be subsequently adopted by individual municipality and county planning offices as a “designated vulnerable area” through the Provincial Policy Statement (PPS), as each jurisdiction sees fit. However this process may not provide a uniform approach to water quantity protection throughout the watershed, including the potential cumulative impacts of development. Alternatively, the Source Protection Planning Process also provides a good opportunity to address the need to protect groundwater quantity across a watershed / subwatershed basis. It is recommended that the Source Protection Committee consider adopting a groundwater quantity protection initiative for SGRAs; such an initiative should include consideration of the total recharge volume, the hydrologic function of recharge from any given area and the uncertainty of estimated recharge rates.

5.3 APPLICATION BEYOND SOURCE PROTECTION

The Stress Assessment calculations provided within this report provide a wealth of insight for watershed management, beyond Ontario’s Source Protection program. The process completed herein identifies areas where Moderate and Significant potential for stress exist under current and/or future municipal demand scenarios. Furthermore, the sensitivity and uncertainty assessments completed provide an understanding of the potential variability in current stress; this is particularly important as agricultural practices in the area are currently changing. Given these changing conditions, this analysis should be updated regularly as agricultural practices that drive water demand change.

The subwatershed-scale insights gained through this work can be used to target local-scale water management initiatives where they are most needed. However, given the scale of the assessment herein, this work does not replace the need for site-specific or smaller-scale cumulative assessments.

6.0 References

AquaResource, Inc. 2009a. *Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget*. Report to the Lake Erie Source Protection Committee, March 2009.

AquaResource Inc. 2009b. *Grand River Watershed Creek Integrated Water Budget.* Report to the Grand River Conservation Authority, February 2009.

AquaResource Inc. 2009c. *Grand River Watershed Tier 2 Water Quantity Stress Assessment.* Report to the Grand River Conservation Authority, February 2009.

AquaResource, Inc. 2008. *Long Point Region, Kettle Creek and Catfish Creek Water Budget and Water Quantity Stress Assessment*. Report to the Lake Erie Source Protection Committee.

COWSEP Steering Committee Meeting Minutes for "Coordinating Crop Irrigation Use Across the Norfolk Sand Plain". July 31st, 2007. Minutes Approved October 24th, 2007.

Grand River Conservation Authority. 2005. *Water Use in the Grand River Watershed.*

Ontario Ministry of the Environment. 2007. *DRAFT Assessment Report: Guidance Module 7. Water Budget and Water Quantity Risk Assessment.*

Ontario Ministry of the Environment. 2008. *Clean Water Act (2006). Technical Rules: Assessment Report.*

Province of Ontario. 2006. *Clean Water Act.*

Schroeter & Associates. 2006a. *Long Point Region Watershed Hydrologic Model: Set-up, Validation and Application.* Report to Long Point Conservation Authority.

Schroeter & Associates. 2006b. *Catfish Creek Watershed Hydrologic Model: Set-up, Validation and Application.* Report to Catfish Creek Conservation Authority.

Schroeter & Associates. 2006c. *Kettle Creek Watershed Hydrologic Model: Set-up, Validation and Application.* Report to Kettle Creek Conservation Authority.

Shifflett, S.J. 2007. *Status Report on Municipal Long Term Water Supply Strategies: Part 1- Future Demand Estimations and Current Capacity Evaluations.* Prepared for the Lake Erie Source Water Protection Region

Waterloo Hydrogeologic Inc., 2007. *Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds*. Report to the Grand River Conservation Authority.

Waterloo Hydrogeologic, Inc., Applegate Groundwater Consultants, Gamsby and Mannerow Ltd., K. Bruce MacDonald Consulting, MacViro Consultants Inc. and Tunnock Consulting Ltd., 2003. *Norfolk Municipal Groundwater Study Final Report*. Prepared for The Corporation of Norfolk County, Long Point Region Conservation Authority, and Haldimand-Norfolk Health Unit.

Wong, A. 2009. *Technical Memo: Trends in Crop Coverage in Norfolk County based on Agricultural Census Data 1991-2006.* Prepared for the Lake Erie Region Source Water Protection Technical Team.