FINAL REPORT

A REVIEW OF ONTARIO'S WATER QUANTITY MANAGEMENT FRAMEWORK:
WATER QUANTITY STUDY AREA REPORT

Prepared for:

Government of Ontario
Ministry of the Environment, Conservation and Parks
Standards Development Branch
7th Floor, 40 St Clair Avenue West
Toronto, ON M4V 1M2

Prepared by:

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Project Number: 180107-06
Submission Date: 28 March 2019

This report has been separated in 5 sections for internet posting.

REPORT BODY AND APPENDIX C

APPENDIX A - PART 1

- FIGURES for Guelph – Centre Wellington, Orangeville and Norfolk Sand Plain Water Quantity Study Areas

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Appendix B has been removed from the posted report in accordance with privacy requirements.

(Inserted by the Ministry of the Environment, Conservation and Parks, June 2020)

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GLOSSARY OF TERMS, ACRONYMS AND DEFINITIONS

Application – Means an application to a Director under section 34 of the Ontario Water Resources Act for a Permit to Take Water.

Aquifer – A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses. Or in Ontario "Aquifer means a water-bearing formation that is capable of transmitting water in sufficient quantities to serve as a source of water supply" (R.R.O. 1990, Reg. 903: WELLS under Ontario Water Resources Act, R.S.O. 1990, c. O.40).

Aquifer (confined) – soil or rock below the land surface that is saturated with water. There are layers of impermeable material both above and below the aquifer. It is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.

Aquifer (unconfined) – an aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall.

Aquitard – a geologic formation or stratum that lies adjacent to an aquifer and that allows only a small amount of liquid to pass.

Artesian water – groundwater that is under pressure and is able to rise above the level at which it is first encountered when tapped by a well. It may or may not flow out at ground level. The pressure in such an aquifer is commonly called artesian pressure, and the formation containing artesian water is an artesian aquifer or confined aquifer. See *Flowing well*.

Baseflow – sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural baseflow is sustained largely by groundwater discharge.

Bedrock – the solid rock beneath the soil and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

Best Practices – are the practices and approaches being used for water management science in Ontario and other jurisdictions under a variety of conditions that are effective and efficient and produce reasonable results.

Bottled water – potable water that is intended for human consumption and that is packaged in bottles or other portable containers.

CA – Conservation Authority

Cumulative Effects/Impacts – changes to surface water or groundwater resources that are caused or altered by an action in combination with other human or natural actions or conditions. In the context of the Assessment of Water Resources to Support a Review of Ontario's Water Quantity Management Framework (2018), Cumulative Effects include not only consideration of the changes to surface water and groundwater caused by multiple takings of surface or groundwater, but also considers the effects of climate change, population growth and related land use changes. In comparison, Cumulative Impacts only considers changes to surface water or groundwater resources that are caused or altered by multiple takings of surface or groundwater and their impact on other human or natural features.

Discharge – the volume of water that passes a given location within a given period of time. Usually expressed as volume over time (e.g. m^3/s).

Drainage basin – land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Grand River, contain smaller drainage basins or sub-watersheds. See *Watershed*.

Drawdown – a lowering of the groundwater surface caused by pumping.

Drought – a period of below-average precipitation in a given region, resulting in prolonged shortages in the water supply, whether atmospheric, surface water or groundwater. What officially constitutes drought differs from jurisdiction to jurisdiction.

Ecosystem-based management – an integrated management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation.

Environmental Setting – the milieu or aggregate of the surroundings including climate, diversity, geographic variability, watershed characteristics, geological and hydrogeological variability and aquifer types.

Environmental Flow Needs – the flows (quantity and timing) and water levels required in a water body to sustain freshwater ecosystems and the ecological function of the flora and fauna present within that water body and its margins.

Evidence-based decision making – means using the best available research, analytics, information and data supported by clear standards to guide decisions on policy and program development, delivery and evaluation process.

Flowing well/spring – a well or spring that taps groundwater under pressure so that water rises above ground surface without pumping. See *Artesian water.*

Freshwater – water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

Gauging station – a site on a stream, lake, reservoir or other body of water where observations and hydrologic data are obtained. Also called a stream gauge when located on a stream, river, or similar body of flowing water.

Groundwater, confined – groundwater under pressure significantly greater than atmospheric, with its upper limit corresponding to the bottom of a bed with hydraulic conductivity distinctly lower than that of the material in which the confined water occurs.

Groundwater – (1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturated zone at atmospheric pressure is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

Groundwater, unconfined – water in an aquifer that has a water table that is exposed to the atmosphere.

Groundwater recharge – inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also used to define the volume of water added by this process. Alternatively, "groundwater recharge" means the replenishment of subsurface water, (a) resulting from natural processes, such as the infiltration of rainfall and snowmelt and the seepage of surface water from lakes, streams and wetlands, and (b) resulting from human intervention, such as the use of stormwater management systems (O. Reg. 140/02: OAK RIDGES MORAINE CONSERVATION PLAN under Oak Ridges Moraine Conservation Act, 2001, S.O. 2001, c. 31)

Headwater(s) – (1) the source and upper reaches of a stream; also the upper reaches of a reservoir. (2) the water upstream from a structure or point on a stream. (3) the small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstream river and main tributaries.

High Use Watershed – the areas shown on the Average Annual Flow Map or the Summer Low Flow Map in Ontario Regulation 387/04 (Water Taking and Transfer).

Impermeable layer – a layer of solid material, such as rock or clay, which does not allow water to pass through.

Infiltration – flow of water from the land surface into the subsurface.

MECP – Ontario Ministry of the Environment, Conservation and Parks, the 'ministry'.

MNRF – Ontario Ministry of Natural Resources and Forestry.

Municipal Water Supply – Means the supply of a large municipal residential system or of a small municipal residential system.

OLWR – Ontario Low Water Response Program

Ontario Water Managers or "Water Managers" – any person responsible for the regulation, planning, development and distribution and use of water resources.

OWRA – Ontario Water Resources Act

Peak flow – the maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.

Percolation – (1) The movement of water through the openings in rock or soil. (2) the entrance of a portion of the streamflow into the channel materials to contribute to groundwater replenishment.

Permeability – the ability of a material to allow the passage of a liquid, such as water, through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable materials, such as clay, do not allow water to flow freely.

Permit Holder – Holder of an active Permit to Take Water.

PGMN – Provincial Groundwater Monitoring Network

Porosity – a measure of the water-bearing capacity of subsurface rock or unconsolidated overburden materials. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected (effective porosity), as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small.

Potentiometric surface/piezometric surface – the imaginary line where a given reservoir of fluid under pressure would rise if allowed to flow, for example if penetrated by wells; a potentiometric surface is based on hydraulic principles.

Precipitation – rain, snow, hail, sleet, dew, and frost.

PTTW/Permit – a permit to take water under the *Ontario Water Resources Act*.

Recharge – water added to an aquifer. For instance, rainfall that seeps into the ground.

Recovery – the hydraulic response at a pumping well or observation well after pumping has stopped.

Reservoir – a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

River – a natural stream of water of considerable volume, larger than a brook or creek.

Runoff – (1) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or groundwater runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

Setting – the physical, chemical and biological environment (such as climate, geology, soil, and plants and animals living in or on the water) in which a resource is situated and which determine its characteristics and behaviour.

Source Water Protection Authority – A conservation authority or other person or body that is required to exercise and perform the powers and duties of a drinking water source protection authority under the Ontario Clean Water Act.

Species at Risk (SAR) – species protected under the federal Species at Risk Act and/or the Ontario Endangered Species Act.

Specific Capacity – the productivity of a well in terms of discharge rate per unit of drawdown in the well.

Spring – a water body formed when the side of a hill, a valley bottom or other excavation intersects a flowing body of groundwater at or below the local water table, below which the subsurface material is saturated with water.

Stakeholders – people who have a share or an interest in water.

Storativity (or Storage Coefficient) – the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in the component of hydraulic head normal to that surface.

Stream – a general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.

Streamflow – the water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Surface water – water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Sustainability – development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. There are three spheres of sustainability: the economy, society and the environment. They have a dynamic relationship, which means that any change to one affects the others. It is the reason why we cannot consider our economy or quality of life separately from the well-being of our natural environment.

Sustainable Yield – Means the maximum rate of taking from an aquifer that can be sustained without causing unacceptable impact on other users and natural system functions, and without causing unacceptable degradation of water quality in the aquifer.

Tool – a process, method or computer program / routine used in the implementation of an "approach" as defined for the purposes of this project. For the purposes of this study, a tool does not include a physical device or physical implement.

Transmissivity (T) – the rate at which groundwater is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is often expressed as the product of hydraulic conductivity and the full saturated thickness of the aquifer and has units of the form m^3/day/m.

Tributary – a smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.

Water Balance – Means a quantification of water input and output and changes in storage of the various components of the hydrologic cycle.

Water bottling facility – any facility that requires a permit for taking groundwater for the purpose of producing bottled water.

Water Bottling Study Area and **WBSA** – areas associated with water bottlers that are being assessed as part of the Assessment of Water Resources to Support a Review of Ontario's Water Quantity Management Framework (2018).

Water Quantity Assessment – the determination of the sources, extent, dependability and quality of water resources for their utilization and control. Water resources in turn can be defined as the water available, or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand.

Water Quantity Management Framework – policies, programs and science, information including data collection and assessment tools, used in the management of water use.

Water Quantity Protection External Working Group – an external working group established by the Ministry to provide an open and collaborative forum to share expertise and provide input to strengthen groundwater and surface water quantity protection as part of Ontario's strategy to better protect water in the province.

Water Quantity Study Area and **WQSA** – each of the 7 areas that are being assessed as part of the Assessment of Water Resources to Support a Review of Ontario's Water Quantity Management Framework (2018).

Water Resources – any groundwater and surface water source that supplies water to the natural environment and that are useful or potentially useful to study. In the context of the Assessment of Water Resources to Support a Review of Ontario's Water Quantity Management Framework (2018), the Great Lakes are not included in the Water Resources being addressed and the focus is on water resources quantity.

Water Security – the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability. (UN-Water, 2013).

Water table – the top of the water surface in the saturated part of an aquifer that is at atmospheric pressure, also referenced as an unconfined aquifer.

Watershed – land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Grand River, contain smaller drainage basins or **sub-watersheds**. See *Drainage basin*.

WWIS – Water Well Information System.

WTRS – Water Taking Reporting System.

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1 INTRODUCTION

The Ontario Ministry of the Environment, Conservation and Parks (MECP, "the Ministry") is completing a review of Ontario's water quantity management framework to assess the current state of understanding and evaluate the ability to manage, protect and conserve water resources locally. The Ministry identified seven (7) Water Quantity Study Areas (WQSAs) where new and/or improved water management approaches may be required considering local challenges, and where a better understanding of the water system's response to factors such as population growth, land use changes, cumulative effects and climate change would allow water managers to better predict, assess and monitor the future state and sustainability of the water resource(s) in each WQSA. The seven WQSAs are shown on **Figure 1-1**, and are listed below along with the water resource(s) of key concern (groundwater (GW) and/or surface water (SW), primary reason for concern):

- Guelph-Wellington County (GW, growth)
- Orangeville (GW, growth)
- Norfolk Sand Plain (GW & SW, demand and drought)
- Innisfil (SW, demand and drought)
- Whitemans Creek (GW & SW, demand and drought)
- Quinte (GW & SW, drought)
- Chapleau (GW)

For some of the WQSAs, a detailed and sophisticated understanding of the flow system and related hydrologic elements and processes of the local water budget already exists; in the lower populated WQSAs, the amount of available information is more limited. For all WQSAs, climate change poses a common and growing concern. The impacts/effects from climate-induced low water conditions have been experienced within many of the WQSAs in recent years. Given all the potential pressures on the sustainability and security of water quantity resources, the assessment herein seeks to better understand Ontario's water management challenges, review current/existing water management approaches, and where appropriate recommend new or improved approaches and tools that could enhance Ontario's water quantity management framework (science, policy and program).

1.1 OBJECTIVES

The objectives of this assessment were to review and summarize the existing available water quantity resource information for each WQSA, assess the current state, review water management approaches and challenges, assess the potential impact(s) of the taking on the sustainability of the resource(s), identify information gaps that may potentially affect current and future water management decisions, and make recommendations for enhancement for resource management approaches for each WQSA, beyond what is currently enabled or applied by the province for each WQSA, considering local water management challenges. More specifically, the objectives for each identified WQSA were to assess the following:

- The current state of the resource, including: how well have water resources been characterized, what are the current demands and what knowledge gaps are present.
- The sustainability of the resource, including an assessment of the security of the resource - a measure of the long term viability of the resources - with respect to the following factors:
    - Cumulative effects of water takings on the natural environment and other water takers.
    - Resiliency of water resources to climate change, population growth, and land use changes.
    - Improvements needed to better predict, assess, and monitor the future state of water resource(s).
    - A qualitative analysis of the economic and societal aspects of the resource sustainability.
- How the local water management concerns and challenges, as well as natural function and ecological needs, are considered in water management decisions, and what alternative or enhanced approaches have been applied.
- Recommendations about management approaches, approaches to address any gaps in knowledge/information and identifying any challenges in accessing information needed to make informed water management decisions.

The evaluation of the available information in each of the identified WQSAs serves to support a broader understanding and target any needed enhancements for the protection of water quantity in Ontario. The report identifies any gaps in knowledge/data, from a science and management perspective, as well as issues and challenges identified by local water managers, and provides recommendations for addressing the gaps and improve the available tools for water management considering identified and/or anticipated pressures locally (e.g., population growth, increased water demand) and more broadly (e.g., climate change).

1.2 SCOPE OF WORK

The Scope of Work for each WQSA, as specified through a Request for Bidders prepared by the ministry (MECP, 2017), included:

1. **Collect existing information on Water Resources and how they are managed**
   - Source Protection water budget, models, risk management plans, etc.
   - Watershed management plans and reports.
   - Existing provincial data.
   - Plans and policies.
   - Feedback from Water Managers.
2. **Characterize Water Resources**
   - Analyze and consolidate the collected information.
   - Build a story of what we know about the state of water resources and in doing so identify the knowledge gaps.
3. **Review of Water Management**
   - Review the approaches and challenges that are specific to each of the WQSAs.
   - Identify what is being done that works and what does not work.
   - Build a story of how the water quantity is being managed.
4. **Assess Sustainability**
   - Based on available studies, assess the current state of water resources.
   - Evaluate how climate change, population growth, cumulative effects and ecological flow are considered now and in the future.
   - Evaluate what is needed to predict and manage sustainability into the future.
5. **Gaps and Opportunities**
   - Identify information about how each WQSA is characterized and managed.
   - Identify gaps and opportunities for improvement.

6. **Recommendations**
   - Management approaches for each study area.
   - Approaches to address gaps in knowledge/information.

1.3 REPORT OUTLINE

The following outlines the overall design of this report:
Section 1 provides a general outline of the scope of work and the objectives of the undertaking.

Section 2 summarizes how the seven WQSA were selected and what the overarching considerations are for the assessment methodology. This section also provides a high level summary of the various water management tools used by the MECP. This subsection is intended to provide the reader with the context in which actions and decisions are taken, to better understand what shapes water quantity management in the WQSAs.

Section 3 describes the assessment methodology and approach and includes a summary of the key local contacts who were consulted (including local MECP reviewers who provided comments on the draft report).

Sections 4 through 10 are independent assessments of the seven WQSA. The assessment of each WQSA is broadly divided into five main parts: introducing and characterizing the physical setting and water resources of the WQSA; an assessment of the sustainability of the water resources based on existing data and information; a summary and evaluation of water management approaches and challenges in the WQSA; identification of any data gaps in the ability to assess the sustainability of the water resources; and recommendations on how to address any existing data gaps. The layout of the report is summarized in more detail as follows:

- **An Introduction to the WQSA**
    - **Available Studies, Models and Data**

- **Water Resources Setting /Characterization**
    - **Land Cover and Use Setting**
    - **Population**
    - **Physiographic Setting**
      Physiography
      Topography
      Climate
      Surface Water Hydrology
      Wetlands
      Groundwater Surface Water Interaction
    - **Geology**
      Surficial Geology
      Bedrock Geology
    - **Hydrogeology**
      Overburden Aquifers
      Bedrock Aquifer
    - **Overview of Water Takings within WQSA**
      Permitted Takings
      Non Permitted Takings
    - **Recommended WQSA Boundaries for Data Review**
- **Resource Sustainability**
    - **Data Review and State of Water Resources**
      Water Shortages
      The Ontario Low Water Response (OLWR) Program
    - **Assessment of Sustainability of Water Resources**
      Climate Change
      Population Growth
      Cumulative Effects
      Environmental/Ecological Flow Needs
    - **Conclusions**
- **Water Management Approaches, Challenges**
- **Identified Data Gaps**
- **Recommendations**
- **References**

It should be noted that unlike the other WQSA assessments Section 4 (Guelph-Wellington County WQSA) incorporates three Water Bottling Study Areas (WBSA) as part of the overall WQSA assessment.

Section 11 is a summary of the assessment of the sustainability of water resources at a provincial scale and includes general gaps in water quantity management policy, program or science in Ontario and recommendations to enhance water quantity management in Ontario.

Finally, **Section 12** identifies documents referenced in other parts of the main report that were not provided at the end of each of the WQSA sections (Sections 4 to 10).

2 BACKGROUND

Five (5) WQSAs were initially selected by MECP based on known/documented pressures including low resiliency to climate change, water quantity stress/risk based on Source Protection (highest tier water budget completed), current or potential challenges in managing multiple water takings and/or growth pressures. Two (2) additional WQSAs were selected based on factors identified by the External Working Group (EWG). The EWG is comprised of representatives from academia, industry, Indigenous communities and municipalities. The EWG recommended additional areas be added that would support a broader understanding of water resources in Ontario (e.g., inclusion of indigenous concerns/study areas, diversity of geography, diversity of growth potential and development stage). Not all of the EWGs recommendations could be incorporated. Approximate geographic boundaries for each WQSA were provided by the MECP (**Figure 1-1**) with the intent that the boundaries for each WBSA would be analyzed and refined based on the findings of each assessment.

2.1 OVERARCHING CONSIDERATIONS

In consultation with the Ministry, the following considerations apply to the entire assessment methodology:

- Ontario has not vested ownership of water and manages water use based on common law and riparian rights and it is assumed that this will not change.
- Ontario manages large water takings using a permit system, where permits are issued to specific individuals or companies for a finite period of time. Ontario also has a "permit by rule" system (i.e., EASRs) for lower risk water takings. Permits cannot be traded among individuals. Permit trading relies on a system of water rights, which Ontario does not have and it is assumed that this will not change.
- The future state of water resources in Ontario may be different than today, considering Climate Change, climate variability, population changes, and changing land use. The focus of the evaluation is on the suitability of Ontario's framework to deal with future scarcity and drought risks, rather than flooding.
- Ontario is a large, diverse province with a range of conditions related to managing water quantity; for example, with respect to: assessment / management needs; environment / water resources settings; water supply and demand (anthropogenic and natural).

2.2 PROVINCE OF ONTARIO WATER MANAGEMENT FRAMEWORK

The following high level summary of the various water management tools used by the MECP is intended to provide the reader with the context in which actions and decisions are taken, to better understand what shapes water quantity management in the WQSAs.

Under English common law, no one owns Ontario's water. Instead, it is "held in common" by everyone. The government is responsible for managing the use and withdrawal of water in Ontario on everyone's behalf. This is done collaboratively by several provincial ministries and government agencies.

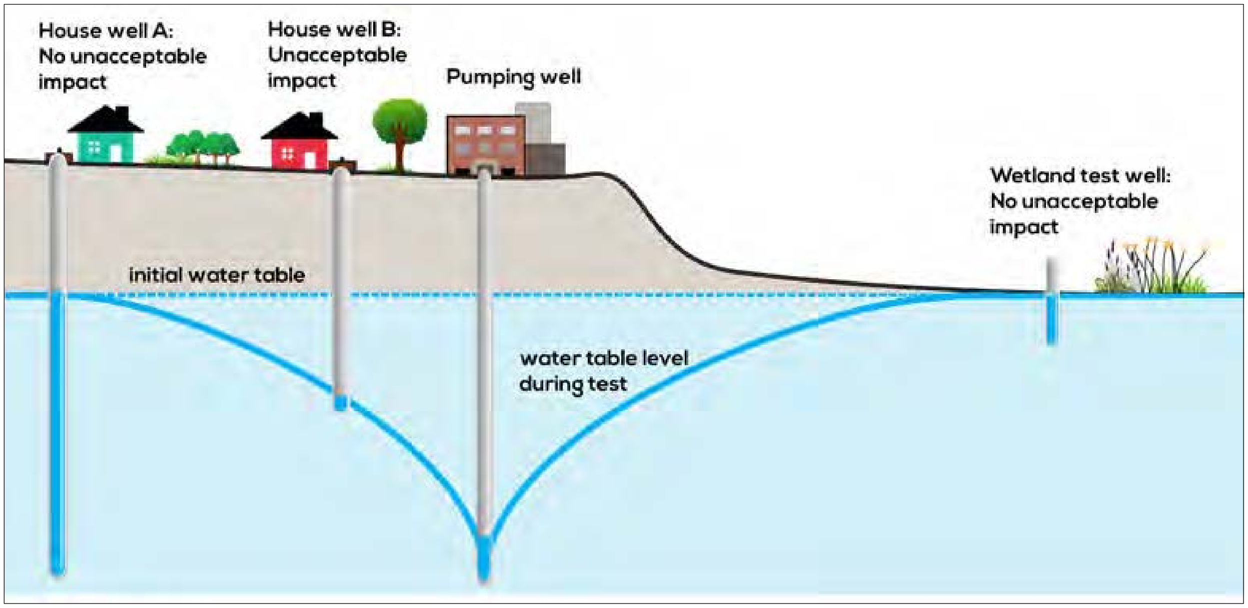
The mandate of the MECP is contained specifically in the Ontario Water Resources Act. The Act gives the Ministry the authority to supervise and manage Ontario's water to "provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, in order to promote Ontario's long-term environmental, social and economic well-being." The Act sets controls regarding the taking of water in the province, along with the Water Taking and Transfer Regulation. Ontario also recognizes the Constitutional rights of Indigenous communities with respect to natural resources, including their water access rights.

The Act and the Regulation establish tools and standards to meet environmental objectives, including to manage large water withdrawals. For example, withdrawals of 50,000 litres or more a day require a permit, with some exceptions. Each application for a "Permit to Take Water" (PTTW) is reviewed by the Ministry before a permit can be issued. Proposed takings that are considered more complex, or those that might pose a risk to the sustainability of water resources, require extra attention. These applications must be accompanied by a technical report prepared by a professional engineer or geoscientist and paid for by the applicants. The reports must show that the water taking can occur without causing unacceptable impacts.

The Ministry considers multiple factors before approving a permit application, including the applicant's intended use for the water, the natural functions of the ecosystem, water availability, how and where the water is being returned, and whether the taking may interfere with other water users. For example, in areas with multiple withdrawals, the cumulative effects of all the takings must be considered before the permit is issued. The extent to which cumulative effects need to be evaluated depends on the characteristics of an area and the number and complexity of the water withdrawals in the area. For example, the presence of sensitive wetlands or fish-spawning areas in an area with multiple withdrawals from a groundwater resource may benefit from an analysis of cumulative effects. The Act and the Regulation also set out requirements for notification and consultation, data collection and reporting.

If the review of an application determines that a water taking will likely lead to unacceptable impacts on the ecosystem or other users, the Ministry can modify or reject the proposed taking. If the proposal is judged unlikely to result in unacceptable impacts (Text Figure 2-1), the Ministry issues a PTTW, specifying the purpose for each taking and the amount of water that can be taken in a single day and over the course of a year. Permits require monitoring and include conditions that require measures be taken to address any unforeseen unacceptable impacts. All holders of a permit must provide the Ministry with a yearly record of the amount of water taken each day from each source; this information is compiled and managed through the Water Taking Reporting System (WTRS).

Even after a permit has been issued, the Ministry can limit, alter, or stop almost any water taking that is deemed to cause an unacceptable impact. This provision allows the Ministry to respond to changing environmental and land use conditions, or deal with unforeseen impacts.



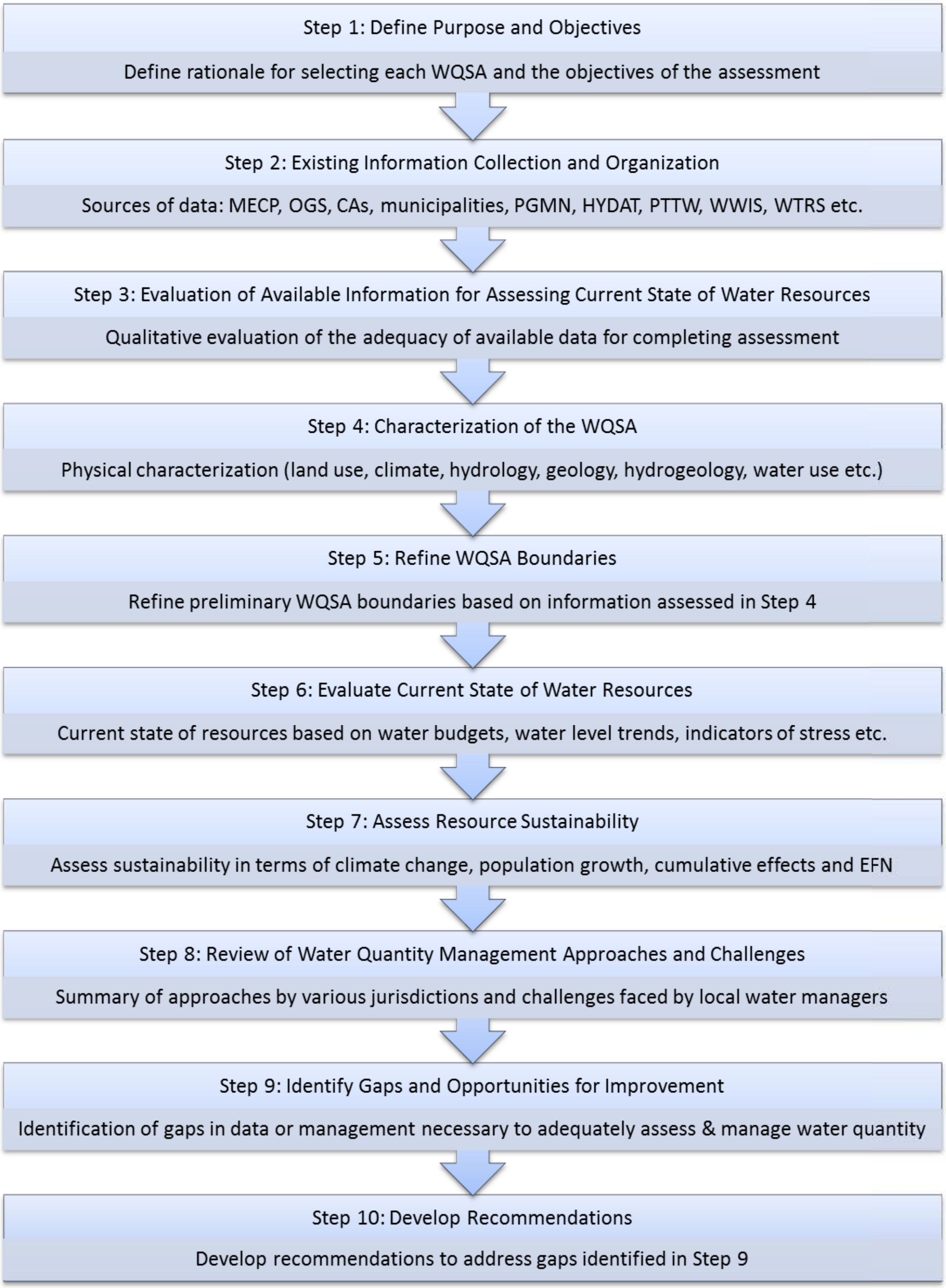
Text Figure 2-1. A possible consideration when evaluating an application for a Permit to Take Water: The water table beneath the pumping well declined during a test, causing unacceptable impacts to Well B. But the water levels at Well A and in the wetland were not affected.

A description of the methodology and approach adopted to complete the assessment in each of the identified WQSAs is provided in the next section.

3 ASSESSMENT METHODOLOGY AND APPROACH

For each WQSA, available information was compiled and evaluated in relation to the current state of water quantity resources, challenges and existing approaches associated to water resources management. Another consideration was the sustainability of the key water resource(s) for the natural environment and other water takers, in light of the anticipated effects of climate change and population growth on future water supply and demand.

The approach developed to complete the assessment in each WQSA is illustrated on Text Figure 3-1. A summary of the methodology of each step associated with the assessment is provided below.



Step 1: Define Purpose and Objectives

Define rationale for selecting each WQSA and the objectives of the assessment

Step 2: Existing Information Collection and Organization

Sources of data: MECP, OGS, CAs, municipalities, PGMN, HYDAT, PTTW, WWIS, WTRS etc.

Step 3: Evaluation of Available Information for Assessing Current State of Water Resources

Qualitative evaluation of the adequacy of available data for completing assessment

Step 4: Characterization of the WQSA

Physical characterization (land use, climate, hydrology, geology, hydrogeology, water use etc.)

Step 5: Refine WQSA Boundaries

Refine preliminary WQSA boundaries based on information assessed in Step 4

Step 6: Evaluate Current State of Water Resources

Current state of resources based on water budgets, water level trends, indicators of stress etc.

Step 7: Assess Resource Sustainability

Assess sustainability in terms of climate change, population growth, cumulative effects and EFN

Step 8: Review of Water Quantity Management Approaches and Challenges

Summary of approaches by various jurisdictions and challenges faced by local water managers

Step 9: Identify Gaps and Opportunities for Improvement

Identification of gaps in data or management necessary to adequately assess & manage water quantity

Step 10: Develop Recommendations

Develop recommendations to address gaps identified in Step 9

Text Figure 3-1. Approach developed to complete the assessment in each WQSA

STEP 1: Define Purpose and Objectives

The objectives of the assessment completed for each WQSA, as defined by MECP RFB#6792 (MECP, 2017) and summarized in Section 1.1, were to:

- Assess, characterize and document the current state of water quantity resources, and the sustainably of the resources in light of climate change, potential for growth and land use changes;
- Assess how the resources are currently being managed;
- Identify gaps in available information and understanding; and,
- Make recommendations on the management of the resources moving forward including identifying gaps that should be filled in policy, program or science and how they might be addressed.

STEP 2: Existing Information Collection and Organization

Existing information related to the water quantity of each WQSA was obtained from the following resources where available:

- Documentation provided by the MECP and Ontario Geological Survey (OGS) relevant to water quantity in each WQSA, including, but not limited to, source water assessment reports, Tier 1, 2, and 3 water budgets, geological, hydrogeological and hydrological studies, ecological studies, existing water management policies and practices, and low water response programs;
- Reports and documentation obtained from Conservation Authorities (CA), Source Protection Committees and Municipalities;
- Published maps depicting the physical characteristics of the area (i.e. geology, physiology, ecologically sensitive areas, land use, habitat and species at risk)
- Municipal planning documents, population statistics and projections;
- Climate data (Environment and Climate Change Canada and local sources where available); and,
- Province-wide databases including the Provincial Groundwater Monitoring Network (PGMN) well network, Hydroclimatological Data Retrieval Program (HYDAT) stream gauges, Permit To Take Water (PTTW), Water Well Information System (WWIS), and Water Taking Reporting System (WTRS).

STEP 3: Evaluation of Available Data/Information for Assessing Current State of Water Resources

The relevance of the data and information collected in Step 2 was then qualitatively evaluated to determine their relevance and quality in relation to the stated objectives of the present study. For example:

- Do the data contribute to the overall understanding of the defined water resource concern?
- What is the quality of the available data/information?
  - Are there any discrepancies between sources for the same WQSA?
  - Is the data/information verifiable?
- What is the temporal scale of the data/information?
  - Is there enough information available to establish trends in natural temporal variation?
  - Is data collected at consistent intervals?
  - Does the scale of available data capture potential seasonal variation?
  - What is the time frame of available data?
- To what extent have the primary water sources been characterized?
  - How has the water quantity been assessed?
  - Have water budgets been developed for the area (e.g., Tier 1, 2 or 3)?
  - Is there a water quantity model(s) (SW, GW or integrated) for the area? How is it used? What are the strengths and weaknesses of available modelling for use in water resources management?
- Have interrelationships between flows and stores been studied?
  - Have interrelationships been characterized?
  - Is data available over a sufficient temporal scale (e.g., 10 years or more) and at sufficient temporal resolution to determine long-term and short-term (seasonal) trends in flows and storage?
- Are the cumulative impacts of multiple takings being addressed? If so, how?
- Are there any studies looking at ecological flow needs? Are ecological flow needs adequately characterized given the local takings, water use activities and potential risks?
- Have cumulative effects and/or resource security and sustainability been considered?
- Have stressors on water quantity been identified and assessed given the intrinsic characteristics of the environment and the potential risks associated with any takings/use?

STEP 4: Characterization of WQSA

A summary of the physical setting of each WQSA was prepared and summarized under the following headings (examples of information that can be found under each heading are provided):

- **Land Use and Administrative Setting** – Summary of land uses
- **Population** – Discussion of major growth/development areas, population projections/growth forecasts (Statistics Canada) and a summary of growth pressures where identified
- **Physiographic Setting:**
    - Physiography – Description of dominant physiographic features within the WQSA
    - Topography – Description of regional topography
    - Climate – General description of climate, climate trends (particularly precipitation) compared with historical averages and climate variability
    - Hydrology – Description of regional hydrology, local surface water features and watershed conditions and a discussion of whether the watershed is classified as high or medium use for summer low flow conditions.
- **Aquatic Habitat and Species –** Description of the aquatic thermal regime of the streams and rivers; list of typical fish species known to occur in the study area; and, list of aquatic Species at Risk and/or their habitat, protected under the federal Species at Risk Act and/or the Ontario Endangered Species Act, that are confirmed or potentially present in the study area.
- **Geology** – Description of quaternary and bedrock geology; distribution of overburden thickness throughout the study area; and, geologic cross-sections.
- **Hydrogeology** – Description of key hydrostratigraphic units, including properties of relevant hydrostratigraphic units; hydraulic connection between aquifers; surface water-groundwater interaction; primary areas of recharge and discharge; areas with no viable groundwater resources or marginal aquifers susceptible to climate variations, if any; and hydrogeological cross-sections and conceptual model(s) where available.

- **Water use** – Discussion of permitted and non-permitted takers, including location, purpose, volumes, taking schedule, variability in taking rates and durations, consumptive use, resources being used and relative reliance on these resources. Three permitted commercial Water Bottling Study Areas (WBSAs) were characterized in greater detail as part of the Guelph-Wellington County WQSA assessment where they are located; using the methodology used to evaluate seven other WBSAs as part of a parallel task under the present project (BluMetric, 2019).

STEP 5: Refine WQSA Boundaries

The preliminary boundaries provided by the MECP for each WQSA were refined using the information compiled and evaluated in Step 4. An internal geoportal was developed for this project using the BluMetric Environmental Information System (EIS) to combine various geospatial datasets, including those listed under Step 2 as well as publicly available geospatial data (e.g., bedrock and surficial geology from the Ontario Ministry of Northern Development and Mines (MNDM)), etc.). The EIS was integral to the refinement of WQSA boundaries as it allowed for easy visualization, data mining and overlay of the relevant geospatial data layers (e.g., geology, watersheds and subwatersheds).

The rationale for refining WQSA boundaries depended largely on the primary water source(s) in each study area (e.g., surface water, groundwater or both) or where a significant amount of historical water quantity assessment work has been completed. Where surface water was established as the primary water source, (sub)watershed boundaries for the primary source(s) were used to develop the refined WQSA boundary.

Step 6: Evaluate Current State of Water Resources

The current state of water resources was evaluated using water budget(s) and stress assessments where available, water level trends (e.g., hydrographs from Water Survey of Canada (WSC) gauges, and PGMN and municipal wells) and any reported indicators of potential stress to water resources/changes in water availability (e.g., low water complaints received by CAs or MECP offices) and low water declarations under the Ontario Low Water Response (OLWR) program).

For water resources that have experienced water shortages, available studies and data were reviewed to assess whether shortages are likely related to seasonal variations in precipitation and/or drought. Any indications of aquifer mining or permitted water takings contributing to water shortages were noted.

Step 7: Assess Resource Sustainability

The sustainability of the principal groundwater and/or surface water resources within each WQSA was assessed based on available information with respect to:

- **Stress on water resource(s)** – areas that have experienced water shortages, and potential future shortages;
- **Current state of the water resource(s) and overall challenges with respect to water resource management** – water budgets where available, water level trends observed considering precipitation, indicators of potential stress to water resources or changes in water availability;
- **Water Use and Availability** – current water use and dependence/reliance on specific water resource(s), ability of the water resource(s) to provide an alternate source of water where water quantity may be an issue;
- **Climate Change (CC)** – anticipated effects on future (mid to late century) water supply and demand;
- **Population growth** – anticipated effects of population growth and changes of land use on future (mid to late century) water supply and demand in the area;
- **Cumulative Effects (CE)** – cumulative effects of water takings on the natural environment and/or other takers, extent to which these have been considered in water management decisions, and assessment of what additional information or analysis is needed relative to potential risks; and,
- **Environmental Flow Needs (EFN)** – where they have been considered, determined or researched to ensure threshold flows are maintained to sustain healthy surface water courses.

For the Guelph WQSA, the impact of water bottlers has been considered on the current and future state and sustainability of water resources, including cumulative effects.

STEP 8: Review of Water Quantity Management Approaches and Challenges

Water quantity management approaches were reviewed and summarized for each WQSA, including those carried out by the Province, Source Protection Authorities, Conservation Authorities and Municipalities. To collect relevant information specific to each WQSA, key local contacts were identified in consultation with MECP, including local water managers and other stakeholders (consultants and MECP technical and management staff) familiar with the technical information and water quantity management approaches, issues and challenges in each WQSA. The key local contacts who were consulted (including local MECP reviewers who provided comments on the draft report) are summarized in Table 3-1. A copy of correspondence with local water managers is provided in Appendix B. Additionally, input on local water management challenges and approaches was obtained from local water managers and stakeholders during workshops held in Kingston, Guelph and Toronto (BluMetric Environmental Inc., 2018).

Water quantity management challenges and/or concerns identified by local water managers were also reviewed and summarized for each WQSA. Input from key local water managers was used to identify additional water management tools and approaches used, and to understand how water management decisions consider or apply aspects such as natural function/ecological needs, adaptive/alternative management practices, municipal growth, future growth from other sectors, drought management, and climate change.

Where deemed appropriate based on this analysis, new management tools needed in a WQSA, beyond what is currently enabled or applied by the province, are provided in the Recommendations subsection for each WQSA, along with a discussion of advantages and challenges of possible approaches.

Table 3-1: Consulted Key Local Water Managers and Stakeholders

Name	Organization	Name	Organization
Guelph Wellington WQSA			
D. Belanger	City of Guelph	K. Landry	Puslinch
C. Neville	S.S. Papadopulos & Assoc.	C. Baker	Centre Wellington
S. Shifflett	Grand River	M. Keller	Grand River
S. Strynatka	Grand River	A. Quyum	MECP
W. Galliher	City of Guelph	S. Day	MECP
K. Davis	Centre Wellington		
Orangeville WQSA			
H. McGinnity	Mun. of Orangeville		
Norfolk WQSA			
C. Jacques	Long Point Region	J. Connelly	MECP
B. Fields	Norfolk County	S. Day	MECP
A. Munro	MECP		
Innisfil WQSA			
R. Post	Nottawasaga Valley CA	P. Alm	Nottawasaga Valley CA
Whitemans Creek WQSA			
S. Shifflett	Grand River	S. Day	MECP
A.l Quyum	MECP		
Quinte WQSA			
Amy Dickens	Quinte Conservation	K. Stephenson	MECP
C. McClure	Quinte Conservation	V. Castro	MECP
M. Boone	Quinte Conservation		
Chapleau WQSA			
S. Gautry	Wood	A. Godwin	MECP
F. Agyemang	MECP	A. Swanson	OWCA

STEP 9: Identify Gaps and Opportunities for Improvement

This step involved an overall assessment of the water quantity information available and the water quantity management measures/tools being used within the WQSA to determine if water quantity is being adequately addressed in relation to the level of current and potential future risk. For example:

- Are cumulative impacts of water takings on the natural environment and other takers being considered in water management decisions?
- Are the potential impacts of climate change adequately understood within the WQSA?
- Is there sufficient information available from the datasets produced through the water quantity management framework? (e.g., timely availability of WTRS information, adequate coverage within PGMN, adequate tools for surface water monitoring, etc.)
- Are water quantity management decisions making adequate use of existing available tools and/or including adequate additional protective measures to address water security and ensure sustainability of the water resource with a changing climate?

Based on this assessment, information gaps and opportunities for improvement were identified for each WQSA.

STEP 10: Develop Recommendations

Recommendations were developed to address gaps identified in Task 9. Depending on the WQSA, recommendations may include additional monitoring or data analysis; additional funding, education or other support to local water managers; and, management approaches that are being used within other WQSAs or jurisdictions that have been successful in addressing the identified gap(s) and better ensure security and sustainability while considering local water management challenges.

4 GUELPH-WELLINGTON COUNTY WQSA

The preliminary boundary of the Guelph-Wellington County WQSA ("Guelph WQSA"), as provided by the MECP, is shown on Figure 4-1. The preliminary WQSA overlaps multiple counties and encompasses a number of population centers. The WQSA partially or fully encompasses multiple watersheds and Conservation Authorities (CAs), including Grand River CA, Credit Valley Conservation, Halton Region CA, and Hamilton Region CA. The largest urban centre in the WQSA is the City of Guelph, located at the centre of the WQSA. Smaller communities within the WQSA include Erin, Hillsburgh, Fergus, Elora, Acton, Rockwood, Eden Mills, Everton, Aberfoyle, Morriston, Maryhill, Marden and Ennotville.

In the Guelph WQSA, both groundwater and surface water resources are utilized for domestic, agricultural, commercial and industrial uses. This WQSA was selected from detailed analysis by the MECP due to known or potential issues associated with growth pressures and predicted stress from prolonged droughts which may be exacerbated in the future as a result of the anticipated impacts of climate change. The objectives of this section are: 1) Provide a characterization of the Guelph WQSA in the context of the major (most used) surface water and groundwater resources; 2) Refine the WQSA boundary based on the physical characterization; and 3) Summarize and evaluate the demands on water resources in the WQSA, and determine the possible impact of projected changes in population, land use, and climate on the quantity of the local resources and future security and sustainability of the water resources in the WQSA based on these changes; 4) identify information gaps and provide recommendations.

4.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives within the preliminary WQSA boundary provided by the MECP. The Guelph WQSA contains multiple watersheds and CAs. The Grand River Watershed makes up the majority of the preliminary WQSA and was therefore the focus of the literature review. Several 3 water budgets were completed within WQSA at both the watershed (Tier 2) and municipal system specific scale (Tier 3), including those completed for the Region of Waterloo, Halton, Milton-Campbellville, Cambridge, and Guelph. The reports listed below, as well as available databases provided by MECP, and input provided by water managers within the WQSA, were used as the primary basis for the WQSA characterization and assessment presented in the following sections. Each resource was categorized in terms of the information presented within.

Table 4-1: Summary of Key References

Resource Reference	Type	Categories
AquaResource Inc. (AquaResource). December 2009. *Tier 2 Water Quantity Stress Assessment Report, Grand River Watershed*.	Report	PC, GWQ, SWQ, CU
Golder Associates and AECOM May 2014.Water Supply Master Plan Update (Draft Final Report), The Corporation of the City of Guelph.	Report	PC, GWQ, CU, FU
Golder Associates. 2011. City of Guelph Tier 3 Water Budget and Local Area Risk Assessment: Characterization Final Report.	Report	PC
Matrix Solutions Inc., 2018. The Guelph – Guelph/ Eramosa Water Quantity Policy Development Study Threats Management Strategy.	Report	GWQ, SWQ, CU, FC
Matrix Solutions Inc., 2018. Assessment of Climate Change and Assessment of Water Quantity Threats in the IPZ-Q in Support of the Guelph-Guelph/Eramosa Water Quantity Policy Study. Lake Erie Source Protection Region.	Report	CC, GWQ, SWQ,
Matrix Solutions Inc. 2017. City of Guelph and Township of Guelph/Eramosa Tier 3 Water Budget and Local Risk Assessment. Lake Erie Source Protection Region.	Report	PC, GWQ, SWQ
Matrix Solutions Inc. and S.S. Papadopulos. 2014. Region of Waterloo Tier 3 Water Budget and Local Area Risk Assessment. Region of Waterloo.	Report	PC, GWQ, SWQ
Stantec Consulting Ltd., 2015. 2013-2014 Monitoring Report Arkell Adaptive Management Plan.	Report	PC, SWQ
Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario. Special Volume 2*. Ontario Geological Survey.	Report	PC
GRCA. 2008. *Grand River Watershed Characterization Report January 2008* - Revision 2.0	Report	PC

Categories:

PC – Physical Characterization

GWQ – Groundwater quantity

SWQ – Surface water quantity

CU – Current water users

FC – Future Conditions

CC – Climate Change

4.2 WATER RESOURCES SETTING /CHARACTERIZATION

4.2.1 Land Cover and Use Setting

Land use within the WQSA includes a mix of agriculture, forest and built-up areas (residential/commercial/industrial) as shown on Figure 4-2. The largest urban centre in the WQSA is the City of Guelph, surrounded by smaller communities. Most of these small urban centres are surrounded by rural areas consisting mainly of agricultural land use (Matrix Solutions Inc., 2017). The land west of the Speed and Eramosa Rivers is predominantly agricultural, consisting of crops and forage. Forested areas and wetlands are found in small pockets throughout this area. The land use east of the rivers is a mix of agricultural and forested areas. The WQSA also includes numerous aggregate extraction sites and golf courses, and are discussed further in the permit to take water section.

Of significance, the Canada Land Inventory (CLI) notes that agricultural lands in the WQSA are primarily Class 1 (no significant limitations) in the west and central areas of the WQSA, transitioning towards Class 2 (moderate limitations, moderate conservation practices required) and Class 3 (moderately severe limitations, special conservation practices) towards the eastern boundary. There are also some isolated small pockets of Class 6 (perennial crops only) located throughout the eastern half of the WQSA (CLI, 2018).

4.2.2 Population

Populations in urban centres with municipal water supplies, located in watersheds which fall within or make up part of the WQSA, are summarized in Table 4-2 and present the most recently available population information. Where a municipal water supply is not available municipal residents are privately serviced, primarily by groundwater.

Table 4-2: Summary of Population Statistics and Water Supply Source

Subwatershed	Upper Tier Municipality	Lower or Single Tier Municipality (Serviced Community)	Water Source for Municipal Supplies with the WQSA	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percentage Change between 2011 and 2016 (%)
16 Mile Creek	Halton Region	Town of Halton Hills (Community of Acton)	Groundwater	59,013	61,161	3.6
Bronte Creek and 16 Mile Creek	Halton Region	Town of Milton (Communities of Milton and Campbellville)	Groundwater	75,880	101, 715	34.0
Upper Grand River Waterhsed	Dufferin County	Township of East Garafraxa	none	2,595	2,579	-0.6
Speed River	Wellington County	Town of Centre Wellington (Communities of Elora and Fergus)	Groundwater	26,693	28,191	5.6
Speed River	-	City of Guelph	Eramosa River, Groundwater	121,688	131,794	8.3
Eramosa River	Wellington County	Township of Guelph/Eramosa Community of Rockwood	Eramosa River, Groundwater	12,380 4,290	12,854 4,629	3.8 7.9
Speed River	Wellington County	Township of Puslinch	none	7,029	7,336	4.4
Eramosa River	Wellington County	Community of Erin	Groundwater (wells not located in Eramosa subwatershed)	2,523	2,647	4.9
Upper Grand River	Region of Waterloo	Township of Woolwich (Community of Maryhill)	none	23,145 574	25,006 576	8.0 0.3
Upper Grand River	Region of Waterloo	City of Waterloo	Groundwater	98,780	104,986	6.3
Upper Grand River	Region of Waterloo	City of Kitchener	Grand River, Groundwater	219,153	233,222	6.4
Speed River	Region of Waterloo	City of Cambridge	Groundwater	126,748	129, 920	2.5

4.2.3 Physiographic Setting

The Guelph WQSA is located in southwestern Ontario, northwest of Lake Ontario and east of Lake Huron. The preliminary WQSA boundary provided by the MECP extends north to Orangeville and as far south as the city of Cambridge.

4.2.3.1 Physiography

The WQSA contains various physiographic regions as identified by Chapman and Putnam (1984), which includes drumlinized till plains surrounded by spillways and thin lines of bevelled Till Plains. There are areas of Kame Moraines to the north of the WQSA, with till moraines and limestone plains along the eastern section of the WQSA. These are shown on Figure 4-3. The landscape within the WQSA is characterized by moraines, and is described as an excerpt from (Karrow, 1968).

Till Plains

Much of the Guelph area consists of till plain, a large portion of which is drumlinized. There is no sharp boundary between drumlinized and undrumlinized till plain so that distribution of the two can only be given generally. The till plain (without drumlins) is found in a belt extending around the periphery of the Guelph drumlin field to the west and north. Vague traces of ice-motion can be seen as broad flutings in the till surface in the inner portion of the belt nearer the drumlins. These, like the drumlins to the east and south, indicate ice movement to the northwest out of the Lake Ontario basin. The outer portion of this till plain is undulating to nearly level, and gives no indication on the surface of the direction of ice-movement. It is interrupted by the terraces of the Grand River but can be found again west of the river extending for a few miles to the terminus of the till sheet that forms it. Most of the till plain of the area is formed of sandy Wentworth Till. A few square miles of till plain in the northwest corner of the area is underlain by a somewhat different till that extends to the north and west and is derived from the Georgian Bay ice-lobe. Both till plains probably owe their level surface to underlying deposits of glacial till and outwash, (Karrow, 1968).

Drumlins

Over half of the till plain of the area is drumlinized, i.e. formed into streamlined elongate hills by the movement of glacial ice. This is the heart of the Guelph drumlin field. About 200 drumlins of this field occurring in the Hamilton and Galt areas to the south have previously been described (Karrow, 1963). Over 300 drumlins have been identified in the Guelph area, but many indistinct forms have not been included. Of these, 66 are east of or within the Paris and Galt moraines; the remainder form the main Guelph drumlin field. In some places, the drumlins crowd upon one another so closely that delineating the individual hills is difficult. Proportions vary widely but the drumlins are commonly about 50 feet high. All the drumlins of the area are composed partly or entirely of sandy Wentworth Till. A few appear to have cores of an older clay or silt till but are veneered by Wentworth Till. Being large massive hills, complete cross-sections through them are seldom exposed. Some drumlins have apparently been truncated by stream erosion but their eroded faces have long since been slumped over and covered by soil and vegetation.

Other deep exposures of drumlins are to be found northeast of Guelph along Highway 24. The long axes of drumlins indicate the direction of ice-movement. In the Guelph area, these trends vary from almost due west to N450W, suggestive of the fanning-out of the ice-lobe from the Lake Ontario basin. Adjacent drumlins are not always parallel and a few drumlins are slightly curved. Near Guelph, faint flutings occasionally diverge from the drumlin trends by about 10 degrees. These features may indicate slight changes in direction of ice-movement during the formation of the drumlins, comparable to the formation of crossed striae under conditions of thinning ice.

Moraines

Parts of several previously-known end moraines have been identified in the area. In addition, there are numerous areas of hummocky topography whose relationship to known moraines is unknown. Probably the oldest end moraine is the Breslau moraine. Formed of clay till during an earlier ice-advance, it has its strongest development as a till moraine at Maryhill (New Germany) where it rises about 75 feet above the surrounding plains of sandy Wentworth Till. Its flanks and parts of its crest are mantled by the younger sandy till. The Breslau moraine is predominantly a till moraine in the Guelph map-area, in contrast to its more kamey nature in the Galt area to the south.

Intermittent tracts of morainic topography can be traced from west of Elora to east of Fergus. They are likely related to the terminus of the Wentworth Till, of which they appear to be formed. Their relationship to the Elmira moraine to the west and the Orangeville moraine to the north is not entirely clear but they seem to form a link between them. The extensive area of hum mocky topography east of Fergus is thought to be a southward extension of the Orangeville moraine; the southern portion has been overridden and capped by Wentworth Till and can be traced as buried sands southeastward almost to the Paris moraine. The best-known end moraines of the area are the Paris and Galt moraines, which together form a moraine belt 4 to 5 miles wide. These moraines enter the area southeast of Guelph and leave it northeast of Acton. The two moraines are so closely associated that they cannot be separated through much of their extent in the area. They are formed mainly of sandy Wentworth Till although kame deposits of gravel and sand are common as well. These moraines are the best examples of morainic topography in the area and contrast sharply with the smooth outwash plain in some areas, such as southeast of Guelph. The Paris and Galt moraines were formed by the Ontario ice-lobe during its retreat into the Ontario basin. Just east of and closely associated with the Galt moraine, are the Moffat moraines, a series of up to four small hummocky ridges formed of Wentworth Till. Because of their location, they must be slightly younger than the Galt moraine, but become indistinguishable from it north of Acton, where they merge into kame deposits. As noted by Chapman and Putnam (1951) the moraines east of Guelph sometimes partly cover drumlins. This indicates clearly that the moraines were formed after the drumlins.

Located to the south of the Orangeville Moraine, the Waterloo Moraine is one of the largest moraines within the Grand River watershed. This moraine contains a complex set of stratigraphic and topographic elements, including extensive areas of sand hills and gravel terraces that readily allow precipitation to infiltrate and recharge several overburden aquifer systems. These aquifer systems discharge groundwater to the headwater wetlands and streams and contribute baseflow.

The Paris Moraine and the Galt Moraine have internal structures that are a complex mixture of till, stratified drift and discontinuous layers of more permeable material. Recently, a detailed review of the state of knowledge of these moraines was completed by Blackport and AquaResource (2009). The work was undertaken to better understand the hydrogeology of the moraines and identify threats and impacts to the hydrologic functions of the moraines to protect groundwater and surface water through provisions, policies and legislation. The Port Stanley Till and the Wentworth Till are the two most prevalent till units present at surface in the WQSA. The Port Stanley Till is present in areas west of the Paris Moraine and the Wentworth Till is present in areas on and east of the Paris Moraine (McKenzie, 1990).

Kames

Irregular hummocky accumulations of sand and gravel, called kames, were formed where meltwaters poured off the ice. These ice-contact deposits of stratified drift sometimes grade into esker ridges or, in directions away from a former ice-front position, into outwash. Kames are abundant in the northern and eastern parts of the map-area and are generally associated with end moraines. Thus, extensive kames occur east of Fergus as a probable extension of the Orangeville moraine. Other substantial kame deposits are situated southeast of Guelph and in a belt from Rockwood to Brisbane in association with the Paris and Galt moraines. Kame gravels near and north of Acton are probably related in part to the presence of the re-entrant in the Niagara Escarpment. Similar concentrations of kames are common in most Escarpment re-entrants north and south of the area.

4.2.3.2 Topography

The ground surface elevation varies by approximately 270 m, from a high of 500 masl in the northernmost part of the WQSA (north of Hillsburgh) to a low of 230 masl below the Niagara Escarpment in the southeast, as shown on Figure 4-4. Superimposed on this general trend are the topographic ridges of the various moraines described above in Section 4.2.3.1. The area lies primarily within the Grand River Watershed with surface drainage controlled by the Grand River and its numerous tributaries, including the Speed River, Eramosa River and Mill Creek. Surface water flow in the area is generally in a southerly direction with a southwesterly component evident in the main tributaries. Some of these tributaries are often deeply incised into well-defined valleys, many of which are cut into the underlying bedrock (Matrix Solutions Inc., 2017).

4.2.3.3 Climate

The climate of the WQSA is considered to be moderate to cool temperate. The headwaters area of Dufferin County is about 500 masl, in the cool temperate region, and the mouth of the river at Lake Erie is substantially lower, at 175 masl, in the moderate temperate zone (Matrix Solutions Inc. and Papadopulos, 2014).

The Grand River watershed covers several climatic regions which results in slight differences in temperature, precipitation and onset of the seasons. Average monthly temperatures are coldest in January (-9°C) in the north and warmest in the south in the month of July (21°C). Extreme temperatures can reach as low as -35°C in the winter and up to 40°C in the summer. Temperatures in urban regions tend to be slightly higher than surrounding regions. Daily weather patterns can show dramatic temperature fluctuations.

Precipitation in the Grand River watershed ranges from 800 to 1,025 mm per year (climate normals between 1971-2000; Environment Canada, 2005). Precipitation patterns within the watershed show a slightly decreasing north to south trend, while the general precipitation pattern of southwestern Ontario shows slightly decreasing amounts of precipitation moving eastward (GRCA, 2008). Precipitation values were collected from meteorological stations shown in and surrounding the WQSA on Figure 4-5.

There is no rainy season in this region, as precipitation is fairly evenly distributed year round. Precipitation is variable month to month and the amount of rain and snow can vary greatly; a dry month will cause noticeably lower streamflows. The majority of precipitation in winter is in the form of snow. A winter with little snow accumulation will lead to moderate spring flows, whereas cold winters with heavy snow can lead to heavy spring runoff and floods. Precipitation characteristics in the Grand River watershed are quite varied, including short intense rainfalls and thunderstorms in the summer due to convection, to steady gentle rainfalls in the autumn, to heavy snowfalls that can last for days in the winter, and flashy spring downpours. There are some months which have higher and lower precipitation values, for example February typically has the lowest precipitation and August has the highest precipitation value. The warmer temperatures in the summer months enable the air to hold more moisture than in the winter months, producing more precipitation.

Extreme weather is not uncommon in the Grand River watershed. The region has experienced tornadoes, extreme snow days, droughts and other unpredictable weather events such as remnants of hurricanes. Summer is the time when most droughts occur because of the high water demands and high evapotranspiration rates. The summer can also see extreme thunderstorms due to convection or weather fronts, which can result in high amounts of rainfall in short durations, and thus, it is not uncommon that the summer experiences short stints of heavy rainfall followed by longer stretches of little to no rainfall (GRCA, 2008). The winter months contend with various kinds of precipitation from rain to snow, including sleet, freezing rain, heavy wet snow, blizzards with extreme wind storms and ice conditions.

In summary, climatic patterns in the Grand River watershed, as well as the rest of southern Ontario, are constantly changing. The four seasons experienced here have typical weather patterns but are also coupled with unpredictable weather patterns due to its geographic location. Daily weather within each of the seasons could be typical of the current season, or of the previous or following season, such as having a snowy day in October followed the next week by a heat wave.

The Ontario Ministry of Natural Resources published a report in 2007 identifying the key potential impacts of climate change for different regions of Ontario. For the Southern central Ontario, these potential impacts including warmer temperatures, decreased precipitation, increased evapotranspiration, less snow/ice cover, increase in extreme weather events, change in distribution of flows in surface water, less groundwater recharge, and less baseflow (MNR, 2007).

4.2.3.4 Surface Water Hydrology

The Guelph WQSA overlaps with the watershed divide separating the Grand River watershed from the watersheds of the Credit River, Bronte Creek, Sixteen Mile Creek and Spencer Creek (see Figure 4-4). The surface water hydrology for the watersheds is discussed in the subsections below. General information regarding the watersheds is provided in Table 4-3.

With the exception of Puslinch Lake (a large, relatively shallow natural kettle lake in the southern portion of the WQSA), there are no large natural surface water bodies in the Guelph WQSA. Some artificial lakes and reservoirs have been constructed for flood control and recreational purposes including: Belwood Lake in Centre Wellington; and, Guelph Lake in Guelph-Eramosa (Matrix Solutions Inc., 2017). They are located in the northwest portion of the WQSA, and within the Township of Guelph/Eramosa, north of Hamilton Drive and the City of Guelph, respectively. In the Region of Halton to the southeast, the Mountsberg Reservoir lies south of Highway 401, and Valens Reservoir lies along the east side of the Grand River watershed boundary in the southern part of the WQSA (Matrix Solutions Inc., 2014).

Table 4-3: Summary of Subwatersheds in Guelph WQSA

Region	Conservation Authority	Subwatershed		Drainage area (km^2) [A]	Surface Water (SW) Municipal Systems/Sources in WQSA
Wellington, Region of Waterloo, Dufferin, Halton	Grand River	Speed River		503	None
		Eramosa River		270	Guelph Eramosa/Arkell intake
		Mill Creek		82	None
		Central Subwatershed	Grand Above Shand (Dam) to Legatt	426	None
			Grand Above Conestogo (River) to Shand (Dam)	640	None
			Grand Above (Village of) Doon to Conestogo (River)	248	Region of Waterloo Mannheim intake
Wellington, Dufferin, Halton	Credit River	West Credit River		105.56	None
		Black Creek		79.28	None
Halton	Halton	Bronte Creek		317	None
		Sixteen Mile Creek		371	None
Hamilton	Hamilton	Spencer Creek		280	None

[A] The entire drainage area of the subwatershed is reported here, not only the portion of the subwatershed located within the boundaries of the WQSA.

