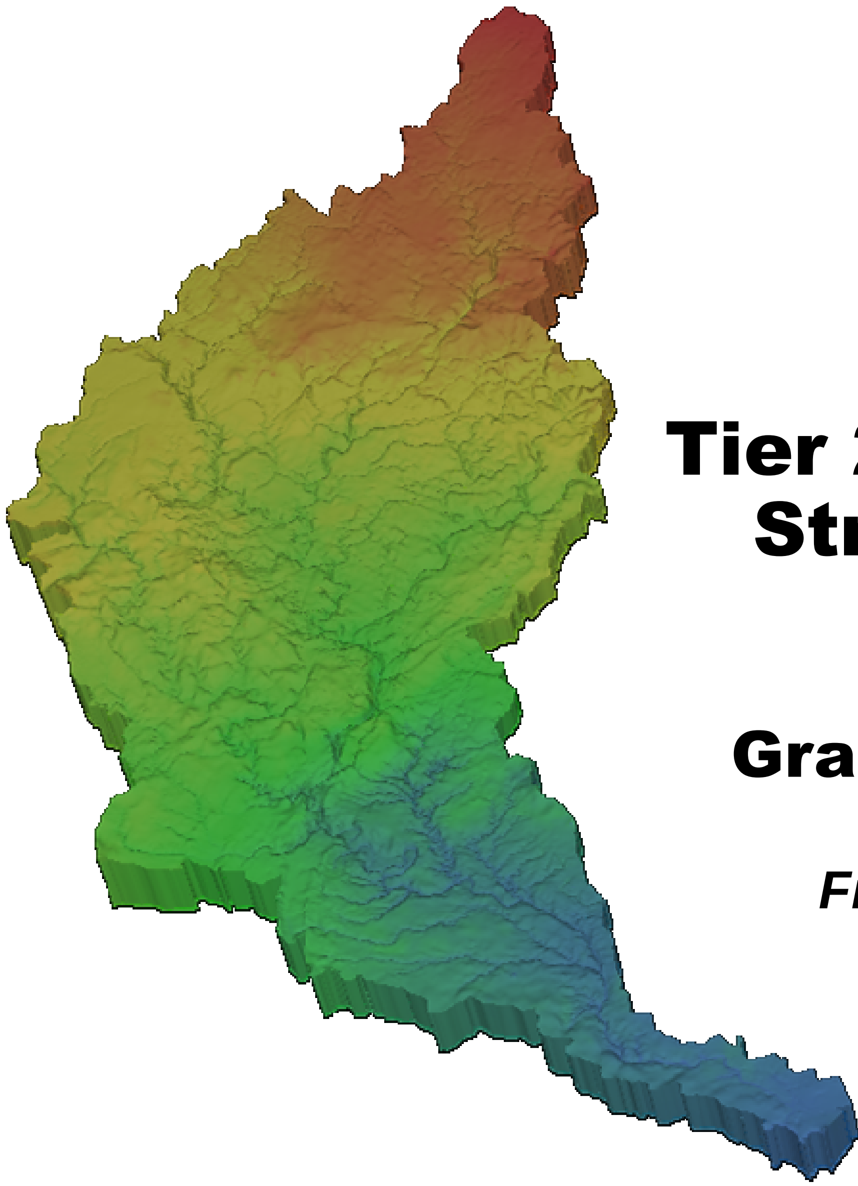
Grand River
Conservation Authority



Tier 2 Water Quantity Stress Assessment Report

Grand River Watershed

Final Report December 2009

Prepared by

AquaResource Inc.
Integrity · Technology · Solutions

Executive Summary

The Grand River Watershed is 6,800 km^2 in size and currently has 900,000 residents. The population is expected to grow significantly over the next 20 years, and with this growth there will be increased water demands in the Watershed.

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 will identify potential risks to local water supply sources and will 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 the development of a subwatershed-based water budget, the Clean Water Act (2006) requires the completion of a Water Quantity Stress Assessment to estimate potential subwatershed stress. This assessment estimates a Percent Water Demand for each subwatershed by calculating the ratio of estimated water demands to available surface and groundwater supply and then assigns a level of stress to the watershed based on the Percent Water Demand. The Stress Assessment is a two-tiered process whereby subwatershed areas identified to have higher water demands are studied in greater detail than those subwatersheds that have lower water demand.

The Grand River Conservation Authority (GRCA) has completed numerous water resources studies that are now being refined in support of the Clean Water Act. The GRCA released an Integrated Water Budget Report (AquaResource, 2007) which estimated the key components of the hydrologic cycle, including anthropogenic water takings. The updated Water Budget Report is released as a companion to this Water Quantity Stress Assessment Report (AquaResource, 2009).

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 instruction on how to complete a Subwatershed Stress Assessment. As outlined in the Guidance Document, the stress assessment determines the level of potential stress in each assessment area or subwatershed by using the Percent Water Demand calculations and the potential stress thresholds for both surface water and groundwater.

The stress assessment calculations performed for both surface water and groundwater identify areas in the Grand River Watershed that have a potential for stress. The assessment areas classified by this Subwatershed Stress Assessment may be under a **Moderate** or a **Significant** potential for stress. This classification is important for municipalities having water supplies located in those areas, because those municipalities may be required to complete a Tier 3 Water Quantity Risk Assessment. The objective of a Tier 3 Assessment is to estimate the potential that a municipal water supply would not be able to meet its planned pumping rates. If the supply is not able to meet its planned pumping rates, then the municipality must identify any significant threats to water quantity (i.e., threats that may be responsible for a supply not meeting its planned rates).

The following table lists the Subwatersheds located within the Grand River Watershed that are classified as having a *Moderate* or *Significant* potential for stress from a surface water perspective:

Subwatershed	Municipal Water Supplies
Eramosa Above Guelph Subwatershed	Guelph Eramosa / Arkell Intake
McKenzie Creek Subwatershed	None
Whiteman's Creek Subwatershed	None

As listed above, the Guelph Eramosa Intake is the only municipal surface water supply located in a Subwatershed classified with the potential for stress. As a result, the Technical Rules require a local water budget and risk assessment (Tier 3) be completed for the Eramosa Intake. This report provides a temporal analysis of potential stress. The analysis suggests that the potential stress identified in the Eramosa Above Guelph Subwatershed may be a reflection of natural hydrologic variability, whereas the stress identified for the McKenzie Creek and Whiteman's Creek Subwatersheds are observed annually in response to agricultural irrigation water demands.

This report describes the delineation of new groundwater assessment areas in support of the Subwatershed Stress Assessment for groundwater. These new areas were delineated to encompass larger municipal groundwater supplies and their respective aquifer systems. The following table lists the groundwater assessment areas located within the Grand River Watershed that are classified as having a *Moderate* or *Significant* potential for stress from a groundwater perspective:

Groundwater Assessment Area	Municipal Groundwater Supplies
Big Creek Assessment Area	Lynden
Canagagigue Creek Assessment Area	RMOW (West Montrose, Conestogo Plains, Elmira)
Central Grand Assessment Area	RMOW (Integrated System St. Agatha, New Dundee)
Irvine River Assessment Area (Future Conditions Only)	Centre Wellington (Elora, Fergus)
Mill Creek Assessment Area	None
Upper Speed River Assessment Area	City of Guelph, Guelph/Eramosa, Rockwood
Whiteman's Creek Assessment Area (Drought Conditions Only)	Bright

As listed above, there are numerous municipal groundwater supplies located within the identified assessment areas. As per the Technical Rules, these municipal systems would be subject to the requirement of completing a local area water budget and risk assessment (Tier 3). The Region of Waterloo and City of Guelph are the largest of these municipal groundwater supplies; preliminary results of the stress assessment for those municipalities indicated that they would be required to complete a Tier 3 Assessment. Given the high level of certainty of the preliminary results, those municipalities were provided funding by the Province to complete Tier 3 Assessments. These Tier 3 Assessments were initiated in 2008.

The municipal systems of Lynden, Rockwood and the RMOW-operated systems of West Montrose, Conestogo Plains and St. Agatha have much smaller water demands than the City of Guelph and the RMOW Integrated Urban System, but are located in assessment areas having the potential for stress. Therefore, they also meet the requirement to complete a Tier 3 Water Quantity Risk Assessment.

The Irvine River Assessment Area was classified as having a *Moderate* potential for stress based solely on estimated future water demands. The estimated future water demands for Centre Wellington (Elora and Fergus) resulted in a calculated Percent Water Demand for the Assessment Area that is equal to the lower threshold that classifies the assessment area as being potentially stressed. Given the relatively low estimate of Percent Water Demand and given that the estimate is based on future water demand projections, the need to complete a Tier 3 Assessment for those supplies may not be immediately necessary. A decision to complete the work may be made in the future when more information is available.

The Whiteman's Creek Assessment area was classified as having a *Moderate* potential for stress based on drought impacts simulated to occur at the Bright #4 well, and supplemental information provided by County of Oxford hydrogeological support staff. Based on this classification, the Bright system meets the requirement under the Technical Rules for the completion of a local water budget and risk assessment.

In addition to the Subwatershed Stress Assessment, the Province's Water Budget Framework specifies that a Tier 2 Water Budget and Water Quantity Stress Assessment needs to include the delineation of Significant Groundwater Recharge Areas (SGRAs). The Water Budget Guidance Module (MOE, 2007) states that SGRAs should be delineated and mapped to identify and protect the drinking water across the broader landscape. This study follows a straightforward and reproducible procedure for delineating SGRAs as described in the Technical Rules. This report initially identifies areas having an estimated groundwater recharge rate equal to or greater than 115% of the average rate in the surrounding landscape. SGRAs are delineated by considering only those areas of high recharge that have a contiguous land area greater than one square kilometer.

Table of Contents

Appendixes (Provided on CD-ROM)

Appendix A – All Results of Surface Water Percent Water Demand Variability
Appendix B – All Results of Groundwater Percent Water Demand Variability
Appendix C – Summary of Drought Scenario

List of Tables

List of Figures

1.0 Introduction

This document describes the Grand River Watershed 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 Grand River Watershed 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 Grand River Watershed, including consumptive water demand estimates, watershed characterization, and surface water and groundwater model development. The water budget information is critical background information relating to this Water Quantity Stress Assessment report.

Under Ontario's Clean Water Act, Source Protection Regions are required to work through the Water Budget and Water Quantity Stress Assessment 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 of municipal water supplies that are located within subwatersheds having a 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 within this document. 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 are not subject to additional water budget requirements.

- Tier 2 – Water Budget and Subwatershed Stress Assessment. The Tier 2 Assessment is completed similarly 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 high demand for drinking water. The Percent Water Demand calculations are the same as those used in Tier 1.

- 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 assessment areas classified with a *Moderate* or a *Significant* potential for stress in the Tier 2 Assessment.

The Grand River Conservation Authority (GRCA) began with a Tier 2 Subwatershed Stress Assessment for the Grand River Watershed without completing a Tier 1 study. With the approval of the Ministry of Natural Resources, the GRCA did not a complete a Tier 1 Assessment due to the availability of existing surface water and groundwater flow models and the high demands for drinking water in the Watershed. The Integrated Water Budget Report was originally released in draft in 2007 (AquaResource, 2007) and released again (AquaResource, 2009a) with this report as a supporting companion document.

1.1 THE GRAND RIVER WATERSHED

The Grand River Watershed is the largest Watershed in southwestern Ontario. The Watershed boundary, with relevant base mapping information, is illustrated on Figure 1. Located to the west of the Greater Toronto Area (GTA), the Grand River begins its 310 km long journey near the village of Dundalk, in the Dundalk Highlands. The Grand River joins with its major tributaries, the Conestogo, the Speed and the Nith Rivers, as it flows by the urban centers of Kitchener, Waterloo, Cambridge, and Brantford. The City of Guelph is another urban centre in the Grand River Watershed, located on the confluence of the Speed and the Eramosa Rivers. Downstream of Brantford, the Grand River passes by the Six Nations Indian Reserve, as well as the towns of Caledonia, Cayuga and Dunnville, before flowing into Lake Erie at Port Maitland.

1.1.1 Summary of Water Use in the Grand River Watershed

The Grand River Watershed Integrated Water Budget Report (AquaResource, 2009a) provides a detailed assessment of water use across the Watershed. Much of this assessment is based on an analysis of Permits To Take Water (PTTWs) which represent water takings of more than 50,000 L/day. The distribution of PTTWs across the Grand River Watershed for both surface water and groundwater takings are shown in Figures 2 and 3, respectively. These figures demonstrate that the density and nature of water takings is variable across the Watershed. For example, agricultural permits primarily related to irrigation are prevalent in the lower areas of the Watershed. Also, municipal supply wells pumping groundwater are prevalent in the urban areas of the Watershed primarily in the City of Guelph and the Region of Waterloo.

The Grand River Integrated Water Budget Report identifies major water use sectors based on recent water taking estimates and reported values. The report classifies these major water users based on estimates of *consumptive* water use. The percentage breakdown of how water is consumed in the Watershed according to this study is shown in Table 1-1. The term *Consumptive use* refers to the portion of water that is not returned to the original source of the taking within a reasonable amount of time. Water takings from the Great Lakes were not considered; only local groundwater and surface water sources were taken into account in the Report.

Table 1-1 - Summary of Estimated Consumptive Water Use in the Grand River Watershed (AquaResource, 2009a)

Water Use Sector		Percentage of Consumptive Water Demand
1.	Municipal Water Supply	53%
2.	Dewatering	9%
3.	Industrial	8%
4.	Commercial	9%
5.	Agricultural	7%
6.	Non-Municipal Drinking Water Supply	4%
7.	Livestock	5%
8.	Remediation	3%
9.	Miscellaneous/Other	2%

As listed in the above table, municipal drinking water is the largest consumptive water use in the Watershed. Many other users rely on the resource, with some of them being concentrated in specific areas of the Watershed.

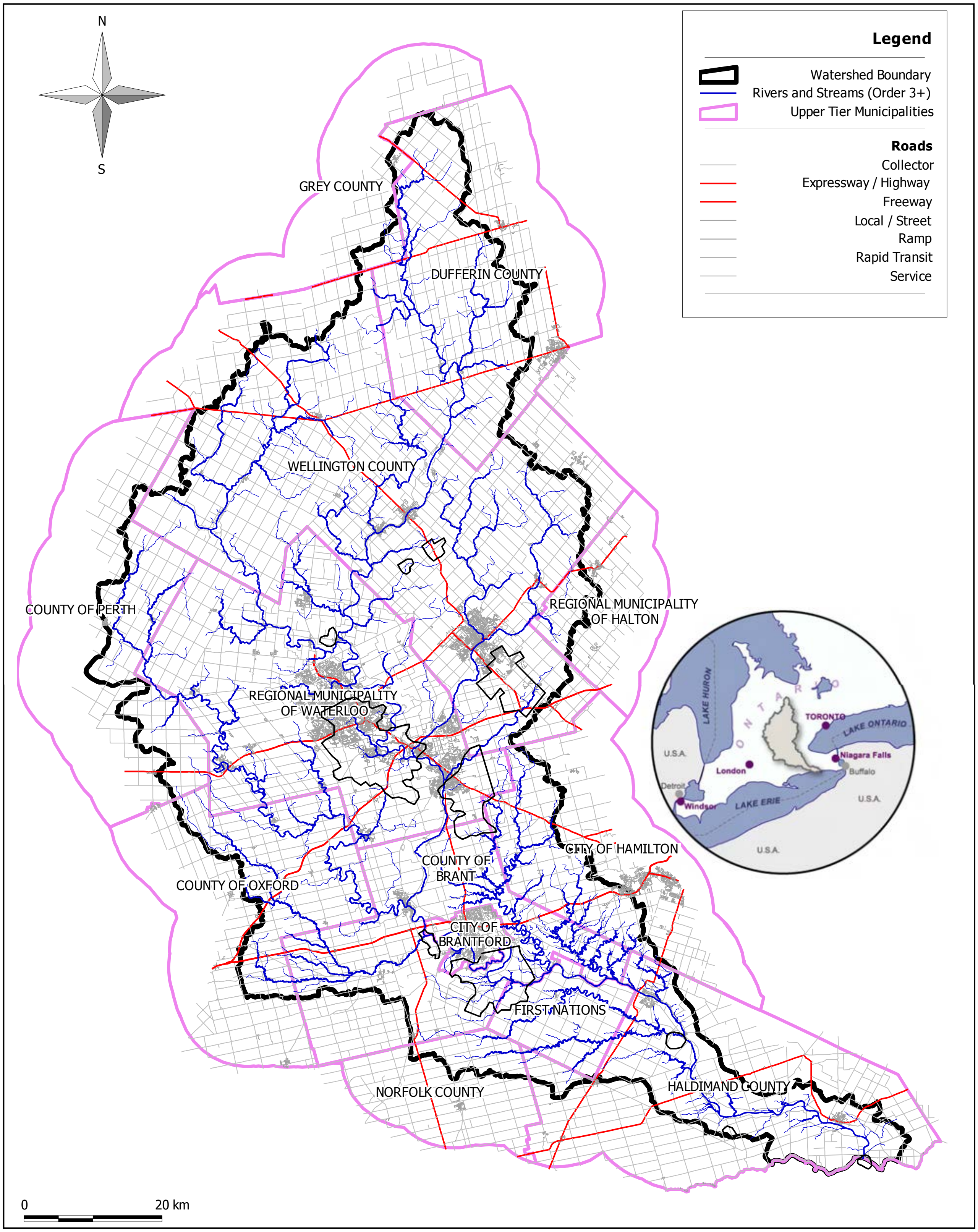


Figure 1
Grand River Watershed

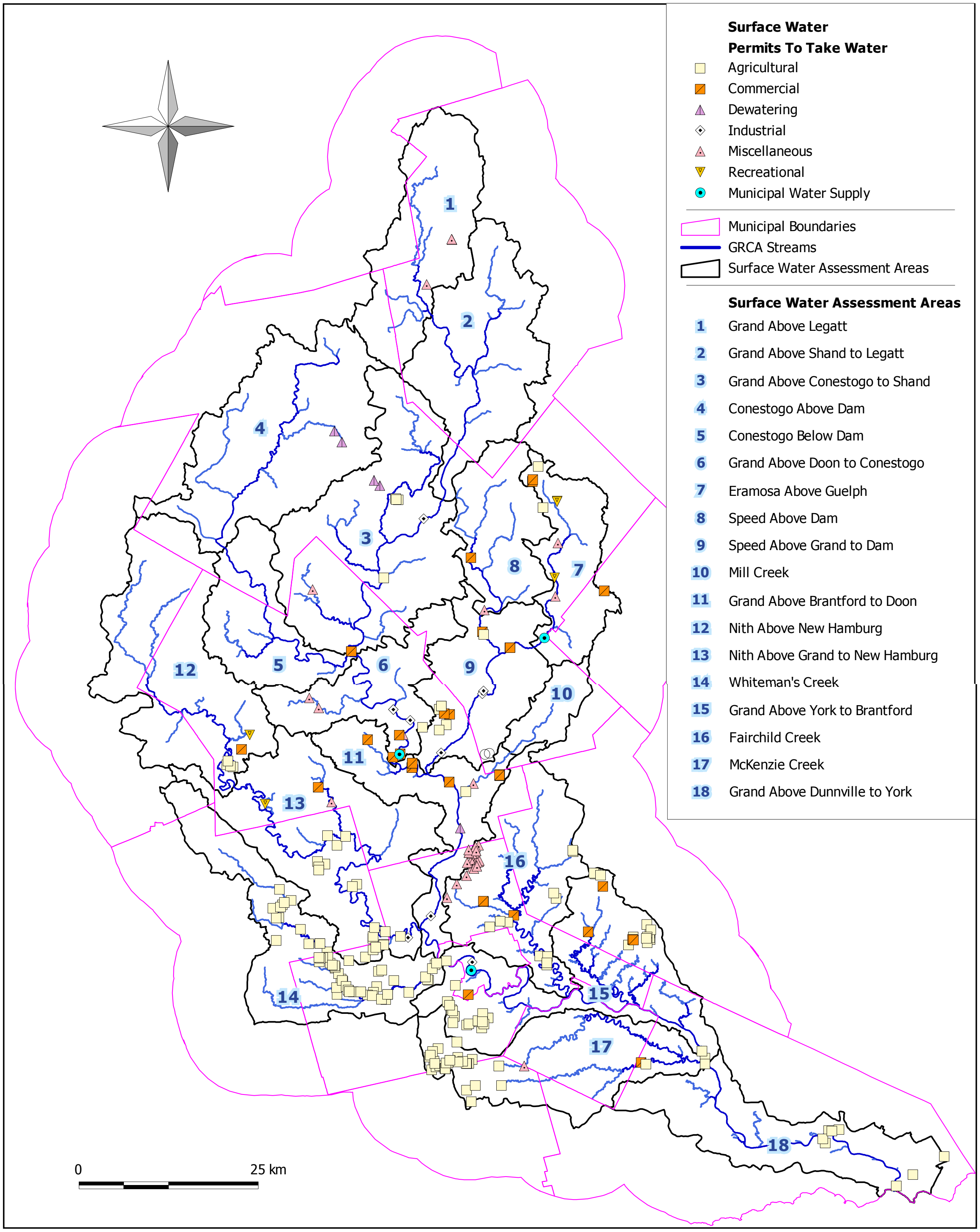


Figure 2
Surface Water
Permits To Take Water

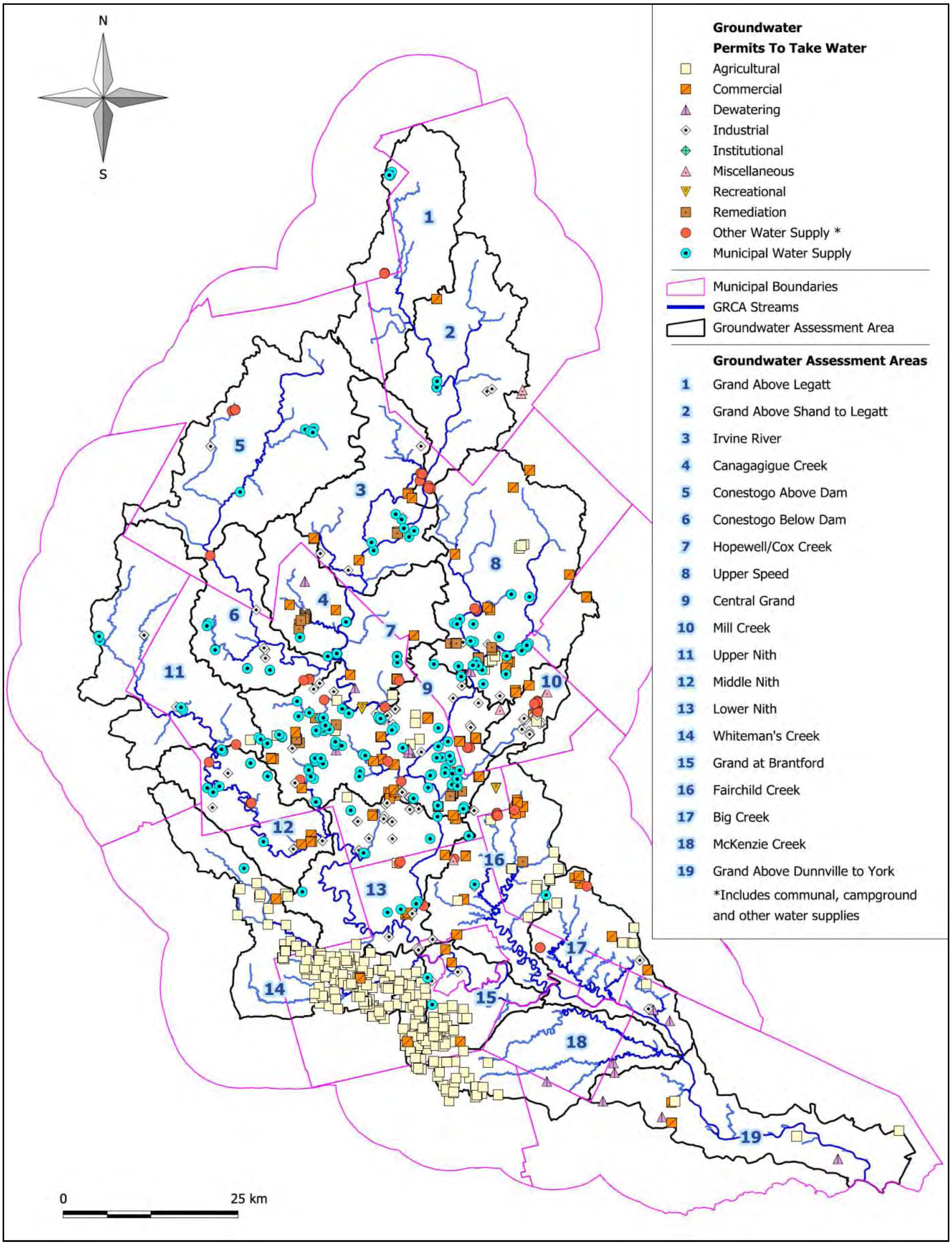


Figure 3
Groundwater
Permits To Take Water

1.2 SOURCE 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 Guidance Document, the Stress Assessment determines the level of potential stress in each assessment area or subwatershed by utilizing the Percent Water Demand calculations and the potential stress thresholds for both surface water and groundwater.

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 water budget studies required under the Clean Water Act is provided in the following sections.

1.2.1 Conceptual Water Budget

The Technical Rules 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.

1.2.2 Tier 1 Water Budget and Subwatershed Stress Assessment

The goal of the Tier 1 Water Budget and Subwatershed 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 classified as having a *Moderate* or *Significant* potential for stress and require more detailed study (Tier 2). Watersheds calculated as having a low Percent Water Demand are classified as having a *Low* potential for stress and will not be subject to additional water budget requirements.

1.2.3 Tier 2 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 model and a calibrated groundwater flow model.

The GRCA proceeded with a Tier 2 Subwatershed Stress Assessment for the Grand River Watershed and this document outlines the methodologies and results of this Assessment. The methodologies used throughout this Assessment are consistent with the methodologies required by the Technical Rules.

1.2.4 Local Area (Tier 3) Water Budget and 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 demands. 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 Technical Rules as well as the Province's Guidance Module for Water Budget and Water Quantity Risk Assessment (Guidance Module 7; MOE, 2007). This Guidance Document prescribes an approach for estimating subwatershed stress based on estimates for 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 model results, the water demand is estimated using the Permits To Take Water and other information as described in the Integrated Water Budget Report (AquaResource, 2009a).

1.3.1 Stress Assessment Methodology

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

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

Based on the above scenarios each subwatershed is classified as having a *Low*, *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 scenario.

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)*, according to the thresholds listed in Table 1-2.

Table 1-2 - 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 1-3.

Table 1-3 – 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 having a *Low* potential for Stress, but also having a Percent Water Demand close to the thresholds given within Table 1-2 and Table 1-3. 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 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 classified as having a *Moderate* potential for stress. Further explanation of this is detailed in Sections 2.8 and 3.8.

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 involves 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 simulated 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 Local Area (Tier 3) Assessments

Subwatersheds containing municipal systems and classified as having a *Moderate* or *Significant* potential for stress will be studied in more detail as part of the Local Area (Tier 3) Water Budget and Water Quantity Risk Assessment. The 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).

Subwatersheds identified as having a *Significant* or *Moderate* potential for stress are not necessarily experiencing 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 Grand River Watershed

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 somewhat to be applied to the Grand River Watershed Tier 2 Stress Assessment. Specific details relating to the methodology used for the Grand River Watershed are summarized below.

The Technical Rules and the Guidance Module require that stress be estimated on a subwatershed basis, and that these subwatersheds are delineated to encapsulate major water users within hydrological boundaries. The subwatersheds used to estimate potential surface water stress are illustrated in Figure 4 and are consistent with GRCA's historically delineated subwatersheds. GRCA originally delineated these subwatersheds with the goal of estimating surface water flows; this is consistent with the calculations needed for the surface water stress assessment. The surface water delineated subwatersheds, however, were found to be less appropriate for the delineation of stress when assessing groundwater takings. In particular, those subwatersheds did not reflect the large aquifer systems associated with the City of Guelph and the Region of Waterloo water supplies. The subwatershed boundaries were therefore modified to better represent and encompass the groundwater systems. These boundaries are shown in Figure 5.

This Stress Assessment Report estimates the Percent Water Demand for each surface water and groundwater assessment area following the process outlined in the Guidance Module. Estimates of water budget parameters are made using the GAWSER (continuous streamflow-generation) and the FEFLOW (groundwater-flow) models developed for the Grand River Watershed (AquaResource, 2009a). The Assessment is completed using estimates of both current and future water demands.

This report completes a drought assessment for both surface water and groundwater as outlined in the requirements of the Technical Rules (MOE, 2008). For groundwater, the Technical Rules suggest that a 2-year drought screening scenario be initially completed; this evaluates the impact of removing all groundwater recharge over a 2-year period. If the screening scenario shows possible impacts on groundwater levels over the 2-year period, a drought scenario using a longer term (e.g., 10 years) climate period that represents historical drought conditions is completed. The GRCA's GAWSER continuous streamflow generation model predicts groundwater recharge over the 1960 to 2000 climate period. The drought assessment was designed to utilize this complete period of recharge, and any drought periods within it, rather than isolate separate 2 year or 10 year droughts. The formal drought scenario, described later in this report, focuses on the drought period 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 better understand the significance of the stress classifications. This variability is also an indicator of the degree to which the estimated 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 average annual groundwater recharge rate estimates from the GAWSER continuous streamflow generation model, the methodology initially identifies areas having estimated groundwater recharge rates equal to or greater than 115% of the average rate in each of the three main physiographic areas of the Watershed. This initial step identifies many small isolated areas with high groundwater recharge. SGRAs are further delineated by considering only those areas of high recharge that have a contiguous land area greater than one square kilometer.

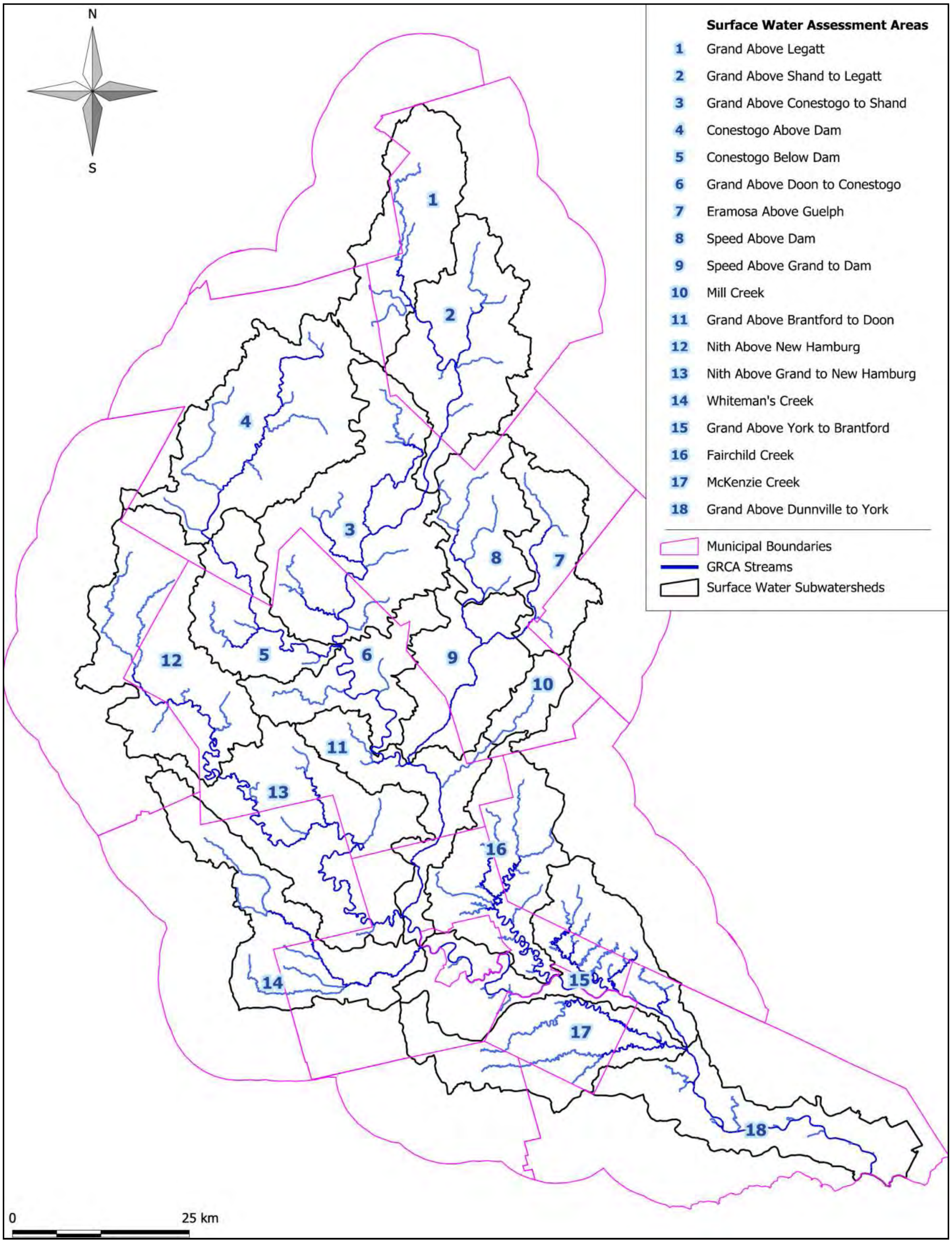


Figure 4
Surface Water Subwatershed Boundaries

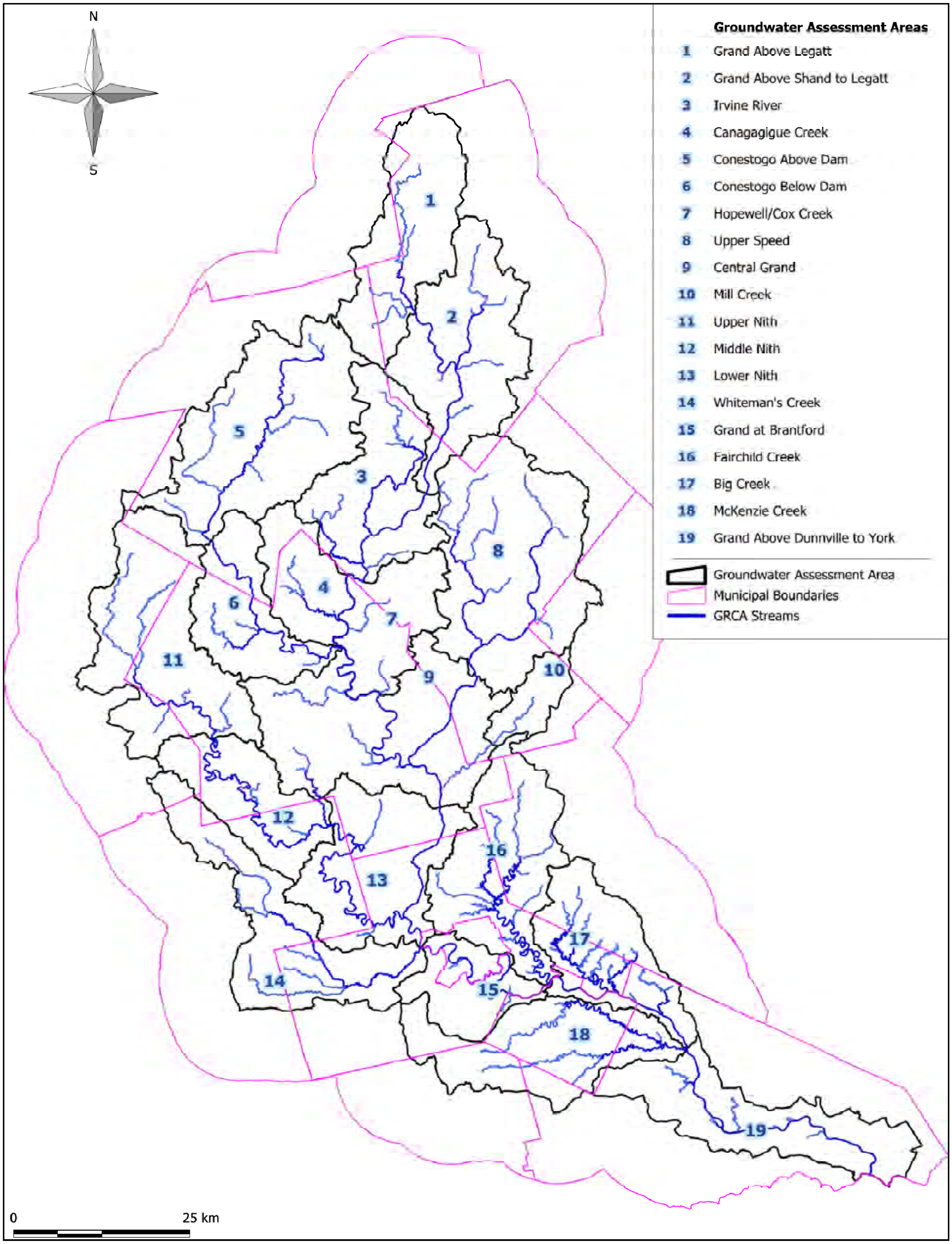


Figure 5
Groundwater Assessment Area Boundaries

2.0 Water Quantity Stress Assessment – Surface Water Demand

This chapter summarizes the results of the surface water Stress Assessment completed for the Grand River Watershed. This Assessment follows the requirements of the Technical Rules (MOE, 2008) and the Water Budget Guidance Module (MOE, 2007).

2.1 SURFACE WATER STRESS ASSESSMENT AREAS

The GRCA delineated the Grand River Watershed into 7 major watershed areas and 18 subwatersheds areas, as listed in Table 2-1 and illustrated on Figure 4. The GRCA delineated these watershed areas and subwatersheds to encompass areas draining to major river systems, and to include areas with similar physiographic features. In most cases a stream gauge is maintained near the outlet of each subwatershed. Subwatershed studies in the past may have delineated subwatershed boundaries using different outlet locations and may report slightly different drainage areas that those used for this study. Subwatershed outlet locations used for this Stress Assessment may be seen on Figure 4.

Table 2-1 - Surface Water Assessment Areas

Watershed Area	Surface Water Stress Assessment Area	Drainage Area (km^2)
Upper Grand River	Grand Above Legatt	365
	Grand Above Shand To Legatt	426
	Grand Above Conestogo To Shand	640
Conestogo River	Conestogo Above Dam	566
	Conestogo Below Dam	254
Central Grand River	Grand Above Doon To Conestogo	248
	Grand Above Brantford To Doon	274
	Mill Creek	82
Speed and Eramosa Rivers	Eramosa Above Guelph	230
	Speed Above Dam	242
	Speed Above Grand To Armstrong	308
Nith River	Nith Above New Hamburg	545
	Nith Above Grand To New Hamburg	583
Whiteman's and McKenzie Creeks	Whiteman's Creek	404
	McKenzie Creek	368
Lower Grand River	Fairchild Creek	401
	Grand Above York To Brantford	476
	Grand Above Dunnville To York	356

The Tier 2 Surface Water Quantity Stress Assessment is based on the GRCA's 18 subwatersheds. These subwatershed areas are used as surface water stress assessment areas in this report.

2.2 HISTORIC CONDITIONS

The City of Guelph operates an Eramosa River Intake to supply water to infiltration galleries. After infiltrating, this water is withdrawn from the groundwater system and provided to the City of Guelph municipal supply system. The Eramosa River intake is located in the Eramosa Above Guelph Subwatershed, upstream of a small dam which maintains water levels sufficiently above the pump elevation during low flow periods.

The City of Guelph's Permit-to-Take-Water for the Eramosa Intake has several pumping restrictions. The City may only pump water from the Eramosa River when streamflow at the Guelph Wastewater Treatment Plant is equal to or greater than 0.85 m^3/s and greater than 0.42 m^3/s at the Water Survey of Canada Eramosa River Gauge 02GA029. This gauge is located approximately 1.5 km downstream of the City of Guelph's Eramosa intake, and approximately 5 km upstream of the confluence of the Eramosa and Speed Rivers in the City of Guelph. Pumping is only permitted between April 15th and November 15th, with a maximum pumping rate in April and May of 369 L/s and a minimum rate of 105 L/s between September and November.

Due to Eramosa River streamflow falling below the thresholds contained within the Permit To Take Water, the City of Guelph has ceased pumping in the past. This has occurred in 1998, as well as in the early 2000's. Because historical low-flow conditions have caused a termination of pumping at this Intake, the Eramosa Above Guelph Subwatershed should be assigned a stress level of *Moderate* according to the Technical Rules as explained in Section 1.3.1.1.

2.3 EXISTING CONDITIONS PERCENT WATER DEMAND

2.3.1 Consumptive Surface Water Use

The Integrated Water Budget Report (AquaResource, 2009a) summarizes the procedure followed to estimate consumptive surface water demand for each subwatershed. Figure 2 shows the locations of all permitted surface water users within the Watershed and the subwatershed boundaries.

The unit consumptive demand is defined as the amount of water pumped from a specific unit (aquifer, watercourse) and not returned to that same unit in a reasonable amount of time. Table 2-2 summarizes the estimated monthly surface water consumptive demand for each subwatershed in the Integrated Water Budget Report. The monthly demand for surface water sources includes agricultural Permits-to-Take-Water (PTTWs), non-municipal and non-agricultural PTTWs, municipal water supply, and livestock (unpermitted) agricultural use. The total consumptive demand for each subwatershed is calculated from a combination of reported and estimated pumping rates:

- Reported Pumping Rates. The rate of water taken or pumped from a specific source is reported by the water user to the GRCA and recorded with the PTTW information. When available, reported pumping rates are used instead of estimated pumping rates.
- Estimated Pumping Rates. Estimated rates are used where no reported rates exist for a known water taking location. The rates are estimated using maximum permitted rates from the PTTW database, adjusted for seasonal or monthly use factors. The seasonal or monthly use factors provide a more realistic estimate of actual pumping rates for a particular water taking. Estimated pumping rates are not as accurate as reported rates, as they are determined with no input from the actual permit holder or water user.

In Table 2-2 below, consumptive factors were applied to both reported and estimated pumping rates for each subwatershed. The table lists the consumptive rate based on reported pumping values, estimated pumping values, and then shows the actual total consumptive demand for each subwatershed. Total Demand shown in Table 2-2 is the sum of Reported and Estimated Demand.

Table 2-2 - Estimated Surface Water Consumptive Demand (L/s)

Sub-watershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grand Above Legatt	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	2	2	2	2	2	2	2	2	2	2	2	2
	Total	2	2	2	2	2	2	2	2	2	2	2	2
Grand Above Shand to Legatt	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	3	3	3	3	3	3	3	3	3	3	3	3
	Total	3	3	3	3	3	3	3	3	3	3	3	3
Grand Above Conestogo to Shand	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	22	22	22	22	22	34	35	34	33	22	22	22
	Total	22	22	22	22	22	34	35	34	33	22	22	22
Conestogo Above Dam	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	12	12	12	12	12	12	12	12	12	12	12	12
	Total	12	12	12	12	12	12	12	12	12	12	12	12
Conestogo Below Dam	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	13	13	13	13	13	13	13	13	13	13	13	13
	Total	13	13	13	13	13	13	13	13	13	13	13	13
Grand Above Doon to Conestogo	Reported	111	102	107	99	119	118	107	112	112	109	106	109
	Estimated	4	4	4	4	4	15	15	15	15	4	4	4
	Total	115	106	111	102	123	133	122	127	126	113	110	113
Eramosa Above Guelph	Reported	0	0	0	28	55	71	62	55	54	51	6	0
	Estimated	5	5	5	5	5	30	31	30	30	5	5	5
	Total	5	5	5	33	60	101	93	85	83	56	12	5
Speed Above Dam	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	14	14	14	14	14	17	17	17	17	14	14	14
	Total	14	14	14	14	14	17	17	17	17	14	14	14
Speed Above Grand to Dam	Reported	0	0	0	1	10	23	24	18	9	1	0	0
	Estimated	17	17	17	17	17	27	31	27	23	17	17	17
	Total	17	17	17	18	28	50	55	45	32	19	17	17
Mill Creek	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	1	1	1	1	1	1	1	1	1	1	1	1
	Total	1	1	1	1	1	1	1	1	1	1	1	1
Grand Above Brantford to Doon	Reported	0	0	0	0	4	8	4	4	5	0	0	0
	Estimated	4	4	4	4	14	55	55	55	55	14	14	4
	Total	4	4	4	4	18	63	60	60	59	14	14	4
Nith Above New Hamburg	Reported	0	0	0	0	2	4	3	3	2	0	0	0
	Estimated	7	7	7	7	7	8	9	8	8	7	7	7
	Total	7	7	7	7	9	13	12	11	10	7	7	7
Nith Above Grand to New Hamburg	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	16	16	16	16	16	55	71	55	38	16	16	16
	Total	16	16	16	16	16	55	71	55	38	16	16	16
Whiteman's Creek	Reported	0	0	0	0	0	1	8	3	0	0	0	0
	Estimated	4	4	4	4	4	141	210	141	73	4	4	4
	Total	4	4	4	4	4	142	218	144	73	4	4	4

Sub-watershed		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grand Above York to Brantford	Reported	102	102	100	110	114	135	137	128	113	113	104	100
	Estimated	6	6	6	6	6	84	108	84	60	6	6	6
	Total	108	108	105	115	120	219	245	212	173	118	109	105
Fairchild Creek	Reported	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated	9	9	9	9	9	46	56	46	36	9	9	9
	Total	9	9	9	9	9	46	56	46	36	9	9	9
McKenzie Creek	Reported	0	0	0	0	0	3	5	3	1	0	0	0
	Estimated	3	3	3	3	3	73	103	73	43	3	3	3
	Total	3	3	3	3	3	76	108	76	44	3	3	3
Grand Above Dunnville to York	Reported	0	0	0	0	10	34	34	34	30	0	0	0
	Estimated	2	2	2	2	2	24	36	24	13	2	2	2
	Total	2	2	2	2	11	58	70	58	42	2	2	2

2.3.2 Surface Water Supply

The surface water stress assessment relies on estimated stream data to represent the amount of water supply available to water users in a subwatershed. The Guidance Module (MOE, 2007) requires that the surface water supply, Q_{SUPPLY}, be estimated on a monthly basis as the median monthly flow. The reserve flow, $Q_{RESERVE}$, is an estimate of the proportion of streamflow that is needed to support ecological requirements and is calculated as the 90th percentile flow (i.e. the flow that is expected to be exceeded 90% of the time).

Monthly estimates of Q_{SUPPLY} and $Q_{RESERVE}$ were calculated for each subwatershed using predicted streamflow data from the GAWSER model output. The Grand River Watershed Integrated Water Budget Report (AquaResource, 2009a) provides background information on the Grand River Watershed GAWSER model.

Table 2-3 shows the surface water supply and reserve estimates, as well as the difference between the two values; this difference is used in the Percent Water Demand equation (Q_{SUPPLY}- $Q_{RESERVE}$) and illustrated on Figure 6.

Water supply and water reserve estimates were determined based on twenty years (1980 to 1999) of observed or simulated data. These values represent the typical conditions expected in each assessment area during that time period. This time period was selected because reservoir operating procedures prior to 1980 were different than they are now, and therefore the flow regime may not represent current conditions. Actual streamflows vary on a daily and annual basis depending on climate conditions.

Table 2-3 - Surface Water Supply Flows (L/s) (1980-1999)

Assessment Area		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grand Above Legatt	Q_{SUPPLY}	2,620	2,050	3,660	6,860	3,560	2,420	1,250	1,010	1,290	3,910	5,010	3,570
	$Q_{RESERVE}$	1,730	1,230	1,790	3,160	2,300	1,170	810	660	590	910	2,640	2,680
	Difference	890	820	1,870	3,700	1,260	1,250	440	350	700	3,000	2,370	890
Grand Above Shand To Legatt	Q_{SUPPLY}	4,100	3,230	7,290	15,860	5,470	4,020	2,050	1,550	2,240	6,700	9,400	5,540
	$Q_{RESERVE}$	2,840	2,000	2,880	4,760	3,580	2,000	1,180	870	800	1,670	4,140	4,140
	Difference	1,260	1,230	4,410	11,100	1,890	2,020	870	680	1,440	5,030	5,260	1,400
Grand	Q_{SUPPLY}	11,520	8,990	16,320	19,800	8,960	7,400	6,290	6,260	6,180	9,350	14,470	13,560

Assessment Area		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Above Conestogo To Shand	$Q_{RESERVE}$	6,550	5,070	7,030	9,250	6,540	5,500	5,160	4,590	4,330	4,070	5,540	7,190
	Difference	4,970	3,920	9,290	10,550	2,420	1,900	1,130	1,670	1,850	5,280	8,930	6,370
Conestogo Above Dam	Q_{SUPPLY}	2,610	2,050	5,400	6,920	2,990	1,700	590	380	500	2,950	4,530	3,410
	$Q_{RESERVE}$	1,500	1,190	1,870	2,610	1,180	320	180	100	80	90	510	1,930
	Difference	1,110	860	3,530	4,310	1,810	1,380	410	280	420	2,860	4,020	1,480
Conestogo Below Dam	Q_{SUPPLY}	5,830	4,180	10,150	9,950	4,520	4,580	4,380	4,910	4,690	6,150	11,830	12,350
	$Q_{RESERVE}$	2,600	1,360	2,550	3,860	3,480	3,350	3,540	3,610	3,340	3,420	4,300	5,540
	Difference	3,230	2,820	7,600	6,090	1,040	1,230	840	1,300	1,350	2,730	7,530	6,810
Grand Above Doon To Conestogo	Q_{SUPPLY}	20,600	16,330	31,700	35,920	16,810	14,800	12,860	13,580	13,480	17,120	30,940	29,090
	$Q_{RESERVE}$	11,120	8,830	12,790	16,500	13,030	11,150	11,010	10,930	9,800	10,050	12,850	17,550
	Difference	9,480	7,500	18,910	19,420	3,780	3,650	1,850	2,650	3,680	7,070	18,090	11,540
Eramosa Above Guelph	Q_{SUPPLY}	2,350	2,060	2,660	2,960	2,500	1,780	1,120	830	780	1,250	2,430	2,440
	$Q_{RESERVE}$	1,280	1,140	1,750	2,090	1,650	880	610	490	430	440	750	1,210
	Difference	1,070	920	910	870	850	900	510	340	350	810	1,680	1,230
Speed Above Dam	Q_{SUPPLY}	2,430	2,080	2,410	2,840	2,360	1,420	690	450	400	1,070	2,680	2,830
	$Q_{RESERVE}$	1,160	1,090	1,620	2,140	1,320	560	330	260	200	190	410	940
	Difference	1,270	990	790	700	1,040	860	360	190	200	880	2,270	1,890
Speed Above Grand To Dam	Q_{SUPPLY}	7,900	6,620	9,190	11,640	7,590	5,490	3,700	3,090	3,330	4,530	7,450	7,910
	$Q_{RESERVE}$	4,260	4,090	5,160	6,940	4,700	3,220	2,630	2,430	2,380	2,250	2,780	4,330
	Difference	3,640	2,530	4,030	4,700	2,890	2,270	1,070	660	950	2,280	4,670	3,580
Mill Creek	Q_{SUPPLY}	900	870	1,070	1,310	1,160	710	310	160	150	330	710	950
	$Q_{RESERVE}$	450	360	630	820	610	240	110	50	30	30	90	400
	Difference	450	510	440	490	550	470	200	110	120	300	620	550
Grand Above Brantford To Doon	Q_{SUPPLY}	45,410	39,890	70,670	79,260	41,850	32,570	25,100	24,110	25,130	35,690	58,340	59,760
	$Q_{RESERVE}$	28,080	22,990	32,980	40,640	29,880	21,590	19,920	19,770	17,690	17,920	23,300	38,380
	Difference	17,330	16,900	37,690	38,620	11,970	10,980	5,180	4,340	7,440	17,770	35,040	21,380
Nith Above New Hamburg	Q_{SUPPLY}	3,180	2,510	8,110	9,170	3,130	1,290	550	260	360	2,810	4,770	4,110
	$Q_{RESERVE}$	2,400	1,830	2,420	2,810	1,460	530	210	90	60	80	500	3,040
	Difference	780	680	5,690	6,360	1,670	760	340	170	300	2,730	4,270	1,070
Nith Above Grand To New Hamburg	Q_{SUPPLY}	9,480	8,400	16,530	17,970	9,200	5,460	3,570	3,400	3,610	6,730	12,200	11,980
	$Q_{RESERVE}$	7,000	5,980	7,720	8,700	5,650	3,240	2,600	2,370	2,280	2,400	3,230	8,590
	Difference	2,480	2,420	8,810	9,270	3,550	2,220	970	1,030	1,330	4,330	8,970	3,390
Whiteman's Creek	Q_{SUPPLY}	4,870	4,160	5,490	5,940	4,470	1,870	790	930	1,060	2,380	4,870	5,490
	$Q_{RESERVE}$	2,730	2,190	3,530	3,660	2,020	540	210	110	70	120	620	3,480
	Difference	2,140	1,970	1,960	2,280	2,450	1,330	580	820	990	2,260	4,250	2,010
Grand Above York To Brantford	Q_{SUPPLY}	58,160	51,270	90,900	102,280	52,780	39,490	29,940	28,980	29,620	43,120	70,810	77,620
	$Q_{RESERVE}$	35,520	31,130	43,640	51,840	35,700	24,680	21,710	21,780	19,450	19,340	27,390	49,010
	Difference	22,640	20,140	47,260	50,440	17,080	14,810	8,230	7,200	10,170	23,780	43,420	28,610
Fairchild	Q_{SUPPLY}	2,830	2,710	5,040	3,760	2,410	1,330	900	1,130	1,140	2,180	2,970	3,730

Assessment Area		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Creek	$Q_{RESERVE}$	1,410	1,360	2,190	2,220	870	130	60	70	100	140	350	1,660
	Difference	1,420	1,350	2,850	1,540	1,540	1,200	840	1,060	1,040	2,040	2,620	2,070
McKenzie Creek	Q_{SUPPLY}	2,260	2,240	4,510	3,660	1,760	1,010	500	380	470	1,500	4,160	3,750
	$Q_{RESERVE}$	1,400	1,280	1,690	1,690	840	250	90	50	40	100	1,090	1,540
	Difference	860	960	2,820	1,970	920	760	410	330	430	1,400	3,070	2,210
Grand Above Dunnville To York	Q_{SUPPLY}	64,440	56,820	101,100	117,220	56,770	43,330	33,720	31,160	31,750	47,910	83,030	90,710
	$Q_{RESERVE}$	39,860	35,040	48,810	56,670	39,050	26,010	23,270	22,580	20,280	20,140	30,230	55,360
	Difference	24,580	21,780	52,290	60,550	17,720	17,320	10,450	8,580	11,470	27,770	52,800	35,350

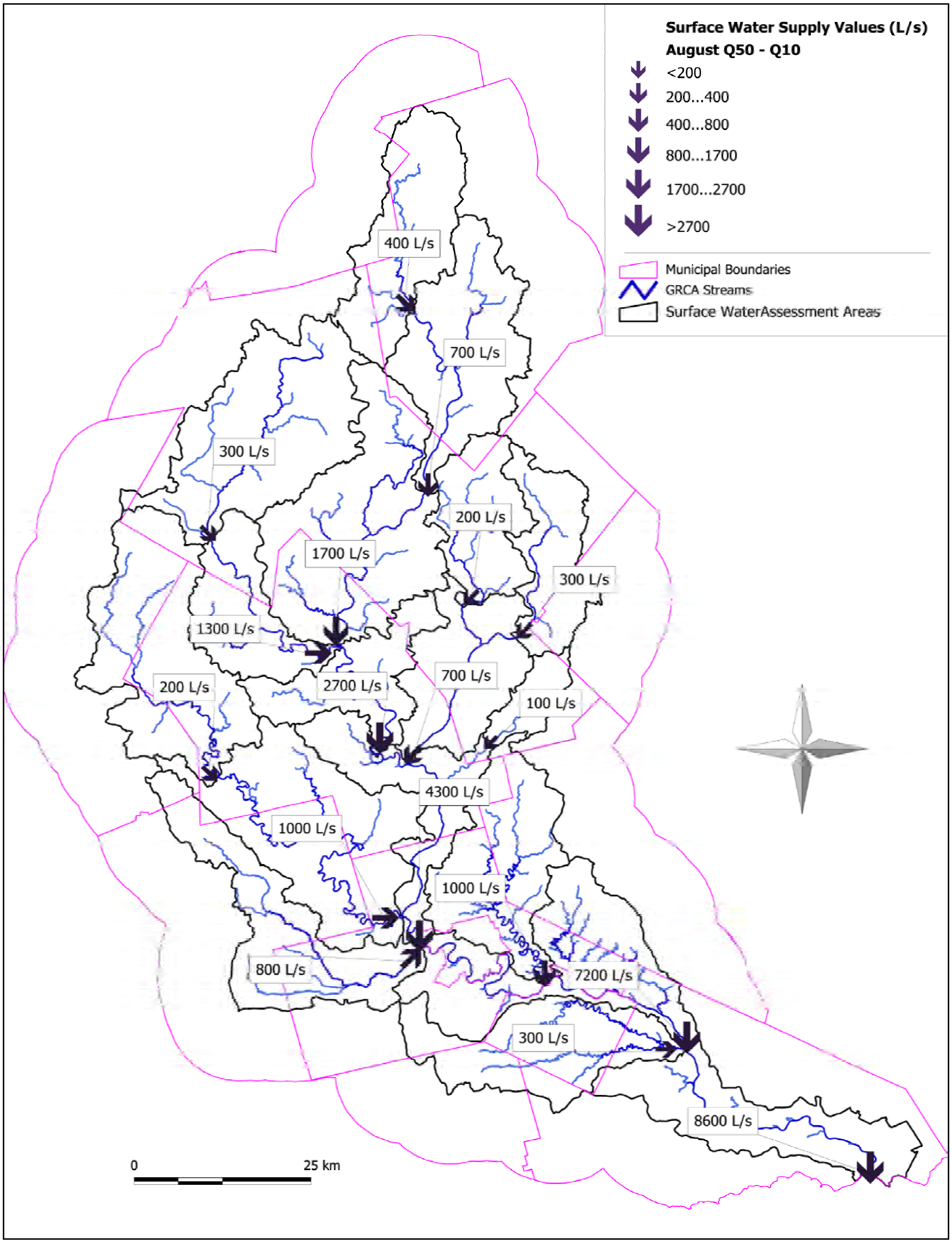


Figure 6
Surface Water Supply
August

2.3.3 Percent Water Demand

Monthly Percent Water Demand for each surface water subwatershed was calculated using the Percent Water Demand equation, the consumptive water demand values shown on Table 2-2, and the Surface Water Supply and Reserve estimates shown on Table 2-3. The results of the surface water Percent Water Demand calculations are shown in Table 2-4.