Source: Matrix Solutions Inc. (2017), LERSPC (2017), CVCA (2015), HHSPR (2015).

Grand River Watershed

The majority of the Guelph WQSA is occupied by the Grand River watershed and its subwatersheds: the Eramosa River subwatershed, located near the centre of the WQSA; the Speed River subwatershed, located immediately west and southwest of the Eramosa River subwatershed; and the Mill Creek subwatershed, located in the southern portion of the WQSA. The Grand River proper flows through the northwestern portion of the WQSA in a general southwestern direction before flowing past the WQSA's western boundary; it then flows back into the southwestern corner of the WQSA in a general southeastern direction. Surface water drainage in the Grand River watershed is in a general south-southwestern direction.

The Speed River subwatershed occupies a total surface area of approximately 503 km^2, and originates in the northern part of the WQSA near the Orangeville Moraine (Matrix Solutions Inc., 2017). The Orangeville Moraine is characterized by a well-defined drainage network, and therefore experiences relatively less groundwater recharge compared to other areas in the subwatershed, which in turn results in the groundwater discharge contribution to the Speed River's flow regime being relatively lower and more variable (LERSPC, 2017). The river flows southward through the Township of Guelph/Eramosa, the City of Guelph, and feeds into the Grand River at the City of Cambridge, at a point approximately 1.9 km south of the WQSA's southern boundary. Flows in the lower portions of the Speed River are regulated by the Guelph Dam, which controls flows in order to augment low flow for waste assimilation purposes, and to control flooding in the City of Guelph (LERSPC, 2017).

The headwaters of the Eramosa River are located in the northern part of the WQSA, on the edge of the Orangeville Moraine near the Village of Hillsburgh. The river flows south through the northern portion of the Township of Guelph/Eramosa, past Everton, through the City of Guelph, and drains into the Speed River. The Eramosa River subwatershed has a total area of approximately 270 km^2, and consists of the Upper and Lower Eramosa River and Blue Springs Creek subwatersheds (238 km^2), as well as the Torrance Creek (11 km^2) and Clythe Creek (21 km^2) subwatersheds (Matrix Solutions Inc., 2017). A large portion of the Eramosa River subwatershed is characterized by moraines with hummocky topography, which collects runoff in its large scale depressions; much of the runoff therefore does not reach a watercourse, but is instead evaporated from and/or infiltrated into the hummocks. The Eramosa River subwatershed is also characterized by pervious material and significant forest cover, which, in addition to the hummocky topography, results in it generating reliable amounts of baseflow.

Mill Creek is located to the southeast and south of the City of Guelph in Puslinch Township, and drains into an area south of the Blue Springs Creek Subwatershed to the confluence with the Grand River in the City of Cambridge (south of the Guelph WQSA). The Mill Creek subwatershed has a total area of approximately 82 km^2 (LERSPC, 2017).

In the integrated surface water budget for the Grand River watershed, the portions of the Grand River overlapping with the Guelph WQSA correspond to the "Grand Above Shand to Legatt", the "Grand Above Conestogo to Shand" and the "Grand Above Doon to Conestogo" subwatersheds, with drainage areas of 426 km^2, 640 km^2 and 248 km^2, respectively (LERSPC, 2017). The upper Grand River, upstream of the Shand Dam Reservoir (between Fergus and Belwood, in the northwestern portion of the WQSA), is runoff-dominated. Runoff from spring snowmelt is used to fill the reservoir at Shand Dam, which holds back water in the spring to mitigate flooding, and releases the water to augment downstream flows during summer low flow conditions. Flows through the central portion of the Grand River are regulated by upstream reservoirs, which capture spring snowmelt in order to reduce the magnitude of spring floods and augment summer low flows for the areas downstream. Summer low flows are augmented in part to ensure sufficient flow for municipal water supply (Region of Waterloo Mannheim intake) and wastewater assimilation (e.g. the wastewater treatment plants for the City of Kitchener and the City of Waterloo; CIMA+, 2018).

Credit River Watershed

Within the Credit River watershed in the northeastern portion of the WQSA, surface water drainage is in a general northeast direction towards the Credit River, which itself crosses through the northeastern corner of the WQSA in a general southeastern direction. The major subwatersheds of the Credit River that are located within the Guelph WQSA include the West Credit River subwatershed and the Black Creek subwatershed, with total drainage areas of 105.56 km^2 and 79.28 km^2, respectively (CVCA, 2015).

Bronte Creek and Sixteen Mile Creek

The Bronte Creek and Sixteen Mile Creek, located in the southeastern portion of the WQSA, are within the jurisdiction of Conservation Halton. Surface water drainage in the southeastern portion of the WQSA is in a general southeastern direction towards Lake Ontario. The subwatersheds for Bronte Creek and Sixteen Mile Creek have total drainage areas of approximately 317 km^2 and 371 km^2, respectively (HHSPR, 2015).

In Mountsberg Creek, a tributary of Bronte Creek and located upstream of the Mountsberg Reservoir (near the southeastern corner of the WQSA), flows are typically permanent, but may be intermittent during periods of drought.

Spencer Creek

The headwaters of Spencer Creek are located in the southeastern portion of the WQSA, immediately west of the Bronte Creek subwatershed. Its cold headwaters, as well as its headwater tributaries, drain the southern edge of the Galt Moraine and the wetlands on the Flamborough Plain. The Spencer Creek subwatershed is within the jurisdiction of the Hamilton Conservation Authority, and surface water drainage is in a general southern direction. The Spencer Creek subwatershed has a total area of approximately 280 km^2, of which roughly 25 km^2 located within the boundaries of the WQSA.

4.2.4 Aquatic Habitat and Species

Aquatic thermal regions for surface water bodies in the WQSA are mapped and illustrated on Figure 4-6. The majority of the water bodies in the WQSA are characterized by cold or cool water regimes; warmwater bodies are largely confined to the southwestern portion of the WQSA, in the lower Speed River and its tributaries. Aquatic habitat and species in the watersheds of the Guelph WQSA are discussed below.

Grand River Watershed

The main channel of the Grand River has numerous areas of active groundwater discharge, providing thermal refuges for fish. The river between Shand Dam to West Montrose (in the vicinity of Elora/Fergus) supports the Grand River Tailwater Fishery, a well-known fishery for brown trout, a cold-water species. A management plan to support the fishery was initiated in 1999 by the Ministry of Natural Resources (now the Ministry of Natural Resources and Forestry), the Grand River Conservation Authority and the Friends of the Grand River, highlighting the biological, social and economic developments of the fishery and the issues it faces (LERSPC, 2017).

Large portions of the Speed River subwatershed remain forested, and the aquatic habitat is therefore less impacted compared to more developed areas of the Grand River watershed. Groundwater discharge feeds some of the Speed River's tributaries and sections of its main stem, allowing coldwater fisheries to exist in the upper watershed of the Grand River. The Speed River transitions into a warmwater fish community in its downstream reaches, past Guelph.

Among the aquatic species at risk (SAR) listed under the federal *Species at Risk Act* and the provincial *Endangered Species Act*, the following aquatic SAR may be present in the Grand River within the Guelph WQSA, on account of them being identified as being present within the broader Grand River watershed (GRSPA, 2015; GRCA, 2018):

- Fish:
  - Silver shiner (Threatened provincially, Special Concern federally);
  - Eastern sand darter (Endangered provincially, Threatened federally);
  - Redside dace (Endangered provincially and federally);
  - Northern brook lamprey (Special Concern federally and provincially);
  - River Redhorse (Special Concern federally and provincially);
  - Black redhorse (Threatened provincially);
- Molluscs:
  - Mapleleaf mussel (Endangered provincially, Threatened federally);
  - Fawnsfoot (Endangered provincially);
  - Kidneyshell (Endangered federally and provincially);
  - Wavy-Rayed Lampmussel (Endangered provincially, Special Concern federally);
  - Round Pigtoe (Endangered federally and provincially);
  - Rainbow mussel (Endangered federally and provincially); and
  - Pygmy pocket moss (Special Concern in Ontario).

Based on mapping of federally-listed SAR developed by Fisheries and Oceans Canada (DFO, 2018), the following species and/or their critical habitat are found and/or may potentially be found in the Grand River watershed within the Guelph WQSA:

- Grand River near Kitchener:
  - Critical habitat for Rainbow mussel found;
  - Rainbow mussels found or potentially found;
- Irvine Creek (tributary to Grand River, in the northwestern portion of the WQSA):
  - Redside Dace found or potentially found.

Credit River Watershed

SAR in the Credit River watershed are mostly terrestrial species (CVCA, 2015). The SAR with the greatest profile in the watershed is the Redside Dace, which is presently or historically known to exist in several creeks, including Caledon Creek in the northeastern corner of the Guelph WQSA (CVCA, 2015). Mapping from DFO (2018) indicates that Redside Dace is found or may potentially be found in the main stem of the Credit River within the boundaries of the Guelph WQSA.

The Atlantic salmon is currently listed as extirpated from Lake Ontario and the Credit River. As part of the Atlantic Salmon Restoration Program for Lake Ontario, the Credit River was selected as one of the three top priority rivers for re-introduction stocking and habitat restoration projects (CVCA, 2015).

Bronte Creek and Sixteen Mile Creek

The upper reaches of Sixteen Mile Creek, which are less developed than its lower reaches, still contain quality coldwater habitat. The lower reaches historically supported coldwater habitat, but became impacted over time by agricultural activities and urbanization.

Significant groundwater input helps to maintain coldwater conditions in the headwaters of Bronte Creek (HHSPC, 2015). The marsh associated with the Mountsberg Reservoir (near the southeastern corner of the Guelph WQSA) is a designated provincially significant waterfowl staging area and a regionally significant waterfowl breeding area, and also acts as a significant migratory stopover area, and supports a warmwater fish community (HHSPC, 2015).

The following provincially or federally-listed SAR have been recorded in Conservation Halton's jurisdiction (Conservation Halton, 2018):

- American eel (Endangered in Ontario)
- Redside Dace
- Silver Shiner
- Atlantic salmon (extirpated, reintroduced in Lake Ontario)

No further specification was provided regarding the location(s) where these species were actually recorded within the Conservation Authority's jurisdiction. Except for the Redside Dace, the habitat requirements of the above-listed species make them unlikely to occur in the headwaters streams located within the Guelph WQSA.

Mapping from DFO (2018) indicates that Redside Dace is found or may potentially be found in the portions of Sixteen Mile Creek and Bronte Creek within the Guelph WQSA.

Spencer Creek

Information about SAR in the headwaters of Spencer Creek was not readily available. Mapping from DFO (2018) indicates that Redside Dace is found or may potentially be found in the portion of Spencer Creek within the Guelph WQSA.

4.2.5 Geology

4.2.5.1 Surficial Geology

The surficial geology of the Guelph WQSA has been described in detail by Karrow (1987, 1968). The OGS surficial Quaternary geology mapping of the WQSA is included on Figure 4-7. Most of the area is covered by varying thicknesses of glacial deposits, with bedrock exposed in some areas primarily within the deeper river valleys (e.g., through Elora, Fergus, Rockwood, Eden Mills and Guelph) and in the eastern portion of the WQSA in Flamborough and Acton.

After a period of marginal ice retreat, a prominent ice-lobe formed in the Lake Ontario basin, advancing westward over the WQSA. These advances formed the most recent Quaternary deposits, with surficial sediments consisting of mainly till deposits with a significant area interspersed with ice-contact stratified deposits and glaciofluvial deposits. Glacial till refers to the poorly sorted mixture of clay, silt, sand and gravel (in varying proportions) that is the principal deposit left behind by continental ice sheets (Golder, 2011d). The most dominant feature found in the WQSA is a stone-poor, carbonate-derived silty to sandy till, found with streaks of glaciofluvial deposits, sandy deposits, and gravelly deposits. To the northern and northwest portion of the WQSA glaciolacustrine-derived silty to clayey till and ice-contact stratified deposits.

In general, the main overburden units present in the WQSA are summarized as follows by the City of Guelph Tier Three Assessment (Matrix Solutions Inc., 2017):

> ***Catfish Creek Till***
>
> *The Catfish Creek Till was deposited by a major glacial advance from the north to northeast that covered all of southern Ontario. The Catfish Creek Till is a dense, stony, sandy silt to silty sand till with little clay content. It is the oldest main Quaternary unit. Although originally deposited over a large area, erosion, glaciations and meltwater events have removed areas of the Catfish Creek Till and it is now discontinuous. Where present, it is usually found immediately overlying bedrock and beneath clayey sediments and is preserved in a few outcrops along the Grand River (Karrow, 1968) and may also be present in deeper older bedrock valleys such as the Rockwood buried valley. It is often interbedded with sand and gravel. The lithology and degree of compaction and/or cementation of the Catfish Creek Till are variable.*
>
> ***Port Stanley Till and associated fine grained drift***
>
> *The Port Stanley Till is a sandy silt to silty sand till and is occasionally stony. The Port Stanley Till was deposited by ice advancing from the Erie-Ontario ice lobe. In the Grand River and Speed River valleys this unit has been largely removed by erosion. This unit is generally finer grained than the younger Wentworth Till.*

4.2.5.2 Bedrock Geology

The bedrock formations in the Guelph WQSA consist of Paleozoic sedimentary rocks, composed of limestone, dolostone and shale sequences that generally ranges from about 40 to 100 m in thickness. The bedrock formations exhibit a gentle regional dip (about 4 degrees) to the southwest. In the east moving toward the Niagara Escarpment, the younger formations have been eroded reducing the overall thickness of the system and exposing the deeper formations at surface. The escarpment represents the easternmost limit of the aquifer system. The exposed bedrock outcrops in the WQSA are limited to a few areas including primarily the deeper river valleys (e.g., through Elora, Fergus, Rockwood, Eden Mills and Guelph) and in the eastern portion of the WQSA in Flamborough and Acton. The bedrock geology of the WQSA, as shown on Figure 4-8, shows an upper Ordovician shale, limestone, dolostone, and siltstone (Queenstone Formation) covering a small section along the eastern WQSA boundary, with a lower Silurian - sandstone, shale, dolostone, siltstone across the remaining WQSA. The lower Silurian section includes the Guelph Formation, Eramosa Formation, Amabel Formation (also known as the Gasport Formation), and a thin section of the Clinton Group; Cataract Group.

The hydrogeological cross section shown on Figure 4-9 better illustrates the revised stratigraphic framework described by the OGS (Brunton, 2009) for the Paleozoic bedrock formations. The Ontario Geological Survey (OGS) is currently mapping the Silurian carbonate strata along the Niagara Escarpment region and has proposed this revised framework for stratigraphy of this area.

A brief description of each of these bedrock formations is provided below (from oldest to youngest), as an excerpt from the City of Guelph Tier 3 Assessment (Matrix Solutions Inc., 2017):

> ***Cabot Head Formation***
> *The Cabot Head Formation, readily distinguished by its grey-green colour, is a non-calcareous shale with thin interbeds of sandstone and limestone. This unit ranges from 10 to 39 m thick (Johnson et al. 1992).*
>
> ***Gasport Formation***
> *The Gasport Formation is a cross-bedded crinoidal grainstone-packstone with sequences of reef mound and coquina (shell bed) lithofacies. This unit has commonly been referred to as the Amabel Formation in previous studies in the area. The Formation generally varies in thickness from about 25 to over 70 m, and the upper sections of the reef mounds, the crinoidal grainstones and the coquina shell beds make this formation highly transmissive, where they are present.*

Goat Island Formation

The Goat Island Formation consists of two members; the lower Niagara Falls Member and the upper Ancaster Member. The Niagara Falls Member is a finely crystalline and cross laminated crinoidal grainstone with small reef mounds. This unit is typically less than 10 m thick. The Ancaster Member is a chert rich, finely crystalline dolostone that is medium to ash grey in colour. This unit generally overlies the Niagara Falls Member although in some cases in the Cambridge and Guelph areas, these units are interfingered.

Eramosa Formation

The Eramosa Formation consists of three members including, from oldest to youngest, the Vinemount Member, the Reformatory Quarry Member and the Stone Road Member. Both the Vinemount and Reformatory Quarry member can be seen in the cross section. The Vinemount Member is comprised of thinly bedded, fine crystalline dolostone with shaley beds that give off a distinctive petroliferous odour when broken (Brunton, 2008). This dark grey to black dolostone unit was commonly identified in water well records as 'black shale' and mapped in previous studies in the City of Guelph as the Eramosa Member. The shaley beds of this Formation significantly reduce the vertical permeability across this unit relative to the other Formations. The Eramosa Formation above the Vinemount Member is described by Brunton (2008) as light brown to cream coloured, pseudonodular, thickly bedded and coarsely crystalline dolostone. This unit is susceptible to karstification due to its uniform fine dolomite crystallinity (Brunton, 2008). This unit also often contains mud-rich and microbial matbearing lithofacies that may act as aquitard materials, reducing the vertical permeability across this unit. This unit was logged as either the Guelph Formation or Eramosa Member in previous studies within the City of Guelph. The Stone Road Member is cream coloured coarsely crystalline Upper Eramosa unit and can be difficult to distinguish from the Guelph Formation.

Guelph Formation

The Guelph Formation consists of two members; the lower Hanlon Member and the upper Wellington Member. The Guelph Formation consists of medium to thickly bedded crinoidal grainstones and wackestones and reefal complexes (Brunton, 2008). The Guelph Formation is cream-coloured and fossiliferous and where present in the Cambridge and Guelph area it is most often the uppermost bedrock

4.2.6 Hydrogeology

Groundwater resources are found in both overburden and bedrock aquifers in the WQSA. Figure 4-10 illustrates defined water quality wellhead protection areas (WHPA) along with all overburden and bedrock wells in the WQSA extracted from the Water Well Information System (WWIS). The bedrock formations described above form a thick (40 to 100 m) and extensive groundwater aquifer system. The municipal supplies for Guelph and Cambridge, Rockwood, Fergus and Elora rely on the Gasport and Guelph Formation units for the majority of their potable drinking water supplies. The Gasport Formation represents the most common aquifer used for groundwater supply within the WQSA due to the transmissive nature of the limestone unit. The Eramosa Formation overlies the Gasport Formation, and the Vinemount Member in particular consists of mud-rich dolostone beds that limit the lateral and vertical flow of water through the unit. The Vinemount Member is extensive throughout the WQSA although it was interpreted to be stratigraphically absent in places (e.g., Erin and Hillsburgh areas – see Appendix 4-A and 4-B, respectively), or has been removed by erosion in some areas, including an area near Rockwood, between Blue Springs Creek and the Eramosa River, as well as northwest Guelph. In the Aberfoyle area, the Eramosa is believed to be present, however its efficiency as an aquitard unit is believed to be minimal, based on road salt impacts migrating through the unit, into the Gasport formation (see Appendix 4-C for details).

Table 4-4: Hydrostratigraphic Units in Study Area

Hydrostratigraphic Unit	Geological Description	Specific Geological Units
Upper Sand and Gravel Aquifer (Overburden A)	Outwash sand and gravel deposits and glacial tills	Coarse sand and gravel, Wentworth Till, Port Stanley Till, Fine-grained Sediments
Lower Till Aquitard (Overburden B)	Glacial tills (dense, sandy, silty) occasionally interbedded with discontinuous lenses of coarse sands/gravels	Wentworth Till, Port Stanley Till, Catfish Creek Till
Contact Zone Aquifer	Fractured bedrock and overlying basal unconsolidated deposits	Coarse, granular deposits overlying weathered bedrock
Bedrock Aquifer/Aquitard	Medium to thick bedded fossiliferous dolostone	Guelph Formation (incl. Eramosa Formation - Stone Road Member)
Bedrock Poor Aquifer/ Poor Aquitard	Thickly bedded, coarsely crystalline dolostone	Eramosa Formation - Reformatory Quarry Member
Bedrock Aquitard	Thinly, shaley bedded, fine crystalline dolostone	Eramosa Formation - Vinemount Member
Bedrock Aquifer/Aquitard	Chert-rich, fine crystalline dolostone and cross-laminated crinoidal grainstone	Goat Island Formation
Bedrock Aquifer	Cross-bedded grainstone-packstone with sequences of reef mound and coquina lithofacies	Upper Gasport Formation
Bedrock Aquifer (High Permeability)	Cross-bedded grainstone-packstone with sequences of reef mound and coquina lithofacies; Highly transmissive with secondary porosity (cavities, vugs, fractures)	Middle Gasport Formation
Bedrock Aquifer	Cross-bedded grainstone-packstone with sequences of reef mound and coquina lithofacies	Lower Gasport Formation (incl. Roch./Iron./Rock./Merri. Fms.)
Bedrock Aquitard	Shale interbedded with sandstone and limestone	Cabot Head Formation

Source: (Matrix Solutions Inc., 2017)

4.2.6.1 Overburden Aquifers

Major moraine systems, including the Orangeville, Paris and Galt, are found in the Guelph WQSA. The moraines are comprised of extensive sand and gravel units and provide significant amounts of groundwater for municipal and private use across the watershed. The Orangeville Moraine, located in the northern portion of the Grand River watershed, is situated on the east side of Belwood Reservoir, and extends up to the west side of Orangeville. A high water table elevation is associated with this feature. A portion of the groundwater within the moraine tends to flow to the northwest towards the Grand River, while the remainder flows to the southwest towards the Credit River watershed. Although not used for municipal supplies, the Orangeville Moraine is a highly permeable feature and has been identified as an area of a significant groundwater recharge area (AquaResource, 2009). The Significant Groundwater Recharge Areas mapping completed in for the Guelph Eramosa Tier Two and Tier 3 Assessments are similar as the thresholds were similar (200 mm/year and 202 mm/year). Both assessments identify large portions of the watershed on the moraines outside the urban areas as high recharge areas and well as the low recharge areas associated with the Port Stanley Till.

Located to the south of the Orangeville Moraine, the Waterloo Moraine is one of the largest moraines within the Grand River watershed. A number of aquifers situated within the moraine are used by the Region of Waterloo for municipal drinking water supply. Groundwater from the large aquifers within the moraine discharges to and maintains baseflow in many small cold water tributaries and provincially significant wetlands.

4.2.6.2 Bedrock Aquifer

Within the WQSA, several bedrock units have the ability to transmit significant quantities of groundwater making them important for municipal and private use. These units include the Gasport Formation, the Guelph Formation and the Salina Formation, and were described in detail in the Grand River Watershed Tier 3 report (Matrix Solutions Inc. and S.S. Papadopulos, 2014).

The Gasport Formation underlies the Guelph Formation throughout the Grand River watershed with the exception of where it outcrops in the eastern extents of the watershed. The formation, which is predominantly comprised of limestone and dolostone, ranges in thickness from 10 to 45 m. Portions of the Gasport Formation have been subjected to varying degrees of solution enhancement (karstification), resulting in areas of higher porosity, which have enhanced the ability of the rock to transmit groundwater. The Gasport Formation is a highly productive aquifer where significant groundwater yields are derived from the middle section of the Formation, as shown on Figure 4-9, which is often termed the 'Production Zone'. The Production Zone exhibits a higher secondary porosity relative to the less fractured upper and lower zones. To date, the exact lateral extents of the production zone are unknown. Near the community of Rockwood, the Gasport Formation is overlain by the Eramosa Formation, which can be up to 20 m thick. The Vinemount member is the portion of the Eramosa Formation, characterized by its black, shale-rich nature, behaves as a regional aquitard. Where the Eramosa Formation is present, the underlying Gasport Formation is not highly influenced by shallow groundwater recharge and discharge (GRCA, 2008).

Overlying the Gasport and Eramosa Formation, the Guelph Formation forms a moderately productive aquifer. The largest groundwater yields from this formation are from the upper portion of the bedrock which exhibits a higher secondary porosity (typically more weathered and fractured) than lower sections of the Formation (GRCA, 2008).

The Salina Formation overlies the Guelph Formation in the western and southern portion of the watershed, as shown on Figure 4-9. This formation is considered a moderately productive regional aquifer, supplying groundwater for both municipal and private use. Higher transmissivity values are a result of mineral dissolution and fractures which have developed in the upper bedrock. There are, however, water quality concerns, as the natural water quality of this aquifer is often poor (GRCA, 2008).

4.2.6.3 Groundwater-Surface Water Interaction

In general, the Gasport Formation aquifer appears to coincide with the surface water divide between the Grand River and Credit River watersheds. This is not the case along the divide between the Grand River Watershed and the Halton and Hamilton Region CA jurisdiction to the south. Significant groundwater discharge occurs in the Eramosa River and Blue Springs Creek where ground surface topography is incised into the deeper bedrock system (Matrix Solutions Inc., 2017). The smaller streams have very little influence on the deep groundwater flow system. There is limited interaction between the deep aquifer and surface water bodies, although interaction can be seen along the Eramosa River upstream of Eden Mills near Rockwood and along Blue Springs Creek. The effects of municipal and non-municipal wells pumping from the Gasport Formation aquifer are seen as depressions in the potentiometric surface around various well fields, and through the middle of the City of Guelph's higher permeability aquifer zones, as modeled in the Guelph Eramosa Tier 3 Report (Matrix Solutions Inc., 2017).

A high proportion of the flow in the Credit River is attributed to groundwater discharge, particularly in the upper portion of the watershed. A large portion of this baseflow originates from the discharge areas along the flanks of moraines (such as the Orangeville Moraine and the Paris Moraine) just west of the Niagara Escarpment, as well as the significant discharge areas associated with the Escarpment itself. At stream gauge 02HB001 (in the northeast corner of the Guelph WQSA), with a mean annual flow of 1.83 m^3/s, CVCA (2015) estimated that 1.36 m^3/s (75%) of the mean annual flow comes from baseflow. Similarly, the Credit River at stream gauge 02HB018 (more than 15 km downstream of gauge 02HB001, and located approximately

3.3 km east of the Guelph-Wellington WQSA), has a mean annual flow of 4.5 m^3/s, of which approximately 3.26 m^3/s (73%) is attributed to baseflow. This indicates that a theoretical reduction in shallow groundwater flow, if significant, could impact surface water flows in the Credit River, particularly during summer low flows that are mostly driven by baseflow.

4.2.7 Overview of Water Takings within WQSA

4.2.7.1 Permitted Takings

Figure 4-11 shows a map of the active surface water and groundwater permitted takings within the Guelph WQSA, categorized by purpose. Percentages and values in the following paragraphs used to characterize water demands by Purpose and Specific Purpose were derived from 2017 PTTW and WTRS data. In Ontario, water takings for ordinary household use and livestock watering are exempted from PTTW requirements for takings up to 379,000 L/day.

Water is used for potable supply to municipalities, private homes and campgrounds as well as for irrigation (e.g. agriculture and golf courses), water bottling, industry, hydroelectric generation, aquaculture, and manufacturing. A review of PTTW and WTRS records indicates that approximately 44% of the permitted takings are designated to Power Production, at approximately 114 million m^3 of surface water. Power Production made up 60% of the permitted volume of water taken in 2017, all extracted from the Grand River. For the purpose of the analysis below, water used for hydroelectricity will not be considered a consumptive use. Water takings and permitted volumes are summarized in Table 4-5.

Table 4-5: Volume of Reported Water Takings vs Maximum Permitted Volume of Surface and Groundwater within WQSA (2017 WTRS)

Sector	Type	Volume of Reported Takings (m^3/yr)	Percent of WQSA Total Reported Takings (%)	Maximum Permitted Volume (m^3/yr)	Permit Utilization (reported takings/maximum permitted volume) (%)
Agriculture	Groundwater	40,166	**0.05**	2,844,850	**1.4**
	Surface and Groundwater	14,117	**0.02**	836,880	**1.7**
	Surface Water	16,884	**0.02**	590,508	**2.9**
Commercial	Groundwater	3,577,552	**4.9**	21,355,038	**17**
	Surface and Groundwater	3,905,201	**5.3**	14,852,690	**26**
	Surface Water	64,886	**0.09**	3,444,114	**1.9**
Dewatering	Groundwater	5,935,848	**8.1**	25,092,710	**24**
	Surface Water	23,203	**0.03**	7,517,700	**0.31**
Industrial	Groundwater	13,888,314	**19**	62,354,690	**22**
	Surface and Groundwater	5,696,219	**7.7**	16,093,049	**35**
	Surface Water	442,957	**0.60**	1,193,550	**37**
Institution	Groundwater	217,860	**0.30**	1,060,467	**21**
Miscellaneous	Groundwater	58,572	**0.08**	229,950	**25**
	Surface and Groundwater	2,927,033	**4.0**	13,776,768	**21**
	Surface Water	790,560	**1.1**	54,864,000	**1.4**
Recreational	Groundwater	0	**0.00**	17,340	**0.0**
	Surface and Groundwater	41,845	**0.06**	57,276	**73**
	Surface Water	51,812	**0.07**	155,000	**33**
Remediation	Groundwater	172,570	**0.23**	995,954	**17**
Water Supply	Groundwater	24,169,285	**33**	115,238,397	**21**
	Surface and Groundwater	9,225	**0.01**	228,475	**4.0**
	Surface Water	11,518,030	**16**	93,338,672	**12**
Total	All Sources	73,562,140	**100.00**	436,138,078	**17**

Water Supply

According to 2017 WTRS data, there are 117 water supply PTTWs in the WQSA. Of these, 77 are for municipal supply, 24 are for communal, and 16 are for other water supply.

Water supply permitted takings represent roughly 49% of the total permitted volume of takings in the WQSA (33% groundwater and 16% surface water). Within the water supply category, municipalities are the dominant takers comprising over 45% of total reported takings in the WQSA, while the remaining non municipal water supply takings make up roughly 3.5% of the total takings in the WQSA. Water supply permit holders reported takings that were approximately 17% of the total permitted amount in 2017.

With the exception of some campground water supply PTTWs, nearly all water supply PTTWs allow for water taking 365 days per year.

Municipal Water Supply

The largest municipal water supply system wholly located the WQSA is the City of Guelph Water Supply (GWS). The GWS has several wells that dominantly draw from the Gasport and Guelph formations. The City of Guelph has 24 wells; 16 open in the Gasport formation, four open across the Guelph and Gasport formation, two open in the Guelph formation, one open between the Eramosa and Gasport formations, and one screened in overburden.

GWS has one surface water intake on the Eramosa River above Guelph. Water from the surface water intake is injected into the overburden via a groundwater infiltration gallery called the Glen Collector, which is eventually pumped out of the ground by GWS well Arkell 1 (the only GWS well screened in within the overburden).

Numerous Region of Waterloo bedrock and overburden water supply wells, and one surface water intake are located in the southwest portion of the WQSA, however, given that the WQSA only covers a small portion of the Region of Waterloo, they are not discussed further in this report.

The towns of Fergus and Elora are located in the west central portion of the WQSA and have an integrated water supply system that draws water from nine bedrock wells. Five of the wells are open between the Guelph and Gasport formations, and four of the wells are open across the Guelph and Goat Island formations (Matrix Solutions Inc 2017b). The Towns of Erin and Hillsburgh have four municipal supply wells that draw water from the Guelph/Amabel formations in the WQSA (CTCSPR, 2015).

Industrial

Industrial related permitted takings represent the second largest taker in the WQSA, with approximately 27% of the total permitted volume taken in 2017 (19% groundwater, 0.6% surface water and 7.7% from users who take from both surface water and groundwater).

Of the industrial permits in the WQSA, aggregate washing is the dominant taker using 19.7% of the total permitted volume taken in 2017, while manufacturing, food processing, cooling water, and other industrial uses taking the remaining 7.5%.

The range of allowable taking days for industrial permits is between 130 and 365 days per year. Actual number of days of water taken in 2017 ranged from 0 to 365 days. The 2017 reported takings for industrial purposes were 31.6% of the permitted volume for this group of takers.

Commercial

Within the WQSA, the third largest type of taking in 2017 was for commercial purposes, with roughly 10.3% of the total permitted volume taken within the WQSA (4.9% groundwater, 0.09% surface water, 5.3% both). Within the Specific Purpose category aquaculture was the dominant taker in 2017, using 7.18% of the total volume taken in the WQSA, while bottled water and golf course irrigation make up the next largest percentage at 1.2% and 1.5%, respectively. Snowmaking, malls/businesses and other commercial uses make up the remaining 0.4% of the total volume taken in the WQSA in 2017.

With few exceptions, aquaculture takings from surface water and groundwater are permitted for 365 days per year, and are commonly utilized 365 days per year. Aquaculture surface water permits utilize 32% of their total permitted volume, the highest rate of any category. Aquaculture utilization of permitted volume is 16% for groundwater takers and 95% for users of both surface water and groundwater. There is one reported case of 502% utilized, exceeding the permitted amount allowed.

The range of allowable taking days per year for golf course irrigation permits is between 150 and 365 days per year. In 2017, the utilization of permitted volume was 7.2% for all golf course takings.

Water Bottling

Three water bottling permits located within the WQSA that utilize groundwater were identified by the MECP for detailed review, referred to as Water Bottling Study Areas (WBSA). Each WBSA study provides an in depth analysis of the current state and sustainability of the water resource. The WBSAs are listed below, and their studies are located in the following appendices:

- Aquaterra Corporation Ltd. – Hillsburgh Site (Appendix 4-A)
- Nestle Waters Canada – Erin Site (Appendix 4-B)
- Nestle Waters Canada – Aberfoyle Site (Appendix 4-C)

A summary of water taking activities at the three WBSAs is provided in Table 4-6 below.

Table 4-6: Overview of Water Taking Activities at Water Bottling Study Areas in the Guelph WQSA

	Aquaterra (Hillsburgh)	**Nestlé (Erin)**	**Nestlé (Aberfoyle)**
Municipality	Erin	Erin	Puslinch
PTTW Number	8664-75QJ2J	3716-8UZMCU	1381-95ATPY
PTTW Issue Date (month/day/year)	08/21/2007	09/28/2012	12/19/2013
PTTW Expiry Date (month/day/year)	07/31/2017	08/31/2017	07/31/2016
Source Description	1 limestone **bedrock well** (53.6 m deep)	1 limestone **bedrock well** (39.01m deep; screened from 21.79m - 39.01m)	1 dolostone **bedrock well** (31.1 m deep; screened from 28.4 to 31 m) for water bottling. 1 dolostone **bedrock well** (58 m deep, screening from 31.7 to 58 m) for firefighting purposes only.
Annual Amount Permitted by the PTTW (Million Litres)	58.5	406.25	1,314
Max. Taken per Day (Litres)	225,000	1,113,000	3,600,000
WTRS Amount Taken in 2017 (% of PTTW)	19.0%	16%	58%

Dewatering

Dewatering PTTWs make up 8.1% of total permitted volume taken in the WQSA in 2017 (8.07% groundwater, 0.03% surface water). Within the Specific Purpose category, pits and quarries were the dominant takers in 2017, using 8.03% of the total permitted volume taken in the WQSA. In 2017, pits and quarries took 27.4% of their permitted volume. These permits allow water to be taken from 30 to 365 days a year. Dewatering permits range from 260 to 365 days a year and utilize 18.3% of permitted water in 2017.

Institutional, Remediation, Recreation and Miscellaneous

Institutional, remediation, recreation and miscellaneous permitted takings account for 0.30%, 0.23%, 0.13%, and 5.2% respectively of the total permitted volume taken in 2017 within the WQSA. The specific purpose of use within these categories include: school, pumping tests, heat pumps, dams and reservoirs, aesthetics and groundwater remediation.

Agriculture

Permitted surface water and groundwater takings for the purpose of agriculture in the WQSA were only approximately 0.1% of total permitted takings in the WQSA in 2017 (0.05% groundwater, 0.02% surface water, 0.02% both). Only 16 PTTWs for agriculture are present in the WQSA.

Within the Specific Purpose categories, irrigation for field and pasture crops make up 0.011% of the total takings in the WQSA in 2017, market gardens/flowers makes up 0.02%, while sod farms and other agricultural type takings make up the remaining 0.065 and 0.025% respectively.

The range of allowable taking days per year for agricultural irrigation permits is between 0 and 365 days per year. On average, agriculture PTTW permit holders utilized approximately 1.6% of the total permitted amount in 2017. This was relatively consistent across surface water users (2.8%), groundwater users (1.4%), and users who used both groundwater and surface water sources (1.7%).

4.2.7.2 Non Permitted Takings

While the total volume of non-permitted takings in the WQSA is unknown the Grand River Tier 2 water budget estimated that within the Upper Speed Assessment Area, which comprises a significant portion of the WQSA, estimated annual non permitted takings accounted 1% of all consumptive takings. Potential impacts of non-permitted groundwater takings on the WQSA's water supply sources were assessed on a local-scale in the well field characterization reports for each of the urban well field areas (Blackport 2012a, 2012b; Golder 2011a, 2011b and 2011c; Stantec 2009, 2012a, 2012b and 2012c) and discussed by (Matrix Solutions Inc. and S.S. Papadopulos, 2014).

4.2.8 Recommended WQSA Boundaries for Data Review

The City of Guelph and Township of Guelph/Eramosa Tier 3 Assessment Study Area (Matrix Solutions Inc., 2017) covers almost the entire WQSA. The Water Managers representing the City of Guelph Water Supply (GWS), GRCA, MECP, and Wellington Source Water Protection (WSWP - a municipal partnership between the Townships of Centre Wellington, Guelph / Eramosa, Mapleton, Puslinch, Wellington North, the Towns of Erin and Minto and the County of Wellington) independently agreed that the most current and comprehensive water quantity assessment is presented in the City of Guelph and Township of Guelph/Eramosa Tier 3 Water Budget and Local Risk Assessment (GGET Tier 3) (Matrix Solutions Inc., 2017). S.S. Papadopulos & Associates Inc., representing Nestlé Waters Canada, also noted that GGET Tier 3 (Matrix Solutions Inc., 2017) provides the best and most recent regional-scale synthesis of the hydrogeology of the WQSA. In addition, the challenges as described by local Water Managers exist within the area assessed in the GGET Tier 3. Accordingly, the recommended Guelph WQSA boundary for assessment purposes is the Tier 3 study area, as it makes use of the existing groundwater modelling results and analysis and allows for a more detailed and current water resource assessment of the Guelph WQSA. Figure 4-12 illustrates the recommended revised WQSA boundary for groundwater quantity assessment purposes. For the assessment of the surface water resources within the WQSA, the preliminary WQSA boundary was used because the GGET Tier 3 boundary does not capture all of the utilized surface water features.

4.3 RESOURCE SUSTAINABILITY

4.3.1 Data Review and State of Water Resources

Available information on the sustainability of water resources in the Guelph WQSA has been reviewed and summarized. The key reports relied upon for the evaluation are listed in Table 4-1. Hydrographs from the Provincial Groundwater Monitoring Network (PGMN) within the WQSA were also reviewed, and conclusions were made based on the general findings of studies/reports/data conducted and collected in the Guelph WQSA.

High Use Watershed Classification

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a Low percent water use based upon the Average Annual Flow and Medium percent water use based upon Summer Low Flow.

4.3.1.1 Groundwater

PGMN Wells

In the Guelph WQSA, hydrographs and a statistical analysis of water levels were provided for eleven PGMN wells located within and surrounding the Guelph-Wellington WQSA, including Mann Kendall (MK) and Seasonal Mann Kendall (SK) monotonic trend analyses (i.e. consistently increases or decreases through time) between 2001 and 2017. These wells are summarized in Table 4-7 and shown on Figure 4-9. The methodology for the analysis is forthcoming from the MECP; however, the results are relied upon here to summarize water level trends in the Guelph WQSA. An overall objective is to determine if there is enough data to support the presence of a widespread decrease in groundwater availability. Shorter trends within the PGMN data record (e.g. lasting for a few years) were not considered and the causes of any trends that were identified were not investigated. Both the data plots and preliminary findings for PGMN well locations within the Guelph-Wellington WQSA were shared by the ministry and are presented and relied on herein. The data plots indicate data available for the well at the time of the assessment. Further, the MECP has indicated that the methodologies used require that certain values be dropped from the data set if the month/year in question does not have a sufficient number of data points. The release of a final report that details the methodology and results from the PGMN data trends analysis is forthcoming from the ministry (MECP, 2018).

Table 4-7: PGMN Wells Summary

PGMN Well ID	Water Well Record ID	Screened Interval (mbgs)	Lithology of Aquifer
W0000003-1	2801739	Slotted Pipe: 7.6 m-14.6 m	Sand, Gravel
W0000008-1	6813466	Open Hole	Limestone
W0000024-2	6711653	Screen: 24.4 m-25.9 m	Silt
W0000024-4	6711653	Screen: 38.1 m-39.6 m	Limestone
W0000026-1	6713771	Open Hole: 8.4 m- 36.0 m	Limestone
W0000028-2	2808070	Screen: 5.2 m- 6.7 m	Gravel, Sand
W0000028-4	2808070	Screen: 21.3 m-22.9 m	Gravel, Sand
W0000031-1	6705976	Open Hole: 4.57 m- 27.4 m	Limestone
W0000046-1	6713287	Open Hole: 6.4 m-30.5 m	Limestone
W0000163-2	4909396	Screen: 6.4 m-7.9 m	Silty Sand, Sandy Silt
W0000163-3	4909396	Screen: 21.6 m-23.16 m	Gravel
W0000164-2[1]	6714839	Screen: 6.4 m-7.9 m	Silty Sand, Sandy Silt, Sand
W0000164-3	6714839	Screen: 11.4 m-12.9 m	Sand, Gravel
W0000337-1	N/A	Screen: 16.8 m- 22.9 m	Dolostone

[1] Ministry staff noted the data for trend analysis purposes is deemed unreliable

The Mann Kendall analysis, which looks at the year over year water levels, determined that of the eleven wells reviewed, ten had no trend, while one well (W0000046-1) had a downward trend.

The Seasonal Mann Kendall analysis, which determines the trend from season to season (i.e., Spring 2010 to Spring 2011) and then adds the sum of each seasonal analysis together, established that seven of the wells had upward trends (W0000003-1,W0000024-2, and W0000024-4, W0000026-1, W0000031-1, W0000164-2, W0000164-3), two wells had no trend (W00000163-3 and W0000164-2), and one well had a downward trend (W0000046-1).

W0000046-1 is located east of the city of Guelph, approximately 1.7 km west of the Guelph Water Supply Arkell Spring Grounds Wellfield. The well is an open hole between 6.4 and 30.5 meters below ground surface (mbgs) in bedrock. Given the depth, the well is likely open to the Guelph and Upper Gasport Formations. Water level data for the well is available for between 2001 and 2017, with data gaps between 2003 to 2005, and 2006 to 2007. In general, there appears to be a downward trend in water levels, with annual static head declining by about 1 m between 2005 and 2017 (317.5 to 316.5 masl). Both the Mann Kendall and Seasonal Mann Kendall trend analysis support the downward trend observation. It should be noted that communication with a local Water Manager determined that W0000046-1 has received significant maintenance during its years as a PGMN well due to technical issues, and there continues to be a level of uncertainty to the water level data and subsequently to the trend analysis. Therefore, this well cannot be relied upon to make conclusions about water level trends in the Guelph WQSA.

In summary, the majority of PGMN historical hydrographs in the WQSA have either an upward or no trend in water levels, with the exception of a downward trend in W0000046-1, which is not considered reliable (see above paragraph).

Tier Two Water Budget Stress Assessments

As part of the Tier Two assessments that were completed in Grand River, Credit Valley, Halton and Hamilton (watersheds which lie, or partially lie within the WQSA), the watersheds were reviewed for water quantity stress. This was done by completing a water budget on a subwatershed/groundwater assessment scale which was used to perform a Stress Assessment. The purpose of the Stress Assessment was to determine the potential for stress under existing and planned (accounting for increased demand) conditions. The results of the Stress Assessment are expressed as "percent water demand", which is calculated using the following equation:

% Demand = Total Demand (takings)/(Total Supply[recharge]-Reserve[10% of discharge])

The MECP Guidelines for Stress Assessments states that an annual average and percent water demand between 10% and 25% for average annual demand is considered a moderate potential for stress, and above 25% is considered significant. Maximum monthly demand between 25% and 50% is considered a moderate potential for stress. If a subwatershed is classified as having moderate or significant potential for groundwater stress under current or future demands and contains a municipal groundwater supply system, a Tier Three Assessment for the area may be required.

Several subwatersheds exist within the WQSA. For the purpose of this study, only subwatersheds which were determined to have moderate or significant potential for stress are discussed here.

Table 4-8: Subwatersheds in the Guelph-Wellington WQSA with moderate or significant potential for groundwater stress (compilation of GRCA, CVC, Hamilton and Halton Tier Two Stress Assessments)

Subwatershed	Current Demand		Future Demand	
	Annual Average	Monthly Maximum	Annual Average	Monthly Maximum
Irvine River (GRCA)	Low	Low	*Moderate*	Low
Upper Speed Assessment Area (GRCA)	Moderate	Low	Moderate	Moderate
Central Grand (GRCA)	**Significant**	**Significant**	**Significant**	**Significant**
Mill Creek (GRCA)	*Moderate*	Low	*Moderate*	Low
Black Creek (CVCA)	Moderate	Low	Moderate	Low
Silver Creek (CVCA)	Moderate	Low	Significant	Moderate
Upper West Branch of Sixteen Mile Creek (Halton)	Moderate	Low	Moderate	Low

With the exception of Mill Creek, municipal groundwater supplies are located in each of the subwatersheds listed in Table 4-8, and Tier Three Assessments have been or are currently being conducted in each subwatershed.

Tier Three Local Area Risk Assessments

As per MECP Technical Rules (MOECC, 2016), any groundwater assessment area which has been designated as having at least a moderate potential for stress must conduct Local Area Risk Assessments centred on municipal water supply systems to assess the risk posed by existing and future (as predicted) conditions to municipal water supply systems.

WHPA-Q Delineation

The risk is assessed over an area called WHPA-Q or Wellhead Protection Area for quantity and is delineated as the combined area that is the cones of influence of each municipal well and the whole of the cones of influence of all other wells that intersect each municipal cone of influence (MOECC 2016).

Local Area Risk Scenarios

The Tier Three Assessments uses groundwater and surface water models to determine if certain receptors (including water levels in municipal wells, and surface water baseflow reduction due to water supply well pumping) will be impacted by future conditions. In general, the long term sustainability of the municipal water supply wells is determined using benchmarks of sustainability established in the province's Technical Rules which include the amount of drawdown in a municipal well and the decline in groundwater discharge to surface water that is caused under a variety of future population/economic growth, land use and climate change scenarios.

Drawdown is modelled in supply wells within the Tier Three assessment area to determine if the wells will be able to supply water at the required rates under future conditions. Based on the geology and well construction, each well has been assigned a Safe Amount of Available Drawdown (SAAD) which is defined as the difference (measured in meters) between the average water level in a pumping well under pumping conditions, and a point in the well typically 1 m above the screen or the lowest possible pump intake. If the modelled drawdown in the well under future conditions does not exceed the SAAD, the taking may be considered sustainable from a water supply perspective.

In addition, the potential for impacts to decreased groundwater contributions to surface water features due to increased pumping to meet future municipal demand was also assessed. Groundwater discharge to streams provides cold temperature baseflow that is vital to the ecology of some creeks and wetlands. Based on the Technical Rules, if baseflow is reduced by 10 percent or less under modelled future conditions, the takings are considered sustainable.

Scenarios can arise where SAAD is not exceeded under future conditions, suggesting that from a water supply perspective the taking is sustainable; however, the same water taking is responsible for a baseflow reduction of greater than 10%. Therefore, a taking could be considered sustainable from a water supply perspective, but not from a baseflow reduction perspective.

Results

It should be noted, that for the purpose and scope of this WQSA chapter, only the results of the GGET Tier Three Assessment are discussed in detail. Several other Tier Three Assessments overlap the WQSA; however the GGET Tier Three includes nearly all of the WQSA and therefore is believed to be the most useful Tier Three Assessment to understand water quantity issues in the WQSA. Tier Three Assessments which significantly overlap the WQSA are briefly summarized below, and the detailed results of their Tier Three findings are available in their respective Source Protection documents. The GGET Tier Three study area and groundwater model encompass a large area, including much of the WQSA. However, the focus of the study is the Upper Speed Assessment Area (USAA) and on the WHPA Q within the USAA. The

Groundwater Budget and the associated stress assessment for the USAA were updated from the Tier Two in the GGET Tier Three and area discussed below.

In the Guelph WQSA, groundwater is used in the WQSA more so than surface water. The Threats Management Strategy evaluated the southern portion of the WQSA and the sustainability of the groundwater usage in terms of a sensitivity analysis. The results were as follows:

"A modelling sensitivity analysis was also run to test impacts at municipal wells if non-municipal non-dewatering permitted pumping was increased. The results show that for average annual climate conditions, all municipal wells could meet future pumping rates. However, the sensitivity analysis also predicts that non-municipal, non-dewatering takings at permitted maximum rates would result in municipal wells not being able to meet future planned demand under drought conditions. This suggests that permitted maximum rates of non-municipal, non-dewatering permits need to be reviewed since the maximum rates are not sustainable. The current non-municipal, non-dewatering permitted takings may be able to increase by approximately three times their current amount before impacts are predicted at municipal wells under drought conditions. The model results also indicate that potentially more water may be available away from municipal wells. One of the assumptions of the sensitivity analysis is that future conservation targets at municipal wells (WSMPU rates) are achieved." (An excerpt from Lake Erie / GRCA staff report for June 21, 2018)

Feedback from water managers for Centre-Wellington indicated that there were two main takeaways from this sensitivity analysis. These were:

- *Under average climate conditions and current land use, pumping is sustainable even if all non-municipal takings were at their maximum permitted rate (which I recognize is very unlikely); and*
- *In future land use scenarios and under drought conditions, the cumulative impact of non-municipal takings at maximum permitted rates leads to predicted impacts to the municipal wells.*

City of Guelph Area (Upper Speed Assessment Area)

The GGET Tier Three Assessment (Matrix Solutions Inc., 2017) assigned a significant risk for water quantity stress to the Wellhead Protection Area for quantity (WHPA-Q, which envelops the City of Guelph and extends into the County of Wellington) under future demand, land use and drought conditions. The study is centred on the Guelph Water Supply system. Note that unacceptable reductions in baseflow contributions were also predicted under future demand scenarios triggering a moderate risk.

Increased demand on the municipal systems, driven by population and economic growth (estimated out to 2031) is the most significant water quantity risk as the confined bedrock aquifers that supplies most of the Guelph Water Supply (Upper and Middle Gasport Formations) are relatively isolated from the effects of land use change (locally reduced groundwater recharge conditions) and drought (the confined nature of the aquifer results in a long recharge cycle which makes water levels more reflective of long term climate patterns, and less so seasonal conditions).

The GGET WHPA Q1 was determined to have a *significant* potential for risk because the Queensdale Well, a bedrock well, is predicted to not be able to meet its supply capacity under the future demand and prolonged drought conditions. The Arkell 1 Well, a shallow overburden well, long predicted to be unable to meet its supply capacity, also had a high uncertainty on whether it could meet the future demand under drought conditions. Given that the SAAD is exceeded in the Queensdale well, future takings at the well may not be sustainable.

The Tier Three Assessment also predicts the potential for reductions in baseflow in surface water under the future demand and drought conditions. The simulated impact on baseflow for rivers, streams and wetlands of interest within the WHPA Q was assessed for scenarios that modelled increased demand, and reduced recharge by comparing the simulated groundwater discharge under each of the model scenarios to the net groundwater discharge under existing conditions. As per the MECP Technical Guidelines, the Risk Assessment only considers the impacts of pumping under the scenario which models increased demand when evaluating risk. Baseflow reductions under increased demand simulations of greater than 10% or more were observed at the following locations:

- Torrance Creek (41%)
- Chilligo/Ellis Creek at Wellington Road 32 (32%)

- Hanlon Creek South Tributary at Highway 6 (31%)
- Blue Springs Creek South Branch at 28th Side Road (27%)
- Hanlon Creek at Waterfowl Park (19%)
- Irish Creek at Townline Road (14%)
- Hanlon Creek at Highway 6 (11%)

As part of the Tier Three Assessment, a groundwater modelling exercise was conducted to provide insight into the sensitivity of the water levels in the municipal wells to increases in non-municipal water takings. The assumption was that non-municipal water taking in the WHPA-Q may increase as a result of population and economic growth; however, it was difficult for this modelling exercise to predict where the increases may occur. The scenario assumed that all non-municipal permitted takers would pump at their maximum permitted amount, which is a very coarse assessment as it does not consider seasonal takings, backup takings and permitted maximums were only used in specific situations. This was undertaken as a proxy for all potential existing and future takers as there is no way to predict future non-municipal water demand. The modelling results show that the municipal wells can maintain their allocated rates under average annual conditions, with non-municipal, non-dewatering pumping rates increasing up to the current maximum permitted consumptive demand. Within the assumptions of this scenario, the current non-municipal, non-dewatering permitted takings may be able to increase by approximately 3 times their current amount before impacts are predicted at municipal wells under drought conditions.

Tier Three Groundwater Budget and Stress Assessment

In the Grand River Tier Two Study, the groundwater assessment area identified as the Upper Speed Assessment Area (USAA) was identified as having a potential for moderate groundwater quantity stress for existing and planned conditions. In the Tier Three Assessment, water budget and stress assessment for the USAA was recalculated and the results are discussed below. The USAA does not include all of the WQSA, however, given that it includes 50% of the WQSA area, and includes many of the significant permitted takings in the WQSA; it is used here to represent general groundwater quantity conditions in the WQSA.

Groundwater Budget

Total inflow for this assessment area (recharge, groundwater flow in, and contribution from the Guelph Water Supply recharge system) totalled 326,200 m^3/day. Total outflows for this area (surface water discharge, permitted groundwater takings, and groundwater flow out) totalled 326,200 m^3/day. Total permitted groundwater takings for the area were estimated to be 62,700 m^3/day.

The Upper Speed Assessment Area includes all of the City of Guelph, Rockwood, and Hamilton Drive municipal supply wells along with all other permitted water takings within the Upper Speed Assessment Area (the budget did not factor in non-permitted takings). Based on historically reported average water takings from between 2008 and 2010 (City of Guelph was 2008, others were 2010), the budget estimated the average taking from permitted takers was 62,700 m^3/day. A review of WTRS data for the approximate area determined that groundwater-only takings accounted for 52,135 m^3/day in 2016 and 60,733 m^3/day 2017. This is within the range of the 62,700 m^3/day value for permitted takings used in the Tier Three groundwater budget for the Upper Speed Assessment Area.

Groundwater Stress Assessment

Percent demand was calculated on an annual and monthly basis to account for demand varying throughout the year in the USAA. Under existing water demand conditions, the annual average and maximum monthly percentage of water demand in the USAA is 21% and 26%, respectively. Under planned conditions (accounting for population and economic growth), the annual average and maximum monthly percent water demand in the USAA is 29% and 35%, respectively.

Therefore, results from the stress assessment suggest that the groundwater supply of the USAA is currently under moderate stress on an average and monthly maximum basis. However, under planned water demand conditions for the USAA, the average annual percent demand is considered significant, however monthly maximum demand is considered moderate.

It should be noted that for the Stress Assessment described herein for the USAA, the planned percent water demand incorporates projected changes in demand (potential increased water takings), however it does not factor in potential land use changes or climate change scenarios. The potential effects of Climate Change on the assessment area have been evaluated in a more recent report with the findings described below.

Centre Wellington Area (Irvine River Subwatershed)

A Tier Three Assessment in the Centre-Wellington area is currently ongoing, centred on the municipal supply systems of Fergus and Elora, which are interpreted to obtain groundwater from the Guelph and Goat Island formations. The municipal supply systems are located in the Irvine River subwatershed of the Grand River Watershed, which was determined by the Tier Two Water Budget for groundwater to be under moderate potential for stress; thus, a Tier Three Assessment was required.

The groundwater model has been constructed; however, results from modelling exercises that will consider the sustainability of the water supply resource are forthcoming and therefore not available at the time this review was being completed.

Acton Area (Black Creek and Silver Creek Subwatershed)

Acton lies within the Silver Creek subwatershed in the Credit Valley Watershed, which had a moderate stress level based on the Credit Valley Tier Two Stress Assessment. As part of the Halton Hills Tier Three Water Budget and Local Area Risk Assessment: Final Risk Assessment Report (AECOM and AquaResource, October 2014), the Acton area municipal supply wells were reviewed for their sustainability under future demand, land use and drought conditions. Of the five municipal wells in the Acton area, the 4th Line Well A triggered a significant risk under the combination of growth and prolonged drought conditions, suggesting the resource in this well area may not be a source of sustainable water supply in the future. No coldwater creeks in the Acton area within the WQSA are expected to (as per modelling) face baseflow declines of greater than 10 percent under the same future conditions.

Milton Area (Upper West Branch Creek Subwatershed)

The Tier Three Assessment for Kelso and Campbellville wellfields (triggered by the Stress Assessment of Upper West Branch Creek) determined that all wells were capable of meeting existing and future demands for current and projected land use conditions under historical climate norms and drought conditions. Both wellfields were considered to be at moderate potential for risk under future conditions, and baseflow reductions to at least one surface water feature was expected to decrease by more than 10%.

Cambridge Area (Central Grand Subwatershed)

A significant portion of the Cambridge Tier Three model boundary is located outside the Guelph WQSA and therefore the results are not presented here. Some of the wells and intakes for Cambridge and Kitchener are located in the southwest portion of the GGET model boundary and are discussed in Appendix H of the GGET Tier Three Assessment titled Local Area Overlap Memo.

4.3.1.2 Surface Water

WSC Gauge Hydrographs

Within the Guelph WQSA, Water Survey of Canada (WSC) gauges are present in the watersheds of the Grand River, Credit River and Bronte River; no gauges are present in the Sixteen Mile Creek and Spencer Creek subwatersheds within the boundaries of the WQSA. The locations of the WSC gauges are illustrated on Figure 4-5, and general information about the stations and flow data are summarized in Table 4-9.

Table 4-9: Water Survey of Canada Stream Gauges Within the WQSA

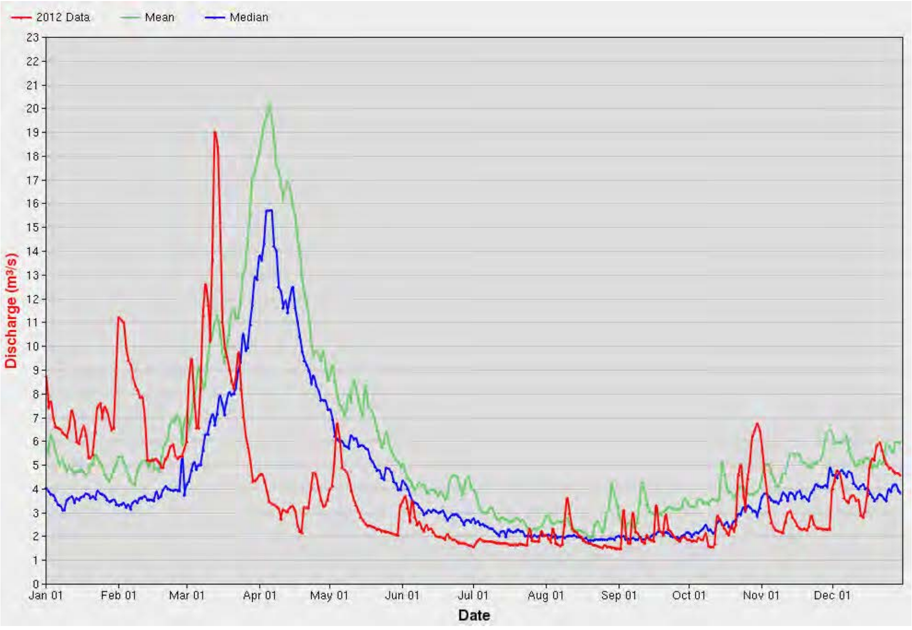
Station No. [1]	Main Watershed	Years	Data Availability	Drainage Area (km^2)	Mean annual flow (m^3/s)
02GA001 (Grand River At Belwood)	Grand River	1913-1923	Flow	769	8.3
02GA007 (Speed River Near Guelph)	Grand River	1913-1917	Flow	180	2.3
02GA008 (Speed River At Hespeler)	Grand River	1913-1949	Flow	707	7
02GA011 (Speed River At Guelph)	Grand River	1913-1913	Flow	500	Insufficient data
02GA012 (Speed River Near Eramosa)	Grand River	1913-1913	Flow	233	Insufficient data
02GA014 (Grand River Near Marsville)	Grand River	1947 - present	Flow and Level	663	8.3
02GA015 (Speed River Below Guelph)	Grand River	1950 - present	Flow and Level	568	5.8
02GA016 (Grand River Below Shand Dam)	Grand River	1950 - present	Flow and Level	784.76	9.2
02GA020 (Speed River Above Guelph)	Grand River	1953-1961	Flow	269	2.5
02GA027 (Grand River Above Lake Belwood)	Grand River	1961-1964	Flow	749	4.2
02GA029 (Eramosa River Above Guelph)	Grand River	1962 - present	Flow and Level	231	2.5
02GA031 (Blue Springs Creek Near Eden Mills)	Grand River	1965 - present	Flow and Level	41.5	0.6
02GA032 (O.A.C. Farm	Grand River	1966-1984	Flow	2.51	0.02

Station No. [1]	Main Watershed	Years	Data Availability	Drainage Area (km^2)	Mean annual flow (m^3/s)
Gauge No. 5 At Guelph)					
02GA033 (Lutteral Creek Near Oustic)	Grand River	1953-1991	Flow	64.8	0.7
02GA040 (Speed River Near Armstrong Mills)	Grand River	1973 - present	Flow and Level	167	2.2
02GA047 (Speed River At Cambridge)	Grand River	2002 - present	Flow and Level	761.59	8.8
02GA048 (Grand River Near Doon)	Grand River	2006 - present	Flow and Level	2490	31.3
02HB001 (Credit River Near Cataract)	Credit River	1915 - present	Flow and Level	209	1.8
02HB019 (Credit River Alton Branch Above Alton)	Credit River	1983-1991	Flow	59.5	0.8
02HB020 (Credit River Erin Branch Above Erin)	Credit River	1983 - present	Flow and Level	32.3	0.5
02HB024 (Black Creek Below Acton)	Credit River	1987 - 2014	Flow and Level	18.9	0.2
02HB031 (Credit River Erin Branch at Hillsburgh)	Credit River	2005 - present	Flow and Level	12.5	0.2
02HB032 (Mountsberg Creek Below Mountsberg Reservoir)	Bronte Creek	2005 - present	Flow and Level	35.6	0.5

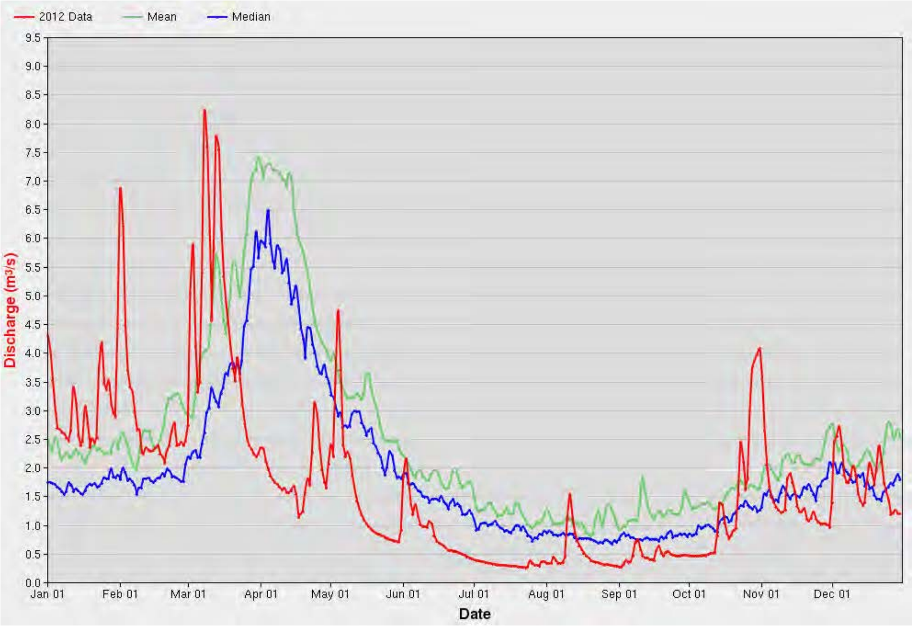
[1] Italicized text: indicates WSC gauges for which hydrographs are provided in the text further below.