Table 2-4 - Percent Water Demand Estimate (Surface Water) Under Existing Conditions

Assessment Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max Monthly Demand
Grand Above Legatt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grand Above Shand To Legatt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grand Above Conestogo To Shand	0%	1%	0%	0%	1%	2%	3%	2%	2%	0%	0%	0%	3%
Conestogo Above Dam	1%	1%	0%	0%	1%	1%	3%	4%	3%	0%	0%	1%	4%
Conestogo Below Dam	0%	0%	0%	0%	1%	1%	2%	1%	1%	0%	0%	0%	2%
Grand Above Doon To Conestogo	1%	1%	1%	1%	3%	4%	7%	5%	3%	2%	1%	1%	7%
Eramosa Above Guelph	0%	1%	1%	4%	7%	11%	18%	25%	24%	7%	1%	0%	25%
Speed Above Dam	1%	1%	2%	2%	1%	2%	5%	9%	8%	2%	1%	1%	9%
Speed Above Grand To Dam	0%	1%	0%	0%	1%	2%	5%	7%	3%	1%	0%	0%	7%
Mill Creek	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grand Above Brantford To Doon	0%	0%	0%	0%	0%	1%	1%	1%	1%	0%	0%	0%	1%
Nith Above New Hamburg	1%	1%	0%	0%	1%	2%	4%	6%	3%	0%	0%	1%	6%
Nith Above Grand To New Hamburg	1%	1%	0%	0%	0%	2%	7%	5%	3%	0%	0%	0%	7%
Whitemans Creek	0%	0%	0%	0%	0%	11%	38%	18%	7%	0%	0%	0%	38%
Grand Above York To Brantford	0%	1%	0%	0%	1%	1%	3%	3%	2%	0%	0%	0%	3%
Fairchild Creek	1%	1%	0%	1%	1%	4%	7%	4%	3%	0%	0%	0%	7%
Mckenzie Creek	0%	0%	0%	0%	0%	10%	26%	23%	10%	0%	0%	0%	26%
Grand Above Dunnville To York	0%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%	1%

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

The monthly maximum Percent Water Demand and the thresholds listed in Table 1-2 are used to estimate the potential stress classification for each area as shown in Table 2-5.

Table 2-5 - Surface Water Stress Classification Under Existing Conditions

Assessment Area	Stress Classification (Based on Maximum Monthly Percent Water Demand)	Municipal Water Supplies
Grand Above Legatt	Low	None
Grand Above Shand To Legatt	Low	None
Grand Above Conestogo To Shand	Low	None
Conestogo Above Dam	Low	None
Conestogo Below Dam	Low	None
Grand Above Doon To Conestogo	Low	RMOW Mannheim Intake
Eramosa Above Guelph	Moderate	Guelph Eramosa/Arkell Intake
Speed Above Dam	Low	None
Speed Above Grand To Dam	Low	None
Mill Creek	Low	None
Grand Above Brantford To Doon	Low	None
Nith Above New Hamburg	Low	None
Nith Above Grand To New Hamburg	Low	None
Whiteman's Creek	Moderate	None
Grand Above York To Brantford	Low	Brantford, Ohsweken
Fairchild Creek	Low	None
McKenzie Creek	Moderate	None
Grand Above Dunnville To York	Low	None

As shown in Table 2-5, the Eramosa Above Guelph, Whiteman's Creek, and McKenzie Creek Subwatersheds are classified as having a *Moderate* surface water potential for stress.

2.4 PERCENT WATER DEMAND - PLANNED DRINKING WATER SYSTEMS

The '*Planned Systems*' scenario is not evaluated within this Tier 2 Subwatershed Stress Assessment. The purpose of the 'Planned System' scenario under the Technical Rules is to evaluate planned municipal water systems that are not included within the Current Demand scenario. Planned Systems were not adequately characterized at the time this report was prepared.

2.5 FUTURE CONDITIONS PERCENT WATER DEMAND

The future demand scenario is completed to estimate the potential effect of estimated future (25-year) demands on the subwatershed stress classifications. This analysis only considers increased municipal demand in the estimation of future demand and does not consider the impact of increased or reduced non-municipal demand on subwatershed stress.

2.5.1 Future Demand

Three municipalities in the Grand River Watershed rely on surface water for some or all of their municipal drinking supply. The City of Guelph Eramosa River intake and the Regional Municipality of Waterloo Mannheim intake are used to supplement larger groundwater-based supplies. The City of Brantford's Holmedale intake meets all of the Brantford's drinking water demands.

For the majority of municipal water supply systems, future water demand was estimated by the GRCA, and is documented within "Status Report on Municipal Long Term Water Supply Strategies" (Shifflett, 2007). The GRCA estimated future water demand rates by taking current average daily per capita water use and multiplying it by the future population for each municipal water system. Future population was based on municipal official plans current to 2006, while current water use data was collected from water system owners and operators. For municipalities with Long Term Water Supply Plans, the GRCA obtained future water demands directly from approved plans. All future water demands were projected to 2031. Further explanation of future water demand calculations can be found within Shifflett (2007). Future municipal water demands for the Regional Municipality of Waterloo were taken from "Region of Waterloo Water Supply Strategy Report" (XCG, 2007).

Future municipal water demand increases for surface water systems are summarized in Table 2-6. For this assessment, the estimates for future water demand need to be allocated to surface water sources or groundwater sources. Table 2-6 also contains the amount of future water demand that will be obtained from surface water sources.

Table 2-6 - Future Municipal Demand Estimates for Systems Served by Surface Water Sources

Municipal System with Surface Water Intake	Assessment Area	Estimated Average Day Municipal Water Demand Increase (L/s)	Future Demand Sourced from Surface Water (L/s)
City of Guelph – Eramosa Intake	Eramosa Above Guelph	200	13 (Apr-Nov)
Region of Waterloo – Mannheim	Grand Above Doon to Conestogo	600	200
City of Brantford - Holmedale	Grand Above York to Brantford	280	280

The estimated future municipal supply required by the City of Guelph is approximately 200 L/s. The Eramosa River Intake currently supplies 87 L/s during the April to November period, and has sufficient capacity to pump a total of 100 L/s (Earth Tech, 2006), an increase of 13 L/s over current pumping rates. This stress assessment assumes that all of this additional capacity will contribute to meeting future demands, with remaining future demand to be met by additional groundwater resources. Because the Eramosa Above Guelph Subwatershed was already identified as having a *Moderate* potential for stress under current conditions, the Technical Rules (MOE, 2008) do not require that the Percent Water Demand for the future scenario be evaluated for this subwatershed. The Eramosa Above Guelph Subwatershed is not considered further in this future scenario.

The Region of Waterloo's Mannheim Intake is located in the Grand River in the City of Kitchener. The Intake is responsible for approximately 25% of the Region's Integrated Urban System (IUS) water supply. The Region of Waterloo Water Supply Strategy Report (XCG, 2007) indicates that the capacity of the Mannheim intake is 800 L/s. The 2006 averaged pumping rate at the Mannheim Intake is approximately 600 L/s, which suggests that there is approximately 200 L/s of additional capacity available. The Region of Waterloo's estimated 25-year water demand increase is approximately 600 L/s (XCG, 2007). It is assumed that all additional capacity of the Mannheim intake (200 L/s) will be utilized to accommodate future demand, with the remaining future demand (400 L/s) serviced by additional groundwater supplies.

The City of Brantford's increase in municipal water requirements was estimated by GRCA (Shifflett, 2007) and for this assessment is assumed to be entirely met by its surface water intake within the Grand Above York to Brantford Subwatershed.

2.5.2 Future Stress Assessment

For this assessment, future municipal water demand estimates are based on future population projections. In this assessment, it is assumed that future landuse changes will not have a significant effect on streamflow within the regulated Grand River, which is the water supply for both the RMOW's and City of Brantford's water takings. Information regarding the potential spatial location or extent of land use changes in the Watershed for the next 25 years was unavailable for this assessment. In general, however, current development patterns in the Watershed focus on re-development and intensification within existing urban areas instead of green field development. This type of development should have a minimal impact on Grand River flows. In addition it is recognized that discharge from upstream reservoirs (Shand, Conestogo and Guelph Dams) is the dominant process with respect to streamflow within the regulated Grand River, and development upstream of the reservoirs is expected to be negligible. As a result, it is assumed that these patterns of development will not result in a significant impact to water supplies and that the existing water supply will be representative of future supplies.

Table 2-7 contains the *Estimated Additional Consumptive Demand* and the *Total Future Consumptive Demand* for the subwatersheds with surface water intakes. The *Estimated Additional Consumptive Demand* is calculated by multiplying the total municipal water demand increase by the consumptive use factor. A consumptive factor of 0.2 was applied to the surface water future municipal takings for Brantford and the Region of Waterloo, as the water is returned to surface water sources in the same subwatershed via wastewater treatment plant effluent. This consumptive factor is consistent with the municipal water supply consumptive factor outlined in the Integrated Water Budget Report (AquaResource, 2009a).

The *Future % Water Demand* in Table 2-7 is an estimate of the 25-year Percent Water Demand for each subwatershed with surface water demand increases.

Table 2-7 - Future Demand and Percent Water Demand Analysis (L/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grand Above Doon to Conestogo												
Supply	20,602	16,335	31,700	35,918	16,808	14,796	12,865	13,581	13,478	17,115	30,941	29,085
Reserve	11,122	8,830	12,789	16,500	13,026	11,151	11,014	10,931	9,796	10,050	12,849	17,546
Current Municipal Demand	111	102	107	98	119	117	107	112	111	108	105	109
Additional Future Municipal Demand	49	58	53	62	41	43	53	49	49	52	55	51
Total Municipal Future Demand	160	160	160	160	160	160	160	160	160	160	160	160
Other Consumptive Water Uses	4	4	4	4	4	15	15	16	15	5	4	4
Total Future Demand	164	164	164	164	164	175	175	176	175	165	164	164
Future % Water Demand	2%	2%	1%	1%	4%	5%	9%	7%	5%	2%	1%	1%
Grand Above York to Brantford												
Supply	58,163	51,267	90,899	102,278	52,782	39,488	29,941	28,977	29,620	43,120	70,815	77,615
Reserve	35,525	31,127	43,642	51,844	35,705	24,678	21,708	21,777	19,446	19,336	27,393	49,014
Current Municipal Demand	102	102	100	110	114	115	122	119	113	113	104	100
Additional Future Municipal Demand	56	56	56	56	56	56	56	56	56	56	56	56
Total Municipal Future Demand	158	158	156	166	170	171	178	175	169	169	160	156

Other Consumptive Water Uses	6	6	6	6	6	104	123	94	61	6	6	6
Total Future Demand	164	164	161	171	176	275	301	268	229	174	165	161
Future % Water Demand	1%	1%	0%	0%	1%	2%	4%	4%	2%	1%	0%	1%

The future Percent Water Demand estimates for both the Grand Above Doon to Conestogo and the Grand Above York to Brantford Subwatersheds are less than 20% and as a result both subwatersheds remain classified as having a *Low* potential for stress under the future demand scenario.

2.6 DROUGHT SCENARIO

The MOE Technical Rules (2008) require that the Stress Assessment be completed under a two-year drought scenario. 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). The surface water flow regime within the Grand River Watershed has changed considerably since many of the reservoir operating rules were changed in 1980 and, therefore, the two-year drought scenario should reference streamflow conditions since that time. The two-year period of lowest streamflow since 1980 occurred during the years of 1998 and 1999; the GAWSER streamflow-generation model includes this time period in its continuous simulation.

The Technical Rules indicate that a subwatershed is assigned a stress level of *Moderate* if during the drought scenario the operation of a surface water intake pump would be terminated because of an insufficient quantity of water being supplied to the intake.

The drought conditions are only evaluated for subwatersheds containing municipal surface water supply systems that have not previously been identified as having a *Moderate* potential for stress.

2.6.1 Drought Scenario for Current Demand

The Eramosa Above Guelph Subwatershed has previously been identified as having a *Moderate* potential for stress under current demand conditions. Due to this, the Technical Rules do not require this subwatershed to be analyzed in the Drought Scenario. Only the Mannheim and Holmedale Intakes will be looked at in further detail for this scenario.

Both the Mannheim and Holmedale Grand River intakes are located upstream of small dam structures that produce a backwater effect, keeping the intake below the water surface at all times. Figure 7 compares the average daily pumping rate and the future pumping rate at the Mannheim Intake to the flow in the Grand River. The figure shows that the flow in the Grand River is much greater than the municipal pumping rates during the drought period of 1998 and 1999.

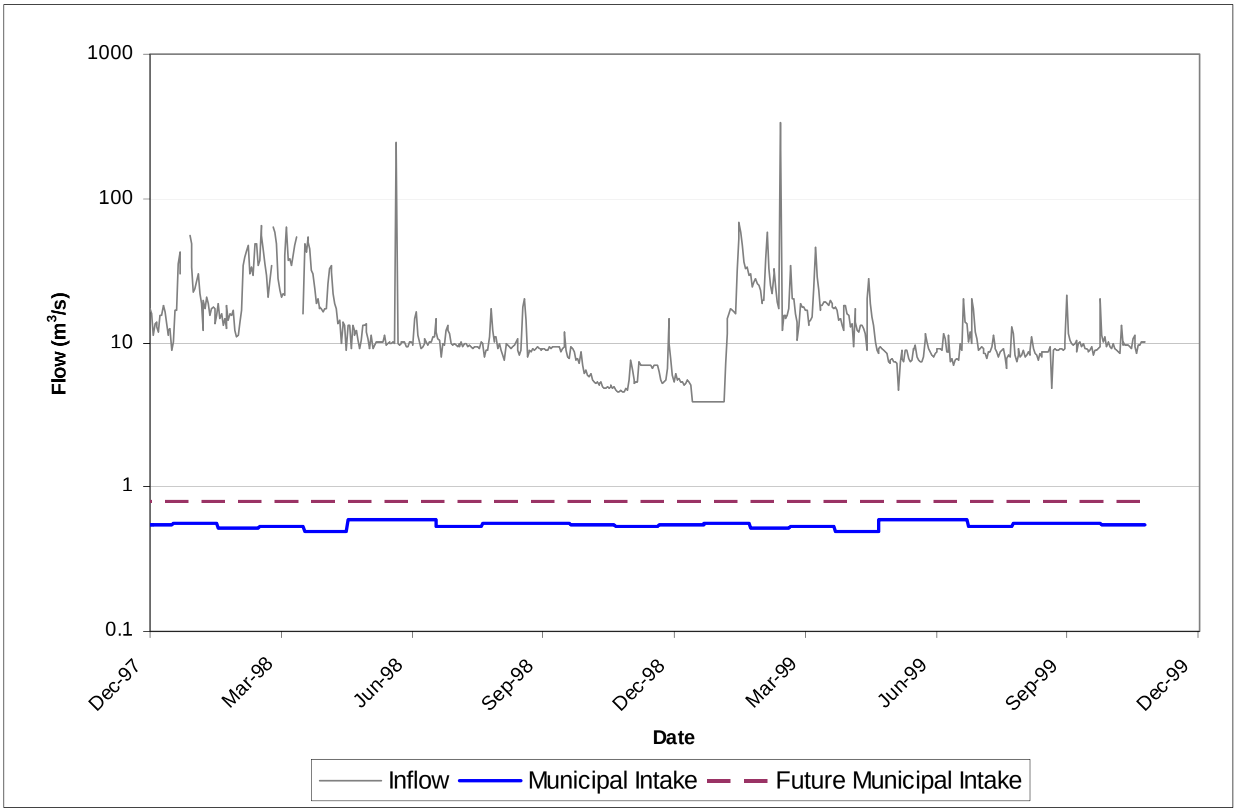


Figure 7 - Municipal Intake and River Flow at Mannheim Intake

Figure 8 shows the river flow and historical and future municipal demand at the City of Brantford's Holmedale intake. The Holmedale intake is protected by a downstream dam structure that maintains the water surface above the intake as long as streamflow exceeds the pumping rate. The figure shows that the flow in the Grand River is an order of magnitude greater than the municipal pumping rates during the drought period of 1998 and 1999.

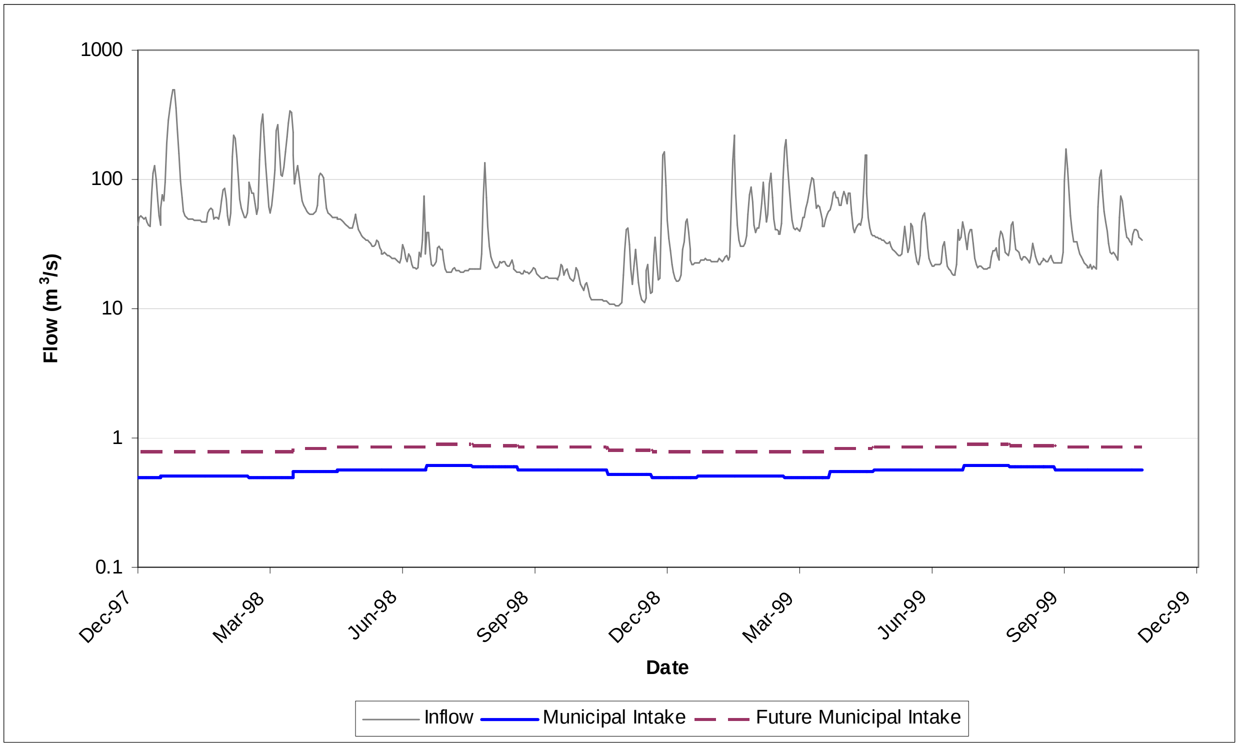


Figure 8 - Municipal Intake and River Flow at Holmedale Intake

The drought scenarios indicate that there would not be a cessation of normal intake operations at the Mannheim and Holmedale Intakes due to drought conditions. As a result, the stress classifications would not be changed to *Moderate* due to the drought scenario.

2.6.2 Drought Scenario for Future Demand

Similar to Section 2.6.1, where the existing demand was compared to streamflow under drought conditions, the Technical Rules (MOE, 2008) also require an evaluation of the future demand of planned systems using the same method. As discussed in Section 2.5, Table 2-6 summarizes potential increased future water demands at the Region of Waterloo's Mannheim Intake and at Brantford's Holmedale Intake. Figure 7 and Figure 8 show estimated future demands, calculated by combining historical pumping rates with potential future increases. Similar to the current conditions, river flow at these two intakes remains significantly higher than the rates needed to sustain the potential future water demands.

This assessment indicates that there would not be an increased stress at the Mannheim and Holmedale Intakes due to drought conditions. As a result, the stress classifications would not change due to future water demands and the drought scenario.

2.7 UNCERTAINTY OF SURFACE WATER STRESS CLASSIFICATIONS

While the surface water stress classification is based on best estimates of consumptive water demand, water supply, and water reserve, there is uncertainty with these estimates that may affect the classification. 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.

This section describes a sensitivity analysis designed to evaluate whether the uncertainty associated with the Percent Water Demand calculations is sufficient to modify the Stress Assessment classification. 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 for estimated consumptive demand (i.e. not reported values) and surface water supply for each subwatershed are increased and decreased by 25%.

When considering uncertainty associated with water use demands, it is recognized there may be greater uncertainty than 25% for individual permitted takings. This is due to uncertainty associated with the pumping rate, seasonality of pumping, and consumptive use factors. Because permitted water takings are grouped and analyzed by subwatershed, the uncertainties of individual takings are averaged over the entire subwatershed. Due to this averaging, varying water demand by +/- 25% within the sensitivity analysis is considered a reasonable range. In addition to the water use sensitivity analysis, additional scenarios were carried out by varying the water supply terms upwards and downwards by 25%.

The results of the sensitivity analysis are shown in Table 2-8. When adjusting the consumptive demand, only the estimated portion of consumptive demand in each subwatershed is adjusted by +/- 25%. The portion of water demand that is reported (e.g. municipal demands), in Table 2-2, is not adjusted as the reported values are actual water takings and not subject to the same level of uncertainty as the estimated values.

Table 2-8 - Sensitivity Analysis for Percent Water Demand under Existing Conditions

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
Grand Above Legatt	0%	0%	1%	1%	0%
Grand Above Shand To Legatt	0%	0%	0%	0%	0%
Grand Above Conestogo To Shand	3%	2%	4%	4%	2%
Conestogo Above Dam	4%	3%	5%	6%	3%
Conestogo Below Dam	2%	1%	2%	2%	1%
Grand Above Doon To Conestogo	7%	5%	8%	9%	5%
Eramosa Above Guelph	**25%**	**23%**	**27%**	**34%**	**20%**
Speed Above Dam	9%	7%	11%	12%	7%
Speed Above Grand To Dam	7%	6%	8%	9%	5%
Mill Creek	0%	0%	1%	1%	0%
Grand Above Brantford To Doon	1%	1%	2%	2%	1%
Nith Above New Hamburg	6%	5%	8%	9%	5%
Nith Above Grand To New Hamburg	7%	5%	9%	10%	6%
Whiteman's Creek	**38%**	**29%**	**47%**	**50%**	**30%**
Grand Above York To Brantford	3%	2%	4%	4%	2%

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
Fairchild Creek	7%	5%	8%	9%	5%
McKenzie Creek	**26%**	**20%**	**32%**	**35%**	**21%**
Grand Above Dunnville To York	1%	1%	1%	1%	1%

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

The sensitivity analysis does not change the final stress assessment classifications. For the three assessment areas classified as having a *Moderate* potential for stress in Table 2-5 (i.e. Eramosa Above Guelph, Whiteman's Creek and McKenzie Creek), the sensitivity analyses resulted in the Percent Water Demand being greater than the 20% threshold value for all scenarios for these three subwatersheds. When considering the uncertainty of the water budget parameters, a high level of confidence exists that these subwatersheds will be classified as having at least a *Moderate* potential for stress using the thresholds and methodology required by the Technical Rules.

Table 2-9 summarizes the results of the sensitivity analysis and the final uncertainty levels. Those subwatersheds which were originally identified as having a *Moderate* or *Significant* potential for stress and retained that classification for all sensitivity scenarios, are 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*.

Table 2-9 - Uncertainty Levels

Subwatershed	Low or High Uncertainty
Grand Above Legatt	Low
Grand Above Shand To Legatt	Low
Grand Above Conestogo To Shand	Low
Conestogo Above Dam	Low
Conestogo Below Dam	Low
Grand Above Doon To Conestogo	Low
Eramosa Above Guelph	Low
Speed Above Dam	Low
Speed Above Grand To Dam	Low
Mill Creek	Low
Grand Above Brantford To Doon	Low
Nith Above New Hamburg	Low
Nith Above Grand To New Hamburg	Low
Whiteman's Creek	Low
Grand Above York To Brantford	Low
Fairchild Creek	Low

Subwatershed	Low or High Uncertainty
McKenzie Creek	Low
Grand Above Dunnville To York	Low

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 2.5, there are no subwatersheds meeting the first criteria. Additionally, presented in Table 2-9, none of the subwatersheds have a *High* uncertainty regarding the stress classification. No additional subwatersheds are classified as having a *Moderate* potential for stress due to this uncertainty assessment.

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 analysis is to estimate the amount of time that subwatersheds would be classified as having stress based on 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 1980 to 1999 period.

Each Percent Water Demand calculation includes the following components for Q_{DEMAND}:

- Agricultural PTTW (Irrigation) Estimated Demand
- Agricultural PTTW (Irrigation) Reported Demand
- Monthly and Annual Municipal PTTW Reported Demand
- Non-Agricultural and Non-Municipal PTTW Estimated Demand
- Non-Agricultural and Non-Municipal PTTW Reported Demand
- Livestock and Rural Domestic Unpermitted Estimated Demand

This temporal analysis only considers estimated variability of agricultural irrigation demands. All other water demands are held constant from year to year and considered to be equal to the current water demand estimates.

2.8.1 Irrigation Event Model and Irrigation Demand

For several of the subwatersheds, agricultural irrigation is the largest water demand and it has the potential to fluctuate significantly from year to year. 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 continuous streamflow generation model's prediction of soilwater in typical soil conditions over the 1980-1999 simulation period. The irrigation event model was first documented in the GRCA Water Use Study (2005) and was also used to predict irrigation events for the Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget and Tier 2 Water Quantity Stress Assessment (AquaResource, 2009b, c). A complete explanation of the model can be found in the Grand River Watershed Integrated Water Budget Report (AquaResource, 2009a). The model assumes that changes in crop type or other farming practices will not occur during the period.

When soil water content predicted by the GAWSER continuous streamflow-generation model reaches approximately 50% of the soil water 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 soil water content by 25 mm. This new water is allowed to evaporate during subsequent time steps. When the soil water content again drops below the specified threshold, another irrigation event is triggered, provided at least one week has passed since the previous irrigation event.

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 1980-1999 simulation period. This is a relative indicator of the need for irrigation based on climate and hydrologic conditions. The irrigation event model used in this analysis was only calculated for climate data and soilwater conditions in the Norfolk Sand Plain in the Watershed. While this does not represent the full climatic variability geographically across the watershed, it is an appropriate indicator of precipitation in the location of the majority of agricultural permits.

Table 2-10 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 2-10 - Irrigation Events Model Output

Year	Number of Irrigation Events												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1980	0	0	0	0	0	3	3	1	1	0	0	0	8
1981	0	0	0	0	0	1	3	0	0	0	0	0	4
1982	0	0	0	0	0	0	4	2	0	0	0	0	6
1983	0	0	0	0	0	2	3	0	0	0	0	0	5
1984	0	0	0	0	0	0	1	4	0	0	0	0	5
1985	0	0	0	0	0	3	2	3	0	0	0	0	8
1986	0	0	0	0	0	1	2	1	1	0	0	0	5
1987	0	0	0	0	0	3	0	0	1	0	0	0	4
1988	0	0	0	0	0	4	2	0	1	0	0	0	7

Year	Number of Irrigation Events												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1989	0	0	0	0	0	4	4	4	4	0	0	0	16
1990	0	0	0	0	0	1	3	4	2	0	0	0	10
1991	0	0	0	0	0	2	3	3	3	0	0	0	11
1992	0	0	0	0	0	4	1	0	0	0	0	0	5
1993	0	0	0	0	0	2	2	4	0	0	0	0	8
1994	0	0	0	0	0	1	0	1	4	0	0	0	6
1995	0	0	0	0	0	2	4	1	4	0	0	0	11
1996	0	0	0	0	0	0	1	2	0	0	0	0	3
1997	0	0	0	0	0	2	4	1	0	0	0	0	7
1998	0	0	0	0	0	4	4	3	4	0	0	0	15
1999	0	0	0	0	0	4	4	4	3	0	0	0	15
MONTHLY AVERAGE	**0**	**0**	**0**	**0**	**0**	**2**	**3**	**2**	**1**	**0**	**0**	**0**	**8**

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. GRCA staff found, by comparing actual reported pumping rates with maximum permitted pumping rates, 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 Grand River Watershed 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.

This method is only used to estimate agricultural demand for Permits To Take Water that do not have reported pumping rates associated with them. For those PTTWs that have reported values, the irrigation model was not used to estimate irrigation rates.

By summing all the permitted irrigation water demands per irrigation event in each surface water subwatershed, a total irrigation demand per irrigation event was calculated for each subwatershed. The demand does not account for permits that have reported rates associated with them, as this tool is used to more accurately represent the *estimated* agricultural demand in the Watershed. These irrigation demands are given in Table 2-11 for each subwatershed.

Table 2-11 - Water Demand per Irrigation Event for each Surface Water Assessment Area

SW Assessment Area	Water Demand per Irrigation Event (L/s)
Grand Above Legatt	0
Grand Above Shand to Legatt	0
Grand Above Conestogo to Shand	1
Conestogo Above Dam	0
Conestogo Below Dam	0
Grand Above Doon to Conestogo	0
Eramosa Above Guelph	1
Speed Above Dam	0
Speed Above Grand to Dam	4
Mill Creek	0
Grand Above Brantford to Doon	0
Nith Above New Hamburg	1
Nith Above Grand to New Hamburg	16
Whiteman's Creek	69
Grand Above York to Brantford	24
Fairchild Creek	10
McKenzie Creek	30
Grand Above Dunnville to York	11

The total irrigation demand for each month was estimated by multiplying the irrigation demand per irrigation event (Table 2-11) by the number of irrigation events each month (Table 2-10). For example, McKenzie Creek has a total irrigation water demand of 30 L/s every time an irrigation event occurs. In 1980, the irrigation model predicted that three irrigation events would occur in June, three would occur in July, one would occur in August, and one would occur in September. The variable agricultural demand in these months would thus be 90 L/s in June, 90 L/s in July, 30 L/s in August, and 30 L/s in September.

These monthly variable agricultural irrigation demands were then summed with all the other surface water demand components (e.g. municipal demand), 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 Surface Water Supply Variability

With the goal of this temporal variability analysis being to estimate the amount of time that subwatersheds would be classified as having stress, each component of the Percent Water Demand calculation must be analyzed over a longer term range of hydrologic conditions; the analysis is completed monthly over the 1980 to 1999 simulation period.

Monthly estimates of surface water supply (Q_{SUPPLY}) were determined using stream gauge flow estimates and the GAWSER continuous streamflow-generation model's flow output for the simulation period. The previously calculated monthly water reserve ($Q_{RESERVE}$) terms (Table 2-3) are used in this analysis and do not change from year-to-year.

2.8.3 Percent Surface Water Demand Variability

The Percent Water Demand was calculated for each month from January 1980 to October 1999 using variable monthly water demands, monthly median flows (Q_{SUPPLY}), and the long-term average 90th percentile flows ($Q_{RESERVE}$).

The purpose of the monthly Percent Water Demand variability calculation is to estimate the frequency that stressed conditions might be observed in the subwatersheds that have been classified as having a potential for stress. The following sections summarize the results of the Percent Water Demand Variability analysis for the three subwatersheds classified as having a *Moderate* potential for stress under existing conditions Results for all assessment areas are provided in Appendix A.

2.8.3.1 Eramosa Above Guelph Subwatershed

The Eramosa Above Guelph Subwatershed was estimated to have a maximum monthly Percent Water Demand of 25% in the Surface Water Stress Assessment in Section 2.3.3 resulting in a subwatershed stress classification of *Moderate*. Figure 9 illustrates the results of the temporal analysis, summarizing the monthly Percent Water Demand results for each year.

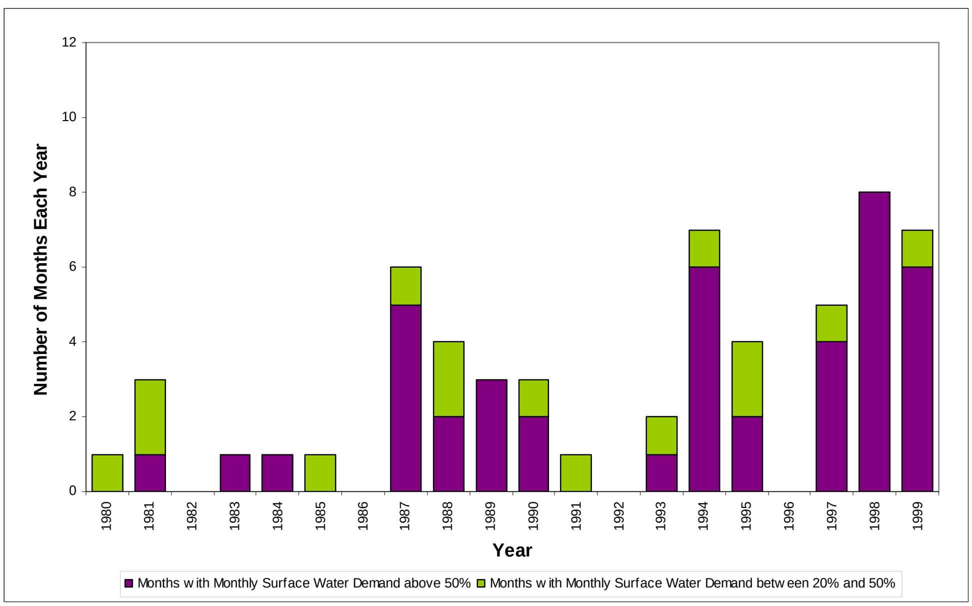


Figure 9 - Eramosa Above Guelph Subwatershed - Annual Number of Months Potentially Stressed

For each year, the figure categorizes each month based on the monthly Percent Water Demand as follows:

- Percent Water Demand is greater than 20% but less than 50%. The Technical Rules identify 20% as the threshold to indicate a *Moderate* potential for stressed conditions.
- Percent Water Demand is greater than 50%. The Technical Rules identify 50 % as the threshold indicating a *Significant* potential for stressed conditions.

As shown in Figure 9 most months, in most years, had a Percent Surface Water Demand less than 20% and most years had at least one month with greater than 20% Percent Water Demand. The results illustrate the variability of Percent Water Demand over time. The temporal trends show years with higher stress followed by periods of time with lower potential stress. The 1997-1999 period, which includes the period used in the Drought Scenario (Section 2.6), has the largest number of months having potential stress.

Figure 10 illustrates a ranked curve of monthly Percent Surface Water Demand showing the threshold for potential stress at 20%. This figure shows that the Percent Water Demand is greater than the 20% threshold for approximately 25% of the months simulated. Furthermore, the Percent Water Demand is greater than 100% for more than 10% 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}) is less than the water reserve estimate; this would be a result of naturally occurring low flow conditions.

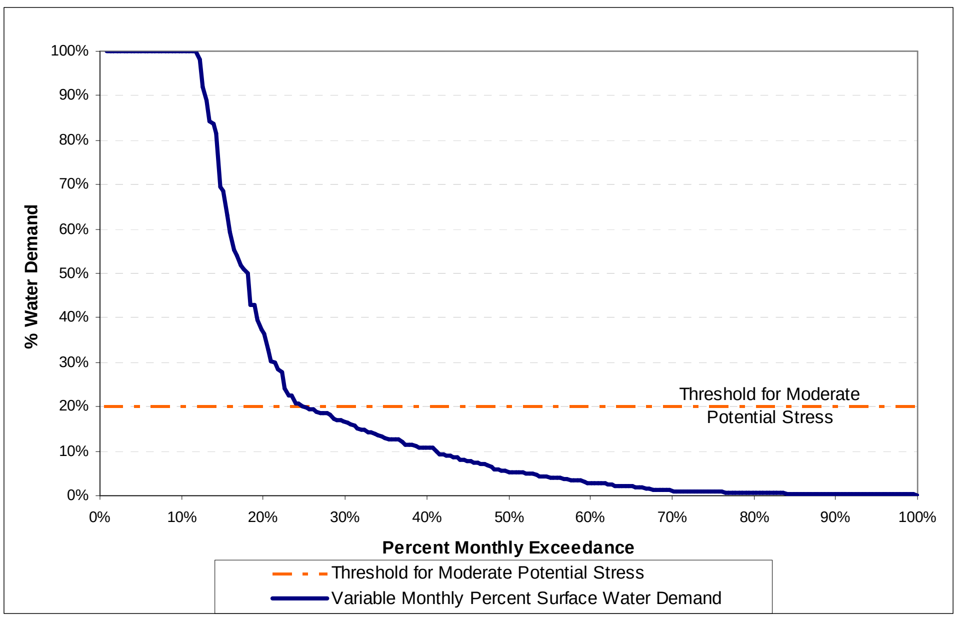


Figure 10 - Eramosa Above Guelph Subwatershed - Ranked Monthly Percent Water Demand

2.8.3.2 McKenzie Creek Subwatershed

The McKenzie Creek Subwatershed area was estimated to have a maximum monthly Percent Water Demand equal to 26% in the Surface Water Stress Assessment in Section 2.3.3, resulting in a *Moderate* subwatershed stress classification. Figure 11 shows the results of the variability analysis on this Subwatershed. Most of the years have at least one monthly Percent Surface Water Demand greater than 20%. Compared to the Eramosa Above Guelph Subwatershed, there are more years showing potentially stressed conditions but there is less variability in the number of months each year that are potentially stressed. This is explained by the fact that McKenzie Creek Subwatershed is a highly agricultural area and there are consistently higher estimated demands in the summer and the early fall low flow months. The Eramosa Above Guelph Subwatershed variability analysis shows greater response to the natural system; even with fairly consistent demand each year, the temporal Percent Water Demand results fluctuate greatly from year to year in response to changing climatic supply.

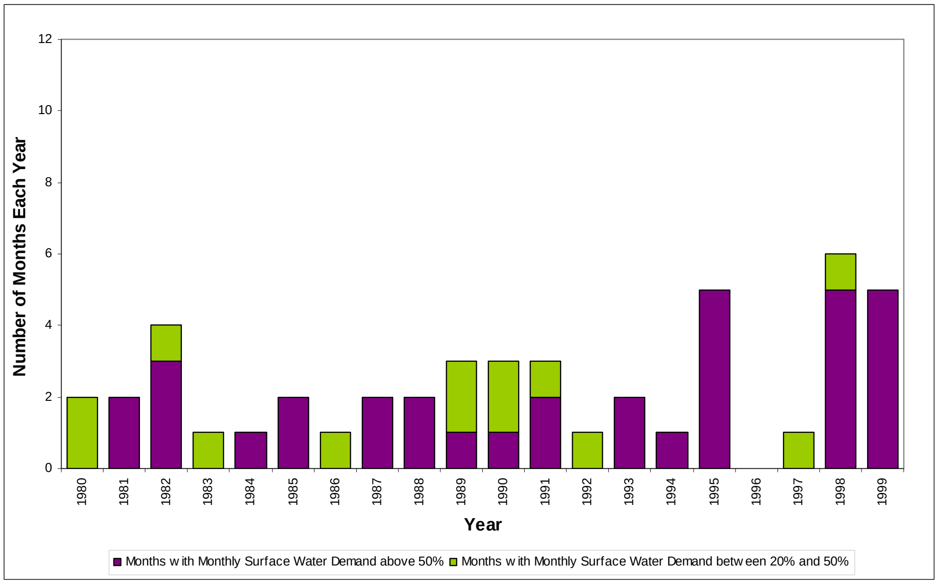


Figure 11 - McKenzie Creek Subwatershed - Annual Number of Months Potentially Stressed

Figure 12 shows a ranked curve of monthly percent surface water demands for the McKenzie Creek Subwatershed. This figure shows that approximately 20% of the months during the 1980-1999 simulation period have a Percent Water Demand greater than 20%. Agricultural water use is the most significant sector water use in the Watershed. Since agricultural water demand is restricted to the growing season, Percent Water Demand is very close to zero for many months of the year.

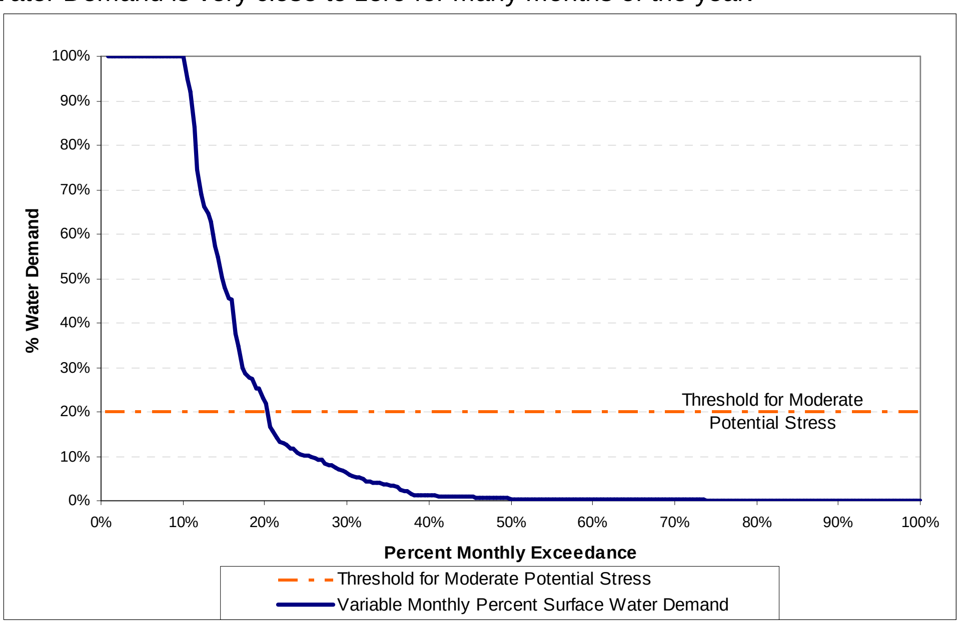


Figure 12 - McKenzie Creek Subwatershed - Ranked Monthly Percent Water Demand

2.8.3.3 Whiteman's Creek Subwatershed

Whiteman's Creek assessment area was estimated to have a maximum Percent Water Demand of 38% in the Surface Water Stress Assessment in Section 2.3.3, resulting in a *Moderate* subwatershed stress classification. Figure 13 shows the number of months each year that are classified as having a potential for *Moderate* or *Significant* stress in the Whiteman's Creek Subwatershed.

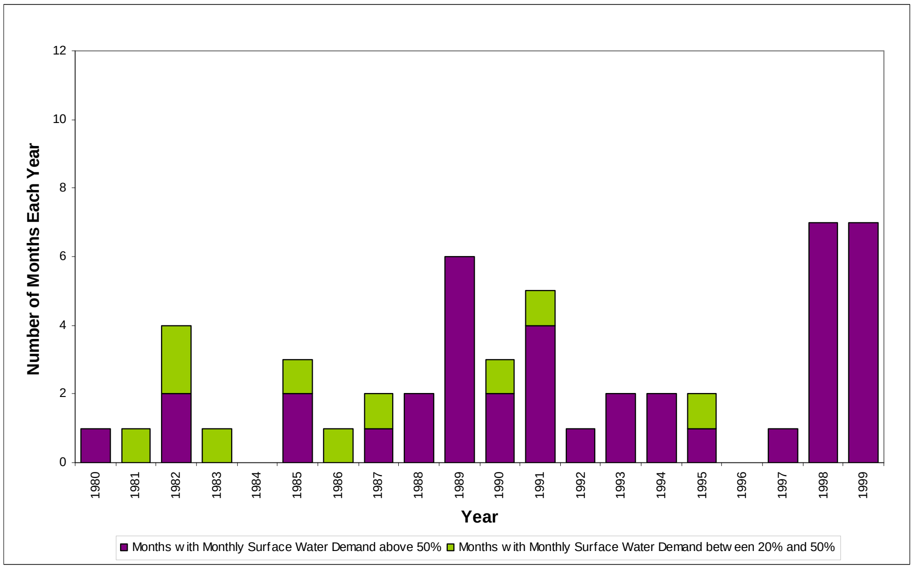


Figure 13 - Whiteman's Creek Subwatershed - Annual Number of Months Potentially Stressed

Most of the years shown in Figure 13 have at least one monthly Percent Surface Water Demand greater than 20%. Comparing this assessment area to McKenzie Creek, both areas are highly agricultural, but Whiteman's Creek Subwatershed has a higher number of months that are potentially stressed. Furthermore, Whiteman's Creek Subwatershed has more months being classified as having a *Significant* potential for stress as opposed to only having a *Moderate* potential for stress.

Figure 14shows a ranked curve of monthly Percent Surface Water Demands for the Whiteman's Creek Subwatershed. This figure shows that approximately 23% of the months during the 1980-1999 simulation period have a Percent Water Demand greater than 20%. Nearly 15% of the months show a Percent Water Demand equal to or greater than 100 %. Agricultural water use is the most significant sector water use in the Watershed. Since agricultural water demand is restricted to the growing season, Percent Water Demand is very close to zero for many months of the year.

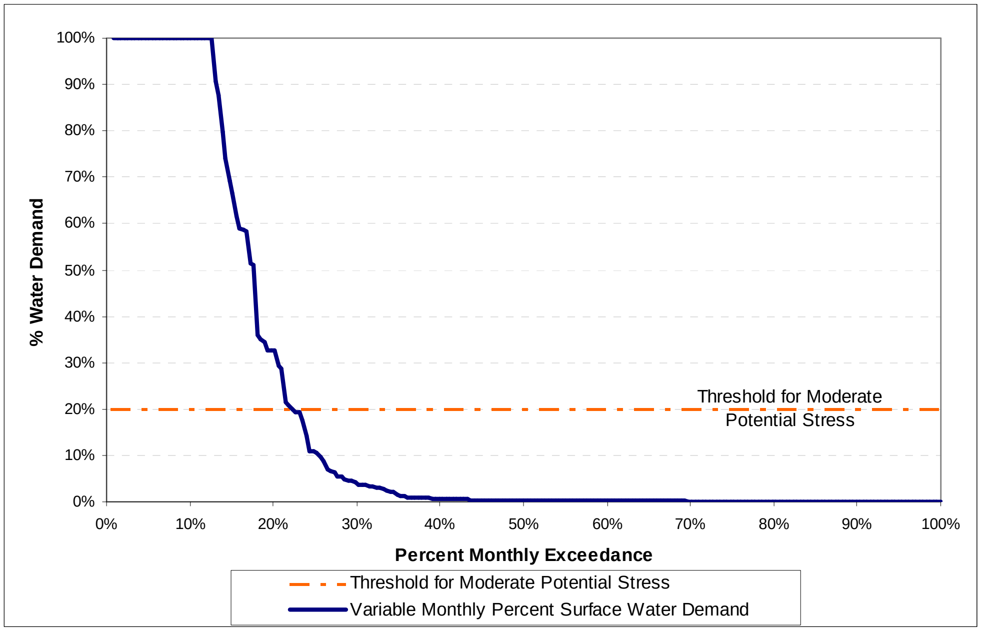


Figure 14 - Whiteman's Creek Ranked Monthly Percent Water Demand

2.9 SURFACE WATER STRESS ASSESSMENT RESULTS

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

- Eramosa Above Guelph Subwatershed;
- Whiteman's Creek Subwatershed; and
- McKenzie Creek Subwatershed.

These subwatersheds had also been previously identified as Areas of Special Concern by the GRCA as part of its Low Water Response program. Figure 15 shows these areas in the Grand River Watershed. It is anticipated that water supply problems may occur at times in these identified areas.

All other subwatersheds in the Grand River Watershed are classified as having a *Low* potential for surface water stress, including some of those containing municipal surface water intakes. Drought conditions do not modify the classification of any subwatersheds containing municipal drinking water intakes. The sensitivity scenarios completed for all subwatersheds, indicated that the stress classification was not sensitive to changes of +/- 25% for either water supply or estimated consumptive water demand.

This section provides additional discussion relating to the three assessment areas classified as having a *Moderate* potential for stress.

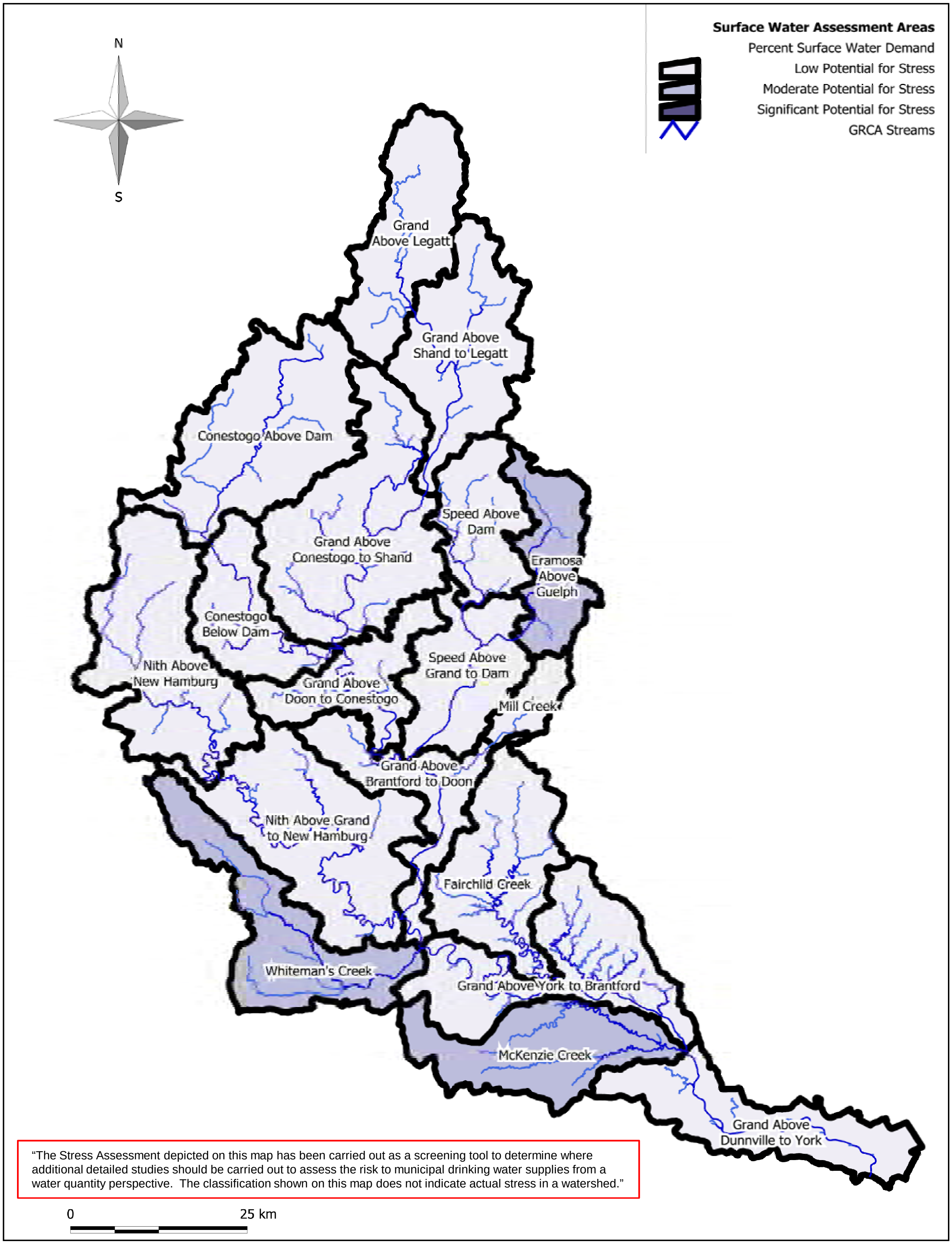


Figure 15
Surface Water Assessment Areas
Potential Stress Classifications

2.9.1 Eramosa Above Guelph Subwatershed

The Eramosa River is northeast of Guelph and joins the Speed River in the City of Guelph. The headwaters are in the northwest portion of Erin Township. Blue Springs Creek, a major tributary of the Eramosa River, joins the Eramosa River in Halton Region. The river drains a significant portion of two major moraines, the Orangeville Moraine and the Paris Moraine. Rain falls on these moraines, enters the ground and eventually makes its way into the Eramosa River. The Eramosa River produces steady baseflow, even during most summer months.

The stress assessment completed for the Eramosa Above Guelph Subwatershed classifies the Subwatershed as having a *Moderate* potential for stress under current water demand conditions. The Subwatershed's maximum monthly Percent Water Demand is estimated to be 25% during the month of August. The Subwatershed contains the City of Guelph's Eramosa River drinking water intake. The City of Guelph's Permit-to-Take-Water regulates the amount of water that can be pumped from this intake; for this assessment it was assumed that these rates could increase up to 100 L/s. The pumping rate used at this intake is currently restricted by infrastructure constraints, as the size of the pump is limited to 93 L/s while the PTTW allows pumping up to 368 L/s. Moreover, the Eramosa River intake is often shut down in the late summer due to low flow in the river. As a result, the City of Guelph's water supply is already limited by lack of flow in the Eramosa River (D. Belanger, Peer Review Process, Feb. 2009). In addition, the City of Guelph has implemented water conservation and water use reduction measures as documented in the Water Conservation and Efficiency Strategy Update (Resource Management Strategies, 2009).

In addition to the municipal intake, there are 10 known permitted surface water takings within this Subwatershed; these include 1 agricultural use permit, 3 commercial use permits, 3 recreational use permits, and 2 miscellaneous use permits. Figure 16 illustrates the estimated monthly Percent Water Demand by sector. The graph shows much higher Percent Water Demand in the summer months which is due to a combination of higher water demand and lower water supply.