Source: WSC (2018)

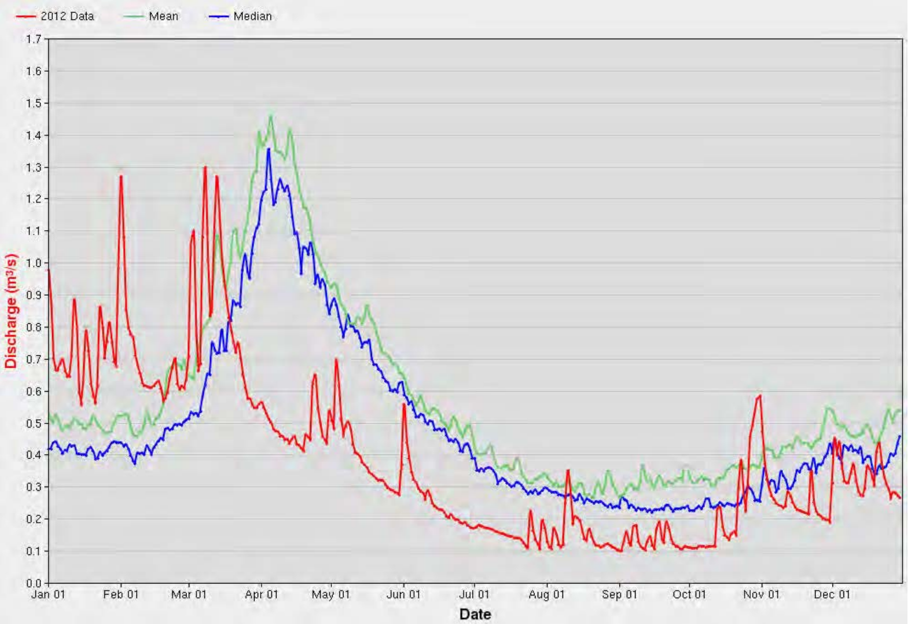
Hydrographs for each of the rivers listed in Table 4-8 are provided on Text Figures 4-13 to 4-19 below. When more than one gauge is present on the same river, a hydrograph was produced for the gauge located furthest downstream. As illustrated on the hydrographs, the rivers all exhibit similar seasonal patterns, with the highest flows being associated with the spring snowmelt, peaking around April, and seasonal low flow occurring in the summer, typically reaching its lowest point around August.



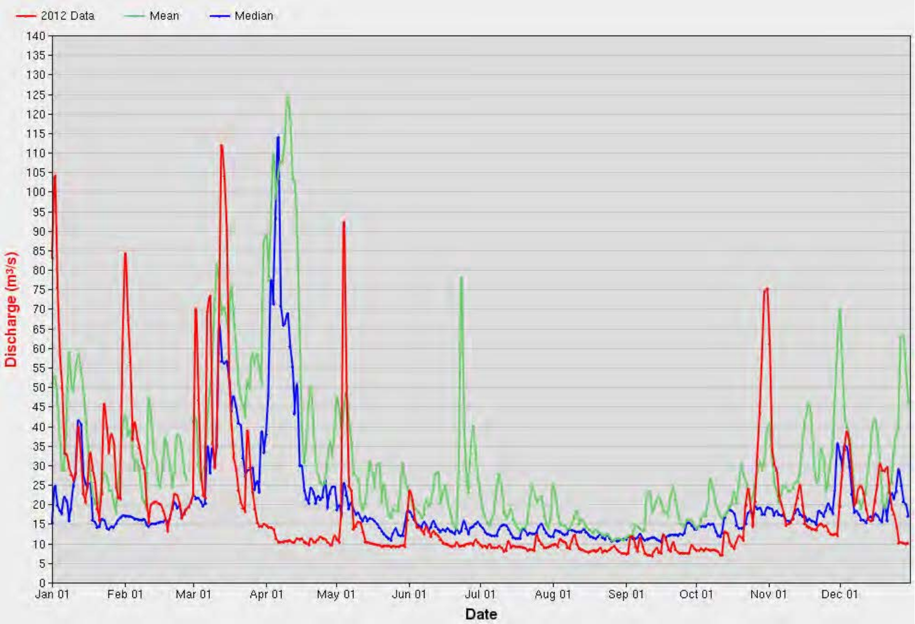
Text Figure 4-13. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GA015 (Speed River Below Guelph). (Source: WSC, 2018).



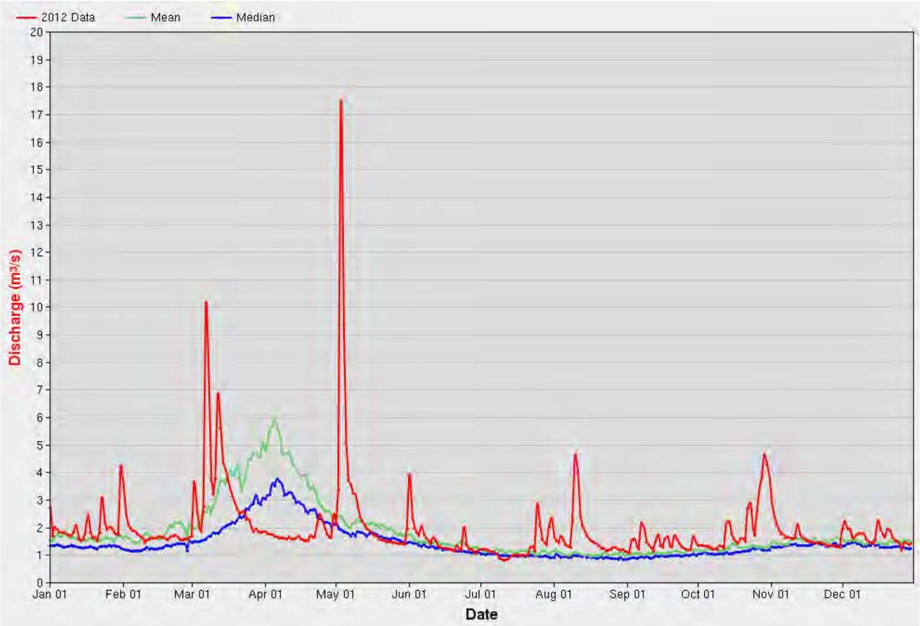
Text Figure 4-14. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GA029 (Eramosa River Above Guelph). (Source: WSC, 2018).



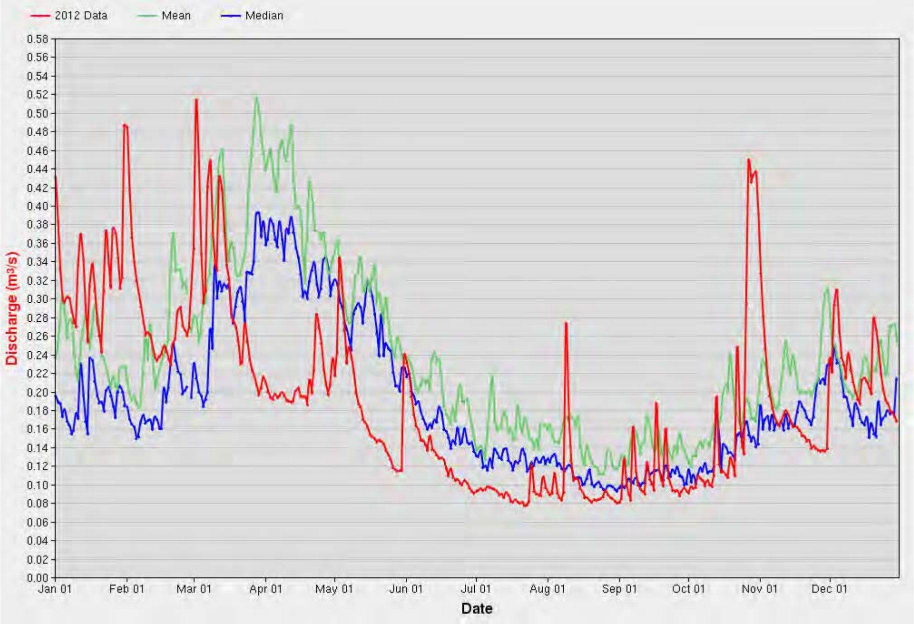
Text Figure 4-15. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GA031 (Blue Springs Creek Near Eden Mills). (Source: WSC, 2018).



Text Figure 4-16. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GA048 (Grand River Near Doon). (Source: WSC, 2018).



Text Figure 4-17. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02HB001 (Credit River Near Cataract). (Source: WSC, 2018).



Text Figure 4-18. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02HB024 (Black Creek Below Acton). (Source: WSC, 2018).

Text Figure 4-19. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02HB032 (Mountsberg Creek Below Mountsberg Reservoir). (Source: WSC, 2018).

Surface Water Budget

The surface water budget components for the subwatersheds within the Guelph WQSA were calculated as part of the Drinking Water Source Protection studies for the Grand River Source Protection Area (SPA), the Credit Valley SPA, the Halton Region SPA, and the Hamilton Region SPA. Findings from the surface water budget study are summarized in their respective Assessment Reports and salient information is discussed below.

Grand River Source Protection Area

Water budget parameters and consumptive demands in the Grand River SPA were calculated as part of a Tier Two Water Budget (AquaResource, 2009). For the Grand River's subwatersheds located within the Guelph WQSA, precipitation inputs range from 888 to 988 mm/year, while 89 to 356 mm/year are transported as runoff, 464 to 529 mm/year is lost to evapotranspiration, and 156 to 292 mm/year goes towards groundwater recharge.

In the subwatersheds within the boundaries of the Guelph WQSA, consumptive demand for surface water is the highest in the "Grand Above Doon to Conestogo" subwatershed (in the southwestern portion of the WQSA), with an average annual surface water demand of 117 L/s, followed by the Eramosa River subwatershed at 45 L/s. The maximum monthly percent water demand for surface water was 25% for the Eramosa River subwatershed, and as such, the subwatershed was assigned a surface water potential stress classification of moderate. All other subwatersheds were determined to have percent water demand estimates below the 20% threshold, and were therefore assigned a surface water potential stress classification of low (the "Grand Above Doon to Conestogo" subwatershed's large surface water demand was counter-balanced by its large surface water supply flows).

As the Eramosa River subwatershed was determined to have a moderate potential for surface water stress, and also contains the City of Guelph's Eramosa River drinking water intake, the City of Guelph was required to complete a Tier Three Water Quantity Risk Assessment. The objective of the Assessment was to determine the potential that the city would not be able to obtain its permitted pumping rates at this intake.

City of Guelph Surface Water Intakes – Tier Three Water Budget and Local Area Risk Assessment

A Tier Three Water Budget and Local Area Risk Assessment (Matrix Solutions Inc., 2017) was completed for the City of Guelph and the Township of Guelph/Eramosa, as their municipal water supplies are located in areas determined to have a moderate level of surface water and groundwater potential stress.

As described in Section 4.2.6.1, water is pumped from the Eramosa River in order to recharge the shallow overburden aquifer supplying the Glen Collector. Water pumped from the river is therefore not fed directly into the municipal drinking water system.

A Surface Water Vulnerable Area (IPZ-Q) was delineated for the Eramosa River intake, representing the drainage area and associated recharge area that contribute to that point of the river; the IPZ-Q includes the Eramosa River upstream of the intake, and tributaries that supply flow to the Eramosa River.

Since water pumped from the Eramosa River intake is not fed directly into the drinking water system, and as the Glen Collector was included in the Risk Assessment for groundwater, a Risk Assessment for the surface water supply was not completed. However, the IPZ-Q was assigned the same risk level as the Groundwater Vulnerable Area containing the Glen Collector (determined to be significant).

As the IPZ-Q was assigned a risk level of significant, all consumptive demands or activities reducing groundwater recharge to an aquifer within the area were classified as Significant Water Quantity Threats. The identified Significant Water Quantity Threats included:

- 12 municipal takings
- 13 non-municipal, permitted takings
- 2,671 non-municipal, non-permitted takings (e.g. domestic water wells)
- A 1.04 km^2 reduction in recharge area, equivalent to 0.4% of the IPZ-Q (future developments in Rockwood and the Town of Erin that are defined in their Official Plan).

A threats ranking exercise was undertaken as part of a Risk Management Measures Evaluation Process to further define the significance of each Water Quantity Threat to the risk level (Matrix Solutions Inc., 2018). Domestic takings were omitted from the assessment, as they are relatively small. Similarly, the reduction in recharge area was very small and was considered unlikely to have any impact on streamflow and the amount of available water for surface water takings; the impact of the recharge reduction areas was therefore not considered further. Among the permitted takings in the original list of Significant Water Quantity Threats, municipal consumptive takings (where water is not returned to the source) in the IPZ-Q in 2015 totalled approximately 0.349 m^3/s, and non-municipal consumptive takings totalled approximately 0.042 m^3/s. It was estimated that the total potential influence of municipal and non-municipal takings on streamflow in the Eramosa River at WSC stream gauge 02GA029 is a reduction in streamflow of 0.287 m^3/s, equivalent to approximately 12% of the mean annual flow (2.3 m^3/s), and approximately 67% of the threshold below which the City of Guelph cannot pump the river (0.42 m^3/s). Based on the magnitude of the predicted reduction in streamflow in the Eramosa River, the relative risks of the Water Quantity Threats were ranked as follows (from highest to lowest risk):

- City of Guelph Arkell wells, with an estimated influence of 0.148 m^3/s on baseflow in the Eramosa River;
- Glen Collector, with an estimated influence of 0.086 m^3/s on baseflow in the Eramosa River;
- Non-municipal PTTWs, with an estimated influence of 0.042 m^3/s on baseflow in the Eramosa River; and

- The Rockwood Wells, with an estimated influence of 0.011 m^3/s on baseflow in the Eramosa River.

Matrix Solutions Inc. (2018) recommended that the City of Guelph maintain its current groundwater and surface water monitoring program to ensure that the hydrologic regime in the Eramosa River is maintained.

Credit Valley Source Protection Area

Water budget parameters and consumptive demands in the Credit Valley SPA were calculated as part of a Tier Two Water Budget (CVCA, 2015). For the Credit River's subwatersheds located within the Guelph WQSA, precipitation inputs range from 779 to 920 mm/year, while 122 to 271 mm/year are transported as runoff, 411 to 566 mm/year is lost to evapotranspiration, and 179 to 319 mm/year goes towards groundwater recharge.

For the Credit River subwatersheds within the boundaries of the Guelph WQSA, estimates of maximum monthly percent water demand remained consistently below the threshold of 20% for moderate level of potential stress. As a result, all subwatersheds of the Credit River located within the Guelph WQSA were determined to have a surface water potential stress classification of low. Due to this classification, as well as the absence of municipal drinking water intakes using surface water, a Tier Three Water Quantity Stress Assessment was not required.

Halton Region Source Protection Area

Water budget parameters and consumptive demands in the Halton Region SPA were calculated as part of a Tier One Water Budget (HHSPC, 2015). Surface water use in the SPA was predominantly for agricultural and commercial use, representing 56.2% and 42.9% of consumptive surface water takings, respectively. The remainder was attributed to industrial (0.4%) and miscellaneous (0.5%) uses.

Within the subwatersheds falling within the Guelph WQSA, the Mountsberg Creek subwatershed and the Middle Branch of Sixteen Mile Creek subwatershed (located in the southeastern portion of the WQSA) were identified as having a moderate level of surface water stress. The level was low for the remainder of the Halton SPA within the WQSA. As there are no surface water municipal drinking water intakes in these subwatersheds, a Tier Two Water Quantity Stress Assessment was not required.

Hamilton Region Source Protection Area

Water budget parameters and consumptive demands in the Hamilton Region SPA were calculated as part of a Tier One Water Budget (HHSPC, 2015). Surface water use in the SPA was predominantly for agricultural use, representing 90% of surface water consumptive demand. The remaining 10% was attributed to commercial use (i.e., golf course irrigation).

In the upper portion of the Spencer Creek watershed overlapping with the Guelph WQSA, the surface water stress level was determined to be low. Due to this classification, as well as the absence of municipal drinking water intakes using surface water, a Tier Two Water Quantity Stress Assessment was not required.

Ontario Low Water Response

The Ontario Low Water Response (OLWR) program was initiated in 2000 and is managed by the Ministry of Natural Resources and Forestry (MNRF). The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the Water Survey of Canada (WSC) stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels based on surface water indicators. Presently, static groundwater level elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%;
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

> Note: Specific Permits to Take Water may have conditions requiring mandatory reductions of water takings during low water events. Upon renewal of their water bottling permit, the above decreases will be mandatory based on 3-month average actual flow as outlined in the guidance for bottled water renewals (MOECC, 2017).

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the OLWR program was not developed for this purpose but rather as a means to support coordination between the Province and local responders in the event of a drought. There are local considerations that can be taken into account by the Water Response Teams (WRT) before making a low water declaration; also the makeup of the WRT changes over time. These factors and others need to be considered when comparing declarations across the province or looking for trends in the same area over time. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the WQSA.

Credit Valley CA

A review of the OLWR database indicates that a total of 11 Level 1 notifications and two Level 2 notifications were sent to the Credit Valley CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2001 (two Level 1 notifications), 2012 (one level 1 and one Level 2 notifications), and 2018 (two Level 1 notifications). The Credit Valley CA posted Low Water Condition Alerts during two periods: a Level 1 Low Water Alert was posted from mid-May to mid-October 2012, and again from July 2016 to early February 2017 (this was raised to a Level 2 Low Water Alert between early August and mid-September 2016).

Conservation Halton

A review of the OLWR database indicates that a total of 14 Level 1 notifications, four Level 2 notifications and one Level 3 notification were sent to Conservation Halton between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2004 (two Level 1 notifications), 2005 (two Level 1 notifications), 2012 (one Level 1 and two Level 2 notifications), 2015 (three Level 1 notifications), 2016 (one Level 2 and one Level 3 notifications) and 2018 (two Level 1 notifications). Conservation Halton posted Low Water Condition Alerts during five periods:

- Periods when only a Level 1 Low Water Condition Alert was posted:
    - Mid-July 2005 to mid-February 2006;
    - August to mid-November 2011;
    - Late May 2012 to end of December 2012;
- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
    - Mid-July 2007 to end of January 2008: a Level 1 Low Water Alert was posted in mid-July 2007, which was raised to a Level 2 in mid-August, and lowered back down to a Level 1 in mid-January 2008. The Low Water Condition Alert was removed entirely at the end of January 2008;
    - July 2016 to early February 2017: a Level 1 Low Water Alert was posted in early July 2016, which was raised to a Level 2 in mid-August, and lowered back to a Level 1 in mid-November. The Low Water Condition Alert was removed entirely in early February 2017.

Hamilton Region CA

A review of the OLWR database indicates that a total of 19 Level 1 notifications and five Level 2 notifications were sent to the Hamilton Region CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2001 (two Level 1 notifications), 2002 (two Level 1 and one Level 2 notifications), 2003 (three Level 1 notifications), 2004 (two Level 1 and one Level 2 notifications), 2005 (two Level 1 and one Level 2 notifications), 2010 (two Level 1 notifications), and 2012 (two Level 1 and one Level 2 notifications). Halton Region CA posted Low Water Condition Alerts during eight periods:

- Periods when only a Level 1 Low Water Condition Alert was posted:
    - Mid-September 2002 to mid-January 2003;
    - Mid-September 2003 to mid-October 2003;
    - Mid-October 2004 to mid-December 2004;
    - Mid-July 2005 to mid-March 2006;
    - Mid-August 2011 to end of October 2011;
- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
    - Mid-July 2007 to mid-January 2008: a Level 1 Low Water Alert was posted in mid-July 2007, which was raised to a Level 2 in mid-August, and lowered back down to a Level 1 in mid-November 2007. The Low Water Condition Alert was removed entirely in mid-January 2008;

    - Mid-May 2012 to mid-November 2012: a Level 1 Low Water Alert was posted in mid-May, which was raised to a Level 2 in mid-July, and lowered back down to a Level 1 in early November. The Low Water Condition Alert was removed entirely in mid-November;
    - July 2016 to mid-March 2017: a Level 1 Low Water Alert was posted in early July 2016, which was raised to a Level 2 in late July, and lowered back to a Level 1 in mid-September. The Low Water Condition Alert was removed entirely in mid-March 2017.

Grand River CA

A review of the OLWR database indicates that a total of 22 Level 1 notifications, three Level 2 notifications and one Level 3 notification were sent to the Grand River CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2000 (three Level 1 notifications), 2001 (two Level 1 notifications), 2004 (two Level 1 and one Level 2 notifications), 2005 (two Level 1 notifications), 2010 (four Level 1 notifications), 2012 (two Level 1 notifications), 2015 (three Level 1 notifications), 2016 (one Level 1, one Level 2 and one Level 3 notifications) and 2017 (two Level 1 notifications). The Grand River CA posted Low Water Condition Alerts during 15 periods for the Grand River watershed as a whole:

- Periods when only a Level 1 Low Water Condition Alert was posted:
    - July 2003 to end of March 2004;
    - Late September 2004 to early February 2005;
    - Mid-August 2006 to early October 2006;
    - Mid-September 2009 to early October 2009;
    - Mid-August 2010 to early October 2010;
    - Mid-July 2011 to end of October 2011;
    - Late August 2013 to mid-October 2013;
    - Late May 2015 to mid-June 2015;
    - August 2015 to mid-November 2015;
    - Mid-July 2018 to end of August 2018;

- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
    - Mid-September 2002 to mid-January 2003: a Level 1 Low Water Condition Alert was posted in mid-September 2002, which was raised to a Level 2 in early January 2003. The Low Water Condition Alert ended entirely in mid-January 2003;
    - July 2005 to early December 2005: a Level 1 Low Water Alert was posted in early July, which was raised to a Level 2 in mid-July, and lowered back down to a Level 1 in mid-October. The Low Water Condition Alert was removed entirely in early December;
    - Late June 2007 to end of May 2008: a Level 1 Low Water Alert was posted in late June 2007, which was raised to a Level 2 in late September, and lowered back down to a Level 1 at the end of February 2008. The Low Water Condition Alert was removed entirely at the end of May 2008;
    - Late April 2012 to end of October 2012: a Level 1 Low Water Condition Alert was posted in late April, which was raised to a Level 2 in mid-July. The Low Water Condition Alert ended entirely at the end of October;
    - Late June 2016 to mid-April 2017: a Level 1 Low Water Alert was posted in late June 2016, which was raised to a Level 2 in early August, and lowered back down to a Level 1 in mid-January 2017. The Low Water Condition Alert was removed entirely in mid-April 2017.

Low Water Condition Alerts were also posted to individual subwatersheds. When a Low Water Condition Alert was posted for the Grand River watershed as a whole, the same level or lower was generally also posted to the subwatersheds. Instances when the subwatersheds were under a higher Low Water Condition Alert than the watershed as a whole included:

- Mid-July 2002 to late August 2003: While the watershed as a whole was under a Level 1 (and briefly, a Level 2) Low Water Condition Alert from mid-September 2002 to mid-January 2003, the Level 1 Low Water Condition Alert began two months earlier for its subwatersheds, and did not end until August 2003 for most of them. The Upper Speed River, Eramosa River and Mill Creek subwatersheds were also under a Level 2 Low Water Condition Alert for almost three months in 2002 (July to October). The Mill Creek subwatershed was under a second Level 2 Low Water Condition Alert for the month of July 2003;

- July 2007 to mid-September 2007: while the watershed as a whole was under a Level 1 Low Water Condition Alert, the Upper Speed River was under a Level 2 Low Water Condition Alert during this time;
- Middle to end of July 2016: while the watershed as a whole was under a Level 1 Low Water Condition Alert, the Mill Creek subwatershed was under a Level 2 Low Water Condition Alert during this time.

Overall, the OLWR database indicates that the Credit Valley CA, Conservation Halton, Hamilton Region CA and Grand River CA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts. For the Credit Valley CA, Level 1 and Level 2 Low Water Condition Alerts were declared in 2012 and in 2017-2018, whereas none were declared prior to 2012. The more recent declarations of Low Water Condition Alerts indicate a possible, but not definitive, decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area. In contrast, no specific trends can be discerned in the frequency of Low Water Condition Alerts for Conservation Halton, Hamilton Region CA and Grand River CA, nor in the frequency of OLWR notifications for any of the four CAs. Overall, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends. As notifications and alerts are on a watershed scale rather than subwatershed basis, applying them locally and relevance to specific subwatersheds within is not readily determined from the available posted data.

4.3.1.3 Water shortages

Based on available reports and consultation with local Water Managers from City of Guelph, GRCA, Centre Wellington Township, and the MECP, water shortages in the Guelph WQSA have not been an issue.

Ontario Low Water Response (OLWR) Levels 1 and 2 have been declared in watersheds within the WQSA numerous times since the program began in 2000. These declarations typically happen in very dry years suggesting that declarations are climate driven, rather than due to water takings. These declarations are often watershed wide and therefore not always reflective of specific conditions within the Guelph WQSA. As well, OLWR declarations are based on surface water indicators of streamflow and precipitation, and while they may reflect shallow well conditions, they would not reflect deep groundwater conditions, where the majority of Guelph's water supply originates.

Municipal Supply Water Shortages

Based on Tier Three Assessment findings and communication with Water Managers representing municipalities in the WQSA, there is no record of municipal supply water shortages and shortages are not ongoing.

The City of Guelph Water Managers noted that the public often perceives the enforcement of municipal by laws that limit outside water use during Level 1 and Level 2 OLWR declarations as real shortages in the Guelph supply aquifers. Therefore there is a perception the City of Guelph faces periodic shortages, however it does not. City of Guelph Water Managers have reported that despite ongoing declarations, there are no historical or ongoing shortages from a municipal supply perspective.

Water Shortages outside Municipal Centres

Level 1 and Level 2 OLWR declarations have been enacted multiple times in the last 18 years. However, according to local Water Managers, water shortages for users outside municipal centres have not been and are not ongoing issues.

Potential Water Shortages

While shortages have not been recorded nor are ongoing, technical studies under source protection implementation assessed the potential for municipal wells not being able to meet demand as a result of future municipal growth, prolonged drought and climate change (Matrix Solutions Inc., 2017).

As discussed, the WHPA-Q (which encompasses the City of Guelph and extends into Wellington County) was determined to have a significant potential for risk because the Queensdale Well may not be able to meet its supply capacity under the future demand and prolonged drought conditions. The predictions about the sustainability of the Arkell 1 Well, a shallow overburden well, had a high uncertainty as to whether it could meet the future demand under drought conditions, which is also a trigger of risk under the source protection water quantity technical framework.

Another potential source of concern is the expansion of non-municipal water takings, which are not subject to as much review and public consultation as municipal supplies. In the Threats Management Strategy, the Tier Three model was used to evaluate what would happen if there is an increase in non-municipal pumping in the future, using the maximum permitted takings for all permits in the WHPA-Q. This was undertaken as a proxy for all potential existing and future takers as there is no way to predict future non-municipal needs. It determined that the municipal supply in its current configuration could not sustain all permit holders pumping at their permitted rates. This scenario however, is extreme and does not consider current or future permit conditions restrictions, such as maximum hourly pumping per day, or the seasonal nature of many takings, and is unlikely, based on actual recorded takings in the area over time, to occur. While it is unlikely that all permitted water takers would pump at their maximum permitted rates, this demonstrates, based on the Tier 3 modelling, the Ministry may need to consider the future needs of the City of Guelph and the Tier 3 water budget results in assessing possible interactions between water takers in approving PTTW application for new or expanded takings.

4.3.2 Assessment of Sustainability of Water Resources

4.3.2.1 Climate Change

In the early 2010s, climate change scenario modelling was implemented for the individual subwatersheds in the Grand River watershed, in order to model potential changes to annual precipitation, evapotranspiration, runoff and groundwater recharge and discharge under future (2050s) climate change scenarios (Shifflett, 2014). The modelling involved the use of ten climate change scenarios that differed from one another in terms of the relative change in mean annual precipitation and in mean annual temperature. Changes in mean annual precipitation represented by the ten scenarios ranged from an approximate 5% decrease to a 13% increase, while increases in mean annual temperature ranged from approximately 1.8°C to 4°C.

Among each of the subwatersheds within the Guelph WQSA, annual precipitation was predicted to be greater than baseline for five of the ten scenarios and less than baseline for one to two of the scenarios. Annual evapotranspiration was predicted to be greater than baseline for at least six of the ten scenarios as a result of higher temperatures. In general, evapotranspiration rates were predicted to increase with temperature, except when water availability was low due to extreme low precipitation.

The response of runoff to the different climate change scenarios was not consistent across the watershed. Among the subwatersheds within the Guelph WQSA, the "Eramosa Above Guelph" and the "Speed Above Dam" subwatersheds were predicted to experience lower than baseline runoff in the majority of the scenarios, whereas the other subwatersheds were predicted to experience lower than baseline runoff in only 3 out of 10 scenarios. Mill Creek was predicted to experience higher than baseline runoff in 7 out of 10 scenarios, but this was believed to be the result of it being the smallest subwatershed with the smallest runoff, and therefore all increases in runoff would be relatively large.

Regional trends in groundwater recharge were observed, with the northern subwatersheds having more scenarios with increased recharge and fewer scenarios with decreased recharge compared to the rest of the watershed. This was attributed in part to a reduction in the number of days with frozen ground, allowing for more recharge during the winter period.

Regional trends were also observed in groundwater discharge, with discharge being greater than baseline for most scenarios for the northern subwatersheds, and lower than baseline in at least half of the scenarios for the rest of the subwatersheds (including the Eramosa River, one of the key discharge reaches in the Grand River watershed).

As noted in Section 4.3.1.2, all subwatersheds of the Grand River that are located within the Guelph WQSA have a surface water potential stress classification of low, except for the Eramosa River subwatershed, which has a classification of moderate. Under the ten climate change scenarios, the only subwatersheds that were projected to experience any change to their surface water potential stress classification were the upper half of the Speed River and the Eramosa River. For the upper half of the Speed River, the stress classification was projected to increase to moderate in five scenarios, and remain unchanged for the other scenarios. For the Eramosa River, the stress classification was projected to decrease to low under the scenario with the largest increase in precipitation of all scenarios; the stress classification was projected to increase to significant under three scenarios, and remain unchanged in the remaining six scenarios. For all other subwatersheds within the Guelph WQSA, the surface water potential stress classification was projected to remain low under all climate change scenarios.

Climate Change Impacts on the Eramosa River Intake

A climate change assessment was conducted by Matrix Solutions Inc. (2018) to determine how future climates might change the hydrology in the area surrounding the Guelph-Guelph/Eramosa municipal water supply systems. Future climate datasets were compiled and used in conjunction with a water balance model and GAWSER hydrology model.

Streamflow on the Eramosa River at WSC gauge 02GA029 (near the Eramosa intake) was predicted under four climate change scenarios, which differ from one another in terms of the relative change in mean annual precipitation and in mean annual temperature. Changes in mean annual precipitation represented by the four scenarios ranged from a 1.05% decrease to a 12.82% increase, while increases in mean annual temperature ranged from 2.23°C to 4.33°C. Streamflow under the four climate change scenarios was simulated in order to predict the relative changes to mean annual flow, the 7Q20 low flow, and the number of days when the Eramosa River intake cannot be pumped according to minimum flow restrictions on the PTTW (i.e. water cannot be pumped when flows fall below 0.42 m^3/s).

Under three of the four climate change scenarios, the mean annual flow was predicted to increase by up to 10% from baseline conditions. The increase in mean annual flow was attributed to the greater amount of flow predicted to occur during the first four months of the year. In the remaining scenario, the decrease in mean annual flow was predicted to be only 0.3%.

The 7Q20 was observed to be similar among all scenarios (ranging from 0.366 m^3/s to 0.370 m^3/s, compared to a baseline 7Q20 of 0.366 m^3/s), though this may have been due to model limitations at such low flow rates.

The predicted number of days when the Eramosa River intake cannot be pumped varied among scenarios, with two scenarios predicting that there would be 61 and 95 more days (over a 45-year simulation period) when the river cannot be pumped, while the other two scenarios predicted that there would be 26 and 4 more days (over a 45-year simulation period) when the river *can* be pumped. However, the range of results was within 1% of the baseline scenario (where there was insufficient flow to pump the river on 7,298 days over the 45-year period from 1960 to 2005).

The future climate scenarios predicted that average and high streamflow at WSC gauge 02GA029 was likely to increase, and there was a potential for lower flows to decrease by 2% to 6% compared to current conditions. As noted above, the proportion of days when the City of Guelph would be unable to pump the Eramosa River due to flows being below 0.42 m^3/s was not expected to change by more than 1%. Matrix Solutions Inc. (2018) concluded that the impacts of climate change may result in minimal to no additional risk to the City of Guelph's Eramosa River intake.

Climate Change Impacts on WHPA Qs Local Area Assessment

As a follow up to the GGET Tier 3 Study, a Climate Change Assessment was conducted for the GGET WHPA Q area by modelling predicted Climate Change scenarios to determine potential impacts on the sustainability of the groundwater and surface water resources (Matrix Solutions Inc., 2018). Due to expected warmer temperatures and increased precipitation in the winter, the modelling exercise suggests a slight increase in recharge; thus, no impact to the sustainability of the groundwater resource is anticipated.

4.3.2.2 Population Growth

In the Local Area Risk Assessments GGET Tier 3 study area, described in Section 4.3.1.1, allocated demand was the largest contributor to increased drawdown in 24 of the 28 municipal supply wells in the City of Guelph area (including the Rockwood and Hamilton Drive wells). While the purpose of the Local Areas Risk Assessments is to determine the sustainability of the municipal supply well, the fact that population growth and associated increased water demand is by far the largest stressor on future water levels would suggest that population growth is the most significant stressor on the groundwater resources in general. Additionally, while the specific Local Area Risk Assessments findings are only relevant to the Guelph municipal supply wells, understanding that increased demand (if applicable) is typically the biggest stressor on water resources that utilize wells screened in the Guelph and Gasport formations and should be considered for groundwater management in other areas of the Guelph WQSA.

4.3.2.3 Cumulative Effects

Based on available reports and consultation with local Water Managers from the City of Guelph, GRCA, Centre Wellington Township, and the MECP, water shortages in the Guelph WQSA have not been identified as an issue (Section 4.3.1.3). BluMetric has also not identified nor been made aware of any reported interference issues between permitted and non-permitted water takings.

There is a moderate density of permitted takers in the Guelph WQSA, with most takings concentrated around population centres (e.g. City of Guelph, Fergus, Aberfoyle, Cambridge, Belfountain, Caledon Village) (Figure 4-11). Water takings for the purpose of water supply represent roughly 49% of the total permitted volume of takings in the WQSA (33% groundwater and 16% surface water), of which municipalities are the dominant takers, comprising over 45% of the total reported takings in the WQSA (Section 4.2.7.1). Industrial related permitted takings represent the second largest taker in the WQSA, with approximately 27% of the total permitted volume taken in 2017 (19% groundwater, 0.6% surface water and 7.7% from users who take from both surface water and groundwater) (Section 4.2.7.1).

No evidence of interference or impacts to the natural functions of the ecosystem has been identified. Environmental flow thresholds have nonetheless been recommended for the Eramosa River and the Speed River (Section 4.3.2.4). Both rivers have had periods of particularly low flows, but these low flow events have not been explicitly attributed to water withdrawals from multiple takers.

No significant declines in hydraulic head have been identified. The majority of the PGMN historical hydrographs in the WQSA have either an upward or no trend in water levels, with the exception of a downward trend in one well that is not considered reliable due to technical issues in said well over the years (Section 4.3.1.1). The absence of an observable, regional downward trend across the PGMN wells indicates it is unlikely that the groundwater takings in the WQSA are resulting in regional scale impacts.

Review of the OLWR database indicates that the Credit Valley CA, Conservation Halton, Hamilton Region CA and Grand River CA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts (Section 4.3.1.2). Recent declarations of Low Water Condition Alerts by the Credit Valley CA indicate a possible, but not definitive, decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area. In contrast, no specific trends can be discerned in the frequency of Low Water Condition Alerts for Conservation Halton, Hamilton Region CA and Grand River CA, nor in the frequency of OLWR notifications for any of the four CAs in the Guelph WQSA. Overall, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends.

The Guelph WQSA is nonetheless an area where cumulative effects may potentially become a concern in the future. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Guelph WQSA lies within a watershed that is classified as having a Low percent water use based upon the Average Annual Flow and Medium percent water use based upon Summer Low Flow. Though there are no ongoing water shortages, the GGET Tier Three Assessment found that the WHPA-Q (enveloping the City of Guelph, and extending into the County of Wellington) has a significant potential for risk of water shortages as two of its supply wells may not be able to meet their supply capacities under the future demand and/or prolonged drought conditions (Sections 4.3.1.1 and 4.3.1.3). In addition, it was determined that the municipal supply in its current configuration could not sustain all permit holders pumping constantly at their permitted rates under future conditions (discussed in Sections 4.3.1.1. and 4.3.1.3). As part of the GGET Tier Three Assessment, the WHPA-Q was assigned a significant risk for water quantity stress under future demand, land use and drought conditions (Section 4.3.1.1). Increased demand on the municipal systems, driven by population and economic growth, was identified as the most significant water quantity risk.

The risk of future water shortages has been attributed to two of the City of Guelph's supply wells potentially not being able to meet their supply capacities under future demand and/or prolonged drought conditions (Sections 4.3.1.1 and 4.3.1.3). Numerical modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

Water Bottling Study Areas in the Guelph WQSA

As noted in Section 4.2.7.1, three Water Bottling Study Areas (WBSAs) in the Guelph WQSA were evaluated in the context of the current state and sustainability of water resources (see Appendices A, B and C). Based on information reviewed concerning regional groundwater resources and water taking activities (e.g. pumping test, annual monitoring reports), the following was noted of the water bottling activities' impact on the sustainability of existing and future water resources at their current levels of taking:

- At the Aquaterra (Hillsburgh) site (Appendix A), flowing artesian well conditions have been maintained at the production well since its construction in 1988. There are no indicators of the Aquaterra Hillsburgh water taking having an impact on the sustainability of existing and future water resources at the current levels of taking. Current Permit requirements/conditions in place appear to be suitable in identifying potential issues should climate change and growth pressures become a larger factor in the sustainability of local water resources under current water taking quantities. However, there are uncertainties around the future sustainability of the taking if the maximum allowed taking were taken over maximum allowed pumping duration. Further work, such as modelling, would be required to determine the potential impacts on the municipal water supplies from the pumping of the Hillsburgh well at the maximum permitted rate;
- At the Nestlé (Erin) site (Appendix B), there are no indications that the Nestlé (Erin) water taking is having an impact on the sustainability of existing and future water resources at the current or permitted levels of taking. Consequently, it is BluMetric's opinion that the water taking is being managed sustainably. Current permit requirements/conditions in place appear to be suitable in identifying potential issues should climate change and growth pressures become a larger factor in the sustainability of local water resources under current water taking quantities;
- At the Nestlé (Aberfoyle) site (Appendix C), there are no indicators of the Nestlé (Aberfoyle) water taking having an impact on the sustainability of existing and future water resources at the current levels of taking; the water taking was determined to have a predicted maximum percent impact of 1% on municipal wells in the area (Matrix Solutions Inc., 2018). Consequently, it is BluMetric's opinion that the water taking is sustainable under current conditions. Additional insight on the sustainability of the groundwater resource under future climate scenarios will be possible based on the additional Tier Three Modelling when completed. The current permit requirements in place, including the ongoing adherence to the monitoring and mitigation plans required by the permit, are deemed adequate to identify any unacceptable changes to Site conditions.

4.3.2.4 Environmental Flow Needs

A 2005 EFN study (GRCA, 2005, as cited by Wong & Boyd, 2014) determined that empirical methods (e.g. Tennant, Tessmann) are not suitable for Ontario and the Grand River, as the landforms and fish assemblages are not comparable to those in Montana's mountain stream ecology, where the thresholds were developed. The study further noted that for the Grand River watershed, statistical analyses of historic streamflow data (long impacted by agricultural water takings) is not a suitable approach for characterizing EFNs. The use of the hydraulic/geomorphic assessments was considered more suitable in these locations. Within the Guelph WQSA, environmental flows were quantified for the Speed River at Guelph (at the location of WSC stream gauge 02GA015) and the Eramosa River above Guelph (at the location of WSC stream gauge 02GA029); these were reported in Wong & Boyd (2014) and are described below.

Important environmental low flows described in Wong & Boyd (2014) include the littoral zone maintenance flows and the longitudinal connectivity flows. The littoral zone (close to the shore) provides important fish nursery habitat and refuge, and requires flows to pass over the area to prevent stagnation. Longitudinal connectivity of a river is maintained when there is a sufficient flow depth to allow fish to migrate from pool to pool along the river; the longitudinal connectivity flow is calculated based on a minimum recommended flow depth over riffle crests (the high points in the bed of the river), which is 10 cm for warmwater fish communities, and 20 cm for coldwater fish communities. For the Speed River at Guelph, hydraulic modelling was used to estimate the baseflow threshold at which the littoral zone would have 10 cm of flow depth; the littoral zone maintenance flow was estimated to be 1.1 m^3/s. Longitudinal connectivity was calculated using a minimum depth of 7 – 10 cm of depth on riffle crests, and was determined to be 0.52 m^3/s. The target for flow releases from the Guelph Lake Dam, upstream of the Speed River at Guelph, is above the 1.1 m^3/s threshold, so the littoral zone maintenance flow has been adequately achieved in most years. There were instances in 1984 and 1997 when flows dropped below 1.1 m^3/s for over a week.

In the Eramosa River, the greatest occurrence of low flows is in September; a low flow month in August is typically a precursor to worse conditions in September (Wong & Boyd, 2014). Particularly low flows have occurred in 1989, 1998, 1999 and 2007. The longitudinal connectivity flow was considered the key ecological flow threshold for low flows in the Eramosa River, below which fish passage becomes constrained. Hydraulic modeling was used to estimate the longitudinal connectivity flow at WSC stream gauge 02GA029 (Eramosa River Above Guelph), where a minimum flow depth of 20 cm (threshold for coldwater fish communities) is maintained over riffles. The longitudinal connectivity flow was estimated to be 0.5 m^3/s, and therefore the key environmental flow threshold was recommended to be 0.5 m^3/s.

Per the requirements of the City of Guelph's PTTW for pumping water from the Eramosa River, water cannot be pumped when flows fall below 0.42 m^3/s. Wong & Boyd (2014) considered the PTTW requirement to be well-aligned with the environmental flow needs of the river, and that there would be no need to increase the PTTW cut-off.

Under the Tier 2 Water Budget (LERSPC, 2017), the reserve flow (used for calculating the percent water demand) for the Eramosa River subwatershed ranges from 0.43 to 0.49 m^3/s in August to October. Wong & Boyd (2014) noted that if the reserve flow was increased to meet the longitudinal connectivity flow of 0.5 m^3/s, the availability of flow is only marginally lower, and the river's classification as having a moderate level of potential stress would not change.

Wong & Boyd (2014) concluded that an environmental flow of 0.5 m^3/s, if maintained as a minimum for short periods of time, should support a healthy cold-water fishery in the Eramosa River by sustaining flow connectivity between pools.

4.3.3 Conclusions

Groundwater

It is the opinion of BluMetric that groundwater quantity stress is currently not a major concern for most of the Guelph WQSA, though a potential for stress exists in the Upper Speed Assessment area, from which water is pumped for the Guelph-Guelph/Eramosa (GGET) municipal water supply systems, and which was determined to have a groundwater potential stress classification of moderate. As discussed in Section 4.3.1.1, The Tier Three Assessment (which was triggered by the moderate classification) determined the WHPA-Q for the GGET area is considered at *significant* potential for risk as one of the municipal wells has been simulated to not be able to meet future allocated demand. Simulated increased demand due to population growth was determined to be the largest single stressor to the Guelph municipal supply, while simulated recharge reduction due to land use change is expected to have minimal influence. While these finding are specific to municipal supplies, they may have broader implication for groundwater management in similar geologic settings throughout the WQSA. A climate change modelling assessment (Matrix Solutions Inc., 2018) that ran four climate change scenarios determined that a slight increase in recharge, particularly in the winter, is expected. The increased recharge might offset increased pumping from future demand. While these results are specific to the municipal supply wells, a net increase in recharge would suggest that climate change may not have a negative impact on the groundwater resource.

Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater resources appear to be sustainable under existing conditions, but they may become unsustainable in some parts of the WQSA in the future due to population growth and the associated increase in water demand from municipal wells.

As noted in Section 4.3.1.1 two main take conclusions from the sensitivity analysis are that under average climate conditions and current land use, pumping is sustainable even if all non-municipal takings were at their maximum permitted rate (recognize as being very unlikely) and in future land use scenarios and under drought conditions, the cumulative impact of non-municipal takings at maximum permitted rate leads to predicted impacts to the municipal wells.

Surface Water

It is BluMetric's opinion that surface water quantity stress is currently not a major concern for most of the Guelph WQSA, though a potential for stress exists for the Eramosa River in the Grand River watershed. The Eramosa River, from which water is pumped for the Guelph municipal water supply systems, was determined to have a surface water potential stress classification of moderate. Under three of the ten climate change modelling scenarios run by Shifflett (2014), the potential stress classification for the Eramosa River was projected to increase to significant. In a separate climate change assessment (Matrix Solutions Inc., 2018), where four climate change scenarios were considered and which assumed a continued minimum flow restriction as per the PTTW (water cannot be pumped when flows fall below 0.42 m^3/s), it was determined that the impacts of climate change may have minimal or negligible additional risk to the intake. The results indicate that municipal needs for surface water can continue to be met despite climate change, if the demand remains relatively stable over time. However, an increase in surface water stress may nonetheless affect any coldwater fisheries in the river by potentially reducing flows, reducing the availability of thermal refuges and/or the affecting the ability of fish to reach thermal refuges in the event the hydraulic connectivity of the river is broken during extreme low flow events.

Similarly, the Speed River (of which the Eramosa River is a tributary), currently has a surface water potential stress classification of low, but under five of the ten modelled climate change scenarios (Shifflett, 2014), the upper portion of the Speed River was projected to experience a moderate potential for surface water stress. With an increase in potential surface water stress, the river's coldwater fisheries may be affected as described for the Eramosa River above.

Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, surface water resources in the WQSA appear to be sustainable under current conditions. Increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs. Ongoing monitoring of surface water flows should continue in order to determine whether adjustments to water taking restrictions during low flow events are warranted.

In summary, the sustainability of the water resources in the Guelph WQSA under current and future conditions is as follows:

Groundwater Under Current Conditions

- **Regional scale** - groundwater resources are sustainable under current conditions.
- **Local scale** - the groundwater resources in the Upper Speed Assessment Area (USAA) are sustainable under current conditions.

Groundwater Under Future Conditions

- **Regional scale** – the sustainability of the groundwater resources in the wider WQSA is uncertain under future conditions because the groundwater resources may be unsustainable in some parts of the WQSA in the future due to population growth and the associated increase in water demand in some areas. Based on the unlikely event that the 'worst case scenario' assumptions occur as per the City of Guelph and Township of Guelph/Eramosa Tier 3 Water Budget and Local Risk Assessment (GGET Tier 3) (Matrix Solutions Inc., 2017), the groundwater resources in the wider area may be unsustainable; however, it is more likely that this may only occur for local takings in some parts of the WQSA. The model is widely accepted as the best and most recent regional-scale synthesis of the hydrogeology of the WQSA. In addition, based on the expected warmer temperatures and increased precipitation in the winter, the modelling exercise suggests a slight increase in recharge. The increased recharge might offset increased pumping from future demand which is the single biggest stressor on the regional groundwater resource. It is important to recognize that the assessment on which this conclusion is based focuses on the sustainability of the municipal water supply and that the future sustainability of the non-municipal groundwater resources needs to be further assessed and monitored.

- **Local scale** – the groundwater resources in the Upper Speed Assessment Area is unsustainable under future conditions. The groundwater resources are uncertain in the Centre-Wellington area where a Tier Three stress assessment is currently being completed. This assessment is centred on the municipal supply systems of Fergus and Elora. In addition, GGET Tier 3 modelling and Climate Change assessment indicate that one of the City of Guelph's municipal wells will not be able to meet future allocated demand due to population growth and is therefore unsustainable.

<u>Surface Water Under Current Conditions</u>

- **Regional scale** – surface water resources are sustainable under existing conditions.
- **Local scale** – The Speed River and Eramosa River tributary are sustainable under existing conditions as per Matrix Solutions Inc. (2018).

<u>Surface Water Under Future Conditions</u>

- **Regional scale** – surface water resources are unsustainable with respect to ecological flow needs in the future due to an increase in water demand. Ongoing monitoring of surface water flows should continue in order to determine whether adjustments to water taking restrictions during low flow events are warranted.
- **Local scale** – The Eramosa River is unsustainable under future conditions based on climate change modelling scenarios run by Shifflett (2014). However, the use of the Eramosa River for municipal water supply purposes is sustainable if there is a continued minimum flow restriction applied as per the PTTW associated with the Guelph municipal water supply systems.

4.4 WATER MANAGEMENT APPROACHES AND CHALLENGES

A combination of available reports and communication with Water Managers knowledgeable of local water use/issues in the Guelph WQSA was used to summarize approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in

Section 4.6 of this report, what, if any, new management tools are needed in the Guelph WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches.

Current Approaches

MECP's West Central regional office manages the PTTW program in the Guelph WQSA and the local district office responds to well water and drought complaints.

Based on the current assessment, it is noted that the technical studies relating to water quantity, as completed under the requirements of Source Water Protection (SWP), largely inform water quantity management decisions within the Guelph WQSA.

More so than most of the other WQSAs, the approaches taken by water managers in the Guelph WQSA have been significantly shaped by a number of different water management tools used under Ontario's legislative and regulatory framework. This is in part due to the current and anticipated population growth, the density of permitted takings from the regional groundwater resource for municipal water supply, commercial and industrial purposes, as well as known environmental flow needs in the watershed and the anticipated impact of climate change.

Both strategic management and responsive management tools (described in Section 2.1 and Section 2.2) have in some form been considered and/or applied to water management in the Guelph WQSA in the recent past. In BluMetric's opinion, the Guelph WQSA has a significant amount of data and information. The data and information on which to base estimates and make assumptions is extensive and complete, both spatially and temporally, compared to other WQSAs assessed. However, the data and information is not necessarily managed and assessed on a regional scale or in a coordinated way among public and private agencies and organizations. Some of the conditions triggering further assessment to support a PTTW (see Section 2.2) have been documented within the Guelph WQSA which has resulted in the MECP requiring more regional scaled assessments and management strategies, such as Adaptive Management Plans, as part of the PTTW application process. Based on BluMetric's consultation with the Water Managers in the Guelph WQSA, additional requirements were placed on the taking due to conditions driven by concern related to the potential for impacts to the baseflow of the Eramosa River and Blue Springs Creek, and potential effects on the ecosystem because of the proposed increased water taking at Arkell. A larger area of study resulted from a larger zone of influence. The conditions triggering additional work are not necessarily connected from an evidence-based science perspective in terms of the local versus regional impact a proposed taking may have on the groundwater and/or surface water resources. Nevertheless, these conditions do trigger the need for a more regional scaled assessment and management strategy to help in the assessment of whether a proposed taking may impact the sustainable use of the surface and groundwater resources and the ability to ensure the fair sharing, conservation and sustainable use of the surface and ground waters in the WQSA. For example, as noted above, groundwater quantity stress is currently not a major concern for most of the Guelph WQSA (regional scale), though a potential for stress exists in the Upper Speed Assessment area, from which water is pumped for the Guelph-Guelph/Eramosa municipal water supply systems. The Tier Three assessment (which was triggered by the moderate classification) and specifically focuses on the risk to the municipal supply determined the WHPA-Q1A area, which contains the city of Guelph, is considered to be at a *significant* potential for risk.

According to water managers in Centre-Wellington the technical work to incorporate the results of the sensitivity analysis (Section 4.3.1.1) are currently being incorporated into the GGET Tier 3 policy framework including policies directed at the MECP to review maximum rates and the establishment of a working group between the multiple water and land use agencies. This work is ongoing at this time (Email communication from Kyle Davis, December 6, 2018).

The source protection process, specifically the implication of the Tier Three model results, is culminating in policies that will direct the assessment of sustainability of the resource. Given the many agencies involved (GRCA, municipalities, Province) a working group has been proposed to coordinate within the GGET Tier Three WHPA-Q.

Water managers also note that municipalities do not have authority to change non-municipal water takings, however, comments are often provided to MECP for PTTW renewals (i.e. Harden Environmental on behalf of Puslinch Township, staff or consultant for the Township of Centre Wellington and Guelph-Eramosa Township (Burnside). This process works well and authority should remain with the Province.

Based on BluMetric's review, Water Managers appear to be seeking solutions on how to sustainably manage the resources in the WQSA based on regional scale assessments and information but only having site scale instruments such as the PTTW program available to do so.

<u>Challenges</u>

The challenges discussed herein are specific to the Guelph WQSA as determined by the outcomes from previous deliverables within the MECP's larger State of the Science and Jurisdictional Review of Water Quantity Resources and Assessment of Ontario's Ground Water Quantity Resources project including comments received through the Water Managers Workshops completed in the Spring of 2018, and the feedback received from the local Water Managers noted above. The feedback at these workshops highlighted a number of similar challenges, discussed below.

<u>Assessing cumulative effects and sustainability on a regional scale</u>

The PTTW Manual has limited guidance on what specific triggers are needed for actions beyond a local scale and there is limited to no direction or guidance provided for methods to undertake regional (such as watershed scale), assessments such as for cumulative effects or for the development of a management strategy beyond a cumulative effects assessment.

Despite the abundance of data available within the Guelph WQSA and Tier 3 Water Budget models, the assessment of cumulative effects is limited by the availability of assessment tools. The current understanding of the sustainable use of the regional resources is largely based on the Tier 3 modelling which considers all large takers, land use and climate change, but is somewhat limited based on its focus on the risk to municipal water supplies rather than the risk to regional aquifer sustainability and cumulative effects. For example, the model does not appropriately assess potential impacts to surface water from individual water takings as these are not assessed by conservation authorities and MECP at the regional scale but rather the reach scale<u>. Also, the model would be less reliable in areas further away from the municipal wells where less data was used to calibrate the model.</u>

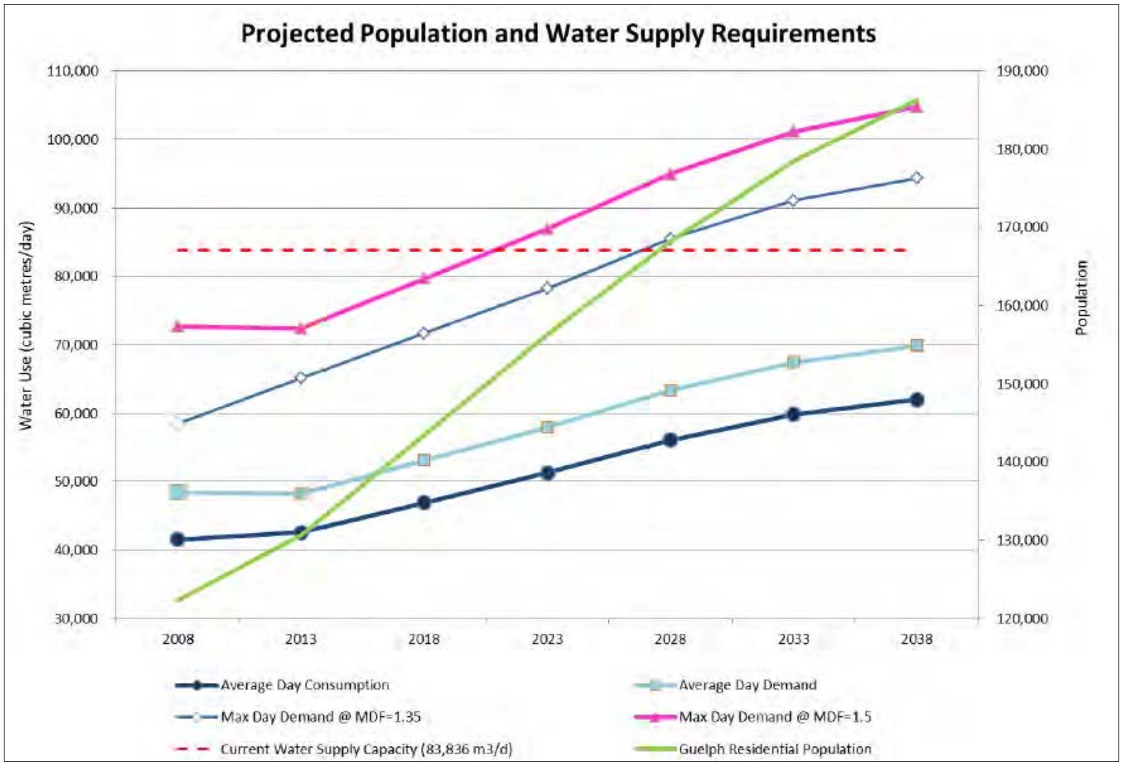
However, as noted in Section 4.3, this is supported by a significant amount of high-quality data for both groundwater and surface water that indicate that under existing conditions, the groundwater resource is sustainable.

According to water managers, the Tier 3 models are critical tools (but not the only tool). It is recognized that they need to be funded and maintained. Water managers in the WQSA indicated that the effort needs to be a partnership as the Tier Three models are owned by either the GRCA or municipalities but should be used at all levels of government (Province, CA, municipalities) (Email communication from Kyle Davis, December 6, 2018).