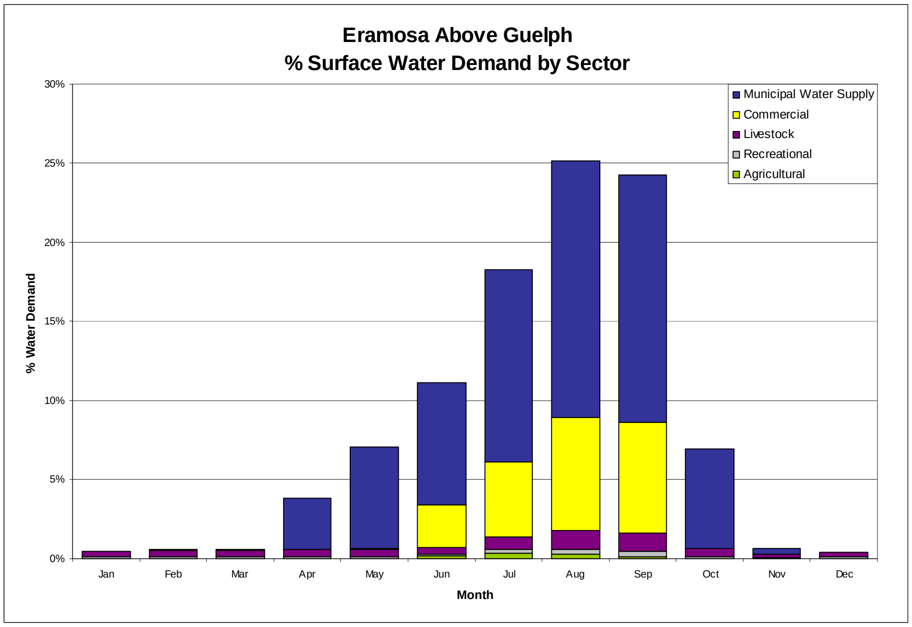


Figure 16 - Eramosa Above Guelph % Surface Water Demand by Sector

Surface water demand is very low from November to March but rises significantly from April to October. The majority of the water demand in this assessment area is due to the municipal water demand taken from the Eramosa River. The higher demand from April to November reflects the City of Guelph's Permit-to-Take-Water from the Eramosa River.

Baseflow in the Eramosa River is typically very high throughout the year due to the considerable amounts of groundwater discharge into the River and its tributaries. In addition, the pervious nature of the Subwatershed tends to dampen runoff, allowing actual streamflow to remain constant during a given month. Due to high baseflow conditions, the monthly surface water reserve, $Q_{RESERVE}$, is not much lower than the calculated water supply, Q_{SUPPLY}. As a result of the high water reserve estimate, the maximum monthly Percent Water Demand in this Subwatershed is 25%. Total water takings, however, are usually a much lower percentage of the actual streamflow.

The Percent Water Demand Variability analysis for the Subwatershed shows that the estimated Percent Water Demand changes considerably from year to year as a result of hydrologic conditions. This analysis suggests that consumptive water demand may not be as significant as hydrologic variability and low flow conditions in terms of its influence on potential stress. The drought scenario evaluated for the Eramosa Intake indicates that the City had to reduce its surface water takings during the 1998-1999 drought period.

The City of Guelph has been found to meet the requirements set out by the Technical Rules (MOE, 2008) to complete a Tier 3 Water Quantity Risk Assessment for the Eramosa River Intake. The Eramosa Above Guelph Subwatershed is classified as having a *Moderate* potential for stress for surface water. The objective of the Tier 3 Water Quantity Risk Assessment is to estimate the potential that the City of Guelph would not be able to obtain its permitted water pumping rates at this intake.

2.9.2 Whiteman's Creek Subwatershed

Whiteman's Creek, located in the western portion of the County of Brant near Burford, enters the Grand River just upstream of Brantford. This creek has two main tributaries, Kenny Creek (in Norwich Township) and Horner Creek (in Blandford-Blenheim Township). The flows in Whiteman's Creek are largely dependent on groundwater from the high water table. Whiteman's Creek, before it enters the Grand River, flows through the Norfolk Sand Plain for approximately 20 kilometers. The Norfolk Sand Plain is a shallow sand aquifer that feeds Whiteman's Creek, and provides agricultural and rural domestic water supplies.

The stress assessment completed for Whiteman's creek assessment area classifies the Subwatershed as having a *Moderate* potential for stress under current water demand conditions. There are no planned municipal systems in this assessment area and, therefore, the future demand and drought scenarios were not evaluated for this Subwatershed. Without having a municipal surface water intake in the Subwatershed, there is not a requirement for the completion of a Tier 3 Water Quantity Risk Assessment as a result of the *Moderate* classification.

There are 55 identified permitted agricultural surface water takings within the Whiteman's Creek Subwatershed. The only additional water demand estimated for the Subwatershed is the unpermitted agricultural (livestock) surface water demand, estimated to be 4 L/s throughout the year. As shown on Figure 17, the estimated water demand has a very high monthly variability due to the seasonal nature of the agricultural irrigation water takings. The Percent Water Demand from October to May is close to zero, while the Percent Water Demand is 38% and 18% for the months of July and August, respectively. Water demand is well distributed between the 55 water takings.

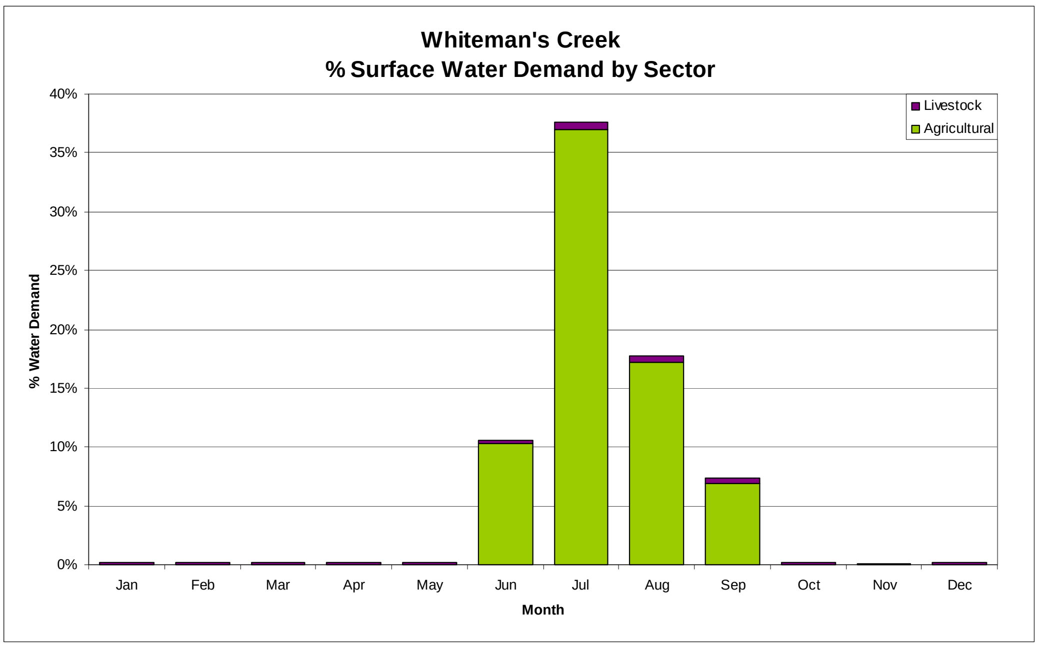


Figure 17 - Whiteman's Creek Subwatershed - Percent Surface Water Demand by Sector

The Integrated Water Budget Report (AquaResource, 2009a) provides a detailed discussion on the procedure followed to estimate the agricultural water demand for this Subwatershed. Without having reported water takings for most of the permits, there is a relatively high level of uncertainty in the estimated Percent Water Demand. This uncertainty is particularly high when dealing with irrigation permits-to-take-water, where the frequency, duration, and magnitude of the pumping is highly variable and there is a high consumptive use factor.

The assignment of a *Moderate* classification for this Subwatershed is consistent with field observations. The hydrologic and ecological impacts of high water demands associated with irrigation in the

Subwatershed are well documented. The GRCA has worked with water users in the Whiteman's Creek Subwatershed to implement ways to reduce the impact of water taking during exceptionally dry weather. As an example, The Brant Federation of Agriculture and the GRCA have joined forces with local Federations of Agriculture to support farmer lead Irrigation Advisory Committees. These initiatives offer training, education workshops, and guidelines to committee members and the wider irrigation community to promote fair and responsible agricultural water use.

2.9.3 McKenzie Creek Subwatershed

McKenzie Creek, including Boston Creek, is a tributary of the Grand River in the southern portion of the Grand River Watershed. The headwaters of both creeks begin in Brant County, where the shallow Norfolk Sand Plain aquifer supplies groundwater baseflows. McKenzie Creek continues through the Haldimand clay plain in the Six Nations Territory and joins with Boston Creek just south of the Town of Caledonia. The combined flows enter the Grand River at the Village of York.

The stress assessment classifies the McKenzie Creek Subwatershed as having a *Moderate* potential for stress under current water demand conditions. There are no planned municipal systems in this assessment area and, therefore, the future water demand and drought scenarios were not evaluated for this Subwatershed. Without having a municipal surface water intake in this Subwatershed, there are no requirements for the completion of a Tier 3 Water Quantity Risk Assessment as a result of the *Moderate* classification.

The Subwatershed is primarily rural land use. Similar to Whiteman's Creek assessment area, agricultural irrigation is a major water use in the summer months, especially in the Norfolk sand plain area. There are 35 identified surface water permits-to-take-water in the Subwatershed, mostly for irrigation. Figure 18 illustrates estimated monthly Percent Water Demand for each water use sector.

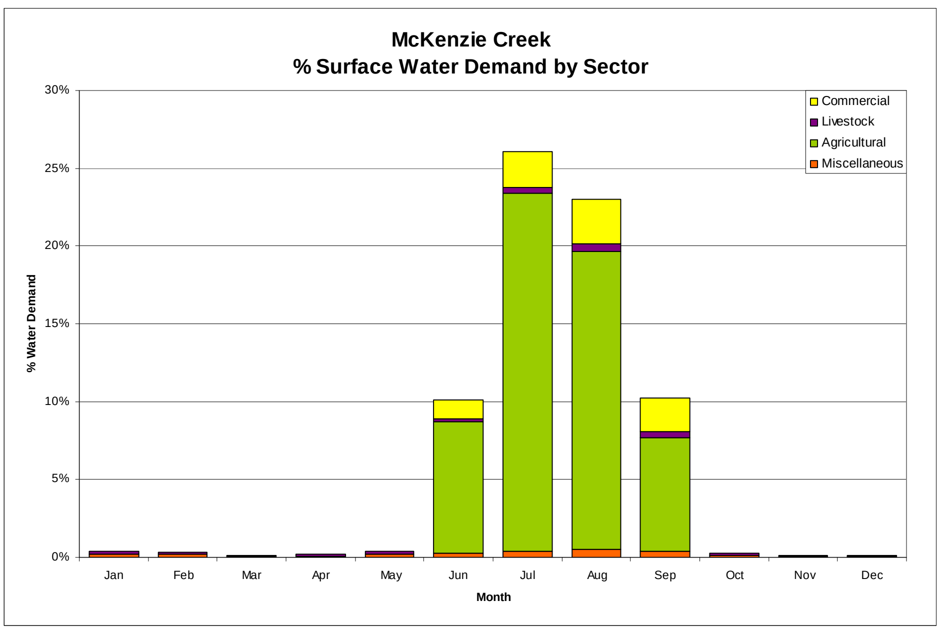


Figure 18 - McKenzie Creek Subwatershed - Percent Surface Water Demand by Sector

The heavy irrigation demand from June through until September put the Creek under stress from online surface water takings as well as groundwater takings. Cash crops in this area include tobacco, potatoes, ginseng, and more recently, a large increase in vegetable crops, all of which contribute to the large demands for irrigation water.

The Integrated Water Budget Report (AquaResource, 2009a) provides a detailed discussion on the procedure followed to estimate the agricultural water demand for this Subwatershed. Similar to the Whiteman's Creek Subwatershed, without having reported water takings for most of the permits-to-take-water, there is a relatively high level of uncertainty associated with the estimated Percent Water Demand. This uncertainty is high when dealing with irrigation permits where the frequency, duration, and magnitude of pumping is variable and there is a high consumptive use factor.

The assignment of a *Moderate* classification for the McKenzie Creek Subwatershed is consistent with field observations. The hydrologic and ecological impacts of high water demands associated with irrigation in this Subwatershed are well documented. The GRCA has worked with water users in the Subwatershed to implement ways to reduce the impact of water taking during exceptionally dry weather. These initiatives offer training, education workshops, and guidelines to committee members and the wider irrigation community to promote fair and responsible agricultural water use.

3.0 Water Quantity Stress Assessment – Groundwater Demand

This chapter contains the Tier 2 Water Quantity Stress Assessment for groundwater supplies in the Grand River Watershed. The potential for stress is estimated by comparing the ratio of current and future water demand to water supply. A drought scenario identifies any municipal drinking water systems that have the potential to be susceptible to drought conditions. The goal of the Water Quantity Stress Assessment is to identify municipal drinking water supplies that are located in assessment areas having the potential for stress. Under the Technical Rules (MOE, 2008), developed for the Clean Water Act (2006), these will be required to complete a Tier 3 Water Quantity Risk Assessment.

The hydrogeological parameters required to support the groundwater Stress Assessment include: groundwater recharge, lateral groundwater flow-in from adjacent assessment areas, groundwater reserve, and average and maximum monthly demand. Groundwater supply is calculated as the annual amount of recharge plus the amount of total groundwater flow-in. The groundwater reserve component is calculated as 10% of the estimated groundwater discharge. Average and monthly maximum unit consumptive water demands were previously estimated in the Grand River Watershed Integrated Water Budget Report.

3.1 GROUNDWATER ASSESSMENT AREAS

Under the requirements of the Technical Rules (MOE, 2008), the Water Quantity Stress Assessment is carried out on a subwatershed basis. For the preliminary groundwater stress assessments, the surface water-based subwatersheds (Figure 4) were used for preliminary groundwater stress assessments. While these delineated subwatersheds reflected surface water demands and hydrology well, they did not adequately reflect the major aquifer systems in the watershed, existing municipal wells systems and capture zones for those systems. The surface-water based subwatersheds subdivided several of the large aquifers and wellfields into separate assessment areas, and this resulted in groundwater demand from the same aquifer being split into separate subwatersheds.

Figure 5 illustrates a new set of groundwater assessment areas delineated to better represent water demand and aquifer systems. The new groundwater boundaries were developed to encompass groundwater demand systems from the same aquifer in a single assessment area. These areas are listed in Table 3-1 with a description of how these boundaries were derived. ,

Table 3-1 - Groundwater Assessment Areas

Groundwater Assessment Area	Area (km^2)	Description of Boundary Modification
Grand Above Legatt	365	No Change from Surface Water Subwatershed
Grand Above Shand to Legatt	426	No Change from Surface Water Subwatershed
Irvine River	359	Delineated as the upper portion of the Grand Above Conestogo to Shand Subwatershed
Canagagigue Creek	177	Delineated as the southwest portion of the Grand Above Conestogo to Shand Subwatershed
Conestogo Above Dam	566	No Change from Surface Water Subwatershed
Conestogo Below Dam	254	No Change from Surface Water Subwatershed

Groundwater Assessment Area	Area (km^2)	Description of Boundary Modification
Hopewell/Cox Creek	208	Delineated as the southeast portion of the Grand Above Conestogo to Shand Subwatershed joined with the northeast portion of the Grand Above Doon to Conestogo Subwatershed
Upper Speed	614	Delineating by combining the Eramosa River, Speed Above Dam, and upper portion of the Speed Above Grand to Dam Subwatersheds. This area encompasses the City of Guelph drinking water systems and capture zones.
Central Grand	562	Delineated by combining portions of the Nith Above Grand To New Hamburg, Grand Above Doon to Conestogo, Speed Above Grand to Dam, and Grand Above Brantford to Doon Subwatersheds. This area encompasses most of the Region of Waterloo's municipal wells.
Mill Creek	82	No Change from Surface Water Subwatershed
Upper Nith	496	Delineated as the original Nith Above New Hamburg Subwatershed, subtracting the small lower portion of the subwatershed
Middle Nith	259	Delineated as the lower portion of the original Nith Above New Hamburg Subwatershed joined with an upper portion of the Nith Above Grand to New Hamburg Subwatershed
Lower Nith	395	Delineated as the lower portion of the Nith Above Grand to New Hamburg Subwatershed combined with the lower portion of the Grand Above Brantford to Doon Subwatershed
Whitemans Creek	404	No Change from Surface Water Subwatershed
Grand at Brantford	181	Delineated as the western portion of the Grand Above York to Brantford Subwatershed
Fairchild Creek	401	No Change from Surface Water Subwatershed
Big Creek	295	Delineated as the eastern portion of the Grand Above York to Brantford Subwatershed
McKenzie Creek	368	No Change from Surface Water Subwatershed
Grand Above Dunnville To York	356	No Change from Surface Water Subwatershed

3.2 HISTORIC CONDITIONS

The authors of this report are unaware of any historical events where pumping at municipal well locations was affected by low groundwater levels in any of the assessment areas. As a result, none of the groundwater assessment areas would be classified with a *Moderate* stress level due to historical conditions.

3.3 EXISTING CONDITIONS PERCENT WATER DEMAND

3.3.1 Consumptive Groundwater Use

Figure 3 shows both the locations of all permitted groundwater users in the Grand River Watershed and the groundwater assessment area boundaries. The Integrated Water Budget Report (AquaResource, 2009a) describes the procedure used to estimate consumptive groundwater demands for these groundwater users across the Watershed. Table 3-2 contains the monthly estimates of unit consumptive groundwater demands calculated for the groundwater assessment areas. Table 3-2 also includes the amount of total water demand that is derived from reported values (*Rep*), versus the amount of water that is estimated from the Permit To Take Water database (*Est*).

Table 3-2 - Estimated Current Groundwater Consumptive Demands (L/s)

Groundwater Assessment Area		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max Month
Grand Above Legatt	Rep	8	8	8	8	8	8	8	8	8	8	8	8		
	Est	16	16	16	16	20	20	20	20	20	16	16	16		
	Total	23	23	23	23	27	27	27	27	27	23	23	23	25	27
Grand Above Shand to Legatt	Rep	7	7	7	7	7	9	10	8	8	7	7	7		
	Est	53	53	53	53	67	67	67	67	67	67	67	53		
	Total	60	60	59	59	75	76	77	76	75	74	74	60	69	77
Irvine River	Rep	60	64	63	73	71	74	67	64	67	67	65	64		
	Est	14	14	14	14	14	15	15	15	15	14	14	14		
	Total	74	78	77	87	85	89	83	79	82	81	79	78	81	89
Canagagigue Creek	Rep	103	106	105	109	112	114	112	103	115	114	130	109		
	Est	53	53	53	53	53	53	53	53	53	53	53	53		
	Total	156	160	159	162	166	167	165	156	169	168	183	163	164	183
Conestogo Above Dam	Rep	22	23	22	22	22	25	23	23	24	23	24	24		
	Est	13	13	13	13	15	15	15	15	15	13	13	13		
	Total	35	36	36	35	38	40	39	38	39	37	37	37	37	40
Conestogo Below Dam	Rep	8	8	8	12	20	22	22	21	14	12	13	11		
	Est	32	32	32	32	32	32	32	32	32	32	32	32		
	Total	39	40	40	43	52	54	53	53	45	44	44	43	46	54
Hopewell/Cox Creek	Rep	3	3	2	3	3	4	4	4	3	3	2	3		
	Est	70	70	70	70	70	104	104	104	104	70	70	70		
	Total	72	73	72	72	73	108	108	108	107	72	72	72	84	108
Upper Speed	Rep	772	785	839	728	865	838	840	884	859	895	855	838		
	Est	66	66	66	66	66	148	154	148	141	66	66	66		
	Total	838	851	905	794	931	985	994	1,032	1,000	960	921	904	926	1,032
Central Grand	Rep	1,345	1,389	1,380	1,399	1,409	1,616	1,525	1,491	1,423	1,400	1,377	1,295		
	Est	384	384	352	352	365	580	584	580	576	361	361	384		
	Total	1,729	1,773	1,732	1,750	1,775	2,197	2,109	2,071	1,999	1,761	1,738	1,679	1,859	2,197
Mill Creek	Rep	32	29	28	37	43	47	47	45	40	37	43	32		
	Est	18	18	18	18	59	67	68	67	67	55	55	18		
	Total	50	46	46	55	102	114	114	112	107	91	98	50	82	114
Upper Nith	Rep	15	15	15	16	16	24	24	16	15	16	15	16		
	Est	17	17	17	17	17	17	17	17	17	17	17	17		
	Total	32	32	32	32	33	41	41	32	32	32	32	32	34	41
Middle Nith	Rep	131	84	96	112	116	123	106	117	112	112	120	112		
	Est	11	11	11	11	11	11	11	11	11	11	11	11		
	Total	142	95	107	123	127	134	117	128	123	123	131	123	123	142

Groundwater Assessment Area		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max Month
Lower Nith	Rep	77	78	155	136	90	143	149	95	82	171	79	77		
	Est	49	49	49	49	63	111	121	111	101	63	63	49		
	Total	126	126	203	185	153	254	271	207	183	234	141	126	184	271
Whitemans Creek	Rep	1	1	1	8	16	47	52	45	43	11	1	1		
	Est	9	9	9	9	9	278	412	278	143	9	9	9		
	Total	10	10	10	16	24	325	465	323	186	20	9	9	117	465
Grand at Brantford	Rep	15	15	15	19	17	19	25	21	15	15	15	15		
	Est	10	10	10	10	17	143	186	143	100	17	17	10		
	Total	26	26	26	30	34	162	211	163	115	33	33	26	74	211
Fairchild Creek	Rep	12	11	12	12	14	22	23	19	18	17	12	12		
	Est	71	71	71	71	72	87	94	87	80	71	71	71		
	Total	83	83	83	83	86	109	117	106	98	88	83	83	92	117
Big Creek	Rep	2	2	2	2	6	9	6	9	5	2	2	2		
	Est	129	129	129	129	133	189	195	189	183	129	129	129		
	Total	130	130	130	130	139	198	201	198	189	131	130	130	153	201
McKenzie Creek	Rep	0	0	0	0	1	1	2	2	0	0	0	6		
	Est	3	3	3	3	3	148	221	148	76	3	3	3		
	Total	3	3	3	3	4	149	223	150	76	3	3	9	53	223
Grand Above Dunnville to York	Rep	50	34	30	17	21	8	9	10	17	59	43	36		
	Est	57	57	57	57	57	77	79	77	75	57	57	57		
	Total	106	91	87	74	78	86	88	87	93	116	99	93	91	116

3.3.2 Groundwater Supply and Reserve

Estimated water budget parameters for the surface water subwatersheds are summarized in the Integrated Water Budget Report (AquaResource, 2009a). Table 3-3 and Table 3-4 summarize these estimates for the for the revised groundwater assessment areas.

Table 3-3 - Groundwater Assessment Areas Water Budget Data from GAWSER Output (mm/y)

Groundwater Assessment Area	Area (km^2)	Precip	ET	Runoff	Recharge
Grand Above Legatt	365	988	465	349	174
Grand Above Shand to Legatt	426	988	461	359	168
Irvine River	359	894	449	306	139
Canagagigue Creek	177	967	506	299	162
Conestogo Above Dam	566	936	485	328	123
Conestogo Below Dam	254	968	486	365	117
Hopewell/Cox Creek	208	929	556	169	204
Upper Speed	614	892	512	145	236
Central Grand	562	899	493	169	236
Mill Creek	82	888	509	87	292
Upper Nith	496	993	504	350	139
Middle Nith	259	954	501	238	215

Groundwater Assessment Area	Area (km^2)	Precip	ET	Runoff	Recharge
Lower Nith	395	934	517	116	301
Whitemans Creek	404	945	513	176	257
Grand at Brantford	181	945	495	275	176
Fairchild Creek	401	866	469	262	135
Big Creek	295	866	493	291	82
McKenzie Creek	368	945	481	337	127
Grand Above Dunnville To York	356	945	462	394	89
Total Watershed	**6,769**	**933**	**491**	**266**	**176**

Table 3-4 - Groundwater Assessment Areas Water Budget Data from FEFLOW Output (mm/y)

Groundwater Assessment Area	Area (km^2)	Recharge	Surface Water	Wells	Inter-Subwatershed Flow	Inter-Watershed Flow
Grand Above Legatt	365	177	-158	-1	-18	0
Grand Above Shand to Legatt	426	169	-160	-4	-2	-2
Irvine River	359	140	-110	-7	-24	0
Canagagigue Creek	177	161	-117	-29	-15	0
Conestogo Above Dam	566	125	-69	-2	-23	-31
Conestogo Below Dam	254	117	-208	-4	95	0
Hopewell/Cox Creek	208	209	-196	-2	-10	0
Upper Speed	614	239	-218	-40	25	-6
Central Grand	562	232	-145	-95	9	0
Mill Creek	82	294	-208	-40	-45	0
Upper Nith	496	138	-63	-1	-44	-30
Middle Nith	259	221	-238	-22	39	0
Lower Nith	395	304	-288	-16	0	0
Whitemans Creek	404	256	-211	-14	-6	-25
Grand at Brantford	181	178	-231	-12	76	-11
Fairchild Creek	401	136	-131	-7	-2	4
Big Creek	295	83	-56	-9	21	-39
McKenzie Creek	368	126	-93	-11	-25	3
Grand Above Dunnville To York	356	90	-82	-5	-8	5
Total Watershed	**6,769**	**177**	**-152**	**-18**	**0**	**-8**

The groundwater supply term used in the Percent Water Demand calculations is the sum of the recharge term from Table 3-4, output from the FEFLOW model, summed with the positive groundwater flow in to an assessment area from an adjacent area. The groundwater reserve term used for Percent Water Demand calculations is taken as 10% of the groundwater discharge to surface water in Table 3-4.

3.3.3 Percent Water Demand

This section describes the current groundwater demand stress assessment based on calculating Percent Water Demand for each assessment area and classifies each groundwater assessment area with respect to its potential for stress. A sensitivity analysis identifies assessment areas that may be further classified as having a potential for stress based on the water budget parameter uncertainty.

Percent Water Demand for groundwater is calculated for each groundwater assessment area using estimates of groundwater supply, groundwater reserve, and consumptive demand. The results are listed in Table 3-5 and calculated as follows:

- Groundwater Supply is calculated as the sum of the average annual recharge and the total amount of groundwater flowing laterally into each assessment area. The GAWSER continuous streamflow-generation modelling results predicted groundwater recharge and the FEFLOW steady-state groundwater-flow model estimated the groundwater flowing laterally into each assessment area. Both the GAWSER continuous streamflow-generation model and the FEFLOW steady-state groundwater-flow model are discussed in the Integrated Water Budget Report (AquaResource, 2009a). The groundwater supply for each assessment area is illustrated on Figure 19. This Figure summarizes each relevant water budget parameter for every subwatershed/assessment area, and also shows the direction of groundwater flow across each assessment area boundary. The groundwater Flow In for each assessment area is calculated from the model results as the sum of all positive flow vectors into each area.

- Groundwater Reserve is calculated as 10% of the estimated groundwater discharge to surface water in each assessment area. The purpose of the groundwater reserve is to introduce a measure of conservativeness into the Percent Water Demand equation and to represent a portion of groundwater discharge needed to sustain ecological function. An estimate of 10% of groundwater discharge for the reserve is suggested in the Technical Guidance Module 7 (MOE, 2007) for completing the Stress Assessment. It is noted that the total amount of groundwater discharge needed to maintain ecological functions is greater than this amount; however, the need to maintain current groundwater discharge rates is built into the stress assessment thresholds, which effectively require that groundwater demand is well below 10% of groundwater supply to maintain a '*Low*' stress level.

- Average and monthly maximum water demand values correspond to unit consumptive demand estimates as listed in Table 3-2.

- Percent Water Demand is calculated using the Percent Water Demand equation presented in Section 1.3.1.2 of this report.

Table 3-5 - Groundwater Stress Assessment Components (Current Demands)

Assessment area	Groundwater Supply (L/s)			Groundwater Reserve (L/s)	Demand (L/s)		Percent Water Demand	
	Recharge	Flow In	Supply		Average Annual	Maximum Monthly	Average Annual	Max Monthly
Grand Above Legatt	2,046	0	2,046	183	25	27	1%	1%
Grand Above Shand to Legatt	2,286	157	2,443	217	69	77	3%	3%
Irvine River	1,595	58	1,653	125	81	89	5%	6%
Canagagigue Creek	905	157	1,063	66	164	183	**16%**	18%
Conestogo Above Dam	2,245	42	2,287	124	37	40	2%	2%
Conestogo Below Dam	944	789	1,734	168	46	54	3%	3%
Hopewell/Cox Creek	1,376	181	1,557	130	84	108	6%	8%

Assessment area	Groundwater Supply (L/s)			Groundwater Reserve (L/s)	Demand (L/s)		Percent Water Demand	
	Recharge	Flow In	Supply		Average Annual	Maximum Monthly	Average Annual	Max Monthly
Upper Speed	4,652	480	5,132	425	926	1,032	**20%**	22%
Central Grand	4,132	456	4,588	259	1,859	2,197	**43%**	***51%***
Mill Creek	764	0	764	54	82	114	**12%**	16%
Upper Nith	2,163	133	2,296	98	34	41	2%	2%
Middle Nith	1,815	517	2,332	196	123	142	6%	7%
Lower Nith	3,807	234	4,041	361	184	271	5%	7%
Whiteman's Creek	3,274	120	3,395	271	117	465	4%	15%
Grand at Brantford	1,023	438	1,461	133	74	211	6%	16%
Fairchild Creek	1,735	203	1,938	167	92	117	5%	7%
Big Creek	777	198	975	52	153	201	**17%**	22%
McKenzie Creek	1,471	119	1,590	108	53	223	4%	15%
Grand Above Dunnville To York	1,019	54	1,073	92	91	116	9%	12%

Note: Subwatersheds with **Highlighted** Percent Water Demand are above Moderate Stress Threshold
Subwatershed with ***Highlighted*** Percent Water Demand Estimates are above Significant Stress Threshold

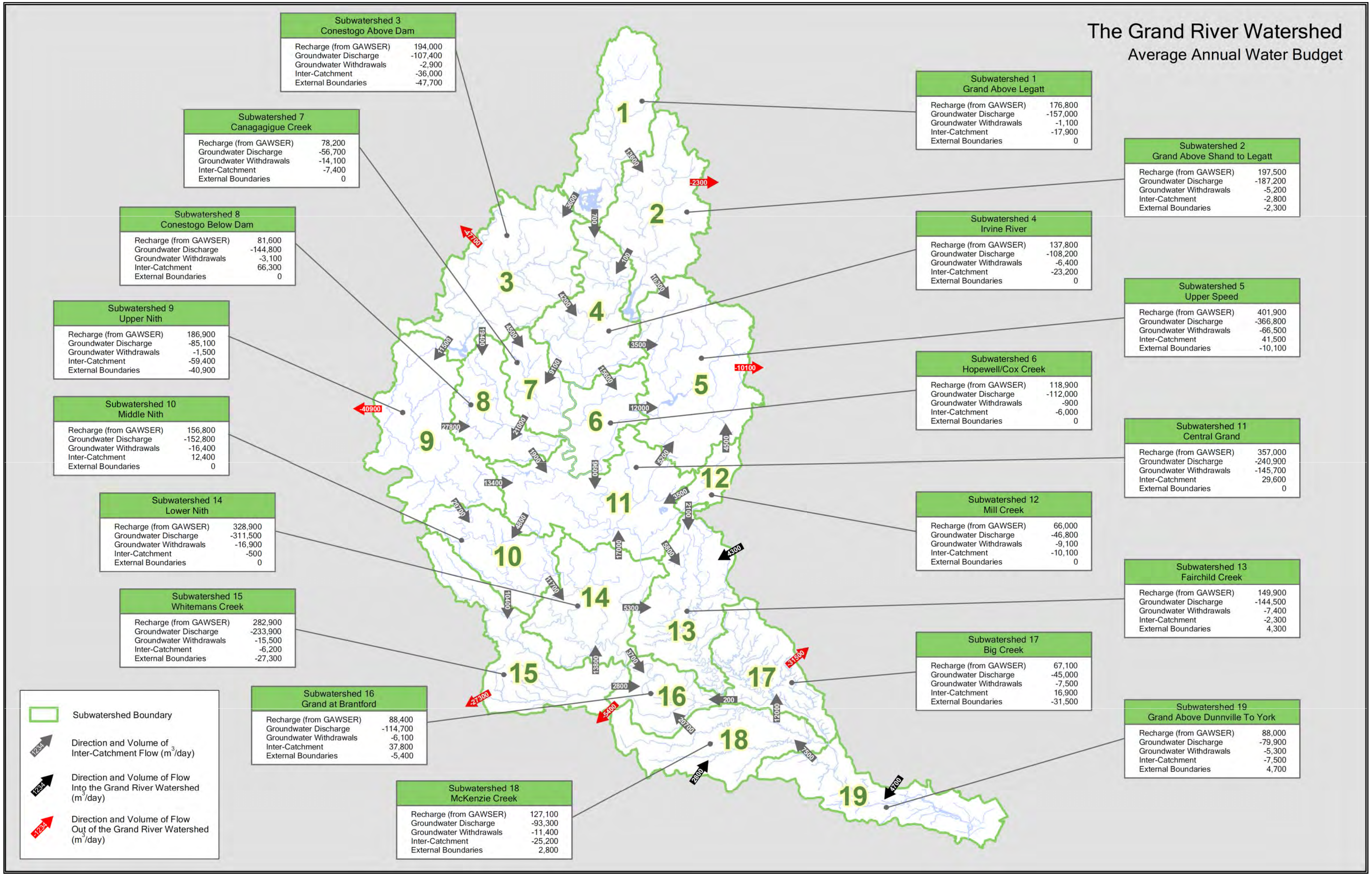


Figure 19
Groundwater Supply

Table 3-6 contains the estimated potential for stress under average annual and maximum monthly water demands for each assessment area. These classifications are based on the Percent Water Demand estimates in shown Table 3-5, and the Province's thresholds for groundwater listed in Table 1-3.

Table 3-6 - Groundwater Stress Classification (Current Demand)

Assessment Area	Potential Stress (Average Demand)	Potential Stress (Maximum Monthly Demand)	Municipal Water Supply
Grand Above Legatt	Low	Low	Dundalk
Grand Above Shand To Legatt	Low	Low	Grand Valley, Waldemar Marsville
Irvine River	Low	Low	Elora, Fergus
Canagagigue Creek	**Moderate**	Low	RMOW (West Montrose, Conestogo Plains, Elmira)
Conestogo Above Dam	Low	Low	Arthur, Drayton, Moorefield
Conestogo Below Dam	Low	Low	RMOW (Heidelberg, Linwood, St. Clements)
Hopewell/Cox Creek	Low	Low	RMOW (Maryhill, Maryhill Heights, Conestogo Golf)
Upper Speed	**Moderate**	Low	City of Guelph, Guelph/Eramosa, Rockwood
Central Grand	**Significant**	**Significant**	RMOW (Integrated Urban System, St. Agatha, New Dundee)
Mill Creek	**Moderate**	Low	Puslinch Mini-Lakes (communal)
Upper Nith	Low	Low	Milverton, RMOW (Wellesley)
Middle Nith	Low	Low	RMOW (Integrated Urban System, New Hamburg, Foxboro), Plattsville
Lower Nith	Low	Low	RMOW (Ayr, Branchton, Roseville), Drumbo, Paris
Whiteman's Creek	Low	Low	Bright
Grand at Brantford	Low	Low	Airport, Mt Pleasant
Fairchild Creek	Low	Low	St. George
Big Creek	**Moderate**	Low	Lynden
McKenzie Creek	Low	Low	None
Grand Above Dunnville To York	Low	Low	None

3.4 PLANNED CONDITIONS PERCENT WATER DEMAND

Planned Systems were not fully characterized at the time this report was prepared and therefore were not evaluated within this Tier 2 Subwatershed Stress Assessment. The purpose of the 'Planned System' scenario under the Technical Rules is to evaluate planned municipal water systems that are not included within the Current Demand scenario.

3.5 PERCENT WATER DEMAND - FUTURE CONDITIONS

Table 3-7 lists the estimated future water demand requirements for each municipal groundwater supply system. As described in Section 2.5, these values are derived from GRCA's summary report "Status Report on Municipal Long Term Water Supply Strategies" (Shifflett, 2007), as well as the "Region of Waterloo Water Supply Strategy Report" (XCG, 2007). Where the municipal system relies upon both groundwater and surface water, the total future demand requirement was split between sources as described in Section 2.5.

The Water Quantity Stress Assessment evaluates the impact of increased future municipal demand on the potential for subwatershed stress. Future non-municipal water demand is assumed equal to current non-municipal water demand.

Table 3-7 - Future Increase in Municipal Groundwater Demand

GW Assessment Area	Municipal Water Supply System	Est. 2031 Population	Total Increase in Municipal Demand (m^3/d)	Increase Supplied by Additional Groundwater Sources	
				(m^3/d)	(L/s)
Grand Above	*Dundalk*	2,995	316	316	4
Grand Above Shand to Legatt	*Grand Valley*	3,650	533	533	6
	Waldemar	425	45	45	1
	Marsville	143	9	9	0
Irvine River	*Fergus-Elora*	31,180	6,266	6,266	73
Canagagigue Creek	*RMOW - West Montrose*	185	*n/a*	*n/a*	*n/a*
	RMOW - Conestogo Plains	370	*n/a*	*n/a*	*n/a*
	RMOW - Elmira Backup Well	*n/a*	*n/a*	*n/a*	*n/a*
Conestogo Above Dam	*Arthur*	3,275	616	616	7
	Drayton	3,780	776	776	9
	Moorefield	855	*n/a*	*n/a*	*n/a*
Conestogo Below Dam	*RMOW - Heidelberg*	1,065	*n/a*	*n/a*	*n/a*
	RMOW - Linwood	807	*n/a*	*n/a*	*n/a*
	RMOW - St. Clements	1,580	40	40	0
Hopewell/Cox Creek	*RMOW - Conestogo Golf*	491	*n/a*	*n/a*	*n/a*
	RMOW - Maryhill	160	*n/a*	*n/a*	*n/a*
	RMOW - Maryhill Heights	127	*n/a*	*n/a*	*n/a*
Upper Speed	*Rockwood*	2,995	1,276	1,276	15
	Hamilton Drive	1,001	*n/a*	*n/a*	*n/a*
	Guelph	166,750	17,280	16,156	187
Central Grand	*RMOW - Integrated Urban System (Kitchener, Waterloo, Cambridge, Elmira, St. Jacobs, Breslau, Brown) Subdivision)*	662,542	51,840	34,560	400
	RMOW - New Dundee	1,136	*n/a*	*n/a*	*n/a*
	RMOW - St. Agatha	85	*n/a*	*n/a*	*n/a*
Mill Creek	*No municipal systems*	*n/a*	*n/a*	*n/a*	*n/a*
Upper Nith	*RMOW - Wellesley*	4,150	349	349	4
	Milverton	2,485	203	203	2
Middle Nith	*RMOW - New Hamburg/Baden*	17,850	2,272	2,272	26
	RMOW - Foxboro	*397*	*n/a*	*n/a*	*n/a*
	Plattsville	2,175	686	686	8

GW Assessment Area	Municipal Water Supply System	Est. 2031 Population	Total Increase in Municipal Demand (m^3/d)	Increase Supplied by Additional Groundwater Sources	
				(m^3/d)	(L/s)
Lower Nith	*RMOW - Ayr*	7,800	1,413	1,413	16
	RMOW - Branchton	*125*	*n/a*	*n/a*	*n/a*
	Drumbo	797	86	86	1
	Paris	11,000	922	922	11
	RMOW - Roseville	*277*	*n/a*	*n/a*	*n/a*
Whiteman's Creek	*Bright*	454	26	26	0
Grand at Brantford	*Mount Pleasant*	1,790	273	273	3
	Airport	597	24	24	0
Fairchild Creek	*St George*	5,237	1,304	1,304	15
Big Creek	*Lynden*	495	34	34	0
McKenzie Creek	*No municipal systems*	*n/a*	*n/a*	*n/a*	*n/a*
Grand Above Dunnville To York	*No municipal systems*	*n/a*	*n/a*	*n/a*	*n/a*

Notes: n/a – no projected increased municipal water demand.

3.5.1 Future Percent Water Demand

Table 3-8 contains estimated average annual and maximum monthly future water demands calculated by adding the future increased municipal water demand (Table 3-7) to the current water demand. Future non-municipal water demand estimates are assumed equal to current estimates. With these estimated future demands, the Percent Water Demand is calculated using the same approach as followed for current conditions (Table 3-5).

Table 3-8 - Groundwater Stress Assessment Components with Future Demand Estimates

Assessment area	Groundwater Supply (L/s)			GW Reserve	Future Water Demand (L/s)		Percent Water Demand	
	Recharge	Flow In	Total Supply		Average Annual	Maximum Monthly	Average Annual	Maximum Monthly
Grand Above Legatt	2,046	0	2,046	183	29	31	2%	2%
Grand Above Shand to Legatt	2,286	157	2,443	217	76	84	3%	4%
Irvine River	1,595	58	1,653	125	154	161	**10%**	11%
Canagagigue Creek	905	157	1,063	66	164	183	**16%**	18%
Conestogo Above Dam	2,245	42	2,287	124	53	56	2%	3%
Conestogo Below Dam	944	789	1,734	168	46	54	3%	3%
Hopewell/Cox Creek	1,376	181	1,557	130	84	108	6%	8%
Upper Speed	4,652	480	5,132	425	1,128	1,234	**24%**	**26%**
Central Grand	4,132	456	4,588	259	2,259	2,597	***52%***	***60%***
Mill Creek	764	0	764	54	82	114	**12%**	16%
Upper Nith	2,163	133	2,296	98	40	48	2%	2%
Middle Nith	1,815	517	2,332	196	157	177	7%	8%
Lower Nith	3,807	234	4,041	361	212	299	6%	8%

Assessment area	Groundwater Supply (L/s)			GW Reserve	Future Water Demand (L/s)		Percent Water Demand	
	Recharge	Flow In	Total Supply		Average Annual	Maximum Monthly	Average Annual	Maximum Monthly
Whiteman's Creek	3,274	120	3,395	271	117	465	4%	15%
Grand at Brantford	1,023	438	1,461	133	77	214	6%	16%
Fairchild Creek	1,735	203	1,938	167	107	132	6%	7%
Big Creek	777	198	975	52	154	202	**17%**	22%
McKenzie Creek	1,471	119	1,590	108	53	223	4%	15%
Grand Above Dunnville To York	1,019	54	1,073	92	91	116	9%	12%

Note: Subwatersheds with **Highlighted** Percent Water Demand are above Moderate Stress Threshold
Subwatershed with ***Highlighted*** Percent Water Demand Estimates are above Significant Stress Threshold

Table 3-9 lists the stress classifications for the future water demand estimates. Irvine River Assessment has an estimated Percent Water Demand equal to 10% under future conditions and is the only area having a stress classification increase from *Low* to *Moderate*.

Table 3-9 - Groundwater Area Stress Classifications with Future Demand Estimates

Assessment Area	Average Percent Water Demand	Maximum Monthly Percent Water Demand	Municipal Water Supply
Grand Above Legatt	Low	Low	Dundalk
Grand Above Shand To Legatt	Low	Low	Grand Valley, Waldemar Marsville
Irvine River	**Moderate**	Low	Elora, Fergus
Canagagigue Creek	**Moderate**	Low	RMOW (West Montrose, Conestogo Plains, Elmira)
Conestogo Above Dam	Low	Low	Arthur, Drayton, Moorefield
Conestogo Below Dam	Low	Low	RMOW (Heidelberg, Linwood, St. Clements)
Hopewell/Cox Creek	Low	Low	RMOW (Maryhill, Maryhill Heights, Conestogo Golf)
Upper Speed	**Moderate**	**Moderate**	City of Guelph, Guelph/Eramosa, Rockwood
Central Grand	**Significant**	**Significant**	RMOW (Integrated Urban System, St. Agatha, New Dundee)
Mill Creek	**Moderate**	Low	Puslinch Mini-Lakes (communal)
Upper Nith	Low	Low	Milverton, RMOW (Wellesley)
Middle Nith	Low	Low	RMOW (Integrated Urban System, New Hamburg, Foxboro), Plattsville
Lower Nith	Low	Low	RMOW (Ayr, Branchton, Roseville), Drumbo, Paris
Whiteman's Creek	Low	Low	Bright
Grand at Brantford	Low	Low	Airport, Mt Pleasant
Fairchild Creek	Low	Low	St. George
Big Creek	**Moderate**	Low	Lynden
McKenzie Creek	Low	Low	None
Grand Above Dunnville To York	Low	Low	None

3.6 DROUGHT SCENARIO

According to the Technical Rules, groundwater assessment areas are also classified as having a potential for *Moderate* stress if either of the following circumstances occurs within the assessment area during observed or simulated drought conditions:

> *(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 specify both a two year and a ten year drought scenario. The two year scenario is specified as a simulated two year period with no groundwater recharge. The ten year scenario means the continuous ten year period for which precipitation records exist with the lowest mean annual precipitation. Furthermore, the scenarios need to be assessed for both existing and planned systems. The two year period is intended as a screening scenario where the ten year scenario would considered only if the two year scenario resulted in groundwater declines that would result in problems at a well.

Instead of completing the two-year drought scenario, this study proceeded directly with 10-year drought scenario using the monthly groundwater recharge rates estimated by GAWSER for the 1960-2000 climate period. Information relating to planned pumping rates for municipal wells was not available and therefore the drought assessment is only carried out for existing pumping rates.

3.6.1 Methodology

The GAWSER continuous streamflow-generation model simulates daily recharge rates for each hydrologic response unit (HRU) across the Watershed. 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 1960-1999 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 are not constant, they are assumed to be representative of relative changes in climate across the Watershed over the simulation period. Similarly, it is assumed that monthly adjustments to recharge are an appropriate temporal simplification of the daily recharge estimates.

The GAWSER model assumes a uniform unsaturated zone thickness for similar hydrologic response units, and does not vary this thickness seasonally. Therefore, estimates of monthly groundwater recharge rates may not be consistent with local areas within the watershed where the depth to groundwater is significantly greater, or less, than typical conditions.

Figure 20 illustrates the monthly recharge adjustment factors estimated from the 1960-1999 simulation. The figure also shows a 12-month moving average of the monthly adjustment factors, which removes monthly variability to highlight more significant trends.

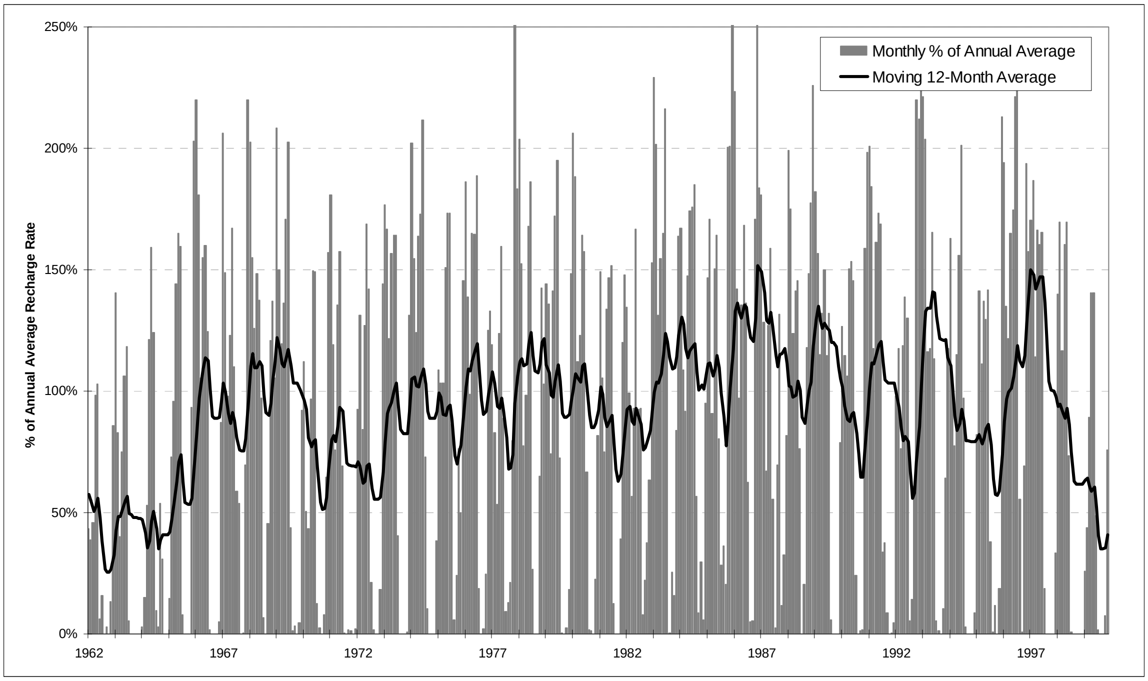


Figure 20 - Monthly Recharge Adjustment Factors

The FEFLOW steady-state groundwater-flow model was configured to use the time series of monthly recharge adjustment factors for the complete 1960-1999 simulation. Within each month, the FEFLOW groundwater-flow model adjusts the simulation timestep automatically to achieve a proper numerical solution. The groundwater-flow model 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 1960-1999 transient simulation.

3.6.2 General Results

With respect to the Technical Rules, the purpose of the Drought Scenario is to identify any assessment areas having municipal wells with the potential to be affected by a drought. Any assessment area having municipal wells potentially affected by drought is classified as having a *Moderate* potential for stress. Assessment areas already classified as having a *Moderate* or *Significant* potential for stress cannot be affected by the results of the drought scenario. As a result, the Canagagigue Creek, Upper Speed, Central Grand, and Mill Creek assessment areas were not evaluated in detail for drought impacts.

Figure 21 to Figure 24 illustrate groundwater levels simulated at the locations of four municipal wells throughout the Grand River Watershed. These 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 1970, representing the 1960's drought period and a recovery period following the drought. Water levels are shown relative to the initial conditions used for the simulation. The simulations also assume constant pumping from each of the wells and therefore the estimated water level fluctuations do not include the impact of variations in pumping rates.

Figure 21 illustrates the simulated response in water levels at the location of the City of Guelph's Arkell 1 well. This figure shows that groundwater levels fall approximately 4 m in response to the 1960's drought. The City of Guelph's Arkell wells are located to the east of the City. The Arkell Well 1 is an overburden well, and the water level fluctuations (4 m) seen in Figure 21 would be indicative of a water table response to changes in recharge.

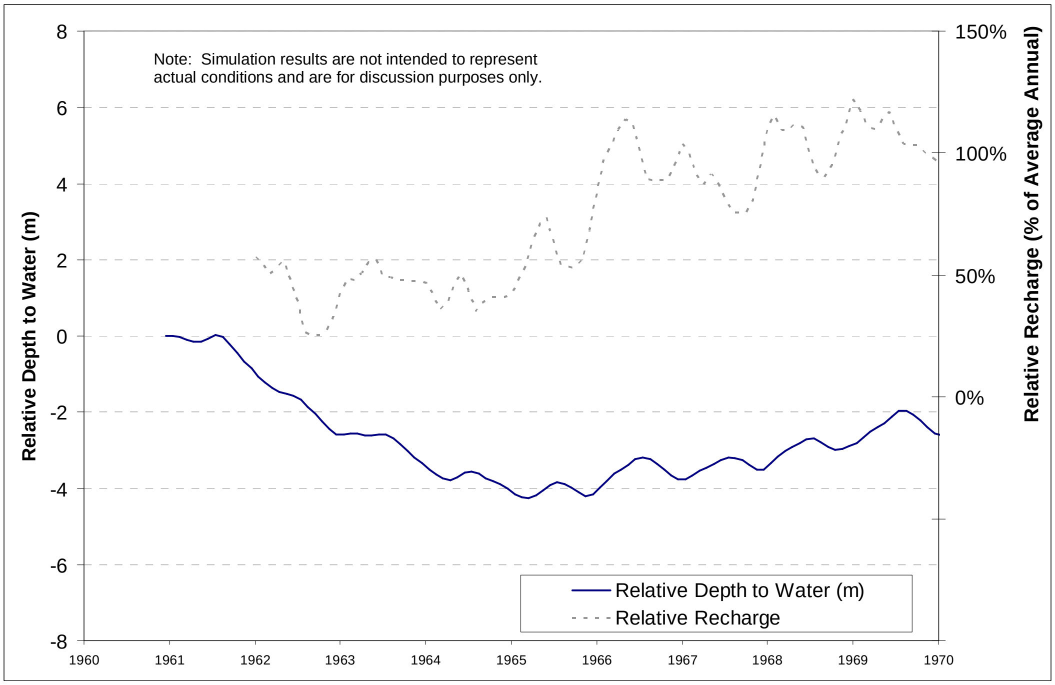


Figure 21 - Drought Scenario Water Level Changes (Arkell Well 1)

Figure 22 illustrates the response in water levels at the City of Guelph's Dean Well. Groundwater levels at the Dean Well are shown to fall by approximately 1 m following the drought period. This well is located in the Amabel Aquifer, which within the City is simulated as being overlain completely by the low-permeability Eramosa Aquitard. As a result of this aquitard and the depth of the aquifer, groundwater levels in the lower aquifer do not respond to drought conditions to the same extent as those seen in the Arkell Well 1. Because this assessment area is already classified as having a *Moderate* potential for stress, no further analysis of wells in the area are done for the drought scenario.

Figure 23 illustrates the simulated response in water levels at the location of the Region of Waterloo's G4 well in Cambridge in the deep Amabel aquifer. The groundwater level decrease at this location, in response to drought conditions, is approximately 0.6 m from initial conditions.

Figure 24 illustrates the simulated response in water levels at Bright municipal well #4. This well is completed in a sand aquifer, with the top of screen 21.6 m below ground surface and the bottom of screen 23.5 m below ground surface. The maximum water level decrease in the well is simulated to be approximately 7 m from initial conditions. Following this period of maximum water level decline, water elevations are simulated with a large amount of annual fluctuation.