Meeting future water demand in the City of Guelph

The City of Guelph relies upon its Water Supply Master Plan (WSMP) to provide water supply system capacity updates, measured past and future estimates of demand and proposed new supply sources. According to the City of Guelph Water Supply Master Plan Update (AECOM and Golder Associates, May 2014), the total equivalent population (i.e. the projected residential population plus the additional population representative of industrial, commercial and institutional (ICI) land use, excluding students) in 2038 will be 285,779. Based on residential and employment (ICI) consumption and Non-Revenue Water (NRW) (the difference in water consumed by customers that is measured directly through utility billings and that which is pumped at water facilities to the water distribution system) the projected Average Day Demand in 2038 will be 69,872 m^3/day while the Maximum Day Demand which includes a Maximum Day Factor (MDF) of 1.5 is projected to be 104,808 m^3/day. The Current Water Supply Capacity is 83,836 m^3/day which represents normal operating conditions (i.e. non-drought conditions). This includes permitted pumping from the new Arkell pumping wells (Arkell 14 and Arkell 15) and recognizes interference effects amongst the groundwater supply sources as well as other interferences such as that from existing non-municipal third party permits.

The shortfall is graphically presented on Text Figure: 4-20 below. It should be noted that while the Average Day Demand can be met by the existing water supply, the current water supply system will not be able to meet Maximum Day Demand by 2023. This is not related to water resource availability, but instead to infrastructure and water quality. As per Table 4-5, in 2017 municipal water supply PTTWs only utilized a small portion of their permitted takings (21% for groundwater, 4% for surface water – groundwater and 12% for surface water).



Text Figure 4-20. The City of Guelph Projected Population and Water Supply Requirements. (Source: City of Guelph, Water Supply Master Plan Update, Draft Final Report, May 2014).

In addition to the projected shortfall, another area of uncertainty and challenge facing the City of Guelph water managers are the potential for changes by the Ministry to long-standing (30+ years) its Permits to Take Water through periodic renewals, which may challenge municipal water servicing standards/capacity to support provincially mandated growth. Based on recent PTTW renewals, the City of Guelph has noted conflicts between Source Water Protection objectives/products and current PTTW renewal processes (quantity/quality).

Another area of uncertainty is around the actual takings and potential for future impact from non-municipal third party permitted takers on the availability of water resources for municipal supply, as discussed in s.4.3.1.2.

Water supplies for the City of Guelph limited to its municipal boundaries

Although the hydrogeological investigations included areas outside the City boundaries, the City is a single-tier municipality largely constrained to its municipal boundaries for its water supply. In BluMetric's opinion, limiting water supply to municipal boundaries limits consideration of alternatives that involve coordination between public sector agencies, private organizations and municipalities. An example of such alternatives might include the development of a shared water management strategy, including a drought management plan, that considers options of shared storage and using limited groundwater resources, from a yield and interference perspective, to meet Maximum Day Demands.

Limited collaboration between the GRCA and the MECP

BluMetric has noted in other submissions within the larger project, that coordination between public agencies and adjacent jurisdictions (municipal) with respect to sharing data and the PTTW review process would be beneficial. It is noted, that Conservation Authorities are notified to increase local awareness of permit activities and to share local sources of information. However, in BluMetric communication with GRCA Water Managers, they indicated that while they are notified of PTTW applications that are subject to posting on the Environmental Registry under the Environmental Bill of Rights, 1993, the GRCA indicated they have limited resources and capacity to review and comment on PTTW applications or renewals for large takers. GRCA agrees that a review by the Conservation Authority is useful as they are well informed on local conditions and issues; however, without additional resources and capacity, it is difficult to conduct an adequate review of PTTW applications or renewals for large takings.

Evaluation of how water management concerns are considered in water management decisions

As noted in *Challenges* (*Meeting future water demand in the City of Guelph)* above, the Tier 3 water budget indicates that water demand from planned growth for the City of Guelph, and the potential for growth in the needs of non-municipal third-party takers, may impact on the sustainability of the groundwater resource in the longer term if they are not considered in tandem as part of the permitting process moving forward. To help mitigate against its needs and projected shortfall in meeting Maximum Day Demand by 2023, the City of Guelph has implemented its Water Efficiency Strategy for demand management through conservation and efficiency programs and an Outside Water Use program for water conservation in times of low water and drought. The City of Guelph has also implemented an Environmental Monitoring Program to monitor groundwater in and around its wellfields. However, it is generally accepted that these measures alone will not address the issue of the Current Water Supply Capacity not being able to meet the projected Maximum Day Demand by 2023. The water supply demand forecast indicates that under a "do nothing" scenario with continued growth, the City would require an additional capacity of 20,000 m^3/day to satisfy Maximum Day Demand including an allowance for security of supply (approximately 10 to 15% of the total system capacity).

In addition, the City, since 2007, has implemented a number of programs and studies to maintain and optimize existing supply facilities and infrastructure, including:

- Completed construction of new well facilities (Arkell 14 and 15) and commencement of the Arkell Adaptive Management Plan and Operational Testing Program;
- Completed Class Environmental Assessment (EA) for the existing Burke Well facility;
- Commenced Class EA for the Guelph Southwest Quadrant Water Supply which included evaluation of existing supplies in that quadrant as well as new test wells; and,
- Completed treatability assessments of municipal wells which were previously taken off line due to water quality issues: Clythe, Smallfield and Sacco Wells.

The WSMP Update (AECOM and Golder Associates, May 2014) also reports that the short to mid-term implementation strategy also included the initiation of various hydrogeological investigations. Some of these were inside the City and some just outside the City's boundaries. The purpose of these studies was to explore the potential for new water supplies in these areas, including the Guelph South Groundwater Supply Investigation. In addition, the following regional studies and plans were also initiated to ensure the protection and long term sustainability of the existing water supply system:

- The Guelph Tier Three Water Budget and Local Area Risk Assessment was completed to evaluate the sustainability of the City's water supply system from a quantity perspective and to identify potential threats to that sustainability; and
- The Guelph Drinking Water Source Protection Plan was developed within a watershed context to identify and evaluate potential quality and more recently quantity threats to the municipal supply system. The City, through the Lake Erie Source Protection Authority and with other municipalities within the Grand River Watershed, have and are developing policies to protect existing and future drinking water sources.

The 2014 WSMP Update (AECOM and Golder Associates, May 2014) summarized the water supply alternatives considered to address the noted shortfall between the Current Water Supply Capacity and the projected Maximum Day Demand. These alternatives included water conservation and demand management and centralized wastewater re-use and reclamation; expansion of the existing groundwater supply system (inside the City limits and 5 km outside); and establishment of a new local surface water supply. The alternative of expanding the existing groundwater supply system included a review of existing and future well supplies on a quadrant basis and included the following alternative options:

- Optimize existing operating municipal wells;
- Restoration of existing off-line municipal wells;
- Develop existing municipal test wells;
- Install new wells inside City boundaries;
- Install new wells outside City boundaries; and
- Install new ASR wells inside City to optimize excess Arkell Collector system volumes.

The WSMP Update Draft Final Report states that each of the alternatives do not address the problem as a stand-alone solution. Nevertheless, the feasibility of each alternative was evaluated on its own merit for consideration as being part of an overall solution. Important to note is the fact that there were considerable challenges associated with all alternatives ranging from the impact on nearby surface water features including the need to meet environmental flow needs, to cumulative effects on other permitted takings to the need for significant capital cost expenditures.

Consideration of key topics in water management decisions

The following points describe if and how key topics are considered in water management decisions in the Guelph WQSA.

- Climate change: efforts have been made to predict the potential effects of climate change on groundwater and surface water resources through the use of climate change modelling scenarios (Section 4.3.2.1). Based on the information reviewed as part of this study, there do not appear to be formal policies, or specific guidance, in place for considering the effects of climate change in water management decisions;

- Adaptive/alternative management: The Ministry has indicated that they will employ adaptive management to better respond to evolving environmental conditions. The Arkell PTTW has an adaptive management plan built into the PTTW conditions. Another example is the combined management of the Guelph Lake Dam and Speed River (discussed below under ecological flow needs). Other specific policies and approaches may exist but were not identified in this study in the Guelph WQSA as explicitly addressing the use of adaptive or alternative management. The province's PTTW program allows for the use of adaptive/alternative management, like the one for Arkell, as the Ministry has the authority to limit, alter or stop a water taking that is considered to cause an unacceptable impact, even after a permit has been issued;
- Municipal growth: in the Guelph WQSA, population growth and the associated increased water demand was identified as the largest stressor on future groundwater levels, indicating that population growth is the most significant stressor on groundwater resources in general (Section 4.3.2.2). In order to help mitigate against the projected shortfall in meeting future demands, the City of Guelph implemented various strategies and approaches, such as its Water Efficiency Strategy, an Outside Water Use program, an Environmental Monitoring Program (for monitoring groundwater in and around its wellfields), and various programs and studies to maintain and optimize existing supply facilities and infrastructure (see "Evaluation of how water management concerns are considered in water management decisions" in Section 4.4);
- Drought: The Ontario Low Water Response program is the principal provincial program related to drought response with a surface water focus. The City of Guelph's Outside Water Use program, which involves water conservation in times of low water and drought, provides specific policies and approaches used within the boundaries of the City of Guelph to address drought; Drought scenario's in groundwater were also explored, as part of the GGET Tier Three Assessment (Section 4.3.1.1).

- Natural function/EFN: the importance of EFN and aquatic habitat in the Guelph WQSA has been recognized, and EFN thresholds have been quantified and proposed (Section 4.3.2.4). The target for flow releases from the Guelph Lake Dam, upstream of the Speed River at Guelph, is above the recommended threshold for maintaining the littoral zone maintenance flow of 1.1 m^3/s. Per the requirements of the City of Guelph's PTTW for pumping water from the Eramosa River, water cannot be pumped when flows fall below 0.42 m^3/s, which is relatively close to the recommended key environmental flow threshold for the Eramosa River (0.5 m^3/s). However, it could not be confirmed what influence the recommended EFN thresholds had in the establishment of these minimum flow requirements (1.1 m^3/s from the Guelph Lake Dam and 0.5 m^3/s for the Eramosa River). There is also a general lack of information on EFN for other surface water bodies in the WQSA.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

As noted in *Challenges* (Meeting future water demand in the City of Guelph) above, a major challenge facing City of Guelph Water Managers is the potential for changes by the Ministry to its long-standing (30+ years) Permits to Take Water through periodic renewals, which may challenge municipal water servicing standards/capacity to support provincially mandated growth. In addition, the City of Guelph has experienced conflicts between Source Water Protection objectives/products and current PTTW renewal processes (quantity/quality). In BluMetric's opinion, this is an issue of uncertainty with respect to the process of obtaining a PTTW. This issue is more about municipal water security rather than water sustainability.

Based on the examples and experiences shared with BluMetric, it is our opinion that harmonization needs to happen between the legislated purpose and objectives of Source Water Protection under the Clean Water Act and the overarching policy of ensuring the fair sharing, conservation and sustainable use of the surface and groundwater in the province as per the requirements of the PTTW program. This would also form a holistic, "best science" procedure for review and decision making to ensure consistent evaluation, interpretation and technical direction by MECP professional reviewers.

The Tier Three models for Guelph's WHPA-Q and the soon to be completed model for Guelph-Centre Wellington are the best available regional assessments at this time, and need to be considered in making PTTW decisions.

In BluMetric's opinion, water management in the Guelph WQSA would benefit greatly from the broader use of the Tier Three groundwater model in the evaluation of PTTW applications as it would contribute to a more consistent way to evaluate and assess other proposed water takings in the WQSA. Considerations might include: an online data management tool such as that used for water management in the area of the Oak Ridges Moraine; data quality, including currency, accuracy and relevancy; management body and funding; adaptation of model for regional resource assessment purposes; and, model management and maintenance etc.

4.5 IDENTIFIED DATA GAPS

Following a review of the available reports and communication with water managers knowledgeable of local water use/issues in the Guelph WQSA, there are no identified data gaps that precluded an assessment of the sustainability of water resources. However, more data will always strengthen management decisions.

In addition, although municipalities have specific monitoring responsibilities as per PTTW, Class EA and SDWA etc., according to municipal water managers in Centre-Wellington, overall ecosystem and water resource monitoring is best completed by either the Province through MECP or the conservation authorities.

Finally, additional stress and climate change assessments centred on non-municipal water takings would address issues of uncertainty with respect to future non-municipal groundwater demand and including consideration of climate change conditions. An example of such an assessment is currently being completed using the Tier Three model but centred on the non-municipal taking at the Nestlé (Aberfoyle) site. The results of this assessment were not available for the current review and therefore represent a gap.

4.6 RECOMMENDATIONS

Based on the available reports and communication with Water Managers knowledgeable of local water use/issues in the Guelph WQSA, the following recommendations are provided as possible mitigative measures to address the identified challenges (Section 4.4) related to water quantity management and help in avoiding potential future water quantity issues.

1. As noted in Section 4.4, under *Challenges*, a key challenge in the Guelph WQSA is the assessment of cumulative effects and sustainability on a beyond the local or regional scale (i.e. watershed, aquifer, Tier 3 model, etc.). The province should consider amending or enhancing the PTTW program to incorporate additional guidance and methodology describing under what circumstances a beyond local or regional scale assessment of cumulative effects and environmental flow needs are required. In BluMetric's opinion, this guidance should be harmonized with the guidance provided under Source Water Protection and the related process of the development of a Source Protection Plan (SPP), as it relates to water quantity risk.
2. Developing a system or protocol that allows for the existing Tier 3 model groundwater model to be used by permit holders/applicants in areas where the MECP is concerned about the particular taking may be useful to predict the impacts of the existing/potential taking and develop or issue the permit accordingly. Although the Tier Three model area includes both Nestlé Waters Canada wells (discussed in detail in Appendices B and C), the model was calibrated in only a rough sense in these areas and the representation of conditions at the two locations was approximate at best. To complete a fulsome evaluation of Nestlé's Aberfoyle and Erin supplies using the model (as suggested in the Water Bottling Guidance), the model was refined with site specific geology and hydrogeology data to more accurately reflect conditions near Nestlé. The model was re-calibrated to long-term monitoring data and pumping test data from work completed by Nestlé and contributes to the regional assessment of cumulative effects and sustainability in the Guelph WQSA (identified as a challenge in Section 4.4) beyond the needs of the City of Guelph and Nestle.
3. The City is also largely constrained to its municipal boundaries for its water supply. The province should consider encouraging and, as appropriate, assisting neighbouring municipalities in developing shared water management strategies;

4. Coordination between public agencies and adjacent jurisdictions (municipal) with respect to sharing data and the PTTW review process would be beneficial, especially when assessing Cumulative Effects and related environmental flow needs on a regional scale. It is noted that O.Reg. 387/04 requires notification to CAs and municipalities within whose area of jurisdiction the proposed water taking is located, are therefore notified of PTTW applications that are subject to posting on the Environmental Registry under the Environmental Bill of Rights. This has many benefits including increased local awareness of permit activities and sharing local sources of information. However, while data may be available to share, the capacity, resources and mandate of the Conservation Authority and the local Municipality are limited in terms of being able to provide technical review and comment on PTTW applications or renewals for large takers. As noted in Section 4.4, under Challenges (Limited collaboration between the GRCA and the MECP), the GRCA indicated they have limited resources and capacity to review and comment on PTTW applications or renewals for large takers
5. In order to allow for broader use of the Tier Three groundwater models to evaluate PTTW applications, an online portal could be developed in a similar manner to the tool used for water management in the area of the Oak Ridges Moraine (see also the discussion in Section 4.4, under "Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers"). Based on this review, the permit review process and water management in the WQSA would benefit from:

   - a more collaborative (see also the discussion on "Limited collaboration between the GRCA and the MECP" under the *Challenges* section above)
   - apply a holistic, more regional scale cumulative effects assessment in areas of water quantity concern, not just to be evaluated on an individual site basis in consideration of limited information and individual opinions (recall the discussion on "Assessing cumulative effects and sustainability on a regional scale" under the Challenges section above) using a "best science" approach to decision making
   - The Tier Three models for Guelph's WHPA-Q and the soon to be completed model for Guelph-Centre Wellington are the best regional scale assessments currently available, and needs to be considered in making PTTW decisions.

4.7 REFERENCES

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5 ORANGEVILLE WQSA

The preliminary boundary of the Orangeville WQSA, as provided by the MECP, is shown on Figure 5-1. The preliminary WQSA is approximately 140 km^2 and overlaps multiple town and township boundaries, including the Town of Orangeville (population centre), Town of Mono, Town of Caledon, Township of East Garafraxa and Township of Amaranth. The WQSA partially or fully encompasses multiple watersheds and Conservation Authorities, including Credit Valley (CVC), Grand River (GRCA), and Nottawasaga Valley (NVCA). Revised boundaries of the WQSA based on the work conducted are discussed in Section 5.2.7.

In the Orangeville WQSA the major uses of groundwater and surface water are municipal water supply for the Town of Orangeville and maintaining water levels in Island Lake Reservoir, respectively. This WQSA was selected for detailed analysis by the MECP due to known or potential issues associated with population growth pressures. The objectives of this section are to provide a characterization of the Orangeville WQSA in the context of the major (most used) surface water and groundwater resources, refine the WQSA boundary based on the physical characterization, summarize and evaluate the demands on water resources in the WQSA, approaches and challenges for resource management, and determine to what extent the possible impact of projected changes in population, land use, and climate have and their potential impact on future security and sustainability in the WQSA.

5.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives for the WQSA and the preliminary WQSA boundary provided by the MECP. The CVC, GRCA, and NVCA make up the preliminary WQSA and were therefore made the focus of the literature review conducted. The review and input provided by water managers within the WQSA, the reports listed below, as well as available databases provided by MECP were used as the primary basis for the WQSA characterization and assessment presented in the following sections. Each resource was categorized in terms of the information presented within.

Table 5-1: Summary of Key Resources for Orangeville WQSA

Resource Reference	Type	Categories
AquaResource, 2011. Orangeville, Mono and Amaranth Tier Three Water Budget and Local Area Risk Assessment - Final Report. May 2011	Report	PC, GWQ, SWQ, CU, FC (CC)
Bradford, A and Van Vliet, D., 2011. Evaluating Potential Impacts of Groundwater Withdrawals on Ecosystem Water Needs in Ontario, Canada	Report	GWQ, EFN
CVC, 2009. Headwaters Subwatershed Study Phase I: Characterization Report. August 2009	Report	PC, GWQ, SWQ, CU, FC (CC)
Matrix Solutions Inc, 2014. Orangeville, Mono and Amaranth Water Quantity Risk Management and Climate Change Adaptation Assessment Pilot Study. August 2014	Report	GWQ, FC(CC)

Categories:

PC – Physical Characterization
GWQ – Groundwater Quantity
SWQ – Surface Water Quantity
CU – Current Water Users
EFN – Ecological Flow Needs
FC – Future Conditions
CC – Climate Change

5.2 WATER RESOURCES SETTING /CHARACTERIZATION

5.2.1 Land Cover and Use Setting

Land cover in the Orangeville WQSA (Figure 5-2) includes a community/infrastructure core surrounded by predominantly Agricultural and other rural land with pockets of mixed trees, swamps and bogs.

5.2.2 Population

Populations in urban centers with municipal water supplies located in watersheds which fall within or make up part of the WQSA are summarized using the most recently available population information in the table below:

Table 5-2: Summary of Population Statistics and Water Supply Source in Orangeville WQSA

Watershed	County	Municipality	Municipal Water Source	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percent Change 2011 to 2016 (%)
Credit Valley	Dufferin	Orangeville	Groundwater	27,975	28,900	+ 3.3
Nottawasaga	Dufferin	Town of Mono	Groundwater	7,546	8,609	+ 14.1
Grand River	Dufferin	Town of Amaranth	Groundwater	3,963	4,079	+ 2.9

The Town of Orangeville is the only significant population centre in the WQSA and the majority of the population relies on an extensive network of groundwater production wells for its municipal supply.

The towns of Amaranth and Mono are rural jurisdictional boundaries rather than actual population centres. Much of their population relies of private domestic wells, however both contain subdivisions which are located within the WQSA immediately outside the Town of Orangeville and rely on a network of municipal supply wells (AquaResource 2009).

5.2.3 Physiographic Setting

5.2.3.1 Physiography

Physiographic regions within the WQSA as defined by the OGS are illustrated on Figure 5-3. The Orangeville moraine (kame Moraine) is oriented north-south in the central portion of WQSA, and is flanked to west by drumlinized till Plain and Spillways further west, also oriented north-south. To the east of the Orangeville moraine, Spillways make up a significant portion of the WQSA oriented along the Credit and Nottawasaga valleys. A minor area of kame Moraine is present in the south east, and a minor area of Till Plain in the northeast.

5.2.3.2 Topography

Topography in the Orangeville WQSA (Figure 5-4) is variable ranging from the topographic highs of the Orangeville moraine in the central-west part of the WQSA to topographic lows located in the Nottawasaga Valley (northeastern part of WQSA) and Credit Valley (southern portion of WQSA).

Peak ground surface elevation along the Orangeville moraine is 525 masl, while the elevation drops to 310 masl within the Nottawasaga valley.

5.2.3.3 Climate

The climate of the Orangeville WQSA is similar to much of southern Ontario and is, characterized by warm summers, mild winters, and a long growing season typically with reliable rainfall (CVC, 2009).

The mean annual precipitation in the WQSA is 892 mm of which 18% falls as snow. Precipitation patterns in the WQSA are due partially to the influence of "lake effect" rain or snow originating from Lake Ontario and Lake Huron. Based on a period between 1971 and 2000, August, September and November are typically the wettest months, whereas January and February are the driest (CVC, 2009). The ground is typically frozen between November and February which can yield high runoff flows in the spring.

Evapotranspiration in the WQSA area was determined in a study conducted by the CVCA in 1998 to be 650 mm/year. The mean annual temperature for the area is 6°C with the mean monthly low of -8 °C occurring in January and the mean monthly high of 19 °C occurring in July (CVC, 2009). Figure 5-5 displays the location of meteorological stations in the WQSA.

5.2.3.4 Surface Water Hydrology

The headwaters of two significant river systems, the Credit and the Nottawasaga Rivers, lie within the Orangeville WQSA. The Island Lake Reservoir is situated on the northeast margin of the Town of Orangeville and feeds both river systems. A dam at the north end of the Reservoir marks the start of the Nottawasaga River which flows north to Georgian Bay (Lake Huron). A dam at the south end of the Reservoir marks the start of the Credit River which flows south to Lake Ontario.

Two main creek systems, the Monora and Eastern Tributaries, provide all of the inflow to the Island Lake Reservoir. The Eastern Tributaries lie on the east side of the Reservoir and flow through dominantly agricultural land. The Monora Creek System is located on the western side of the reservoir and flows across a portion of the Orangeville WQSA. As discussed in detail below (Section 5.3.1), under modelled growth and climate change scenarios the Monora Creek System may potentially experience decreased groundwater discharge, which could limit its contribution to the reservoir in the future (AquaResource, 2011).

From a local water demand perspective, the Island Lake Reservoir plays a crucial role in the functionality of the Orangeville Water Pollution Control Plant (WPCP). A key reason the reservoir was constructed in 1967 was to provide consistent influent flow of water to the Credit River that would allow for the assimilation of treated WPCP effluent downstream of the discharge point. The steady flow of water provided by the reservoir works to dilute the WPCP effluent, ensuring that downstream water quality objectives are met as required by the WPCP discharge permit environmental compliance approval.

South of the Monora Creek System is Mill Creek which drains eastward to the Credit River; while south of the Eastern Tributaries are the Caledon Tributaries which drain westward to the Credit River. Flow rates in the Credit River at Orangeville are seasonally variable and range between 0.06 m^3/s and 0.93 m^3/s (Hutchinson Environmental, 2014).

Table 5-3: Summary of Subwatersheds in Orangeville WQSA

Region	Main Watershed	Subwatershed	Drainage Area (km^2)	Municipal Systems/Sources in WQSA
Dufferin	Grand River	Grand Above Shand to Legatt	426	-
Dufferin	Nottawasaga Valley	Upper Nottawasaga	338	Mono Cardinal Woods Subdivision (GW)
Peel	Credit Valley	19	62	Town of Orangeville (GW)

Sources: Aqua Resource (2009), NVCA (2010) and CVC (2009)

5.2.3.5 Wetlands

Within the WQSA The Orangeville Wetland Complex is the only Provincially Significant Wetland The wetland is approximately 340 ha in area and includes wetlands that surround the Island Lake Reservoir, the Credit River, North Branch of Lower Monora Creek, Middle Monora Creek, the eastern portion of Upper Monora Creek, and the riverine wetlands south of Island Lake that support coldwater fish communities (AquaResource, 2011). Mapping from the Tier Three Assessment shows the wetlands as areas with low groundwater recharge rates and neutral or positive hydraulic head gradients, suggesting the wetlands receive groundwater discharge contribution, typical of wetlands.

5.2.3.6 Groundwater Surface Water Interaction

Aquatic thermal regimes for the surface water in the WQSA are mapped and illustrated on Figure 5-6. With the exception of the Island Lake Reservoir (Orangeville Reservoir), nearly the entire WQSA is mapped as cold water or unknown thermal status making much of the tributaries, the Credit and Nottawasaga Rivers suitable for cold water fisheries. This suggests that groundwater discharge to surface water is significant in the WQSA which is consistent with modelling conducted in the Tier 3 study (AquaResource, 2011). The study concluded that pumping from both overburden and bedrock wells are capable at contributing to baseflow reduction of surface water features. This suggests that both overburden and bedrock aquifers contribute to discharge (discussed in 5.3.1).

Groundwater recharge is highly variable within the WQSA. In topographically high areas with coarse glaciofluvial sediments, such as the Orangeville Moraine (kame moraine), recharge can be as high as 320 mm/year, while in low lying saturated wetlands (typically areas where groundwater is discharging), recharge can be 0 mm/year.

5.2.4 Geology

The Orangeville WQSA is underlain by a series of gently dipping Paleozoic sedimentary rocks consisting of deep-water shales interbedded with shallow water carbonates and sandstone. These rocks are overlain by unconsolidated Quaternary-aged sediments of variable thickness that were laid down after the last glaciation. Surficial and bedrock geology of the Orangeville WQSA are presented on Figures 5-7 and 5-8, respectively, and are described below.

5.2.4.1 Surficial Geology

Overburden deposits in the Orangeville area date back to the Wisconsinan glaciation of the Pleistocene Epoch. The three main overburden units in the Orangeville area can be categorized into outwash deposits, ice contact stratified drift, and glacial till (see Figure 5-7). These units occur in differing sequences depending on location and are not necessarily indicative of a younging direction. Overburden thickness ranges from 10 m in the central Orangeville area to 90 m in the Credit River valley (Burt and Dodge, 2016; Gartner Lee Limited, 1998).

Outwash deposits are composed of horizontally stratified permeable sand, gravel and sandy gravel. Along topographic highs, outwash deposits act as recharge areas while in low-lying areas such as the Credit River valley they can act as discharge areas. Thickness ranges between 3 and 30 m.

Ice contact stratified drift contains moderate to highly permeable sands and gravels with occasionally interbedded sandy-silt till or silt. Due to the sporadic nature of the interbedded silt, the unit can contain both confined and unconfined aquifers, however in general it is unconfined, and its thickness reaches up to 50 m. Glacial till contains sandy-silt till and is of low permeability and typically acts as an aquitard.

5.2.4.2 Bedrock Geology

The Town of the Orangeville lies on the western flank of a buried Paleozoic bedrock valley. Beneath central Orangeville, the bedrock surface is approximately 430 masl and dips eastward to a valley low of approximately 380 masl. The valley plunges southeastward with the bedrock valley floor declining to 320 masl. Given the valley cuts through the gently westward dipping Paleozoic bedrock stratigraphy, multiple formations are exposed at the overburden bedrock contact depending on the location within the study area. From youngest to oldest, these include the Guelph Formation, the Amabel Formation, and the Clinton – Cataract Group (see Figure 5-8).

As part of a Class EA that is commencing in 2019 (see Section 5.4 – Approaches), Orangeville plans to drill a high quality bedrock borehole, but that information is not yet available. This will help further characterize the local bedrock geology, which in the opinion of the OGS lacks high quality characterization. The lack of high quality boreholes available bedrock, constitute a data gap which limits the ability to accurately characterize the local geology.

5.2.5 Hydrogeology

Table 5-4 lists and Figure 5-9 illustrates the eleven hydrostratigraphic units identified within the Study Area: five overburden and six bedrock units. Overburden aquifers are typically associated with ice-contact sand and gravel deposits and similar coarse grain sediments that were deposited within the Orangeville Moraine, or the buried bedrock valley associated with the Credit River. Productive carbonate bedrock aquifers underlay the overburden aquifers within the WQSA; however the level of productivity will vary with local fracture regimes and porosity development (AquaResource, 2011).

Table 5-4: Hydrostratigraphic units in Orangeville WQSA (adapted from AquaResource, 2009)

Hydrostratigraphic Unit	Geologic Description	Specific Geological Unit
Upper Sands (unsaturated)	Glaciofluvial and glaciolacustrine outwash	Coarse-grained outwash sand deposits.
Upper Tills (unsaturated)	Fine-grained subglacial till sheets, localized glaciolacustrine clays	Newmarket Till, glaciolacustrine clays, Singhampton Moraine
Intermediate Aquifer (Upper Sands)	Coarse-grained glaciofluvial/glaciolacustrine/ outwash/ ice-contact sands and gravels	Orangeville Moraine Spillway/ outwash sand deposits
Lower Aquitard (Lower Till)	Lower fine-grained subglacial till sheets, and lacustrine clays	Tavistock Till, Port Stanley Till, Catfish Creek Till
Lower Aquifer (Lower Sands)	Discontinuous sand and gravel deposits overlying weathered bedrock surface	Sand and gravel overlying bedrock
Lower Aquifer	Weathered bedrock surface	Contact zone aquifer
Bedrock Aquifer	Dolostone	Guelph Formation
Bedrock Aquitard	Argillaceous dolostone, shale	Eramosa Member of the Amabel
Bedrock Aquifer	Dolostone	Amabel Formation
Bedrock Aquitard	Interbedded shale, sandstone and dolostone	Clinton- Cataract Group
Bedrock Aquitard	Shale	Queenston Formation

In general, regional groundwater flows from west to east beneath the Town of Orangeville, towards the Credit River. Water table potentiometric topography generally follows the surficial topography that slopes eastward from the topographic high of the Orangeville Moraine towards the Credit River. East of the Credit River, groundwater flows westward toward the Credit River.

5.2.5.1 Overburden Aquifers

Overburden aquifers used for municipal water supply and some residential water supply (wells shown on Figure 5-10) include the Intermediate Aquifer (Upper Sands) and the Lower Aquifer (Lower Sands). The Town of Orangeville has two municipal supply wells which draw from the Intermediate Aquifer (Upper Sands); wells 5/5A. Three municipal wells; Well 10, and the Mono Coles Wells 1 and 2 obtain groundwater from the Lower Sands overburden aquifer. All other municipal supply wells in the WQSA draw water from the bedrock aquifers (AquaResource, 2011).

5.2.5.2 Bedrock Aquifer

The Guelph and Amabel Formation represent the main bedrock aquifers used for water supply within the WQSA. Of the two, the Amabel is particularly productive, exhibiting high secondary porosity (AquaResource, 2011). Stratigraphically, the Eramosa member of the Amabel Formation overlies the aquifer portion of the Amabel, separating it from the overlying Guelph Formation. While the Eramosa is known to act as a good aquitard where present, its spatial continuity is poorly understood due to a lack of deep, good quality boreholes in the WQSA (AquaResource, 2011).

5.2.6 Overview of Water Takings within WQSA

5.2.6.1 Permitted Takings

Water takings at a rate of over 50,000 litres per day are governed under the MECP PTTW program. Water takings in Ontario are governed by the Ontario Water Resources Act (OWRA) and the Water Taking Regulation (O. Reg. 387/04) a regulation under the Act. Section 34 of the OWRA requires anyone taking more than a total of 50,000 litres of water in a day, with some exceptions, to obtain a Permit from a Director appointed by the Minister for the purposes of Section 34. The purpose of the PTTW program is to ensure the conservation, protection and wise use and management of the waters of the province. Permits are controlled, and not issued if the taking of more water in a given area would adversely affect existing users or the environment.

This section summarizes and reviews the reported takings in the WQSA based on the 2017 WTRS data collected by MECP and the 2008 water taking data from the Tier Three Assessment (AquaResource, 2011). This annual snapshot data constitutes the most recent available information on actual water takings, and within the scope of the project are considered the most accurate description of the actual permitted water use in the WQSA. The total permitted volume for all purposes in 2017 was 1.8×10^8 m^3 annually, while total reported volume taken was 1.0×10^7 m^3, or 5.6 % of permitted.

Permitted takings in the Orangeville WQSA are dominated by the takings to maintain Island Lake Reservoir system (surface water), and water supply for the Town of Orangeville and subdivisions within Mono and Amaranth. Together in 2017, these two purposes accounted for approximately 97% (9.8×10^6 m^3) of the total takings and 99% (1.8×10^8 m^3) of the total permitted volume. The remaining 3% of the total takings and 1% of total volume permitted was used for the purposes of agriculture, golf course irrigation, other-commercial, snow making, aggregate washing, heat pumps, other miscellaneous and other water supply.

Figure 5-11 shows a map of the active surface and groundwater permitted takings within the Orangeville WQSA, categorized by purpose. Percentages and values in the following paragraphs used to characterize water demands by Purpose and specific Purpose were compiled from the 2017 WTRS data. Permitted versus actual water takings of surface and groundwater within WQSA is summarized in Table 5-5.

Table 5-5: Volume of Reported Water Takings vs Maximum Permitted Volume of Surface and Groundwater in Orangeville WQSA (2017 WTRS)

Sector	Type	Volume of Reported Takings (m^3/yr)	Percent of WQSA Total Reported Takings (%)	Maximum Permitted Volume (m^3/yr)	Permit Utilization (reported takings/ maximum permitted volume) (%)
Agriculture	Groundwater	0	0	11,784,000	0
Commercial	Surface and Groundwater	15,999	0.16	249,340,000	0.0064
	Surface Water	269,632	2.6	1,002,517,440	0.027
Industrial	Groundwater	0	0	995,520,000	0
Miscellaneous	Groundwater	33,793	0.33	183,857,070	0.018
	Surface Water	6,248,124	61	169,304,155,000	0.0037
Water Supply	Groundwater	3,708,899	36	10,116,383,840	0.037
Total	All Sources	10,276,447	100	181,863,557,350	0.0057

Water Supply

Permitted municipal water supply takings in 2017 represented roughly 36% of the total permitted takings in the WQSA (all groundwater). When the amount of water used by Island Lake Reservoir is removed from the total takings, water supply represented 99% of all takings in 2017, and 88% of the total permitted volume (all categories confounded) for groundwater.

Water supply PTTWs allow for water taking 365 days per year (366 on leap years), as the Town of Orangeville and surrounding areas are reliant on water supply systems require access to provide potable water year around.

In 2008, the existing demand for municipal water use within the WQSA was 9,089 m^3/day (AquaResource, 2011). In comparison, WTRS reported taking data for 2017 indicate that municipal consumption was 10,161 m^3/day in the WQSA. This represents roughly a 10% increase in consumption over 9 years and is still below the existing plus committed plus planned water demand, which in 2009 was estimated at 12,637 m^3/day (AquaResource, 2011). The takings remain well below the maximum permitted daily volume, which in 2009 was 24,652 m^3/day, while in 2017 it was 27,716 m^3/day.

Agriculture

The total agricultural permitted water use is insignificant compared with the total permitted volume in the WQSA (< 0.1%). One Agriculture permit exists in the WQSA with a maximum permitted volume of 11,784 m^3/year, and is limited to 12 days of use annually. This taking is from a groundwater fed pond. No water was recorded to be used by the permit holder in 2017.

Commercial

Permitted water takings for the purpose of Commercial uses in 2017 within the WQSA represented 2.78% of the total takings and 0.7% of total permitted volume. The sources for commercial water takings are made up of a combination of groundwater only permits, and permits for both surface and groundwater. Specific Purposes of Commercial permits include golf course irrigation, snow making, and other Commercial. Within the Town of Orangeville, water for commercial purposes is provided through the municipal water supply.

Given the seasonal nature of commercial purposes, Commercial permits in the WQSA are not issued for use year around. The number of permitted days for the permits range from 120 to 214.

Industrial

Permitted taking for Industrial purposes within the WQSA is limited, representing 0.6% of the total permitted volume. In 2017 no water taking was recorded for the one groundwater industrial permit (aggregate washing).

Similar to commercial water users, within the Town of Orangeville, water for industrial purposes in provided through the municipal water supply

Institutional, Remediation, Miscellaneous

The specific purpose of dam and reservoirs falls under the miscellaneous purpose category which includes the permit for the Island Lake Reservoir Dam, the largest single user of water in the WQSA. The permit accounts for 93% of total volume permitted within the WQSA, and 60% of the reported total volume taken. While the Island Lake Dam represents a large volume of water taken in 2017, its consumptive factor is low. Consumptive factors are applied to water uses to account for how (or if) the water is returned to the source after use. This allows for water budgets to accurately reflect the degree to which water is taken permanently from the source. Dams and Reservoirs typically have a low consumptive factor of 0.1 (as per MECP Technical Guidance rules), which suggests that 90% of the water used is immediately returned to the source, as the water from the Island Lake Reservoir flows though the dam and back into the Credit River. Conversely, a consumptive factor of 0.90 suggest that only up to 10% of the water used may be not be returned to the source due to inefficiencies in the dam or evaporation. In contrast, municipal water Supply, the other main permitted use in the WQSA, has a consumptive factor of 1, which indicates that all water used by a municipal water supply does not return to the source (bedrock and overburden aquifers).

As discussed in 5.2.3.4, a key role of the Island Lake Reservoir is to provide assimilation capacity for treated effluent discharged from the Orangeville WPCP downstream of the reservoir.

5.2.6.2 Non Permitted Takings

Non – permitted takings represent water takings for domestic use and some agricultural uses that are less than 50,000 litres per day. Consumptive non-permitted takings in Subwatershed 19 (which represent a significant portion of the WQSA) is estimated to be 95 m^3/day based on the amount of domestic wells. This represents less than 1% of the municipal water use in the WQSA and therefore is not considered significant (AquaResource, 2011). This value is based on number of unserviced residences in the Orangeville area (assumed to have one domestic well) multiplied by an average 3.2 people per residence using 335 litres per day of water, multiplied by a consumptive factor of 0.2 (80% of water returning to source via septic beds) (AquaResource 2009).

5.2.7 Recommended WQSA Boundaries for Data Review

The WQSA boundaries should be revised to utilize the study area boundaries set out by the existing Tier 3 study for Orangeville, Amaranth, and Mono which almost entirely envelops the current WQSA (Figure 5-12). Advantages to using the Tier 3 boundaries include:

1. Ensuring all Well Head Protection Areas (WHPAs) are entirely within the WQSA (some currently extend past the preliminary boundary)
2. Modelling data for the Orangeville area has been obtained based on the study area boundaries. Changing the WQSA boundaries to match the Tier 3 boundary allows for data obtained in the study to directly apply to the WQSA, efficiently utilizing existing data.

It should be noted that two minor areas in the northern part of the current WQSA would be excluded if the Tier 3 boundary was adopted. However no permitted takings lie within or are near these areas.

5.3 RESOURCE SUSTAINABILITY

5.3.1 Data Review and State of Water Resources

Available information on the sustainability of water resources in the Orangeville WQSA has been reviewed and summarized. The key reports relied upon for the evaluation are listed in Table 5-1. Hydrographs from the Provincial Groundwater Monitoring Network (PGMN) within the WQSA were also reviewed, and conclusions were made based on the general findings of studies/reports/data conducted and collected in the Orangeville WQSA.

<u>High Use Watershed Classification</u>

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Orangeville WQSA lies within a tertiary watershed that is classified as having a Medium percent water use based upon both the Average Annual and Summer Low Flow.

PGMN Hydrographs

The MECP provided hydrographs and a statistical analysis of water levels for all PGMN wells in all WQSAs. In the Orangeville WQSA hydrographs and a statistical analysis of water levels were provided for seven PGMN wells located within and surrounding the Orangeville WQSA, including Mann Kendall (MK) and Seasonal Mann Kendall (SK) monotonic trend analyses (i.e. consistently increases or decreases through time) between 2001-2017. These wells are summarized in Table 5-6 and shown on Figure 5-10. The methodology for the analysis is forthcoming from the MECP; however the results are relied upon here to summarize water level trends in the Orangeville WQSA. The statistical analyses were performed using robust and defensible methodologies to look for longer-term trends in groundwater levels. These wells include W0000486-1 (located northwest of Orangeville) and W0000019-1 (located southwest of Orangeville) (Figure 5-10). The methodology for the analysis is forthcoming from the MECP; however the results are relied upon here to summarize water level trends in the Orangeville WQSA. Hydrographs of the above wells are located in Appendix C.

Table 5-6: PGMN Wells in Orangeville WQSA

PGMN Well ID	Water Well Record ID	Screened Interval (mbgs)	Ground Elevation (masl)	Lithology of Aquifer
W0000019-1	1705664	Screen: 17.9 m-19.2 m	448.85	Sand, Gravel, Clay
W0000486-1	N/A	Screen: 17.3 m- 20.9 m	497.29	Sand, Gravel

The Mann Kendall analysis, which looks at the year over year water levels, determined that both wells had no trends. The Seasonal Mann Kendall analysis, which determines the trend from season to season (i.e., Spring 2010 to Spring 2011) and then adds the sum of each seasonal analysis together, established that one well had an upward water level trend(W0000486-1), while the other had no trend.

Both W0000486-1 and W0000019-1 are screened between 18 and 22 meters below ground surface in overburden. Based on well PGMN well depths geology logs from the area, these wells are likely screened in the Intermediate Aquifer (Upper Sands).

Based on the hydrographs from these two PGMN wells, regional water levels in the Intermediate Aquifer (Upper Sands) appear unimpacted by any water takings or climate stress. PGMN wells are placed in areas believed to be representative of ambient regional groundwater levels in areas not directly impacted by any specific groundwater taking, and therefore do not replace water level data collected by town of Orangeville staff from monitoring wells designed to monitor the impacts of water taking within the immediate vicinity of municipal supply pumping wells (AquaResource, 2011). However, given that municipal supply wells represented 99% of the 2017 consumptive takings in the WQSA (and likely a similar amount in previous years), and W0000486-1 and W0000019-1 have had either upward or no trend, respectively, it is unlikely that the water supply takings in the WQSA are causing regional scale impacts to water levels in the Intermediate Aquifer (Upper Sands).

It should be noted that the water supply wells in the Orangeville WQSA draw water from either the Bedrock Aquifer or Lower Aquifer (Lower Sands) which are in different hydrostratigraphic units than the interpreted PGMN well units (Intermediate Aquifer (Upper Sands)). However, given the potential for water supply pumping to affect groundwater discharge to surface water modelled in the Tier Three Assessment (discussed below), if pumping from water supply wells in the WQSA was not sustainable or resulting in aquifer mining, this would likely be observed in the PGMN wells (located between bedrock and surface water).

Tier Three Assessment for Orangeville, Amaranth, and Mono

The Tier Three Water Budget and Local Area Risk Assessment for Orangeville, Amaranth, and Mono, which is roughly equivalent to the preliminary Orangeville WQSA, represents the most detailed account of water quantity issues in the WQSA currently available and is summarized below.

The key findings of the Tier Three Assessment suggest that Orangeville is not currently facing water quantity issues; however, given projected population growth and planned land use development, the study found that a significant water quantity risk level exists within a portion of the Tier Three Assessment study area called Local Area A. The water quantity risk potential designation is due to the results of modelled future demand and climate scenarios that show excessive drawdown and impacts to groundwater discharge rates. This is discussed in detail below. Tier Three Assessment modelling was performed as per MECP Technical Rules for Source Protection Area Assessments.

The Risk Assessment for Local Area A, as defined in the Tier 3 study, includes much of the Town of Orangeville, and the area immediately to the west. This area includes many permitted takings, including 16 municipal wells (12 in Orangeville, 3 in Mono, and 1 in Amaranth [Pullen Well]). Of these 16 wells, 14 draw water from bedrock, while 2 draw from overburden. These wells make up a significant majority of the WQSAs permitted municipal water supply.

Other areas within the study boundary (approximately reflective of the WQSA boundary) that were analyzed in detail for potential water quantity issues included Local Areas B, C and D. Modelling for projected population growth and any potential land use changes within these areas were determined to have a low potential to cause water quantity issues.

The Risk Assessment for Local Area B is within the Town of Mono on the eastern shore of the Island Lake Reservoir and is centered on the three water supply wells for a nearby subdivision. Local Area C encompasses the Coles business/residential area of Mono which contains two water supply wells and one commercial permitted taking for both surface and groundwater. Local Area D is centered on Orangeville water supply Well 10 located immediately west of Highway 10 near the north Credit River bridge.

Local Area A findings

The Tier Three Assessments uses groundwater and surface water models of the areas around municipal water supplies to determine if certain receptors will respond to future conditions. In general, the long term sustainability of the water resource in the modelled area is determined by the extent to which future scenarios which consider population/economic growth, land use and climate changes cause a decline in potentiometric surface. Areas for detailed investigation are called Local Area Assessments which typically surround the area that will be influenced by or influences municipal water supply takings.

The benchmarks of sustainability measured from the modelling exercise include the amount of drawdown in a supply pumping well and the decline in groundwater discharge to surface that is caused under a variety of future population/economic growth, land use and climate change scenarios.

Drawdown is measured in supply wells within the Tier Three assessment area to determine if the wells will be able to supply water at the required rates under future conditions. Based on the geology and well construction, each well has a Safe Amount of Available Drawdown (SAAD) which is defined as the difference (measured in meters) between the average water level in a pumping well under pumping conditions, and a point in the well typically 1 m above the screen or the lowest possible pump intake. If the modelled drawdown in the well under future conditions does not exceed the SAAD, the taking may be considered sustainable from a water supply perspective.

Groundwater discharge to surface water features such as cold water streams provides cold temperature baseflow that is vital to the ecology of some creeks and wetlands. The sustainability of water takings is also quantified by how much (in litres per second) modelled water takings under future condition contribute to a decline in baseflow to creeks and wetlands. Generally, if baseflow is reduced by 10 percent or less under modelled future conditions, the takings are considered sustainable.

Scenarios can arise where SAAD is not exceeded under future conditions suggesting that, from a water supply perspective, the taking is sustainable, however the same water taking is responsible for a baseflow reduction of greater than 10%. Therefor a taking could be considered sustainable from a water supply perspective, but not from a baseflow reduction perspective.

Tier Three Assessment modelling attempted to predict future water quantity conditions in the Orangeville area (modelling was performed in 2011) by incorporating existing (current) demand, and the committed and planned (accounts for the demand that would result from fulfilling the Official Plan for the Town of Orangeville [as per the 2007 Official Plans used in the Tier Three Assessment] as the town grows). The Official Plan for Orangeville includes planned land use changes. The Tier Three Assessment model incorporates land use changes by assuming that land use conversion from non-developed (forest or agriculture for example) to developed (commercial or residential for example) will directly correlate with reduced recharge areas based on the assumption that developed parcels would be 100% impervious surface. According to the Official Plan, the most notable change in land use that may occur in the area is the conversion of agricultural land to high density residential land along the Highway 9 corridor west of the Town of Orangeville boundary with the Townships of Amaranth and East Garafaraxa. The modelling scenarios looked at how both groundwater and surface water would be affected by projected future demand, land use, and climate changes.

Groundwater level drawdown

The study found that under normal climate conditions, accounting for existing and future water demand (population growth) and decreased recharge areas (conversion of land from non-developed to developed as per the Official Plan), Wells 5 and 5A (Orangeville), along with the Cardinal Woods # 3 Wells (Mono) were projected to experience drawdown that is greater than or close to the SAAD established for each well. When prolonged (10 year) drought conditions were added to the growth conditions, Well 6 and Well 9A/B were also projected to experience drawdown that is greater than or close to the SAAD.

It should be noted that modelling future conditions is inherently somewhat uncertain. While modeling a ten year drought period provides insights into possible "worst case scenarios", this may be an extreme example as the Credit Valley Source Protection Area (CVSPA) updated water quantity assessment report indicates that the annual precipitation in Southern Ontario has increased since 1999 by 5-35% and future climatic projections for next 20-50 years predicts an increasing annual precipitation (CVSPA, 2015).

Surface Water

The identical modelling scenarios described above were also reviewed for how surface water in Local Area A may be affected by a combination of increased demand and reduced recharge area. The results of the scenarios showed a significant decrease in baseflow contribution (L/s groundwater discharge) to multiple cold water creeks that supply the Island Lake Reservoir and the Credit River. These included all arms of Monora Creek and Mill Creek.

Modelled reductions in baseflow to Monora Creek ranged from 20-37 %, while reductions to Mill Creek ranged from 73% -91%. In most cases, reductions in recharge areas accounted for the significant majority of baseflow reduction to surface water.

As described in section 5.2, Monora Creek provides a significant portion of inflow to the Island Lake Reservoir. If the Monora Creek contribution to the reservoir decreased, this could possibly impact the ability for it to provide assimilation capacity to the Orangeville WPCP treated effluent discharge to the Credit River downstream. It should be noted that the Tier Three Assessment determined a level of uncertainty around modelled baseflow declines in the creeks:

> *The lack of continuous flow gauging stations on sensitive creeks such as Mill or Monora Creek, and the Island Lake Reservoir is a data gap in the Subwatershed. The lack of long term gauged flow data limits the ability to examine the long term trends in these surface water features.*

As per Orangeville's PTTW Environmental Monitoring Plan (EMP) (SLR, 2012), flow in Monora and Mill Creek is now monitored. Results of the monitoring programs have been mixed, with minimal correlation observed between pumping and baseflow changes in Monora Creek. Results are discussed in detail in section 5.4 – Challenges.

Wetlands

The Caledon Lake area portion of the Orangeville wetland complex falls within Local Area A (Figure 5-1). Modelling for the area suggests that under future demand and reduced recharge conditions, groundwater discharge to the wetland may be reduced by 20%.

5.3.1.1 Water Shortages

Based on communication with local water managers, water shortages in the Orangeville WQSA are not currently an ongoing issue (Town of Orangeville, personal communication). Times when water shortages have been a potential concern have been due to operational factors, such as a well taken out of service for unplanned maintenance or repairs. Having sufficient water supply may become more of a concern as the population of the Town continues to grow, as discussed in the Tier 3 reports summarized above.

5.3.1.2 The Ontario Low Water Response (OLWR) Program

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater level elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%;
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the WQSA.

Credit Valley CA

A review of the OLWR database indicates that a total of 11 Level 1 notifications and two Level 2 notifications were sent to the Credit Valley CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2001 (two Level 1 notifications), 2012 (one level 1 and one Level 2 notifications), and 2018 (two Level 1 notifications). The Credit Valley CA posted Low Water Condition Alerts during two periods: a Level 1 Low Water Alert was posted from mid-May to mid-October 2012, and again from July

2016 to early February 2017 (this was raised to a Level 2 Low Water Alert between early August and mid-September 2016).

Nottawasaga Valley CA

A review of the OLWR database indicates that a total of ten Level 1 notifications, and two Level 2 notifications, were sent to the NVCA between 2000 and August 2018. It should be noted that these are watershed wide and there have been no recorded instances where notifications have been made as a result of local conditions in individual subwatersheds. Instances where more than one notification was issued in the same calendar year occurred in 2002 (3 Level 1 notifications), 2003 (3 Level 1 notifications), 2006 (3 Level 1 notifications), 2010 (4 Level 1 notifications), 2012 (3 Level 1 notifications) and 2015 (3 Level 1 notifications).

The NVCA posted Low Water Condition Alerts (all Level 1) during 8 periods for the watershed as a whole:

- July 2001 to early November 2001;
- Mid-August 2003 to early December 2003;
- Early August 2005 to early December 2005;
- Late June 2007 to late November 2007;
- Mid-July 2011 to early September 2011;
- Early July 2012 to mid-August 2012;
- Late August 2012 to late September 2012;
- Mid-July 2016 to mid-November 2016.

From 2007 to 2018, NVCA began posted Low Water Condition Alerts to select subwatersheds, including the Innisfil Creek subwatershed. Periods when Level 1 and Level 2 Low Water Condition Alerts were posted to the Innisfil Creek subwatershed included:

- Late June 2007 to early November 2007: a Level 1 Low Water Condition Alert was posted in late June 2007, which was raised to a Level 2 in late July, and lowered back down to a Level 1 in mid-October. The Low Water Condition Alert ended entirely in early November 2007;
- Mid-July 2011 to end of July 2011: a Level 1 Low Water Condition Alert was posted;
- Early July 2012 to end of September 2012: a Level 1 Low Water Condition Alert was posted.

Overall, the OLWR database indicates that the Credit Valley CA and Nottawasaga Valley CA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts. For the Credit Valley CA, Level 1 and Level 2 Low Water Condition Alerts were declared in 2012 and in 2017-2018, whereas none were declared prior to 2012. The more recent declarations of Low Water Condition Alerts indicate a possible, but not definitive, decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area. In contrast, no specific trends can be discerned in the frequency of Low Water Condition Alerts for the Nottawasaga Valley CA, nor in the frequency of OLWR notifications for either CA. Overall, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends. As notifications and alerts are on a watershed scale rather than subwatershed scale, the relevance to specific subwatersheds within the WQSA cannot be readily determined from the available posted data.

5.3.2 Assessment of Sustainability of Water Resources

5.3.2.1 Climate Change

As a follow up study to the Tier 3, Matrix Solutions (2014) conducted additional groundwater modelling which attempted to model and evaluate the potential effects of 1) implementation of Risk Mitigation Management options (pump optimizations, water supply system integration, low impact development on significant recharge areas), and 2) future climate change scenarios on water quantity. These scenarios were modelled using the allocated pumping rates for all water supply wells, which accounts for projected population growth in the Town of Orangeville. The results of the study provide insight into the effects of climate change and multiple RMM options on water quantity issues within the WQSA and are summarized below. The evaluation of the RMM options are discussed in 5.3.2.3.

The Matrix Solutions (2014) climate change modelling utilized ten possible climate change scenarios based on the MNRF Future Climate Data Application. The period 1961 to 1990 was used as the baseline and weather data taken from the Orangeville weather station (Figure 5-5) and 2011 to 2040 was used for the future time period.

The scenarios included a variety of projected climate patterns that included a range of average annually temperature increases, and a range of average annually precipitation increases, with the exception of one scenario which projected decreased precipitation.

Groundwater

The climate change scenarios were applied to the groundwater-surface water model in conjunction with the most advanced Risk Mitigation Management option which included the pump optimization and full integration of water supply wells in the Town of Orangeville, and the townships of Mono, and Amaranth, and only a 10% reduction in recharge area due to implementation of low impact development policies.

It is understood that the authors of the Matrix Solutions (2014) study modelled the effects of climate change in conjunction with the most advanced Risk Mitigation Management option implemented to determine the “best case scenario”, that is what water quantity issues would look like under the effects of climate change if Orangeville, Mono, and Amaranth employed the most advanced mitigative and adaptive policies.

Seven of the ten projected climate change scenarios resulted in increased groundwater recharge, while two resulted in a decrease and one showed no change. Averaging the effects of the ten hypothetical scenarios, mean annual temperature was projected to increase by 1.5 °C, mean annual precipitation was projected to increase by 3.3% which culminated in a mean predicted annual recharge increase of 5%.

Compared to existing climate conditions, when the effects of each climate change scenario were averaged across the study area, future water levels in all water supply wells in Orangeville, Mono, and Amaranth were predicted to either increases or remain the same when pumped at future demand rates.

Surface Water

In additions to modelling the effects of climate change on groundwater levels, The Matrix Solutions (2014) study also looked at the possible impacts on groundwater discharge to surface water features under the same ten climate change scenarios.

In contrast to the groundwater water modelling, the discharge to surface water results did not incorporate any Risk Mitigation Management options (current recharge areas were used), however the modelling did use allocated pumping rates (accounts for increased pumping due to the projected population growth). This was done as per the MECP Technical Rules for Source Protection studies.

Seven of the ten climate change scenarios resulted in a decreased groundwater discharge to some surface water features. When the scenarios were averaged, the Monora creek system was the only group of surface water features that experienced a net loss of groundwater discharge. As discussed in the section 5.2.3.4 above, since Monora Creek provides significant flow into the Island Lake Reservoir, climate change impacts may affect the ability for the reservoirs ability to provide assimilation capacity to the downstream WPCP on the Credit River.

While the Matrix Solutions (2014) study showed an average 5% increase in precipitation that would influence recharge and ultimately groundwater discharge, it is possible that the increased precipitation may also contribute to higher streamflows via runoff as well, however this could be offset by evapotranspiration increases. This was not quantified in the study.

5.3.2.2 Population Growth

The WQSA lies within the County of Dufferin and the Region of Peel. Statistics Canada has estimated that these counties will grow by over 25% between 2017 and 2041 (1% annual growth). These administrative districts are located within the Province of Ontario Growth Plan and are subject to conditions in the Places to Grow Act of 2005. This projected rate of growth is comparable to the 1.1% average annual population experienced by the Town of Orangeville between 2011 and 2016 (StatsCan). The results of Tier Three groundwater modelling scenarios suggest that future increased demand (due to population and economic growth) is the most significant factor contributing to increased drawdown in pumping wells. Conversely, reduction in available recharge area is the most significant factor contributing to groundwater discharge. Both of these factors are due to the projected population and economic growth forecasted for the Orangeville area. The modelled impacts of population growth related pressures are discussed in detail in Section 5.3.1.

Results of Risk Management Measures

Introduced in 5.3.2.1, a series of Risk Management Measures (RMM) were applied to the Tier Three Assessment Water Budget groundwater model. The RMMs included: pump optimization, integrating Orangeville, Mono, and Amaranth water supply systems in various combinations, and maintaining pre development recharge. Any combination of the RMMs which included a form of water supply system integration brought the Significant potential for risk Stress Assessment classification to Moderate. All combinations which changed the classification from Significant to Moderate were able to meet pumping demands, not exceed SAAD, and contribute to a groundwater discharge decline between 10% and 20% under future demands in drought conditions. It should be noted that while the RMMs that considered water supply system integration were able to meet pumping demands and reduced drawdown stress, it did decrease groundwater discharge to some surface water features to between 10% and 20% in areas that were previously modelled to decline by less than 10% without RMM consideration.

5.3.2.3 Cumulative Effects

Interference issues resulting from multiple water takings have not been identified in the Orangeville WQSA. Based on communication with local water managers, water shortages in the Orangeville WQSA are not currently an ongoing issue (Town of Orangeville, personal communication; see also Section 5.3.1.1). Times when water shortages have been a potential concern have been due to operational factors, such as a well being taken out of service for unplanned maintenance or repairs (Section 5.3.1.1). In addition, BluMetric had not identified nor been made aware of any reported interference issues between permitted and non-permitted water takings.

There is also not a high density of permitted takers in the Orangeville WQSA compared to other WQSAs: as discussed in Section 5.2.6.1, permitted takings are dominated by those to maintain the Island Lake Reservoir system (surface water), and water supply for the Town of Orangeville and subdivisions within Mono and Amaranth. Together, in 2017, these two purposes accounted for approximately 97% (9.8x106 m^3) of the total takings and 99% (1.8x108 m^3) of the total permitted volume. The remaining 3% of the total takings and 1% of total volume permitted was used for the purposes of agriculture, golf course irrigation, other-commercial, snow making, aggregate washing, heat pumps, other miscellaneous and other water supply.

No evidence of interference or impacts to the natural functions of the ecosystem has been identified. However, it should be noted that while existing groundwater models appear to be capable of accurately predicting groundwater discharge to surface water (Section 5.3.2.4), these models do not yet appear to have been used for the specific purpose of identifying actual interference or impacts to surface water systems.

No significant declines in hydraulic head have been identified. Based on the hydrographs of the two PGMN wells in the WQSA, regional water levels in the Intermediate Aquifer (Upper Sands) appear unimpacted by any water takings or climate stress (Section 5.3.1). The absence of an observable downward trend in the PGMN wells indicate it is unlikely that the water takings in the WQSA are regional scale impacts to water levels in the Intermediate Aquifer (Upper Sands).

Review of the OLWR database indicates that the Credit Valley CA and Nottawasaga Valley CA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts (Section 5.3.1.2). The more recent declarations of Low Water Condition Alerts within the Credit Valley CA indicate a possible, but not definitive, decreasing trend in the availability of surface water (and possibly shallow groundwater) in the watershed. However, no specific trends can be discerned in the frequency of Low Water Condition Alerts for the NVCAnor in the frequency of OLWR notifications for either CA. Overall, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends.

The Orangeville WQSA is nonetheless an area where cumulative effects may potentially become a concern in the future. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Orangeville WQSA lies within a tertiary watershed that is classified as having a Medium percent water use based upon both the Average Annual and Summer Low Flow (Section 5.3.1). In addition, given the projected population growth and planned land use development, the Tier Three assessment found that a significant water quantity risk level exists within a portion of the Tier Three Assessment study area called Local Area A (Section 5.3.1). The water quantity risk potential designation is due to the results of modelled future demand and climate scenarios that show excessive drawdown and impacts to groundwater discharge rates.

Numeric modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

5.3.2.4 Environmental/Ecological Flow Needs

As part of the Tier Three Assessment, detailed technical guidance on integrating ecosystem water needs was developed. Part of the assessment was to suggest potential targets which could be incorporated into the Orangeville Tier 3 Water Quantity Risk Assessment and to document a methodology for developing potential targets. In attempts to determine targets, Monora Creek was selected for a site specific ecological flow needs assessment (Bradford, 2009). This work was performed in conjunction with the Tier Three study. Stream geometry mapping was conducted along the creek. This site specific field work confirmed that groundwater discharge to the stream was consistent with the range predicted by the groundwater flow model, and under current conditions (which estimates between 5 and 38

L/s), hydraulic connections are maintained along the channel, which are required for ecological functions. A conclusion of the study was that it is possible for groundwater models to accurately predict groundwater discharge to the streams.

As per the Town of Orangeville's PTTW (discussed at detail in 5.4- A*pproaches)* Monora and Mill Creek have been extensively characterized including habitat condition, stream channel condition, as well as routine monitoring of flow conditions and fishery (SLR, 2012). These are the only two surface water locations in the WQSA where groundwater takings were known to limit baseflow (SLR, 2012). As a result, these are the only surface water locations with environmental flow needs established in the WQSA.

5.3.3 Conclusions

Groundwater

The groundwater resources as modelled (46-year simulation) may (depending on the modelling scenario) be put at a significant potential for water quantity stress due to development pressures from population growth and land use changes, along with climate change projections. The Tier 3 risk assessment determined that under future demand and modelled climate change scenarios, some municipal wells may not be sustainable based on available drawdown able to yield enough water to sustain growth, and significant impactful baseflow reductions in groundwater contributions to coldwater streams may occur from increased municipal pumping.

A summary of the Risk Assessment Drawdown Results from the Tier Three Water Budget and Local Area Risk Assessment (AquaResource Inc., 2011) are provided in Section 5.3.1. The modelled results from the Tier Three Water Budget and Local Area Risk Assessment (AquaResource Inc., 2011) indicate that the predicted drawdown under average climatic conditions, is less than the safe additional drawdown at all wells except Wells 5/5A and Cardinal Woods Well 3. This suggests that if municipal pumping were to increase to planned plus committed plus existing rates, or reductions in recharge were to take place, or both all municipal wells except Well 5/5A and Cardinal Woods Well 3 would be able to pump sustainably under average climatic conditions.

Similarly, under drought conditions the simulated cumulative impact of increased municipal pumping rates and reductions in recharge, or increased pumping, or only the reductions in recharge indicated that drawdown at Wells 5/5A, Well 6, Wells 9A/9B and Well 3 all exceed or approach the safe additional drawdown. Of note, the Wells 5/5A are able to meet their allocated rates when considering only the impacts of increased pumping. It is also noted that recharge reductions at Wells 9A/9B have a much greater impact on water levels in these wells than increased municipal pumping.

Surface Water

In terms of the sustainability of surface water resources in the WQSA, modelled reductions in baseflow to Monora Creek ranged from 20-37 %, while reductions to Mill Creek ranged from 73% -91%. In most cases, reductions in recharge areas accounted for the significant majority of baseflow reduction to surface water.

As described in Section 5.2, Monora Creek provides a significant portion of inflow to the Island Lake Reservoir. If the Monora Creek contribution to the reservoir decreased, this could possibly impact the ability for it to provide assimilation capacity to the Orangeville WPCP treated effluent discharge to the Credit River downstream. It should be noted that the Tier Three Assessment determined a level of uncertainty around modelled baseflow declines in the creeks:

The lack of continuous flow gauging stations on sensitive creeks such as Mill or Monora Creek, and the Island Lake Reservoir is a data gap in the Subwatershed. The lack of long term gauged flow data limits the ability to examine the long term trends in these surface water features.

As per Orangeville's PTTW Environmental Monitoring Plan (EMP) (SLR, 2012), flow in Monora and Mill Creek is now monitored. Results of the monitoring programs have been mixed, with minimal correlation observed between pumping and baseflow changes in Monora Creek. Results are discussed in detail in section 5.4 – Challenges.

Certain risk management measures were identified which include identifying additional supply, pump optimization and system integration between the supply systems. However, the question of whether the groundwater and surface water resources are sustainable into the future remains uncertain. The following data gaps will need to be addressed before a more definitive assessment about future sustainability of the resources in the WQSA can be made. The data gaps as noted in the Tier Three Water Budget and Local Area Risk Assessment (AquaResource Inc., 2011) can be summarized as follows:

- A lack of water level data from the production aquifer;
- A lack of knowledge about the current and expected reduction of recharge that exists due to leaky infrastructure and what may arise due to development of land as outlined on the Official Plans;
- A lack of long term flow data on sensitive creeks such as Mill or Monora Creek, and the Island Lake Reservoir;
- A lack of understanding of the hydraulic properties of the Caledon Lake Provincially Significant Wetland Complex; and
- Uncertainty associated with the depth, location, and sediment infill of the buried bedrock valleys beneath the Credit River and the valley that underlies the western reaches of Island Lake and trends towards the Nottawasaga River Valley.

Addressing these data gaps would enhance the calibration of the model, and thereby reduce the uncertainty associated with the model predictions on the matter of sustainability of the local water resources as described herein.

In summary, the sustainability of the water resources in the Quinte WQSA under current and future conditions is as follows:

<u>Groundwater Under Current Conditions</u>

- **Regional scale** – the groundwater resources are sustainable in the broader WQSA under current conditions.
- **Local scale** – the groundwater resources are sustainable under current conditions.

Groundwater Under Future Conditions

- **Regional scale** – the groundwater resources are unsustainable under future conditions, unless normal climate conditions exist into the future and the Towns of Orangeville, Mono, and Amaranth employ the most advanced mitigative and adaptive policies with respect to maintaining current recharge conditions. Modelled results indicated that the groundwater resources would be able to meet future pumping demands; however, this would result in a groundwater discharge decline between 10% and 20% under future demand under drought conditions.
- **Local scale** – Based on modelled results for future conditions, including population growth and a decrease in recharge areas, Wells 5 and 5A (Orangeville) and the Cardinal Woods # 3 Wells (Mono) would be unsustainable in the future, and if a prolonged (10-year) drought condition were to occur, then in addition to these wells, Well 6 and Well 9A/B would also be unsustainable.

Surface Water Under Current Conditions

- **Regional scale** - sustainability of surface water resources is uncertain based on the frequency of OLWR notifications and alerts which do not provide any clear indication of a decreasing trend in the availability of surface water in the WQSA, nor any indication of any specific climate change trends. However, a conclusion of the flow needs assessment (Bradford, 2009) was that it is possible for groundwater models to accurately predict groundwater discharge to the streams and therefore the current sustainability assessment reflects the conclusions of the Tier Three Assessment results. Nevertheless, it should be noted, numeric modelling and predictions of future climate scenarios have inherent uncertainties associated with them.

- Local scale – the sustainability of surface water resources is uncertain as notifications and alerts are on a watershed scale rather than subwatershed scale, and the relevance to specific subwatersheds within the WQSA cannot be readily determined from the available posted data. Monora Creek and Mill Creek are the only two surface water locations in the WQSA where groundwater takings reportedly limit baseflow (SLR, 2012). However, similar to the regional scale, it should be noted that the Tier Three Assessment determined a level of uncertainty around modelled baseflow declines in the creeks. Specifically, the Tier Three Assessment states that there is a data gap of continuous flow gauging stations on sensitive creeks, such as Mill Creek or Monora Creek, and the Island Lake Reservoir and that the lack of long term gauged flow data limits the ability to examine the long term trends in these surface water features. At the time of this current assessment, flow in Monora and Mill Creeks has been monitored. Results of the monitoring programs have been mixed, with minimal correlation observed between pumping and baseflow changes in Monora Creek.

Surface Water Under Future Conditions

- Regional scale – the surface water resources are unsustainable into the future based on modelling. It should be noted, numeric modelling and predictions of future climate scenarios have inherent uncertainties associated with them.
- Local scale – the surface water resources are unsustainable into the future based on modelling. It should be noted, numeric modelling and predictions of future climate scenarios have inherent uncertainties associated with them.

5.4 WATER MANAGEMENT APPROACHES, CHALLENGES

A combination of available reports (Table 5-1) and communication with Water Managers with knowledge of local water use/issues in the Orangeville area was used to summarize current approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in Section 5.6 of this report, what, if any, new management tools are needed in the Orangeville WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches. Water managers from Credit Valley Conservation, the Town of Orangeville, the Townships of Amaranth and East Garafraxa, and the MECP were contacted to provide input to this study. Responses were received from the Town of Orangeville.

Current Approaches

MECP's West Central regional office delivers the PTTW program in the Orangeville WQSA and responds to well water and drought complaints.

The Town of Orangeville management approach to water supply is largely based on the policies in the CTC (Credit Valley-Toronto Region-Central Lake Ontario) Source Protection Plan. Of note, is the requirement for new developments to maintain predevelopment groundwater recharge through the use of Low Impact Development options or other best management practices, particularly in the urban part of the WQSA. This is the only policy in the Source Protection Plan to be made into an actual requirement in the Town of Orangeville. The Town also promotes water conservation with a toilet rebate program for residents who replace old high volume flush toilets with new low or dual flush toilets.

Another policy implemented from the CTC Source Protection Plan requires a joint municipal approach to managing the groundwater resources across multiple administrative districts including town (or townships) Orangeville, Mono, Amaranth and East Garafraxa. Based on communication with water managers, approaches for a joint approach have been put forward by all towns and townships involved to council, however differences remain in how the decision making and funding process would be conducted. Obstacles to achieving a joint approach to water resource management are political and non-technical.

The Orangeville WQSA also utilizes provincial water quantity management mechanisms under the PTTW program and the OLWR program. These are discussed in detail in 5.2.6.1 Permitted Takings, and 5.3.1.2 – Ontario Low Water Response Program.

The Town of Orangeville is required to conduct environmental monitoring as per their Environmental Monitoring Plan (EMP) (SLR, 2012) in accordance with conditions contained in the consolidated PTTW. The EMP divides the water supply wells on the PTTW into groups which require varying types of environmental monitoring including, groundwater, surface water and fisheries monitoring (biomass surveys, stream reach characterizations). For well groups that are not expected to impact surface water features, only groundwater level, or no monitoring is required. For well groups that have been shown to or are interpreted to impact cold water creeks, groundwater levels, surface water flow and levels, and fisheries monitoring is required.

The Town of Orangeville is currently investigating if the Pullen well located in the Township of Amaranth could be added to their water supply system. The existing well does not have a sufficient diameter for the pump required, and a new test well has been drilled within 20 m to the same elevation within bedrock. Well testing to determine potential water yields is forth coming along with a Class EA for the well which will commence in 2019.

Challenges

Based on reports available at the time of writing and communication with Orangeville-based water managers, the water supply systems for Orangeville, and the Townships of Mono and Amaranth and East Garafraxa are not currently facing any shortage issues and the current takings are believed to be sustainable under existing conditions. However, as determined by the Tier Three Assessment modelling work, which assessed the ability of the municipal wells to meet demands considering future growth and the effects of a prolonged drought, the challenges for the Orangeville WQSA primarily lie with the ability to meet the demands of future growth and possible issues arising from projected climate change. One major challenge in addressing growth concerns has been identifying additional locations for water supply wells, which to date has had limited success, with the exception of potentially adding the Pullen well to the Town of Orangeville water supply system, as discussed in Approaches. An additional challenge is ensuring that the effects of municipal water takings on local surface water are understood and minimized. In addition, the lack of knowledge about the current and expected reduction of recharge that exists due to leaky infrastructure and what may arise due to development of land as outlined on the Official Plans is an ongoing challenge in the management of the water resources in the Orangeville WQSA. These challenges and others are discussed in more detail below.

Identifying additional water supply sources

As discussed in *Current Approaches*, the drilling of a test well at the Pullen well site may provide additional capacity to the Orangeville water supply if yield testing and a Class EA, which are to commence in 2019, are successful. However, historically Orangeville has struggled to identify a suitable location with adequate yield and of a water quality suitable for municipal supply. It is BluMetric's opinion that, while the addition of the Pullen well may provide some additional water supply capacity, adding future supply wells beyond the Pullen well faces the same historical challenges outlined below.

In 2001, Orangeville initiated the Long Term Servicing Strategy (LTSS), which was designed to identify a sustainable strategy to develop water resources to support the Town's future water supply and sewage treatment servicing. A key recommendation from the LTSS involved exploring locations for additional water supply wells. Two areas had previously been identified from historical water supply investigations, one located northeast of the Orangeville and one southwest.

Based on the investigations, it was determined that the areas northeast and southwest of Orangeville identified by the LTSS were not suitable for water supply purposes due to low yield, unacceptable impacts to surface water and/or poor water quality.

Determining efficacy of surface water monitoring programs

A major challenge faced by the Town of Orangeville regarding its water supply wells is determining what impacts its pumping activities are having on local surface water. The results of pumping tests from the 1990s indicate that pumping at the wells is resulting in baseflow reductions in Mill Creek and in Lower Monora Creek, and the Tier Three Assessment indicates the potential for planned water demands to affect groundwater discharge to cold water streams in these locations. In contrast, the preliminary monitoring results obtained by a consultant working with the Town of Orangeville suggest there is no clear correlation between changes in the natural ecosystem in Monora Creek and on-going water takings for municipal water supply. Due to the conflicting findings, it is uncertain whether municipal pumping is indeed resulting in impacts on surface water, and in turn whether the monitoring conditions on the Town's PTTW should to be retained or removed. The uncertainty regarding impacts to surface water, if unresolved, is a challenge with respect to any future plans to install additional water supply wells.

A report prepared by the consultant, including the data supporting their conclusions, is forthcoming and is expected to be provided to the Town of Orangeville in 2019.

Regional Water Supply Strategy

The Tier Three Assessment determined that the Orangeville water quantity vulnerable area (WHPA-Q1 (A)), is classified as having a Significant Water Quantity Risk Level. The area extends across the municipal boundaries of the Town of Orangeville and the Townships of Mono, Amaranth and East Garafraxa. To address the risk, the source protection plan policies directed local water managers to manage groundwater as a shared resource. However, the approach has been implemented with limited success. Getting municipalities to accept a shared-resource management approach to groundwater resources has been one of the greatest management challenges in this area. As discussed above in *Current Approaches*, a joint approach option has been put forward to all towns and townships councils; however differences remain in how the decision making and funding process would be managed. Obstacles to achieving a joint approach to water resource management are political and non-technical.

Future Changes to the Official Plan

As discussed in detail in 5.3.1, based on the results of groundwater modelling, land use change as per the Official Plan may significantly impact recharge rates, ultimately impacting groundwater levels and possibly contributing to baseflow reduction. Potentially exacerbating the issue is the uncertainty about the availability of a suitable water supply to support the planned growth for the town. This modelling is based on the Official Plan as of 2011. If the Official Plan undergoes changes or expansion in the future, and includes more or less development, groundwater modelling may have to be calibrated to account for the changes.

Evaluation of how water management concerns are considered in water management decisions

One of the key water management concerns for the Orangeville WQSA is the potential increase in demand for groundwater and associated drawdown in pumping wells due to the population and economic growth that is projected for the area. A series of Risk Management Measures (RMM) (e.g. pump optimization, integrated municipal water supply systems) were applied to the Tier Three Assessment Water Budget groundwater model, and the results indicated that the measures may be effective in meeting pumping demands and reducing drawdown stress. Whether the RMM are or will be incorporated into water management decisions could not be confirmed as part of the present study. However, the Town of Orangeville's current approach for managing water supply does, to a certain extent; attempt to reduce the overall demand on groundwater supplies by requiring the use of Low Impact Development options or other best management practices for new developments, and promoting water conservation measures for residents.

Under modelled growth and climate change scenarios, the Monora Creek System may potentially experience decreased groundwater discharge, which could limit its contribution to the Island Lake Reservoir in the future, and in turn may affect the ability for the reservoir's ability to provide assimilation capacity to the downstream Water Pollution Control Plant on the Credit River. How or whether water management decisions currently take this concern into consideration in unknown.

Consideration of key topics in water management decisions

The following points describe if and how key topics are considered in water management decisions in the Orangeville WQSA.

- Climate change: efforts have been made to predict the potential effects of climate change on groundwater and surface water resources through the use of climate change modelling scenarios (see Section 5.3.2.1). Based on the information reviewed as part of this study, there do not appear to be formal policies in place for considering the effects of climate change in water management decisions;
- Adaptive/alternative management: no policies and approaches were identified in the Orangeville WQSA that explicitly address the use of adaptive or alternative management. However, the province's PTTW program allows for the use of adaptive/alternative management, as one of the principles of the program is that the MECP "will employ adaptive management to better respond to evolving environmental conditions" (Permit to Take Water Manual, 2005). For example, the Ministry has the authority to limit, alter or stop a water taking that is considered to cause an unacceptable impact, even after a permit has been issued;
- Municipal growth: in the Orangeville WQSA, municipal growth and the associated pressures on groundwater supplies are taken into consideration in water management decisions, as shown by the requirement for new developments to implement Low Impact Development options or other best management practices. In order to plan for future water needs, the City of Orangeville is also investigating the possibility of adding capacity to their existing water supply system (e.g. through the use of the Pullen Well in the Township of Amaranth and East Garafraxa; see *Current Approaches* under Section 5.4);

- Drought: no policies and approaches were identified in the Orangeville WQSA that explicitly address drought. However, this topic has been explored as part of the Tier Three Assessment modelling work (summarized in Section 5.3.1), indicating that drought is recognized as a potential concern in the WQSA;
- Natural function/EFN: the importance of EFN and aquatic habitat in Monora Creek and Mill Creek has been recognized, through extensive characterization and/or site-specific ecological flow needs assessments, as well as the requirement for routine monitoring of these creeks as per the Town of Orangeville's PTTW (summarized in Section 5.3.2.1). EFNs have only been established for these two water bodies in the WQSA, due to groundwater takings being known to limit baseflow. There is a general lack of information on EFN for other surface water bodies in the WQSA.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

As noted under "Regional Water Supply Strategy", one of the greatest water management challenges in the Orangeville WQSA is getting municipalities to adopt a shared-resource management approach due to political obstacles. Approaches for resolving this challenge have not been identified by water managers. Continued efforts to find a shared approach to water resource management should be encouraged. For example, a working group made up of key informants and stakeholders could be established to help develop a framework to manage an inter-jurisdictional water management plan.

5.5 IDENTIFIED DATA GAPS

Regional Hydrostratigraphic Data

The LTSS identified two areas for water supply exploration that were thought to be the most probable to contain productive aquifers based on the available data (geologic logs and follow up gravity geophysical survey). However, as discussed above, the water bearing units in these locations were not suitable for municipal supply. It has been suggested by local water managers that performing downhole geophysical well log surveys in existing production and monitoring wells within the WQSA would improve geological characterization and possibly assist with the search for additional water supply sources. Such detailed site specific data may help determine if known hydrostratigraphic units in specific areas may be appropriate for municipal water supply pumping.

A geophysical well log survey may help better refine hydrostratigraphic unit properties and thicknesses, which could include identifying productive aquifers. For example, resistivity logs can help identify coarse grain horizons in overburden, and sonic logs along with resistivity logs can help in identifying fractures zones or areas with reef mounding in bedrock. These structural details can vary within units laterally and vertically, and such variation is typically not well defined in regional scale models.

Well construction techniques must be accurately known so that any geophysical signature originating from well construction can be removed from the interpretation of true overburden and bedrock signatures. Insight into the hydrostatigraphy gained from geophysical well logs could also be used in the groundwater modelling layers by ensuring the physical properties reflected in the logs were reflected in the modelled hydrostratigraphic units.

5.6 RECOMMENDATIONS

Based on the available reports and communication with Water Managers knowledgeable of local water use/issues in the Orangeville WQSA, the following recommendations are provided as possible mitigative measures to address the identified challenges (Section 5.4) and gaps (Section 5.5) related to water quantity management, and help in avoiding potential future water quantity issues.

The province should consider the following recommendations:

1. As noted in Section 5.4, under *Challenges* (Future Changes to the Official Plan), there is uncertainty about the availability of a suitable water supply to support the planned growth for the Town of Orangeville. It was similarly noted (under *Challenges*, Identifying additional water supply sources) that the town has historically struggled to identify a suitable location for additional water supply, with adequate yield of water of a quality suitable for municipal supply. The province should ensure that the municipalities in the Orangeville WQSA identify in their servicing master plans and Official Plans prospective water supply sources capable of supporting any planned growth;

2. As noted in Section 5.4, under *Challenges* (Determining efficacy of surface water monitoring programs), there are conflicting findings from separate technical studies about whether pumping at the Town of Orangeville's water supply wells is impacting local surface water. The additional study being completed by the town's consultant, expected in 2019, should be reviewed by the province to determine whether the discrepancy has been resolved, or whether additional study is required;
3. As noted in Section 5.4, under *Challenges* (Regional water supply strategy), the local source protection plan policies direct local water managers to manage groundwater as a shared resource, but achieving consensus among the Town of Orangeville and the Townships of Mono, Amaranth and East Garafraxa on a joint approach has been challenging. The province should investigate what is needed to develop an effective shared integrated water resource management strategy that would be accepted by all parties. The potential need for provincial facilitation should be recognized.

5.7 REFERENCES

AquaResource, 2009. Integrated Water Budget Report: Tier 2 Credit Valley Source Protection Area. April 2009.

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GRCA, 2008. Grand River Watershed Characterization Report. January 2008.

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Matrix Solutions Inc, 2014. Orangeville, Mono and Amaranth Water Quantity Risk Management and Climate Change Adaptation Assessment Pilot Study. August 2014.

NVCA, 2014. Groundwater-Surface Water Drought Declaration Period Correlation Study. March 2014.

SLR, 2012. Environmental Monitoring Plan for the Consolidated Permit to Take Water for the Town of Orangeville. October 2012.

6 NORFOLK SANDPLAIN

The preliminary boundary of the Norfolk Sand Plain Water Quantity Study Area (WQSA), as provided by the MECP, is shown on Figure 6-1. The preliminary WQSA overlaps multiple counties and encompasses a number of population centres along the northern shore of Lake Erie. The WQSA partially or fully encompasses multiple watersheds and Conservation Authorities, including Kettle Creek, Catfish Creek, Long Point, Upper Thames River and Grand River.

In the Norfolk Sand Plain WQSA both groundwater and surface water resources are utilized for domestic, agricultural, and industrial uses. The specific drivers for this WQSA being selected for an assessment is the significant level of reliance on local surface water and groundwater resources by agricultural permit holders, reported cumulative impacts and the area's vulnerability to drought which may be exacerbated in the future as a result of climate change impacts. The objectives of this section are: to provide a characterization of the Norfolk Sand Plain WQSA in the context of the significant surface water and groundwater resources, to refine the WQSA boundary based on the physical characterization, to summarize and evaluate the demands on water resources in the WQSA, and to determine the possible impact of projected changes in population, land use, and climate on the quantity of the local resources and the future security and sustainability of the water resources in the WQSA based on these changes.

6.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives for the WQSA and the preliminary WQSA boundary provided by the MECP. The Lake Erie Source Protection Region, including the Long Point, Catfish Creek, Kettle Creek, and a portion of the Grand River Watersheds make up the majority of the preliminary WQSA and were therefore made the focus of the literature review conducted. Together the Long Point, Catfish Creek, Kettle Creek, and Grand River Watersheds intersect the counties of Norfolk, Oxford, Elgin, Middlesex, Haldimand (outside the preliminary WQSA) and Brant with Norfolk County making up the majority of the WQSA. Based on the review and input provided by water managers within the WQSA the reports listed in Table 6-1, as well as available databases (e.g. WWIS, PTTW, WTRS) as provided by MECP, were used as the primary basis for the WQSA characterization and assessment presented in the following sections. Each resource was categorized in terms of the key information presented within.

Table 6-1: Key Reports and Information Sources for Norfolk Sand Plain WQSA

Resource Reference	Type	Categories
Lake Erie Source Protection Region (LESPR), 2015 (as updated). Approved Assessment Report, Long Point Region Source Protection Area	Report	PC, FC, CC
LESPR, 2014. Approved Assessment Report, Catfish Creek Source Protection Area.	Report	PC
AquaResource, 2009. Integrated Water Budget Long Point, Kettle Creek & Catfish Creek	Report	PC, GWQ, SWQ, CU,
Matrix Solutions Inc. (Matrix), 2013. Tier Three Water Budget and Local Area Risk Assessment, Long Point Region.	Report	PC, GWQ, SWQ, CU, FC
Matrix Solutions Inc. (Matrix), 2016, Community of Simcoe, Ontario Water Quantity Risk Management Measures Evaluation Process.	Report	PC, GWQ, CU
Marich, 2014. An Assessment of Subsurface Sediments in the Central Norfolk Sand Plain, Norfolk and Oxford Counties, Southern Ontario; Ontario Geological Survey Groundwater Resources Study 14	Report	PC, GWQ
Waterloo Hydrogeologic, Inc., 2003. Norfolk Municipal Groundwater Study	Report	PC, GWQ
Schroeter & Associates: Kent Creek Water Balance (2006) and Long Point Region Watershed Hydrologic Model (2008)	Report	SWQ
AMEC, 2008. Norfolk Agricultural Water Assessment and Management Strategy	Report	PC, GWQ, SWQ, CU

Categories:

PC – Physical Characterization
GWQ – Groundwater Quantity
SWQ – Surface Water Quantity
CU – Current Water Users
FC – Future Conditions
CC – Climate Change

6.2 WATER RESOURCES SETTING /CHARACTERIZATION

6.2.1 Land Cover and Use Setting

Land cover in the Norfolk Sand Plain WQSA (Figure 6-2) is predominantly (approximately 78%) agricultural and undifferentiated rural lands with pockets of mixed treed areas and a few small urban commercial, industrial and residential centres surrounded by less-populated rural land used for intensive agricultural production.

Under the Canada Land Inventory (CLI), agricultural lands in the WQSA are primarily Class 4 (Severe Limitation - Agriculture) and Class 5 (Forage crops improvement practices feasible) with the exception of lands along the shore of Lake Erie which are Class 2 (Moderate limitations, moderate conservation practices required) and isolated small pockets of Class 1 (No significant limitations) located throughout the WQSA (CLI, 2018). Soils in Class 4 "have severe limitations that restrict the choice of crops, or require special conservation practices and very careful management, or both". Class 5 soils also have severe limitations. Crops grown in the WQSA include soybeans, tobacco, fruits and nuts, and wheat (OMAFRA, 2011). The Norfolk Sand Plain has substantial amounts of root crops, vegetables, some fruits and nursery crops. These high value crops require very careful management; soil nutrient levels must be maintained within a narrow range to achieve optimal quality as well as yield. Vegetables and crops such as tobacco and potatoes generally have smaller field sizes but higher water requirements than other row crops. The concentration in the sand plain also poses risks to reduced water availability for crops due to fast infiltration rates. Supplemental water from irrigation is required during dry weather (Long Point Region Watershed Characterization Report, 2008).

As reported in LPRCA (2008), approximately 35% of farms reported using irrigation, accounting for 15.35% of the cropped land area; however, in one basin more than half of the farms irrigate, accounting for as much as 27% of the cropped land area.

6.2.2 Population

Populations in urban centres with municipal water supplies located in watersheds which fall within or make up part of the WQSA are summarized using the most recently available population information in the table below:

Table 6-2: Summary of Population Statistics and Water Supply Source in Norfolk Sand Plain WQSA

Watershed /S.P.A	County	Municipality / Community	Municipal Water Source	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percentage Change (%)
Long Point	Oxford	Tillsonburg	Groundwater	14,933	15,872	4.4
Long Point	Oxford	Norwich Township (Oxford South)		10,721	11,001	2.6
Long Point	Oxford	Springford	Groundwater		Inc. in Norwich Township	
Long Point	Oxford	Otterville	Groundwater		Inc. in Norwich Township	
Long Point	Oxford	Norwich	Groundwater		Inc. in Norwich Township	
Long Point	Oxford	Dereham Centre	Groundwater		ND	
Long Point	Norfolk	Simcoe	Groundwater	13,383	13,922	4.0
Long Point	Norfolk	Waterford	Groundwater	3,027	3,132	3.5
Long Point	Norfolk	Delhi/ Gilbertville	Surface Water and Groundwater	4,172	4,240	1.6
Long Point	Norfolk	Port Dover/Woodhouse Acres	Surface Water (L. Erie)	5,710	6,161	7.9
Long Point	Norfolk	Port Rowan	Surface Water (L. Erie)	1,069	1,102	3.1
Long Point	Haldimand	Hagersville, Jarvis, Townsend, New Credit Reserve	Nanticoke Water system – Surface Water (L. Erie)	2,579, 913, ND, 655	>5,897 (2939, 1037, ND,ND)	14.0, 6.5, ND, ND
Long Point	Elgin	Village of Richmond (Municipality of Bayham)	Groundwater	ND	ND	ND
Catfish Creek	Oxford	Brownsville	Groundwater	ND	ND	ND
Kettle Creek	Elgin	Belmont (operated by Municipality of Central Elgin)	Groundwater	1,026	1,140	11.1
Upper Thames River	Middlesex	Municipality of Thames Centre	Groundwater	13,000	13,191	1.5

The total population of Norfolk County, which falls almost entirely within the WQSA, was 64,044 in 2016 according to data available through statistics Canada. Approximately half of the population of Norfolk County (32,200) relies on municipal water supplies (LESPR, 2015). The adjacent counties of Haldimand, Oxford, Elgin, Middlesex and Brant had populations of 44,876, 110,862, 50,069, 71,551 and 36,707 respectively in 2016. A small percentage of the population in all four counties is in sparsely populated rural areas which are not serviced by municipal water supplies.

Based on the Ontario Population Projection Update, 2016-2041 by the Ministry of Finance, the population in the census divisions that incorporate the WQSA are expected to grow between 0 and 15% between 2016 and 2041. This growth is expected to be primarily focused in the urban centres which are currently reliable on groundwater resources. The population of Southwestern Ontario as a whole is projected to grow from 1.62 million in 2016 to 1.84 million in 2041, an increase of 13.25%. However, growth rates vary within Southwestern Ontario with some counties southwest of the WQSA expecting their population to decline in this same time period.

6.2.3 Physiographic Setting

The Norfolk Sand Plain WQSA is located in southwestern Ontario along the northern shore of Lake Erie between Port Dover in the east and Port Stanley in the west. The preliminary WQSA boundary provided by the MECP extends north to a point approximately 10 km east of London Ontario and to a point along the southwest side of the Six Nations Indian Reserve No. 40 (Oshweken). The two major watersheds which comprise the Norfolk Sand Plain WQSA are the Long Point Region watershed and the Catfish Creek watershed. Combined these two watersheds cover an area of approximately 3,390 km^2 with 2,900 km^2 attributed to the Long Point Region Watershed and 490 km^2 attributed to the Catfish Creek Watershed. The WQSA also partially intersects the adjacent Kettle Creek and Grand River watersheds.

6.2.3.1 Physiography

The WQSA is located within the West St. Lawrence Lowlands subregion of the larger St. Lawrence lowlands physiographic region. The West St. Lawrence Lowlands lies between the Canadian Shield and Lakes Huron, Erie and Ontario. The West St Lawrence Lowland consists of limestone that is separated by broad shale lowland from a broader dolomite and limestone plateau west of Lake Ontario. This plateau is bounded by the Niagara Escarpment. From the escarpment the plateau slopes gently southwest to lakes Huron and Erie. Glaciation has mantled this subregion with several layers of glacial till (i.e., an unsorted mixture of clay, sand, etc.), the youngest forming extensive, undulating till plains, often enclosing rolling drumlin fields (Figure 6-3). Prominent moraines on the western plateau and north of Lake Ontario mark temporary pauses in the retreat of glaciers, between 14,500 and 12,500 years ago. Level clay and sand plains, which were deposited in glacial lakes, fringe the present lakes. Major physiographic features in the preliminary WQSA include the Norfolk Sand Plain, the Horseshoe Moraines, Mount Elgin Ridges, The Ekfrind Clay Plain, and the Haldimand Clay Plain. Physiography has a direct effect on groundwater and surface water hydrology. Clay-rich soils like those in the Haldimand Clay Plain and Ekfrind Clay Plain have a low infiltration capacity, and as a result, these areas tend to have more tributaries than in areas where coarser grained sediments dominate like in the Norfolk Sand Plain. Rather than flowing overland, precipitation falling on areas dominated by coarse-grained surficial sediments is more likely to infiltrate and recharge the local groundwater system (LESPR 2015).

Norfolk Sand Plain

The Norfolk Sand Plain is bordered by the Mount Elgin Ridges to the northwest, the Horseshoe Moraines to the northeast, the Haldimand Clay Plain to the east and the Ekfrind Clay Plain to the west (Chapman and Putnam, 1984; Matrix, 2013). The Norfolk Sand Plain is characterised as a low-relief, silty sand and gravel sand plain. The Norfolk Sand Plain covers most of the western and central portions of the Long Point watershed, the southern portions of Catfish Creek watershed, the southern third of the Kettle Creek Watershed and a small area along the west side of the Grand River watershed within the counties of Brant and Oxford but not including the entire City of Brantford. The Sand Plain is wedge shaped with a broad curved base along the shore of Lake Erie tapering northward toward a point at Brantford on the Grand River (LESPR, 2014 and 2015). The wedge shaped sand plain is bounded to the north by Brantford, Norwich, Otterville, Tillsonburg, Brownsville, Springfield, Aylmer and Sparta.

Horseshoe Moraines/Mount Elgin Ridges

The Horseshoe Moraines physiographic region includes the Paris and Galt Moraines that are located in the central portion of the Long Point Region and portions of the Grand River Watershed in the Counties of Brant and Oxford. The Horseshoe Moraines provide low to moderate relief above the surrounding sand plain. The Paris and Galt Moraines, oriented in a north-south direction, are scarcely visible in the Long Point Region as they have been either eroded or buried by overlying glaciolacustrine or glaciofluvial sediments (Barnett, 1982).

The Mount Elgin Ridges are situated in the northwestern portion of the Long Point Region. They include several end moraines that provide low to moderate relief above the surrounding sand plain and in some areas exhibit slightly hummocky topography. Several of these moraines were deposited at the front of the Lake Erie ice sublobe during the Wisconsin glaciation (Chapman and Putnam, 1984). These moraines, which run east-west roughly paralleling the current Lake Erie shoreline, include (from north to south) the St. Thomas, Norwich, Tillsonburg, Courtland, and Mabee Moraines.

All the end moraines within the region are kilometres in length. In general, the surface relief of the moraines decreases southward toward Lake Erie. The moraines located nearest to Lake Erie (including the north-trending Paris and Galt moraines) are smaller because they have been more subjected to erosion and burial by the encroachment of glacial Lake Erie (Barnett 1982; Chapman and Putnam 1984). The St. Thomas Moraine (the oldest of the moraines in the area) shows the greatest relief (Chapman and Putnam 1984). It is located in the northwest corner of the watershed, and extends beneath the towns of Mount Vernon and Mount Elgin (Barnett, 1982).

Ekfrind Clay Plain

The Ekfrid Clay Plain comprises a fairly large area in the Lake Erie region and approximately 110 square kilometres in the central portion of the Kettle Creek watershed. It is the dominant feature in the west-central portion of the Catfish Creek watershed. The flat lying area is characterized by clay and silt deposits providing little relief and poor drainage.

Haldimand Clay Plain

The area east of the communities of Waterford and Simcoe, located in the lower portion of the Grand River Watershed, is characterized by a low-relief lacustrine clay plain (Chapman and Putnam, 1984) referred to as the Haldimand Clay Plain. The Clay Plain consists of fine-grained silts and clays deposited at the bottom of a deep glacial lake basin during the Port Huron Stade, about 13,000 years ago. It is characterized by heavy clay soils which are relatively impermeable, resulting in a high level of runoff and little groundwater recharge. Much of the land is poorly drained and is used predominantly as livestock pastures and for soybean, corn and hay production.

Of note, the physiography of this region results in specific water resource challenges. Specifically, groundwater is generally obtained from the bedrock of the Dundee Formation and the Detroit River Group because sufficient quantities of water cannot be obtained from the overburden. In addition, groundwater drawn from the bedrock aquifers in this area is often poor in quality as a result of naturally elevated concentrations of sulphur, salts and minerals in the water.

6.2.3.2 Topography

The preliminary Norfolk Sand Plain WQSA has flat to undulating topography which slopes upward to the northwest from the north shore of Lake Erie (Figure 6-4). The present day ground surface topography in the WQSA evolved from erosional and depositional processes that occurred during glacial and post-glacial times. Valleys created by tributaries and rises characteristic of glacial drumlin features are the dominant topographic features throughout the WQSA.

Elevation of the Long Point Region watershed ranges from 357 m above sea level (masl) in the northwest on the St. Thomas Moraine, to 169 masl in the southeastern limits along the Lake Erie shoreline. The ground surface topography of the Catfish Creek watershed varies from 275 masl in the north to approximately 180 masl along the Lake Erie shoreline. The Kettle Creek watershed is characterized by deeply incised valley systems and a steep descent of watercourses from headwater areas to Kettle Creek's outlet at Port Stanley. Topography of the Grand River Watershed in the County of Brant is relatively flat with the most significant topographic feature being the valley cut by the Grand River running northwest to southeast through the County (LESPR, 2014 and 2015). Generally, bedrock topography slopes from the north towards the south across the WQSA.

6.2.3.3 Climate

The majority of the WQSA has low latitude and elevation compared to other parts of southern Ontario, has a moderate temperate climate with moderate, even distribution of precipitation throughout the year and temperatures ranging from warm to hot and humid in summers to below freezing in winter. Winters are mild compared to the rest of Ontario. With Lake Erie to the south, winds coming across the lake are warmer in winter and cooler in summer than the land, thereby moderating air temperatures over the WQSA. Due to reliance on shallow groundwater resources it is worth noting that temporal effect of prevailing winds on near-shore shallow groundwater levels have been reported (i.e. the seiche). Winter is generally considered to have temperatures lower than 0°C, beginning in December and lasting until late February or early March. Spring usually lasts two months, followed by four months (June to September) of summer and two months of autumn. The average annual temperature is about 7.5 to 8.5°C. Annual average precipitation over the watershed is generally between 950 to 1,075 mm. There is no rainy season in this region; however in summer many of the rainfall events are intense with short durations. The short duration of events, coupled with the high evapotranspiration rates between events, leaves an impression of less rain than in other seasons in terms of frequency of rain-created runoff and recharge. In winter, most of the precipitation is rain. Even in January, the coldest month, more than half the precipitation is rain. The total snowfall across the WQSA is between 100 and 150 cm between November and April. Figure 6-5 displays the meteorological stations in the WQSA.

Provincial estimates of mean annual evapotranspiration have been documented within the Water Quantity Resources of Ontario (MNR, 1984), by subtracting mean annual streamflow from mean annual precipitation. Over the long term, the difference between annual streamflow and precipitation equals annual evapotranspiration (assuming negligible net groundwater outflow/inflow from the watershed). For the WQSA, evapotranspiration is shown to be approximately 550-600 mm per year. It is important to consider that in southern Ontario, evapotranspiration totals for a particular year are dependent on the amount of water that is available to be evaporated. Areas with an unlimited supply of water will evaporate at the potential evapotranspiration rate. Areas that have a limited supply of water, and rely on precipitation events to replenish the soil water supply will evaporate water at an actual evapotranspiration rate that is less than the potential rate for that type of surface when fully wetted. The difference can be very significant in years of drought, where very little soil water is replenished due to the reduced precipitation. This can result in observations that seem counter-intuitive to some, where in a drought, actual evapotranspiration can be drastically reduced (AquaResource, 2009).

6.2.3.4 Surface Water Hydrology

The Norfolk Sand Plain WQSA overlaps with the jurisdictions of five Conservation Authorities (see also Figure 6-1): most of the WQSA is within the jurisdiction of the Long Point Region Conservation Authority, with the west-central portion of the WQSA being within the jurisdictions of the Catfish Creek CA and Kettle Creek CA. The northwestern portion of the WQSA overlaps with the jurisdiction of the Upper Thames River CA, and a relatively small area (roughly 40 km^2) in the northeastern corner of the WQSA overlaps with the jurisdiction of the Grand River CA. General information about the watersheds within the WQSA is provided below and summarized in Table 6-3.

Table 6-3: Summary of Subwatersheds in Norfolk Sand Plain WQSA

Main Watershed (Conservation Authority)	Subwatershed	Drainage Area (km^2) [A]	Surface Water (SW) Municipal Systems/Sources in WQSA
Big Otter Creek (Long Point Region CA)	Otter Above Maple Dell Road	99	None
	Otter at Otterville	75	None
	Otter at Tillsonburg	153	None
	Spittler Creek	116	None
	Lower Otter	168	None
	Little Otter	118	None
Lake Erie tributaries (west of Big Creek) (Long Point Region CA)	South Otter	120	None
	Clear Creek	87	None
Big Creek (Long Point Region CA)	Big Above Cement Road	89	None
	Big Above Kelvin Gauge	64	None
	Big Above Delhi	154	None
	North Creek	58	Delhi (combination SW/GW)
	Big Above Minnow Creek	72	None
	Big Above Walsingham Gauge	123	None
	Venison Creek	98	None
	Lower Big	96	None
Lake Erie tributaries (east of Big Creek) (Long Point Region CA)	Dedrick Creek	138	None
	Young/Hay Creek	120	None
Lynne River (Long Point Region CA)	Lynne River	172	None
	Black Creek	134	None
Nanticoke Creek (Long Point Region CA)	Upper Nanticoke	114	None
	Lower Nanticoke	85	None
Catfish Creek (Catfish Creek CA)	West Catfish	147	None
	Catfish Above Aylmer	143	None
	Lower Catfish Creek	103	None
	Silver Creek	95	None

Main Watershed (Conservation Authority)	Subwatershed	Drainage Area (km^2) [A]	Surface Water Municipal Systems/Sources
Kettle Creek (Kettle Creek CA)	Upper Kettle	199	None
	Lower Kettle	148	None
Grand River (Grand River CA)	McKenzie Boston	368	City of Brantford (outside the WQSA)
Upper Thames (Upper Thames River CA)	Cedar Creek	95.1	None
	Reynolds Creek/Thames River above Ingersoll	348.5	None
	Middle Thames River	327.7	None
	Waubuno Creek/Thames River Tributaries	307.5	None
	Thames River between the Forks and Dutton	763.7	None

[A] The entire drainage area of the subwatershed is reported here, not only the portion of the subwatershed located within the boundaries of the WQSA.

Source: AquaResource (2009), LERSPC (2017), TSRSPC (2015)

Long Point Region Watershed

The Long Point Region watershed is defined as the area, approximately 2,782 km^2 in size, centered over Norfolk County that is drained by more than 30 creeks and tributaries (LPRCA, 2018). The watershed is divided into six main subwatersheds (from west to east): Big Otter Creek, South Otter/Clear Creek, Big Creek, Dedrich/Young/Hay Creek, Lynn River/Black Creek and Nanticoke/Sandusk/Stoney Creek (LPRCA, 2018).

Table 6-3 presents the prominent streams in the region including Big Creek, Big Otter Creek, Lynn River, Nanticoke Creek, and Sandusk Creek, the drainage area and the associated municipal systems. Figure 6-4 illustrates the WQSA surface hydrology. The combined length of all the streams and their tributaries within the Long Point Region is over 3,700 kilometres. Most of the western watersheds are found largely within the Norfolk Sand Plain; an area characterized by low runoff, high soil infiltration and sustained baseflows. The upper and western parts of Big Otter Creek are located in the till plain. The eastern watersheds drain through the Haldimand Clay Plain, an area characterized by high runoff and low soil infiltration. The eastern watersheds have a higher density of tributaries than the western watersheds with the river systems being shallower with a tendency to dry up during the summer months (LESPR, 2015).

The only municipal drinking water supply using inland surface water (i.e. not from Lake Erie) in the Long Point Region watershed is associated with the Town of Delhi, which provides water to approximately 6,000 people within the Town of Delhi and the Village of Courtland (LESPR, 2015). The system, operated by Norfolk County, consists of two groundwater wells and one surface water intake drawing water from the Lehman Reservoir on North Creek. The reservoir is formed by an earthfill dam built in 1965; maintenance and operation of the dam itself is the responsibility of LPRCA. Water is provided to the municipal intake through a valve-controlled opening; the surface water is blended with water from the municipal groundwater wells and delivered to the population as a single system (AECOM, 2010, as cited by Matrix Solutions Inc., 2015). The Delhi municipal water system also provides potable water to the community of Courtland, located approximately 10 km west of Delhi. Based on current and historical surface water and groundwater pumping and monitoring data, it was found that the Delhi water supply water system has not experienced water quantity limitations (Matrix Solutions Inc., 2015). The PTTW for the municipal surface water taking (No. 6423-89RPHE) allows a maximum daily withdrawal of 6,815 m^3/day, however, reliance on the reservoir as a water supply has significantly declined since the mid-1990s, and is predominantly used in a back-up capacity (Matrix Solutions Inc., 2015). In 2016 and 2017, an average of 139 m^3/day and 144 m^3/day, respectively, was pumped from the reservoir.

Catfish Creek Watershed

Catfish Creek and its Lake Erie tributaries drain approximately 490 km^2. The watershed is divided into four subwatersheds: West Catfish, Catfish above Aylmer, Lower Catfish Creek and Silver Creek. The surficial materials of the watershed dominate the surface hydrology. Upper and western portions of the watershed are largely comprised of low relief tight soils with high surface runoff and little soil infiltration. The lower and eastern portions of the watershed contain areas of Norfolk Sand Plain with little runoff and high groundwater recharge. The Catfish Creek watershed is predominantly influenced by two hydrologic processes: surface runoff and shallow groundwater-surface water interactions. In the north-western portion of the watershed, the surficial geology is predominantly Port Stanley Till, a fine-grained clay till with a low permeability. The surficial geology inhibits water flow through the upper overburden layers and creates an effective barrier between the surface water and groundwater systems. Subsequently, the surface water hydrology of this area is almost entirely driven by runoff. Lower in the watershed, groundwater has a larger influence in the surface water flow regime. The southeastern portion of the watershed contains deposits of coarse-grained sands and gravels, part of the Norfolk Sand Plain. This highly permeable surficial geology allows water to flow through it fairly easily. Watercourses in this area have higher and more stable baseflows as a result of groundwater discharge (LESPR, 2014).

Kettle Creek Watershed

Kettle Creek is predominantly a surface water driven system with a clay-rich till plain covering the majority of the watershed. The watershed is divided into three subwatersheds: Dodd Creek, Upper Kettle and Lower Kettle. The WQSA overlaps with the upstream (northeastern) portion of the Upper Kettle subwatershed, and the southeastern portion of the Lower Kettle subwatershed, the latter consisting of smaller tributaries draining directly into Lake Erie.

The low permeability of the till cover tends to inhibit infiltration and produce large quantities of runoff during rain events. Flows in the creek, which pass quickly through the watershed due in part to the steep elevation drop between the headwaters in the north and the outlet to Lake Erie and the nature of the till cover, tends to result in low baseflows and flashy flood events. Groundwater has little influence on the surface water system except in the headwaters where Kettle Creek is fed by a groundwater maintained kettle lake and in the southeast corner where a shallow groundwater system contributes to a cool water fishery in Beaver Creek (LESPR, 2014).

Upper Thames River Watershed

The Upper Thames River watershed spans approximately 3,423 km^2, and includes all areas draining into the Thames River above the community of Delaware. The watershed is divided into 11 subwatersheds, of which four overlap with the WQSA; none are located entirely within the WQSA. The key waterbodies crossing through the WQSA include Reynolds Creek, near the southeastern boundary of the Upper Thames River watershed, and the middle and south branches of the Thames River proper, which flows in a general southwestern direction through the northwestern corner of the WQSA.

The Upper Thames River is characterized by rocky riverbeds and steep valley slopes, and about 40% and 60% of its flow originates from surface runoff and baseflow, respectively. In addition to groundwater inputs, the baseflow includes contributions from tile drains, flow augmentation from reservoirs, and treated sewage effluent discharge (TSRSPC, 2015).

Grand River Watershed

The Grand River watershed has 8 subwatersheds, of which only one (McKenzie Boston subwatershed) intersects the Norfolk Sand Plain WQSA. The major surface water features in this subwatershed are the Grand River, McKenzie Creek, and Boston Creek. McKenzie Creek drains 171 km^2, including portions of the Six Nations Territory and Haldimand County; only a relatively small portion (roughly 40 km^2) of the subwatershed's headwaters are located within the WQSA. The watershed is largely comprised of Haldimand Clay, with the upper portion draining an area of the Norfolk Sand Plain.

6.2.4 Aquatic Habitat and Species

The aquatic thermal regime for the streams and rivers in the WQSA are illustrated on Figure 6-6, and summarized below. Species at Risk (SAR) confirmed or potentially present in the WQSA are also discussed. Unless stated otherwise, information on aquatic habitat and species, including SAR, are sourced from the Assessment Reports of the Long Point Region SPA (LESPR, 2015), Catfish Creek SPA (LESPR, 2014), Kettle Creek SPA (LESPR, 2014), and Upper Thames River SPA (TSRSPC, 2015).

<u>Long Point Region Watershed</u>
Most of the water bodies in the Long Point Region watershed are characterized as cold water habitat, though the subwatersheds draining the clay plain in the eastern portion of the watershed tend to have warm water habitats. There is, however, a warming trend in summer stream temperatures across several subwatersheds, limiting the ability of the creeks to support cold and coolwater fish species. The warming trend can be attributed in part to impacts on the watershed by human activity, through actions such as deforestation, channel straightening, and impoundments, resulting in the degradation of many of the natural cold-water habitats in the region, and contributing to thermal regimes more conducive to warm water fish species.

Fish species reported in the cold water streams in the Long Point Region watershed include resident and migratory salmonid populations, such as brook trout, brown trout, rainbow trout and Pacific salmon. Species reported in the warm water systems include bass, pike, perch, sunfish, bullhead, channel catfish and other panfish species.

There are also several significant lake and lake-like aquatic habitats in the Long Point Region watershed, many of which are small reservoirs or rehabilitated gravel extraction pits (such as the Waterford Ponds). Fish species in these lakes and ponds include largemouth bass, yellow perch, sunfish and crappie.

Among the aquatic SAR listed under the federal Species at Risk Act and the provincial Endangered Species Act, the following aquatic SAR may be present in the WQSA, since they have been identified within the broader Long Point Region watershed:

- Fish:
    - Lake Sturgeon (Upper Great Lakes/St. Lawrence population) (Endangered provincially);
    - Eastern Sand Darter (Endangered provincially, Threatened federally);
    - Redside Dace (Endangered provincially and federally);
    - Lake Chubsucker (Threatened provincially, Endangered federally);
    - Grass Pickerel (Special Concern provincially and federally);
    - Northern Brook Lamprey (Special Concern federally and provincially);
    - Spotted Gar (Endangered provincially, Threatened federally);
    - Silver Chub (Threatened provincially);
    - Pugnose Shiner (Threatened provincially, Endangered federally);
    - Silver Shiner (Threatened provincially, Special Concern federally);
    - Channel Darter (Special Concern provincially);

- Molluscs:
    - Round Pigtoe (Endangered federally and provincially);
    - Mapleleaf (Special Concern provincially, Threatened federally);
    - Fawnsfoot (Endangered provincially).

Based on mapping of federally-listed SAR developed by Fisheries and Oceans Canada (DFO, 2018), the following species and/or their critical habitat are found and/or may potentially be found in the Long Point Region watershed within the WQSA:

- Big Otter Creek and tributaries near Port Burwell
    - Channel Darter and Eastern Sand Darter found or potentially found.
- Big Otter Creek, Little Otter Creek and tributaries near Tillsonburg:
    - Eastern Sand Darter, Northern Brook Lamprey and Grass Pickerel found or potentially found.
- Big Otter Creek near Norwich:
    - Eastern Sand Darter found or potentially found.
- Big Creek, Trout Creek and tributaries near Delhi:
    - Lake Chubsucker and Northern Brook Lamprey found or potentially found.
- Big Creek between Langton and the outlet to Lake Erie:
    - Critical habitat for Pugnose Shiner and Eastern Sand Darter found;
    - Grass Pickerel, Lake Chubsucker, Eastern Sand Darter and Warmouth (Endangered provincially, Special Concern federally) found or potentially found.

- Lake Erie tributaries, west of Big Creek:
    - Grass Pickerel and Lake Chubsucker found or potentially found.
- Lake Erie Tributaries, east of Big Creek:
    - Grass Pickerel found or potentially found.
- Lake Erie, Inner Bay and Long Point Bay:
    - Critical Habitat for Pugnose Shiner, Lake Chubsucker, Eastern Pondmussel (Special Concern provincially, Endangered federally) and Eastern Sand Darter found.
    - Pugnose Shiner, Lake Chubsucker, Grass Pickerel, Spotted Gar, Warmouth, Eastern Pondmussel, Rainbow mussel and Channel Darter found or potentially found.

Catfish Creek Watershed

Watercourses in the northern portion of the Catfish Creek watershed, characterized by relatively low topographic relief, tend to be warm water fish habitat. Extensive removal of woodlots, riparian vegetation and wetlands has adversely impacted fish communities and habitat in this area.

Watercourses in the lower part of the watershed are fed by relatively more baseflow, and are typically associated with deeply incised valleys bisecting portions of the Norfolk Sand Plain. As a result, most watercourses in the southern portion of the watershed are classified as cool or coldwater. The number of dams and online ponds for irrigation may have negatively affected the baseflow and temperatures in some of the streams.

Fisheries in the Catfish Creek watershed are limited by factors such as reservoir management practices, habitat fragmentation, water quality impairment, maintenance of environmentally sensitive areas, watercourse alterations and agricultural practices.

Among the aquatic SAR listed under the federal Species at Risk Act and the provincial Endangered Species Act, the following aquatic SAR are assumed to be present in at least the western portion of the WQSA, since they have been identified within the Catfish Creek watershed:

- Fish:
    - Lake Sturgeon (Upper Great Lakes/St. Lawrence population) (Endangered provincially);

  - Eastern Sand Darter (Endangered provincially, Threatened federally);
  - Lake Chubsucker (Threatened provincially, Endangered federally);
  - Grass Pickerel (Special Concern provincially and federally);
  - Northern Brook Lamprey (Special Concern federally and provincially);
  - Silver Chub (Threatened provincially);
  - Pugnose Shiner (Threatened provincially, Endangered federally);
  - Silver Shiner (Threatened provincially, Special Concern federally);
  - Channel Darter (Special Concern provincially);

- Molluscs:
  - Mapleleaf Mussel (Special Concern provincially, Threatened federally);
  - Fawnsfoot (mollusc) (Endangered provincially).

Based on mapping of federally-listed SAR developed by Fisheries and Oceans Canada (DFO, 2018), the following species and/or their critical habitat are found and/or may potentially be found in the Catfish Creek watershed within the WQSA:

- Catfish Creek near Sparta and near its outlet into Lake Erie:
  - Eastern Sand Darter found or potentially found.

Kettle Creek Watershed

The upper portion of the Kettle Creek watershed, overlapping with the WQSA, is characterized as warm water habitat. In fisheries surveys conducted in 1974, 1993 and 1994, a total of 26 warm water species were reported in the Upper Kettle Creek subwatershed, including smallmouth and largemouth bass. No information was identified on the thermal regime of the small, Lake Erie tributaries in the southeastern portion of the Kettle Creek watershed.

Most of the tributaries within the Kettle Creek subwatershed are thermally stressed. Water temperatures as high as 28°C have been reported, which is approaching the upper threshold for many warm water species. The effects are exacerbated in the upper Kettle Creek subwatershed by the relatively low natural baseflows, which tend to be intermittent during the dry season.

Among the aquatic species at risk (SAR) listed under the federal Species at Risk Act and the provincial Endangered Species Act, the following aquatic SAR may be present in the WQSA, since they have been identified within the broader Kettle Creek watershed:

- Fish:
    - Lake Sturgeon (Upper Great Lakes/St. Lawrence population) (Endangered provincially);
    - Lake Chubsucker (Threatened provincially, Endangered federally);
    - Northern Brook Lamprey (Special Concern federally and provincially);
    - Spotted Gar (Endangered provincially, Threatened federally);
    - Silver Chub (Threatened provincially);
    - Pugnose Shiner (Threatened provincially, Endangered federally);

- Molluscs:
    - Mapleleaf Mussel (Special Concern provincially, Threatened federally);
    - Fawnsfoot (mollusc) (Endangered provincially).

Mapping of federally-listed SAR developed by Fisheries and Oceans Canada (DFO, 2018) did not identify any SAR species or their habitat as being found or potentially found in Kettle Creek within the boundaries of the WQSA.

Upper Thames River Watershed

More than 90 fish species are found in the Thames River watershed as a whole. Among the aquatic species at risk (SAR) listed under the federal Species at Risk Act and the provincial Endangered Species Act, the following aquatic SAR may be present in the WQSA, since they have been identified within the broader Thames River watershed:

- Fish:
    - Gravel chub (extirpated in Ontario);
    - Northern madtom (Endangered provincially and federally);
    - Eastern Sand Darter (Endangered provincially, Threatened federally);
    - Spotted Gar (Endangered provincially, Threatened federally);
    - Black redhorse (Threatened provincially);
    - Northern Brook Lamprey (Special Concern federally and provincially);
    - Grass Pickerel (Special Concern provincially and federally);
    - Silver Shiner (Threatened provincially, Special Concern federally);

  - Pugnose minnow (Threatened provincially, Special Concern federally);
  - River redhorse (Special Concern provincially and federally);
  - Spotted sucker (Special Concern provincially and federally);

- Molluscs:
  - Snuffbox (Endangered federally and provincially);
  - Round hickorynut (Endangered federally and provincially);
  - Kidneyshell (Endangered federally and provincially);
  - Salamander mussel (Endangered federally and provincially);
  - Rayed Bean (Endangered federally and provincially);
  - Rainbow (Endangered federally and provincially);
  - Mapleleaf (Endangered provincially, Threatened federally);
  - Wavyrayed Lampmussel (Endangered provincially, Special Concern federally);
  - Fawnsfoot (Endangered provincially);
  - Round Pigtoe (Endangered federally and provincially).

Based on mapping of federally-listed SAR developed by Fisheries and Oceans Canada (DFO, 2018), the following species and/or their critical habitat are found and/or may potentially be found in the Upper Thames River watershed within the WQSA:

- Upper Thames River and tributaries near Dorchester:
  - Critical habitat for Round Pigtoe found;
  - Wavy-Rayed Lampmussel, Round Pigtoe, Rainbow mussel and Rayed Bean found or potentially found.
- Upper Thames River and Middle Thames River near Piney Creek:
  - Critical habitat for Rainbow Mussel found;
  - Wavy-Rayed Lampmussel, Round Pigtoe and Rainbow mussel found or potentially found.
- Upper Thames River near Ingersoll:
  - Round Pigtoe and Rainbow mussel found or potentially found.

6.2.5 Geology

The WQSA is underlain by a series of gently dipping Paleozoic sedimentary rocks consisting of deep-water shales interbedded with shallow water carbonates and sandstone. These rocks are overlain by unconsolidated Quaternary-aged sediments of variable thickness that were laid down after the last glaciation. Paleozoic rocks outcrop in the Long Point Region in only a few areas in the east near Hagersville; in the remainder of the WQSA bedrock is buried beneath a thick veneer of sediments (LESPR, 2014) ranging in thickness from zero along some river valleys and on the Haldimand Clay Plain, to over 115 m in areas where end moraines overlie thick till deposits (LESPR, 2015).

6.2.5.1 Surficial Geology

Quaternary overburden sediments in the WQSA were deposited during the glacial and interglacial events that occurred as part of the Wisconsinan Glaciation (115 to 7 kilo annum (ka, i.e. thousand years) before present) and consist of glaciomarine deposits, glaciofluvial outwash deposits and tills as shown on Figure 6-7.

The predominant surficial deposits (shown in yellow on Figure 6-7) are composed of glaciomarine sand, gravelly sand and gravel nearshore beach deposits which make up the Norfolk Sand Plain physiographic region.

Glacial Lake Whittlesey followed by Glacial Lake Warren each flooded the southern portion of the WQSA throughout the Port Huron Stade (Barnett, 1992). It was at the base of these lakes that the Haldimand Clay Plain and extensive Norfolk Sand Plain were deposited (Barnett, 1982). The Haldimand Clay Plain was deposited in the eastern part of the WQSA as fine-grained silts and clays settled to the bottom of the deep lake basin. The Norfolk Sand Plain lies across the western and central parts of the WQSA and forms an extensive surficial feature deposited when the sediment laden Grand River (historic alignment) emptied into the deep glacial lake. The Grand River deposited a deltaic sequence of sands and silts throughout the western portion of the WQSA at the front of the eastward retreating ice front (Chapman and Putnam, 1984). Norfolk Sand Plain sands are described as fine to medium-grained, ranging in thickness from less than 1 m to roughly 27 m (although this estimate may include deeper, and older sands; Barnett, 1982). Within the Long Point Region watershed area, the Norfolk Sand Plain forms an important aquifer across the area (LESPR, 2015).

The thickest overburden materials are found in the vicinity of Straffordville, Vienna, Port Burwell and Port Rowan, all located in the southern regions of the Study Area along the Lake Erie shoreline (AquaResource, 2009).