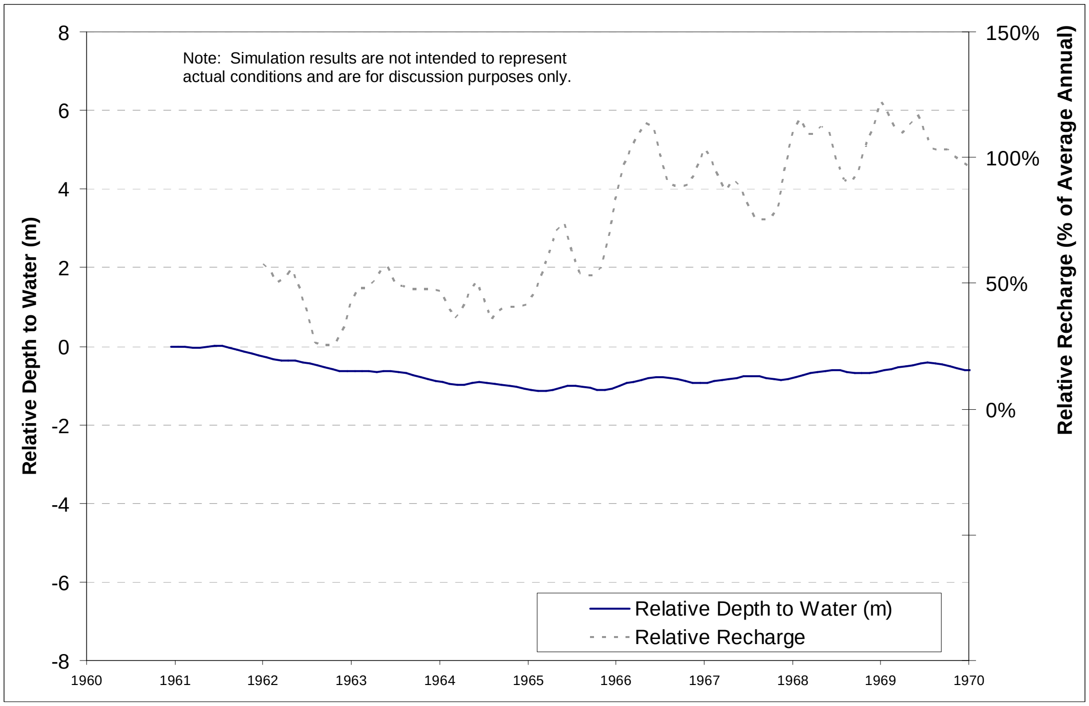


Figure 22 - Drought Scenario Water Level Changes (Guelph Dean Well)

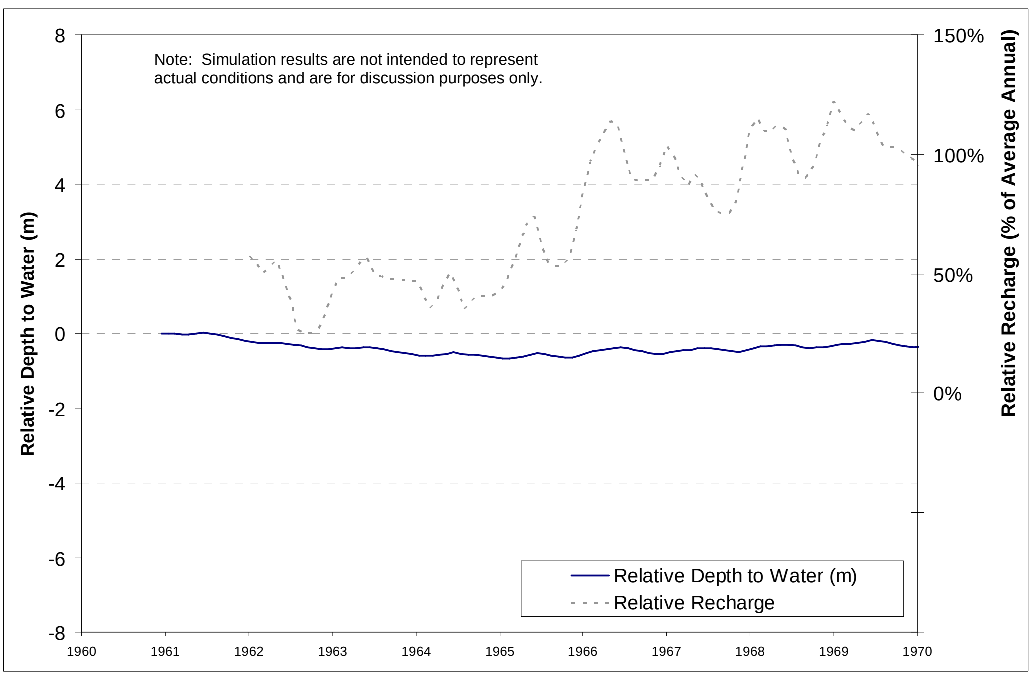


Figure 23 - Drought Scenario Water Level Changes (Region of Waterloo G4)

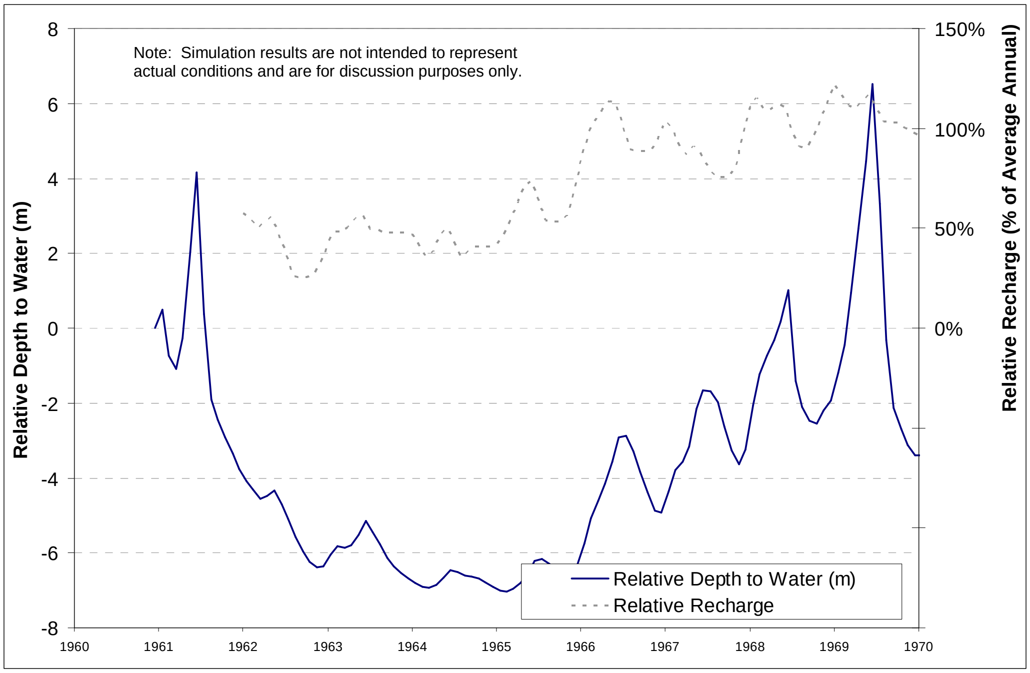


Figure 24 - Drought Scenario Water Level Changes (Bright Well 4)

In general, the results of the drought scenario are consistent with expectations. Shallow wells tend to have water levels that fluctuate more than those for deeper wells. However, the Grand River groundwater flow model has not been calibrated to any wellfield conditions. Hydrogeologic parameters near wellfields including specific storage, hydraulic conductivity, and aquifer thickness each have a role in the simulation of transient water levels and without having these values calibrated there cannot be a high level of confidence in predicted values. However, the results of the 1960-1999 simulation are useful to identify wellfields where there is a potential for drought impacts and then to focus additional effort on those areas.

The objective of the drought assessment is to identify any additional assessment areas that should be classified as having a *Moderate* potential for stress due to the drought scenario. Since the model is not calibrated to wellfield conditions, the results of this drought assessment should only be used as a screening tool to identify areas where there is a potential for drought impacts and therefore to collect more information. Wells located in assessment areas already classified as having a *Moderate* or *Significant* potential for stress under the Percent Water Demand assessment are not evaluated in the drought scenario. Table 3-10 lists the municipal wells having a simulated drawdown greater than 3 m during the drought scenario.

Table 3-10 - Wells with Simulated Water Level Decreases Greater than 3 metres in Assessment Areas with Low Potential for Stress

Municipality	Municipal System	Assessment Area	Well Name	Maximum Water Level Decrease Below Initial Condition (m)	Maximum Water Level Increase Above Initial Condition (m)	Absolute Variability in Water Level Fluctuations (m)	Available Drawdown (m)
County of Brant	Airport Well Supply	Grand at Brantford	Airport Well	-3.8	+0.7	4.5	11
County of Oxford	Bright	Whiteman's Creek	Well_4	-7.0	+7.6	14.6	6.7
RMOW	Roseville	Lower Nith	R6	-3.0	+0.1	3.1	32
RMOW	Heidelberg	Conestogo Below Dam	HD1	-3.1	+0.2	3	27
			HD2	-3.5	+0.2	3	27
RMOW	Foxboro Green	Middle Nith	FG_1	-3.8	+0.9	4.7	25
		Middle Nith	FG_2	-3.8	+1.0	4.8	12
RMOW	St. Agatha	Upper Nith	SA6	-5.8	+1.9	7.7	11
Centre Wellington	Fergus	Irvine River	Fergus_6	-3.6	+2.3	5.9	30
	Elora	Irvine River	Elora_E1	-4.3	+0.1	4.4	17

The 3 metre limit was chosen to identify those wells simulated to have the greatest water level decreases in the drought scenario. It is very unlikely that a municipal well would be operating with less than 3 metres of available drawdown in normal operating conditions. For those wells with greater than 3 m of simulated water level decline, well completion data was collected from municipalities to determine if the well could accommodate the simulated declines. Typically the information provided by the municipalities included the depth of water (during normal pumping and static conditions) from top of well, and this information was used to estimate the height of water above the top of well screen. This information is shown in Table 3-10 as the *Available Drawdown* field. Where the depth of water above the screen would be greater than the simulated water level decline caused by drought, this assessment concludes that the well would not be impacted by the simulated drought conditions.

Most of the municipal wells have sufficient available drawdown to withstand simulated water level fluctuations due to drought. Roseville, Heidelberg, Foxboro Green #1, Fergus and Elora wells have approximately 20-30 m of water above the screens. The Brant County Airport well, Foxboro Green #2 and St. Agatha #6 have less water above the screen (11-12 m); however, this depth is significantly greater than the simulated drought impact of 4-6 m.

The drought assessment estimates a seven metre reduction in groundwater level at the Bright #4 well. Figure 25 shows depth to water at the Bright Well #4 from 2001 until 2008 in addition to the depths to the top and bottom of well screen. The observation data provided by the municipality indicates that the depth to groundwater during 2008 was approximately 15 to 18 metres. If groundwater levels dropped seven metres during a large drought, the depth to groundwater in the well could range from 22-25 m, which would be below the well screen. In these conditions, normal operation of the well would not be possible due to the water level being below the well pump. This analysis relies on local predictions of a transient regional model, which has not been calibrated to transient conditions. As such, the uncertainty associated with this analysis is high. However, in the case of the Bright Well, the potential susceptibility of this well to drought has been confirmed by a Mr. Tony Lotimer, P .Geo, a respected hydrogeologist with significant experience with that well (personal communication, June 2009).

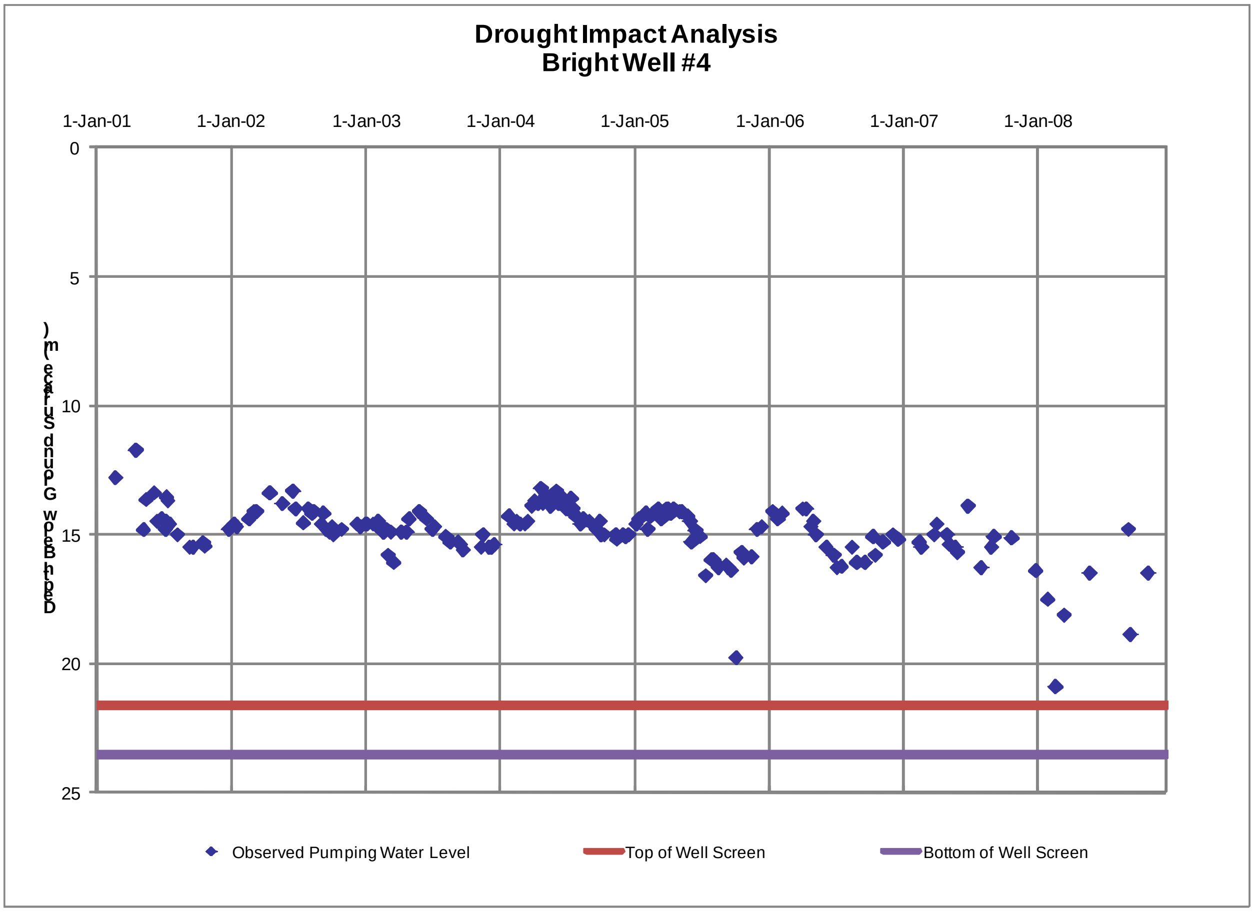


Figure 25 - Water Level Above Well Screen: Bright Well 4

Based on this additional information, as well as the results of the drought assessment, the Whiteman's Creek Assessment Area is classified with a *Moderate* stress level due to drought conditions at Bright Well #4.

Appendix C summarizes the results of the drought scenario for all municipal wells located outside of the assessment areas already classified as having a *Moderate* or *Significant* potential for stress. The appendix lists the maximum water level decreases and water level increases calculated with respect to the initial water levels at each well location. The difference between the maximum and minimum water levels over the 40-year period is shown as *Absolute Variability* in the table.

3.7 UNCERTAINTY IN GROUNDWATER STRESS CLASSIFICATIONS

While the stress classification is based on best estimates of consumptive water demand, water supply, and water reserve, there is uncertainty with these estimates that may affect the classification. The

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

This section describes a sensitivity analysis designed to evaluate whether the uncertainty associated with the water demand or supply components is sufficient to modify the Stress Assessment classification. 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 that do not change stress levels within the sensitivity analysis, an uncertainty classification of *Low* is assigned.

The Whiteman's Creek Assessment area was classified as having a *Moderate* potential for stress due to drought impacts at the Bright #4 well. Since the drought assessment relies on the regional groundwater flow model that is not calibrated to conditions at that well the uncertainty level assigned to this stress classification is *High*.

The following sensitivity analysis presents four scenarios where estimated consumptive demand (i.e. not reported values) and groundwater supply for each subwatershed are increased and decreased by 25%. The sensitivity scenarios are completed for both the annual and maximum monthly demand conditions.

When considering uncertainty associated with water use demands, there may be greater uncertainty than 25% for individual permitted takings. This is due to uncertainty associated with the pumping rate, seasonality of pumping, and consumptive use factors. Because permitted water takings are grouped and analyzed by subwatershed, the uncertainties of individual takings are averaged over the entire subwatershed. As a result, a variation in water demand by +/- 25% within the subwatershed is considered reasonable. In addition to the water use sensitivity analysis, uncertainty associated with water supply terms were considered by varying these terms by +- 25%. A 25% range of uncertainty on total subwatershed recharge rates is considered conservative.

Table 3-11 summarizes the results of the sensitivity analysis for the groundwater stress assessment under average annual and maximum monthly conditions.

Table 3-11 - Groundwater Sensitivity Analysis (Current Water Demand)

Assessment Area	(1) Estimated Water Demand x 125 %		(2) Estimated Water Demand x 75 %		(3) Recharge x 125%		(4) Recharge x 75%	
	Average Annual	Max Monthly	Average Annual	Max Monthly	Average Annual	Max Monthly	Average Annual	Max Monthly
Grand Above Legatt	2%	2%	1%	1%	1%	1%	2%	2%
Grand Above Shand to Legatt	4%	4%	2%	3%	2%	3%	4%	5%
Irvine River	6%	6%	5%	6%	4%	5%	7%	8%
Canagagigue Creek	**18%**	20%	**15%**	17%	**13%**	15%	**22%**	24%
Conestogo Above Dam	2%	2%	2%	2%	1%	1%	2%	2%
Conestogo Below Dam	3%	4%	2%	3%	2%	3%	4%	5%
Hopewell/Cox Creek	7%	9%	4%	6%	5%	6%	8%	10%
Upper Speed	**20%**	23%	**19%**	21%	**16%**	18%	***26%***	**29%**
Central Grand	***45%***	***54%***	***40%***	**47%**	***34%***	**41%**	***57%***	***68%***
Mill Creek	**13%**	19%	**10%**	14%	9%	13%	**15%**	22%

Assessment Area	(1) Estimated Water Demand x 125 %		(2) Estimated Water Demand x 75 %		(3) Recharge x 125%		(4) Recharge x 75%	
	Average Annual	Max Monthly	Average Annual	Max Monthly	Average Annual	Max Monthly	Average Annual	Max Monthly
Upper Nith	2%	2%	1%	2%	1%	1%	2%	2%
Middle Nith	6%	7%	6%	7%	5%	5%	8%	9%
Lower Nith	5%	8%	5%	7%	4%	6%	7%	10%
Whiteman's Creek	5%	18%	3%	12%	3%	12%	5%	20%
Grand at Brantford	7%	19%	4%	12%	4%	13%	7%	21%
Fairchild Creek	6%	8%	4%	5%	4%	5%	7%	9%
Big Creek	**21%**	**27%**	**13%**	17%	**13%**	17%	**22%**	**29%**
McKenzie Creek	4%	19%	3%	11%	3%	12%	5%	20%
Grand Above Dunnville To York	**11%**	13%	8%	10%	7%	9%	**12%**	16%

Note: Subwatersheds with **Highlighted** Percent Water Demand are above Moderate Stress Threshold
Subwatershed with ***Highlighted*** Percent Water Demand Estimates are above Significant Stress Threshold

For the subwatersheds originally classified as having a *Low* potential for stress, there is only one subwatershed (Grand Above Dunnville to York) whose classification was shown to change due to the sensitivity calculations. If recharge decreased by 25% or demand increased by 25%, this subwatershed may move to a *Moderate* potential for stress classification.

The five subwatersheds identified as having either a *Moderate* or *Significant* potential for stress in the Groundwater Stress Assessment in Table 3-6 (i.e. Canagagigue Creek, Upper Speed, Central Grand, Mill Creek, and Big Creek) maintain estimated Percent Water Demands consistent with their original classification. The only exception to this is Mill Creek. When recharge is increased by 25%, Mill Creek is classified as having a *Low* potential for stress under average and maximum monthly conditions.

Despite large changes to demand and supply parameters, the sensitivity analysis shows that the Stress Assessment results for most subwatersheds are not sensitive to uncertainty associated with water demand and groundwater recharge estimates. This confirmation of the stress classification provides additional confidence in the classification.

Table 3-12 summarizes the results of the sensitivity analysis. Those assessment areas 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 3-12 - Low or High Uncertainty based on Sensitivity Analysis

Assessment Area	Low or High Uncertainty
Grand Above Legatt	Low
Grand Above Shand to Legatt	Low
Irvine River	Low
Canagagigue Creek	Low
Conestogo Above Dam	Low
Conestogo Below Dam	Low
Hopewell/Cox Creek	Low
Upper Speed	Low
Central Grand	Low
Mill Creek	**High**
Upper Nith	Low
Middle Nith	Low
Lower Nith	Low
Whiteman's Creek	**High**
Grand at Brantford	Low
Fairchild Creek	Low
Big Creek	Low
McKenzie Creek	Low
Grand Above Dunnville To York	**High**

3.8 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 #35, 2h and 2i):

1. The Percent Water Demand for the average month is between 8% and 10%, or the Percent Water Demand for the maximum month is between 23% and 25%;
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*.

The only assessment area that meets the first criteria is Grand Above Dunnville to York, seen in Table 3-5. This assessment area also meets the second criteria, as it was labeled as having a *High* uncertainty in regards to its classification in Table 3-12. The Groundwater Sensitivity Analysis in Table 3-11 suggests that Grand Above Dunnville to York could have a *Moderate* potential for stress under two different sensitivity scenarios.

Because all the criteria for the uncertainty assessment are met for the Grand Above Dunnville to York Assessment Area, a *Moderate* potential for stress could be assigned to this assessment area. However, since the Grand Above Dunnville to York Assessment Area does not contain any municipal groundwater supplies, a *Moderate* stress classification has no implication on the requirement for future work under the Clean Water Act. As such, a Low stress classification is assigned to the Grand Above Dunnville to York.

3.9 PERCENT GROUNDWATER DEMAND VARIABILITY

Similar to percent surface water demand variability, percent groundwater demand variability was calculated using variable supply and demand from the years 1980 to 1999. 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.

3.9.1 Groundwater Demand Variability

Similar to Surface Water Demand Variability explained in Section 2.8, each groundwater demand component is kept consistent for all Percent Water Demand calculations from 1980 to 1999, with Agricultural PTTW Estimated Demand being the exception. Agricultural irrigation demand varies with climate; the method for determining how that demand would change with annual climates experienced from 1980 to 1999 is outlined below.

3.9.1.1 Irrigation Event Model and Irrigation Demand

Section 2.8.1 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 as described in Section 2.8.1. The one difference between the estimation of irrigation between surface water and groundwater is 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. A total irrigation demand per irrigation event was estimated for each assessment area by summing all the irrigation groundwater demands per irrigation event in each groundwater assessment area. As this is a tool to estimate the variability in estimated agricultural demands, only estimated values of irrigation demands are used in this analysis. These irrigation demands are given in Table 3-13 for each groundwater assessment area.

Table 3-13 - Irrigation Demand per Irrigation Event for each Groundwater Assessment Area

GW Assessment Area	Irrigation Demand per Irrigation Event (L/s)
Grand Above Legatt	0
Grand Above Shand to Legatt	0
Irvine River	0
Canagagigue Creek	0
Conestogo Above Dam	0
Conestogo Below Dam	0
Hopewell/Cox Creek	0
Upper Speed	6
Central Grand	4
Mill Creek	0
Upper Nith	0
Middle Nith	0

GW Assessment Area	Irrigation Demand per Irrigation Event (L/s)
Lower Nith	10
Whiteman's Creek	135
Grand at Brantford	43
Fairchild Creek	7
Big Creek	6
McKenzie Creek	72
Grand Above Dunnville to York	2

The above irrigation event water demands are multiplied by the number of irrigation events for each month of the year, as given in Table 2-10 to determine the irrigation demand for every year of climate data available. When summed with the other groundwater demand components for each year, a current water demand estimate for the entire time period from 1980 to 1999 was created for the percent groundwater demand variability calculations.

3.9.2 Groundwater Supply Temporal Variability

For this analysis of Percent Water Demand Variability, the annual variability of groundwater supply was estimated by adjusting annual recharge for each assessment area for the years 1980 to 1999. The annual adjustment factor for each assessment area was calculated by comparing the total annual recharge for a representative HRU in the assessment area against the average for that HRU in the period 1980 to 1999. Recharge rates for HRUs in the assessment area were obtained from the GAWSER streamflow generation model results.

Figure 26 illustrates the average annual recharge adjustment factors calculated for the Mill Creek assessment area. Over the 1980-1999 period, estimated annual recharge varies from as low as 50% of the average annual value to almost 180% of the average annual value. The significance of drought conditions in the late 1990's is shown with several years having annual recharge rates well below average.

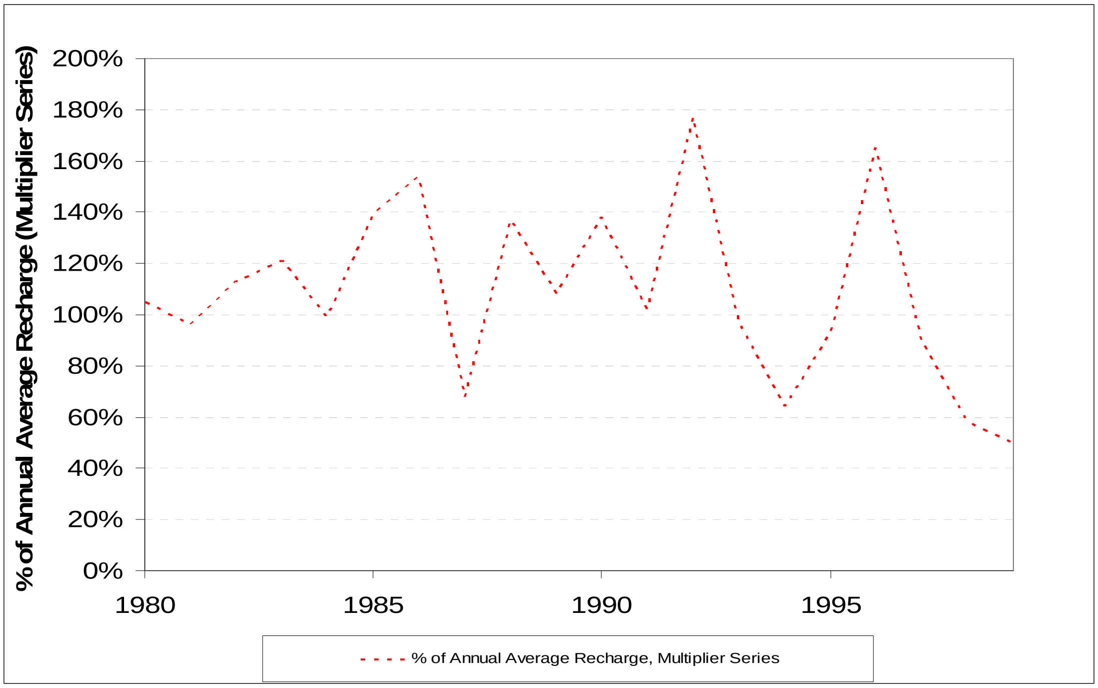


Figure 26 - Mill Creek Assessment Area - Example of Recharge Variability

3.9.3 Percent Groundwater Demand Variability

Annual Percent Water Demand was calculated for each assessment area using the adjusted annual recharge rates from 1980 to 1999. Where applicable, annual water demand estimates were also adjusted based on estimated irrigation requirements for that year.

The following discussion focuses on the six groundwater assessment areas having a Percent Water Demand greater than 10% for existing demand. The results are presented as a ranked curve of variable annual percent groundwater demands for each area. Results for all remaining assessment areas are provided in Appendix B.

As shown on Figure 27, annual Percent Water Demand for Groundwater in the Canagagigue Creek Assessment Area varies from 12% to 32% for the period of 1980 to 1999. The Percent Water Demand threshold for a *Moderate* potential for stress is exceeded for all years.

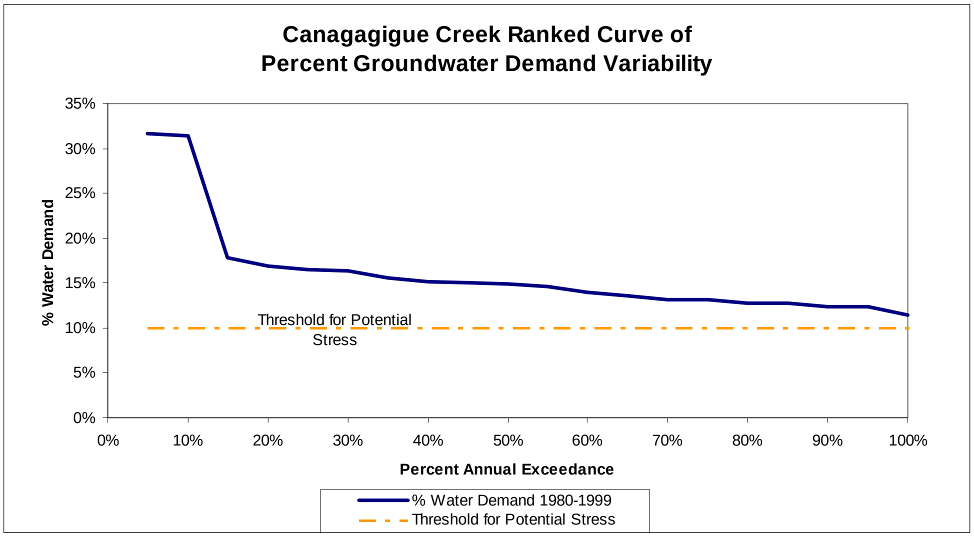


Figure 27 - Canagagigue Creek Assessment Area - Ranked Annual Percent Groundwater Demand

As Shown on Figure 28, annual Percent Water Demand for Groundwater in the Upper Speed Assessment Area varies from 11% to 42% for the period of 1980 to 1999.

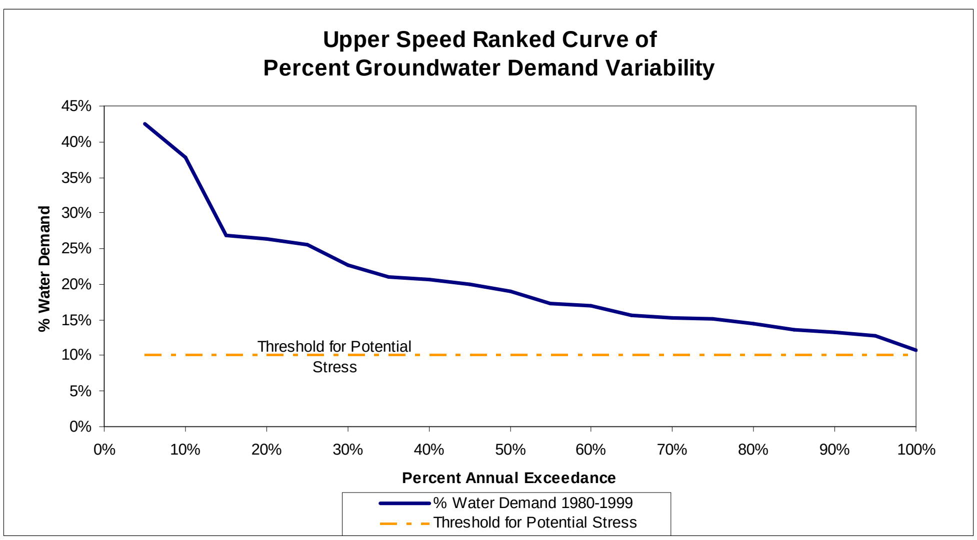


Figure 28 - Upper Speed Assessment Area – Ranked Annual Percent Groundwater Demand

As shown on Figure 29, annual Percent Water Demand in the Central Grand assessment area ranges from a low of 27% up to 77%. Percent Water Demand is greater than 25% for all years of the time period, representing the assessment area's *Significant* potential for stress.

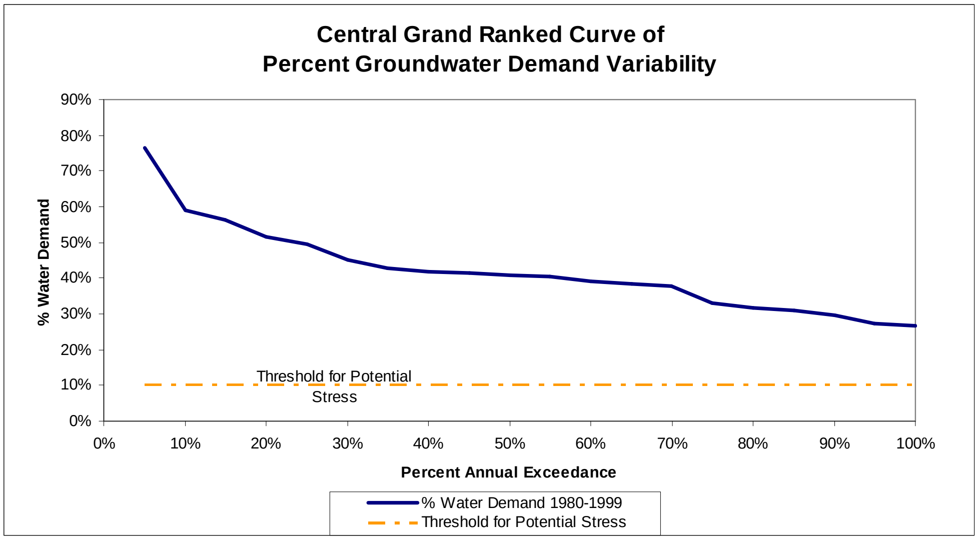


Figure 29 - Central Grand Assessment Area – Ranked Annual Percent Groundwater Demand

Shown in Figure 30, annual Percent Water Demand in the Mill Creek Assessment Area ranges from 6% up to 25% over the 1980 to 1999 period. Percent Water Demand is greater than 10% approximately 65% of the time, which suggests that the hydrological impacts of water use may be infrequent.

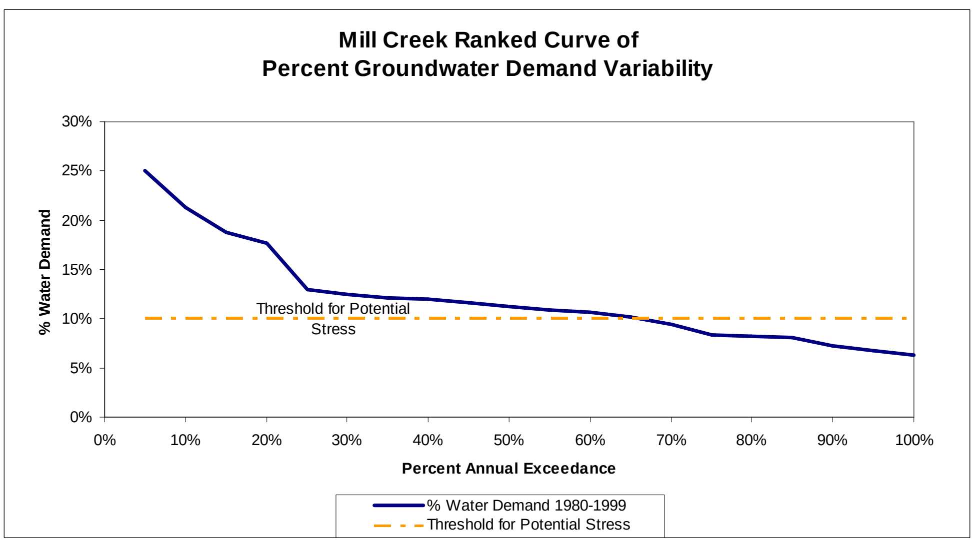


Figure 30 - Mill Creek Assessment Area - Ranked Annual Percent Groundwater Demand

As shown on Figure 31, Percent Water Demand for groundwater in the Big Creek assessment area ranged from 10% to 28%. The results are above the *Moderate* threshold for all years.

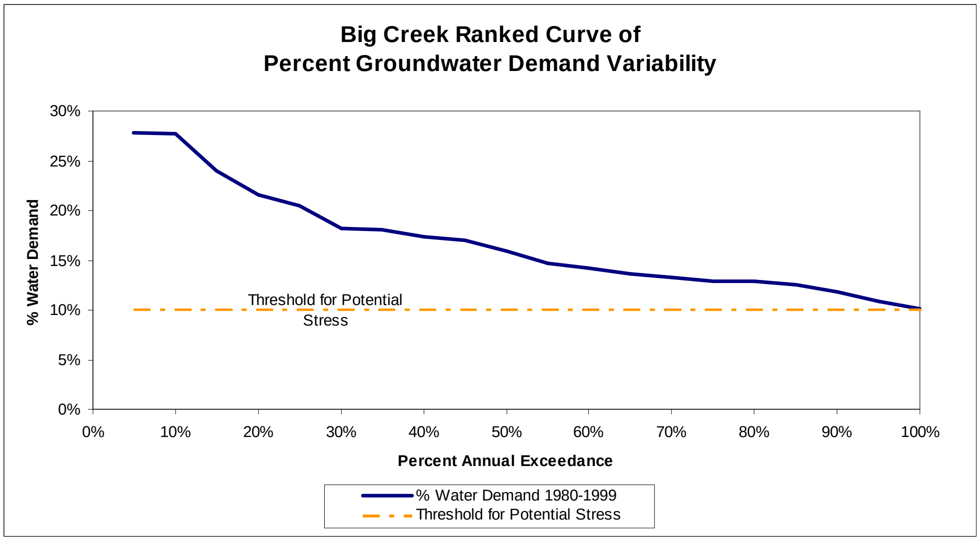


Figure 31 - Big Creek Assessment Area - Ranked Annual Percent Groundwater Demand

As illustrated on Figure 32, the estimated annual Percent Water Demand ranges from 6% to 22% for the Grand Above Dunnville to York Assessment Area. The Percent Water Demand is only above the *Moderate* threshold 15% of the time, indicating that the potential for stress is relatively infrequent. However, the chart also shows that the Percent Water Demand curve is very close to the *Moderate* threshold for a large portion of time. Should the Percent Water Demand be increased by only a few percent, the Percent Annual Exceedance of the *Moderate* threshold could increase to 50% due to the low slope of the line. This suggests the Stress Classification could be sensitive to uncertainty associated with demand or supply terms.

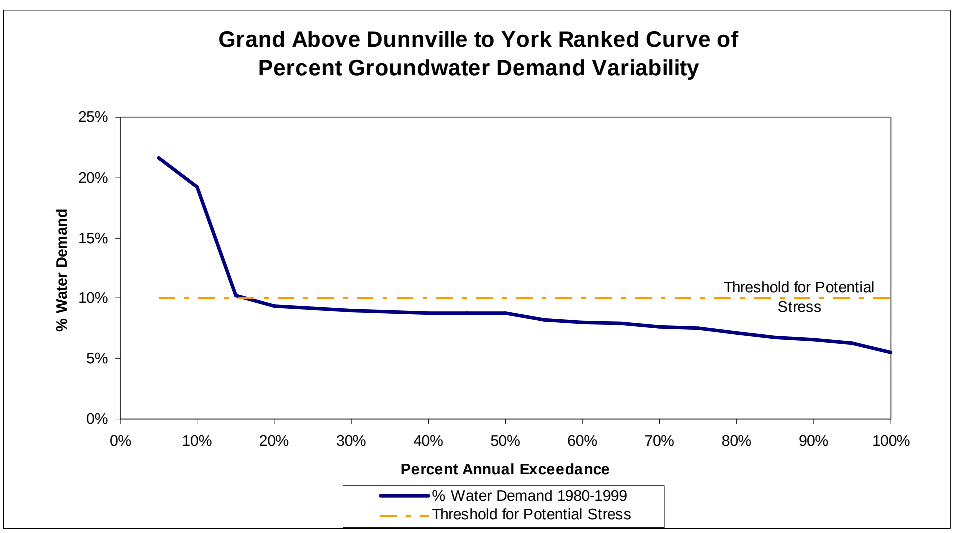


Figure 32 - Grand Above Dunnville to York Ranked Curve of Percent Groundwater Demand Variability

3.10 DISCUSSION

The following sections describe the assessment areas classified as having a *Moderate* or *Significant* potential for stress relating to groundwater. The sections make reference to Table 3-14, below, which provides a breakdown of the water demand for each sector in the assessment area.

Figure 33 illustrates the results of the groundwater stress assessment for the entire Grand River Watershed. All areas determined to have a *Moderate* or *Significant* potential for stress under either current or future demand conditions are highlighted on the map.

Table 3-14 - Breakdown of Consumptive Groundwater Demand, By Sector

Groundwater Assessment Area	Total Demand		Consumptive Water Demand Breakdown By Sector										
	Demand (L/s)	Average % Water Demand	Com-mercial	Dewat-ering	Ind-ustrial	Instit-utional	Rec-reation	Remed.	Private Water Supply	Misc.	Agric. Irrigation	Livestock & Rural Domestic	Munic. Water Supply
Grand Above Legatt	25	1%	53%	0%	0%	0%	0%	0%	7%	0%	0%	9%	30%
Grand Above Shand to Legatt	69	3%	0%	0%	12%	0%	0%	0%	66%	5%	0%	6%	11%
Irvine River	81	5%	1%	0%	6%	0%	0%	3%	0%	0%	0%	13%	77%
Canagagigue Creek	164	**16%**	61%	11%	2%	0%	0%	21%	0%	0%	0%	3%	1%
Conestogo Above Dam	37	2%	0%	0%	9%	0%	0%	0%	6%	0%	0%	31%	53%
Conestogo Below Dam	46	3%	0%	0%	33%	0%	0%	0%	15%	0%	0%	33%	19%
Hopewell/Cox Creek	84	6%	13%	75%	0%	0%	0%	0%	2%	0%	0%	6%	4%
Upper Speed	926	**20%**	5%	17%	3%	0%	0%	0%	0%	2%	0%	1%	71%
Central Grand	1,859	***43%***	6%	1%	12%	0%	0%	4%	6%	0%	0%	1%	71%
Mill Creek	82	**12%**	37%	0%	42%	0%	0%	0%	19%	1%	0%	1%	0%
Upper Nith	34	2%	0%	0%	21%	0%	0%	0%	2%	0%	4%	27%	46%
Middle Nith	123	6%	3%	0%	2%	0%	0%	0%	3%	0%	0%	4%	88%
Lower Nith	184	5%	6%	0%	24%	0%	0%	0%	5%	0%	4%	4%	58%
Whiteman's Creek	117	4%	2%	0%	0%	0%	0%	0%	0%	0%	91%	6%	1%
Grand at Brantford	74	6%	21%	0%	12%	0%	0%	0%	0%	0%	42%	5%	21%
Fairchild Creek	92	5%	26%	0%	12%	0%	0%	3%	27%	0%	5%	13%	15%
Big Creek	153	**17%**	11%	66%	15%	0%	0%	0%	2%	0%	3%	4%	1%
McKenzie Creek	53	4%	0%	0%	0%	0%	0%	0%	0%	0%	94%	6%	0%
Grand Above Dunnville to York	91	9%	6%	89%	0%	0%	0%	0%	0%	0%	1%	4%	0%
Grand Total	**4,295**	**-**	9%	10%	10%	0%	0%	3%	5%	0%	5%	3%	55%

3.10.1 Canagagigue Creek Assessment Area

The Canagagigue Creek Assessment is a relatively small assessment area with an estimated Percent Water Demand of 16% under average demand conditions and 18% under maximum demand conditions. These estimates result in the area being classified as having a *Moderate* potential for stress under average demand conditions and a *Low* potential for stress under maximum demand conditions. Estimated future demands do not change these classifications.

Most of the estimated consumptive demand for this area is related to a combination of commercial (61%) and remediation (21%) water uses as indicated in Table 3-14. The estimated commercial demand is based on PTTWs for aquaculture and golf course irrigation and most of this estimate is supported by reported pumping rates. All of the groundwater demand relating to groundwater remediation is based on reported pumping rates from the PTTW database. There are very few estimated demands in this assessment area, therefore there is high certainty regarding the classification of Canagagigue Creek having a *Moderate* potential for stress.

The RMOW municipal groundwater supplies for Elmira (emergency backup well), West Montrose, and Conestogo Plains are located within this assessment area. These municipal demands represent only 1% of the total estimated consumptive water demand; however, according to the Technical Rules, this assessment area meets the requirements for a Tier 3 Water Quantity Risk Assessment.

3.10.2 Upper Speed Assessment Area

The Upper Speed assessment area has an estimated Percent Water Demand of 20% under average demand conditions and 22% under maximum demand conditions. These estimates result in the Assessment Area being classified as having a *Moderate* potential for stress under average demand conditions and a *Low* potential for stress under maximum demand conditions. When accounting for estimated future municipal demands, the Percent Water Demand increases to 24% under average conditions and to 26% under maximum monthly conditions. These Percent Water Demands produce a classification of *Moderate* potential for stress under average demand conditions and a *Moderate* potential for stress under maximum demand conditions.

The largest water use sector in the assessment area is municipal water supply which represents 71% of the average annual consumptive water demand. Quarry dewatering is responsible for 17% of the estimated demand. Other water uses include commercial use (i.e. golf course irrigation, aquaculture, and bottled water), industrial use (i.e. brewing and soft drinks, cooling water), institutional use, miscellaneous use (i.e. heat pumps), remediation use, and agriculture. Out of the total groundwater demand in the assessment area, 90% of the estimated demand is calculated using reported pumping rates which increases the confidence of the values.

The City of Guelph is the largest groundwater user in the Upper Speed Assessment Area. The City maintains an aquifer monitoring program to ensure that the City's groundwater supplies are sustainable and do not cause adverse impacts to other users. In addition, monitoring is required as part of the Permits to Take Water issued by the Ontario Ministry of the Environment for the groundwater supply system.

The City's ongoing groundwater monitoring results show that the City continuously meets the requirements of its Permits to Take Water and that it is managing the groundwater resource in a responsible manner. For example, the City of Guelph has implemented water conservation and water use reduction measures as documented in the Water Conservation and Efficiency Strategy Update (Resource Management Strategies, 2009). Additionally, groundwater levels in the city do not show any significant downwards trends, indicating that current pumping rates can be maintained in the future.

The stress assessment results for the Upper Speed Assessment Area should not be interpreted as an indication of the sustainability of drinking water supplies. Rather, the stress assessment identifies a need for further work under the requirements of the Clean Water Act, and the need for this work is consistent with the value of the groundwater resource in the area.

The Upper Speed assessment area meets the requirements for a Tier 3 Water Quantity Risk Assessment. The municipal systems affected by the Tier 3 study include:

- City of Guelph;
- Rockwood; and
- Guelph/Eramosa (Hamilton Drive).

A Tier 3 Water Quantity Risk Assessment is currently underway for the City of Guelph as a pilot project for the Ministry of Natural Resources; however, this Tier 3 Assessment does not currently include the Rockwood or Hamilton Drive wells.

3.10.3 Central Grand Assessment Area

The estimated Percent Water Demand for the Central Grand assessment area is 43% under average demand conditions and 51% under maximum conditions. Based on these estimates, the Central Grand assessment area is classified as having a *Significant* potential for stress under average demand conditions, and a *Significant* potential for stress under maximum demand conditions. After accounting for future water demands into account, the Percent Water Demand for this assessment area is 56% under average demand estimates and 64% under maximum conditions. These estimates classify the area as having a *Significant* potential for stress under both average and maximum future demand conditions.

The Central Grand Assessment Area contains the urban areas of Kitchener, Waterloo and Cambridge and includes a wide variety of water users, including municipal supply, commercial use, groundwater remediation and other industrial purposes. Municipal water demands represent 71% the total demand. Approximately 76% of the total consumptive demand is calculated from reported pumping rates, which indicates a relatively high level of confidence in estimated demand.

The Regional Municipality of Waterloo is the largest groundwater user in the Central Grand Assessment Area. Approximately 75% of the Region's water supply is provided by groundwater, the remaining 25% by surface water. In 1994, the Region began implementing a comprehensive Water Resources Protection Strategy (WRPS) to ensure that the Region's groundwater supplies are sustainable and do not cause adverse impacts to other users. Groundwater level monitoring is an integral component of the WRPS. In addition, monitoring is required as part of the Permits to Take Water issued by the Ontario Ministry of the Environment for the groundwater supply system.

The Region's ongoing groundwater monitoring results show that the Region continuously meets the requirements of its Permits to Take Water and that it is managing the groundwater resource in a responsible manner. Groundwater levels in the aquifers do not show any significant downwards trends, indicating that current pumping rates can be maintained in the future.

The stress assessment results for the Central Grand Assessment Area should not be interpreted as an indication of the sustainability of drinking water supplies. Rather, the stress assessment identifies a need for further work under the requirements of the Clean Water Act, and the need for this work is consistent with the value of the groundwater resource in the area.

Municipal groundwater supplies within this assessment area meet the requirements for completing a Tier 3 Water Quantity Risk Assessment, as follows:

- RMOW - Integrated Urban System Supply Wells
- RMOW - St. Agatha Supply Wells
- RMOW - New Dundee Supply Wells

A Tier 3 Water Quantity Risk Assessment is currently underway for the Regional Municipality of Waterloo Integrated Urban Supply Wells as a pilot project for the Ministry of Natural Resources.

3.10.4 Mill Creek Assessment Area

The Mill Creek Assessment Area is located between the Galt and Paris Moraines, east of the City of Cambridge and South of the City of Guelph. The estimated Percent Water Demand for this assessment area is 12% and 16% under average and maximum demand conditions, respectively. These Percent Water Demands result in the classification of a *Moderate* potential for stress under average demand conditions and a *Low* potential for stress under maximum demand conditions. Major water use sectors in the Mill Creek area are the commercial (i.e. bottled water and golf course irrigation) and industrial (i.e. aggregate washing and manufacturing) sectors. Other groundwater demands include limited agricultural uses, some miscellaneous uses (i.e. heat pumps), communal water supply, and unpermitted agricultural demand. Industrial uses account for 42% of the total groundwater demand. The commercial water use forms 37% of total demand in the Mill Creek area. A further 19% is associated with communal water supply uses.

Approximately 47% of the total demand is from reported water taking rates. While there are reported pumping rates for a number of the aggregate operations, a large portion of the estimated consumptive demand is a reflection of the consumptive factor applied to those pumping rates. Due to the uncertainty associated with aggregate washing consumptive use factors, there is a relatively high uncertainty in the estimated consumptive demand for these uses. As a result the Percent Water Demand for the assessment area may be over-estimated.

There are no municipal groundwater supplies within this Subwatershed.

3.10.5 Big Creek Assessment Area

The estimated Percent Water Demand for the Big Creek assessment area is 17% under average demand conditions and 22% under maximum monthly conditions. Based on these estimates, the Big Creek assessment area has been classified as having a *Moderate* potential for stress under average demand conditions, and a *Low* potential for stress under maximum demand conditions. Future water demands do not increase the Percent Water Demand estimates.

The largest water use sector in Big Creek is dewatering which comprises 66% of the consumptive water demand within the area. Industrial use (i.e. manufacturing and food processing) represents 15% of groundwater demand while commercial use (i.e. golf course irrigation) represents 11% of the estimated demand. Other water uses include agricultural use, water supply, and unpermitted agricultural demand.

The ground water supply for the Village of Lynden is located within this assessment area, and based on this classification, meets the requirements for a Tier 3 Water Quantity Risk Assessment.

3.10.6 Irvine River Assessment Area

The Irvine River assessment area contains the municipal groundwater supplies for Elora and Fergus in the Municipality of Centre Wellington. The assessment area is classified as having a *Low* potential for stress, with a Percent Water Demand of 5% under average conditions and 6% under maximum demand conditions. Estimated future municipal demands increase the Percent Water Demand to 10% which would classify the area as having a *Moderate* potential for stress.

Under the future water demand scenario, the Elora and Fergus systems would meet the requirements for a Tier 3 Water Quantity Risk Assessment.

3.10.7 Whiteman's Creek Assessment Area

The Whiteman's Creek assessment area contains the municipal water supply system for the village of Bright. The assessment area was classified as having a *Low* potential for stress under existing conditions, both for annual average pumping conditions (4%) and monthly maximum demand (15%). The impact of drought conditions on the Bright supply was considered using transient output from the regional groundwater flow model. This analysis indicated that there may not be a sufficient depth of water within the #4 Bright well to accommodate simulated water level fluctuations caused by drought. Following consultation with County of Oxford hydrogeological support staff, and as per the Technical Rules, the Whiteman's Creek assessment area was assigned a classification of having a *Moderate* potential for stress under Drought Conditions.

Based on this classification, the Bright system meets the requirement for a Tier 3 Water Quantity Risk Assessment. Given the high degree of uncertainty associated with this analysis, the need for a Tier 3 assessment for the Bright system should be prioritized, with respect to other Tier 3 investigations.

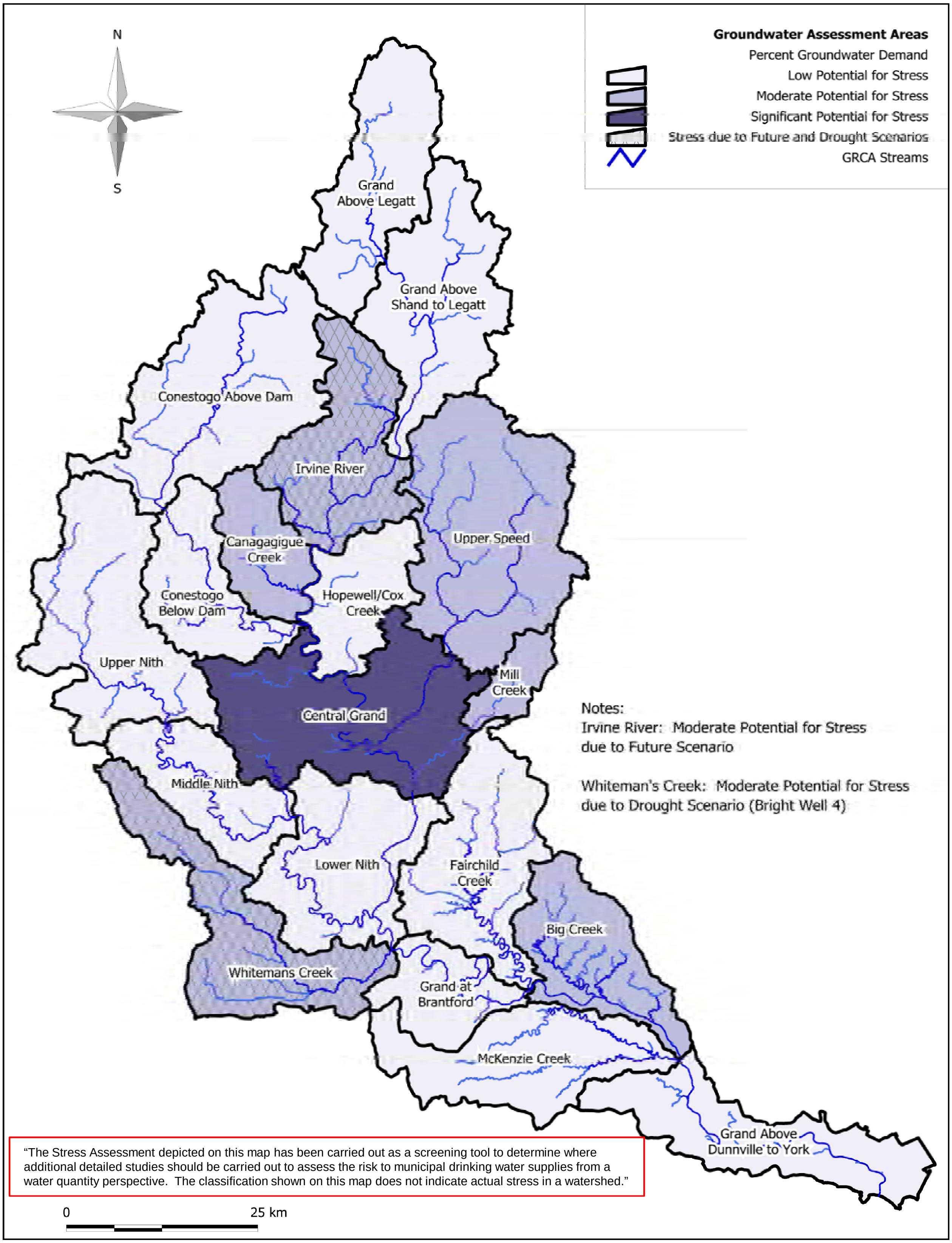


Figure 33
Groundwater Assessment Areas Potential Stress Classifications

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 subdivided by areas of groundwater vulnerability as part of the Water Quality Threats Assessment process.

Recharge is the hydrogeologic process described by the flow of water moving from the ground surface through the unsaturated zone to the underlying saturated groundwater. Groundwater recharge occurs across a watershed at a range of rates depending on soil type, land use, slope, and climate. Within the Grand River Watershed, the GAWSER continuous streamflow-generation model 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 provide a straightforward methodology to delineate SGRAs from the modelled simulation results. This chapter follows this methodology with several enhancements.

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; a review of estimated recharge distribution across HRUs of the Watershed provide further justification of the threshold value used. The "related groundwater recharge area" identified in Rule 44(1) was taken to be the entire area of the Grand River Watershed. This is consistent with the guidance, which recommends that this assessment is performed at the watershed scale.

After estimating the Significant Groundwater Recharge Areas, small isolated areas of land that (<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

The Grand River Watershed is very large, encompassing large regions of different physiographic, hydrologic, and hydrogeologic conditions. Figure 35 illustrates average annual groundwater recharge rates across the Watershed and also shows the boundaries between the three physiographic regions. AquaResource (2009a) describes the modelling process used to estimate the average annual groundwater recharge rates. A large portion of the upper Watershed is dominated by lower permeability till plains, the central Watershed is composed mainly of higher permeability sand and gravel moraines, and the lower Watershed is mainly covered by low permeability clay plains. The differences in physiography in the Watershed result in most of the recharge occurring in the central moraine areas, and therefore most of the delineated Significant Groundwater Recharge Areas are contained within the central Watershed.