An overburden drilling program was conducted within the central part pf the Norfolk sand plain to support a Tier 3 Water Budget and Risk Assessment for the Lake Erie source water protection region (March, 2014). Seven sedimentary units of varying degrees of thickness and continuity were identified:

1. Catfish Creek Till
2. Erie Phase deposits
3. Port Stanley Till
4. Fine-textured Erie basin deposits (glacial Lakes Maumee, Arkona)
5. Coarse-textured Lake Ypsilanti low level deposits
6. Fine- to medium-textured Erie basin deposits (Whittlesey-Warren lakes)
7. Wentworth Till

A generalized conceptual geologic model for the central Norfolk sand plain is provided on Figure 6-8. The model depicts a subsurface environment that is dominated by glaciolacustrine sediments of variable continuity. These glaciolacustrine sediments are interrupted by the three till units; the Catfish Creek Till which is monstly continuous to the west; the Port Stanley Till which exhibits at least three main beds that rise up through the subsurface to the west; and, the Wentworth Till which was observed on the crest of the Paris Moraine (Marich, 2014).

6.2.5.2 Bedrock Geology

Glacial sediments in the Long Point Region are underlain by Upper Silurian to Middle Devonian bedrock consisting mainly of limestones, dolostones and shales. This Paleozoic succession is subdivided into 10 formations. In order from oldest to youngest, these are the Salina, Bertie, Bass Island, Oriskany, Bois Blanc, Onondaga, Amherstburg, Lucas, Dundee and Marcellus Formations. Figure 6-9 illustrates the bedrock geology underlying the WQSA.

The oldest bedrock unit is located in the northeastern corner of the study area. The Upper Silurian Salina Group consists primarily of interbedded shale and gypsum with lesser dolostone (Armstrong and Carter, 2010; Armstrong and Dodge, 2007). Within the Long Point Region, the Salina subcrops in the far northern reaches near Hagersville (Johnson et al., 1992), and outside the village of Springvale. The Upper Silurian Bass Island Formation, overlying the Salina Group, to the south, is a dark brown to grey-tan dolostone that is variably laminated, mottled, argillaceous and bituminous (Marich, 2014). The Bass Island Formation grades eastward into the Bertie Formation which consists of sparsely fossiliferous dolostones and argillaceous dolostones with minor shale (Armstrong and Carter, 2010; Armstrong and Dodge, 2007).

Overlying the Bass Island and the Bertie formations is the Lower Devonian Bois Blanc Formation consisting of a resistant cherty and fossiliferous limestone with lesser dolostone that disconformably overlies the Silurian strata (Marich, 2014).

The Onondaga Formation is found in a band trending southeast in the northern half of the study area and consists of fossiliferous to argillaceous limestone, sometimes biohernal, and contains cherty sections (Armstrong and Carter, 2010; Armstrong and Dodge, 2007). The Middle Devonian Amherstburg Formation consists of fine- to coarse-grained, bituminous, bioclastic, fossiliferous limestone and dolostones. The Amherstburg Formation grades into the Onondaga Formation to the east exhibiting similar characteristics although with cherty sections (Armstrong and Carter, 2010; Armstrong and Dodge, 2007). The Middle Devonian Lucas Formation limestones and dolostones contain anhydritic beds and local sandy limestones (Marich, 2014).

The Dundee Formation is a grey to brown fossiliferous limestone that outcrops along Black Creek, Nanticoke Creek, a small area just north of the town of Nanticoke, as well as along the Lake Erie shoreline between Port Dover and Nanticoke. Several karst features have been mapped in association with the Dundee Formation (Barnett, 1978). Barnett (1982) mapped several sinkholes within the Long Point Region, ranging up to 15 m in diameter and 8 m deep. The Marcellus Formation is described as a black, organic-rich shale, with a few minor, thin, impure carbonate interbeds and ranges in thickness between 3 and 15 m (Barnett, 1982, 1993; Johnson et al., 1992). This formation is restricted to the southwestern portions of the Long Point Region on the north shores of Lake Erie where it conformably overlies the Dundee Formation (LESPR, 2015).

6.2.6 Hydrogeology

Groundwater resources are found in both overburden and bedrock aquifers in the WQSA. Figure 6-10 illustrates the defined WHPAs area along with all overburden and bedrock water supply wells in the WQSA. The vast majority of domestic wells are drilled into overburden, while bedrock wells are found mainly in the northern and eastern extremities of the WQSA. Multiple overburden aquifers associated with the Norfolk Sand Plain and deeper confined sand and gravel lenses within the Port Stanley Till and underlying Catfish Creek Till have been identified. In the eastern extents of the WQSA, in the vicinity of the Haldimand Clay Plain, the Dundee Formation is utilized as a productive bedrock aquifer as the clay-rich overburden sediments are not able to yield significant quantities of groundwater. Although the Dundee formation underlies a large portion of the western extent of the WQSA, it is not highly exploited used as a groundwater resource in these areas due to the relative abundance of surface water resources (LESPR, 2014 & 2015). The Bois Blanc Formation and the underlying Bass Islands are separated by a major regional unconformity (Johnson et al., 1992). This unconformity may be significant from a hydrogeologic perspective as the upper surface of the Bois Blanc is interpreted to be weathered, highly fractured and therefore, able to transmit greater volumes of water than the more competent rock at depth (LESPR, 2015).

A generalized conceptual geologic model for the central Norfolk sand plain is provided on Figure 6-8. Marich (2014) concludes that the discontinuous nature of fine-textured glaciolacutrine sediments would allow for groundwater to move throughout the sediment column. Slug test data indicate that there is little if any difference in water levels between aquifers that occur at different levels and that are separated by aquitards suggesting that the aquitards are discontinuous. The connection between sand units will allow groundwater to pass through the subsurface; tills and very fine-textured glaciolacustrine sediments may serve locally as aquitards, but not as broad regional aquitards.

6.2.6.1 Overburden Aquifers

Shallow Overburden Aquifer

The upper, shallow aquifer is unconfined and consists of sand and gravel deposits associated with the Norfolk Sand Plain. This aquifer supports municipal wells for a number of communities and is the primary groundwater resource in the Long Point, Catfish Creek and Kettle Creek watersheds. On the Long Point Watershed, thicknesses of the upper aquifer reportedly ranges from <3 m to about 30 m (LESPR, 2015). In the Catfish Creek Watershed, the shallow overburden aquifer is unconfined to semi-confined and generally limited to within 20 m of ground surface. This primary aquifer within the Catfish Creek watershed is a broad shallow unconfined sand and gravel aquifer mainly located between Aylmer and Lake Erie. The upper aquifer is absent in the central portion of the Catfish Creek watershed and along the western boundary with the Kettle Creek watershed; the upper 20 to 30 m of overburden in this area are Port Stanley Till and similar fine-grained sediments. The primary aquifer in the Kettle Creek Watershed is comprised of broad unconfined shallow (< 20 m) sand and gravel units located between St. Thomas and Lake Erie (southern portion of watershed).

Groundwater flow in the shallow unconfined aquifer is predominantly from north to south toward Lake Erie. Groundwater elevations in the shallow aquifer, as aggregated and reported in the Approved Assessment reports for the Long Point, Catfish Creek and Kettle Creek Watersheds, are a subdued refection of the ground surface topography and range from approximately 290 masl in the north to 180 masl in the shore of Lake Erie.

Intermediate Overburden Aquifer

In the Long Point Watershed, the unconfined aquifer is underlain by an aquitard which consists of sandy silt and clay glaciolacustrine deposits (Waterloo Hydrogeologic Inc. *et al.*, 2003) and ranges in thickness from 0 to 30 m thick in the morainal areas of the Big Creek drainage area and in much of the area south of Delhi. The presence of the aquitard has not been reported in the Catfish Creek and Kettle Creek Watersheds. Below the aquitard, an intermediate aquifer is present. The intermediate aquifer is discontinuous owing to the absence of the aquitard in areas where the saturated thickness of the upper unconfined aquifer is greater than 20 m. In these areas, there is no separation between the upper and intermediate overburden aquifers. In some areas the aquitard is thick and directly overlies the bedrock surface and there is no intermediate aquifer. The intermediate aquifer consists of medium sand under the western portion of the Big Creek drainage area, grading to fine sand or silty sand under the central portions of the Big Creek watershed. Further to the east, the intermediate aquifer thins and grades into clayey sediments. Potentially high yield wells (>200 L/min) have been identified east of Delhi (municipal wells). From south of Kelvin, there is generally an upward gradient from the intermediate aquifer to the upper aquifer.

The regional groundwater flow directions are very similar to those seen in the shallow unconfined aquifer whereby the dominant groundwater flow direction is from north to south towards Lake Erie.

Based on the material reviewed as part of this assessment, it is unclear if this intermediate aquifer is currently being used as a municipal supply.

Deep Overburden Aquifers

Deeper overburden aquifers, generally located at depths greater than 20 m, are reportedly present in both the Catfish Creek and Kettle Creek Watersheds within the basal portions of the Port Stanley Till and the underlying Catfish Creek Till where discontinuous sand and gravel lenses exist (LESPR, 2014 & 2015). The deep overburden aquifer has also been identified in isolated locations in the Long Point Watershed (primary locations: east of Burgessville, south of Burford, in central part of Venison Creek Subwatershed) (AqaResource, 2009). The sand and gravel lenses are generally less than 5 m thick. In the Long Point Watershed, the deep overburden aquifer is often hydraulically connected to upper bedrock (AquaResource, 2009). The deep overburden unit is considered to be semi-confined to confined and the general groundwater flow directions are very similar to those seen in the shallow unconfined aquifer whereby the dominant groundwater flow direction is from north to south towards Lake Erie. It is noted that groundwater flow within the southern portions of both watersheds is locally influenced by Catfish Creek and Kettle Creek. This is likely the case for all overburden aquifers. The potentiometric surface elevations in the deep overburden aquifers vary from 290 masl in the northern areas of the watersheds to 150 masl along the Catfish Creek, Kettle Creek, and the shore of Lake Erie.

6.2.6.2 Bedrock Aquifer

Domestic bedrock wells within Long Point Region are typically completed into the upper 10 to 30 m of the Dundee Formation (Waterloo Hydrogeologic Inc. *et al.*, 2003) especially in the eastern reaches of the watershed where the overburden is comprised of fine-grained Haldimand Clay Plain sediments. In other areas, including the Norwich municipal wells, the bedrock wells are interpreted as having been completed in the Detroit River Group. Higher groundwater elevations (314 masl) are located in the northwestern portion of the Long Point Region, sloping towards lows (144 masl) adjacent to the Lake Erie shoreline. Groundwater flow direction in the bedrock is from north to south towards Lake Erie (Waterloo Hydrogeologic Inc. et al., 2003). Under the Norfolk Sand Plain area, there is generally an upward gradient from the lower aquifer / bedrock into the overlying overburden units.

Within the Catfish Creek watershed, the bedrock potentiometric surface is similar, but more subdued when compared to the overburden potentiometric surfaces. Groundwater flows from the north- northeast to the south towards Lake Erie. Bedrock groundwater elevations are similar to the deep overburden potentiometric surface, and range from 270 masl in the northeast of the watershed, to 170 to 190 masl along the Lake Erie shoreline.

Within the Kettle Creek watershed, the bedrock potentiometric surface is similar to the overburden potentiometric surfaces, and groundwater flow is from the northeast towards the Lake Erie shoreline in the south. Surface water features do not appear to have a significant impact on the bedrock groundwater flow directions. Bedrock groundwater elevations range from approximately 270 masl in the northeast to 170 to 190 masl along the Lake Erie shoreline.

6.2.6.3 Groundwater Surface Water Interaction

Across the WQSA, interactions between groundwater and surface water are known to be more significant in areas where surficial materials are comprised of medium and coarse grained sands and gravels of the Norfolk Sand Plain. In general, groundwater surface water interactions are limited in areas where surficial materials are comprised of fine grained clays and till material (i.e. Halimand and Ekfrind clay plains and tills that comprise the Horseshoe Moraines and Mount Elgin Ridges). As noted above, groundwater flow in the overburden aquifers within the southern portions of the relevant watersheds is locally influenced by Catfish Creek and Kettle Creek.

In the Long Point Region, groundwater and surface water interaction occurs predominantly in the central/western portion of the watershed, where a shallow groundwater system is located within the sandy, coarse-grained deposits of the Norfolk Sand Plain. Temperature mapping of the water courses in this area are typically classified as cool water with sustained baseflows indicating groundwater discharge into the creeks and streams (Figure 6-6). In the eastern portion of the watershed region, the low permeability Haldimand Clay Plain limits the interaction between the groundwater and surface water features. The watercourses in this area are runoff-driven and there is little baseflow provided by groundwater discharge. In the central, northern and western portions of the region, Big Creek, Big Otter Creek and Little Otter Creek and their associated tributary creeks (e.g., Spittler Creek) are supported by significant groundwater discharge. (AquaResource, 2009).

In the Catfish Creek Watershed, thick deposits of low permeability till located in the northern and eastern parts of the watershed inhibit the interaction between the groundwater and surface water systems. There are low baseflows during dry periods in the upper branches of Catfish Creek, which lie within the till plain. In the southern part of the watershed, surficial sands of the Norfolk Sand Plain are the dominant surficial sediments and stronger interactions between surface and groundwater are reported. The Catfish Creek has eroded a deep valley into the overburden and it intersects the water table allowing for discharge from groundwater to supply baseflows to the creek. Similarly, Silver Creek, located in the southeastern part of the watershed in the Norfolk Sand Plain, has flows supported by groundwater discharge. Most water courses in the southern part of the watershed are classified as cool water with sustained baseflows indicating discharge from groundwater (AquaResource, 2009).

In the Kettle Creek watershed, the thick fine-grained overburden with low permeability inhibits a large degree of interaction between the groundwater and surface water systems. Groundwater influences the surface water system in the headwaters of Kettle Creek by feeding

Lake Whittaker which in turn produces baseflows for the creek. Beaver Creek in the south travels through sandy deposits and groundwater discharge supports a cool water fishery in this creek (AquaResource, 2009).

On the McKenzie subwatershed, groundwater discharge to tributaries is higher in areas where channels cut through surficial sand and gravel of the Norfolk Sand Plain. Stream groundwater discharge on this subwatershed has been estimated to range from 5 to 30 L/s/km based on regional groundwater modeling (LESPR, 2015).

6.2.7 Overview of Water Takings within WQSA

6.2.7.1 Permitted Takings

Water takings at a rate of over 50,000 litres per day are governed under the MECP PTTW program. Water takings in Ontario are governed by the Ontario Water Resources Act (OWRA) and the Water Taking Regulation (O. Reg. 387/04) a regulation under the Act. Section 34 of the OWRA requires anyone taking more than a total of 50,000 litres of water in a day, with some exceptions, to obtain a Permit from a Director appointed by the Minister for the purposes of Section 34. The purpose of the PTTW program is to ensure the conservation, protection and wise use and management of the waters of the province. Permits are controlled, and not issued if the taking of more water in a given area would adversely affect existing users or the environment.

The Long Point Region has among the highest number of permitted surface and groundwater users of any area in Southern Ontario (LPRCA, 2008). As of 2017, there were 1,942 active PTTWs within the WQSA boundaries, which equates to approximately 17% of all PTTWs in Ontario (11,688 total). Of all the 4,099 PTTWs used for agriculture in Ontario, 1,748 (approximately 43%) are located within the Norfolk Sand Plain WQSA.

The WTRS data used to estimate demand in this report is based on 2017 values as they were available to BluMetric. Precipitation values for 2016 were provided by the Tilsonburg Station. It is known that 2016 was a dry year. Using the Delhi and Tilsonburg meteorological stations as representations of the WQSA, the area received 69% of normal precipitation between the beginning of May through the end of September 2016 (see table below). While not quantified in this report, as a multiyear analysis is beyond the scope of this report, it is likely that water usage may have been higher in 2016 compared with other years.

Table 6-4: Precipitation values (Environment Canada) in Norfolk Sand Plain WQSA

Month	Delhi Station Precipitation Monthly Averages for 1981-2010 (mm)	Tilsonburg Station 2016 Monthly Precipitation Recordings (mm)
May	88.9	20.2
June	88.8	39.2
July	96.6	100.4
August	83.6	57.4
September	99.2	96.9
Total	457.1	314.5
Percentage of May-September Normal Precipitation	100%	69%

Demand for irrigation water during the summer months can affect streamflow throughout the region, but is focused in the western watersheds on the Norfolk Sand Plain. Based on the most recently available (2011) Census of Agriculture conducted by Statistics Canada from which the data was aggregated by the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA), the eight townships which make up Norfolk county have the highest concentration of farms reporting irrigation use (100-300 per Township) in all of southern Ontario. Townships in the neighboring Counties of Elgin, Oxford, Brant and Haldimand have lower reported numbers of irrigation dependent farms (5 – 100 per township) (OMAFRA, 2011).

Figure 6-11 shows a map of the active surface and groundwater permitted takings within the Norfolk Sand Plain WQSA categorized by purpose. Percentages and values in the following paragraphs used to characterize water demands by Purpose and Specific Purpose were obtained using 2016 WTRS data. A summary of the permitted versus actual tables can be found in Table 6-5.

Table 6-5: Volume of Reported Water Takings vs Maximum Permitted Volume of Surface and Groundwater (2017 WTRS) in Norfolk Sand Plain WQSA

Sector	Type	Volume of Reported Takings (m^3/yr)	Percent of WQSA Total Reported Takings (%)	Maximum Permitted Volume (m^3/yr)	Permit Utilization (reported takings/maximum permitted volume) (%)
Agriculture	Groundwater	11,725,034	28	95,007,949	12
	Surface and Groundwater	2,560,671	6.0	35,475,511	7.2
	Surface Water	3,074,324	7.2	43,663,455	7.0
Commercial	Groundwater	472,792	1.1	4,534,161	10
	Surface and Groundwater	5,701,175	13	30,740,838	19
	Surface Water	8,700,247	20	9,748,256	89
Industrial	Groundwater	1,533,186	3.6	9,642,602	16
	Surface and Groundwater	282,198	0.66	4,007,880	7.0
	Surface Water	0	0.0	864,000	0.00
Miscellaneous	Groundwater	697	0.0016	40,924	1.7
Institutional	Surface Water	406	0.0010	19,200	2.1
Remediation	Groundwater	322,194	0.76	407,573	79
Water Supply	Groundwater	6,823,819	16	37,677,981	18
	Surface and Groundwater	0	0.0	18,250	0.0
	Surface Water	1,353,967	3.2	8,481,607	16
Total	All Sources	42,550,710	100.0	280,330,187	15

The Tier 2 water budget study for the Long Point, Kettle Creek and Catfish Creek watersheds (AquaResource 2009), which largely makes up the Norfolk Sand Plain WQSA states while the total permitted volume amounts to 58 m^3/s, the estimated permitted takings based on reported and estimated (permitted takings that were not reported) values are closer to 4 m^3/s. Values are reported as an annual average.

By comparison, WTRS data for 2017 showed significantly lower permitted volume and reported usage. It should be noted that the WQSA boundaries are similar to the Long Point, Kettle Creek and Catfish Creek watersheds, but are not identical and may include permitted takings the WQSA does not.

Water Supply

Water supply permitted takings represent roughly 19% of the total volume of takings in the WQSA (16% groundwater, 3.2% surface water). Within the Water Supply category, Municipalities are the dominant takers for the Specific Purpose of Municipal water systems. Municipal takings comprise over 18% of total takings, while the remaining Water Supply Specific Purpose takings (Campground, Communal, and Other) make up roughly 1% of the total takings. Water Supply permit holders utilized approximately 18% of their total permitted amount in 2017.

With the exception of some campground Water Supply PTTW, nearly all Water Supply PTTWs allow for water taking 365 days per year (366 on leap years). This is largely because Municipalities have the majority of Water Supply PTTW in the WQSA which require continuous access to water year round.

Municipalities within the Long Point Region that rely on groundwater sources include the towns and villages of Simcoe, Tillsonburg, Courtland, Waterford, Norwich, Otterville, Springford, Straffordville, and Dereham Centre. Communities located adjacent to Lake Erie use the lake itself for municipal water. Communities reliant on Lake Erie for their water supply include Port Rowan, Port Dover, Hagersville, Jarvis and Townsend. Some communities to the west within the Municipality of Bayham, Township of Malahide, in Elgin County also obtain their water supplies from Lake Erie. Delhi has the only in-land surface water supply, and it obtains its water from North Creek, a tributary of Big Creek, but also obtains municipal water from groundwater wells. It should be noted that the WQSA boundaries significantly overlap the three watersheds in the Tier 2 Water Budget, however are not identical, and some municipalities in the Water Budget are not located in the WQSA.

Agriculture

Permitted surface and groundwater takings for the purpose of agriculture represents the single largest group of users by number of permits and volume of water taken in the WQSA at approximately 41% of reported takings in the WQSA (28% groundwater, 7.2% surface water, 6.0% both). Permits for Agriculture represent 90% of active PTTW in the WQSA.

Within the Specific Purpose categories, irrigation for field and pasture crops make up 15% of the total takings in the WQSA, irrigation of tobacco makes up 18%, while fruit orchards, market gardens, nurseries, sod farms, and other agriculture make up the remaining 7%.

Multiple types of water sources are used in the WQSA for agricultural PTTWs. For groundwater based sources these can include a water well, or a dugout groundwater pond that is fed by groundwater seepage and rainfall. These types of ponds are useful when the water table is unconfined and very shallow (within a few meters of surface). Surface water sources can include pumping directly from a creek, a pond connected to a creek. A common water storage practice is the use of an impoundment pond or storage pond which is used to store water pumped from a lake or creek. A dugout groundwater pond and impoundment pond are both considered offline ponds; however the dugout groundwater pond is the actual source of the water, whereas the impoundment pond is only for storage, and would not be listed as source on the permit, as the actual source would be a creek or lake which is pumped to the pond.

Reported water taking volumes for agriculture permits are highly variable between years due to weather, and the type of crop being grown. For agriculture permits, maximum days of water taking per year ranges from one to 365, however the average number of permitted days is 79 days, which generally span the irrigation season from June to September. However, the actual number of days when water usage was reported averaged 26 days.

On average, agriculture PTTW permit holders utilized approximately 10% of their total permitted amount in 2017. This was equal across surface water users, groundwater users, and users who used both. While this suggests a low utilization rate, a review of daily or monthly taking rates would be useful to determine if at a particular month during the irrigation season the permitted volume utilization becomes much higher than 9%.

It is noted that permitted agricultural water takings can vary significantly from year to year depending on climate and the type of crop. It is also noted that the irrigation demand appears to have decreased due to a decrease in the amount of tobacco being grown (AMEC, 2008). In wet or normal years, the reviewed information and data suggests that supply can meet agricultural demand. However, as reported by water managers, the outstanding issue is that in dry years, the surface water takings for irrigation and lack of precipitation results in low flow conditions. This has reportedly (Schroeter and Associates et al, 2002) resulted in ecological impact (fish kills) and a strain on continued surface water takings.

Commercial

After Agriculture, Commercial PTTW make up the second largest demand roughly 35% of total volume taken in the Norfolk Sand Plain WQSA (1% groundwater, 20% surface water, 13% both). Within the Specific Purpose category Aquaculture is the dominant taker, using 27% of the total volume taken, while Golf Course Irrigation and Other Commercial uses make up 8% of the total.

With few exceptions, Aquaculture takings from surface water and groundwater are permitted for 365 days per year, and are commonly utilized 365 days per year. Aquaculture surface water permits utilize 29% of their total permitted volume, the highest rate of any category. Utilization of permitted volume is 10% for groundwater takers and 19% for users of both surface water and groundwater. This is considered high compared to the average utilization percentage of 15% for all PTTW categories.

The range of allowable taking days per year for Golf Course Irrigation permits is between 40 and 220 days per year, spanning the golf season. Utilization of permitted volume in 2017 was 57% for all Golf Course takings. Similar to agricultural irrigation, golf course irrigation occurs more in years with little precipitation/drought years, and less in years with plentiful and regular precipitation patterns.

Industrial

Industrial related permitted takings represent approximately 4.26% of the total permitted volume taken in 2017 from within the WQSA (3.6% groundwater, and 0.66% from users who take from both surface water and groundwater). The WQSA has a relatively low permitted volume for Industrial PTTW compared to other purposes. This is possibly due to the nature of the economy having little demand for water consumption for industrial purposes; however this may also be the result that much of the WQSA has a High Use Watershed Designation, which places significant restrictions on obtaining PTTW for Industrial purposes (O. Reg. 387/04 Section 5. High Use Watershed).

Of the Specific Purpose categories within Industrial permits, Aggregate Washing is the dominant taker in the WQSA, taking 3.4%, while manufacturing, food processing, cooling water, and other industrial uses consumed the remaining 0.86%.

The range of allowable taking days per year for Industrial permits is between 170 and 365 days per year. Actual days when water was taken ranges from 0 to 335 in 2017. Utilization of permitted volume is 12.5% for all Industrial takings.

Institutional, Remediation, Miscellaneous

Institutional, Remediation, Miscellaneous permitted takings account for less than 1% of total volume taken in 2017 within the WQSA. Specific purpose for use within these categories include: school, pumping tests, and groundwater remediation.

6.2.7.2 Non Permitted Takings

As no reporting for Non Permitted takings is required, estimating usage can be difficult to quantify and is therefore associated with some uncertainty. The Tier 2 study for the Long Point, Kettle Creek and Catfish Creek watersheds (AquaResource 2009) estimates the non-permitted agriculture takings amount to 0.1 m^3/s, while non-permitted residential takings amount to 0.2 m^3/s. Compared to estimated permitted takings (discussed in 6.2.7.1), total estimated non-permitted takings represent roughly 8% (0.3 m^3/s) of estimated permitted takings.

6.2.8 Recommended WQSA Boundaries for Data Review

Refining the Norfolk Sand Plain physiographic region coupled with the three major watersheds that intersect it (Long Point, Kettle Creek, and Catfish Creek) would allow for a more focused and efficient way of assessing the Norfolk area. Figure 6-12 illustrates the recommended revised WQSA boundaries.

The Norfolk Sand Plain physiographic region was chosen as one of two parameters to influence the refined WQSA boundary as it includes much of the significant recharge area for the shallow unconfined aquifer which is heavily used in the WQSA (Earth FX, 2010).

Watershed boundaries were used as the second factor to define the WQSA extent as surface water accumulation, flow, and fate are typically controlled by these boundaries. Blending these two spatial boundaries together results in the refined WQSA displayed on Figure 6-12.

It should be noted that a significant portion of the Norfolk Sand Plain extends north of the refined WQSA boundary; however, this portion the Norfolk Sand Plain is evaluated under the Whitemans Creek WQSA (Chapter 8).

6.3 RESOURCE SUSTAINABILITY

6.3.1 Data Review and State of Water Resources

Available information on the sustainability of water resources in the Norfolk Sand Plain WQSA has been reviewed and summarized. Tier Two and Tier Three water budgets, stress assessments, and hydrographs were reviewed, and conclusions were made based on the general findings of several studies/reports conducted in the Norfolk Sand Plain WQSA.

Water budgets look at estimated annual yields for surface and groundwater within the watersheds. Stress assessments look at how the estimated maximum monthly demand compares to available water in the watershed or subwatershed as a percentage, called percentage demand. These estimates represent the potential for stress, not specific conditions expected to occur. Hydrographs for surface and groundwater are used in Tier Two and Tier Three studies to assess trends in groundwater levels and surface water flows.

A Tier Two study for the Long Point, Catfish Creek and Kettle Creek watersheds and their individual subwatersheds was conducted as part of the Tier Two study for the area (Aqua Resources, 2009a). The study, which included a water budget and stress assessment covered just under 4,000 km^2, much of which is shared with the WQSA, and is therefore used here as a representative budget for the WQSA.

A Tier Three Local Area Risk Assessment (LARA) was subsequently completed for a limited area within the Tier Two study area, specifically the municipal drinking water systems of the Towns of Waterford, Delhi and Simcoe (Matrix, 2013). The objective of the Tier Three assessment was to determine the level of potential threat to water quantity at each municipal supply. The assessment determined that Local Area A in the Town of Simcoe, which surrounds the Cedar Street Wells along the Kent Creek corridor, was considered a Significant Water Quantity Risk Level. This Risk Level led to the designation of any consumptive water use or any activity that reduces groundwater recharge within the Local Area as a Significant Water Quantity Threat, while the other municipal supplies in the Tier Three study were considered to be at a low level of risk.

High Use Watershed Classification

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a High percent water use based upon both the Average Annual and Summer Low Flow.

6.3.1.1 Groundwater

PGMN Wells

The MECP provided hydrographs and a statistical analysis of water levels for all PGMN wells in all WQSAs. In the Norfolk Sand Plain WQSA hydrographs and a statistical analysis of water levels were provided for eighteen PGMN wells located within and surrounding the Norfolk Sand Plain WQSA, including Mann Kendall (MK) and Seasonal Mann Kendall (SK) trend analyses between 2001-2017. The methodology for the analysis is forthcoming from the MECP; however the results are relied upon here to summarize water level trends in Norfolk Sand Plain WQSA. A summary of these wells is found in Table 6-7.

Table 6-6: PGMN Wells in Norfolk Sand Plain WQSA

PGMN Well ID	Water Well Record ID	Screened Interval (mbgs)	Lithology of Aquifer
W0000009-1	4400966	Screen: 9.6 m-10.2 m	Sand
W0000013-1[1]	4403134	Open Hole at the bottom: 6.25 m	Sand, Gravel
W0000014-1[2]	4403135	Open Hole at the bottom: 37.5 m- 39.0 m	Gravel
W0000015-1	1300721	Open Hole: 9.2 m-9.9 m	Gravel
W0000016-3	1300722	Open Hole: 23.77 m- 24.23 m	Limestone
W0000055-1	4706368	Open Hole: 63.1 m-96.6 m	Limestone
W0000107-1	N/A	N/A - to be determined	N/A
W0000169-1	4407897	Screen: 9.5 m-12.5 m	Sand
W0000170-2	4407913	Screen: 6.1 m-7.6 m	Sand
W0000170-3	4407912	Open Hole: 45.1 m- 48.5 m	Limestone, Shale
W0000171-2	4407892	Screen: 4.6 m-7.6 m	Sand
W0000215-1	4702076	Open Hole: 33.6 m-37.5 m	Limestone
W0000335-2[1]	2006112	Screen: 9.5 m-10.9 m	Sand, Silty Clay
W0000335-3[1]	2006112	Screen: 15.7 m- 18.8 m	Silty Sand
W0000352-2	2006116	Screen: 5.5 m-11.6 m	Sand, Gravel
W0000352-3[1]	2006116	Screen: 31.1 m-37.2 m	Sand, Gravel
W0000353-1	2006111	Screen: 51.8 m- 53.3 m	Sand, Gravel
W0000372-1	4106430	Screen: 40.2 m-41.2 m	Sand, Gravel

[1] Ministry staff noted the data for trend analysis purposes is deemed unreliable

The Mann Kendall analysis, which looks at the year over year water levels, determined that 16 of the 18 wells had no trends in water levels year over year, while two wells had upward trends. The Season Mann Kendall analysis, which determines the trend from season to season (e.g., Spring 2010 to Spring 2011) and then adds the sum of each seasonal analysis together, established that 13 wells had upward water level trends, three had no trend, and two had a downward trend.

The two wells that exhibited downward trends when the Seasonal Mann Kendall analysis was performed were W0000055-1 and W0000171-2. W0000055-1 is located in the village of Mt. Elgin and is an open hole in bedrock between 63.1 and 96.6 meters below ground surface. W0000171-2, located 10 km northwest of Turkey Point is screened in sand between 4.6 and 7.6 mbgs.

While it is not within the scope of this study to attribute downward water level trends to specific water takings, it's possible that the downward trend observed in W0000055-1 corresponded to the interference issue that was addressed in 2016 between the Mt. Elgin water supply wells and a neighboring PTTW permit holder. As discussed in section 6.3.1.1, the issue was resolved by the neighboring PTTW holder reducing pumping rates and instead pumping their well for a longer duration.

W0000171-2 is screened in the unconfined shallow sand aquifer (based on depth and screen lithology in the analysis report) which is present throughout most of the Norfolk Sand Plain physiographic region in the WQSA. Based on the lithology and screen depths of the PGMN wells in the WQSA, it has been interpreted that five other PGMN wells in the WQSA are also screened in the unconfined shallow sand aquifer. These wells for which the MECP provided statistical analysis, reveals either an upward trend or no trend in water levels. This would suggest that the downward trend exhibited at W0000171-2 is a result of localized conditions and not a regional downward trend in water levels within the unconfined shallow sand aquifer.

In addition to the PGMN wells, hydrographs from municipal wells in Waterford, Simcoe, and Delhi (Matrix, 2013) do not show any decreasing trends in the year to year static water level.

The community of Waterford has two active groundwater wells for water supply screened between 7 and 13 meters below ground surface which pump from a shallow unconfined sand and gravel aquifer. Hydrograph records available between 2009 and 2013 show no trend in water levels.

The town of Simcoe has nine groundwater wells. The main aquifer for these wells is the shallow sand a gravel deposits in the surrounding area which is generally interconnected with adjacent water bodies (AquaResources, 2009a). Hydrographs for the nine wells are available between 2009 and 2013 (or a shorter period within this time depending on the well). A qualitative review of the hydrographs suggest no long term trends with the exception of Well 5 which appears to have a slight downward trend over the period of 2011 to 2013. The Town of Simcoe has attempted to identify supplemental groundwater water supply locations as water quality has impacted some of the water supply capacity. However, complex spatial variability in overburden aquifer properties has made it difficult to establish additional supply that is not expected to have unacceptable impacts on existing users.

The town of Delhi uses two groundwater wells for water supply in conjunction with surface water from the Lehman reservoir. The two groundwater water supply wells are completed to 39 meters below ground surface in a deeper sand and gravel aquifer which is believed to be interconnected with the shallow unconfined sand aquifer. Hydrographs for the two wells suggest no water level trends over the available period between 2009 and 2013 (Matrix, 2013). Although a minor deficit in the Tier 2 study water budget predicted a minor deficit in the groundwater budget (0.2 m^3/s), the available PGMN data and water supply hydrographs discussed above suggest that a deficit scenario or aquifer mining is not persisting on a wide scale across the WQSA. This would suggest that groundwater takings are broadly sustainable in the WQSA.

Groundwater Water Budgets and Stress Assessment

Tier Two Water Budget

The Tier Two groundwater budget in the area similar to the WQSA estimated a -0.2 m^3/s net loss of groundwater when recharge, external boundary flow, discharge to surface water, and groundwater takings were considered (Aqua Resources, 2009a). This would suggest that broadly across the three watersheds, there may be a slight deficit for groundwater resources. In comparison to the 2009 Tier Two Study, which used an annual average taking rate of 1.7 m^3/s, the 2017 WTRS reported taking data suggest that annual average groundwater taking rate in the WQSA is approximately 0.8 m^3/s. This is significantly less than the 1.7 m^3/s used in the Tier Two groundwater budget and would change the groundwater budget to a surplus if used.

It should be noted, that while the WQSA boundaries are not identical to the boundaries of the Long Point, Catfish Creek and Kettle Creek Integrated Tier Two water budget, they are very similar. As well, the 2017 WTRS data does not factor in non-permitted takings, however these are only estimated to be 0.3 m^3/s for surface and groundwater (see 6.2.6.2).

Tier Two Stress Assessment

As part of the Tier Two assessment, a stress assessment was conducted based on the water budget. The purpose of the stress assessment was to determine potential for stress under existing and planned (accounting for increased demand) conditions. The results of the stress assessment are expressed as "percent water demand", which is calculated using the following equation:

$$\% \text{ Demand} = \text{Total Demand (takings)}/(\text{Total Supply[recharge]} - \text{Reserve[10\% of discharge]})$$

Percent demand was calculated on an annual and monthly basis to account for demand varying throughout the year, with the highest demand occurring in July, primarily due to agricultural irrigation. The MECP Guidelines for stress assessments states that an annual average and maximum monthly percent water demand below 10% and 25% respectively is considered low.

Of the 31 subwatersheds considered in the Tier Two groundwater stress assessment under estimated maximum demand conditions, 25 have a low potential for stress, 4 have a moderate potential for stress and 2 have significant potential for stress (Aqua Resources, 2009b).

The subwatersheds with significant and moderate potential for stress include:

Significant

- Big Creek above Kelvin Gauge
- Upper Nanticoke Creek

Moderate

- Big Above Delhi
- North Creek
- Big Above Minnow Creek
- Lynn River

Based on the Tier Two stress assessment, it appears that many of the subwatersheds may not be experiencing groundwater quantity issues; however certain subwatersheds, particularly in the Big Creek area may be prone to water quantity issues when maximum demand scenarios occur.

Tier Three

As per MECP Technical Guidelines, a Tier Three study was conducted in the subwatersheds which were rated as having a Moderate or Significant potential for stress, and had municipal supply wells. The Tier Three study area was centred around Simcoe, Delhi, Tillsonburg, and Waterford.

The Tier Three risk assessment modelling exercise include the amount of drawdown in a supply pumping well and the decline in groundwater discharge to surface that is caused under current conditions and a variety of future population/economic growth, land use and climate change scenarios. The results of the modelled current conditions are discussed in this section, and the results of the future scenarios are discussed in 6.3.2 – Assessment of Sustainability of Water Resources.

Drawdown is measured in supply wells within the Tier Three assessment area to determine the ability of the wells to supply water at the required rates under current and future conditions. Based on the geology and well construction, each well has a SAAD which is defined as the difference (measured in meters) between the average water level in a pumping well under pumping conditions, and a point in the well typically 1 m above the screen or the lowest possible pump intake. If the modelled drawdown in the well under futures conditions does not exceed the SAAD, the taking may be considered sustainable from a water supply perspective.

Groundwater discharge to surface water features such as cold water streams provides cold temperature baseflow that is vital to the ecology of some creeks and wetlands. The sustainability of water takings is also quantified by how much (in litres per second) modelled water takings under current and future condition contribute to a decline in baseflow to creeks and wetlands. Generally, if baseflow is reduced by 10 percent or less under modelled future conditions, the takings are considered sustainable.

Under current conditions, the only wells that exceed SAAD in the Tier Three study area were four of the five Cedar St wells in Simcoe. This is due to the fact that under current conditions, the wells have a negative SAAD, which means they have a high potential for operational issues under the current condition. A lack of SAAD was confirmed by wellfield operators who have documented the water level periodically falling below the top of screen (Matrix Solutions, 2015). However, at this point there has been no documented inability to provide adequate amount of water from the Cedar St water supply system.

The Tier Three studies measure a reduction in baseflow by comparing current baseflow rates to future baseflow rates impacted by future demand/climate/land use scenarios. These results are discussed below in 6.3.2 – Assessment of Sustainability of Water Resources.

6.3.1.2 Surface Water

WSC Gauge Hydrographs

Twenty-seven WSC gauges are located within the boundaries of the WQSA, of which two are located within the Upper Thames River watershed, four are located in the Catfish Creek watershed, and 21 are located in the Long Point Region watershed. No gauges are located in the Kettle Creek or Grand River watersheds within the boundaries of the WQSA. The locations of the gauges are illustrated on Figure 6-5, and general information about the stations and flow data are summarized in Table 6-6 (note: WSC gauge 02GD016 (Thames River at Ingersoll) is located immediately outside the WQSA, but is included in the table as a substitute for gauge 02BD006 (Thames River Near Ingersoll), which only has flow data up to 1957. Gauge 02GD016 is located approximately 4.6 km upstream of gauge 02GD006).

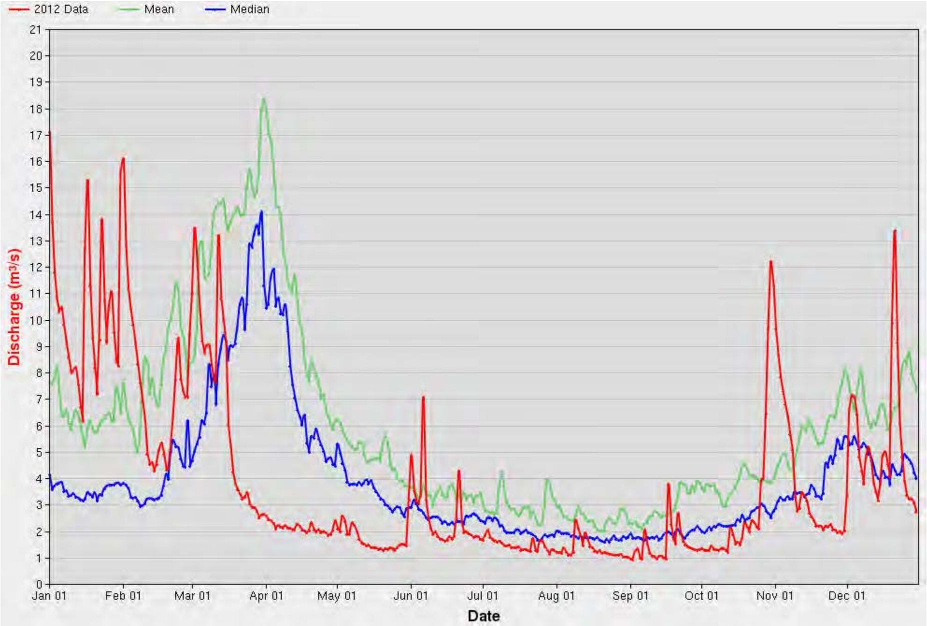
Table 6-7: Water Survey of Canada stream gauges in Norfolk Sand Plain WQSA

Station No.	Main Watershed	Years	Data Availability	Drainage Area (km^2)	Mean annual flow (m^3/s)
02GD006 (Thames River Near Ingersoll)	Upper Thames River	1938-1957	Flow	554	6.9
02GD016 (Thames River At Ingersoll) [1]		1957-present	Flow and Level	510	5.9
02GD027 (Reynolds Creek Near Putnam)		2002-present	Flow and Level	145.14	1.7
02GC018 (Catfish Creek Near Sparta)	Catfish Creek	1964-present	Flow and Level	295	3.4
02GC024 (Silver Creek Near Copenhagen)		1970-1978	Flow	27.2	0.3
02GC030 (Catfish Creek At Aylmer)		1987-present	Flow and Level	126.7	1.4
02GC036 (Silver Creek Near Grovesend)		2007-present	Flow and Level	40.3	0.5
02GC001 (Big Creek Near Port Rowan)	Long Point Region (Big Creek watershed)	1945-1948	Flow	699	8.6
02GC006 (Big Creek Near Delhi)		1955-present	Flow and Level	369.83	4.2
02GC005 (North Creek At Delhi)		1954-1966	Flow	54.4	0.6
02GC007 (Big Creek Near Walsingham)		1955-present	Flow and Level	567	6.8
02GC009 (Venison Creek Near Big Creek)		1963-1966	Flow	81.4	1.1
02GC011 (Big Creek Near Kelvin)		1963-present	Flow and Level	154.04	1.6
02GC021 (Venison Creek Near Walsingham)		1966-present	Flow and Level	68.4	1.2
02GC038 (Venison Creek Near Langton)		2015-present	Flow and Level	44.2	0.6
02GC004 (Big Otter Creek Near Vienna)	Long Point Region (Big Otter Creek watershed)	1948-1975	Flow	697	7.5
02GC010 (Big Otter Creek At Tillsonburg)		1960-present	Flow and Level	354.1	4.2
02GC015 (Little Otter Creek Near Straffordville)		1963-1992	Flow	104	1.5

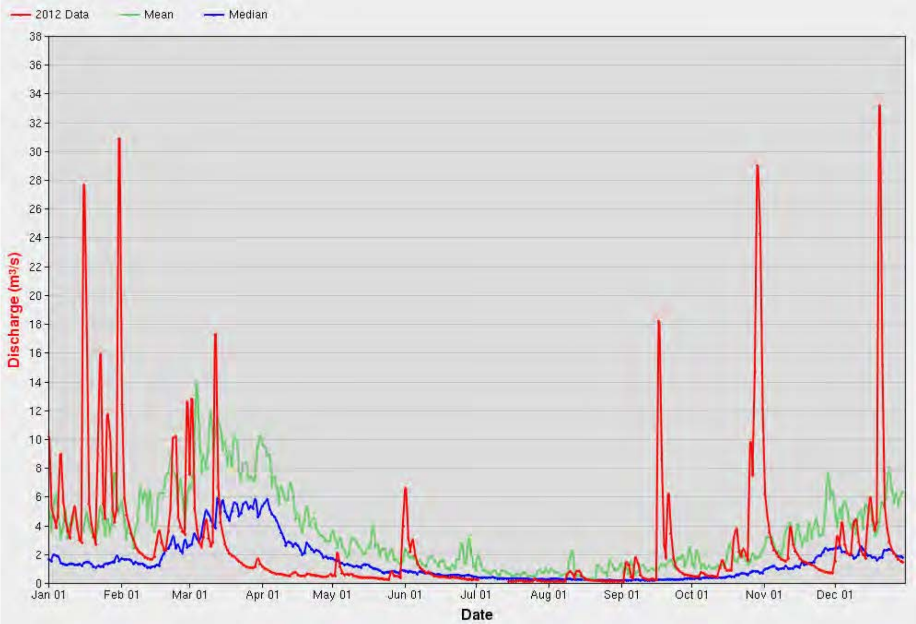
Station No.	Main Watershed	Years	Data Availability	Drainage Area (km^2)	Mean annual flow (m^3/s)
02GC017 (Big Otter Creek Above Otterville)		1964-present	Flow and Level	101.08	1.2
02GC026 (Big Otter Creek Near Calton)		1975-present	Flow and Level	665	9.2
02GC008 (Lynn River at Simcoe)	Long Point Region (Lynne River watershed)	1957-present	Flow and Level	144	1.8
02GC012 (Patterson Creek Near Simcoe)		1963-1991	Flow	51.3	0.7
02GC013 (Dedrick Creek Near Port Rowan)	Long Point Region (Lake Erie tributaries, east of Big Creek))	1963-1984	Flow	75.9	1
02GC014 (Young Creek Near Vittoria)		1963-2008	Flow and Level	65.8	0.8
02GC023 (Fishers Creek Near Fishers Glen)		1969-1976	Flow	5.18	0.1
02GC016 (South Otter Creek Near Port Burwell)	Long Point Region (Lake Erie tributaries, west of Big Creek))	1964-1978	Flow	109	1.4
02GC025 (Hemlock Creek Near Port Burwell)		1970-1976	Flow	10.1	0.1
02GC037 (Nanticoke Creek Near Dundurn)	Long Point Region (Nanticoke Creek watershed)	2015-present	Flow and Level	22.2	0.2

[1] Gauge 02GD016 is located immediately outside the WQSA, but is included in the table as a substitute for gauge 02GD006, which only has flow data up to 1957. 02GD016 is located approximately 4.6 km upstream of 02GD006.
Source: WSC (2018)

Hydrographs for select WSC gauges listed in Table 6-6 are provided on Figures 6-13 to 6-20 below. When more than one gauge is present on the same watershed, a hydrograph was produced for the gauge located furthest downstream and/or with the longer period of record. As illustrated on the hydrographs, the rivers all exhibit similar seasonal patterns, with the highest flows being associated with the spring snowmelt, peaking around March-April, and seasonal low flow occurring in the summer, typically reaching its lowest point around August-September.

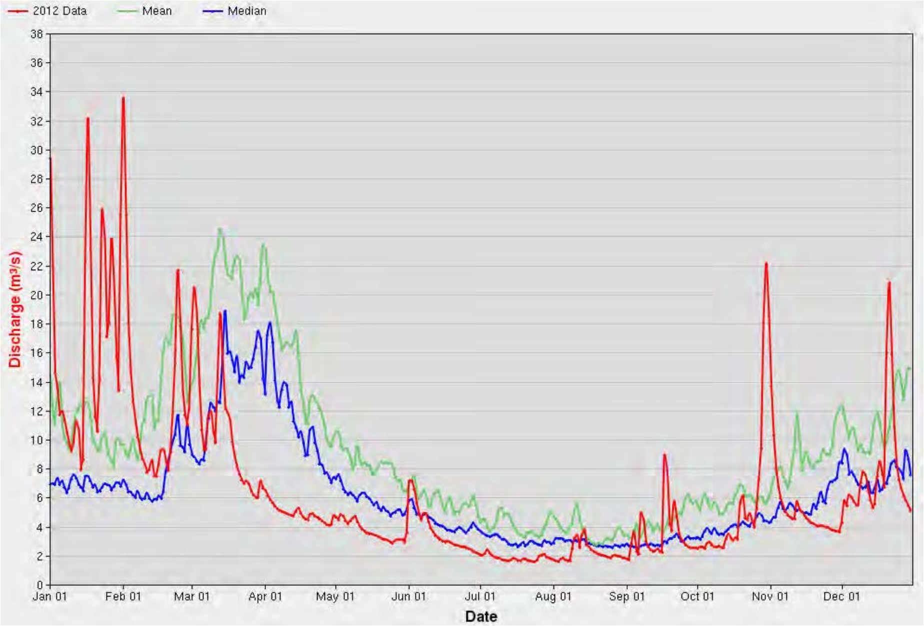


Text Figure 6-13. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GD016 (Thames River At Ingersoll). (Source: WSC, 2018).

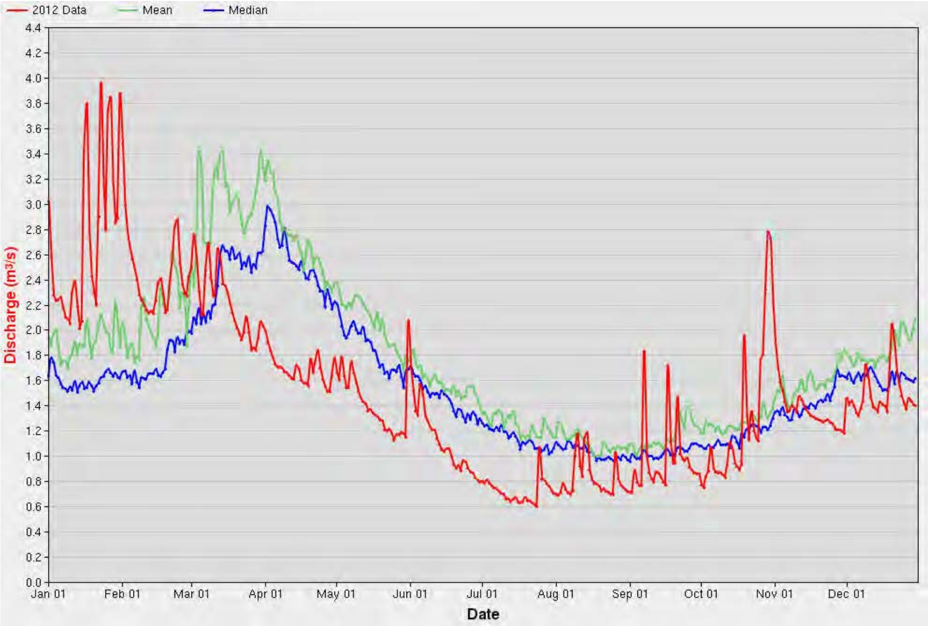


Text Figure 6-14. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GC018 (Catfish Creek Near Sparta). (Source: WSC, 2018).

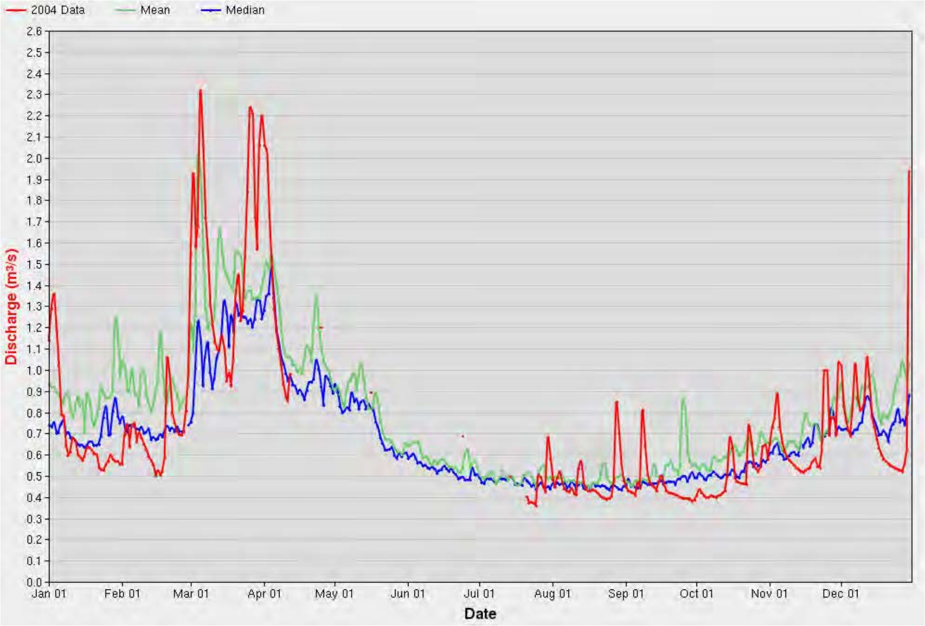
Text Figure 6-15. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GC007 (Big Creek Near Walsingham). (Source: WSC, 2018).



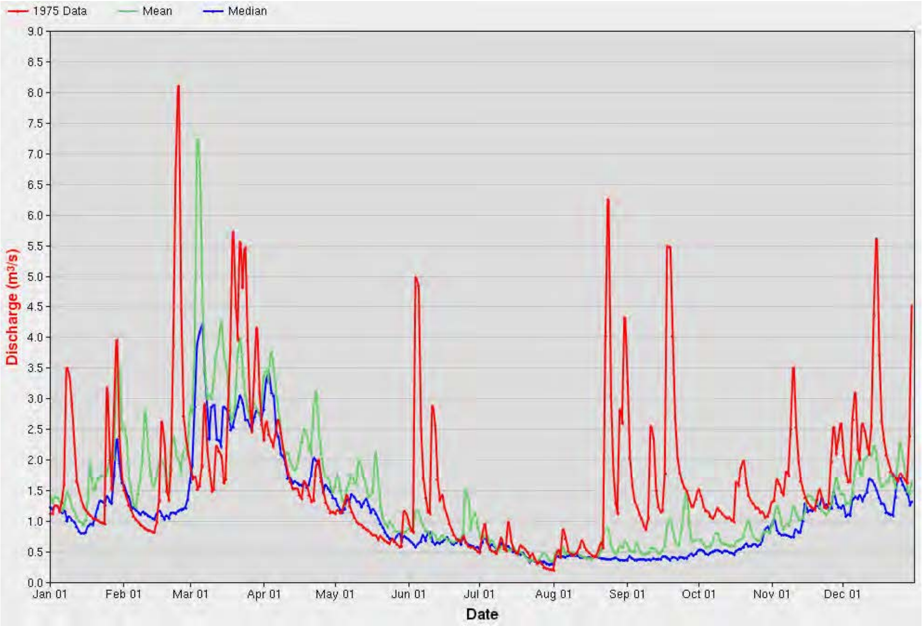
Text Figure 6-16. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GC026 (Big Otter Creek Near Calton). (Source: WSC, 2018).



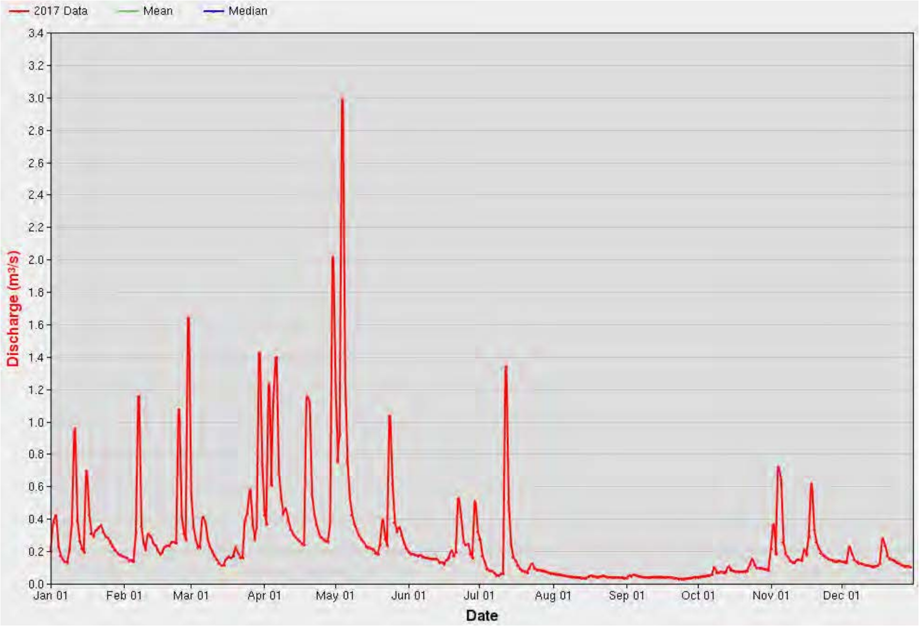
Text Figure 6-17. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GC008 (Lynn River at Simcoe). (Source: WSC, 2018).



Text Figure 6-18. Mean daily streamflow (green line), median daily streamflow (blue line) and 2004 (relatively low flow year) daily streamflow (red line) at 02GC014 (Young Creek Near Vittoria). (Source: WSC, 2018).



Text Figure 6-19. Mean daily streamflow (green line), median daily streamflow (blue line) and 1975 (relatively low flow year) daily streamflow (red line) at 02GC016 (South Otter Creek Near Port Burwell). (Source: WSC, 2018).



Text Figure 6-20. Daily streamflow from 2017 (red line) at 02GC037 (Nanticoke Creek Near Dundurn). Period of record only goes back to 2015, so there is insufficient data to produce mean and median flows. (Source: WSC, 2018).

Surface Water Budget – Long Point Region Watershed

The surface water budget components for the Long Point Region watershed were calculated as part of a larger study encompassing Catfish Creek, Kettle Creek and LPR. As such, Conceptual Water Budget and Tier One assessments were not required to be completed separately. The results of the water budget and Tier Two stress assessment are documented in the Assessment Report for the Long Point Region Source Protection Area (LESPR, 2015), and discussed below.

Precipitation inputs into the watershed were estimated at approximately 85.5 m^3/s (956 mm/year); of this, approximately 48.4 m^3/s (542 mm/year) is lost to evapotranspiration, 17.1 m^3/s (191 mm/year) is transported as runoff, 17.1 m^3/s (191 mm/year) goes towards recharging the aquifers, and approximately 0.79 m^3/s (9 mm/year) is consumed and not immediately returned to the surface water system. Precipitation and evapotranspiration rates are fairly consistent across the watershed. Runoff and recharge rates have significant spatial variability due to differences in soils, surficial geology and land cover. For example, for the subwatersheds within the WQSA, runoff rates vary from 81 mm/year (0.18 m^3/s) in the "Big Above Minnow Creek" subwatershed (south of Delhi) to 281 mm/year (0.86 m^3/s) in the Lower Big Creek subwatershed. Recharge rates vary from 163 mm year (0.69 m^3/s) in the Black Creek subwatershed to 348 mm/year (0.80 m^3/s) in the "Big Above Minnow Creek" subwatershed.

Throughout the Long Point Region watershed, surface water consumptive demand varies seasonally, typically being significantly larger during the June – September period compared to the rest of the year. Summer surface water demand is the highest in the "Big Above Walsingham" subwatershed (peaking at 251 L/s in August) and in the "Big Above Delhi" subwatershed (peaking at 264 L/s in August). For seven of the subwatersheds in the WQSA, the maximum monthly percent water demand for surface water exceeds 20% (the threshold for a surface water potential stress classification of Moderate):

- South Otter: 44% (September)
- Big Above Delhi: 22% (September)
- North Creek: 69% (August)
- Venison Creek: 33% (July and September)
- Dedrick Creek: 22% (September)
- Young/Hay Creeks: 55% (June)
- Nanticoke Upper: 35% (August)

As the maximum monthly percent water demand for the Young/Hay Creeks subwatershed and the North Creek subwatershed exceeded 50%, they were determined to have a surface water potential stress classification of Significant; the five other subwatersheds listed above were assigned as potential stress classification of Moderate. Based on the results of an uncertainty analysis, in which it was determined that the Lynn River subwatershed (with a maximum monthly percent water demand was 19%) had an uncertainty classification of High, the surface water potential stress classification of the Lynn River subwatershed was raised from Low to Moderate.

Of the subwatersheds with a potential stress classification of Moderate or Significant, only the North Creek subwatershed supports a municipal water supply using surface water, namely the Lehman Reservoir intake for Delhi. The Delhi surface water intake therefore met the requirements for a Tier Three Water Quantity Risk Assessment.

A Tier Three Water Budget and Local Area Risk Assessment was completed for the Delhi water supply system by Matrix Solutions Inc. (2015). The objective of the Tier Three assessment was to evaluate the risk associated with a municipality not being able to meet its future water quantity requirements, accounting for factors such as municipal water demand, future land development, drought conditions, and other water uses. For the Lehman Reservoir intake, the impact of takings on downstream water uses was assessed by running a set of risk assessment scenarios; the scenarios differed from one another in terms of land cover (existing vs. planned), water demand (existing vs. allocated), and water levels (average vs. minimum over the time period 1960 to 2010). Based on the simulated decline in reservoir water level relative to the reservoir overflow structure under average and drought conditions, it was determined that there would be a Low Risk Level, with High certainty, associated with the operation of the Lehman intake.

The drainage area contributing surface water and the area providing recharge to an aquifer that contributes groundwater discharge to the drainage area (IPZ-Q) was delineated for the Lehman Reservoir intake as part of the Tier Three assessment. The IPZ-Q was determined to include the reaches and tributaries of North Creek and South Creek west of Delhi. A limited volume of groundwater discharging into the streams is predicted to come from outside the catchment area.

Surface Water Budget – Catfish Creek Watershed

The surface water budget components for the Long Point Region watershed were calculated as part of a larger study encompassing Catfish Creek, Kettle Creek and Long Point Region. As such, Conceptual Water Budget and Tier One Assessments were not required to be completed separately. The results of the Water Budget and Tier Two Stress Assessment are documented in the Assessment Report for the Catfish Creek Source Protection Area (LESPR, 2014), and discussed below.

Precipitation inputs into the watershed were estimated at approximately 14.14 m^3/s (914 mm/year); of this, approximately 8.85 m^3/s (573 mm/year) is lost to evapotranspiration, 2.85 m^3/s (185 mm/year) is transported as runoff, 2.42 m^3/s (157 mm/year) goes towards recharging the aquifers, and approximately 0.07 m^3/s (5 mm/year) is consumed and not immediately returned to the surface water system. Precipitation inputs and evapotranspiration rates are fairly consistent across the watershed. Runoff is relatively higher and recharge is relatively lower in the upper half of the watershed (consisting mainly of low relief tight soils) compared to the lower half (mainly Norfolk Sand Plain): average annual runoff in the West Catfish and Catfish above Aylmer subwatersheds are 235 mm/year and 202 mm/year, respectively, compared to 142 mm/year and 124 mm/year in the Lower Catfish and Silver Creek subwatersheds, respectively. Average annual recharge in the West Catfish and Catfish above Aylmer subwatersheds are 109 mm/year and 135 mm/year, respectively, compared to 203 mm/year and 215 mm/year in the Lower Catfish and Silver Creek subwatersheds, respectively.

Throughout the Catfish Creek watershed, surface water consumptive demand varies seasonally, typically being significantly larger during the June – September period compared to the rest of the year. Summer surface water demand is the highest in the Lower Catfish subwatershed, peaking at 93 L/s in August. In comparison, the peak monthly surface water demand in Silver Creek, West Catfish and Catfish Above Aylmer are 80 L/s, 3 L/s and 19 L/s, respectively, also occurring in August (except for the West Catfish subwatershed, where monthly surface water demand is constant at 3 L/s year-round). The maximum monthly percent water demand for surface water exceeds 20% for three of the four subwatersheds in Catfish Creek:

- Catfish Above Aylmer: 22% (August and September)
- Lower Catfish: 36% (August)
- Silver Creek: 57% (August)

The Catfish Above Aylmer and Lower Catfish subwatersheds were assigned a surface water potential stress classification of Moderate. As the maximum monthly percent water demand for Silver Creek exceeds 50%, it was assigned a surface water potential stress classification of Significant. The maximum monthly percent water demand for the West Catfish subwatershed is 12% (occurring in August), so the subwatershed was assigned a potential stress classification of Low.

There are no municipal water supplies using surface water in the Catfish Creek watershed, so a Tier Three stress assessment was not required for any of the subwatersheds.

Surface Water Budget – Kettle Creek Watershed

The surface water budget components for the Kettle Creek watershed were calculated as part of a larger study encompassing Catfish Creek, Kettle Creek and Long Point Region. As such, a conceptual water budget and Tier One assessments were not required to be completed separately. The results of the water budget and Tier Two stress assessment are documented in the Assessment Report for the Kettle Creek Source Protection Area (LESPR, 2014), and discussed below.

Precipitation inputs into the Upper Kettle Creek watershed were estimated at approximately 6.12 m^3/s (970 mm/year); of this, approximately 3.84 m^3/s (608 mm/year) is lost to evapotranspiration, 1.50 m^3/s (237 mm/year) is transported as runoff, 0.79 m^3/s (125 mm/year) goes towards recharging the aquifers, and less than 0.01 m^3/s (1 mm/year) is consumed and not immediately returned to the surface water system.

Precipitation inputs into the Lower Kettle Creek watershed were estimated at approximately 5.84 m^3/s (970 mm/year); of this, approximately 3.70 m^3/s (615 mm/year) is lost to evapotranspiration, 1.09 m^3/s (181 mm/year) is transported as runoff, 1.05 m^3/s (174 mm/year) goes towards recharging the aquifers, and approximately 0.01 m^3/s (2 mm/year) is consumed and not immediately returned to the surface water system.

Surface water consumptive demand in the Upper Kettle subwatershed is fairly low throughout the year, peaking slightly at 5 L/s from June to September, and remaining at 3 L/s for the remainder of the year. Surface water consumption is greater in the Lower Kettle subwatershed, ranging from 31 to 43 L/s in the summer (peaking in August), compared to 3 L/s during the remainder of the year. The potential for surface water stress in the two subwatersheds was classified as Low. Due to this classification, and the absence of municipal water supplies using surface water in the Kettle Creek watershed, a Tier Three stress assessment was not required.

Surface Water Budget – Upper Thames River Watershed

The surface water budget components for the Upper Thames River watershed were calculated as part of a conceptual water budget and Tier One water budget, the results of which are documented in the Assessment Report for the Upper Thames River Source Protection Area (TSRSPC, 2015), and discussed below.

Precipitation inputs into the Reynolds Creek subwatershed were estimated at approximately 417,016 m^3/day, of which 247,516 m^3/day is lost to evapotranspiration and 168,107 m^3/day leaves the subwatershed as surface water outflow. The remaining 1,393 m^3/day is inferred to go towards groundwater recharge.

For the subwatersheds located within the WQSA, precipitation inputs range from 906 to 999 mm/year, of which 542 to 573 mm/year is lost to evapotranspiration. Demand for surface water is highest during the June to September period, typically peaking in July. Average surface water demand in July ranges from 1,748 m^3/day in the Cedar Creek subwatershed, to 23,810 m^3/day in the "Waubuno Creek/Thames River Tributaries" subwatershed (TSR, 2010).

For all subwatersheds of the Upper Thames River overlapping with the WQSA, the potential for surface water stress was determined to be Low. Due to this classification, and the absence of municipal water supplies using surface water in the Upper Thames River watershed, no further assessment of surface water stress was required.

6.3.1.3 Water shortages

Municipal shortages

Determining the existence and cause of water shortages at municipal supplies is often aided by a sophisticated monitoring program, typically required by the permit, which includes high resolution pumping and water level monitoring data. This allows the permit holder to quickly determine the existence of the shortage, and vector in on the source of the shortage using monitoring and pumping data. Through communications with water managers at the MECP and in the Norfolk Sand Plain WQSA, two documented instances of water shortages at municipal supply sources are summarized below:

Springford/Otterville:
Static groundwater levels in the confined overburden and bedrock aquifers have been observed to drop by several metres during the summer months in the area near Springford and Otterville, located to the northeast of Tillsonburg and in the north-central portion of the study area. The Ministry has determined that this seasonal drop in groundwater levels is primarily attributed to water taking from the confined overburden and bedrock aquifers for the purpose of agricultural irrigation. There are several PTTW holders in the local geographic area that are known to take groundwater from the confined overburden and bedrock aquifers for agricultural irrigation.

The County of Oxford operates two municipal supply wells in the community of Springford. The municipal wells are installed within the confined overburden aquifer which lies immediately above the bedrock. Since approximately 2012, these municipal supply wells have been taken offline due to low groundwater levels in the summer months. Municipal water for the community has since been provided by a piped supply from the nearby communities of Otterville and Norwich. The County has indicated that they would like to re-establish a viable groundwater supply in Springford. There are indications that private water supply wells in the area may also be impacted by the seasonal drop in groundwater levels.

As a result of the potential for groundwater interference, the Ministry is requiring more stringent monitoring conditions for PTTW issued in the local geographic area, including requirements for groundwater level monitoring and reporting. The Ministry has also worked with the County of Oxford and private well owners to establish a monitoring network to evaluate groundwater levels during the irrigation season. The Ministry has been collecting and reviewing the monitoring data in the area with the goal of evaluating the cumulative impact of multiple large groundwater users. MECP and OMAFRA staff have also met with PTTW holders to review their data and water taking practices to ensure PTTW holders are using the groundwater resource as efficiently as possible.

The Ministry will continue to work with local PTTW holders including the agricultural community and municipalities as well as OMAFRA to develop a long-term solution to manage the groundwater resource in this area.

Mt. Elgin:

The County of Oxford operates a municipal water supply well in the community of Mt. Elgin, located approximately 10 km north of Tillsonburg in the north-central portion of the study area. In 2016, the Ministry was contacted by representatives of the County of Oxford regarding groundwater level interference that was causing operational issues for the Mt. Elgin supply well. It was subsequently determined that groundwater taking by another nearby PTTW holder was causing excessive drawdown in the municipal supply well. Both wells obtain water from the same confined bedrock aquifer.

A solution to manage the interference problem was found as a result of the ministry working collaboratively with the County and the neighboring PTTW holders. The interference problem was resolved by reducing the pumping rate for the PTTW holder that was causing the interference. As a result, the same volume of groundwater is withdrawn from the aquifer, but at a lower rate and over a longer time period. This solution allowed both the municipality and the neighbouring PTTW holder to satisfy their water taking needs.

In addition to the documented water shortages the Tier Three Local Area Risk Assessment model simulations completed for the Town of Simcoe determined that the towns Cedar St water supply wells may be stressed under existing conditions and future demand conditions. The results of the simulation are discussed in detail in section 8.3.1.3.

Non Municipal Shortages

The main mechanism for determining a pattern of non-municipal water shortages in the WQSA is a review of the frequency and level of OLWR declarations since a significant number of PTTW holders rely on surface water and shallow groundwater resources. A qualitative review of these is discussed later in this section on a watershed basis. The OLWR program is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre which utilizes the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater level elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in the future.

When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR notification combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies a Low Water Conditions Alert 'may' be posted by the CA/municipality. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 – A voluntary reduction of 10%
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

OLWR declarations are typically watershed wide, however in larger watersheds, such as in the Long Point Region; the Long Point Region Conservation Authority (LPRCA) has divided the watershed into three Low Water Response Zones, which roughly represent the eastern, central, and western areas of the watershed.

While OLWR declarations allow for water conservation practices to be enacted periodically based on the declaration level, they are based on flow gauges and precipitation, and not instances of actual shortages reported by PTTW holders. It may be useful to develop a system that allows PTTW holders to report water shortages in the same way that water taking are reported annually. A farm survey conducted in 2007 as part of the Norfolk Agricultural Water Assessment and Management Strategy found that of the 81 agricultural PTTW holders that responded to the survey, 18 (22%) reported a water shortage (groundwater, surface water or both) in the previous year (AMEC, 2008). The shortages documented were focused in the North Creek and South Creek watersheds. The report noted that 2007 was significantly drier than most years, having 26% less precipitation than the 30 year average for the Norfolk area between 1971 and 2000.

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'.

Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the WQSA.

Long Point Region Watershed

The OLWR database indicates that a total of 20 Level 1 notifications, 5 Level 2 notifications and one Level 3 notification were sent to the Long Point Region CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2004 (five Level 1 notifications), 2005 (one Level 1 notification and one Level 2 notification), 2006 (two Level 1 notifications), 2010 (four Level 1 notifications), 2015 (three Level 1 notifications) and 2016 (one Level 1 notification and four Level 2 notifications). A Level 3 notification was posted in late July 2012. The Long Point Region CA posted Low Water Condition Alerts during 11 periods for the Long Point Region watershed as a whole:

- Periods when only a Level 1 Low Water Condition Alert was posted:
    - Mid-August 2003, for one week;
    - Mid-September 2003 to mid-December 2003;
    - October 2004 to mid-March 2005;
    - Mid-June 2005 to mid-November 2005;
    - Mid-June 2007 to early February 2008;
    - August 2011 to early October 2011;
    - Mid-July 2016 to mid-May 2017;
- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
    - June 2001 to early November 2001: a Level 1 Low Water Condition Alert was posted in June 2001, which was raised to a Level 2 in late July. The Low Water Condition Alert ended entirely in early November 2001;
    - Mid-July 2002 to mid-September 2002: a Level 2 Low Water Condition Alert was posted for two months;
    - Mid-October 2002 to early May 2003: a Level 2 Low Water Condition Alert was posted in mid-October 2002, which was lowered to a Level 1 in early November 2003. The Low Water Condition Alert ended entirely in early May 2003;
    - Mid-May 2012 to mid-November 2012: a Level 1 Low Water Alert was posted in mid-May 2012, which was raised to a Level 2 in mid-July, and lowered back down to a Level 1 in late October. The Low Water Condition Alert was removed entirely in mid-November.

Low Water Condition Alerts were also posted to the subwatersheds. When a Low Water Condition Alert was posted for the Long Point Region watershed as a whole, the same level or lower was generally also posted to the subwatersheds. Instances when the subwatersheds were under a higher Low Water Condition Alert than the watershed as a whole included:

- 2002: the subwatersheds were under a Level 1 Low Water Condition Alert in mid-July, one week before the Low Water Condition Alert began as a Level 2 for the watershed a whole. In addition, while there was a period of three weeks between mid-September and mid-October when no Low Water Condition Alert was posted for the Long Point Region watershed, the Big Otter and Big Creek subwatersheds were under a Level 2 and a Level 1 Low Water Condition Alert, respectively;
- 2005: While the Level 1 Low Water Condition Alert ended entirely for the Long Point Region watershed in mid-July, it ended one week later for the subwatersheds;
- 2007: While the Long Point Region watershed as a whole was under a Level 1 Low Water Condition Alert, the Big Otter subwatershed and the East Basin were under a Level 2 Low Water Condition Alert from mid-August (for Big Otter) or mid-July (East Basin), until mid-December.

Catfish Creek Watershed

The OLWR database indicates that a total of 15 Level 1 notifications, 10 Level 2 notifications and two Level 3 notifications were sent to the Catfish Creek CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2000 (two Level 1 notifications), 2002 (one Level 1, one Level 2 and one Level 3 notifications), 2004 (one Level 1 and two Level 2 notifications), 2005 (one Level 1 and four Level 2 notifications), 2012 (one Level 1 and one Level 3 notifications), 2013 (two Level 1 notifications), 2015 (two Level 1 notifications), and 2016 (one Level 1 and two Level 2 notifications). The Catfish Creek CA posted Low Water Condition Alerts during 11 periods:

- Periods when only a Level 1 Low Water Condition Alert was posted:
    - October 2004 to early January 2005;
    - Mid-June 2005 to mid-October 2006;
    - June 2010 to early April 2011;
    - Mid-June 2015 to mid-August 2015;
    - Mid-July 2016 to early June 2017;
    - Late August 2017 to early February 2018;
    - Mid-July 2018 to end of August 2018.

- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
    - Late July 2002 to mid-June 2004: a Level 1 Low Water Alert was posted in late July 2002, which was raised to a Level 2 in late August 2002. The Level 2 remained in effect for over a year before it was lowered back down to a Level 1 in mid-November 2003. The Low Water Condition Alert was removed entirely in mid-June 2004;
    - July 2007 to mid-February 2008: a Level 1 Low Water Alert was posted in July 2007, which was raised to a Level 2 in late July 2007. The Low Water Condition Alert was removed entirely in mid-February 2008;
    - Mid-July 2011 to early October 2011: a Level 1 Low Water Alert was posted in mid-July 2011, which was raised to a Level 2 in late July, and lowered back down to a Level 1 at the end of August. The Low Water Condition Alert was removed entirely in early October 2011;
    - Early May 2012 to early July 2013: a Level 1 Low Water Alert was posted in early May 2012, which was raised to a Level 2 in late May 2012, and lowered back down to a Level 1 in mid-October 2012. The Low Water Condition Alert was removed entirely in early July 2013.

Kettle Creek Watershed

The OLWR database indicates that a total of 19 Level 1 notifications and 10 Level 2 notifications were sent to the Kettle Creek CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2002 (two Level 1 and two Level 2 notifications), 2003 (two Level 2 notifications), 2004 (five Level 1 notifications), 2005 (two Level 1 notifications), 2010 (two Level 1 notifications), 2012 (two Level 1 and two Level 2 notifications), 2016 (one Level 1 and two Level 2 notifications), and 2018 (two Level 1 notifications). The Kettle Creek CA posted Low Water Condition Alerts during seven periods:

- Periods when only a Level 1 Low Water Condition Alert was posted:
    - Late August 2002 to mid-June 2004;
    - Mid-September 2010 to early November 2010;
    - Mid-July 2011 to late September 2011;
- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
    - Mid-June 2005 to early May 2006: a Level 1 Low Water Alert was posted in mid-June 2005, which was raised to a Level 2 in mid-July 2005, and lowered back down to a Level 1 in mid-August 2005. The Low Water Condition Alert was removed entirely in early May 2006;

  - Mid-July 2007 to mid-March 2008: a Level 1 Low Water Alert was posted in mid-July 2007, which was raised to a Level 2 in early September 2007, and lowered back down to a Level 1 in mid-January 2008. The Low Water Condition Alert was removed entirely in mid-March 2008;
  - Mid-May 2012 to mid-November 2012: a Level 1 Low Water Alert was posted in mid-May 2012, which was raised to a Level 2 in early August. The Low Water Condition Alert was removed entirely in mid-November 2012;
  - Mid-July 2016 to mid-March 2017: a Level 1 Low Water Alert was posted in mid-July 2016, which was raised to a Level 2 in mid-October 2016, and lowered back down to a Level 1 in late February 2017. The Low Water Condition Alert was removed entirely in mid-March 2017.

Upper Thames River Watershed

The OLWR database indicates that a total of 31 Level 1 notifications, and 8 Level 2 notifications and one Level 3 notification were sent to the Upper Thames River CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2000 (three Level 1 notifications), 2001 (two Level 1 notifications), 2003 (two Level 1 notifications), 2004 (six Level 1 notifications), 2005 (two Level 1 and three Level 2 notifications), 2006 (one Level 1 and one Level 2 notifications), 2007 (two Level 1 notifications), 2010 (two Level 1 notifications), 2011 (two Level 1 notifications), 2012 (one Level 1, one Level 2 and one Level 3 notifications), 2013 (two Level 1 notifications), 2015 (three Level 1 notifications), and 2016 (one Level 1 and two Level 2 notifications). The Upper Thames River CA posted Low Water Condition Alerts during 10 periods:

- Periods when only a Level 1 Low Water Condition Alert was posted:
  - Mid-September 2003 to mid-November 2003;
  - Early July 2005 to mid-March 2006;
  - Mid-July 2006 to mid-October 2006;
  - Early December 2009 to early July 2010;
  - Mid-October 2015 to early April 2016;
  - Mid-October 2017 to mid-January 2018;
- Periods when Level 1 and Level 2 Low Water Condition Alerts were posted:
  - Mid-July 2002 to end of April 2003: a Level 1 Low Water Alert was posted in mid-July 2002, which was raised to a Level 2 in mid-September 2002. The Low Water Condition Alert was removed entirely at the end of April 2003;

- Mid-July 2007 to early February 2008: a Level 1 Low Water Alert was posted in mid-July 2007, which was raised to a Level 2 in mid-August 2007, and lowered back down to a Level 1 in mid-January 2008. The Low Water Condition Alert was removed entirely in early February 2008;
- Late March 2012 to mid-May 2013: a Level 1 Low Water Alert was posted in late March 2012, which was raised to a Level 2 in early May 2012, and lowered back down to a Level 1 in mid-March 2013. The Low Water Condition Alert was removed entirely in mid-May 2013;
- Mid-July 2016 to mid-February 2017: a Level 1 Low Water Alert was posted in mid-July 2016, which was raised to a Level 2 in mid-November 2016, and lowered back down to a Level 1 in mid-January 2017. The Low Water Condition Alert was removed entirely in mid-February 2017.

Overall, the OLWR database indicates that the CAs have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts for their respective jurisdictions. However, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends. As notifications and alerts are on a watershed scale rather than subwatershed scale, the relevance to specific subwatersheds within the WQSA cannot be readily determined from the available posted data.

6.3.2 Assessment of Sustainability of Water Resources

6.3.2.1 Climate Change

Given the climate change statistics available through the Ontario Climate Data Portal, within the Norfolk Sand Plain WQSA it is estimated that precipitation may decrease by 3% in the summer months and increase by 16% in the winter months, while average annual temperature may increase by 3.2°C. It should be noted that these values are projected averages and are associated with a level of uncertainty.

A 2014 climate change modelling study in the Grand River Watershed Management Plan looked at how climate change over the next half century may affect surface water and groundwater resources. The results of this study are summarized below (GRCA, 2014a).

Surface Water

Based on modelling scenarios, surface water may see increased flows during winter months and early spring due to snow pack melt. However, it is predicted that seasonal low flow periods will likely start earlier and end later, possibly spanning the irrigation season. An increase in the intensity and duration of low flow periods may be problematic for surface water users in the WQSA. The Grand River Watershed Management Plan suggests possible mitigation approaches for low flow months including filling reservoirs during spring flows. The establishment and continued implementation of surface water sourced offline impoundment or storage ponds should also be considered, as these would allow surface water takers (and groundwater takers in some cases) to pump water from the source during high flows, which can then be used for irrigation during low flow periods when allowable takings from the source are potentially reduced under the Ontario Low Water Response program for example. These mitigation approaches are mainly directed toward agricultural takers, as 95% of permitted surface water takings in the WQSA are for agriculture.

Groundwater

Modelling by the GRCA (GRCA, 2014a) looked at ten different climate scenarios that may occur in the future in each of the subwatersheds in the Grand River watershed. The ten simulations modelled a combination of potential precipitation and temperature scenarios that may occur in the future due to climate change. In five of the scenarios groundwater recharge decreased slightly, in four it increased, and one remained similar to baseline conditions. Baseline recharge in subwatershed is estimated to be 92 mm/year. Averaging all ten scenarios, recharge is expected to decrease by 1 mm to 91 mm/year. For the Mckenzie Creek subwatershed, located in the northeast portion of the WQSA, a groundwater stress assessment based on the outcomes of all ten scenarios showed the subwatershed remaining within the "low stress" classification.

A portion of the Mckenzie creek subwatershed is within Norfolk Sand Plain (highly permeable material, a shallow groundwater table), which makes up much of the WQSA and thus the above findings may be reasonably relevant to much of the WQSA. In the same GRCA climate change study, the Whitemans Creek subwatershed (also partially located in the Norfolk sandplain immediately north of the Norfolk Sand Plain WQSA), future recharge (average of the ten climate change scenarios) is also modelled to decline from a baseline of 218 mm/year to 215 mm/year (~1% decline), similar to findings in Mckenzie creek.

6.3.2.2 Population Growth

As noted above, current population projections for the Norfolk Sand Plain WQSA suggest that the area is not expected to have significant population growth pressures. Population growth was also considered in the Tier Three studies where it was determined that locally; municipal populations may increase slightly over the coming decades. The Long Point Tier Three study, which covers the municipal water supplies of Simcoe, Delhi and Waterford, determined that the total allocated demand, which combines committed demand (accounts for expected population growth) and existing demand will remain well below the current total permitted rates (Matrix, 2013). Given that permitted rates for municipal water supplies are determined by a rigorous groundwater study to support their Category 3 Permit to Take Water Application, it is assumed that their approval by the MECP satisfies any necessary sustainability requirements. With the exception Cedar St well field identified in the Tier Three Study (Matrix, 2016), municipal supplies in the WQSA, which are largely groundwater takings, are likely sustainable when considering population growth in the municipalities. This statement is further supported by the sustained water levels in the available PGMN network as described above.

6.3.2.3 Cumulative Effects

BluMetric has not identified nor been made aware of any reported interference issues between permitted and non-permitted water takings.

There is a high density of permitted takers in the Norfolk Sand Plain WQSA. The Long Point Region, comprising a large part of the WQSA, has among the highest number of permitted surface and groundwater users of any area in Southern Ontario (LPRCA, 2008; see also Section 6.2.7.1). The density of takers is also illustrated on Figure 6-11. As noted in Section 6.2.7.1, permitted surface and groundwater takings for agriculture represent the single largest group of users by number of permits and volume of water taken in the WQSA at approximately 41% of reported takings in the WQSA (28% groundwater, 7.2% surface water, 6.0% both). Permits for agriculture represent 90% of active PTTW in the WQSA. Commercial permitted takings make up the second largest demand, roughly 35% of total volume taken in the Norfolk Sand Plain WQSA (1% groundwater, 20% surface water, 13% both). Among commercial takings, aquaculture is the dominant taker, using 27% of the total volume taken, while Golf Course Irrigation and Other Commercial uses make up 8% of the total.

There is evidence of historical impacts of water takings on the natural functions of the ecosystem, although this evidence is limited to Big Creek. As noted in a 2002 study, there have been reports of fish kills in Big Creek due to creek water levels falling below low flow targets and sometimes drying up completely in areas below water control structures, which the study attributed to rapid water takings from reservoirs along Big Creek coinciding with high demand water takings for irrigation. Water managers in the Long Point area, who were consulted as part of the present study, were anecdotally aware of these past impacts, but were not aware of such impacts having occurred in recent years. Environmental flow needs and the natural functions of the ecosystem have generally not been adequately characterized in the Norfolk Sand Plain WQSA, particularly outside of Big Creek.

There is no evidence of significant decline in hydraulic head in regional groundwater resources (Section 6.3.1.1). Of the 18 PGMN wells in the Norfolk Sand Plain WQSA, the Mann Kendall analysis determined that 16 of the 18 wells had no trends in water levels year over year, while two wells had upward trends. The Seasonal Mann Kendall analysis established that 13 wells had upward water level trends, three had no trend, and two had a downward trend.

Review of the OLWR database indicates that the CAs in the Norfolk Sand Plain WQSA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts for their respective jurisdictions. However, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends (Section 6.3.1.3).

The Norfolk Sand Plain WQSA is an area where cumulative effects have, and may potentially continue to be a concern in the future, at least at a local level for groundwater supply. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Norfolk Sand Plain WQSA lies within a tertiary watershed that is classified as having a High percent water use based upon both the Average Annual and Summer Low Flow (Section 6.3.1). In addition, of the 31 subwatersheds considered in the Long Point, Catfish Creek and Kettle Creek Integrated Tier Two groundwater stress assessment under estimated maximum demand conditions, 4 have a moderate potential for stress and 2 have significant potential for stress (Aqua Resources, 2009b; see also Section 6.3.1.1). Four of these subwatersheds were subject to a Tier Three assessment to assess the risk of water quantity stress posed to the municipal supply systems based on the findings of the Tier Two study; of these, only the Cedar St Wells (Simcoe water supply) were found to be at risk of water quantity issues, based on no additional available drawdown. With respect to surface water stress, three subwatersheds in the WQSA were classified as having a surface water potential stress classification of Significant, and eight having a surface water potential stress classification of Moderate (Section 6.3.1.2). A Tier Three Water Budget and Local Area Risk Assessment was completed for the Town of Delhi municipal water supply, which simulated declines in reservoir water level relative to the reservoir overflow structure under average and drought conditions. It was determined that there would be a Low Risk Level, with High certainty, associated with the operation of the Lehman intake.

Numeric modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

Through communications with water managers at the MECP and in the Norfolk Sand Plain WQSA, two documented examples of water shortage incidences at municipal supply sources were provided (Section 6.3.1.3).

In the Village of Springford/Otterville, the municipal water supply has historically faced seasonal water level interference issues due to a high concentration of agricultural groundwater takers during irrigation season. To address this, the Ministry collected monitoring data in the area with the goal of evaluating the cumulative impact of multiple large groundwater users. MECP and OMAFRA staff have met with PTTW holders to review their data and water taking practices to ensure PTTW holders are using the groundwater resource as efficiently as possible.

The village of Mt Elgin has also observed and successfully mitigated the cumulative impacts of multiple takers. In the summer of 2016, the Mt. Elgin supply began having well operational issues as a result of excessive drawdown in the well. It was subsequently determined that groundwater taking by another nearby permitted holder contributed to drawdown in the supply well, as both wells obtain water from the same confined bedrock aquifer. The cumulative impacts of multiple takers were mitigated by reducing the pumping rate for the PTTW holder that was causing the interference. As a result, the same volume of groundwater is withdrawn from the aquifer, but at a lower rate and over a longer time period. In contrast to the water shortages in Springford/Otterville, which is attributable to climate conditions (the decline in static groundwater levels are reported to occur in the summer months), the water shortage in the County of Oxford was not explicitly linked to climate conditions or drought.

6.3.2.4 Environmental Flow Needs

Within the WQSA, assessing EFN has currently only focused around the Big Creek watershed. Conservation Ontario in conjunction with the LPRCA conducted an extensive study which looked at establishing the EFN for Big Creek (Conservation Ontario, 2005). A core finding of the study was as follows:

> *"The existing management methods, regulations and controls on instream flows in the Long Point Region need to be reviewed as part of a process to develop ecologically-based instream flow management and to set ecologically realistic controls. As an example of the current situation, actual quantities permitted under existing water taking permits in the Long Point Region could result in taking of water sufficient to dry all flows in many Long Point Region streams…"*

The 2002 Big Creek Basin Water Budget Study (Schroeter and Associates et al, 2002) reported multiple occurrences in particularly dry years (years not stated) of fish kills due to creek water levels falling below low flow targets and sometimes drying up completely in areas below water control structures. The study attributes the fish kills to rapid water takings from reservoirs along Big Creek coinciding with high demand water takings for irrigation. Water managers in the Long Point area confirmed that they were anecdotally aware that drawdown of some reservoirs to sustain downstream flow targets had led to fish kills in the past, but not in recent years. Changes in crop production have also systemically changed the amount of water that is used in the watershed, and may have implications for current ecological conditions compared to past conditions. Historically, tobacco was the dominant crop in the WQSA which consistently required irrigation; however, a significant decrease in tobacco production has correlated with a significant decrease in water use. Work conducted for the Norfolk Agricultural Water Assessment and Management Strategy found that historic annual water volumes used to irrigate tobacco averaged 1,200,000 m^3 (AMEC 2008). The report determined that in 2007 roughly 350,000 m^3 of water was used to irrigate tobacco while water usage for other crop increased only marginally.

Based on the data and information reviewed, Environmental Flow Needs are not adequately characterized with the possible exception of the noted Big Creek study (Schroeter and Associates et al, 2002) and the reported LPRCA Instream Flow Management Framework (Conservation Ontario, 2005). The anecdotal evidence of fish kills etc. have not been linked in the Tier Two or Tier Three water budgets studies and risk assessments. Given the noted level of groundwater/ surface water interaction in the WQSA it would be advisable for the WQSA to collect the necessary information needed to characterize EFN outside of the Big Creek system.

6.3.3 Conclusions

Groundwater

Given the available water budget stress assessments, PGMN well hydrographs, and climate change assessment reports, groundwater resources in the WQSA appear largely sustainable under present and with a greater deal of uncertainty under future conditions. However, making sustainability projections for water resources is inherently associated with uncertainty, and addressing the challenges and recommendations made later in this report will serve to refine predictions and more accurately understand water resource sustainability issues in the WQSA.

Of the 31 subwatersheds in the Long Point Region, Kettle Creek and Catfish Creek Tier Two study stress assessment (similar boundaries to the Norfolk Sand Plain WQSA), seven subwatersheds were rated to have moderate or significant potential for stress. These subwatersheds were either located in the Big Creek area, or host a municipal water supply system. Four of the seven subwatersheds were subject to a Tier Three assessment to assess the risk of water quantity stress posed to the municipal supply systems based on the findings of the Tier Two study. Of the four, only the Cedar St Wells (Simcoe water supply) were found to be at risk of water quantity issues, based on no additional available drawdown.

The PGMN network, which is the only available empirical data to assess groundwater level trends in the WQSA, suggests that groundwater resources are generally sustainable. The Mann Kendall analysis showed 16 of 18 PGMN wells showed neither upward or downward trends, while two showed upward trends. And, the Mann Kendall Seasonal analysis showed 13 of the 18 wells had upward water level trends, three had no trend, and two had a downward trend.

Based on available modelling, groundwater resources in the WQSA are predicted to be minimally impacted by the expected effects of climate change. The Mckenzie Creek subwatershed, located in the northeast portion of the WQSA was included in a GRCA climate change study which found that recharge is expected to decrease by 1 mm to 91 mm/year based on the average of ten climate change scenarios and as a result the subwatershed retains the "low stress" classification. A portion of the Mckenzie Creek subwatershed is within the Norfolk Sandplain (highly permeable material, a shallow groundwater table), which makes up much of the WQSA and thus the above findings may be reasonably relevant to much of the WQSA.

Surface Water

Surface water stress is an issue of concern for the WQSA, with three subwatersheds having been classified as having a surface water potential stress classification of Significant, and eight having a surface water potential stress classification of Moderate. In addition, degradation of coldwater habitat in the Long Point Region watershed has been reported, which is attributed, at least in part, to activities such as deforestation, channel straightening and impoundments, resulting in a warming trend in summer stream temperatures. Though the contribution of surface water takings to the degradation of coldwater habitat has not been studied in depth, the potential for surface water stress in many subwatersheds, particularly in the summer, indicates that surface water takings may compound the impacts currently experienced by aquatic ecosystems in the WQSA.

Despite the potential for surface water stress in many subwatersheds in the Norfolk Sand Plain WQSA, there is little direct evidence that surface water resources are unsustainable. The only in-land municipal water supply is used by the Town of Delhi, whose reliance on surface water has declined significantly since the 1990s, which is now predominantly used in a back-up capacity (Section 6.2.3.4). In contrast, there is anecdotal evidence that surface water takings for irrigation in dry years have resulted in ecological impact (fish kills) in Big Creek, with the creek sometimes drying up completely, and a strain on continued surface water takings (Schroeter and Associates et al., 2002; see also Sections 6.2.7.1 and 6.3.2.4). However, a review of hydrographs in the Norfolk Sand Plain WQSA (Section 6.3.1.2), including flow data from a dry year (2012), do not clearly indicate any severe impacts on surface water resources during the summer. In addition, changes in crop production over time (a significant decrease in tobacco production) have been correlated with a significant decrease in water use (Section 6.2.3.4). As such, surface water resources appear to be sustainable under existing conditions, but may be at risk of becoming unsustainable during dry years if there is a shift back to large scale tobacco production and reliance on surface water for municipal water supply. Continued monitoring of flows at WSC stream gauges and documentation of interference complaints and ecosystem impacts (e.g. fish kills) will allow the province to determine whether this changes.

No climate change modelling appears to have been conducted for surface water resources throughout most of the WQSA. Assessments of future conditions to surface water resources in the Norfolk Sand Plain WQSA appear to be limited to the Tier Three Water Budget and Local Area Risk Assessment for the Town of Delhi's municipal water supply, which evaluated the risk of the municipality not being able to meet its future water quantity requirements, taking into consideration changes in land cover, water demand and drought conditions (Section 6.3.1.2). The results indicate that there would be a Low Risk Level, with High certainty, associated with the surface water taking, and that surface water resources will continue to be sustainable, at least as they relate to the Town of Delhi's municipal water supply needs. However, there is a lack of information on the potential sustainability (or lack thereof) of surface water resources for the remainder of the WQSA. Similar scenario modelling for other areas in the WQSA with high surface water use would be required to address this gap.

In summary, the sustainability of the water resources in the Norfolk Sand Plain WQSA under current and future conditions is as follows:

Groundwater Under Current Conditions

- **Regional scale** – the groundwater resources are sustainable under current conditions based on the available water budget stress assessments and PGMN well hydrographs, and climate change assessment reports.
- **Local scale** – the groundwater resources are sustainable under current conditions, with the noted exception of the Town of Simcoe water supply (Cedar St Wells).

Groundwater Under Future Conditions

- **Regional scale** – the groundwater resources under future conditions are sustainable based on available modelling and the fact that population growth is not expected to be significant.
- **Local scale** – the groundwater resources under future conditions are sustainable based on available modelling and the fact that population growth is not expected to be significant.

Surface Water Under Current Conditions

- **Regional scale** – the surface water resources under current conditions are sustainable under existing conditions, but may be at risk of becoming unsustainable during dry years if there is a shift back to large scale tobacco production and reliance on surface water for municipal water supply.
- **Local scale** – the surface water resources under current conditions are sustainable at a local scale.

Surface Water Under Future Conditions

- **Regional scale** – the sustainability of surface water resources under future conditions is uncertain due to uncertainty related to projected future demand. As noted, some surface water resources may be at risk of becoming unsustainable during dry years if there is a shift back to large scale tobacco production and reliance on surface water for municipal water supply.
- **Local scale** – the surface water resources under future conditions are sustainable, based on the Tier Three Water Budget and Local Area Risk Assessment for the Town of Delhi's municipal water supply. The results indicate that there would be a Low Risk Level, with High certainty, associated with the surface water taking.

6.4 WATER MANAGEMENT APPROACHES AND CHALLENGES

A combination of available reports (Table 6-1) and communication with Water Managers with knowledge of local water use/issues in the Norfolk area was used to summarize current approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in Section 6.6 of this report, what, if any, new management tools are needed in the Norfolk Sand Plain WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches. Water managers from Long Point Region Conservation Authority, Norfolk County and the MECP were contacted and provided input to this study.

Current Approaches

MECP's West Central regional office delivers the PTTW program in the Norfolk Sand Plain WQSA and responds to well water and drought complaints.

Within the Norfolk Sand Plain WQSA, a range of legislation exists across multiple levels of government; however, generally water quantity is managed though the *Ontario Water Resources Act* and O. Reg. 387/04. The WQSA contains parts of both Lake Erie and Thames-Sydenham River Source Protection Committees. Source Protection Committees typically represent multiple Source Protection Areas which are responsible for developing Source Protection Plans which include plan policies that can require actions to reduce, eliminate or manage the identified risks to drinking water in the Source Protection Area. The Lake Erie Source Protection Committee within the WQSA consists of the Grand River, Long Point, Kettle Creek and Catfish Creek Source Protection Areas. The Thames-Sydenham River Source Protection Committee within the WQSA consists of the Upper Thames Source Protection Area.

In 2005, the MECP designated the Long Point, Kettle Creek, and Catfish Creek watersheds (which make up much of the WQSA) as a High Use Watershed based on a preliminary regional assessment (AquaResources 2009a). As discussed in Section 6.2.7.1, the High Use Watershed Designation places significant restrictions on obtaining PTTWs for most Purposes (O. Reg. 387/04 Section 5, High Use Watershed).

Through the *Municipal Act*, local municipalities have in place water use bylaws (such as the Watering Restriction By-Law in Norfolk County that restricts the external use of water (i.e. watering of lawns, filling of swimming pools or washing of vehicles) by premises served by Norfolk County owned water systems between May 15 and September 15 each year, while the provincially run (Ministry of Natural Resources and Forestry) OLWR program requires that low water response teams exist in all relevant watersheds of the Norfolk Sand Plain WQSA. Through correspondence with local water managers in the WQSA, it was determined that a variety of programs, projects and studies have been conducted in the WQSA which include drought contingency projects, water assessment and management strategies, water supply expansion projects, irrigation advisory committees and water users associations, and local stewardship and education/outreach initiatives.

Stakeholders working collaboratively on a case by case basis to solve water quantity issues have produced successful results in some areas. The MECP has worked with local PTTW holders and other stakeholders in Springford Mt. Elgin to resolve local water quantity issues (Section 6.3.1.1). A similar approach may be useful in the future for specific, localized issues in other part of the WQSA.

Challenges

Quantifying Demand

It has been widely recognized that the maximum permitted volumes are not reflective of the actual water use. Using maximum permitted volumes to estimate demand can result in a gross overestimation of the amount of water that is forecasted to be used. Therefore it is crucial that the WTRS continue to be implemented so that actual water use is well documented.

A 2011 Water Use report conducted by the GRCA found that as the WTRS was implemented between 2005 and 2010, the estimated water taking demand dropped from 298 million m^3 to 152 million m^3 despite a 14% growth in population within the Grand River watershed during this time (GRCA 2011). The report suggested that continued implementation and refinement of the WTRS could even further refine the estimated demand as only 55% of water taking activities were reporting their takings in 2011.

Many of the references to recorded water takings in this report cite annual takings as a percentage of the permitted amount, which are typically low. Based on 2017 WTRS takings, agriculture PTTWs had a 10% utilization rate over the year. However, this figure does not capture potential episodic periods of intense irrigation which may cause short term (days to weeks) utilization of the permitted rate to be significantly higher. Being able to easily identify spikes in permit utilization could help water managers understand the frequency or probability for which the theoretical problem of over allocation of water resources becomes a real problem.

Another issue with quantifying demand is the quality of the WTRS data, as it is self-reported, and often estimated based on pump run time and capacity. This is typical of most agricultural PTTWs in the province. With this type of reporting, it is possible that the reported amounts may not accurately reflect the actual amounts being pumped. Also, the water takings are not reported until the following year, as a result there is no way to assess the amount of water being taken in real time.

Degradation of Groundwater-Fed Irrigation Ponds and Switching to Less Stressed Sources

Over time, groundwater dugout irrigation ponds, which are prevalent in the Norfolk Sand Plain WQSA, can build up with fine sediment and become susceptible to bank slumping, both of which may lead to decreased recharge and diminished function as a reliable and efficient irrigation source. Multiple cases have been documented where farmers have reverted to or sought out an on line surface water source to supplement poor performance of their groundwater connected irrigation pond (GRCA 2014b). This type of scenario increases reliance on surface water, rather than decrease it, which may create issues particularly in areas that are susceptible to surface water stress, e.g. Big Creek, which has historically experienced significant reductions in water levels that were attributed to the high demand for irrigation (Section 6.3.2.4).

Underutilization of Deeper Aquifers

It has been noted in previous reports (Schroeter and Associates et al, 2002, AMEC, 2008), that intermediate and deep overburden, and bedrock aquifers in the WQSA are highly underutilized, and may offer a viable access to water for irrigation.

In general, the water takings in the study area appear to be sustainable. Suggestions and approaches made in this section about transitioning from one water source to another may only be appropriate when localized areas appear to be over stressed, or when particular users would like to secure sources that are more resistant to drought conditions. They are not intended as blanket policies for the entire region.

The intermediate and deep overburden aquifers (described in detail in Section 6.2.5.1) have been known to yield good quality water suitable for irrigation at varying yields. Schroeter and Associates et al. (2002) characterized and estimated potential well yields for the three major groundwater bearing units in the Big Creek area: shallow overburden unconfined, intermediate overburden confined, and deep overburden/bedrock. The report characterized the deep overburden and bedrock aquifer as one unit due to the irregular distribution of the deep overburden unit.

The report estimated that the intermediate overburden aquifer had a potential well yield of 10 to 80 litres per minute (LPM) in the Big Creek watershed. The deep overburden/bedrock unit was estimated to yield 30-100 LPM nearly everywhere in the Big Creek watershed, and in localized instances, between 300 and 1,000 LPM.

Historically, the bedrock aquifers have not been exploited or used, as easy access exists to shallow unconfined overburden aquifers and surface water. Bedrock water has been documented as poor and mineralized, however, it has been considered suitable for irrigation, particularly if water is provided residence time in a storage pond prior to use. The dominant obstacle to bedrock aquifer utilization is cost due to high drilling costs and energy utilization for pumps.

High Use Watershed Designation

As discussed in Section 6.2.7.1, the High Use Watershed Designation places significant restrictions on obtaining PTTWs for most Purposes (O. Reg. 387/04 Section 5, High Use Watershed). This is seen as a limit to development in Norfolk County. It is expected that upon review of the recently submitted Source Protection Plans for the area, the MECP may review this status; however, it currently remains in place.

Evaluation of how water management concerns are considered in water management decisions

As noted under *Challenges*, the MECP designated the Long Point, Kettle Creek, and Catfish Creek watersheds (which make up much of the WQSA) as a High Use Watershed, which places significant restrictions on obtaining PTTWs for most purposes. The heavy demand for water is likely a key driver behind the Watering Restriction By-Law in Norfolk County that restricts the external use of water (i.e. watering of lawns, filling of swimming pools or washing of vehicles) by premises served by Norfolk County owned water systems between May 15 and September 15 each year. Programs and projects in the WQSA, such as the creation of irrigation advisory committees and water user associations (see *Current Approaches* above), assist water users in managing water consumption effectively and in compliance with the requirements stemming from water management decisions.

While the above do not directly address the significant restrictions on obtaining PTTWs for most purposes, they may allow users to work with, and therefore apply for PTTWs for, smaller quantities of water while still meeting their water needs.

Consideration of key topics in water management decisions

The following points describe if and how key topics are considered in water management decisions in the Norfolk Sand Plain WQSA.

- Climate change: efforts have been made to predict the potential effects of climate change on groundwater and surface water resources through the use of climate change modelling scenarios (see Section 6.3.2.1). Based on the information reviewed as part of this study, there do not appear to be formal policies in place for considering the effects of climate change in water management decisions;

- Adaptive/alternative management: no policies and approaches were identified in the Norfolk Sand Plain WQSA that explicitly address the use of adaptive or alternative management. However, the province's PTTW program allows for the use of adaptive/alternative management, as one of the principles of the program is that the MECP "will employ adaptive management to better respond to evolving environmental conditions" (Permit to Take Water Manual, 2005). For example, the Ministry has the authority to limit, alter or stop a water taking that is considered to cause an unacceptable impact, even after a permit has been issued;
- Municipal growth: Population growth was considered in Tier Three studies where it was determined that locally; municipal populations may increase slightly over the coming decades (Section 6.3.2.2). However, no policies or approaches were identified in the Norfolk Sand Plain WQSA that explicitly address municipal growth. As noted in Section 6.3.2.2, current population projections for the Norfolk Sand Plain WQSA suggest that the area is not expected to have significant population growth pressures;
- Drought: Drought is likely a key concern that drove the creation of the Watering Restriction By-Law in Norfolk County that restricts the external use of water by premises served by Norfolk County-owned water systems between May 15 and September 15 each year; a variety of programs, projects and studies have also been conducted in the WQSA including drought contingency projects (see *Current Approaches* above). The topic of drought has also been explored as part of the Tier Three Assessment modelling work (Section 6.3.1.2);
- Natural function/EFN: the importance of EFN and aquatic habitat in Big Creek has been recognized (Section 6.3.2.4), although there is no indication that EFNs are currently being taken into consideration in water management decisions in the WQSA. There is also a general lack of information on EFN in other surface water bodies in the WQSA.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

Multiple reports (GRCA 2014b, Schroeter and Associates et al, 2002, AMEC 2008) have recommended that water managers work to promote moving water users off of surface water supplies on to groundwater in areas where surface water is or may become stressed such as the Big Creek system. Unlike surface water, access to groundwater is intrinsically less precarious due to its resiliency to episodic drought conditions allowing for access to water during low flow conditions. However, as identified previously, there is significant groundwater-surface water interaction in the sandplain, which may cause unconfined aquifers in the area to be somewhat more susceptible to the effects of drought and low flow conditions than deeper confined groundwater. While this approach has been proposed, well installation requires significant capital that may be prohibitive for some water users and over use of near-surface unconfined aquifers in some areas may result in unacceptable impacts on surface water features and related Environmental Flow Needs. This makes this approach not necessarily universally acceptable across the WQSA and may require local scale assessments for larger takings.

A number of case studies in the GRCA have also shown that restoration of groundwater-connected irrigation ponds to re-establish significant recharge is possible and can assist farmers to partially or wholly move away from on-line surface water irrigation sources (GRCA 2014b). These restoration projects are typically capital intensive due to significant excavation required and therefore may be out of reach for some water users. Cost sharing programs for this type of project could be considered as a management approach to decreasing agricultural reliance on surface water.

In general, water takings in the study area appear to be sustainable, and approaches suggested in this section may only be appropriate where a localized area appears to be over stressed or when particular users would like to secure sources that are more resistant to drought conditions. These approaches are not intended as blanket policies for the entire WQSA.

6.5 IDENTIFIED DATA GAPS

Cumulative Effects Information

While modelling to determine aspects of cumulative effects has been performed in areas surrounding municipal supplies as part of the Tier Three study, the study does not speak to the possibility of increased takings within the study area for agricultural, commercial or industrial purposes, nor does it speak to the possibility of land use changes reducing recharge to the shallow overburden aquifer as described above. Limited information is available for areas in the WQSA outside the municipal systems subject to Tier Three assessments. As noted in Section 6.3.3, the lack of scenario modelling for other areas (outside of the Town of Delhi) in the WQSA with high surface water use represents a gap in understanding of the sustainability of surface water resources at a regional scale.

Environmental Flow Needs (EFN)

Outside areas within the Big Creek surface water system, EFN thresholds are not well characterized in the WQSA. The Ontario Low Water Response program governs water usage during low water periods and may not accurately characterize flow conditions everywhere as declarations are applied on a watershed or subwatershed scale basis. The lack of EFN information in areas stressed or with the potential to be stressed represents a data gap.

Water Shortages

Understanding the nature and occurrence of water shortages outside municipal water supply systems (which have sophisticated monitoring and documentation programs) currently represents an information gap.

Tier Two Water Budget – Groundwater Takings

While the Tier Two water budget suggests a minor deficit in groundwater supply, the 2017 WTRS data (discussed in section 6.2.1.2) suggests that the groundwater taking value used in the water budget may be significantly higher than the actual water takings. This may suggest that current and slightly increased groundwater takings may not cause a deficit, and could be sustainable. The discrepancy between the Tier Two water budget groundwater annual taking values and the actual annual taking values based on WTRS data constitutes a gap in understanding or the intrinsic uncertainty and variability of annual climate conditions relating to precipitation and recharge.

6.6 RECOMMENDATIONS

- As noted in Section 6.4 (under *Challenges*), an over-reliance on surface water may create issues in areas that are susceptible to surface water stress, e.g. Big Creek, which has historically experienced significant reductions in water levels that were attributed to the high demand for irrigation (Section 6.3.2.4). Where appropriate, the Province should encourage permitted takings for the purpose of irrigation to move away from surface water reliance to groundwater, particularly when irrigating 100 m beyond surface water sources as water taking from such a distance is unlikely to cause a significant effect on baseflow contribution (Schroeter and Associates et al, 2002). While this approach has been proposed, well installation requires significant capital that may be prohibitive for some water users and over use of near surface unconfined aquifers in some areas may result in unacceptable impacts on surface water features and related Environmental Flow Needs. This makes this approach not necessarily universally acceptable across the WQSA and may require local scale assessments for larger takings.

- Further to the point above, consideration should be given to the development of Environmental Flow Needs thresholds for instream flow management in areas that are or have the potential to become stressed. This may require increasing stream monitoring data for tributaries of Big Creek and other surface water features where fish kills have been reported by adding additional hydrometric gauges.
- Where appropriate, consider increased utilization of the bedrock aquifer, including deeper aquifers (see Section 6.4, *Challenges*, Underutilization of Deeper Aquifers).
    - Subwatershed scale investigations into bedrock aquifers would help to characterize and assess the potential yield of water quantity and quality.
- As noted in Section 6.4, under *Challenges* (Quantifying Demand), the use of maximum permitted volumes to estimate demand can result in a gross overestimation of the amount of water that is forecasted to be used. Similarly, there may be a discrepancy in groundwater taking values used in the Tier Two water budget compared to actual takings (Section 6.5). A detailed analysis of the PTTW and WTRS is warranted given that the Long Point Region has among the highest number of permitted surface and groundwater users of any area in Southern Ontario. The analysis should include a summary of data such as use, location, geological unit/surface water source utilized, depth (if dealing with a well), permitted volume, actual volume by year or greater frequency if possible and precipitation data (as detailed as possible).
- The MECP has worked with local PTTW holders and other stakeholders in Springford Mt. Elgin to resolve local water quantity issues (Section 6.3.1.1). A similar approach may be useful in the future for specific, localized issues in other part of the WQSA.
- As noted in Section 6.5, there is an information gap with respect to understanding the nature and occurrence of water shortages outside municipal water supply systems. Consider implementing a method of recording water shortages reported by a permit holder and validated by an MECP officer into a database connected with the PTTW, WTRS and WWIS system. This would allow for the quantification of the occurrence and location of the shortage, which would then allow for useful analysis of WQSA-wide water shortage trends.
- Given the Norfolk Sand Plain WQSA proximity to the Whitemans Creek WQSA, both areas should be studied in tandem when considering the impacts water resource management.

- GRCA showed that restoration of groundwater connected irrigation ponds to re-establish significant recharge is possible and can assist farmers to partially or wholly move away from on-line surface water irrigation sources (GRCA 2014b; see also Section 6.4, *Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers*). These restoration projects are typically capital intensive due to significant excavation required and therefore may be out of reach for some water users. Cost sharing programs for this type of project could be considered as a management approach to decreasing agricultural reliance on surface water.
- Due to the gaps in information associated with cumulative effects, particularly outside of municipal water supply areas (as noted in Section 6.5), consider expanding the Tier Three Local Area Risk Assessment approach. For example: Guide Water Quantity Risk Management Measures Evaluation Process (RMM Evaluation Process; TRCA 2013a) and a Water Quality and Quantity Risk Management Measures Catalogue (RMM Catalogue; TRCA 2013b) used for the Community of Simcoe (Matrix, 2016), could be required before development approvals or PTTW are issued in areas beyond the capture zone of the municipal well field.
- As noted in Section 6.4, under *Challenges* (High Use Watershed Designation), the High Use Watershed Designation places significant restrictions on obtaining PTTWs for most purposes. The designation should be reviewed to determine if the regulation and, based on the Source Protection and other water resource assessment work recommended herein, the designation of this area as a High Use Watershed should be revisited, and a determination made if the requirements attached to that designation, through the regulation and other guidance, are warranted, and if so where within the watershed specifically.

6.7 REFERENCES

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7 INNISFIL WQSA

The preliminary boundary of the Innisfil WQSA, as provided by the MECP is shown on Figure 7-1, with an area of 1,222 km^2. The preliminary WQSA overlaps multiple counties and encompasses a number of population centers along the southwest shore of Lake Simcoe. The WQSA is located within the watershed of the NVCA and to a lesser extent in the watershed of the Lake Simcoe Region Conservation Authority (LSRCA) (23% of the WQSA) and Toronto and Region Conservation Authority (8.5% of WQSA). The preliminary WQSA boundary includes the following municipalities:

- Town of New Tecumseth (all)
- Town of Innisfil (most)
- City of Barrie (southwest area)
- Township of Essa (southeast half)
- Town of Bradford West Gwillimbury (northwest half)
- Township of Adjala-Tosorontio (south half)
- Town of Mono (small area on the western side)
- Town of Caledon (northeast area)
- Township of King (small area of the southern half)

The main area of detailed study and available data within the preliminary WQSA (water resource demands, water resource issues, majority of the permitted water takings) as confirmed by local water managers, is the Innisfil Creek subwatershed. Throughout this report the Innisfil Creek subwatershed within the NVCA is referred to as the Innisfil Creek watershed since there is a quaternary subwatershed with the same name along Cook's Bay within the WQSA, located in the LSRCA. The Innisfil Creek watershed within the jurisdiction of the NVCA has five main tributaries, including Innisfil, Cookstown, Penville, Beeton and Bailey. The Innisfil Creek watershed is situated partially within the municipalities of the Town of New Tecumseth, Town of Innisfil, Township of Essa, Town of Bradford West Gwillimbury, Township of Adjala-Tosorontio and Town of Mono. The main communities in the subwatershed are Beeton, Churchill, Cookstown, and Tottenham (NVCA, 2018).

In the Innisfil WQSA, both groundwater and surface water resources are exploited used for water supply, domestic, agricultural, and industrial uses. This WQSA was selected from detailed analysis by the MECP due to known or potential issues associated with increasing water demand and periodic droughts potentially leading to water supply shortages which may be exacerbated in the future as a result of climate change impacts. The objectives of this section are: to provide a characterization of the Innisfil WQSA in the context of the significant surface water and groundwater resources, to refine the WQSA boundary based on the physical characterization, to summarize and evaluate the demands on water resources in the WQSA, and to determine the possible impact of projected changes in population, land use, and climate on the quantity of the local resources and the future security and sustainability of the water resources in the WQSA based on these changes.

7.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives for the WQSA (Section 7) and the preliminary WQSA boundary provided by the MECP.

A groundwater Tier 2 Stress Assessment as outlined in the Province's Guidance Module for Water Budget and Water Quantity Risk Assessment (MNR and MOE, 2011) was previously completed (AquaResource, 2013) for the Innisfil Creek subwatershed, as described above and shown on Figure 7-1. However, the assessment area model boundary only included the northern part of the preliminary WQSA, covering approximately 285 km^2 and concluded that there is a "Low Potential" for stress on municipal groundwater supplies both with average and maximum demand. A drought evaluation was also completed as part of the Tier 2 Stress Assessment. The drought evaluation monitored the response of streams and wetlands in the area to indicate the potential for drought impacts. The potential for drought impacts was used for this study instead of the expected variability under drought conditions, due to a lack of time-varying water level and stream discharge data for model calibration purposes (AquaResource, 2013). The drought evaluation showed that all creeks experienced reduction in baseflow during the simulated drought period. Since the completion of the Tier 2 Stress Assessment and drought evaluation on the Innisfil Creek subwatershed, the NVCA has identified the entire Innisfil Creek watershed (located southwest of the subwatershed by the same name) as a priority area with respect to sustainable water resource management. The Innisfil Creek watershed has experienced historical water abstraction shortages due to meteorological and agricultural related droughts with related negative socio-economic impacts (NVCA, 2018).

A meteorological drought happens when dry weather patterns dominate an area, where as an agricultural drought refers to circumstances when soil moisture is insufficient and results in the lack of crop growth and production. Accordingly, the NVCA has completed a number of additional detailed assessments and studies since the Tier 2 Stress Assessment, specifically for the 490 km^2 area of the Innisfil Creek watershed, which makes up the majority of the preliminary WQSA. While the characterization of the WQSA is based on more spatially extensive but older reports, the current assessment of the WQSA is primarily based on the more current and detailed reports and studies completed in the Innisfil Creek watershed only.

Table 7-1 includes the reports used as the primary basis for the WQSA characterization and assessment. These reports were confirmed as being key sources of insight by local water managers. In addition to the reports noted in the table below, available databases (e.g. WWIS, PTTW, WTRS) provided by MECP, were also used to characterize and assess the WQSA. Each resource was categorized in terms of the main type of information presented within. It should be noted that a complete list of references used to characterize and assess this WQSA is provided at the end of this section and that the references noted in the table are the primary sources of information.

Table 7-1: Key Reports and Information Sources for Innisfil WQSA

Resource Reference	Type	Categories
NVCA. June 2018. Hydrologic Function: Framework Considerations and Approach to Subwatershed Baseline Characterization.	Report	GWQ, SWQ
Matrix Solutions Inc. (Matrix) and BluMetric Environmental Inc, (BluMetric). 2017. Innisfil Creek Drought Management Plan Pilot. Prepared for Nottawasaga Valley Conservation Authority.	Report	PC, GWQ, SWQ, CU, FC, CC
South Georgian Bay-Lake Simcoe Source Protection Committee (SGBLS SPC). 2015. Approved Assessment Report: Lake Simcoe and Couchiching- Black River Source Protection Area. Part 1: Lake Simcoe Watershed.	Report	PC
Environment and Climate Change Canada (ECCC). 2014. *Water Survey of Canada.*	Report	CU, CC
Nottawasaga Valley Conservation Authority (NVCA). May 2014. Impact assessment of NVCA PGMN groundwater levels to anticipated long-term climatic variation sensitivity.	Report	GWQ, CC
Nottawasaga Valley Conservation Authority (NVCA). January 2014. Agricultural-Water Quantity Climate Change Sensitivity Assessment, NVCA Watershed.	Report	GWQ, SWQ, CC
Nottawasaga Valley Conservation Authority (NVCA). 2013. Innisfil Creek: 2013 Subwatershed Health Check.	Report	SWQ
AquaResource. 2013. Innisfil Creeks Subwatershed Tier Two Water Budget & Water Quantity Stress Assessment And Ecologically Significant Groundwater Recharge Area Assessment	Report	PC, GWQ, SWQ, CU, FC

Categories:

PC – Physical Characterization
GWQ – Groundwater Quantity
SWQ – Surface Water Quantity
CU – Current Water Users
FC – Future Conditions
CC – Climate Change

7.2 WATER RESOURCES SETTING /CHARACTERIZATION

7.2.1 Land Cover and Use Setting

Land cover in the Innisfil WQSA (Figure 7-2) is predominantly Agricultural and Undifferentiated Rural Land with pockets of swamp areas and a few small urban commercial, industrial and residential centers surrounded by less-populated rural land used for intensive agricultural production. Forest loss between 2002 and 2008 has been attributed mainly to development activity and, to a lesser extent, conversion of forested land to agricultural use (NVCA, 2013). Existing wetlands are identified on Figure 7-2 as marshes, swamps, fens and bogs. Urban areas account for a very small portion of the total area. This category includes built-up impervious area, roads, and highways. Larger urban centers in the WQSA include Thornton, Alliston, Cookstown, Palgrave, and the southwest area of Barrie.