Table 4-1 shows the Significant Groundwater Recharge Area threshold calculated for the Grand River Watershed. This threshold is calculated based on the spatially averaged annual recharge rate for the entire Watershed, multiplied by 115%.

Table 4-1 - Significant Groundwater Recharge Area Threshold

Related Groundwater Recharge Area	Average Annual Recharge Rate (AARR) (mm/y)	Threshold Recharge Rate (AARR *115%) (mm/y)
Grand River Watershed	176	202

Technical Rule 46 provides for the ability to evaluate the reasonableness of this threshold recharge value. Figure 34 illustrates the distribution of recharge rates as well as the volume and area exceeding each recharge rate for the Grand River Watershed. The cumulative exceedance curves are calculated as follows:

- % Volume Exceeding Recharge Rate. This curve is calculated as the sum of the total recharge flux for all hydrologic response units with a recharge rate equal to or above the value on the horizontal axis, divided by the total recharge flux;
- % Area Exceeding Recharge Rate. This curve is calculated as the sum of the area associated with all hydrologic response units having a recharge rate equal to or above the value on the horizontal axis, divided by the total area;

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

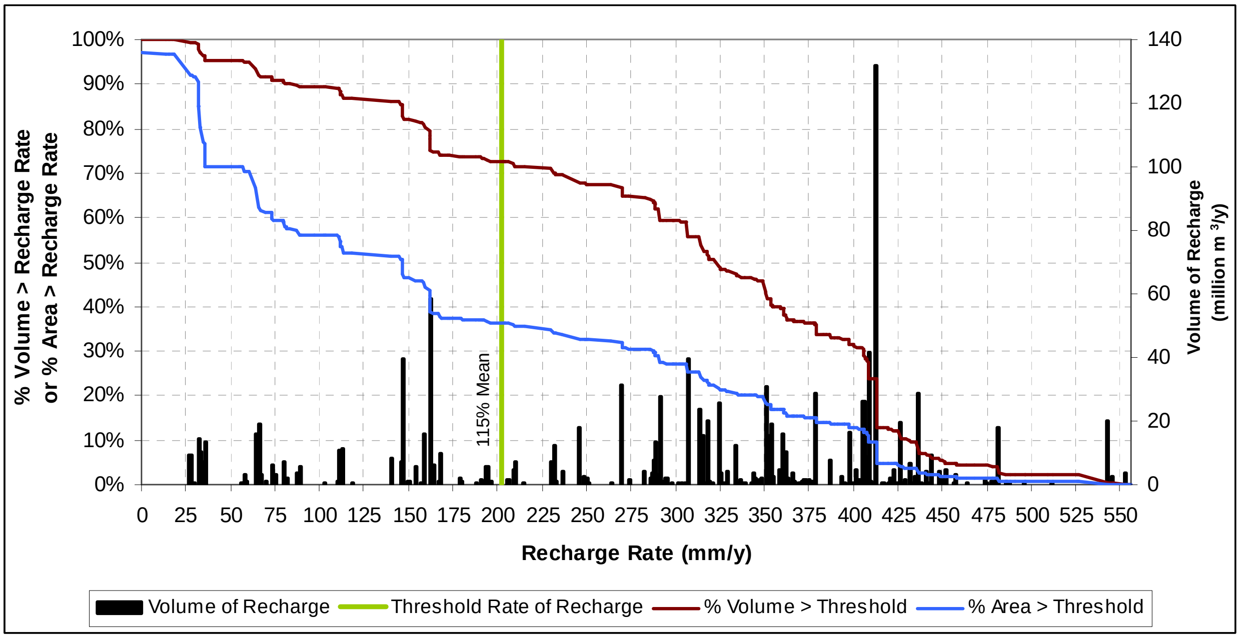


Figure 34 - Cumulative % Recharge Volume and Area in the Grand River Watershed

As illustrated on Figure 34, the computed threshold value lies within an approximate "plateau" of the % volume and % area curves and results in identifying approximately 36% of the area of the Watershed and 73% of the recharge volume as significant. For the Grand River Watershed, it appears that threshold value is reasonable and practical for defining SGRAs since the threshold value encompasses much of the land within the central moraine area as well as portions of the lower permeability regions (upper and lower Watershed) that may be significant compared to its surrounding physiography. Furthermore, the Figure also suggests that at the value of the recharge threshold, the resulting land area is relatively insensitive to the recharge rate. As an example, if the recharge threshold were increased to 275 mm/year, the land area affected would be 30% of the Watershed as opposed to 36%.

Based on this evaluation of the recharge distribution and threshold values, it is concluded that the SGRA threshold is appropriate, as it represents a large proportion of the total recharge into the Watershed while being applicable to only one third of the land area.

Figure 36 illustrates all areas of the Watershed where the estimated average annual groundwater recharge rates are greater than the Threshold Rate determined above (204 mm/y). As shown in this figure, SGRAs are concentrated within the central moraines. SGRAs within the upper and lower Watershed correspond to surficial soils with relatively higher permeability as well as climate conditions (e.g., snowfall) and land cover (e.g., forest) that would tend to increase estimated groundwater recharge rates.

As described in the Integrated Water Budget Report (AquaResource, 2009a), the HRUs are delineated across the Watershed with a very high level of precision as a reflection of detailed geological and land cover mapping. As a result, the map of estimated groundwater recharge is very detailed, showing relatively small parcels of land that are above the SGRA threshold. The high level of precision in the output may not reflect the certainty of the modelling results or certainty in the initial Quaternary geology and land cover mapping, as much of the mapping is not field verified. As well, for the purposes of the Clean Water Act, it will likely be difficult to develop workable policy for these small parcels. Figure 37 illustrates a modification of the SGRA map that removes all isolated polygons with an area less than or equal to 1 km^2 based on the scale of the features reflected in the mapping. This modification focuses the delineated SGRAs to larger geologic and physiographic features that would be more suitable within source protection planning policies.

To show that all delineated SGRAs are hydrologically connected to drinking water systems, domestic wells and municipal well locations are shown on Figure 38**.**

4.3 DISCUSSION

The SGRAs delineated in this chapter represent those areas within the Grand River Watershed having the highest groundwater recharge rates, and when combined together, contribute just over 70% of the total recharge within the watershed. These areas include the Waterloo Moraine, Elmira Moraine, Galt/Paris Moraine, and Orangeville Moraine in the central zone of the Watershed. Other areas within the upper and lower Watershed are classified as being SGRAs due to their higher permeability soils and higher estimated groundwater recharge rates.

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; and,

2. The GAWSER continuous streamflow-generation and FEFLOW steady-state groundwater-flow 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 clear. 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. There is a good opportunity to address the need to protect groundwater quantity within the Source Protection Planning Process, but this opportunity needs to address both the value of total groundwater recharge across a subwatershed as well as those areas having higher than average values. Furthermore, the process needs to address the uncertainty in terms of the magnitude and distribution of recharge rates.

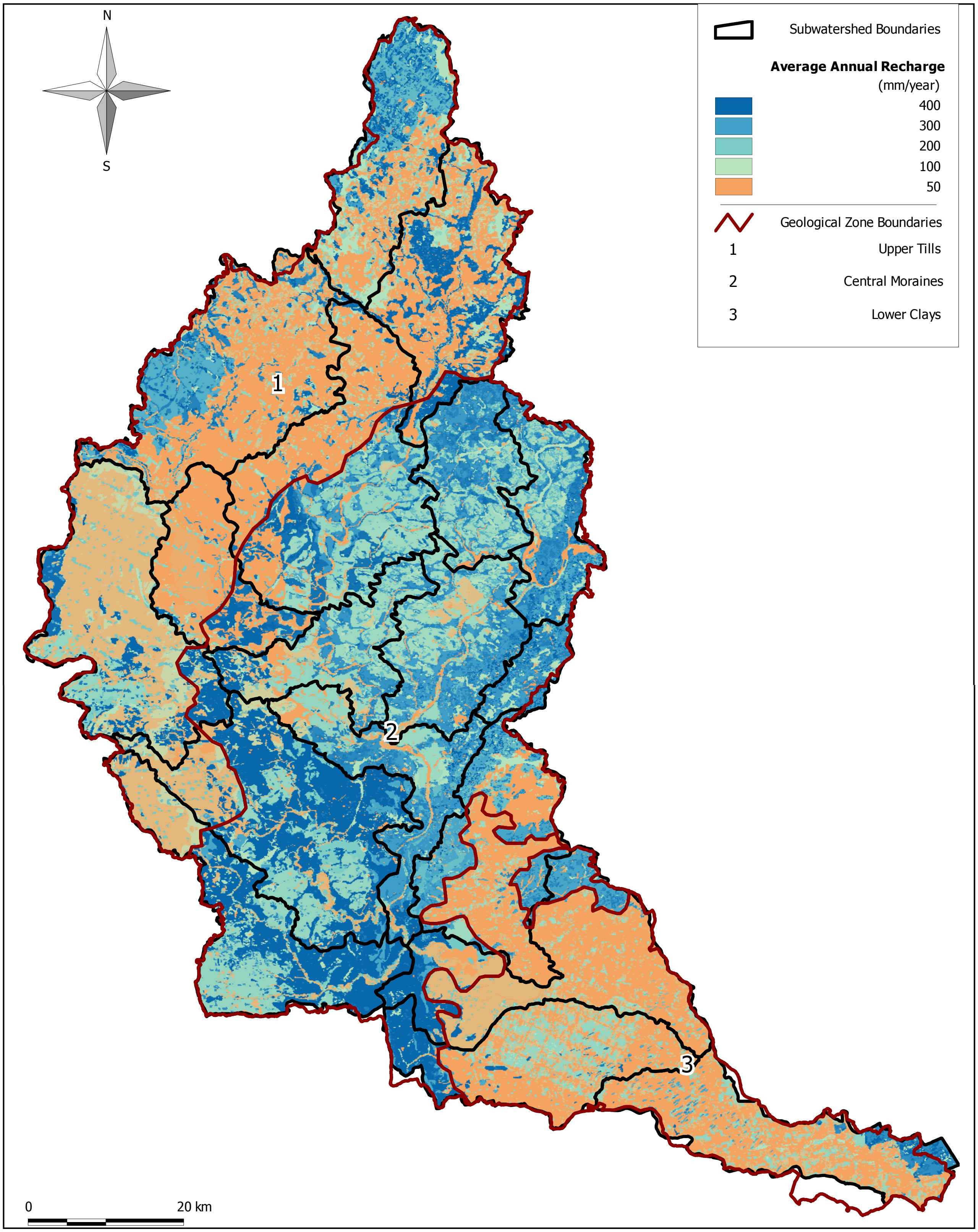


Figure 35
Average Annual Estimated Groundwater Recharge Rates

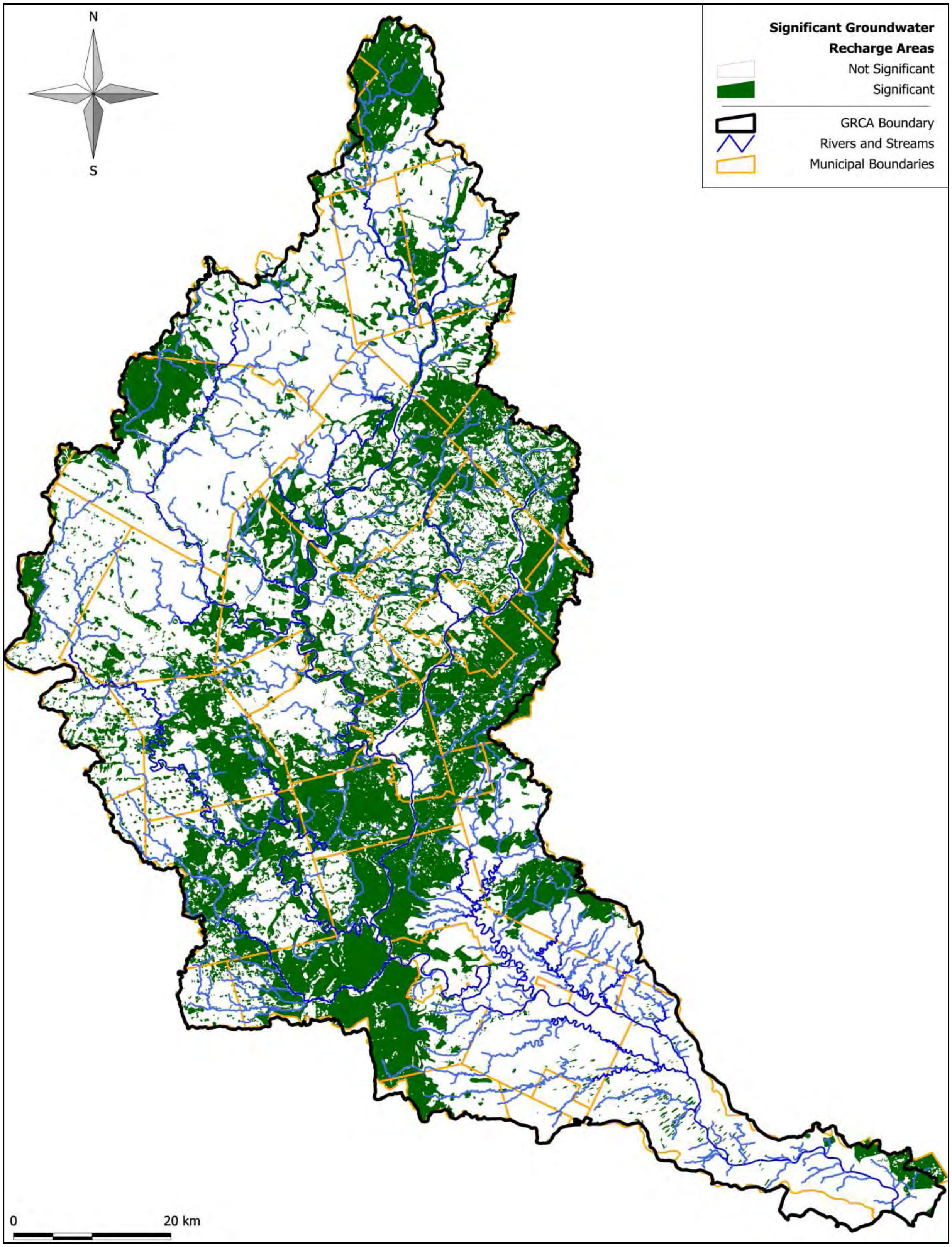


Figure 36
Significant Groundwater Recharge Areas

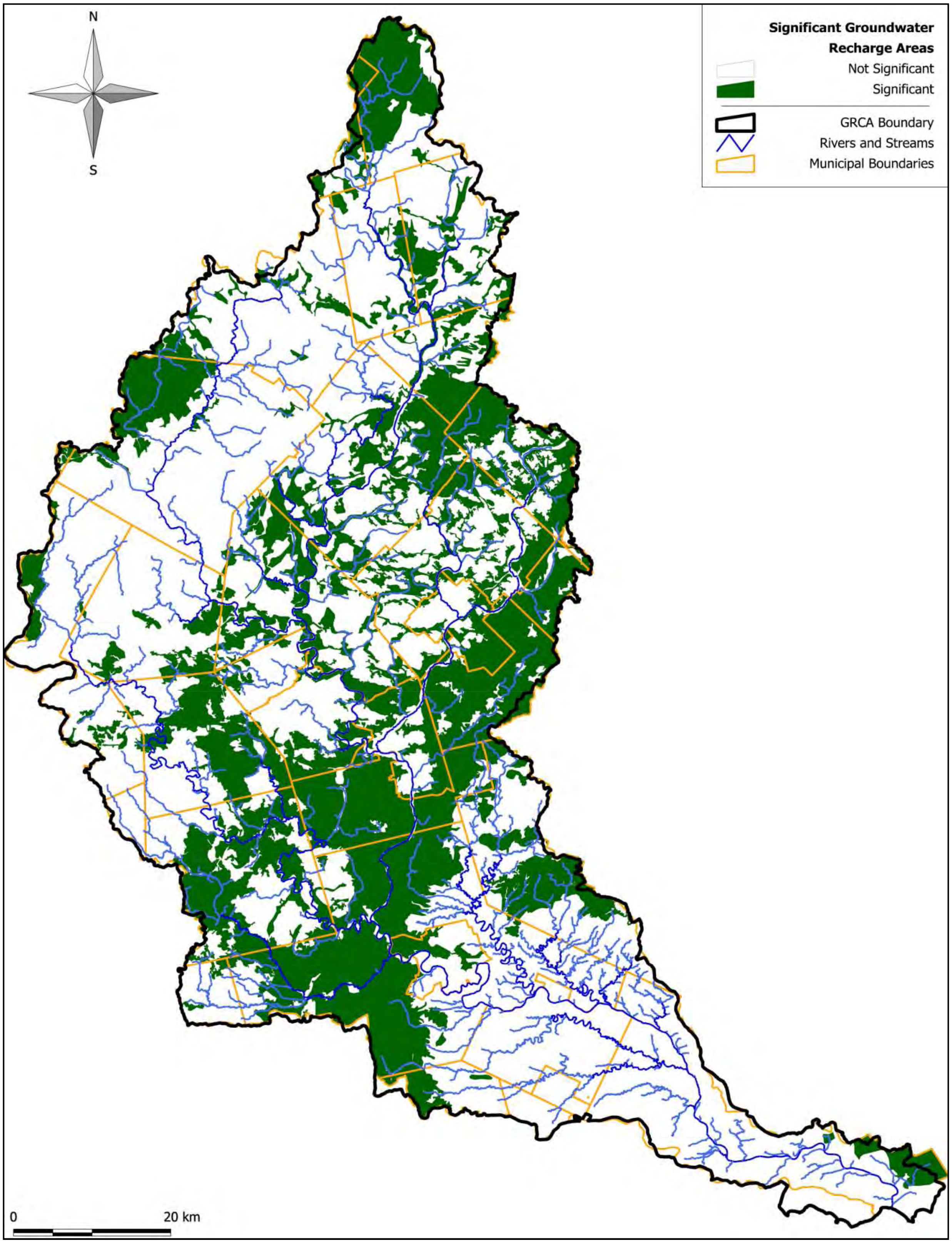


Figure 37
Significant Groundwater
Recharge Areas with 1 km^2 Filter

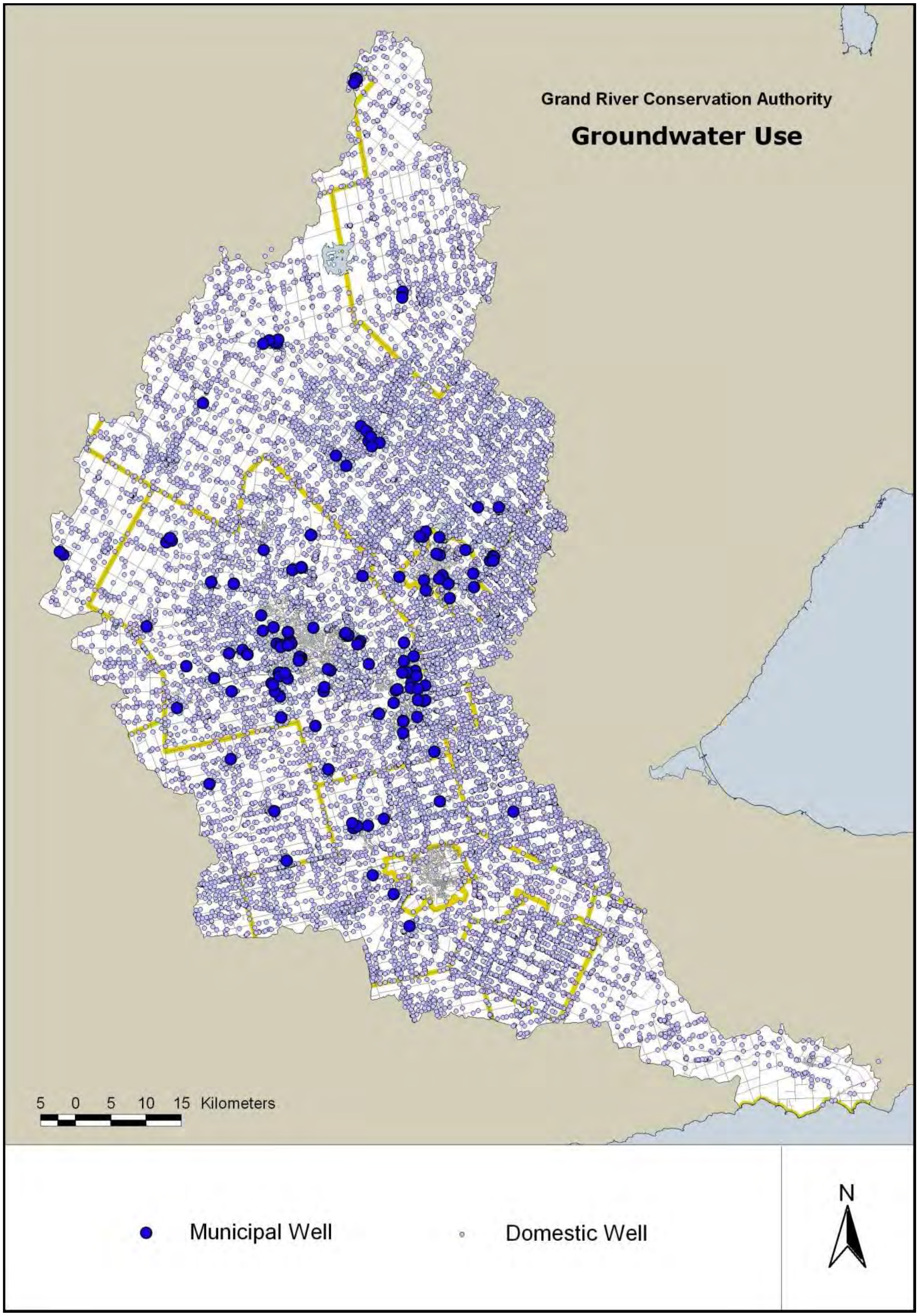


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Figure 38
Groundwater Use
Wells in the GRCA

5.0 Conclusions

The Grand River Watershed is 6,800 km^2 in size and currently has 900,000 residents. The population is expected to grow significantly over the next 20 years, and with this growth there will be increased water demands in the Watershed.

This document describes the Grand River Watershed Tier 2 Water Quantity Stress Assessment prepared to meet the requirements of the Province of Ontario's Clean Water Act (2006). A companion report, the Grand River Watershed Integrated Water Budget Report (AquaResource, 2009a) has also been prepared. This companion report contains information relating to the water budget for the Grand River Watershed, including consumptive water demand estimates, watershed characterization, and surface water and groundwater model development. This water budget information is critical background information relating to this Subwatershed Stress Assessment 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. 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 assessment area or subwatershed by using the Percent Water Demand calculations and the potential stress thresholds for both surface water and groundwater.

The water budget tools developed for the Watershed and described in the Integrated Water Budget Report (AquaResource, 2009a) were applied successfully to meet the requirements of the Stress Assessment. In general, the results of the Tier 2 Stress Assessment are consistent with expectations; areas that are classified as having a *Moderate* or *Significant* potential for stress correspond to areas with larger municipal supplies.

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

- Estimate the stress classification for surface water subwatersheds and groundwater assessment areas within the Grand River Watershed;
- Identify municipal water supplies that are located in surface water subwatersheds or groundwater assessment areas that are classified as having a *Moderate* or *Significant* potential for stress;
- Complete a surface water and groundwater drought assessment for municipal water supplies; and
- Delineate Significant Groundwater Recharge Areas (SGRAs).

5.1 STRESS ASSESSMENT RESULTS

The following table lists the Subwatersheds located within the Grand River Watershed that are classified as having a *Moderate* or *Significant* potential for stress from a surface water perspective:

Table 5-1 - Summary of Surface Water Stress Assessment

Subwatershed	Municipal Water Supplies
Eramosa Above Guelph Subwatershed	Guelph Eramosa / Arkell Intake
McKenzie Creek Subwatershed	None
Whiteman's Creek Subwatershed	None

As listed above, the Guelph Eramosa Intake is the only municipal surface water supply located in a subwatershed classified with a *Moderate* potential for stress. This stress level classification is in response to historical occurrences of low streamflow requiring the Eramosa Intake to be closed, as well as the calculated Percent Water Demand being above Provincial thresholds. As a result, the Eramosa River intake meets the requirement for the completion of a Tier 3 Water Quantity Risk Assessment. This report provides a temporal analysis of potential stress which suggests that the potential stress identified in the Eramosa Above Guelph Subwatershed may be a reflection of natural hydrologic variability, whereas the stress identified for the McKenzie Creek and Whiteman's Creek Subwatersheds are observed annually in response to agricultural irrigation water demands.

This report describes the delineation of new groundwater assessment areas in support of the groundwater stress assessment. These new areas were delineated to encompass larger municipal groundwater supplies and their respective aquifer systems. The following table lists the groundwater assessment areas located within the Grand River Watershed that are classified as having a *Moderate* or *Significant* potential for stress from a groundwater perspective:

Table 5-2 - Summary of Groundwater Stress Assessment

Groundwater Assessment Area	Municipal Groundwater Supplies
Big Creek Assessment Area	Lynden
Canagagigue Creek Assessment Area	RMOW (West Montrose, Conestogo Plains, Elmira)
Central Grand Assessment Area	RMOW (Integrated Urban System, St. Agatha, New Dundee)
Mill Creek Assessment Area	None
Upper Speed River Assessment Area	City of Guelph, Guelph/Eramosa, Rockwood
Irvine River Assessment Area (Future Conditions Only)	Elora, Fergus (Centre Wellington)
Whiteman's Creek Assessment Area (Drought Conditions Only)	Bright

As listed above, a number of municipal groundwater supplies are contained within assessment areas classified with a Moderate or Significant potential for stress. Under the requirements of the Technical Rules, these municipal systems would be subject to the requirement of completing a local area water budget and risk assessment (Tier 3). The Region of Waterloo Integrated Urban System and City of Guelph are the largest of these municipal groundwater supplies, and preliminary results of the stress assessment for those municipalities indicated that they would be required to complete a Tier 3 Assessment. Given the high level of certainty of these preliminary results, those municipalities have been provided funding by the Province to complete Tier 3 Assessments, which were initiated in 2008.

The supplies for St. Agatha, West Montrose, Conestogo Plains (RMOW supplies), as well as Lynden and Rockwood, have much smaller water demands than the City of Guelph and the RMOW Integrated Urban System but are located in areas classified as having a *Moderate* potential for stress, and therefore meet the requirement for a Tier 3 Water Quantity Risk Assessment. Tier 3's for these municipalities have not currently been initiated.

The Percent Water Demand for the Irvine River Assessment Area was estimated to be 10% when considering future (e.g. 25-year) water demands, which results in a *Moderate* potential for stress classification. Given that the estimated Percent Water Demand under current conditions is only 5%, the need to complete a Tier 3 Assessment for those supplies may not be immediate or significant. It may be prudent to delay a decision on proceeding with a Tier 3 Assessment for Elora and Fergus until such time where population projections are refined, and/or a Water Supply Master Plan has been completed for Centre Wellington.

The Technical Rules require that a drought assessment be completed to identify any municipal wells that might be adversely impacted by reduced water levels. For this Assessment, the drought scenario was completed by adjusting monthly average recharge rates across the watershed to be consistent with those for the complete 1960-1999 simulation period. Maximum water level decline, as compared to initial conditions, is recorded at the location of each municipal well as a relative indication of the potential impact of drought at that well.

The objective of the drought assessment is to identify any additional assessment areas that should be classified as potentially stressed due to drought conditions. The impact of the drought scenario on wells located in assessment areas already classified with a *Moderate* or *Significant* stress level under the Percent Water Demand assessment is not evaluated. Table 5-3 lists the municipal wells having a simulated water level decline greater than 3 m during the drought scenario.

Table 5-3 - Municipal Wells with Simulated Water Level Declines Greater than 3 m (Drought Scenario)

Municipality	Municipal System	Assessment Area	Well Name	Maximum Water Level Decline (m)	Available Drawdown
County of Brant	Airport Well Supply	Grand at Brantford	Airport Well	-3.8	11
County of Oxford	Bright	Whiteman's Creek	Well_4	-7.0	6.7
RMOW	Roseville	Lower Nith	R6	-3.0	32
RMOW	Heidelberg	Conestogo Below Dam	HD1	-3.1	27
			HD2	-3.5	27
RMOW	Foxboro Green	Middle Nith	FG_1	-3.8	25
		Middle Nith	FG_2	-3.8	12
RMOW	St. Agatha	Upper Nith	SA6	-5.8	11
Centre Wellington	Fergus	Irvine River	Fergus_6	-3.6	30
	Elora		Elora_E1	-4.3	17

The 3 m limit was chosen to identify those wells simulated to experience the greatest water level decline under drought conditions. For those identified wells, well completion information was collected to determine if the simulated water level declines would have an adverse impact on the operation of the well. The majority of wells have a sufficient depth of water above their screens to accommodate the water level fluctuations predicted by the groundwater model in response to a ten year drought condition. The exception to this is the Bright #4 well, which is estimated to have a 7 m fluctuation in water levels due to drought, and has a normal water level, under pumping conditions, that is 6.7 m above the top of screen. This suggests that operation of the Bright #4 well may be affected by drought conditions. Based on this analysis, the Whiteman's Creek Assessment Area is classified as having a *Moderate* potential for stress due to drought conditions at Bright Well #4.

5.2 SIGNIFICANT GROUNDWATER RECHARGE AREAS

In addition to the Subwatershed Stress Assessment, the Province's Water Budget Framework specifies that a Tier 2 Water Budget needs to delineate Significant Groundwater Recharge Areas (SGRAs). The Water Budget Guidance Module (MOE, 2007) states that SGRAs should be delineated and mapped to identify and protect the drinking water across the broader landscape. This study follows a straightforward and reproducible procedure for delineating SGRAs as described in the Technical Rules (MOE, 2008). This Report initially identifies areas having estimated groundwater recharge rates equal to, or greater than, 115% of the average rate in the surrounding landscape. SGRAs are delineated by considering only those areas of high recharge that have a contiguous land area greater than one square kilometer.

The SGRAs delineated in this Assessment reflect those areas within the Grand River Watershed that when combined contribute approximately 70% of the total recharge in the watershed. These areas include the Waterloo Moraine, Elmira Moraine, Galt/Paris Moraine, and Orangeville Moraine in the central zone of the Watershed. Other areas within the upper and lower physiographic zones are also classified as being SGRAs as their estimated groundwater recharge rates are greater than the threshold for those zones.

The Province's objectives for incorporating SGRAs into the Water Quality Threats Assessment process are clear. However, the role of protecting SGRAs from a water quantity perspective is not prescribed in the Technical Rules. There is a good opportunity to address the need to protect groundwater quantity within the Source Protection Planning Process, but this opportunity needs to address both the value of total groundwater recharge across a subwatershed as well as those areas having higher than average values. Furthermore, the process needs to address the uncertainty in terms of the magnitude and distribution of recharge rates.

6.0 References

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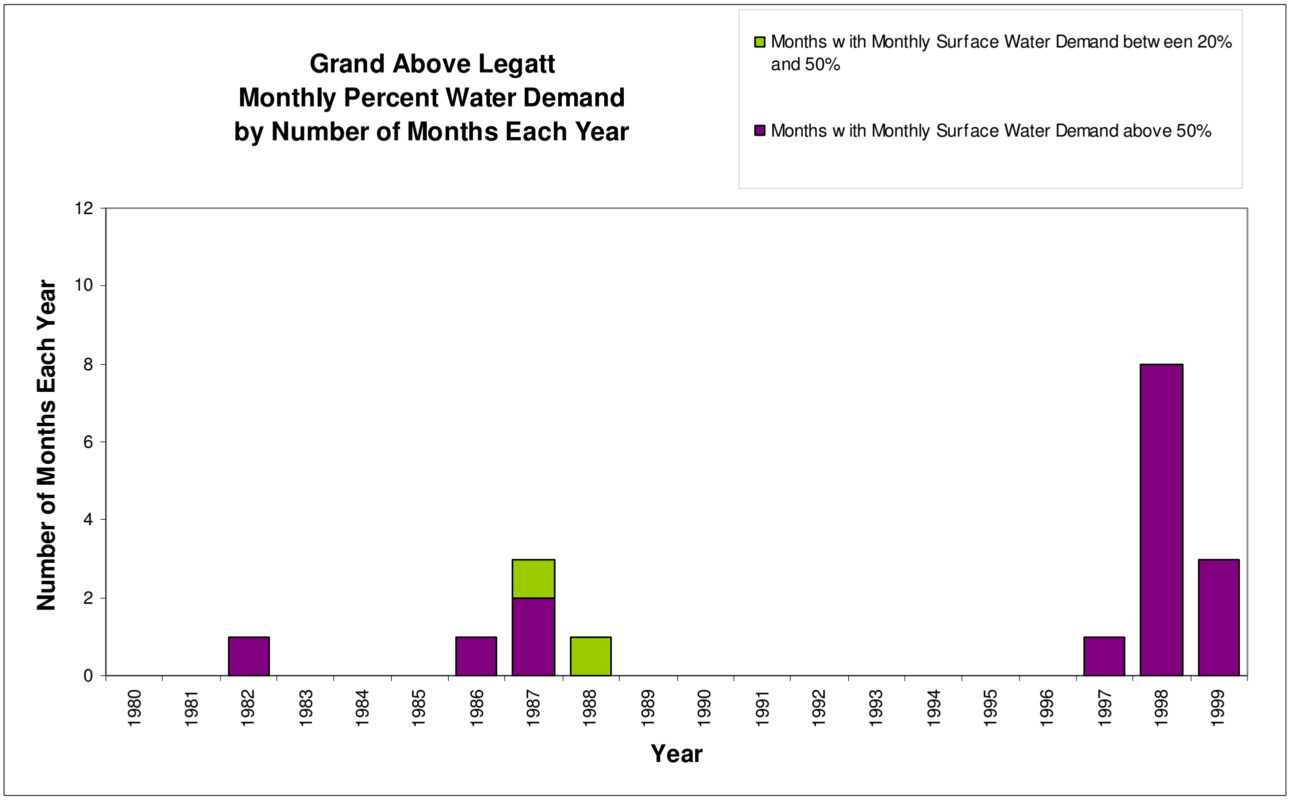
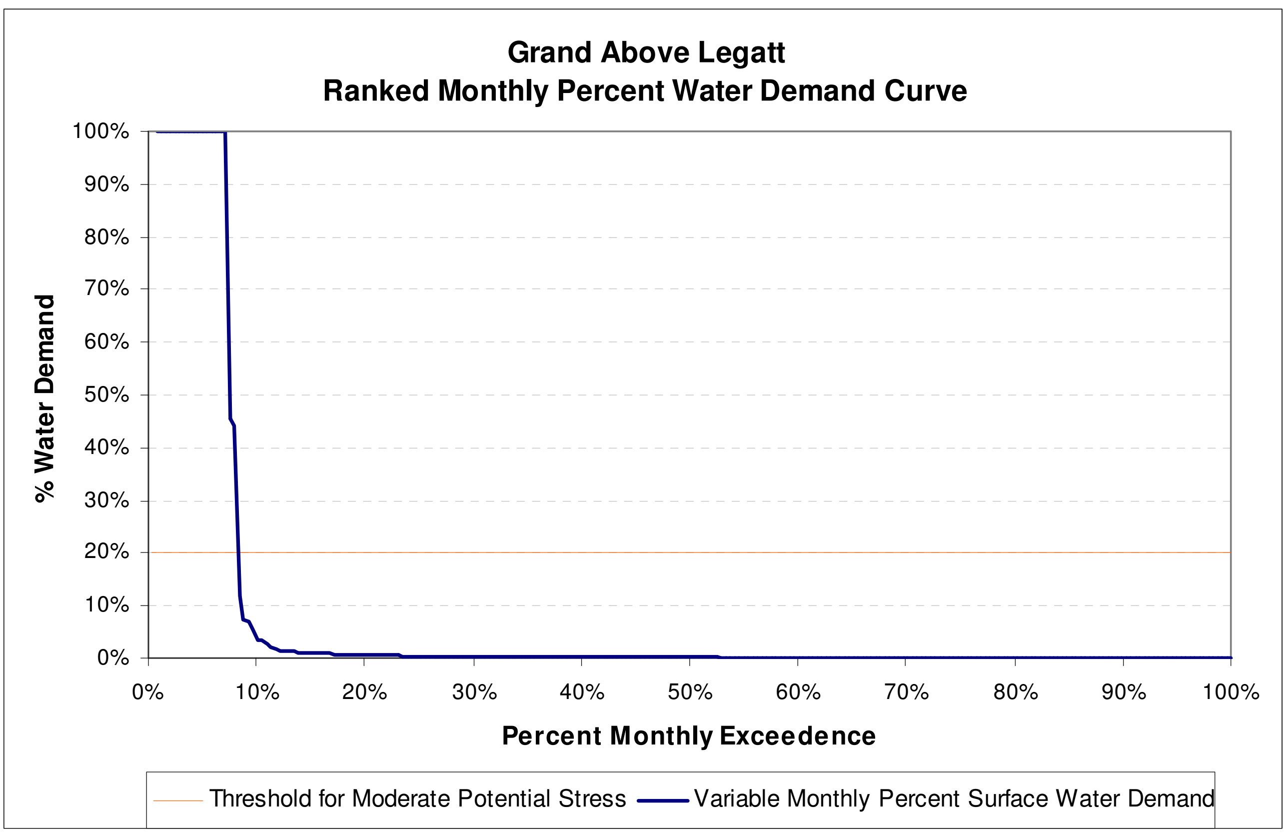
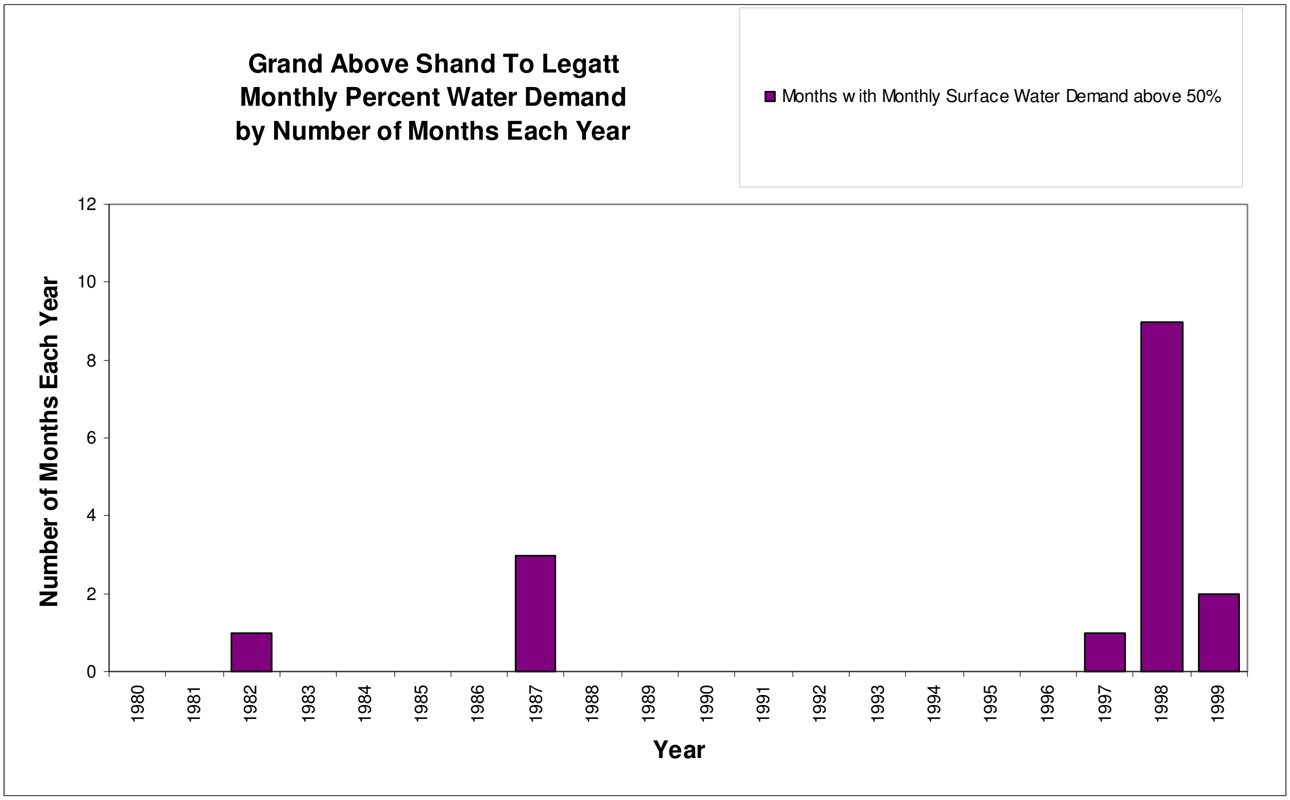
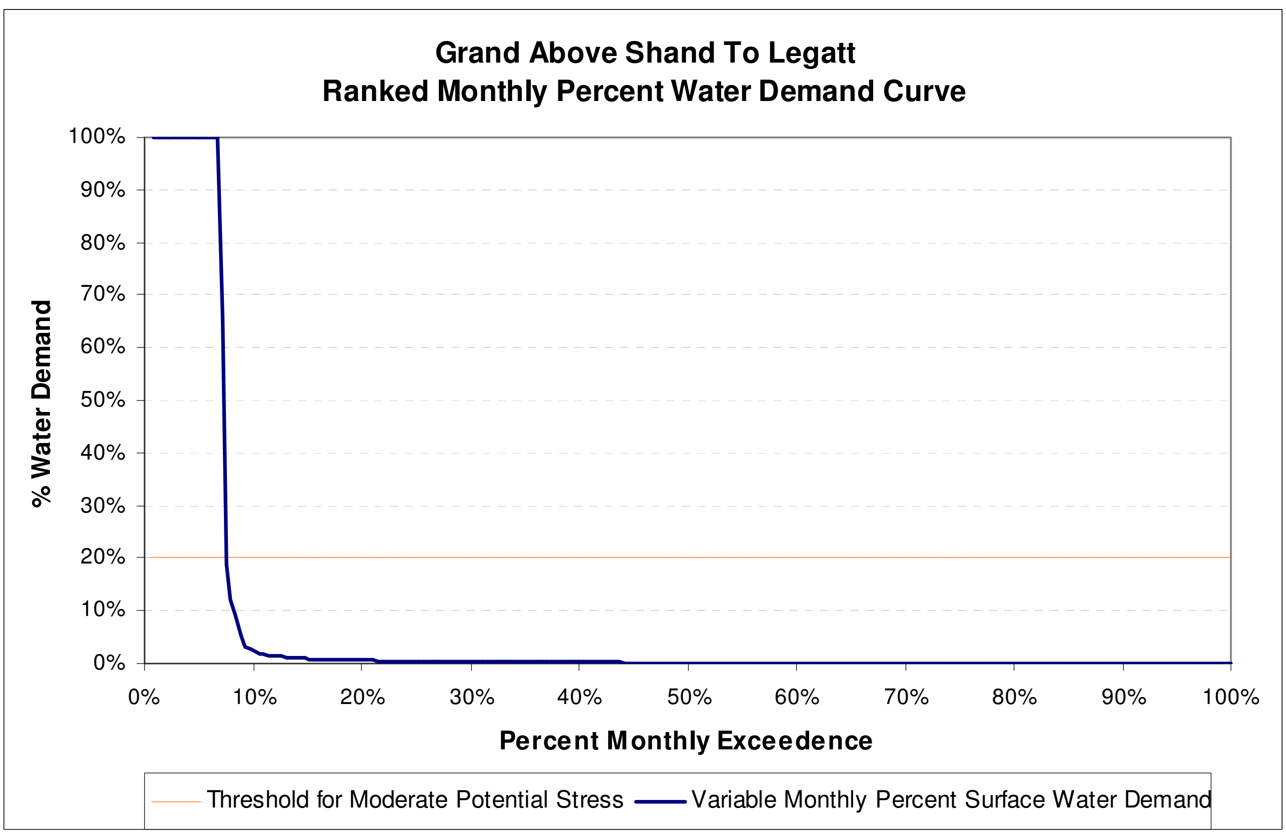


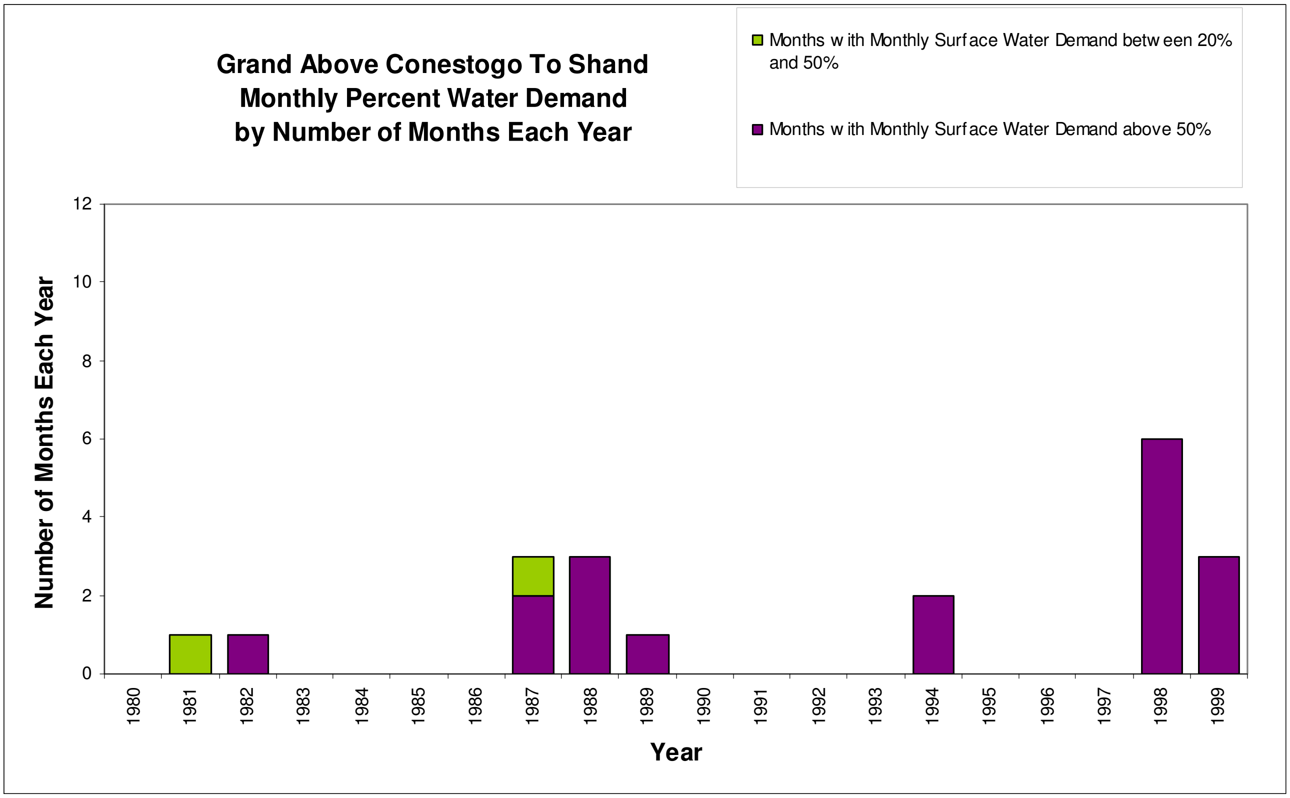


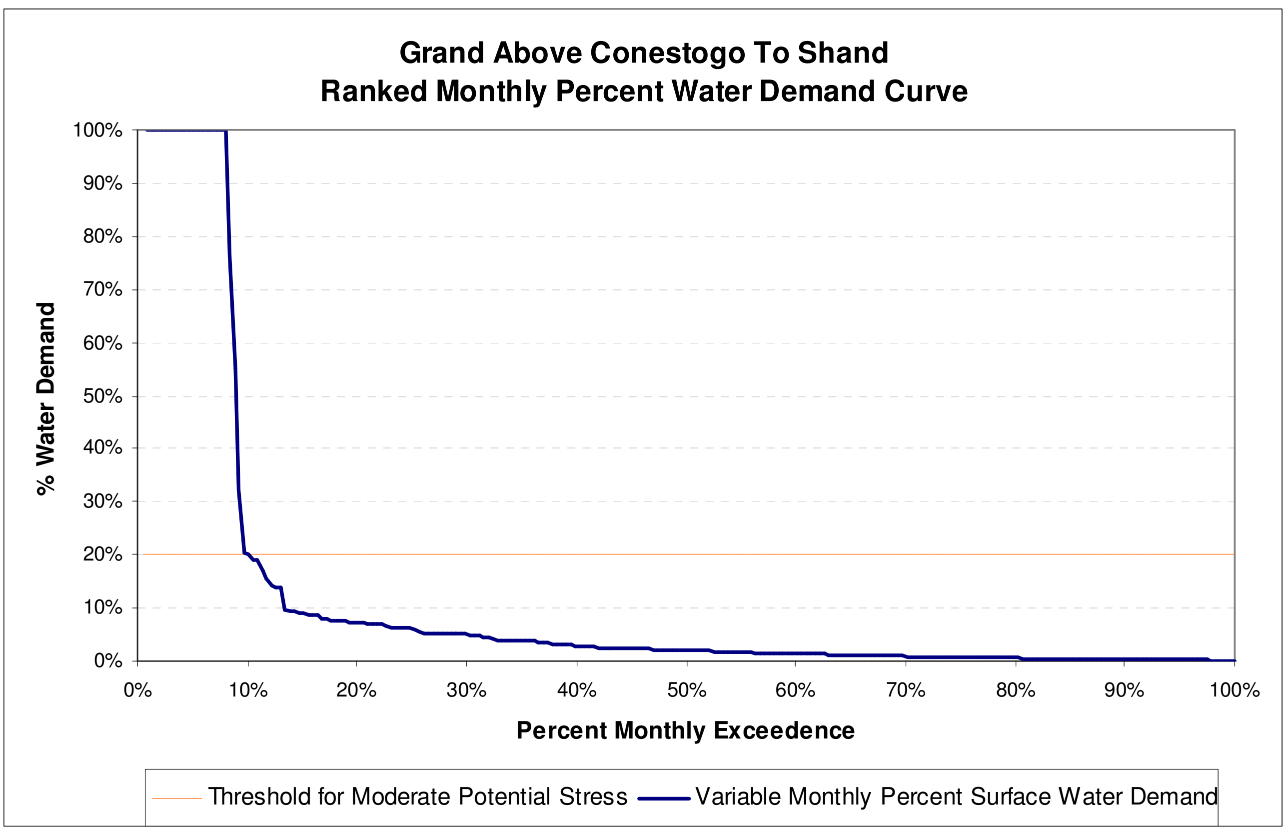
A1. Grand Above Legatt



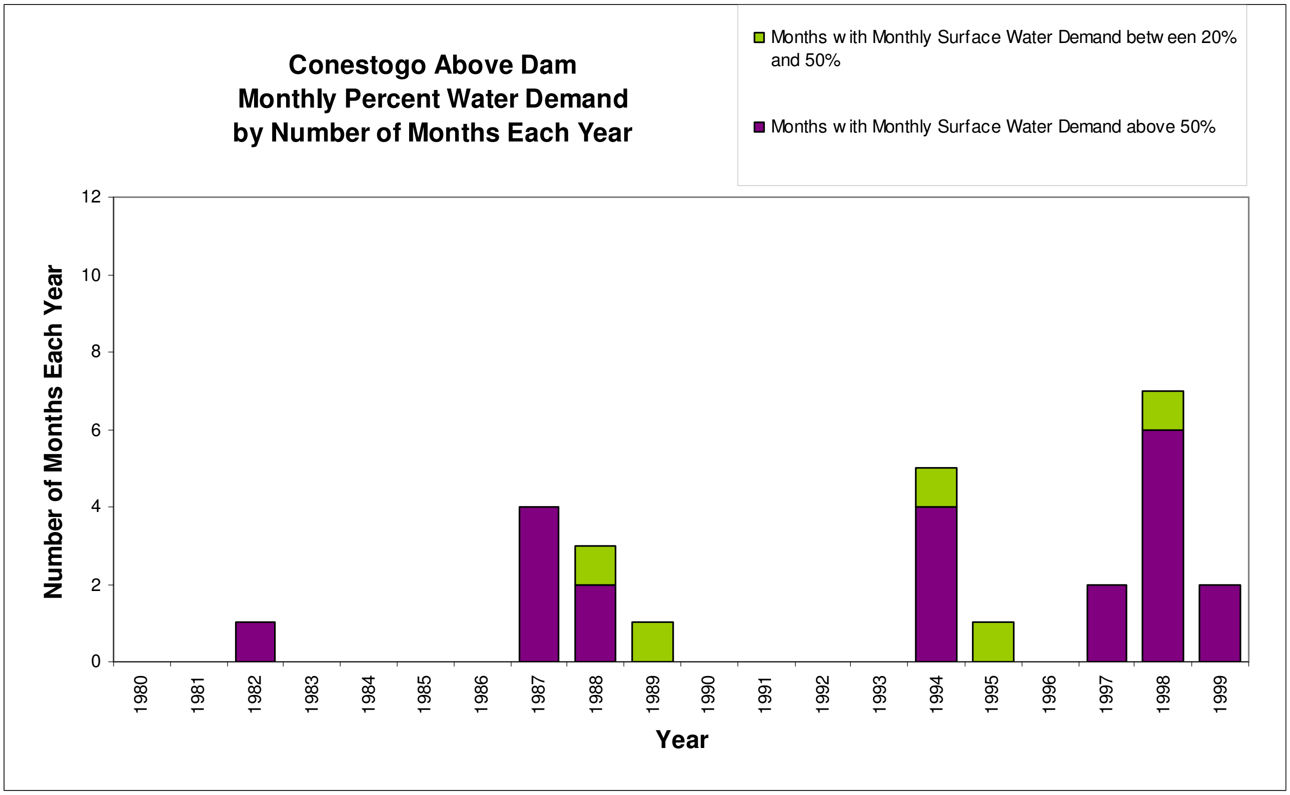


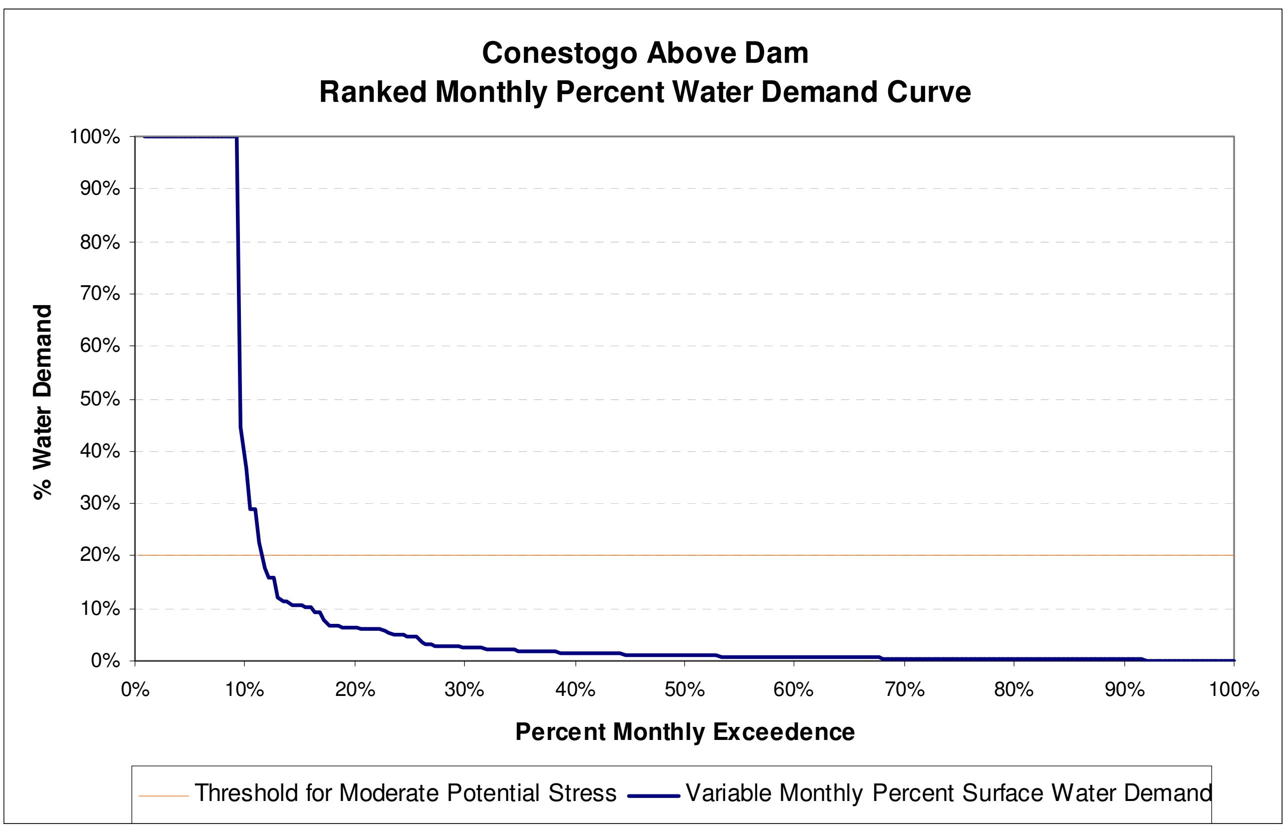
A2. Grand Above Shand to Legatt



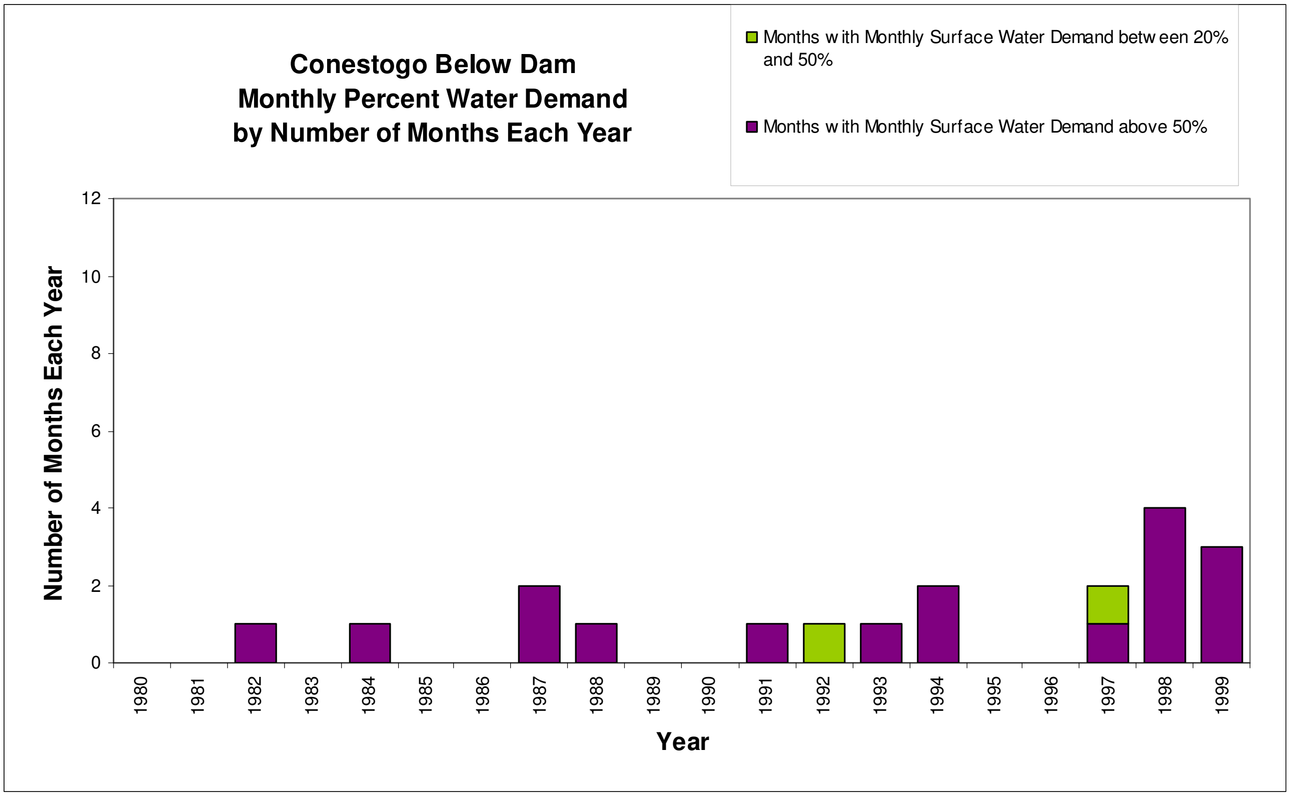


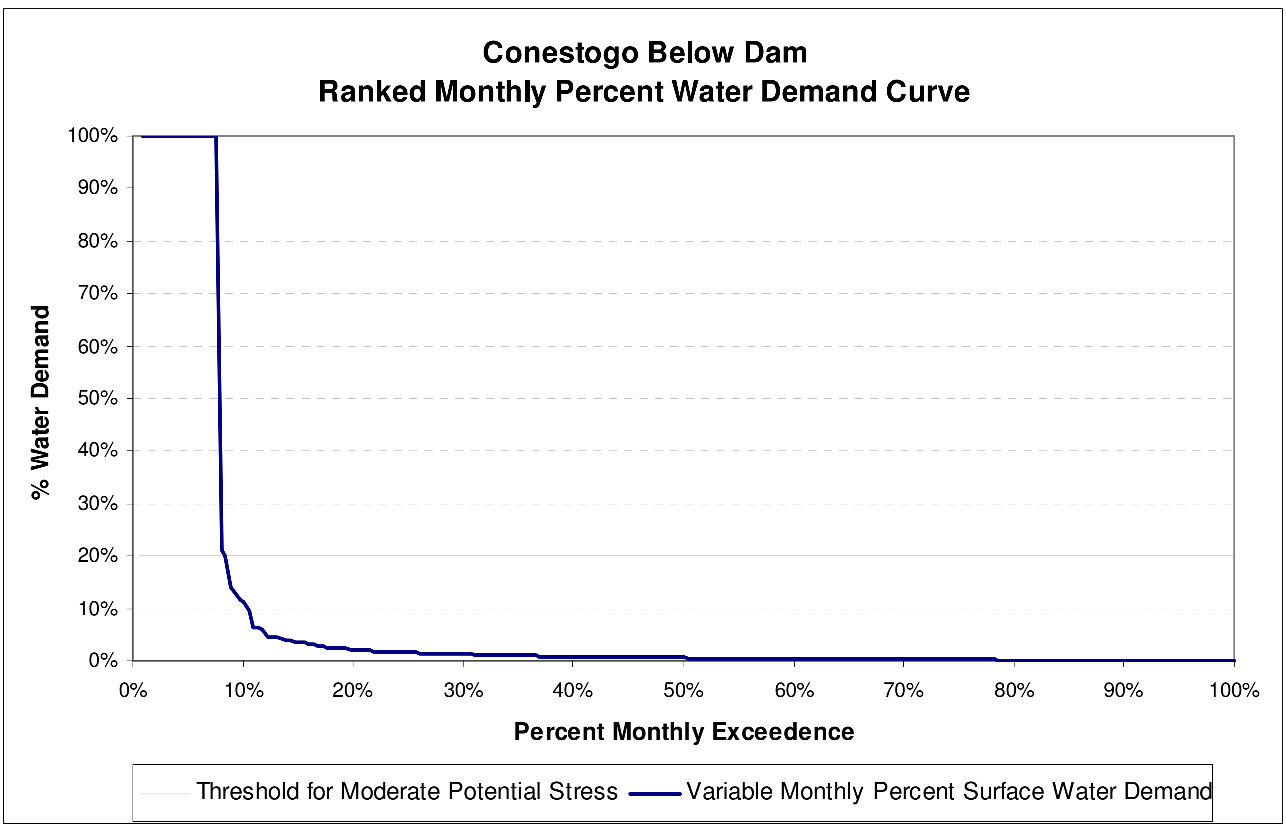
A3. Grand Above Conestogo to Shand



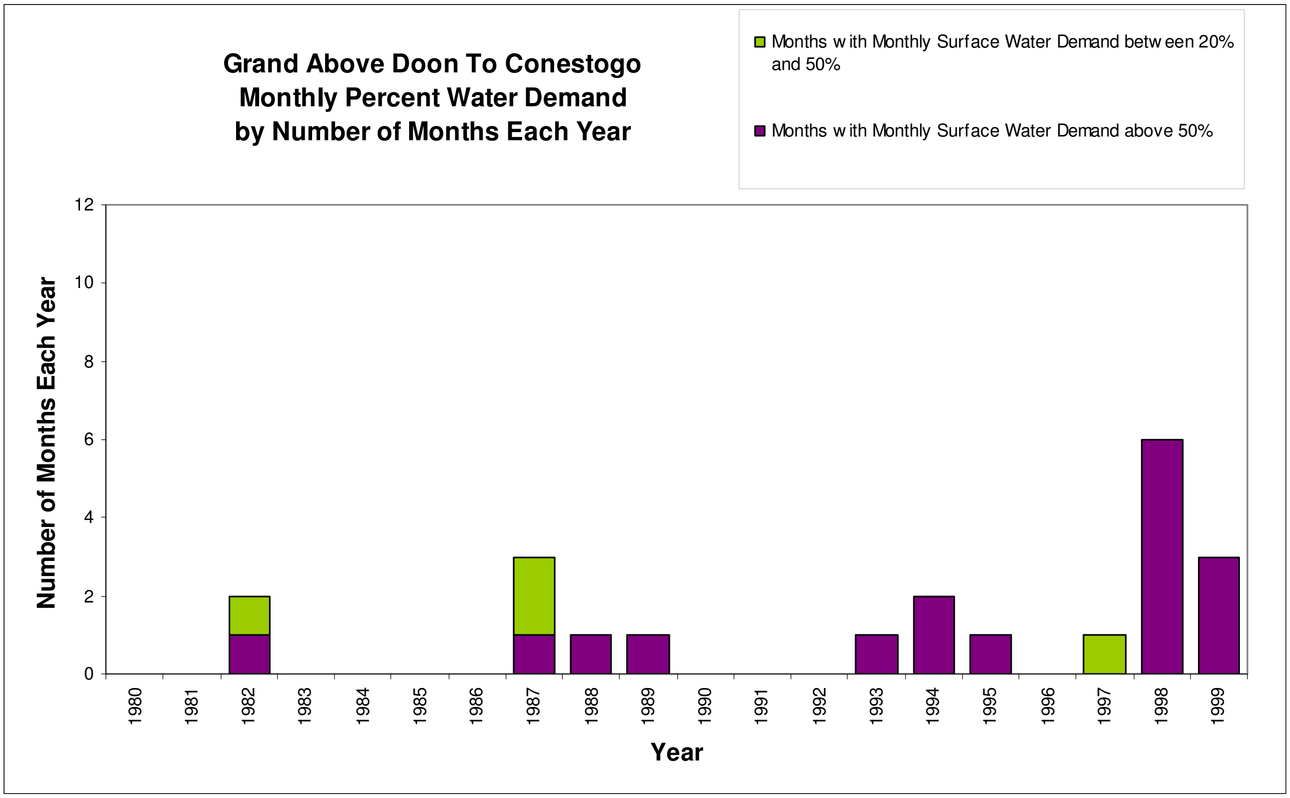


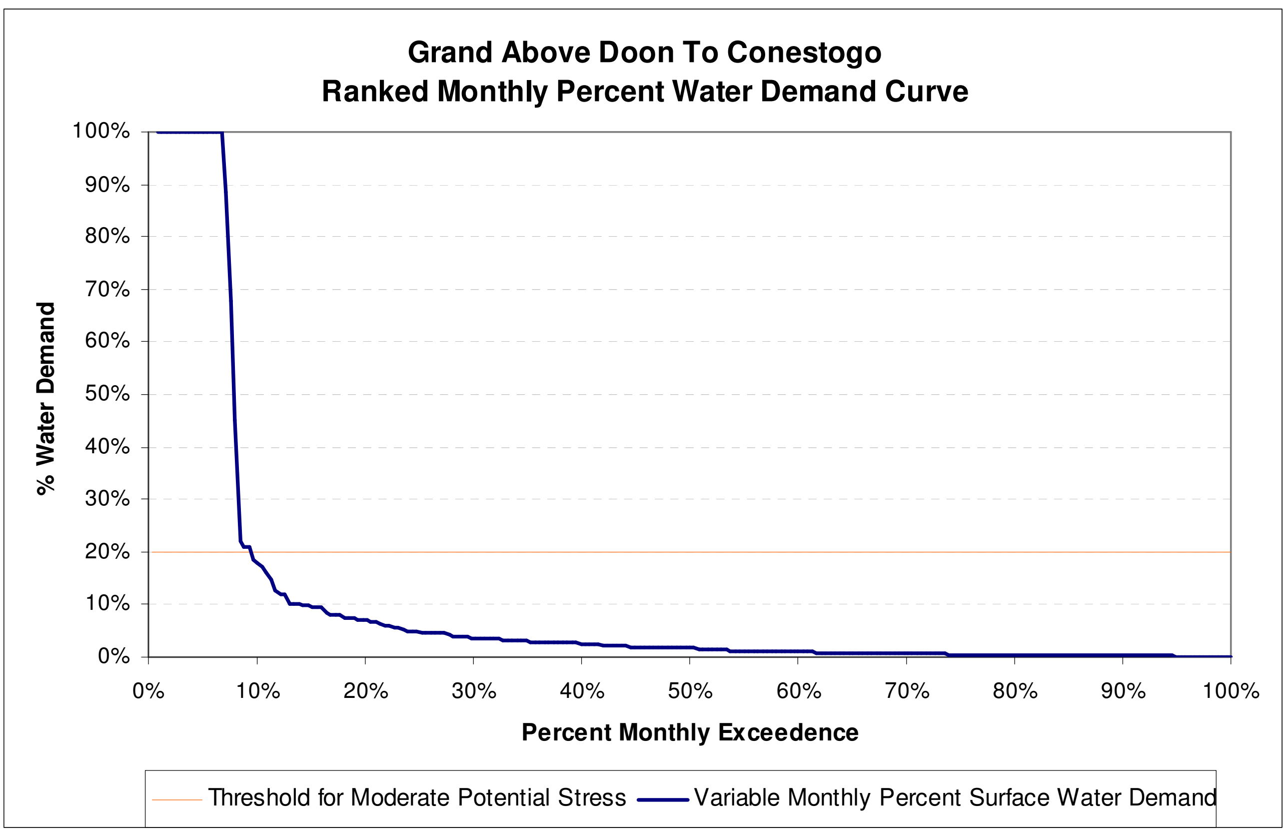
A4. Conestogo Above Dam



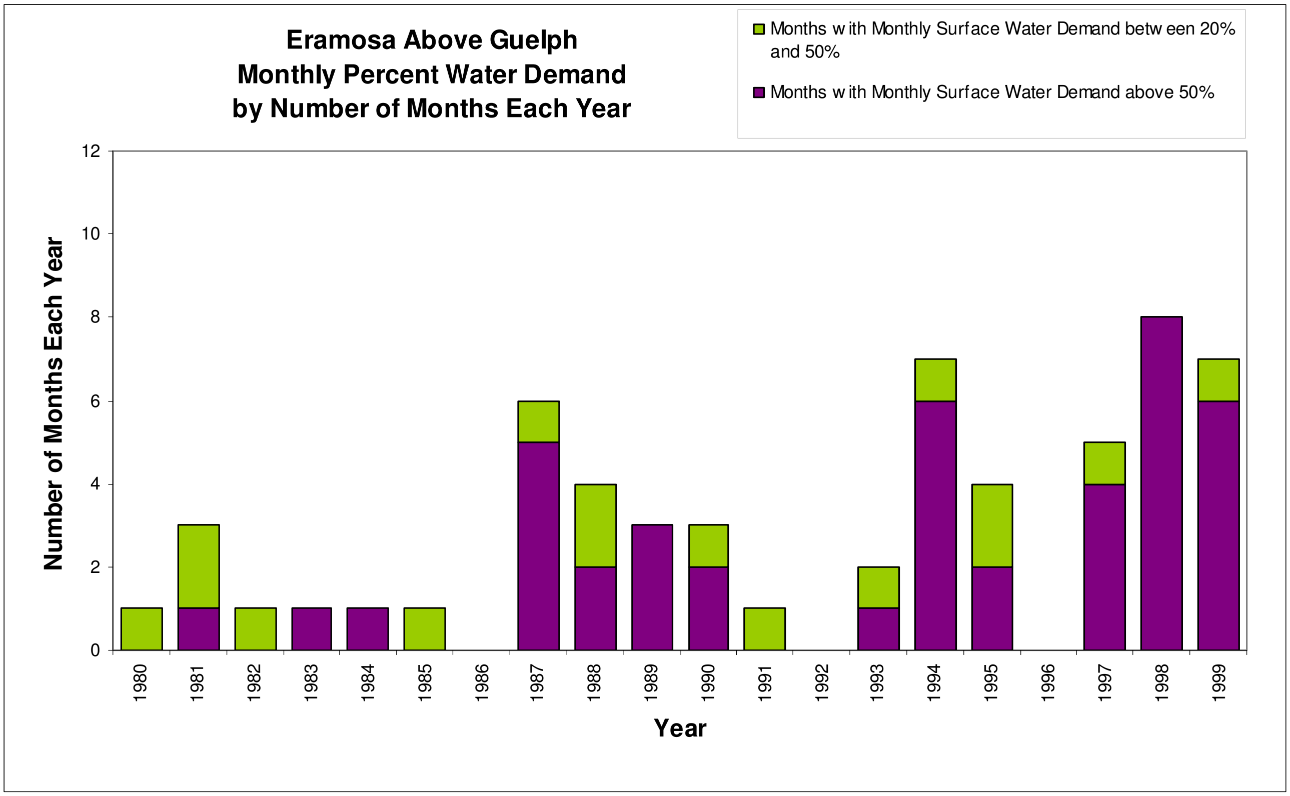


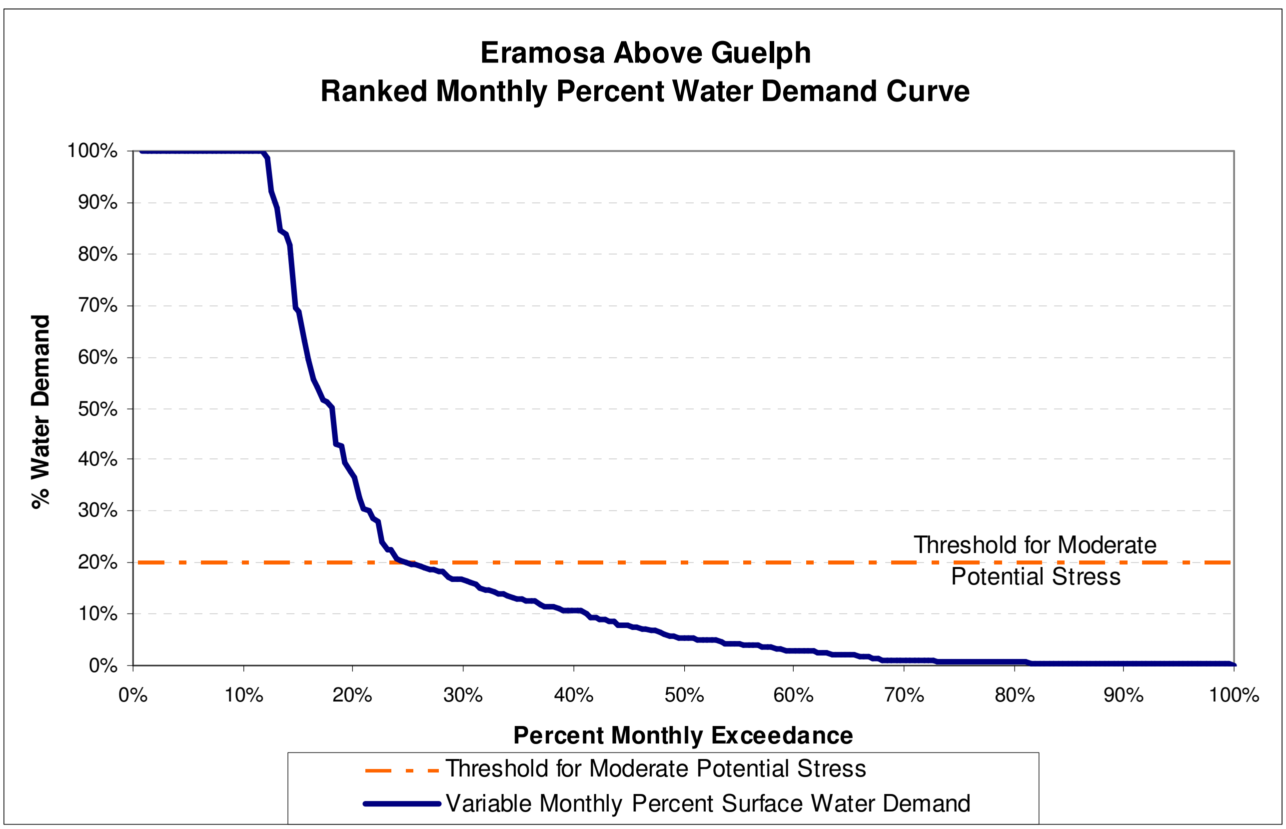
A5. Conestogo Below Dam



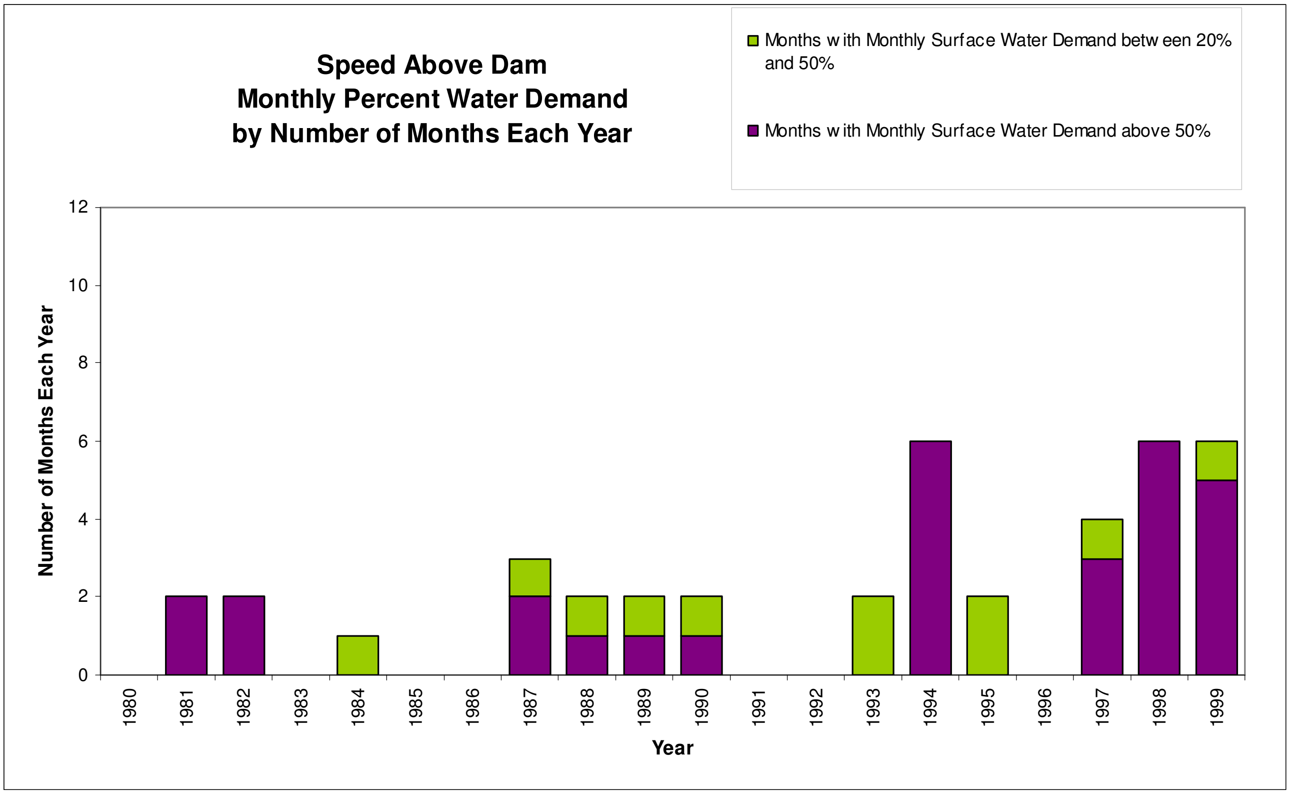


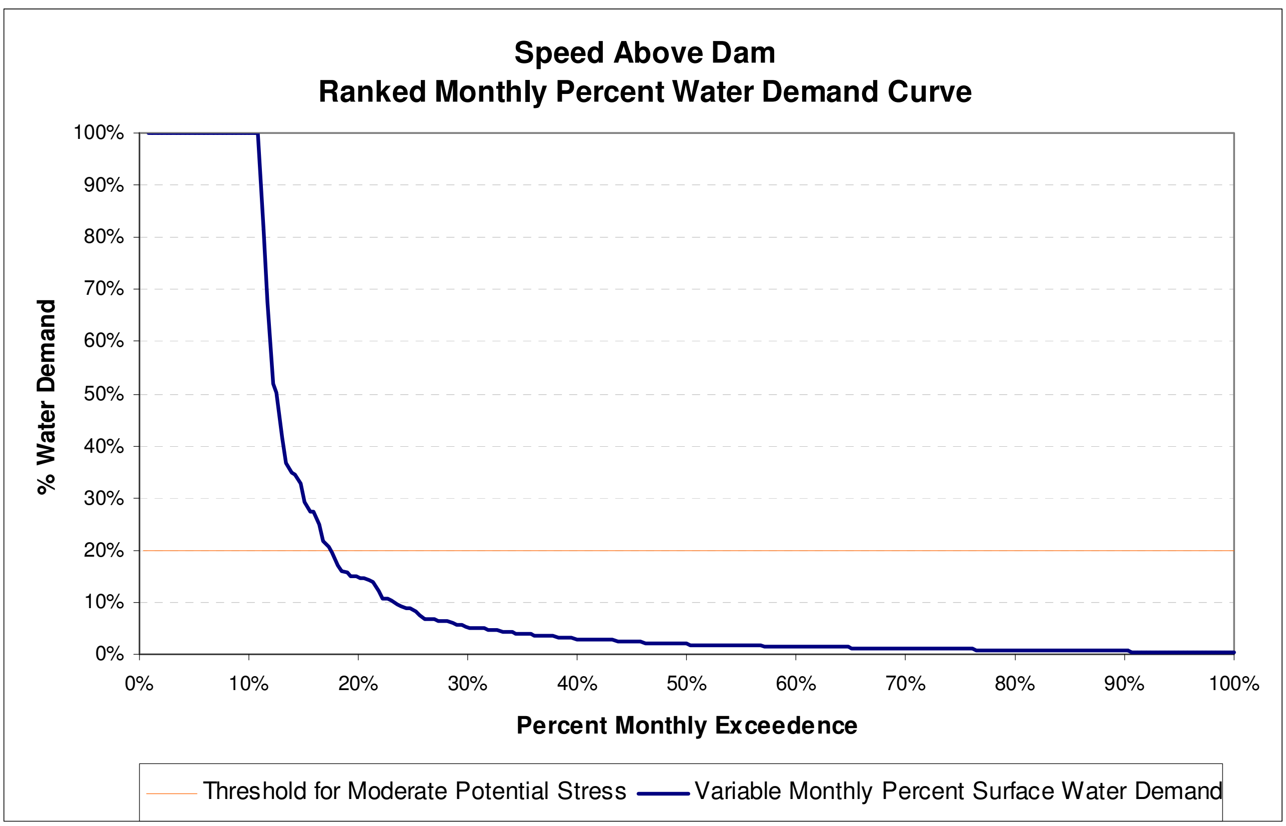
A6. Grand Above Doon to Conestogo



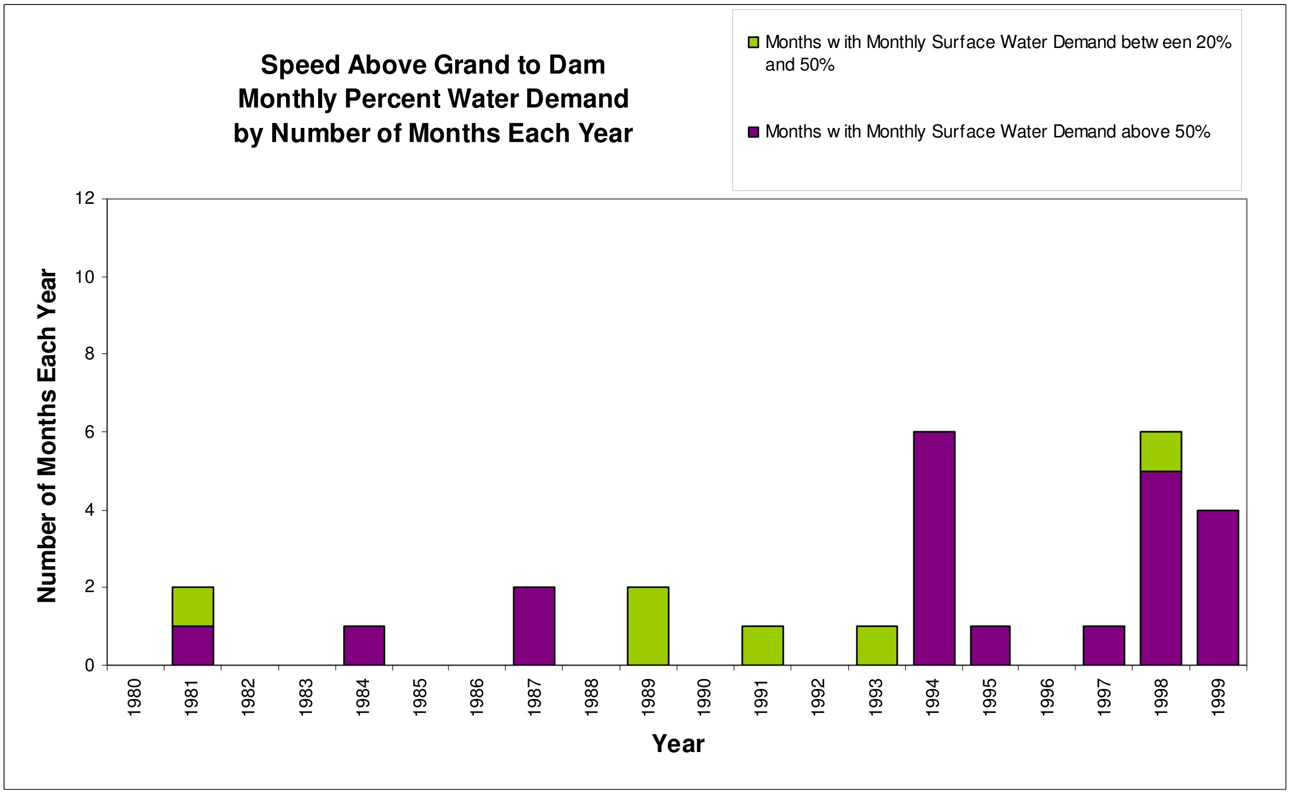


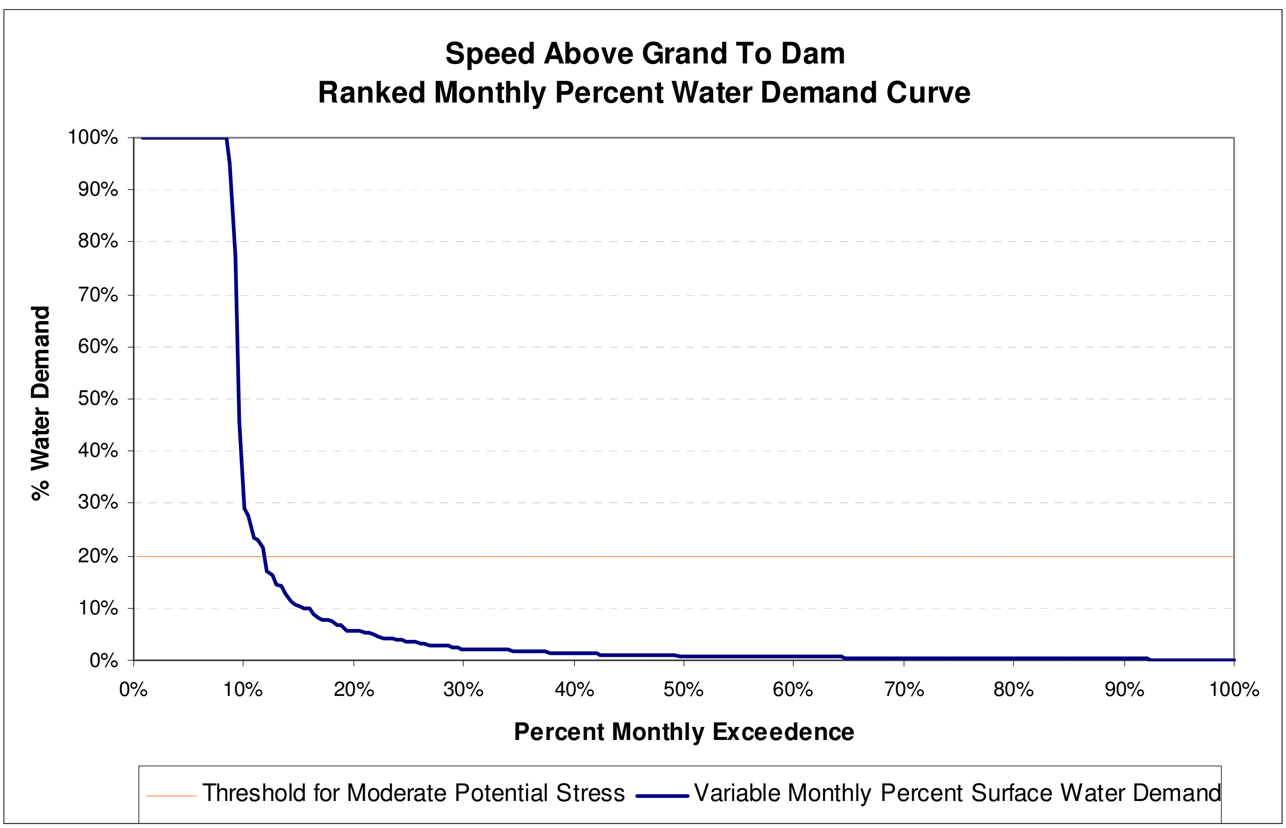
A7. Eramosa Above Guelph



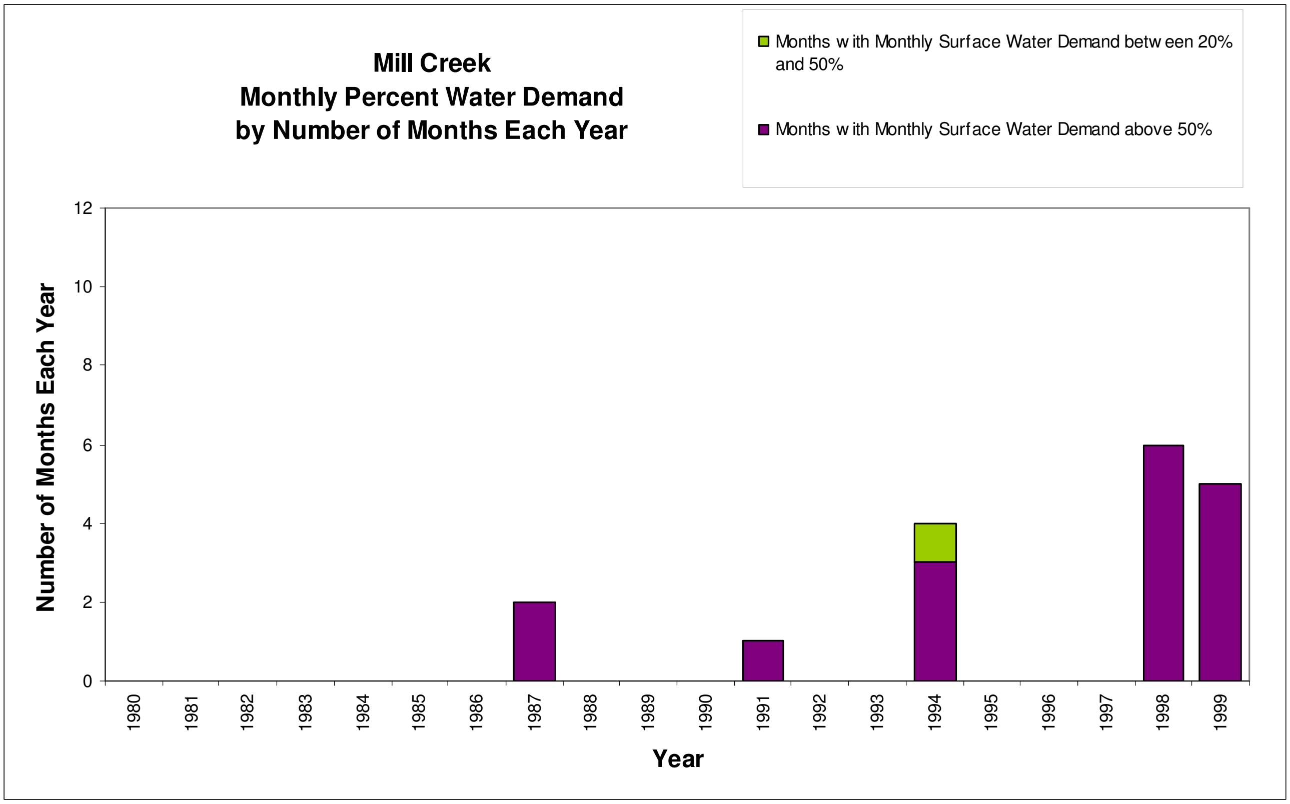


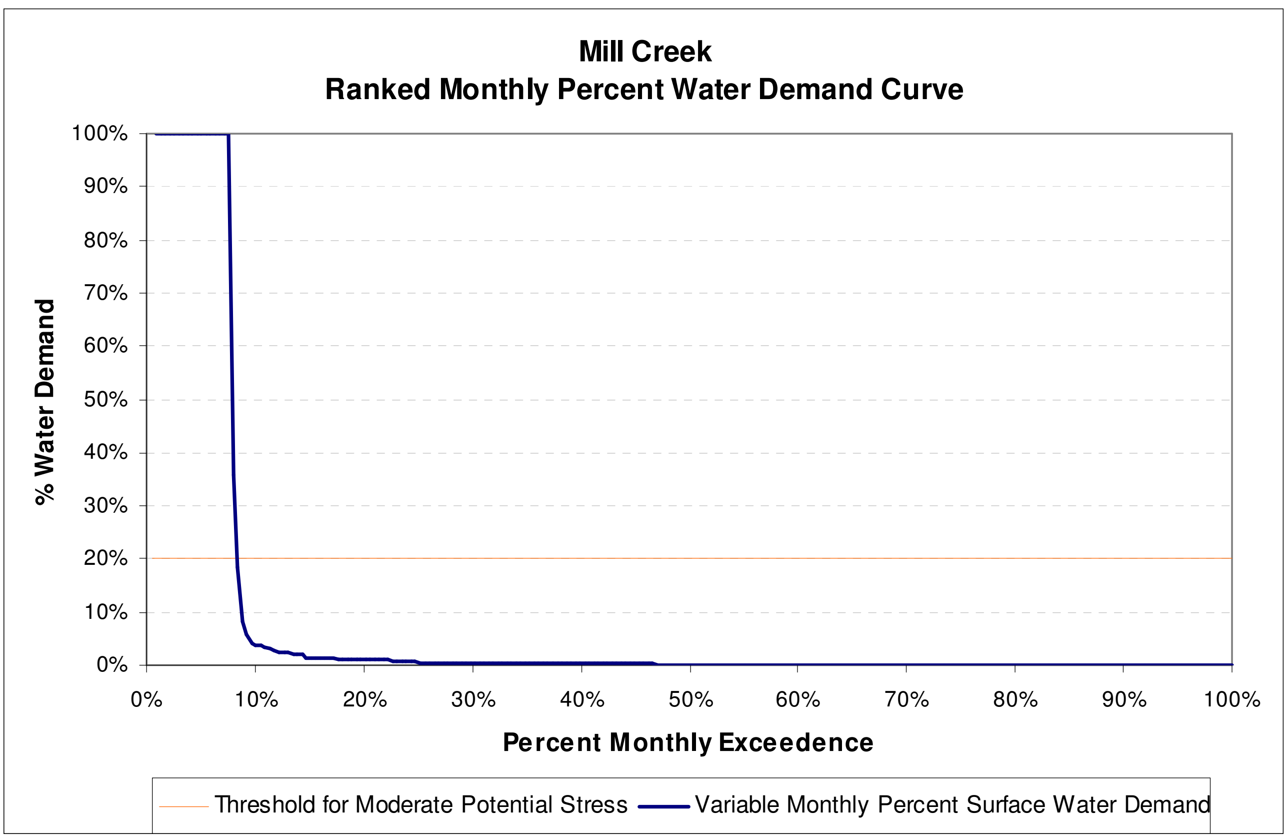
A8. Speed Above Dam



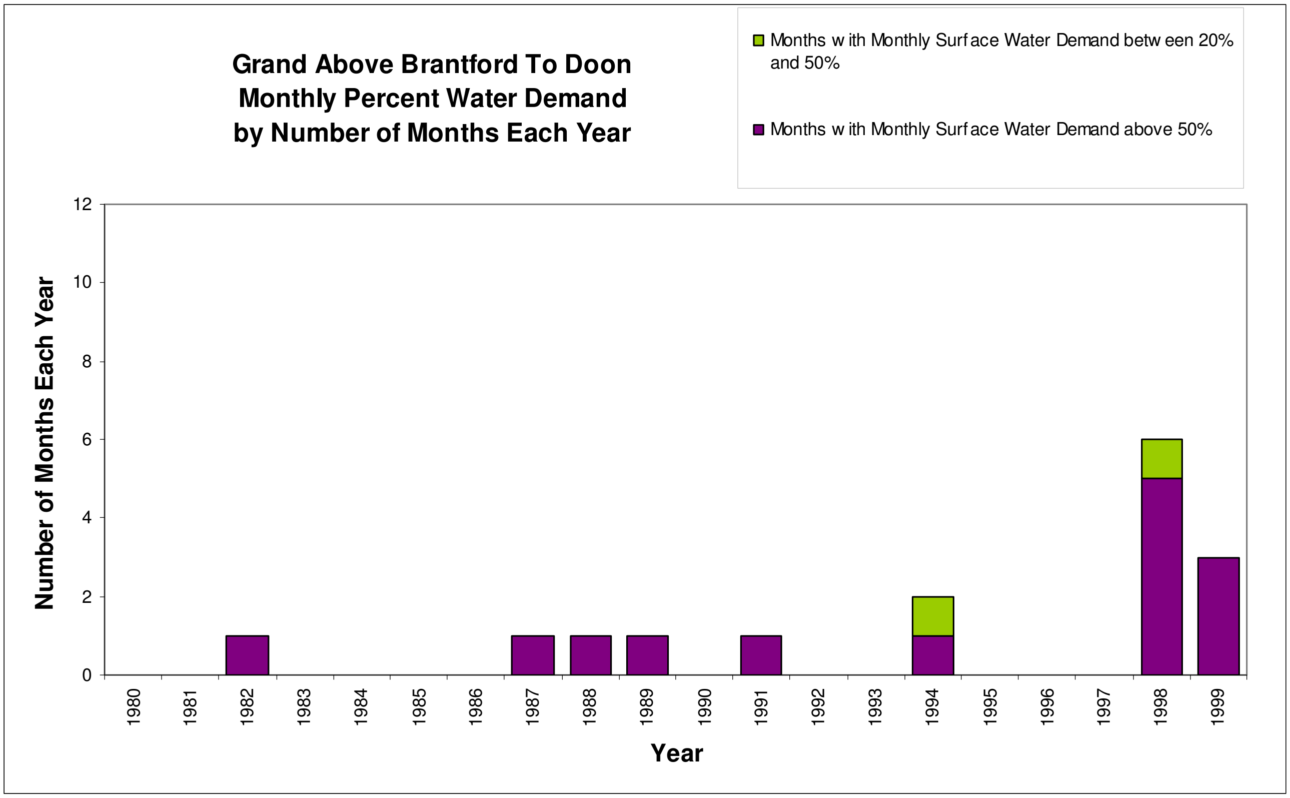


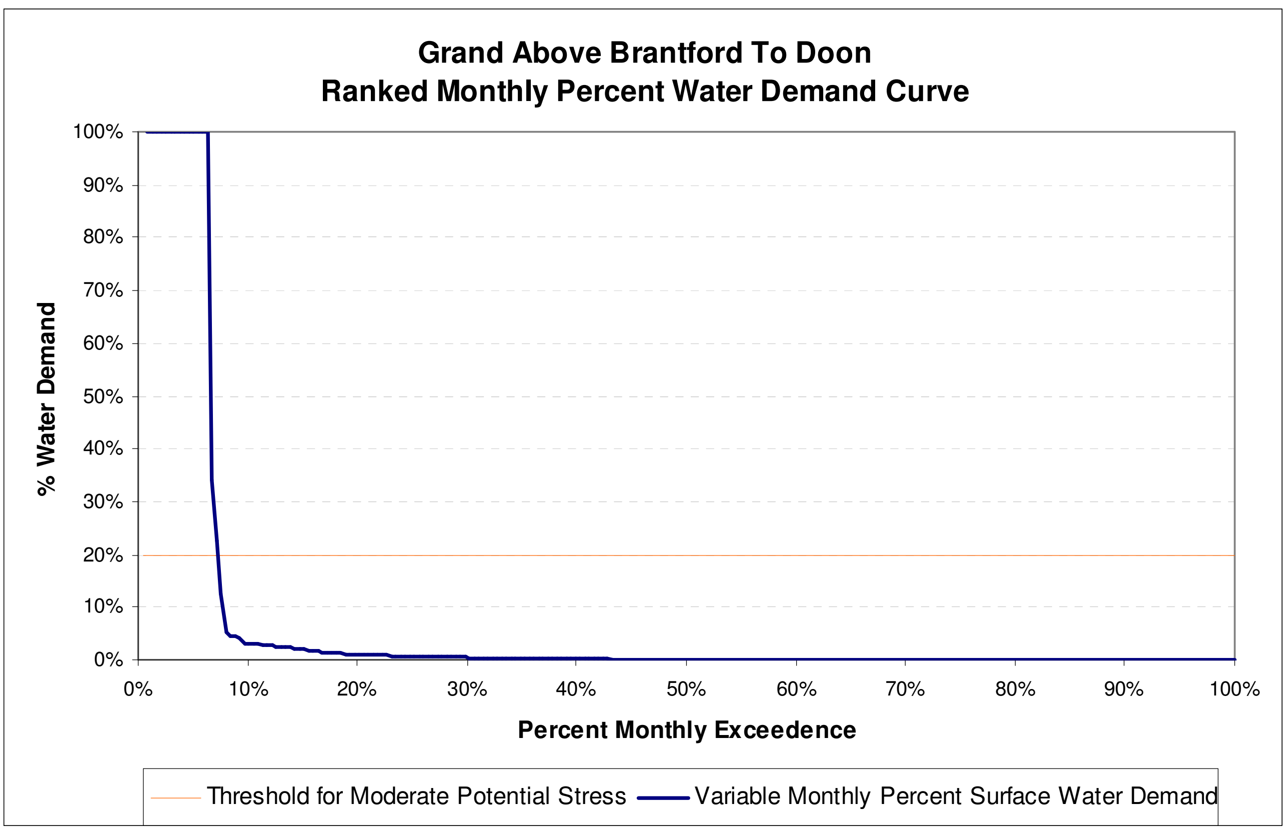
A9. Speed Above Grand to Dam



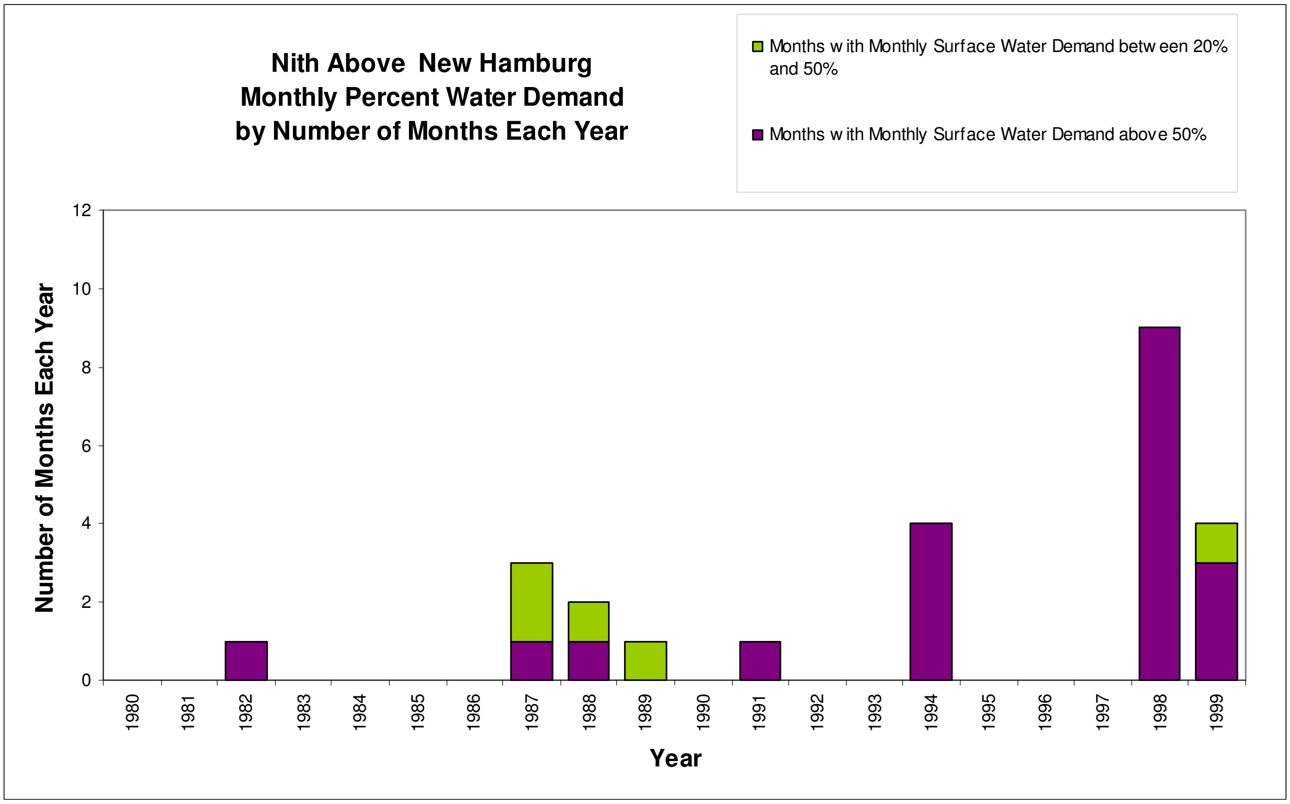


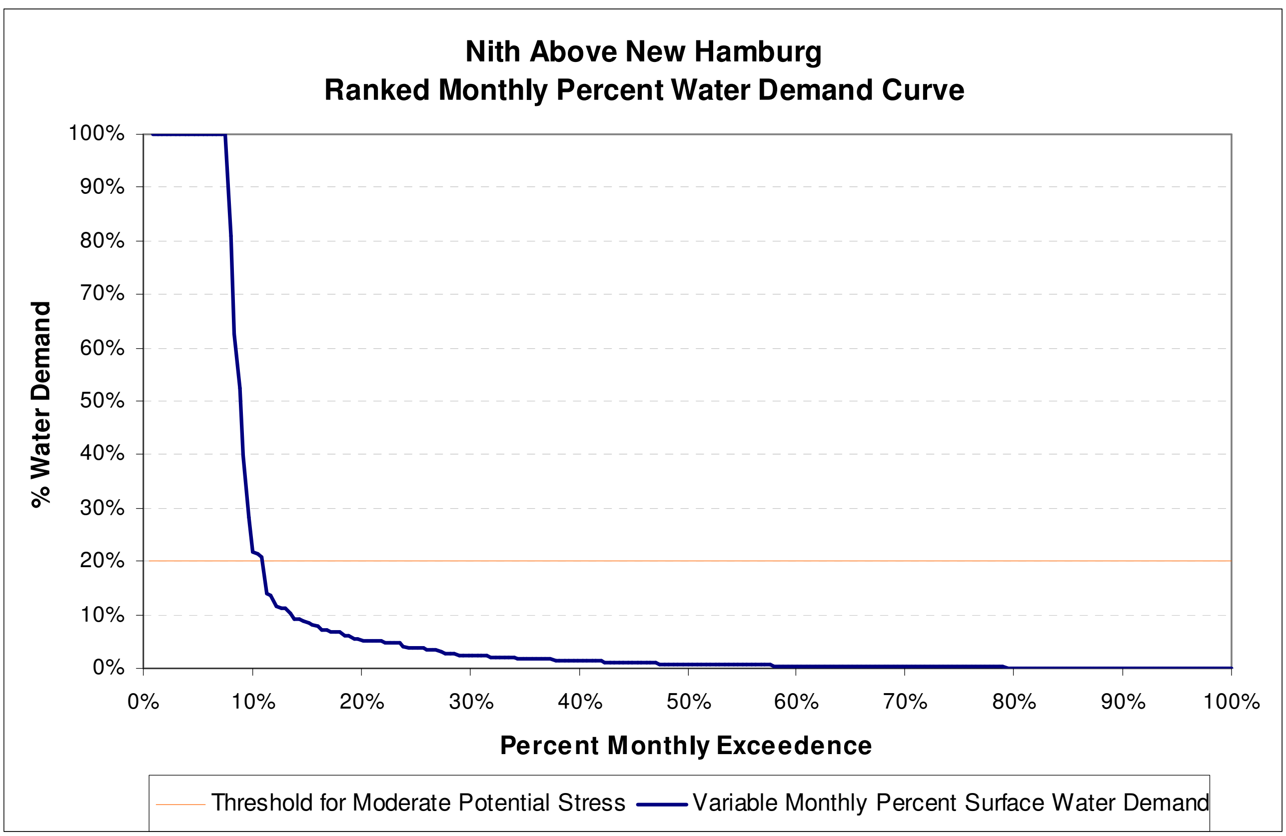
A10. Mill Creek



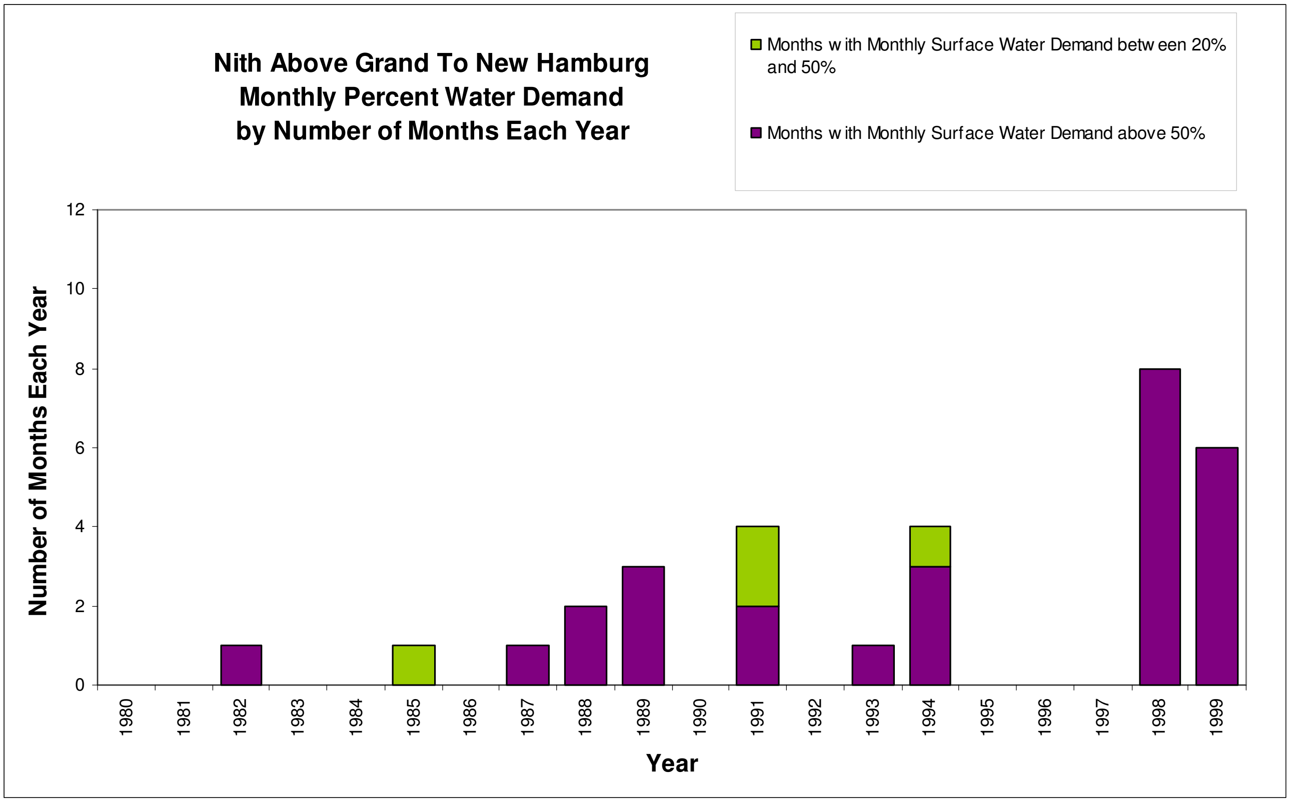


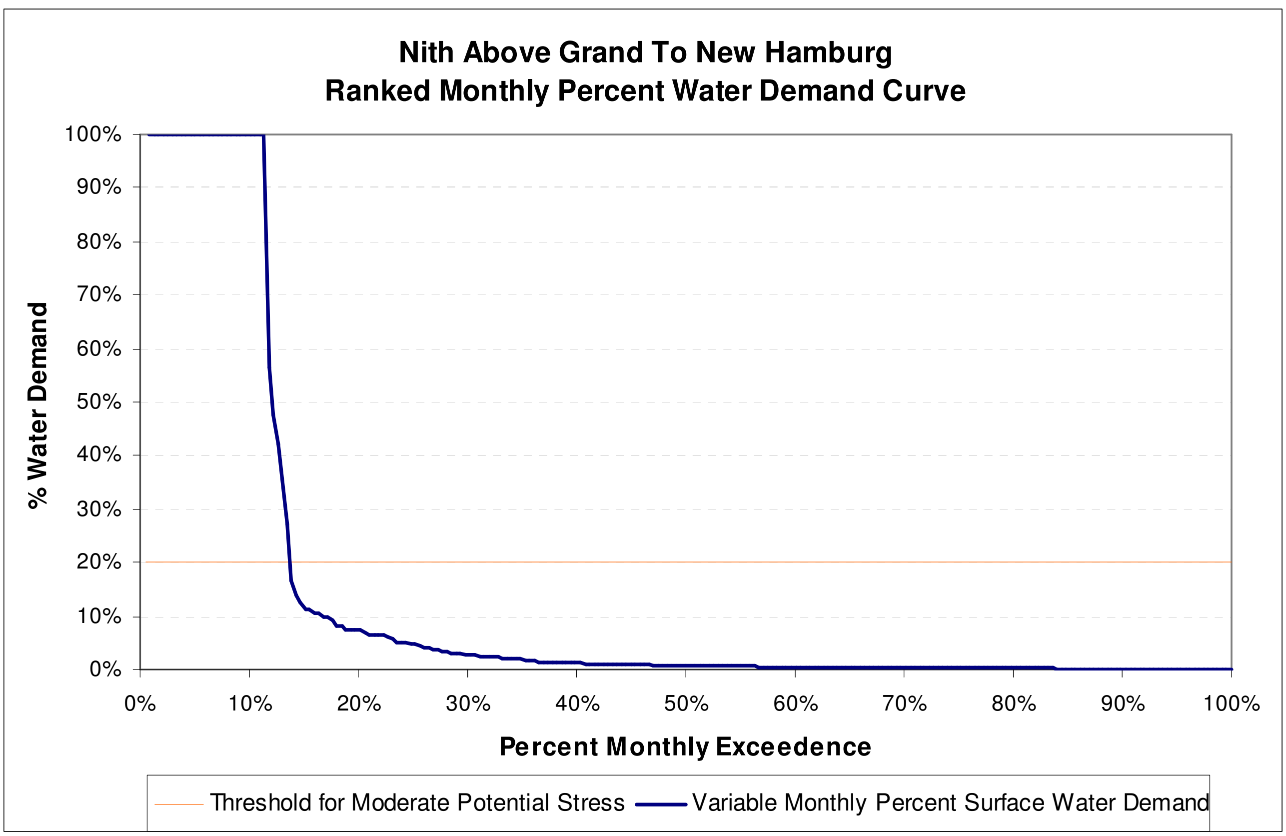
A11. Grand Above Brantford to Doon



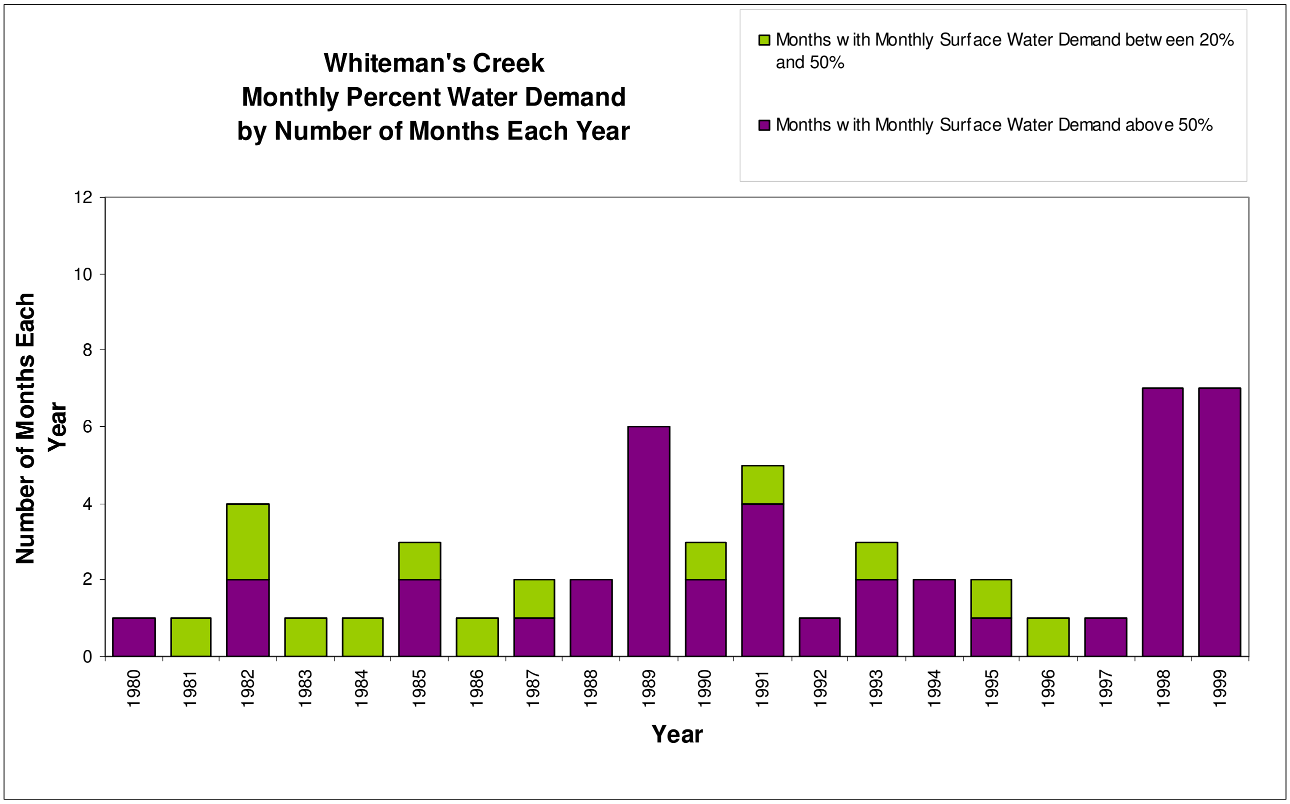


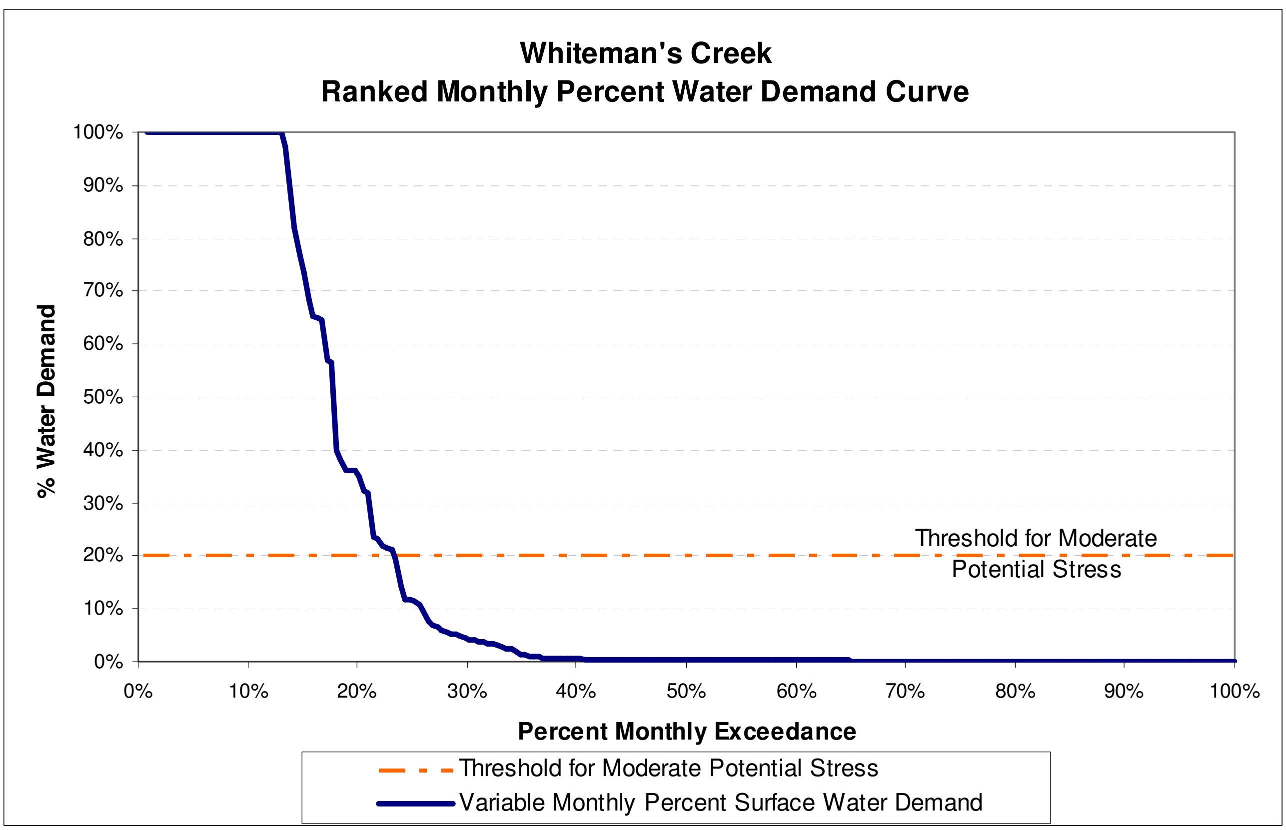
A12. Nith Above New Hamburg



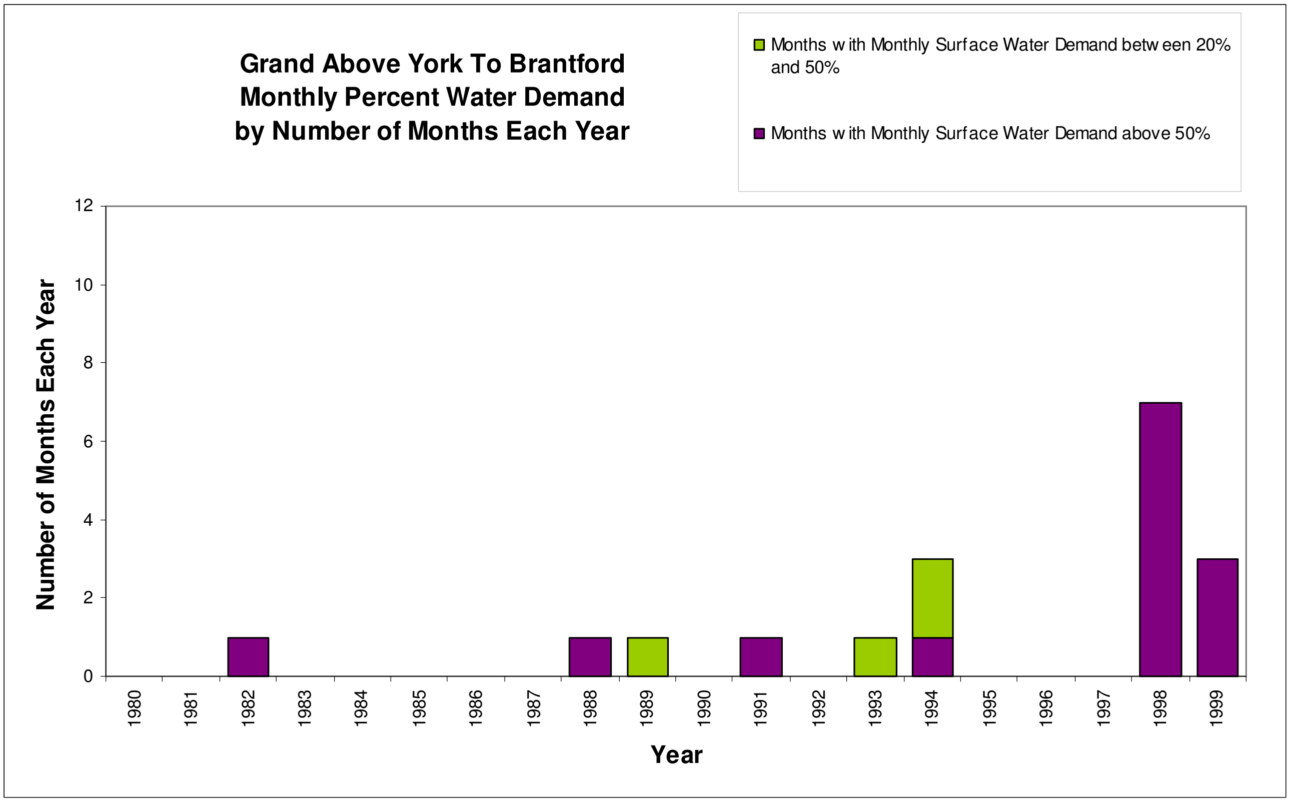


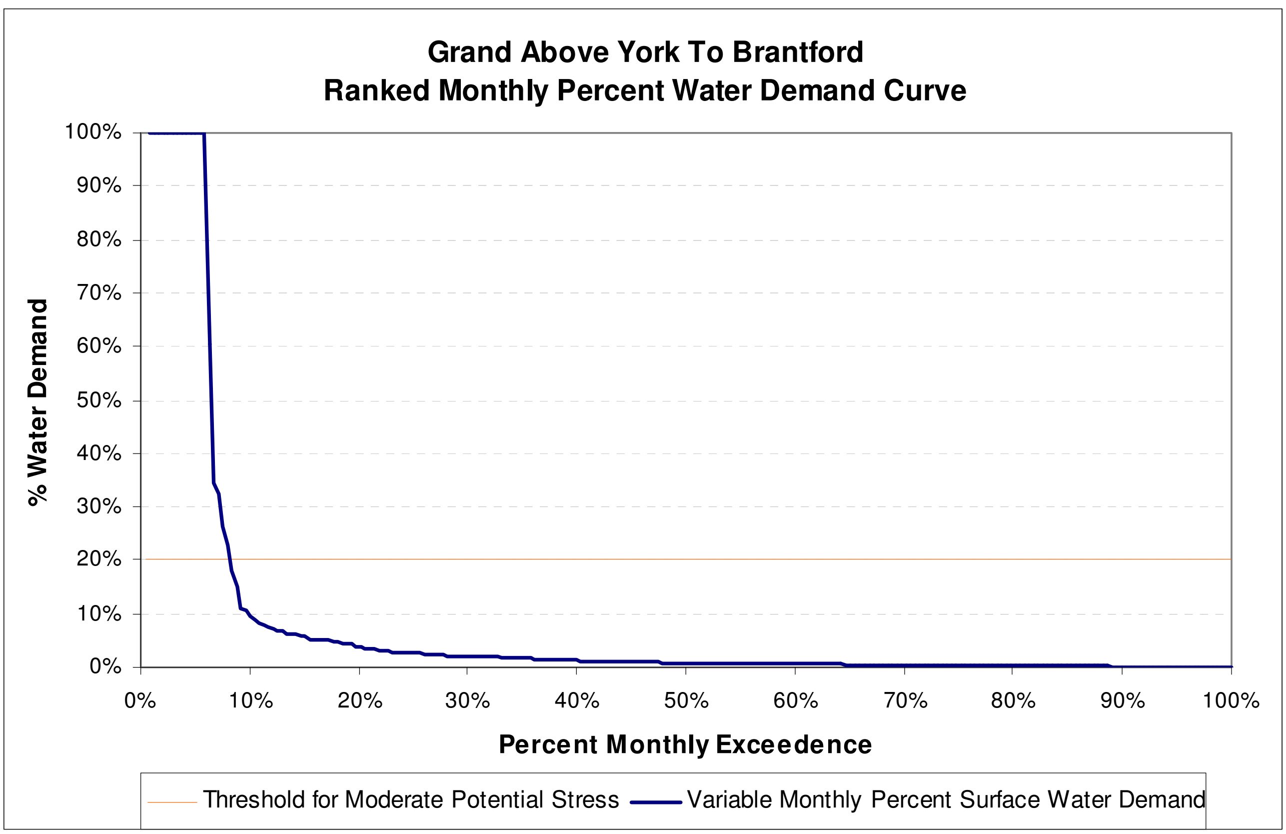
A13. Nith Above Grand to New Hamburg



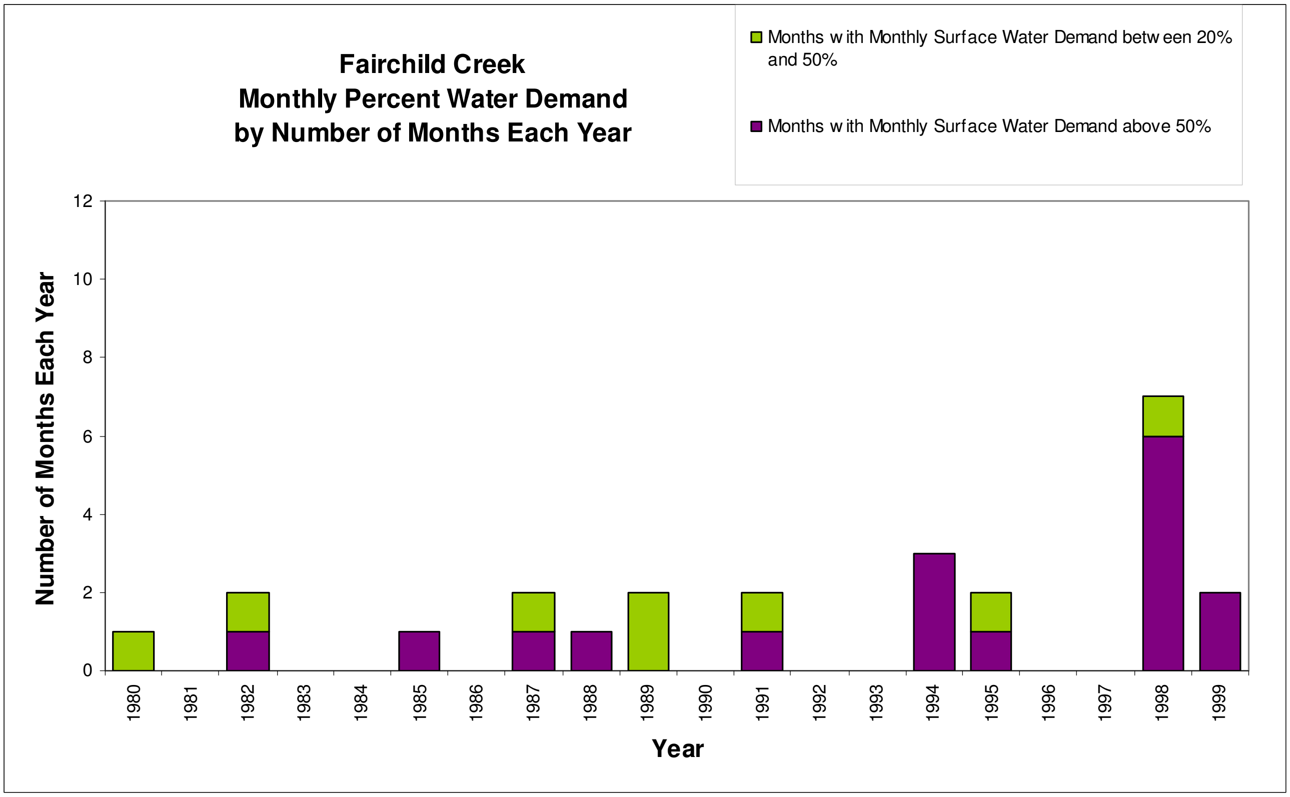


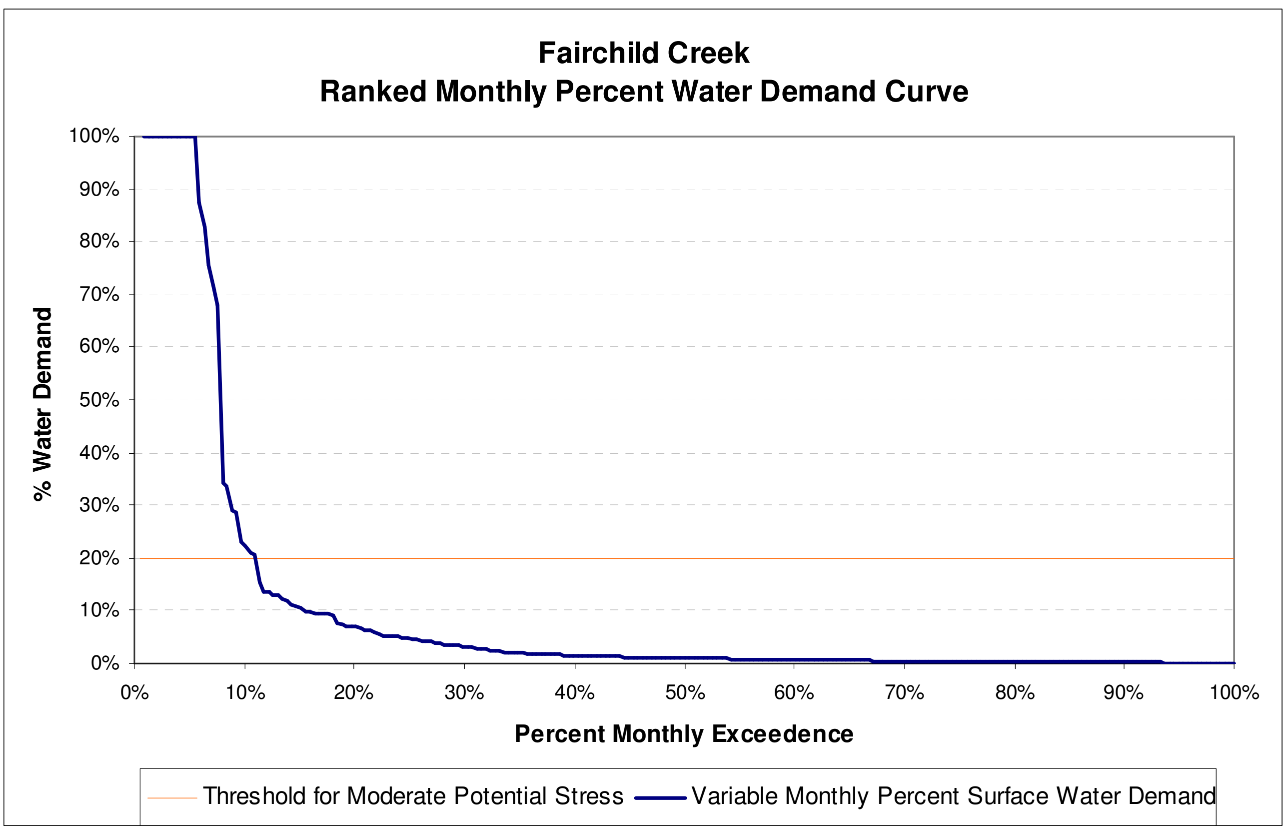
A14. Whiteman’s Creek



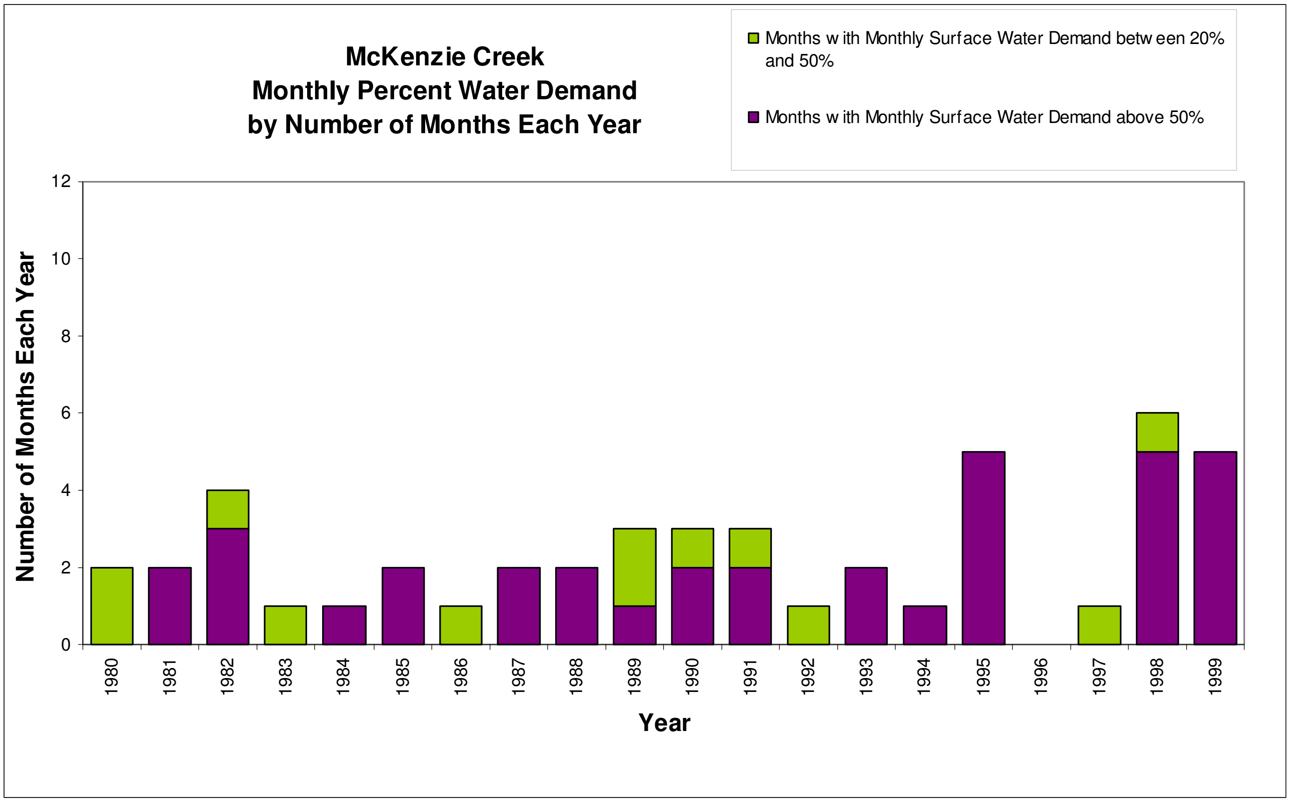


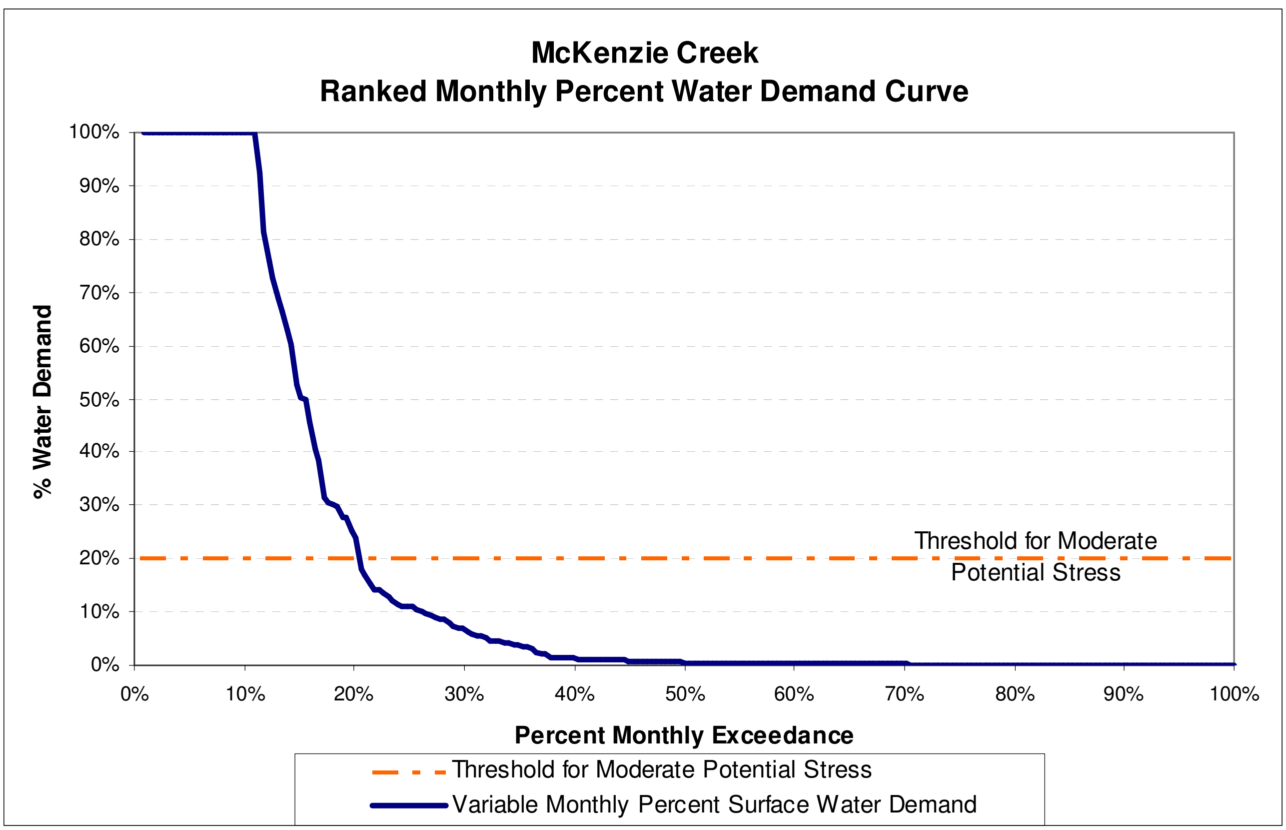
A15. Grand Above York to Brantford



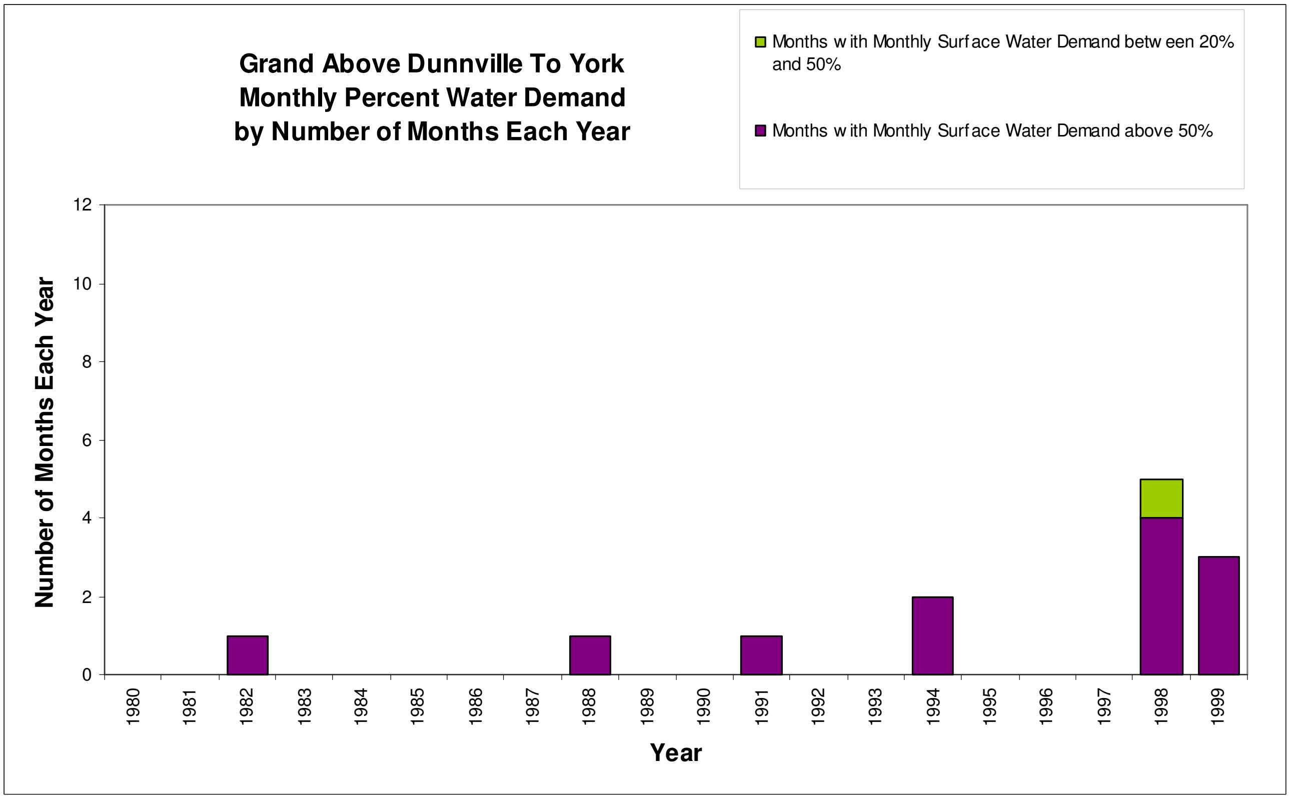


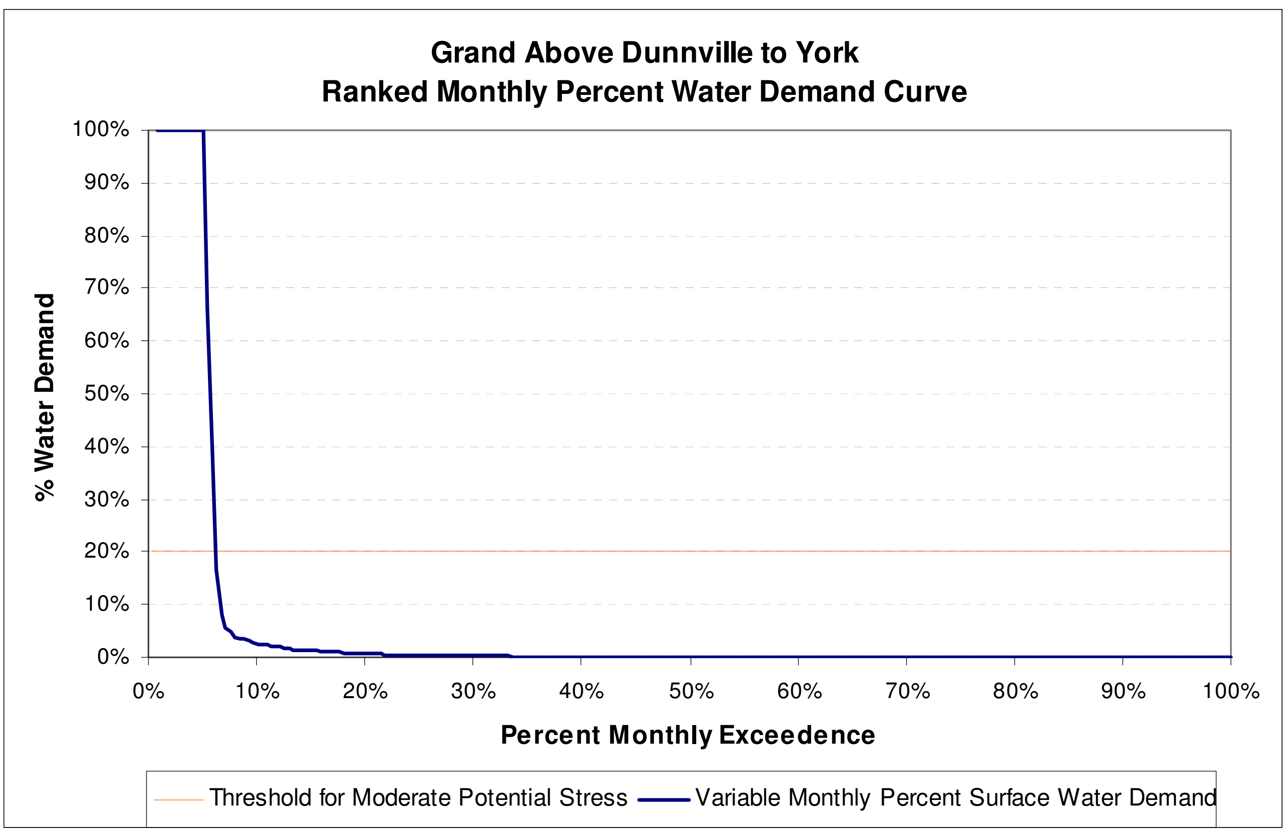
A16. Fairchild Creek



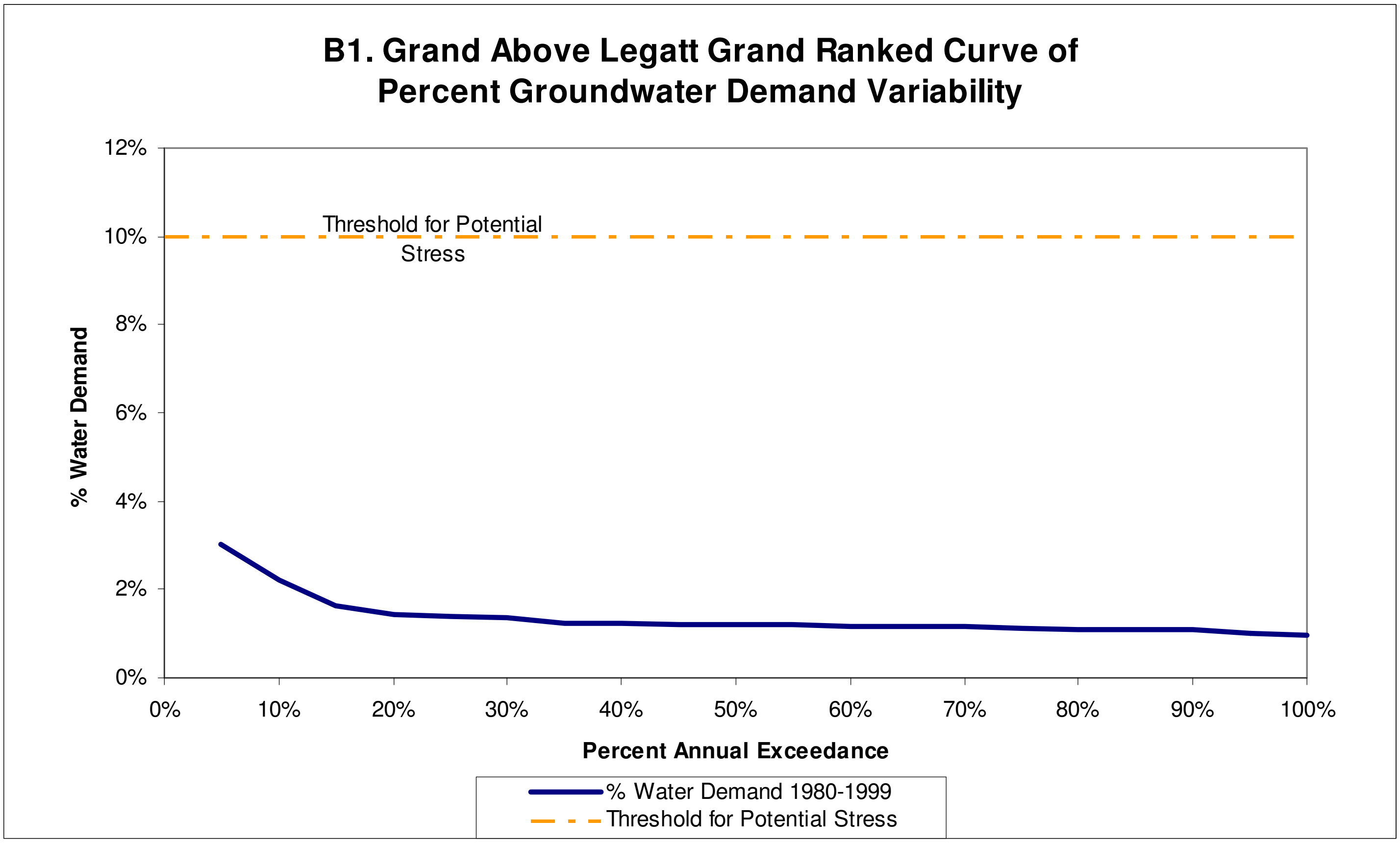


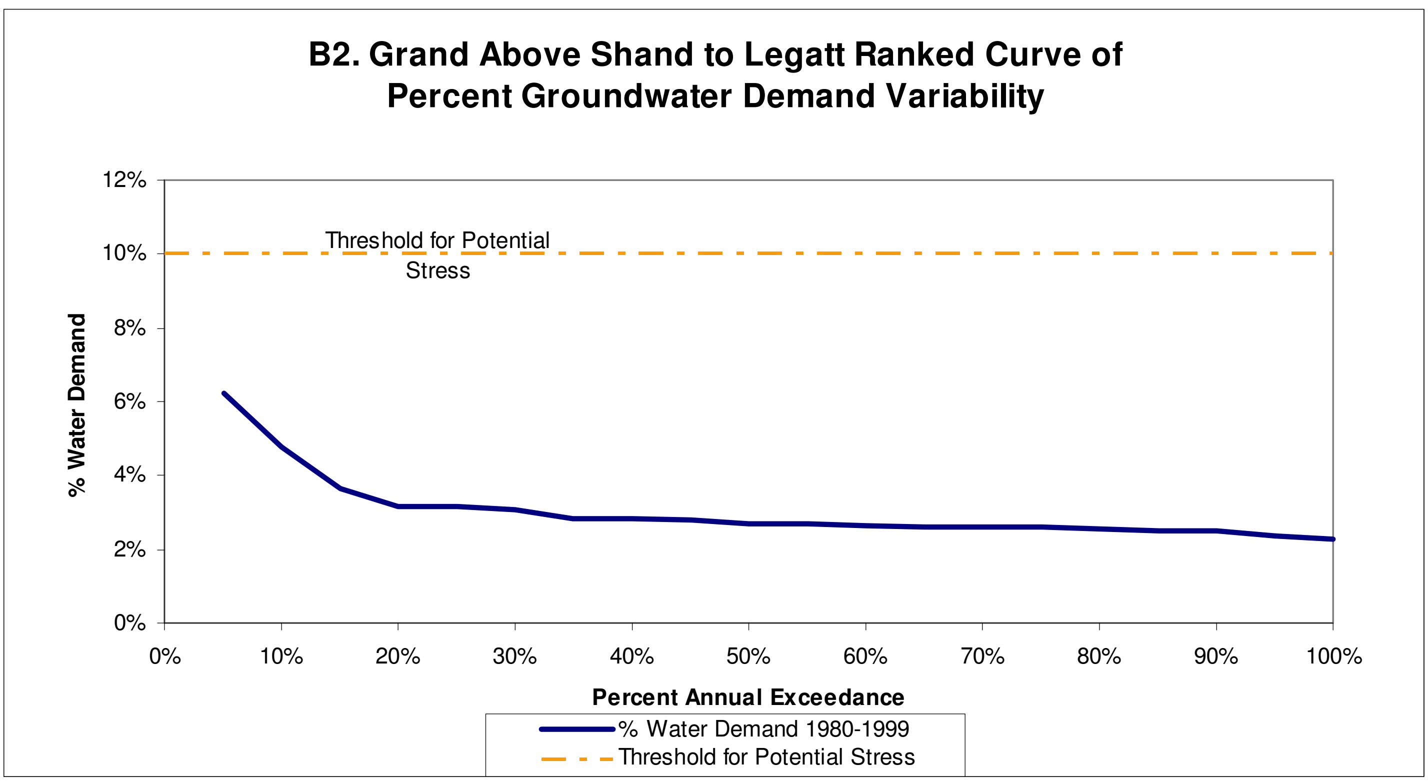
A17. McKenzie Creek

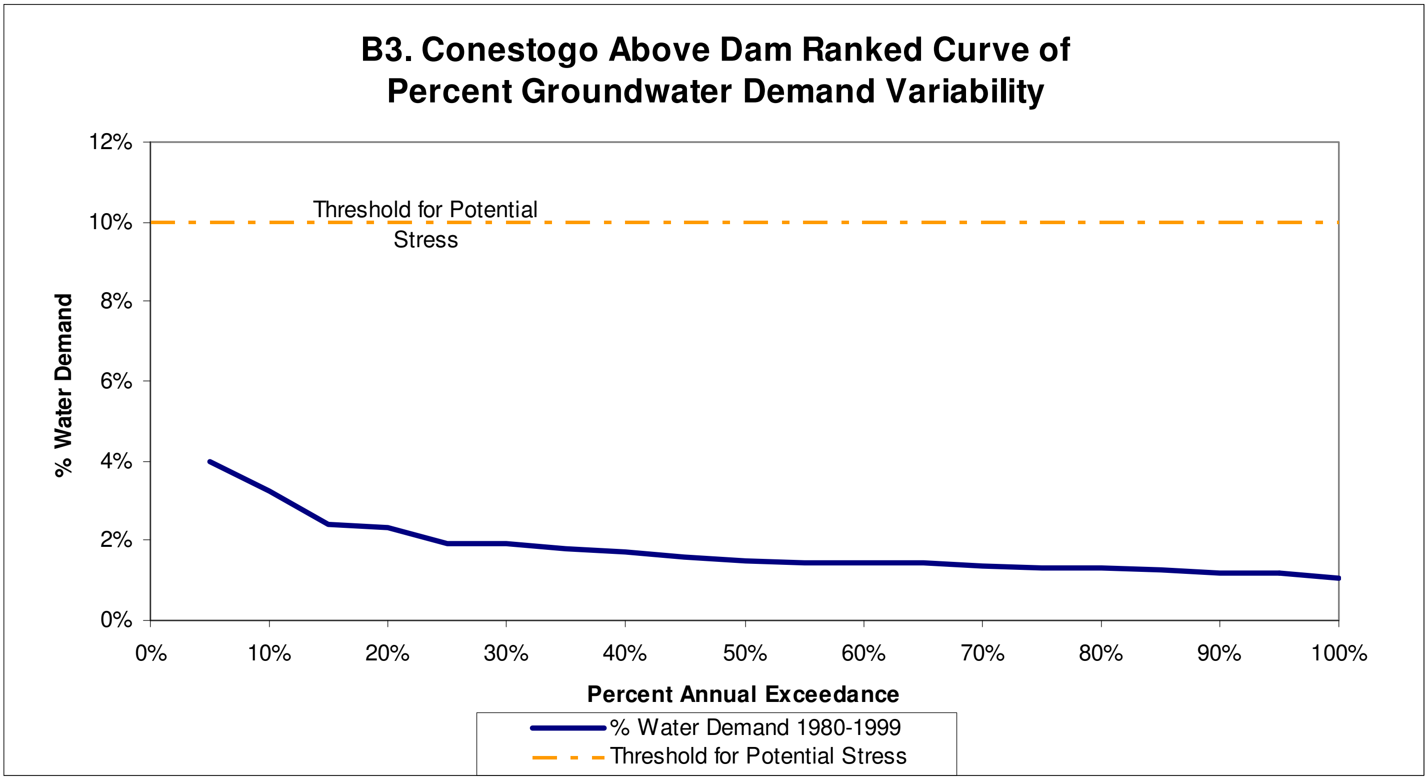


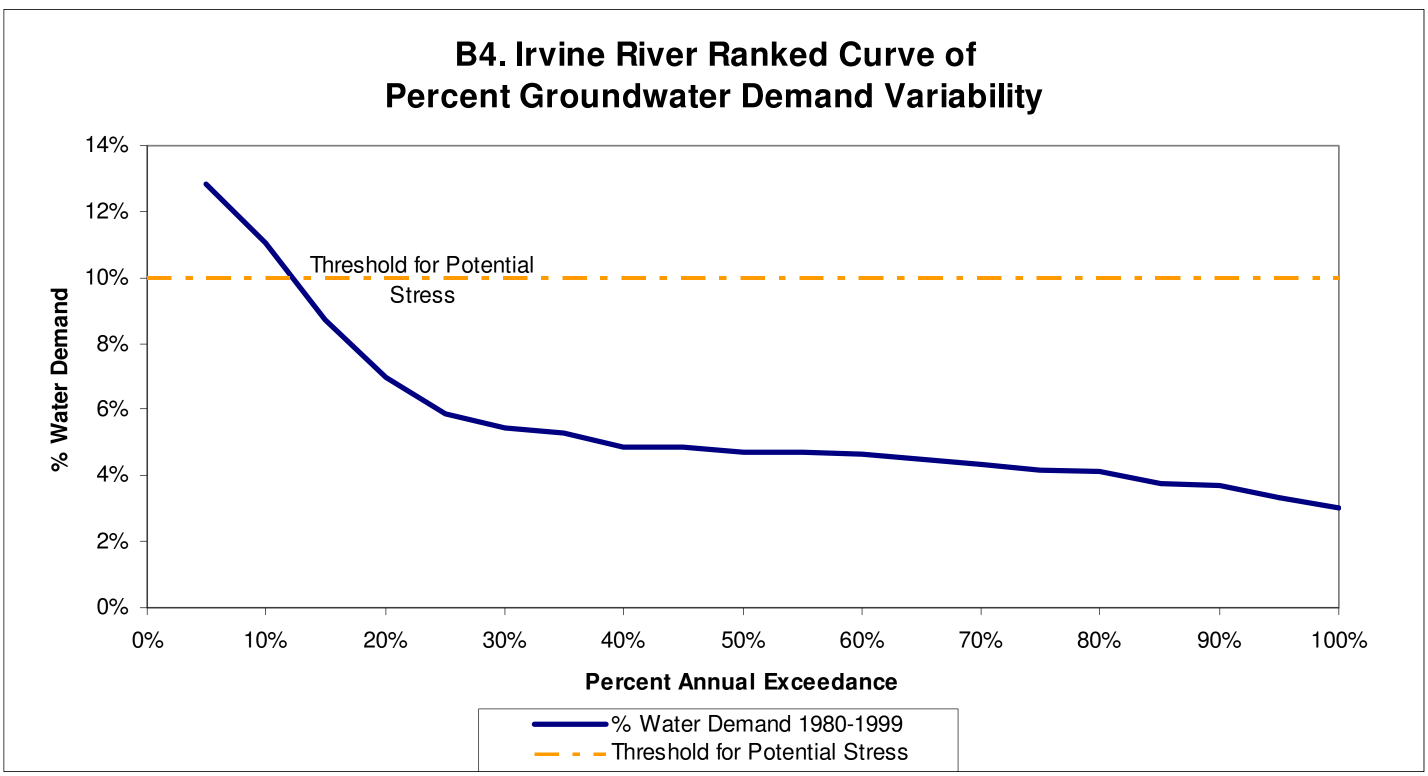


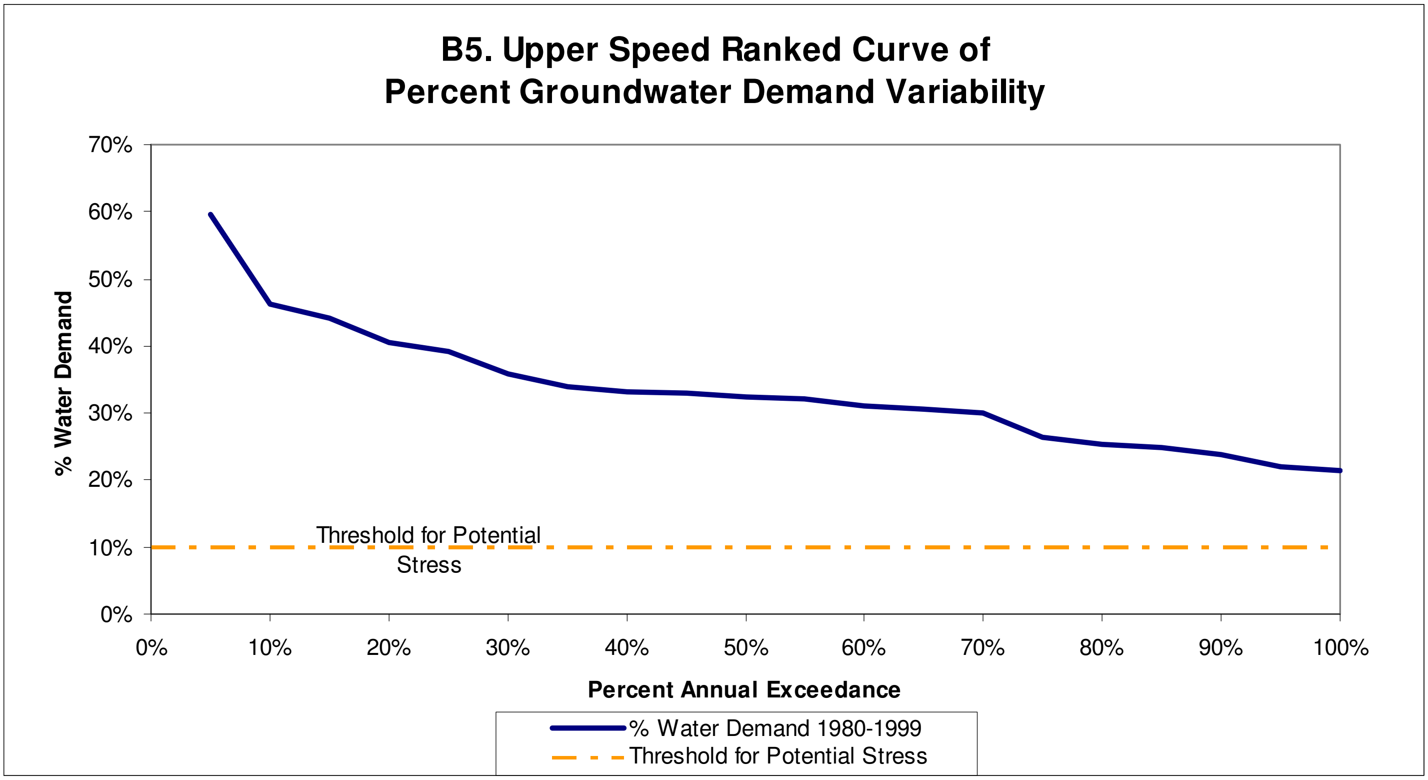
A18. Grand Above Dunnville to York


B1. Grand Above Legatt Grand Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

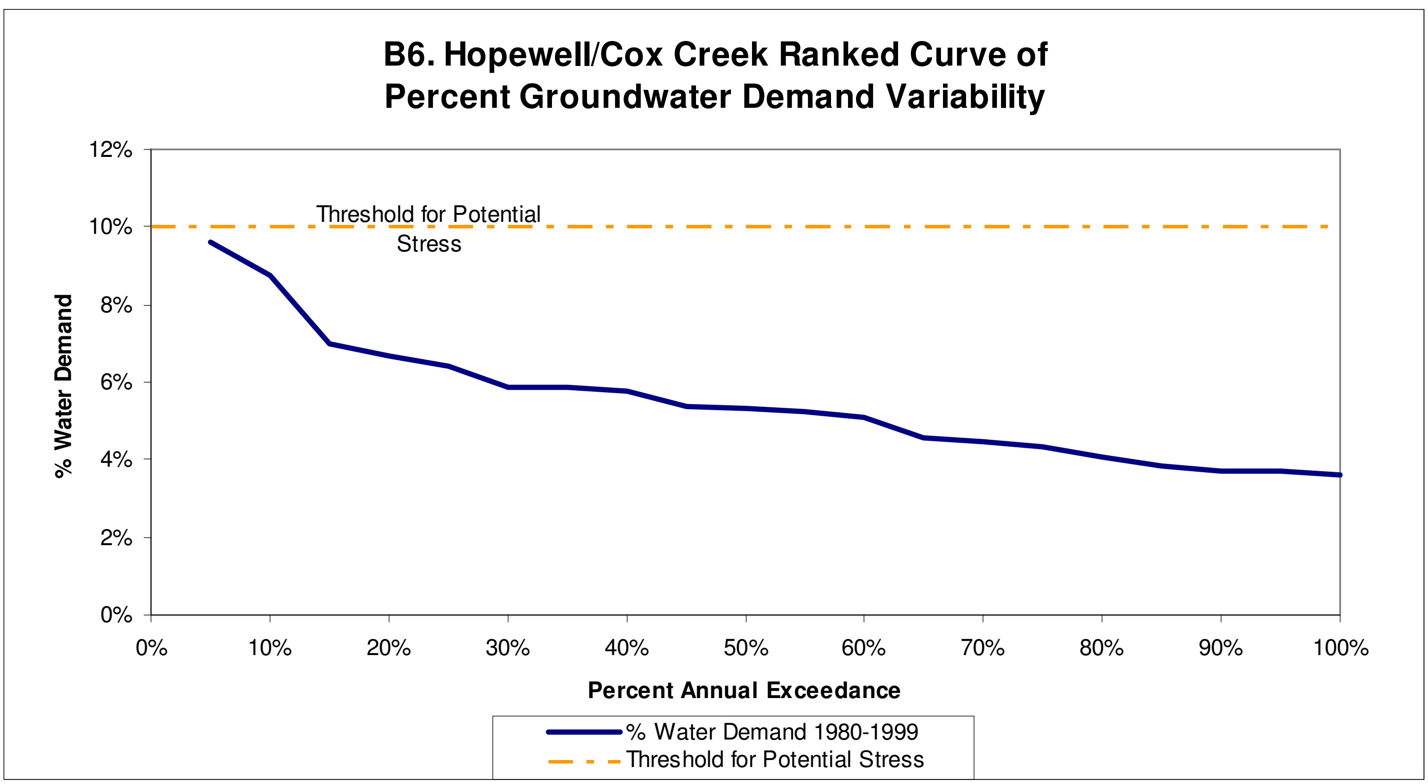

B2. Grand Above Shand to Legatt Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress


B3. Conestogo Above Dam Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

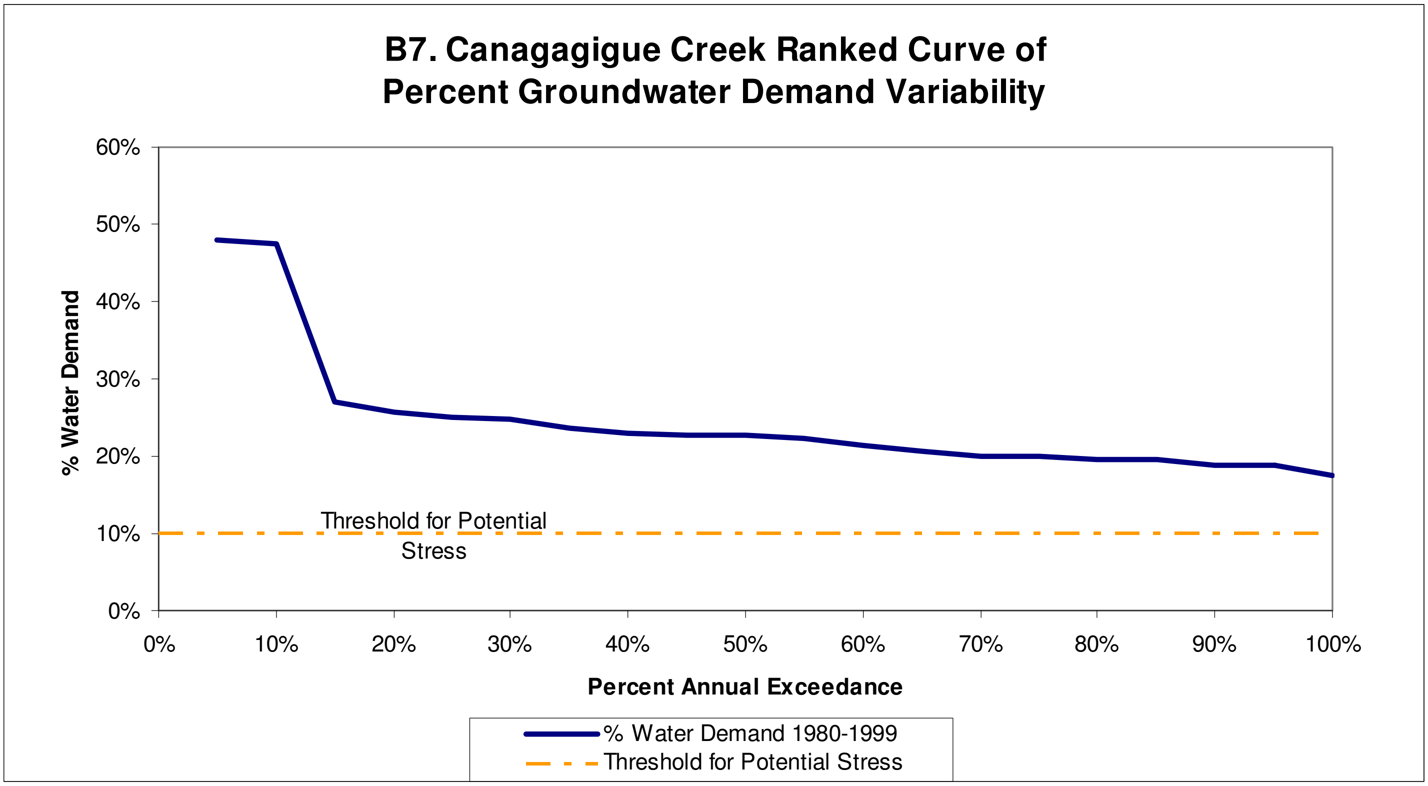

B4. Irvine River Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
14%
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress



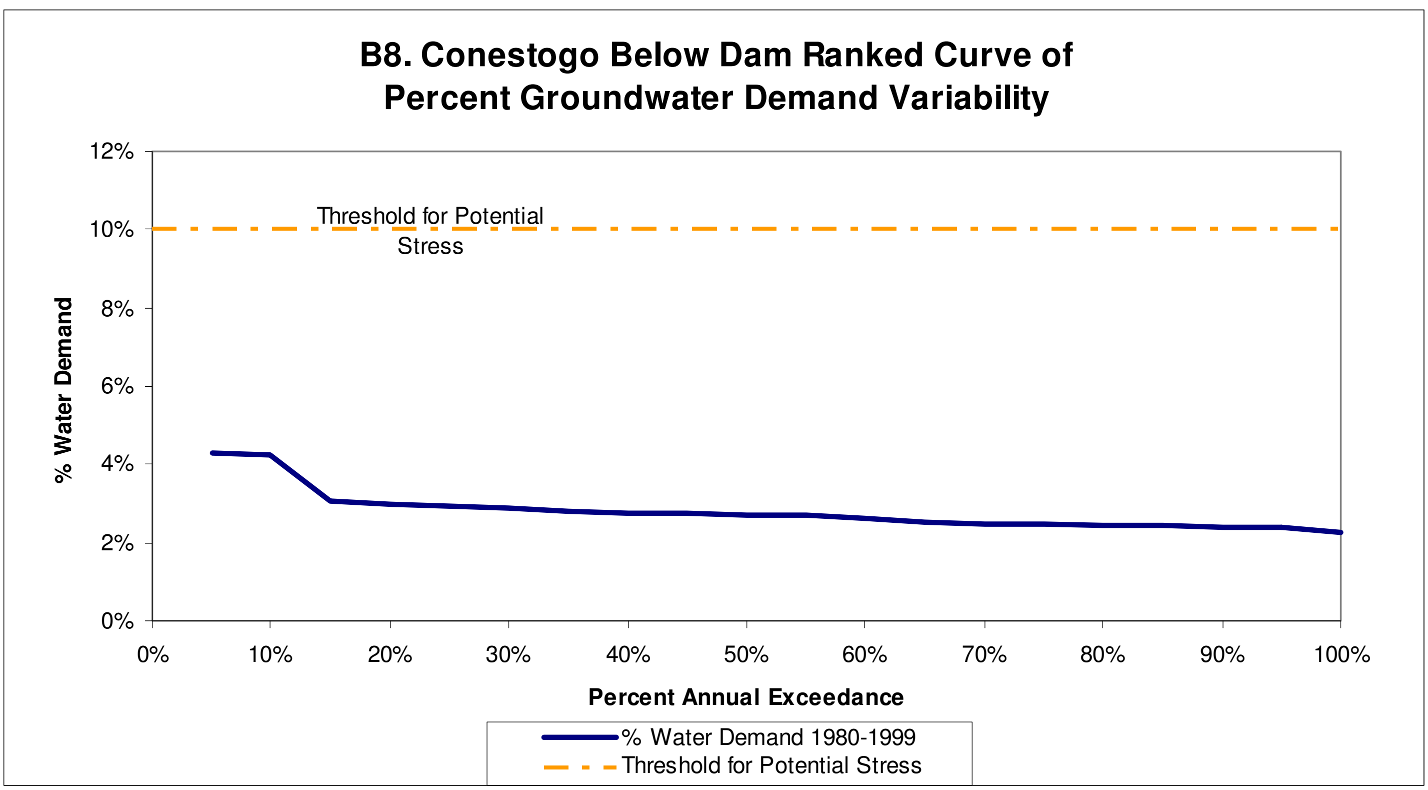
B5. Upper Speed Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
70%
60%
50%
40%
30%
20%
10%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress



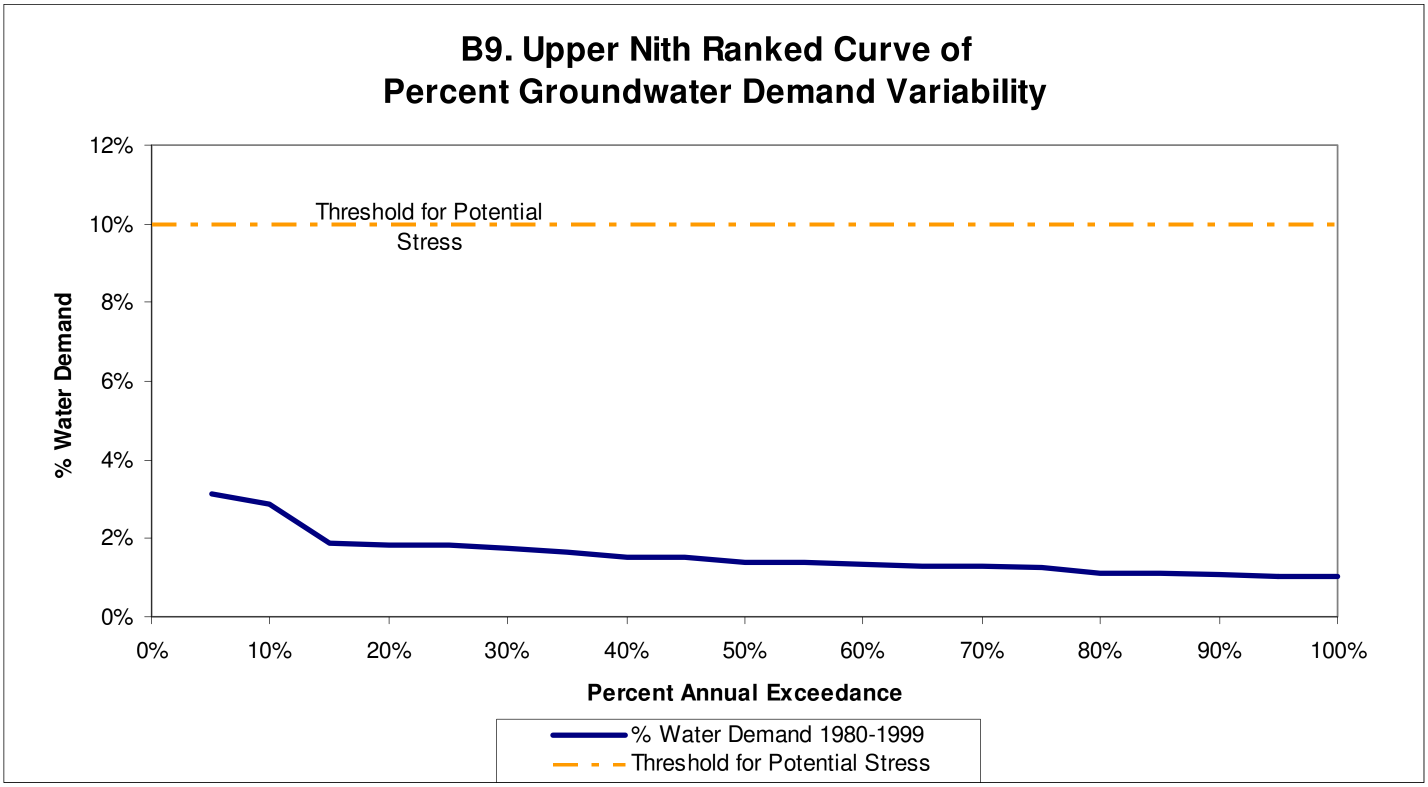
B6. Hopewell/Cox Creek Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

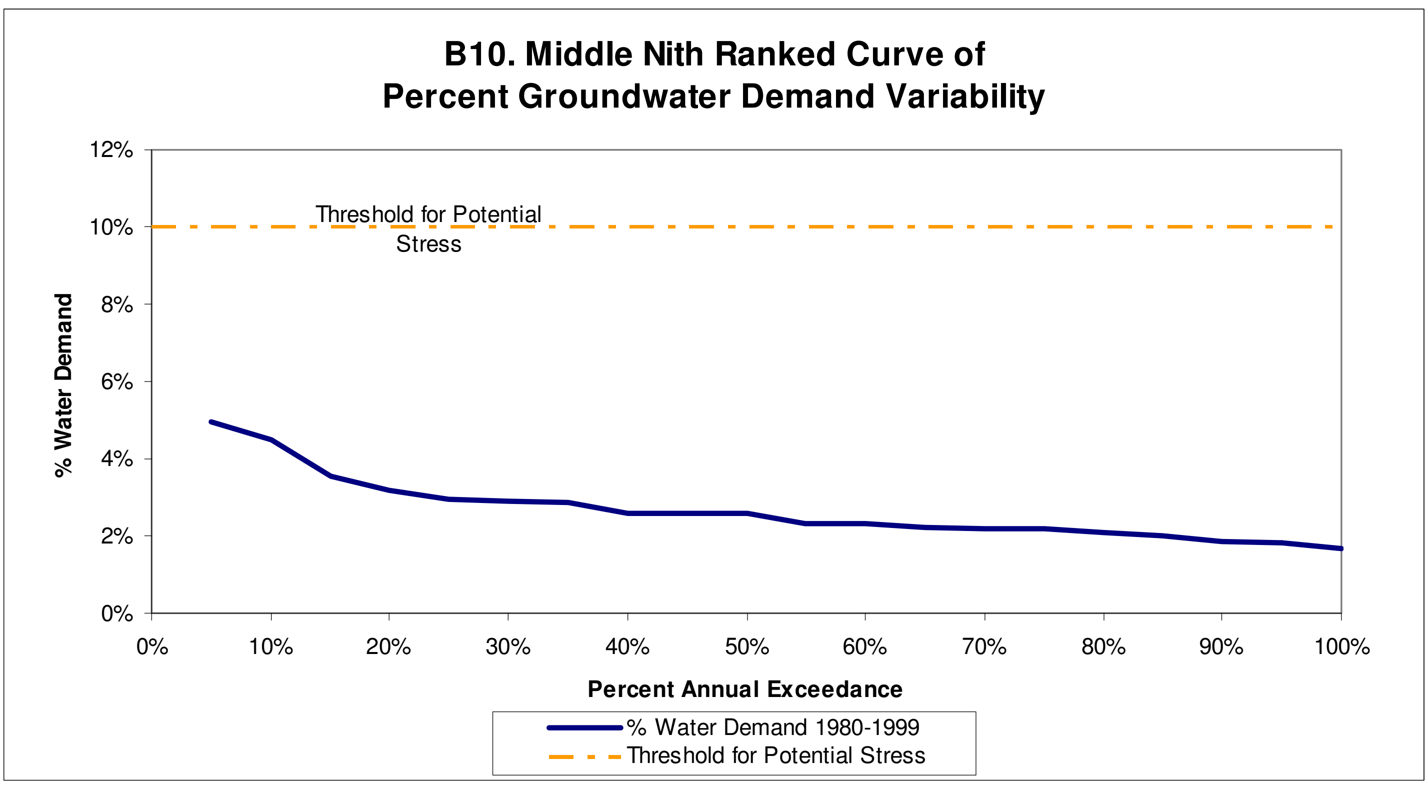


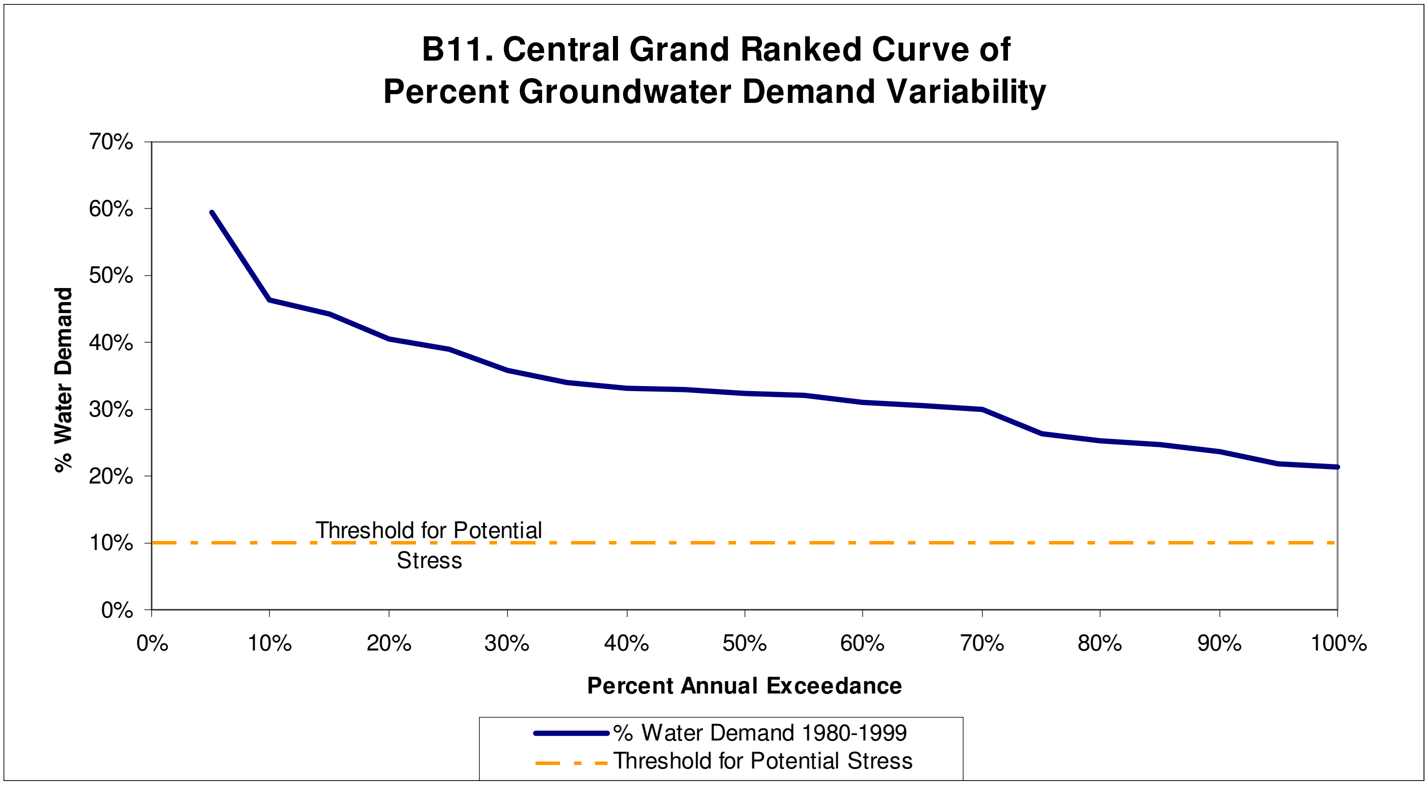
B7. Canagagigue Creek Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
60%
50%
40%
30%
20%
10%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

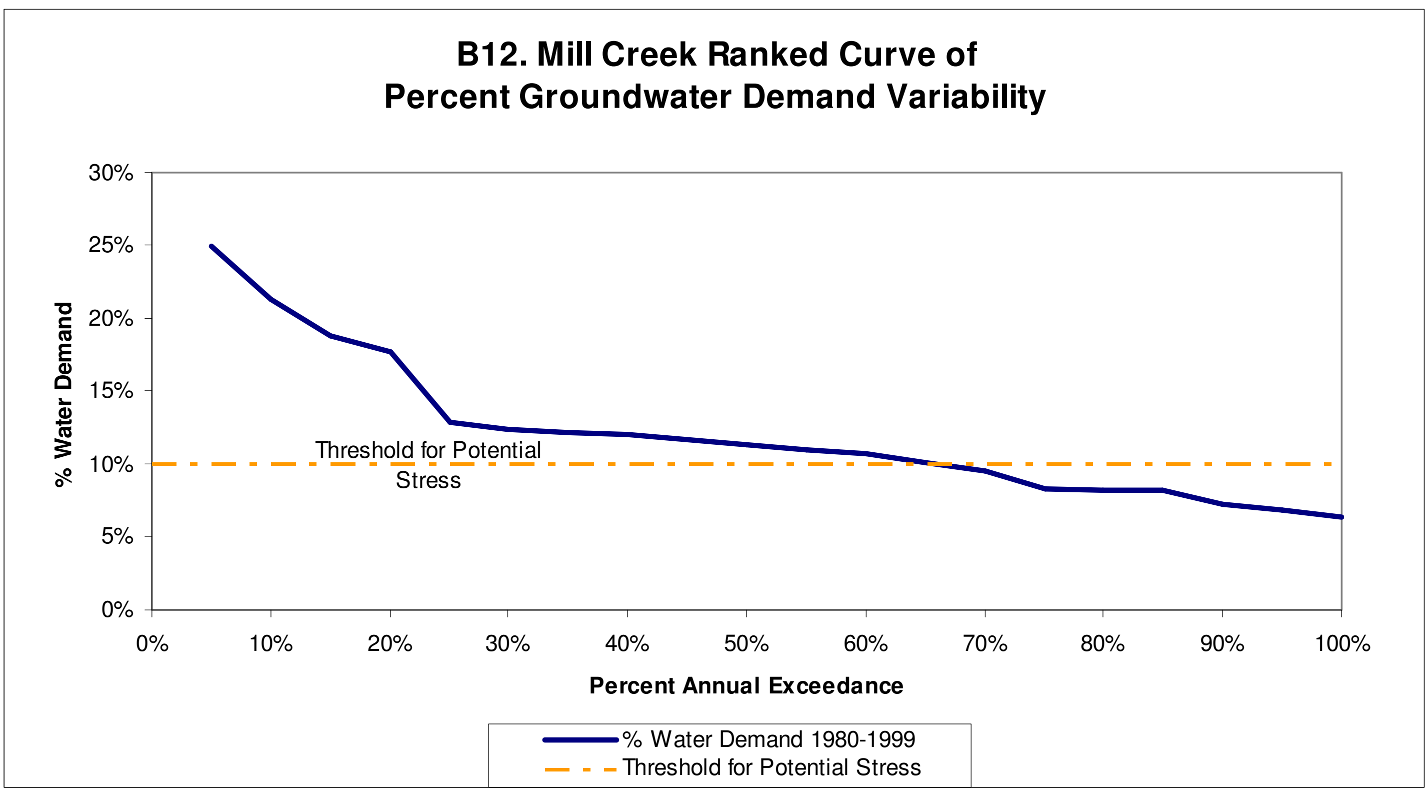


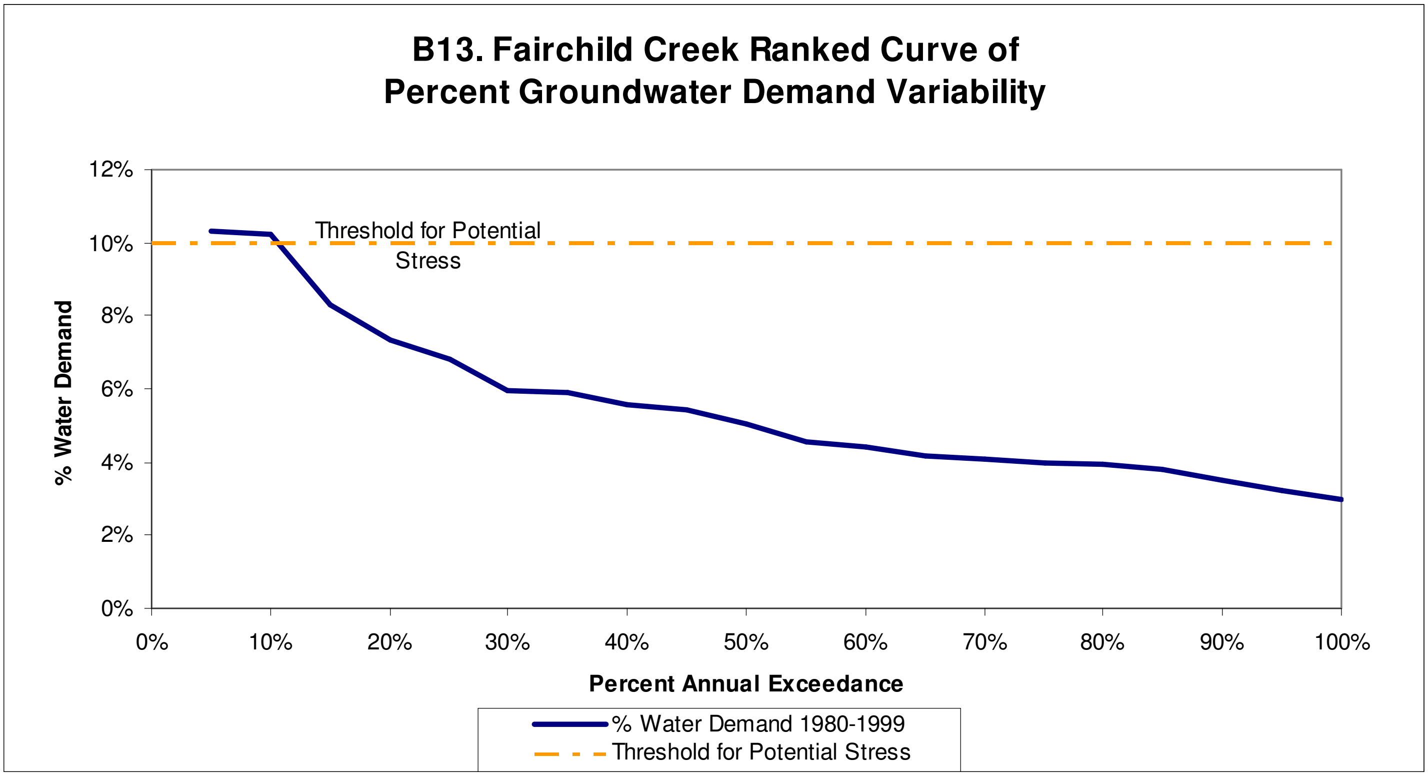
B8. Conestogo Below Dam Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

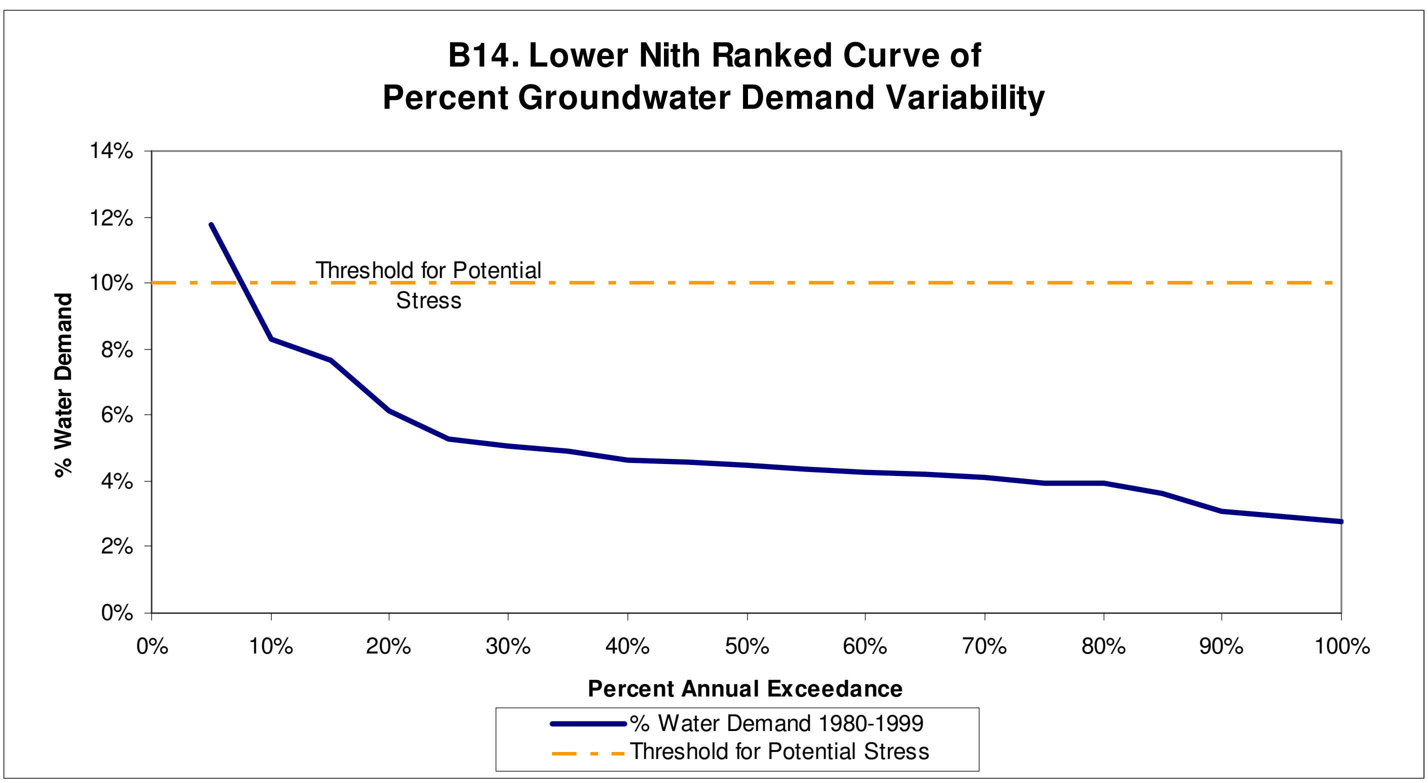

B9. Upper Nith Ranked Curve of
Percent Groundwater Demand Variability
12%
10%
8%
6%
4%
2%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

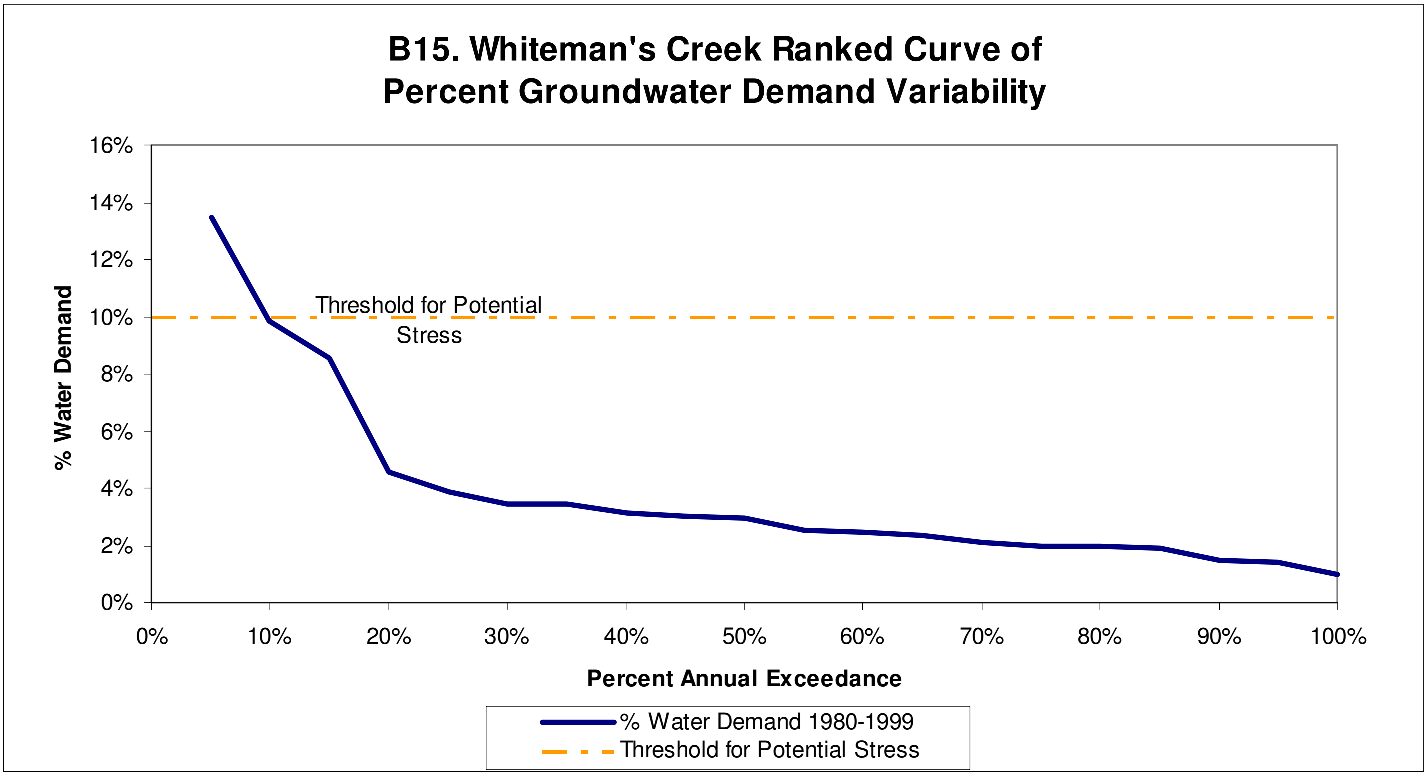

B10. Middle Nith Ranked Curve of
Percent Groundwater Demand Variability
12%
10%
8%
6%
4%
2%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

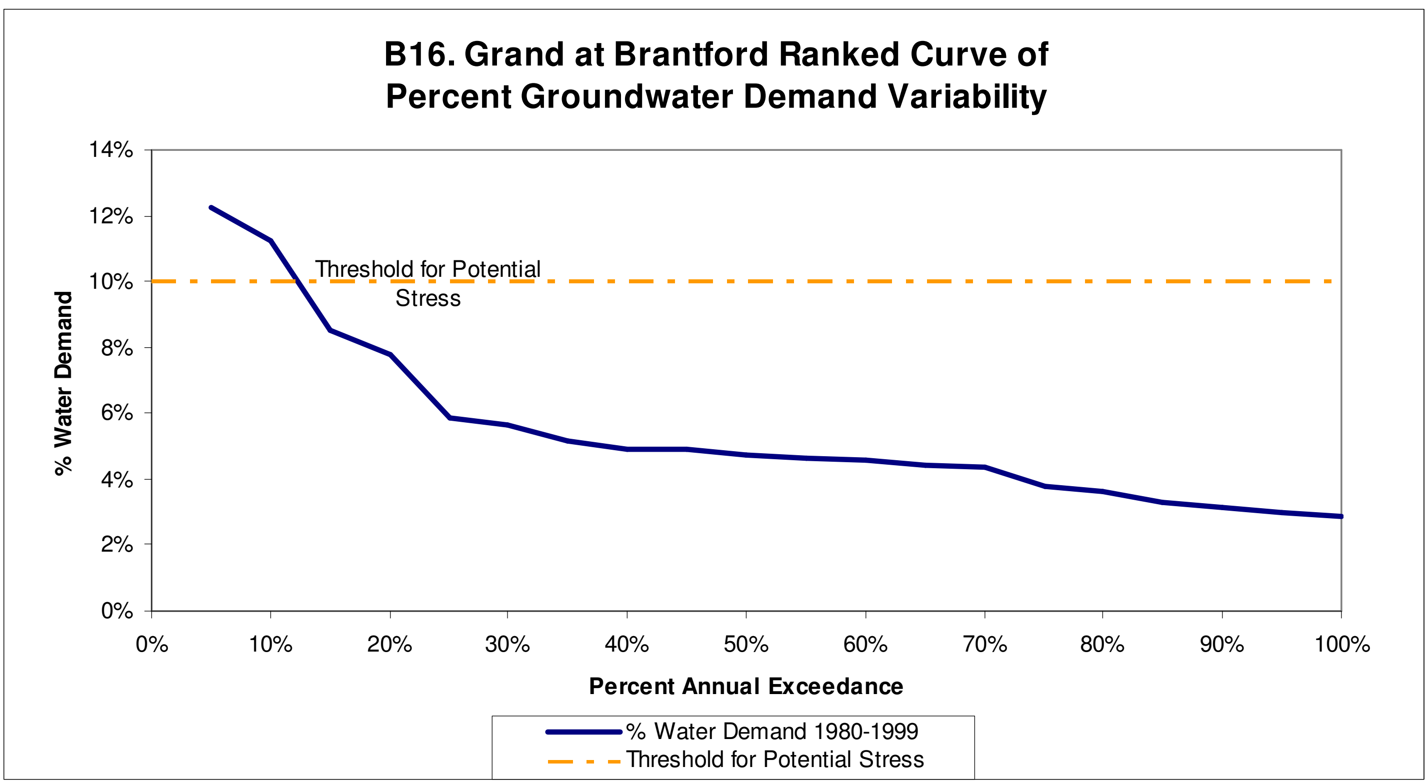

B11. Central Grand Ranked Curve of
Percent Groundwater Demand Variability
70%
60%
50%
40%
30%
20%
10%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

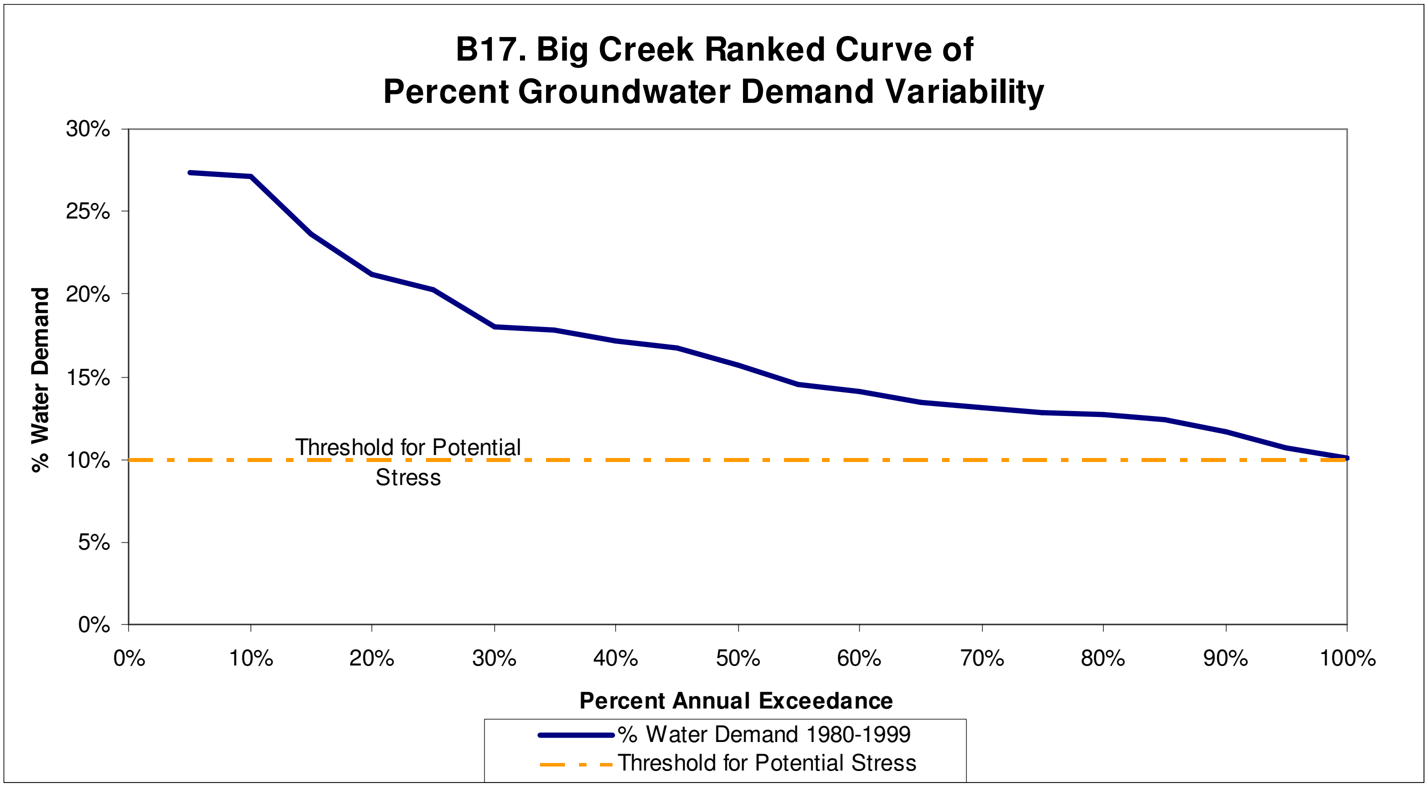

B12. Mill Creek Ranked Curve of
Percent Groundwater Demand Variability
30%
25%
20%
15%
10%
5%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

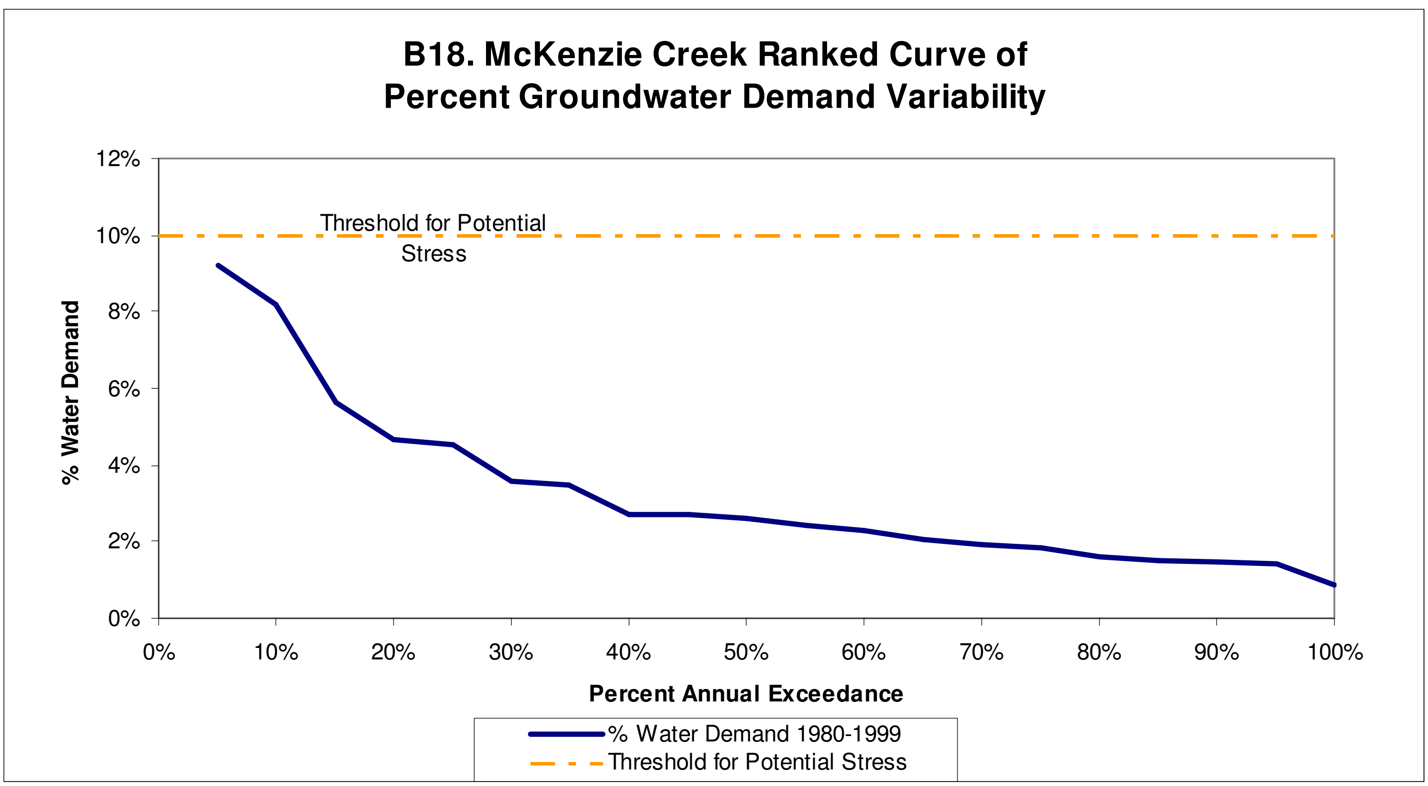

B13. Fairchild Creek Ranked Curve of
Percent Groundwater Demand Variability
12%
10%
8%
6%
4%
2%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

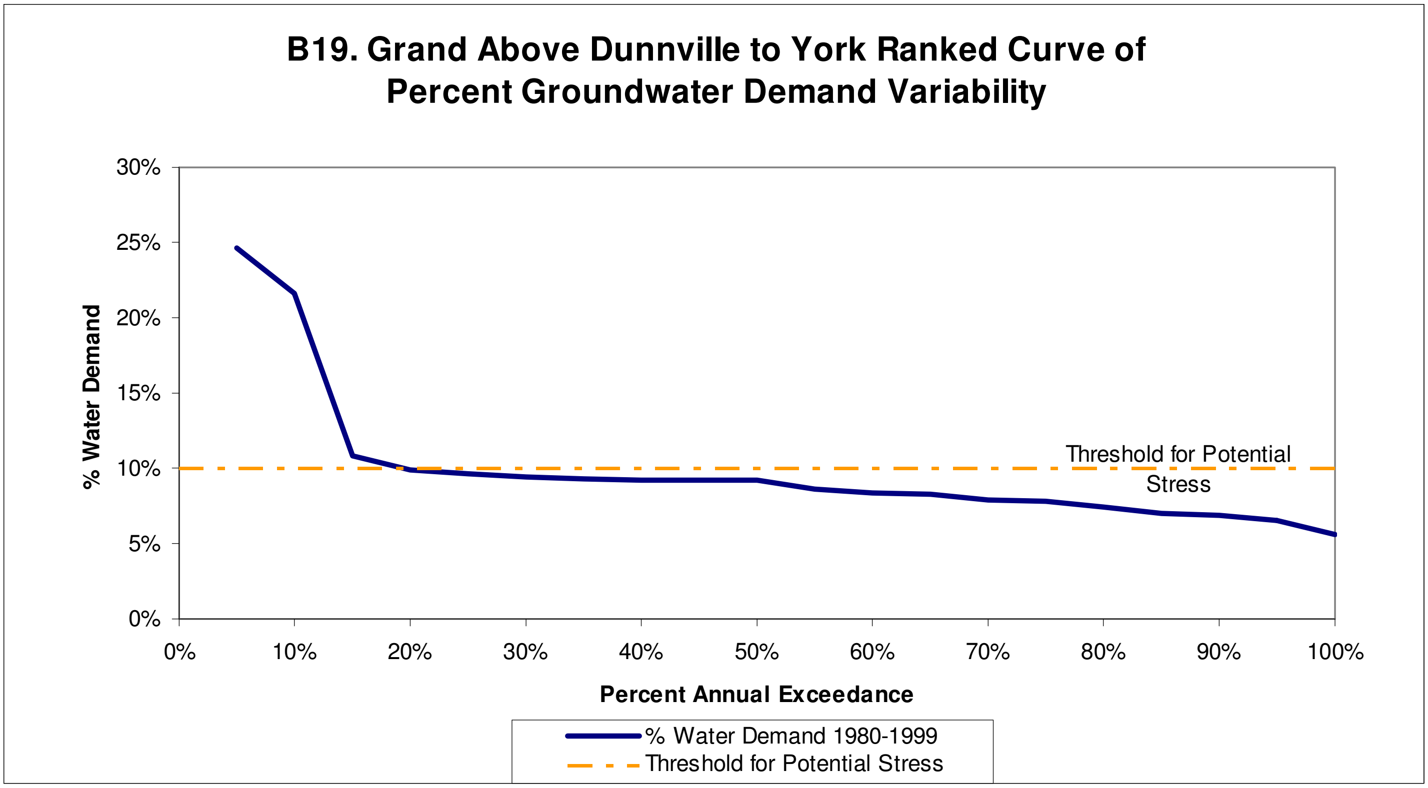

B14. Lower Nith Ranked Curve of
Percent Groundwater Demand Variability
14%
12%
10%
8%
6%
4%
2%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress


B15. Whiteman's Creek Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
16%
14%
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress


B16. Grand at Brantford Ranked Curve of
Percent Groundwater Demand Variability
% Water Demand
14%
12%
10%
8%
6%
4%
2%
0%
Threshold for Potential Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress


B17. Big Creek Ranked Curve of
Percent Groundwater Demand Variability
30%
25%
20%
15%
10%
5%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress


B18. McKenzie Creek Ranked Curve of
Percent Groundwater Demand Variability
12%
10%
8%
6%
4%
2%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress


B19. Grand Above Dunnville to York Ranked Curve of
Percent Groundwater Demand Variability
30%
25%
20%
15%
10%
5%
0%
% Water Demand
Threshold for Potential
Stress
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Annual Exceedance
% Water Demand 1980-1999
Threshold for Potential Stress

Municipality - Lower Tier	GW Assessment Area	Well	Maximum Drawdown (m below initial water level)	Minimum Drawdown (m above initial water level)	Absolute Variability (range in m)
COUNTY OF BRANT	Fairchild Creek	MUN_St__George	-2.14	+0.01	2.15
	Grand at Brantford	MUN_Brantford_Airport	-3.75	+0.71	4.47
		MUN_Mount_Pleasant_(maple)	-2.47	+0.63	3.09
	Lower Nith	MUN_Paris_(Gilbert_-_Lower_Aquifer)	-2.46	+0.31	2.77
		MUN_Paris_(Gilbert_-_Upper_Aquifer)	-2.49	+0.32	2.81
		MUN_Paris_(Telfer)	-2.13	+0.02	2.15
TOWNSHIP OF BLANDFORD-BLENHEIM	Lower Nith	MUN_Drumbo_	-2.70	+0.04	2.74
		MUN_Princeton_	-2.51	+0.34	2.84
		MUN_Plattsville_	-1.86	+0.74	2.60
	Whitemans Creek	MUN_Well_4_Bright	-7.02	+7.58	14.60
TOWNSHIP OF CENTRE WELLINGTON	Irvine River	MUN_Elora_E1	-4.30	+0.08	4.38
		MUN_Fergus_1	-1.16	+0.01	1.18
		MUN_Fergus_2	-2.98	+0.02	3.01
		MUN_Fergus_4	-2.95	+0.19	3.13
		MUN_Fergus_5	-2.76	+0.39	3.15
		MUN_Fergus_6	-3.56	+2.31	5.86
TOWNSHIP OF EAST LUTHER GRAND VALLEY	Grand Above Shand to Legatt	MUN_Grand_Valley_PW-1	-0.67	+0.51	1.18
		MUN_Grand_Valley_PW-3	-0.61	+0.43	1.03
		MUN_Grand_Valley_PW-4	-0.61	+0.43	1.04
TOWNSHIP OF MAPLETON	Conestogo Above Dam	MUN_Drayton_1967	-0.85	+0.03	0.87
TOWNSHIP OF NORTH DUMFRIES	Lower Nith	MUN_A1	-1.31	+0.40	1.70
		MUN_A2	-1.34	+0.40	1.74
		MUN_BM1	-2.05	+0.06	2.11
		MUN_BM2	-2.05	+0.06	2.11
		MUN_R5	-2.96	+0.08	3.04
		MUN_R6	-3.03	+0.06	3.09
TOWNSHIP OF PERTH EAST	Upper Nith	MUN_Milverton_PW-5	-0.35	+0.11	0.47
TOWNSHIP OF SOUTHGATE	Grand Above Legatt	MUN_Dundalk_5043	-2.60	+0.39	2.99
		MUN_Dundalk_897	-2.75	+0.20	2.95
		MUN_Dundalk_898	-2.87	+0.08	2.94
TOWNSHIP OF WELLESLEY	Conestogo Below Dam	MUN_L1A	-1.08	+0.01	1.09
		MUN_L2	-1.08	+0.01	1.08
		MUN_SC2	-2.36	+0.06	2.42
		MUN_SC3	-2.07	+0.05	2.12
	Upper Nith	MUN_WY1	-1.25	+0.21	1.45
		MUN_WY5	-1.42	+0.17	1.59
TOWNSHIP OF WELLINGTON NORTH	Conestogo Above Dam	MUN_Arthur_2	-0.76	+0.01	0.76
		MUN_Arthur_3	-0.75	+0.01	0.75
		MUN_Arthur_4	-0.81	+0.01	0.81
		MUN_Arthur_5	-0.74	+0.01	0.75
		MUN_Arthur_7	-0.65	+0.01	0.66
TOWNSHIP OF WILMOT	Middle Nith	MUN_B1,_1-73	-2.83	+0.01	2.84
		MUN_FG1	-3.75	+0.94	4.69
		MUN_FG2	-3.77	+0.98	4.75
		MUN_K50	n/a	n/a	n/a
		MUN_K51	n/a	n/a	n/a
		MUN_ND4	-1.81	+0.06	1.87
		MUN_ND5	-1.92	+0.05	1.98
		MUN_NH3	-1.51	+0.08	1.59
	Upper Nith	MUN_SA6	-5.78	+1.92	7.70
TOWNSHIP OF WOOLWICH	Conestogo Below Dam	MUN_HD1	-3.12	+0.15	3.27
		MUN_HD2	-3.46	+0.16	3.62
	Hopewell/Cox Creek	MUN_C1	-1.44	+0.68	2.12
		MUN_C2	-1.54	+0.67	2.22
		MUN_C5	-1.54	+0.63	2.17
		MUN_MH1	-1.71	+0.09	1.80
		MUN_MH2	-1.93	+0.27	2.20
		MUN_MH3	-1.75	+0.09	1.85
		MUN_MH4	-1.76	+0.07	1.83