The Simcoe Lowlands region, which corresponds roughly to the south central area of the WQSA, consists mostly of agricultural activity with a significant portion of wetland coverage (15%), while forest cover in the area is low (8%). The Oak Ridges Moraine (ORM) region contains the highest proportion of forest coverage (28%), with the remaining area consisting mainly of agricultural activity. The Simcoe Uplands region has high agricultural coverage and the lowest wetland cover of all regions (3%).

Under the Canada Land Inventory (CLI), agricultural lands in the WQSA are primarily Class 1 (No Significant Limitations) and Class 6 (Perennial Crops) with the exception of lands along Innisfil Creek which are Class 3 (Moderately severe limitations, special conservation practices required) and isolated small pockets of Class 2 (Moderate limitations, moderate conservation practices) and Class 7 (No Capability for Crops) located throughout the WQSA (CLI, 2018). Innisfil WQSA is notably well-suited to support potato farms, sod farms, market farming, and nursery operations (NVCA, 2013). The specific land use within each subwatershed is further detail below.

7.2.2 Population

Populations in urban centres with municipal water supplies, located in watersheds which fall within or make up part of the WQSA, are summarized in the table below:

Table 7-2: Summary of Population Statistics and Water Supply Source in Innisfil WQSA

Watershed/S.P.A	County	Municipality	Water Source	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percentage Change 2011 to 2016 (%)
Innisfil Creek	Simcoe	Town of Innisfil (262 km^2)	Groundwater	32,727	36,566	11.7
Innisfil Creek	Simcoe	Barrie (99 km^2)	Groundwater and Surface Water	136,063	141,434	3.9
Innisfil Creek	Simcoe	Essa (280 km^2)	Groundwater	18,505	21,.083	13.9
Innisfil Creek	Simcoe	Bradford West Gwillimbury (201 km^2)	Groundwater	28,077	35,325	25.8
Innisfil Creek	Simcoe	New Tecumseth (274 km^2)	Groundwater and Surface Water	30,234	34,242	13.3
Innisfil Creek	Simcoe	Adjala-Tosorontio (372 km^2)	Groundwater	10,603	10,975	3.5

The total population of Simcoe County, which falls almost entirely within the WQSA was 305,516 in 2016 according to data available through Statistics Canada. Of note, a part of the total population of the WQSA, resides in sparsely populated rural areas and are not serviced by municipal water supplies as discussed further below.

7.2.3 Physiographic Setting

The Innisfil WQSA is located in southcentral Ontario, south of Georgian Bay and east of Lake Simcoe. The major watershed in the Innisfil WQSA is the Innisfil Creek watershed, with an area of 490km^2. The watershed consists of five tributaries which make up five subwatersheds: Bailey, Beeton, Cookstown, Innisfil, and Penville with areas of 126 km^2, 90 km^2, 33 km^2, 181 km^2, and 60 km^2 respectively.

7.2.3.1 Physiography

The OGS more generally defines the physiographic regions within the WQSA. These regions are illustrated on Figure 7-3 and described as drumlinized till and clay plains stretching from the central to the northern parts of the WQSA. These plains are flanked by sand plains and spillways and kame and till moraines in the south.

The regional physiography of the WQSA can be described as follows:

- **Simcoe Uplands** stretch from the central to northern region, and include the following features:
    - Peterborough Drumlin Field: a rolling drumlinized plain (SGBLS SPC, 2015)
    - Schomberg Clay Plains: flat till plains consisting of stratified clay and silt deposit (Singer et al. 2003)
- **Simcoe Lowlands** are a series of broad sand plains located in the central region along Innisfil Creek (includes the Simcoe Lowlands; SGBLS SPC, 2015).
- **Oak Ridges Moraine** (ORM) is a range of undulating topography consisting of highly permeable rock or unconsolidated material (ORMFA, 2017). This region also contains a small portion of Horseshoe Moraines, which are discontinuous moraine ridges along the west of the Niagara Escarpment.

7.2.3.2 Topography

The topography of the area closely corresponds to the physiographic regions that comprise the watershed. The topographic features in the Innisfil Creek WQSA are coincident with the present-day stream network, as well as their geological history, including significant glacial events. The ground surface topography within the watersheds ranges from 320 masl east of New Tecumseth to 215 masl along the Innisfil Creek as it flows from northwest to southeast. These are shown on Figure 7-4. Generally, the topography slopes from the northwest towards the south across the WQSA.

7.2.3.3 Climate

Figure 7-5 shows the location of the twenty-three weather stations in the WQSA. In addition, Matrix Solutions Inc. and BluMetric Environmental (2017) used monitoring data from eight Environmental Canada climate stations in and around the WQSA to represent climate variability throughout the Innisfil Creek watershed. Average statistics for precipitation and temperature were obtained from Environment and Climate Change Canada's (ECCC) 1981-2010 climate normal database, (ECCC, 2013).

Average annual precipitation at the stations around the watershed ranges from 789 to 912 mm/year. This estimate is consistent with published estimates of mean annual precipitation for the region (MNR, 1984). In general, precipitation increases from the central region of the Innsifil Creek watershed toward the southwest and northeast regions of Alliston-Nelson, and Albion Field Center stations. Long-term average precipitation is fairly equal among stations, with the largest monthly difference being just over 10 mm/month. Although long-term average precipitation is fairly consistent, significant variability in precipitation totals is common when investigating a particular month. This variability is likely to increase during the summer months, when local-scale convective events (i.e., thunderstorms) are common.

Maximum temperatures occur in July, while minimum temperatures occur in January. There is a trend of increasing temperature toward the central part of the Innisfil Creek watershed. An average annual maximum and minimum temperature, produced from published ECCC climate normal data (1981-2010) was prepared by Matrix and BluMetric (2017).

Excluding precipitation, evapotranspiration is the dominant hydrologic parameter, and consumes approximately two-thirds of the annual precipitation total. While techniques to monitor evapotranspiration do exist, they are not widely deployed, and as such, there are few monitoring records of evapotranspiration for southern Ontario. Evapotranspiration has been estimated as part of the *Water Quantity Resources of Ontario* (MNR 1984) and found to be 550 to 600 mm/year near the Innisfil Creek watershed.

7.2.3.4 Surface Water Hydrology

The Innisfil Creek watershed is drained by five main creek systems: Innisfil, Bailey, Beeton, Cookstown, and Penville creeks. Innisfil Creek originates in the Simcoe Uplands region and drains the northern portion of the watershed as it passes through the Simcoe Lowlands. Innisfil Creek enters the Nottawasaga River south of Alliston. Bailey Creek begins on the ORM and drains the southwestern portion of the watershed as it flows northeast through an agricultural and forested area to join Innisfil Creek.

The WQSA contains a mix of cool and cold streams throughout the study area; however most stream temperatures are unknown and/or have not been reported. These thermal regimes can be seen on Figure 7-6. The transition of a stream from cold to cool can be a natural process of decreasing depth of the stream, or external factors such as the reintroduction of water from a dam, as seen in the Tottenham reservoir waters warming the waters of Beeton Creek, bringing it from cold to cool. This figure shows no warm streams reported within the study area with the exception of a small portion of a tributary along the central part of the northwest boundary of the WQSA.

Innisfil Creek arises on the gently rolling sand-silt plains of the Simcoe Uplands south of Barrie. Emerging from headwater forests and wetlands, it flows south into intensively farmed lowlands that extend through Cookstown downstream to the Nottawasaga River. Bailey Creek emerges on the Oak Ridges Moraine near the hamlet of Connor. It winds southeastward through rolling forests and farm fields. Bailey Creek descends into the Schomberg Clay Plains north of Colgan, passing through a mix of agricultural lands and swamp/lowland forest. Downstream, the creek enters an intensive agricultural area within the Simcoe Lowlands as it flows eastward toward Beeton Creek. Beeton Creek arises on the Oak Ridges Moraine south of Tottenham. Flowing north, the creek enters a reservoir at the Tottenham Conservation Area and then continues downstream. An east branch, originating east of Tottenham, flows westward through agricultural lands and enters Beeton Creek north of Tottenham. Beeton Creek continues to flow northward through an agricultural landscape, skirting the west side of Beeton before joining Bailey Creek and then entering Innisfil Creek. Penville Creek emerges within a mix of hills (drumlins) and clay plains near Bond Head, flowing northward through agricultural lands before entering Innisfil Creek north of Newton Robinson.

The 2013 Health Check (NVCA, 2013), described the surface water features in this watershed as being predominantly wetlands, connected by a stream network, with very few open water lakes/ponds. The Significant Groundwater Recharge Areas (SGRAs) within this watershed are widespread, covering 18,072 ha (37%) of the watershed, and when combined with their 120 m buffer, this area spans 24,249 ha covering nearly 50% of the watershed. When combining the spatial extent of the surface water features and SGRAs they cover 36,366 ha (or 74%) of the watershed.

In the WQSA there are eight stream gauges, four operated by the Water Survey of Canada (WSC), and four operated by NVCA. Two of the WSC stream gauges, Innisfil Creek near Alliston and Beeton Creek near Tottenham, have complete datasets to be able to assess annual streamflow from 2000 to 2012. In recent years (>2007), annual streamflow yield has become more variable than observed in the early 2000s. There is also a slight increasing trend in overall streamflow yield; although due to the relatively short time frame, it cannot be determined if this is part of a longer term trend or normal climate variability (Matrix and BluMetric, 2017). The daily flow data for each WSC gauge was also evaluated by Matrix and BluMetric (2017).

The report evaluated seasonal as well as inter-month variability in streamflow by using percentiles. The 10th percentile flow corresponds with the flow value that is in the lowest decile of flow conditions observed for that month (extreme low flow). The 90th percentile flow corresponds with the flow value that is the highest decile of flow conditions observed for that month, (extremely high flow). The highest percentile is seen in March and the lowest is seen in August. The difference between the 25th and 75th percentile represent the flow conditions that would occur 50% of the time. The 50th percentile flow is the median flow condition. Optimal flow conditions have not been established beyond the set threshold levels under the Ontario Low Water Response (OLWR) program discussed below. As discussed below, this is in part due to the fact that it is not likely that Innisfil Creek is receiving significant amounts of groundwater discharge. Based on modeling completed as part of the Drought Management Plan Pilot project (Matrix and BluMetric, 2017), groundwater discharge is estimated to be less than 15% of total streamflow. However it should be noted that key reaches of Innisfil Creek were assessed for aquatic ecology significance based on the historical presence of coldwater species. This was completed as part of the 2017 Drought Management Plan Pilot project (Matrix and BluMetric, 2017) in which Innisfil Creek was characterized in order to determine stream reaches possessing coldwater habitat potential and/or the presence of coldwater fish species.

Potential habitats were evaluated based on temperature surveys, groundwater seepage mapping and visual observation. Coldwater species were inventoried as part of the NVCA's fisheries monitoring assessment program. Habitat characterization was completed on six reaches where property access was obtained. Fisheries inventories were conducted at all six habitat characterization locations, as wells as five additional locations by roadside access. Of the ten locations sampled, seven locations proved to support coldwater species. One additional site was inaccessible due to beaver activity. Of the six locations where habitat evaluation was conducted, two sites showed insufficient habitat characteristics to support coldwater species, and four locations showed modest coldwater habitat characteristics. NVCA recommended that these two locations be considered for "warm water only" designation due to the absence of coldwater species and coldwater habitat. This designation allows for higher withdrawal rates for fisheries in these areas, as they only support marginal habitat and small populations of warm water baitfish species. Portions of the Innisfil Creek watershed remain unsampled as they were not high priority areas in the first round of sampling or property access was restricted.

To aid in the comparison of different WSC gauges, all flow values were converted to units of mm per unit of upstream drainage area.

Based on the guidelines used under the Ontario Low Water Response program, the three levels for Innisfil Creek watershed have been determined to be as follows:

- Level 1 = 0.405 m^3/s (< 70% of lowest average summer month flow)
- Level 2 = 0.29 m^3/s (< 50% of lowest average summer month flow)
- Level 3 = 0.174 m^3/s (< 30% of lowest average summer month flow)

In 2011, the NVCA experienced low water conditions, with a recommendation that several subwatersheds implement a Level 1 condition. In Innisfil Creek watershed, Level 2 conditions were experienced with a warning that the watershed would deteriorate to Level 3 conditions without proper mitigation (NVCA 2011). Previously in 2007, it was confirmed to have also reached Level 2 conditions (MNR 2010). These responses can be seen in Table 7-3 below. It has been noted that since 2016, there have been issues with channel slump impacting the Water Survey of Canada Innisfil Creek gauge. For this reason, flow information for Innisfil Creek has not always been available or reliable, and as a result specific declarations for Innisfil Creek have not been considered in the past few years, (Peter Alm, 2018).

Table 7-3: Ontario Low Water Response Levels declared for NVCA

Year	NVCA Low Water Declaration	Duration (days)
2007	Level 2 (Innisfil, Mad, Pine, Boyne, Mid. Nott.)	74 (Level 1) + 81 (Level 2)
2008	none	
2009	none	
2010	none	
2011	Level 1 (Innisfil Creek, Boyne River, Blue Mountains subwatersheds)	47
2012	Level 1 (watershed wide)	67
2013	none	
2014	none	
2015	none	
2016	Level 1 (watershed wide)	126
2017	none	
2018	none	

The monthly flow regime for Innisfil Creek near Alliston was used by Matrix and BluMetric (2017) to assess streamflow in the WQSA. This is the furthest downstream gauge on Innisfil Creek, and drains approximately 480 km^2. As would be expected, the highest streamflow yield typically occurs in March, with the 90th percentile flow reaching 107 mm. Streamflow yield declines through spring and early summer, reaching a low in August and September. Median streamflow yield during these months is approximately 3 mm/month, with extreme low flows reaching 0.9 mm/month. Streamflow yield gradually recovers through the fall and early winter. With summer low flows reaching such low levels, it is not likely that Innisfil Creek is receiving significant amounts of groundwater discharge. This suggests that the lack of summer flow is not solely caused by surface water withdrawals, but rather is the natural condition of Innisfil Creek.

Beeton Creek near Tottenham is an active WSC gauge that drains 86 km^2 in the southern portion of the Innisfil Creek watershed and is upstream of the Innisfil Creek near the Alliston gauge. The majority of the drainage area is associated with the northern flank of the ORM. Similarly to the Alliston gauge, the peak flow occurs in March; however, the 90th percentile flow for Beeton (80 mm/month) is significantly lower than for Alliston. For most months, the 90th percentile flow for Beeton is less than it is for Alliston. This suggests that the Beeton gauge is less responsive to rain or snowmelt events and is not as dominated by overland flow processes as the Alliston gauge. Summer low-flow conditions are reached by July and extend into September. Median streamflow yield during this time is more than double that of the Innisfil Creek at the Alliston gauge, while extremely low flows can be up to four times that of the Alliston gauge. This suggests a more reliable source of streamflow for Beeton Creek, likely groundwater discharge.

The hydrologic function assessment completed by NVCA (NVCA, June 2018) states that the Innisfil Creek watershed is 490 km^2, and dominated by agricultural activities, have a SGRA extent of 52 % has a proportion of precipitation that directly translates into water yield (19%).

In the Innisfil Creek watershed, maximum hydrologic release occurs in all four seasons, but is most commonly associated with the spring freshet, while lowest hydrologic release generally coincides with the winter period with multiple consecutive days of no hydrologic release. Similarly, maximum streamflow is generally associated with the spring freshet, with lowest flow occurring in the summer. Annual maximum daily average streamflow is generally between 35 and 55 m^3/s, and annual low flow is generally <1 m^3/s (NVCA, June 2018).

The NVCA completed its first Watershed Health Check (Watershed Report Card) in 2013. This Watershed Health Check was completed in accordance with the 2012 Conservation Authority Watershed Report Card Guidelines, designed to develop a set of standardized watershed report cards for all 36 Conservation Authorities in Ontario. The Health Check provides an overview of forest, wetlands, stream and groundwater health. Specifically, stream health considers the indicators of overall Benthic Grade, Total Phosphorous and E.coli. The headwaters of Innisfil Creek are spring-fed and exhibit "unimpaired" to "below potential" stream health as they flow through wetlands and forests on the Simcoe Uplands, (NVCA, 2013). Stream health declines rapidly as Innisfil Creek enters the Simcoe Lowlands due to sparse riparian (streamside) vegetation and field drainage activities. Extensive water taking for field irrigation reduces streamflow to near zero during drier summer conditions.

A 3D fully integrated MIKE SHE model developed by Matrix Solutions Inc. was used to quantify key hydrologic parameters relating to both surface water and groundwater resources (Matrix and BluMetric, 2017). The major findings from this effort can be summarized as follows:

- On average, Innisfil Creek watershed receives 837 mm/year of precipitation, resulting in 606 mm/year of evapotranspiration, 217 mm/year of streamflow, and a groundwater outflow of 14 mm/year.
- MIKE SHE found that the majority of streamflow for the Innisfil Creek watershed is associated with direct overland runoff or quickly responding interflow. Groundwater discharge is estimated to be less than 15% of total streamflow.
- Limited groundwater discharge occurs in the Innisfil Creek valley, and is focussed on the physiographic and topographical boundary between the uplands and valley lowlands.
- Areas of high groundwater recharge include granular deposits within the ORM as well as the surficial sand deposits in the lowlands. Due to the thick glaciolacustrine deposits underlying the surficial sands in the lowlands, much of this groundwater recharge results in quickly responding interflow that does not sustain streamflows during extended dry periods.
- Comparison of model simulations with and without crop irrigation indicates that the frequency of days with streamflow below Level 1 and Level 2 days are not influenced by withdrawals. However, the frequency of more extreme Level 3 days is heavily influenced by withdrawals (more than doubled).

Other reports reviewed as part of this work were consistent with these findings. They describe the areas having the highest groundwater recharge in the watershed as including both the valley (or lowlands) flanking Innisfil Creek and the ORM in the southwest of the watershed. These areas are dominated by sand plains and coarse fill and are consistent with the Significant Groundwater Recharge Areas (SGRAs) defined in the Drinking Water Source Protection Assessment Report for the Nottawasaga Valley Source Protection Area (SGBLS SPC 2015).

The average annual recharge in the sand and gravel areas is 275 mm. The lowlands, comprised mostly of sand, receive approximately 225 mm/year of recharge and the ORM receives approximately 255 mm/year. The average annual recharge in the uplands comprised mostly clay and till regions, is approximately 140 mm/year. The most significant influence on the amount of groundwater recharge generated is surficial geology and how pervious the surficial materials are.

The majority of groundwater discharge in the watershed occurs at the physiographic boundary between the uplands and lowlands. At this point, the tighter Newmarket Till and Thorncliffe equivalents, layers in the uplands are pinched out at the interface between the Simcoe Uplands and the Simcoe Lowlands. As water moves horizontally in the subsurface layers of the uplands, seepage occurs where these layers become exposed along the valley edges and at the base of the valley floor. This results in higher amounts of groundwater discharge along the interior edge of the valley than other locations within the watershed.

7.2.4 Geology

The WQSA is underlain by a series of gently dipping Middle and Upper Ordovician sedimentary rocks consisting of shales interbedded with shallow water carbonates and sandstone. These rocks are overlain by unconsolidated Quaternary-aged sediments of variable thickness that were laid down after the last glaciation.

7.2.4.1 Surficial Geology

Surficial geology is represented using data from the Ontario Geological Survey (OGS 2010) and Mulligan and Bajc (2012). Data from Mulligan and Bajc (2012) was available for the central regions of the watershed, while 2010 data from the OGS (Bajc and Rainsford 2010) was used to infill the remaining portions of the Innisfil Creek watershed. Surficial geology was categorized into seventeen classes, as shown on Figure 7-7. These classes consist of clay, fluvial, organic deposits, gravel, till, and sand.

The predominant surficial deposits (shown in yellow) are composed of foreshore and basinal deposits. The Lowlands region, in the central region along Innisfil Creek, consists primarily of sand (63%), clay (20%), and fluvial and organic deposits (10%), (Matrix and BluMetric, 2017). Similarly, the ORM region, which is the region from which Beeton and Bailey creeks originate, contains sand (82%), clay (10%), and traces of other deposits. Upland areas, in the central to northern region of the WQSA, consist mainly of low permeability materials of clay (47%) and Newmarket Till (36%), with some sand (11%) and traces of other deposits.

Quaternary overburden sediments in the WQSA were deposited during the glacial and interglacial events that occurred as part of the Wisconsinan Glaciation (115 to 7 ka before present) and consist of glaciomarine deposits, glaciofluvial outwash deposits and tills, (Slattery, Gerber, Doughty and Holysh, 2009) as shown on Figure 7-7.

Overburden is quite deep throughout the study area, with depth to bedrock exceeding 200 m in some locations. Due to this great depth, bedrock aquifers are not extensively used for water supply, (Holysh, Davies, and Goodyear, 2004).

7.2.4.2 Bedrock Geology

Glacial sediments in the Innisfil WQSA are underlain by Middle to Upper Ordovician bedrock consisting mainly of limestones, dolostones and shales. This succession is subdivided into nine formations. In order from oldest to youngest, these are the Ottawa Group, Simcoe Group, the Shadow Lake, Georgian Bay, Blue Mountain, Billings, Collingwood, Eastview and Queenstone Formations. Figure 7-8 illustrates the bedrock geology underlying the WQSA.

7.2.5 Hydrogeology

The hydrogeology of the Innisfil Creek Watershed is largely controlled by the sediments discussed above. Groundwater in the Innisfil Creek watershed is hosted within aquifers comprised of (glacio)fluvial sands and gravels, Quaternary channels, sand packages, and near surface glaciolacustrine and fan sands. These deposits create a regionally extensive and complex aquifer system. Till sheets and fine-grained silt and clay packages represent localized and regional aquitards that act to impede the vertical movement of groundwater (and potential contaminants) to underlying aquifers, (Singer, Cheng and Scafe, 2003).

The aquifer system is generally described as containing four major sand and gravel aquifer units (Golder and AquaResource, 2009). These four aquifer units are defined based on their relative stratigraphic position and are commonly identified based on elevation ranges that have been refined through decades of characterization efforts.

Figure 7-9 presents a generalized hydrogeological cross-section representative of the complex aquifer system in the WQSA, as reported by Matrix and BluMetric (2017).

7.2.5.1 Overburden Aquifers

Shallow Unconfined Overburden Aquifer

The most upper, shallow aquifer is the Lake Algonquin Sand Aquifer, and is unconfined and consists of sand and gravel deposits. This aquifer forms the surficial sands found along the valley floor in the central areas of the WQSA or the near-surface subaquatic fan sediment aquifer of the Upland areas, located in the central to northern portion of the WQSA. Springs are commonly seen along the flanks of the Upland areas where water flowing through the upper subaquatic fan sediment aquifer meets the underlying silt and clays (that impede vertical groundwater movement) and groundwater moves horizontally to the surface. The Thornton Sand Aquifer, also unconfined, can be seen in Innisfil and Essa with a thickness between 2 and 30 m. There are limited groundwater resources associated with these surficial sands. It should be noted that in general, shallow dug wells in shallow unconfined aquifers are susceptible to shortages in the short term related to drought conditions, similar to shallow surface water features.

Deep Overburden Aquifers

A deep, highly transmissive aquifer is found under the central portion of the Innisfil Creek valley within the tunnel-channel deposits associated with the Lowland area. This aquifer extends in a north-southwest direction from Innisfil Heights in the north bending southwestwards toward the Thompsonville area (referred to as the Innisfil Valley aquifer).The fining-upwards sequence of this deposit generally results in this aquifer being confined from surficial shallow aquifers by overlying silt and clay aquitard deposits. Flowing artesian conditions have historically been reported for such valley aquifers. Depending on the depth of the Quaternary channels, there may be a hydraulic connection between the Laurentian Valley aquifer, hosted in the coarse-grained valley fill deposits at the base of the Laurentian Valley, and the Innisfil Valley aquifer. These lower aquifer units tend to host significant groundwater resources, and a connection of the two systems would present a regionally extensive, highly transmissive aquifer. The valley fill aquifers may also be connected to aquifers associated with the Thorncliffe Formation or older drift packages.

A map of bedrock and overburden wells, derived from the provincial water well (WWIS) database, can be seen on Figure 7-10, showing that the vast majority of supply wells in the study area are installed in overburden, while the few bedrock wells are concentrated along the south-west region of the WQSA. This figure also shows the location of the Provincial Groundwater Monitoring Network Wells (PGMN) used to monitor ambient groundwater conditions in the WQSA.

7.2.5.2 Groundwater Surface Water Interaction

As part of an Ontario Geological Survey three dimensional (3D) mapping project of Quaternary deposits in the southern part of the County of Simcoe, extensive fieldwork and data collection has been completed (referred to as south Simcoe County; Bajc and Rainsford 2010, 2011; Bajc et al. 2012; Mulligan 2013). It was found that surficial sands are present throughout the central portion of Innisfil Creek watershed; these are thin deposits, which are underlain by thick glaciolacustrine deposits. There are limited groundwater resources associated with these surficial sands and therefore across the WQSA, the groundwater and surface water show little to no evidence of interaction (Matrix and BluMetric, 2017). However, as noted above, in general, shallow dug wells in shallow unconfined aquifers are susceptible to shortages in the short term related to drought conditions, similar to shallow surface water features.

Also as described above, the watershed includes a significant area classified as wetlands including two Provincially Significant Wetlands (PSW), the Cookstown Hollows Swamp and a portion of the Lover's Creek Swamp.; The Bailey Creek Swamp is another larger wetland but it is not identified as a PSW. All of these could be considered as having local near surface groundwater and surface water interaction.

According to the 2013 watershed Health Check for Innisfil Creek (NVCA), satellite photo interpretation, between 2002 and 2008 shows that there was a net subwatershed wetland loss of 51 ha. This represents a 1.3% decrease in wetland cover since 2002. Most wetland loss was associated with agricultural conversion. Wetland conditions within the Innisfil Creek watershed are fair to poor compared to the rest of the Nottawasaga River watershed. Historically, large areas of wetlands in the Innisfil Creek watershed were cleared and drained in the Simcoe Lowlands to provide farmland. Recent Ducks Unlimited Canada data shows historical wetland loss in the Town of New Tecumseth, the largest municipality within the watershed, at 70.1%.

Forest and wetland conditions are only fair while stream health is generally poor, ecologically speaking. The impacts of poor surface water quality extend downstream into the Nottawasaga River and persist downstream to Wasaga Beach (NVCA, 2013).

7.2.6 Overview of Water Takings within WQSA

7.2.6.1 Permitted Takings

The WTRS program database from 2017 reported water takings was used to complete the assessment on actual water demands. For the purposes of this assessment, 14 dewatering permits and 6 temporary permits for aquifer testing were not included because of the short-term nature of these takings.

In 2017, there were a total of 224 active PTTWs with reported takings in the preliminary WQSA. Of the 224 active PTTWs, 154 permits were linked to seasonal water taking (irrigation). Of these, 121 permits were for agricultural use and 33 were associated with golf courses. In all, 43 of the 154 permits linked to seasonal use, draw on groundwater or a combination of both surface and groundwater; 109 permits linked with seasonal use were surface water takings as shown on Figure 7-11. Volumes are described below in Table 7-4.

Table 7-4: Volume of Reported Water Takings vs Maximum Permitted Volume of Surface and Groundwater in Innisfil WQSA (2017 WTRS)

Sector	Type	Volume of Reported Takings (m^3/yr)	Percent of WQSA Total Reported Takings (%)	Maximum Permitted Volume (m^3/yr)	Permit Utilization (reported takings/maximum permitted volume) (%)
Agriculture	Groundwater	7,320	0.16	1,068,150	0.69
	Surface and Groundwater	10,949	0.25	797,084	1.4
	Surface Water	594,802	13	48,091,513	1.2
Commercial	Groundwater	23,473	0.53	490,270	4.8
	Surface and Groundwater	366,703	8.22	3,718,473	10
	Surface Water	109,814	2.5	1,752,654	6.3
Industrial	Groundwater	86,107	1.9	665,187	13
	Surface and Groundwater	2,560	0.06	1,179,532	0.22
Recreational	Surface Water	6,780	0.15	337,392	2.0
Water Supply	Groundwater	2,083,963	47	20,422,619	10
	Surface and Groundwater	2,384	0.053	36,943	6.5
	Surface Water	1,168,263	26	6,624,750	18
Total	All Sources	4,463,124	100	85,184,571	5.3

In addition, there were 33 municipal water supply permits associated with six water systems drawing on groundwater: Adjala-Tosorontio, Alliston, Essa, Innisfil, New Tecumseth, and Newmarket. The remaining permits include a combination of seven communal water supply permits, 15 other types of water supply drawing on both surface water and groundwater, 12 permits for industrial use (aggregate washing, cooling water, food processing and other) and 3 permits for recreational purposes.

The total annual permitted taking in the WQSA is approximately 85.18 million m^3. Of the total permitted taking, approximately 58% is permitted for agricultural purposes, approximately 32% is for water supply, of which 24% are municipal supplies, 7% is for commercial purposes such as golf courses, 2.7% is for industrial use such as aggregate washing, cooling water, food processing and approximately 0.4% is for recreational use.

In comparison, total takings reported for 2017 for both surface water and groundwater were approximately 4.5 million m^3, which only represents about 5.3% of the total permitted taking volume.

Water Supply

Municipal water supplies represent approximately 73% of the total reported takings, about 46% from groundwater and 26% from surface water from Lake Simcoe.

Commercial

Commercial PTTWs make up 11.2% of total volume taken in the Innisfil WQSA (0.53% groundwater, 2.7% surface water, 8.2% both). Within the Specific Purpose category, Golf Course Irrigation is the only recorded taker, using 11.2% of the total volume taken in WQSA. Mall/Business and Other Commercial have permits to take water, however use less than 0.00% of the total volume taken in the WQSA.

Industrial and Recreation

Industrial PTTWs make up 2% of total volume taken in the Innisfil WQSA (1.9% groundwater, 0% surface water, 0.05% both), whereas Recreational and Miscellaneous use approximately 1.45%. Within the Specific Purpose category for Industrial takings, Food Processing is the dominant taker, using 1.55% of the total volume taken in WQSA, followed by cooling water using 0.21%, aggregate washing using 0.06%, and other using 0.17%. Recreational uses 0.15% of total WQSA takings, being used exclusively for Aesthetics.

Agriculture

Reported water takings in 2017 for agricultural and commercial purposes account for approximately 14% and 11% of total reported takings, respectively, the majority of which are seasonal surface water takings. 13.3% of these taking are from surface water sources. This is reflective of the fact that surface water withdrawals represent the most economically feasible source of water, from the perspective of infrastructure costs (Matrix and BluMetric, 2017).

As discussed below, the challenge of water resource sustainability in the WQSA is mainly focused around the issue of adequate surface water resources to meet both agricultural irrigation needs as well as hydrologic function in the watershed. The following provides some context to the issue as well as summarizes aspects of the water takings for agricultural purposes.

The NVCA completed a field-based agricultural resource inventory of the Innisfil Creek watershed in the summer of 2014 (McPhie and Post 2015). The report provides land use data for 2010, 2011, 2012, and 2014. In July 2013, Matrix Solutions Inc. and BluMetric Environmental Inc. completed a windshield survey, which provided information about the total area potentially being irrigated in 2013. This information was further augmented with the 2011 Census of Agriculture data and the related data provided in *Agricultural-Water Quantity Climate Change Sensitivity Assessment, NVCA Watershed* (Post 2014).

Local irrigators reported that due to the primary type of irrigation equipment used in the watershed (i.e., centre pivot, stationary gun, and travelling gun) that irrigation occurs typically where the slope of the land is not greater than 1%. Using this criterion, there are potentially 8,528 ha of land that are suitable for irrigation agriculture in the Innisfil Creek watershed. Primarily the irrigable land is located in the Simcoe Lowlands in the downstream reaches of Innisfil Creek and secondarily the land located in the muck soils at the headwaters of Innisfil Creek in the Cookstown Hollow Swamp area. These two areas strongly correlate with a slope of less than 1%, making it ideal for irrigation. As the field-based inventory indicates, only a very small percentage of this land is actually irrigated on any given year, and it is typically irrigated on a rotating basis from year to year. Therefore, this type of data should be considered a snapshot in time.

The top four irrigated crops grown in the Innisfil Creek watershed are potato, turf, onion, and cabbage. Based on the existing equipment observed in the watershed and the survey data from 2014, the total area covered at any given time by the three top irrigation systems was approximately 1,033 ha. This represents approximately 12% of the potentially irrigated land at any given time. The transportability of travelling guns could potentially increase the area irrigated; however, it would not likely represent a significant increase in any given irrigation season. A significant increase in irrigated land would require additional capital investment in irrigation equipment.

As can be expected, the total amount of water taken for irrigation purposes is generally inversely proportional to the amount of precipitation. In addition, the timing of the irrigation is a critically important consideration. The timing of water availability is a critical issue and varies depending on the crop and the start time of the growing season (late versus early spring). Based on literature values and the 2008 water use survey results, most crops grown in the Innisfil Creek watershed ideally need between 19 mm and 25 mm of water each week in the months of July and August. Although climate and precipitation is inherently variable, the long-term average precipitation between May 1 and September 30 for the WQSA is reported to be between 350-400 mm. Based on the spatial and annual variability, the long-term precipitation average of 350-400 mm over the 20 weeks was used to determine that, theoretically, the weekly average precipitation in the watershed is approximately 18 mm between May and September, (Matrix and BluMetric, 2017).

Based on an assessment of the 2011, 2012 and 2013 reported monthly water taking compared to total monthly precipitation as measured at two separate meteorological stations for the same years, water takings could not be directly correlated (Matrix and BluMetric, 2017). However, it was noted that there is significant variability in precipitation patterns within the watershed. Therefore, a reliable climate station providing accurate precipitation data on a local field and weekly scale would allow for a more accurate assessment of the correlation between precipitation and reported water takings.

7.2.6.2 Non Permitted Takings

The non-permitted estimated water demand includes water used for "unserviced" domestic water use, livestock watering, equipment washing, and any other agriculture water use excluding water used for irrigation. Recent work by NVCA on Agricultural Water Quantity Climate Change Sensitivity Assessment in the NVCA watershed (Post, 2014) reported that total livestock water use in the Innisfil Creek watershed was approximately 330 m^3 per day (120,000 m^3/year) (Matrix and BluMetric, 2017). Earlier estimates of non-permitted takings were completed for the northern part of the WQSA as part of the Tier 2 Stress Assessment. The Tier 2 Stress Assessment included the "unserviced" domestic water use for any household water use that was not supplied by a municipal water source. The estimate of the unserviced domestic water use was determined using the 2006 Statistics Canada census data. The end result was that the unserviced population was multiplied by a per-capita usage of 335 L/day, resulting in an estimate of approximately 550,000 m^3/year of rural domestic water use (AquaResource and Golder 2010).

7.2.7 Recommended WQSA Boundaries for Data Review

The Tier 2 Stress Assessment for groundwater in the north part of the preliminary WQSA concluded that there is a "Low Potential" for stress on municipal groundwater supplies both with average and maximum demand. The Alliston water supply in the Town of New Tecumseth is augmented by a pipeline from Georgian Bay resulting in there being a low potential for stress on municipal groundwater supplies. In addition, the majority of the active PTTWs and most of the reported water shortages fall within the smaller Innisfil Creek watershed boundary. Furthermore, local water managers have identified the Innisfil Creek watershed as an area of concern within the preliminary WQSA area and therefore completed a number of key water resource related studies noted in Table 7-1. Refining the Innisfil WQSA boundary to just the Innisfil Creek watershed, allows for a more detailed and current water resource assessment of the Innisfil WQSA. Accordingly, Figure 7-12 illustrates the recommended revised WQSA boundaries.

7.3 RESOURCE SUSTAINABILITY

7.3.1 Data Review and State of Water Resources

At noted above, the revised WQSA boundary has a relatively significant amount of data and information about the state of the water resources in comparison to some of the other WQSAs. The NVCA has conducted, coordinated and participated in a significant number of studies over the past decade compared to other WQSAs. Some of these studies have been led by NVCA and others have been a partnership of stakeholders drawing on multiple sources of funding and in-kind support. In addition to the required reports under Source Protection for municipal supplies, the NVCA also completed a subwatershed Health Check in 2013 for the revised WQSA which considered the condition of the wetlands, streams and groundwater in the subwatershed. Furthermore, the revised WQSA has data and information from water use surveys, integrated water resource management planning, an impact assessment of the NVCA PGMN groundwater levels to anticipate long-term climatic variation sensitivity as well as completing a drought management plan pilot which included consideration of climate change, population growth and land use change (Matrix and BluMetric, 2017). Most recently (June 2018), NVCA was one of four watersheds used to pilot an evidence-based approach to evaluate the hydrologic function of a watershed. All of these sources of information have been used for the discussion about the resource sustainability in the revised WQSA.

High Use Watershed Classification

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a Medium percent water use based upon both the Average Annual and Summer Low Flow.

PGMN Hydrographs

The MECP provided hydrographs and a statistical analysis of water levels for all PGMN wells in all WQSAs. In the Innisfil WQSA, hydrographs and a statistical analysis of water levels were provided for fifteen PGMN wells (including one multi-level installation) located within and surrounding the Innisfil WQSA, including Mann Kendall and Seasonal Mann Kendall trend analyses between 2001-2017. These wells are summarized in Table 7-5 and shown on Figure 7-10. The methodology for the analysis is forthcoming from the MECP; however the results are reied upon here to summarize water level trends in the Innisfil WQSA.

Table 7-5: PGMN Wells in Innisfil WQSA

PGMN Well ID	Water Well Record ID	Screened Interval (mbgs)	Lithology of Aquifer
W0000058-1	5722961	Screen: 11.0 m-14.0 m	Sand
W0000223-1[1]	N/A[2]	Screen: 73.8 m-76.8 m	Sand
W0000224-1	N/A[2]	N/A[2]	Sand, Gravel
W0000231-1[1]	5705649	Screen: 39.9 m-43.5 m	Gravel
W0000281-1	5737782	Screen: 4.6 m-7.6 m	Sand, Gravel
W0000323-2	5737734	Screen: 15.2 m-18.3 m	Sandy Silt
W0000323-3	5737733	Screen: 29.0 m-32.0 m	Sandy Silt
W0000323-4	5737735	Screen: 102.1 m-105.2 m	Sandy Silt
W0000327-4	4907845	Screen: 79.9 m- 87.1 m	Sand, Silt
W0000328-1	N/A[2]	Open Hole: 11.0 m- 29.1 m	Limestone
W0000329-1[1]	4905007	Screen: 46.9 m- 50.0 m	Sand
W0000330-1	4909344	Screen: 21.0 m-24.0 m	Silt
W0000479-1	N/A[2]	Screen: 83.5 m- 90.2 m	Sand, Silt
W0000480-1[1]	5728376	Screen: 30.2-32.6 m	Sand, Gravel
W0000508-1[1]	N/A[2]	Screen: 150.8 m-152.3 m	till

[1] Ministry staff noted the data for trend analysis purposes is deemed unreliable

[2] Information not provided by Ministry

There are six wells located within the WQSA for which the trend analysis was determined to be reliable. However, the trend analysis for several of the PGMN wells in the Innisfil WQSA have been determined by Ministry staff to be unreliable, typically due to multiple years of missing data; For example, W0000058-1 has no data provided after 2010, W0000224-1 has no data between 2006 and 2009, W0000327-4 has no data after 2010, W0000328-1 has no data before 2004 or after 2013, W0000330-1 has no data after 2012 and W0000479-1 has no data before 2009.

The Mann Kendall analysis, which looks at the year over year water levels between 2001 to 2017, determined that the wells had no trends. The Seasonal Mann Kendall analysis, which determines the trend from season to season (e.g., Spring 2010 to Spring 2011) and then adds the sum of each seasonal analysis together, established that four wells had an upward water level trends (W0000323-3, W0000323-4, W0000327-4, W0000479-1), one (W0000480-1) had no seasonal trend and one (W0000508-1) had a downward seasonal trend.

All PGMN wells are screen in the overburden between 15.2 to 152.3 mbgs with well depths near Tottenham being unknown. The well depth of the PGMN well which had a downward seasonal trend (W0000508-1) was the deepest well, screened in the overburden between 150.8 and 152.3 mbgs. However, the data only represents water levels over two years (2014 to 2016) and is therefore deemed insufficient to make a definitive assessment based solely on this trend.

Based on all the hydrographs from these PGMN wells, regional water levels in the complex overburden aquifer system appear unimpacted by any water takings or climate stress. This is consistent with the recent temporal analysis completed by the NVCA (June 2018) and described below as part of the groundwater assessment.

Stream Flow (HYDAT)

Stream flow gauges in the revised WQSA are all located in the central part of the watershed and are all HYDAT stations. These are on Innisfil Creek near Alliston, on Bailey Creek near Beeton and on Beeton Creek near Tottenham. The data from these stations were analyzed in detail in the process of completing the Drought Management Plan Pilot (Matrix and BluMetric, 2017) and are discussed in more detail below.

WQSA Water Budget (Matrix and BluMetric, 2017)

A water budget for the Innisfil Creek watershed and the five subwatersheds within was determined using a MIKE SHE model. Based on the model output using data between 1983 and 2012, the total change in storage is -3 mm/year. This assumes that 1 mm/year is added via irrigation. It should be noted that this assumption is highly variable between years due to climate differences as it relates to irrigation needs. It should also be noted that evapotranspiration can be highly variable.

In summary, precipitation is highest in the Bailey (855 mm) and Beeton (844 mm) subwatersheds, both located in the southern portion of the watershed with headwaters in the ORM. The Innisfil Creek subwatershed has an evapotranspiration rate (617 mm), followed by Bailey (610 mm) and Penville (608 mm). Evaporation is higher in the Innisfil Creek subwatershed due to both the sandier soils and the shallow depth to water table making water more available.

Streamflow is lowest in the Innisfil and Penville subwatersheds. In the Bailey subwatershed, the largest streamflow contributor is interflow, while in the other watersheds overland flow is the largest streamflow component. The Bailey subwatershed has the least amount of net flow into and out of the model.

Physiographic Zone Water Budget (Matrix and BluMetric, 2017)

The MIKE SHE model also allowed for an integrated water budget for each of the three physiographic zones identified in the refined WQSA, including the sand lowlands, the ORM, and the clay/till uplands to be determined.

In summary, the Lowlands experience a net inflow of 66 mm/year across the lateral boundaries. The inflow is due to groundwater and overland flow entering from the Uplands and then infiltrating the subsurface. The Lowlands receive on average 829 mm/year of precipitation, 100 mm of which is from snowfall. Evapotranspiration (626 mm/year) is higher in this region, even though precipitation is consistent with the Uplands and lower than the ORM. This is due to the presence of sandy soils and wetlands. In the Lowlands, the largest contributor to streamflow is interflow (140 mm/year), followed by overland flow (100 mm/year) and baseflow (19 mm/year). High interflow is consistent with the large amount of tile drainage in the lowlands and near-surface water table. Despite total streamflow (259 mm/year) being the highest in the Lowlands compared to the other physiographic regions, baseflow is lowest (19 mm/year). Even though groundwater heads are closer to ground surface in the Lowlands, groundwater does not support baseflow as much as the other regions. This is due to the glaciolacustrine deposits that infill the majority of the valley. Water withdrawals from irrigation make up the majority of the pumping in the lowlands (3 mm out of 4 mm). Although irrigation is a small contributor in the overall water budget, it is almost exclusively occurs in the Lowlands.

The Uplands experience a 38 mm/year net outflow of water through its lateral boundaries and to adjacent physiographic zones. The water in the Uplands flows both out of the model domain to the Nottawasaga and to the Lowlands. The uplands receive 828 mm/year of precipitation. Due to the high proportion of tills and clays and the presence of more urbanized communities, the Uplands have a lower rate of evapotranspiration (599 mm/year) relative to the watershed average. The Uplands have a streamflow yield of 188 mm/year, of which 60% originates from overland flow. As the water table in the Uplands is lower, the subwatershed produces significantly less interflow than the Lowlands. The tighter soils result in less infiltration (more runoff) and less interflow to the streams due to lower conductivities. The majority of pumping from non-irrigation sources occurs in the Uplands.

The portion of the ORM within the refined WQSA is approximately 77 km^2 and is located along the southern border of the watershed. Over 80% of the area is comprised of sand and gravel deposits, with clay (10%) and Newmarket Till (6%) making up the remaining area. Land cover is predominantly agricultural (63%) with the next largest land cover component being forest (28%). Other minor land uses include wetlands (5%), urban areas (2%), extractions (2%), and open water (1%).

The ORM has the highest precipitation (886 mm/year) seen in the watershed both in terms of rainfall (772 mm/year) and snowfall (114 mm/year). It experiences a net boundary outflow of 49 mm/year to the Uplands and model boundary. Evapotranspiration (603 mm/year) is lower than the Lowlands and higher than the Uplands. This area also has one of the highest streamflow yields (236 mm/year) in the Innisfil Creek watershed. This is partially due to the higher than average precipitation. Of the 236 mm/year of streamflow generated in the ORM, more than half (146 mm/year) is provided through drain flow. Interflow (146 mm/year) and baseflow (41 mm/year) are high, and overland is low (48 mm/year) relative to the other zones due to the highly conductive soil.

Spatial Distribution of Key Water Budget Components (Matrix and BluMetric, 2017)

The Matrix and BluMetric (2017) report also provided the estimated average annual evapotranspiration, groundwater recharge, and groundwater discharge, respectively, rates modelled across the refined WQSA.

The rate of evapotranspiration is highly dependent on the amount of water available that can be evaporated. The average annual evapotranspiration for the entire watershed is 606 mm. In areas with a shallow depth to water, such as along stream channels, in wetlands, and in the lowlands, increased rates of evapotranspiration occur as expected. Similarly, for areas with large amounts of water available (e.g., wetlands or groundwater discharge areas), evapotranspiration is high. This is evident for wetlands located in the northern part of the lowlands valley. Alternatively, when the availability of water to sustain evapotranspiration is limited, estimates of evapotranspiration will be low. Urbanized areas in the region are distinguished by reduced evapotranspiration rates. The reduced evapotranspiration rate in urban areas is consistent with the lack of vegetation and reduced infiltration in these areas. The depth to water table (i.e., shallow in lowlands), urbanization and location of discharge features (i.e. wetlands) have a more significant influence on evapotranspiration than soil type.

Areas having the highest groundwater recharge in the watershed include both the valley (or lowlands) flanking Innisfil Creek and the ORM in the southwest of the watershed. These areas are dominated by sand plains and coarse fill and are consistent with the Significant Groundwater Recharge Areas (SGRAs) defined in the Drinking Water Source Protection Assessment Report for the Nottawasaga Valley Source Protection Area (SGBLS SPC 2015). The average annual recharge in the sand and gravel areas was reported to be 275 mm. The Lowlands, comprised mostly of sand, receive approximately 225 mm/year of recharge and the ORM receives approximately 255 mm/year of recharge. The average annual recharge in the Uplands comprised mostly clay and till regions, was reported to be approximately 140 mm/year. The most significant influence on the amount of groundwater recharge generated is surficial geology and how pervious the surficial materials are.

7.3.1.1 Groundwater

As described above, in 2013 a Watershed Health Check was completed for Innisfil Creek watershed. This Health Check identifies stewardship priorities and programs to improve environmental health of the watershed. Healthy ecosystems sustain healthy communities, as well as future challenges and opportunities for the watershed community. In the 2013 Watershed Health Check, the groundwater quality was considered very good (NVCA, 2013). Water quality parameters for groundwater show all monitoring wells meet Ontario Drinking Water Quality Standards. This in turn indicates that the availability and use of groundwater resources in the watershed are not limited by water quality issues.

More recently, the 2018 hydrologic function assessment (NVCA, June 2018) provided a temporal analysis of the PGMN wells within the revised WQSA. In this assessment four PGMN wells within the WQSA were considered but only one had sufficient data for analysis of both annual and seasonal trends. W0000323-2, a shallow overburden well screened between 15.2 and 18.3 m near Bradford West Gwillimbury, generally has the highest groundwater levels between May and June, and has the lowest levels between December and February, although this can vary between years. Since observations began in 2003, the groundwater levels have fluctuated within a range of just over 4 m.

Based on the annual average climate data (2006 and 2008-2016), 2009 and 2011 were the wettest years, and 2006 and 2015 were the driest years. This is consistent with the temporal analysis on the same well as completed for the Drought Management Plan Pilot (Matrix and BluMetric, 2017).

7.3.1.2 Surface Water

Matrix and BluMetric (2017) determined that the overall impact of irrigation on streamflow shows evidence that the existing irrigation practices in the WQSA impacts the flows most notably during July and August in years with below average precipitation over the same period. As expected, in years when summer precipitation rates are high, the resulting flows is higher than average and therefore the impact of irrigation practices under these conditions is typically not experienced nor are flow conditions impacted by irrigation during the fall and spring (Matrix and BluMetric, 2017). However, it was also noted that the low flow conditions are not only limited to the months with significant irrigation (July and August), but also can extend into September. This suggests that the lack of summer flow is not solely caused by surface water withdrawals, but rather is the natural condition of Innisfil Creek.

Consistent with the results from the streamflow described above, the MIKE SHE model found that the majority of streamflow for the Innisfil Creek watershed is associated with direct overland runoff or quickly responding interflow. Groundwater discharge is estimated to be less than 15% of total streamflow.

Limited groundwater discharge occurs in the Innisfil Creek valley, and is focussed on the physiographic and topographical boundary between the Uplands and valley Lowlands. As noted above the shallow surficial aquifer which supports the limited amount of baseflow does not typically yield enough water to be widely used for a domestic water supply.

7.3.1.3 Water shortages

Low water conditions experienced within the revised WQSA, as described in Table 7-3, were primarily related to surface water resources. Specifically, the ongoing demand on surface water for the purpose of agricultural irrigation together with climate variability in terms of timing and amount of precipitation between May and September contributes to persistent low water conditions in Innisfil Creek. Surface water shortages resulting from these types of conditions were particularly pronounced in 2007, 2012 and 2016. The area is also faced with a low percentage of forest cover, which contributes to reduced stream health according to the Innisfil Creek: 2013 Subwatershed Health Check (NVCA 2013).

As noted above, groundwater-surface water interaction is limited in the watershed. Also noted above, surface water resources are heavily relied upon by seasonal takings for agricultural (irrigation) purposes. As mentioned previously, these seasonal takings are inversely correlated with the amount and timing of precipitation between May and September and therefore water shortages are typically reported in years with below average amounts of precipitation in June, July and August. The timing of the precipitation is also important as the ideal amount is between 19 mm and 25 mm a week for most crops in the WQSA.

As described in the Innisfil Creek watershed Drought Management Plan Pilot (Matrix and BluMetric, 2017), low streamflow conditions can be caused by anthropogenic causes (i.e., water withdrawals), natural conditions (i.e., watershed has limited ability to produce baseflow in dry periods), or it can be a combination of the two. In watersheds with minimal water withdrawals, understanding the factors influencing low water conditions can be straightforward; the geologic and physiographic nature of the watershed precludes sustained flows/levels during dry periods. In such watersheds, there are limited management approaches that can mitigate low water conditions. In watersheds with a moderate to high level of water withdrawals, including for example the revised Innisfil WQSA, understanding the relative importance of individual factors can be more complex, and more sophisticated techniques are required for both surface water and groundwater.

Ontario Low Water Response Program

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater level elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%;
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the WQSA.

A review of the OLWR database indicates that a total of ten Level 1 notifications, and two Level 2 notifications, were sent to the NVCA between 2000 and August 2018. It should be noted that these are watershed wide and there have been no recorded instances where notifications have been made as a result of local conditions in individual subwatersheds. Instances where more than one notification was issued in the same calendar year occurred in 2002 (3 Level 1 notifications), 2003 (3 Level 1 notifications), 2006 (3 Level 1 notifications), 2010 (4 Level 1 notifications), 2012 (3 Level 1 notifications) and 2015 (3 Level 1 notifications).

The NVCA posted Low Water Condition Alerts (all Level 1) during 8 periods for the watershed as a whole:

- July 2001 to early November 2001;
- Mid-August 2003 to early December 2003;
- Early August 2005 to early December 2005;
- Late June 2007 to late November 2007;
- Mid-July 2011 to early September 2011;
- Early July 2012 to mid-August 2012;
- Late August 2012 to late September 2012;
- Mid-July 2016 to mid-November 2016.

From 2007 to 2018, NVCA began posting Low Water Condition Alerts to select subwatersheds, including the Innisfil Creek subwatershed. Periods when Level 1 and Level 2 Low Water Condition Alerts were posted to the Innisfil Creek subwatershed included:

- Late June 2007 to early November 2007: a Level 1 Low Water Condition Alert was posted in late June 2007, which was raised to a Level 2 in late July, and lowered back down to a Level 1 in mid-October. The Low Water Condition Alert ended entirely in early November 2007;
- Mid-July 2011 to end of July 2011: a Level 1 Low Water Condition Alert was posted;
- Early July 2012 to end of September 2012: a Level 1 Low Water Condition Alert was posted.

Overall, the OLWR database indicates that the NVCA has found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts. No specific trends can be discerned in the frequency of Low Water Condition Alerts or OLWR notifications, and therefore do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends.

7.3.2 Assessment of Sustainability of Water Resources

7.3.2.1 Climate Change

In addition to understanding the potential changes to the hydrologic regime in the WQSA from existing irrigation practices, the Matrix and BluMetric (2017) assessment also described the impact of climate change including the worst-case for several different water use scenarios. The five scenarios considered were no water taking, no change in water taking, changing all surface water takings to groundwater takings, irrigating the maximum possible irrigable area and irrigating only one third of the irrigable area. The methodology used in the assessment of the impact of Climate Change followed the methodology outlined in EBNFLO and AquaResource (2010). Ten future climate projections were selected and the climate station considered was the ECCC Beeton Graham climate station, for the period from 2041 to 2070.

As a general statement, future climate is predicted to influence the hydrologic regime in the WQSA with reduced snowpack, more rain, and warmer temperatures predicted. Five of the ten climate change scenarios used in the hydrologic assessment for the WQSA projected an increase in annual precipitation, while eight projected a decrease in snowfall.

Under future simulated conditions, mean annual precipitation ranges from 744 mm to 883 mm. Between 1971 and 2000, the annual average precipitation for the watershed was 797 mm. Regardless of whether precipitation increases or decreases, in all scenarios, evapotranspiration increases due to the increase in temperature. Evapotranspiration has been estimated as part of the *Water Quantity Resources of Ontario* (MNR 1984) and found to be 550 to 600 mm/year near the Innisfil Creek watershed. Changes in evapotranspiration range from 596 mm to 635 mm, with a median of 620 mm.

For all scenarios, including current, overland flow is the largest streamflow component, followed by interflow and baseflow. Under future climate, annual overland flow ranges from 59 mm to 104 mm; annual interflow ranges from 59 mm to 97 mm, and annual baseflow ranges from 22.7 mm to 29.3 mm. The median climate change scenario based on precipitation, predicts a slight decline in annual overland flow (from 87 mm to 83 mm), a slight increase in annual interflow (from 76 mm to 78 mm), and no change in annual baseflow (26 mm). Total streamflow volume is highly dependent on whether the future climate scenario predicts an increase or a decrease in precipitation. For comparative purposes, the available data (1960-2014) from the four WSG stream gauges in the WQSA, indicates annual streamflow ranges between 199 mm (Bailey Creek near Beaton) to 300 mm Nottawasaga River near Alliston and annual baseflow (includes interflow) ranges between 84 mm and 147 mm at the same locations for the same date range. In addition, the output from the developed MIKE SHE model (Matrix and BluMetric, 2017), for Innisfil Creek watershed using available data between 1983 and 2012 shows an annual overland flow ranging between 71 mm (Bailey Creek) and 125 mm (Beeton Creek), an annual interflow ranging between 38 mm (Penville Creek) and 139 mm (Bailey Creek) and an annual baseflow ranging between 23 mm (Cookstown Creek) and 31 mm (Bailey Creek). The output from the MIKE SHE model for the overall watershed indicates an annual overall flow of 98 mm, an annual interflow of 91 mm and an annual baseflow of 28 mm. It should be noted that the baseline scenario in the output for the water budget in the climate change analysis uses a different time period than that used for existing conditions (1983-2012) therefore, the results differ marginally.

Predicted Changes in Streamflow Regime (Matrix and BluMetric, 2017)

In terms of impact to mean annual streamflow, the results of the analysis are variable. Half of the future climate scenarios predict a decrease in the mean annual streamflow of Innisfil Creek; with the remaining half of scenarios predict increases.

Streamflow regime changes were predicted based on ranked duration curves for the future climate scenarios (2041-2070) compared to the baseline scenario (1971-2000), by Matrix Solutions and BluMetric Environmental. The associated reductions in the streamflow would significantly affect the reliability of Innisfil Creek to supply water for both irrigation and ecologic needs.

All future climate scenarios predict higher median winter flows in January and February. This is due to a reduced snowpack, and more precipitation falling as rainfall than snowfall. As the spring freshet is reduced and occurs earlier in the year, future April flows are reduced from baseline conditions. Due to the earlier onset of summer conditions, the majority of scenarios predict lower future median summer flows.

Low flows are expected to change the most in February and March with an increase in flows in response to future climate in all scenarios. Most scenarios from April to July indicate a decrease in flows for those months. While most scenarios in August to October show a similar exceedance in flow to the baseline, two scenarios show a considerably lower flow.

Increases in high flows under future climate occur for the majority of scenarios in January, February, November, and December. These high flows are mostly predicted to reduce in March and April as a result of a smaller freshet.

Changed Irrigation Practices (Matrix and BluMetric, 2017)

With the earlier onset of summer conditions, overall warmer temperatures, and resulting increased evapotranspiration, it is likely that irrigation requirements will also increase due to climate change. As the Innisfil Creek MIKE SHE model simulates irrigation demand, it is possible to estimate the potential change in irrigation demand under a changed climate.

Annual irrigation is predicted to increase in all future climate scenarios. Existing irrigation, estimated to be approximately 470,000 m^3/year, can be expected to increase by a minimum of 40% to 650,000 m^3/year, or a maximum of 90% to 890,000 m^3/year. This assumes the same area of cropland is irrigated in the future as was irrigated in 2012 but this assumption is highly unlikely. As stated above, census data indicates that there has been a steady decline in total area of cropland (25% decrease in farmland) and a steady increase in services residential land use within the WQSA. However, it should be noted in this current assessment that the climate change analysis reported that even for the most optimistic future climate scenario, it is not likely that surface water within the Innisfil Creek watershed can support an irrigation demand increase of 40%.

Low Water Conditions (Matrix and BluMetric, 2017)

Similar to the ranked duration curves, the climate change scenarios project both an increase and decrease in low water conditions.

The median projection predicts almost no change in Level 1 conditions, a 9% increase in number of days with a Level 2 condition and a 25% increase in the number of days with a Level 3 condition. The driest scenario shows a significant increase in all low water days, Level 1, Level 2, and Level 3. Days below the Level 3 threshold are particularly concerning, with an increase of almost 200%. Interestingly, the wettest scenario shows a decrease in the number of low water days for all levels.

The frequency of Level 1 days is expected to slightly increase through spring and summer, increase in early fall, before having a decreasing frequency through winter and early spring. Days with Level 2 flow conditions are simulated to increase in the month of June, as well as the fall months. The occurrence of days with flows below the Level 3 threshold are significantly increasing, with certain periods in the summer months having Level 3 frequencies that more than double.

Worst-case Future Scenario (Matrix and BluMetric, 2017)

The MIKE SHE model output of the number of days with Low Water Conditions under different water use scenarios using future climate conditions (2041-2070) CLM8 (INMCM3.0 SRA2) as compared to the Baseline Climate 1971-2000 is presented and discussed in detail in the Drought Management Plan Pilot report by Matrix and BluMetric (2017). This section is a summary of the more detailed discussion presented in that report.

Comparing the Baseline Climate (1971-2000) with Existing Pumping scenario to the Future Climate (2041-2070) with Existing Pumping scenario, the number of days with Level 1, Level 2, and Level 3 flow conditions over the 29 year time period increase by approximately 1,240 (30%), 1,570 (57%), and 950 (179%) days, respectively. These are significant increases in days with low water, in particular for days below the Level 3 threshold and are an indication of how significantly Climate Change may impact the hydrologic regime of Innisfil Creek. It is interesting to note that under Future Climate, there is relatively minor variation in days below Level 1 and Level 2 for the No Pumping, Existing Pumping, Groundwater, Max Irrigation Area, and 1/3 Max Irrigation Area scenarios. This suggests that the change in climate will have a more significant effect on future low flow conditions than any of the scenarios investigated.

Results of the water use scenarios under the changed climate display a similar pattern as observed under historical climate conditions. Days with Level 3 flow conditions are similar for the No Pumping and Groundwater scenarios, while the Existing Pumping scenario shows a 15% increase in Level 3 days over the No Pumping scenario. Both the Max Irrigation Area and 1/3 Max Irrigation Area scenarios display significant increases (28% and 47%, respectively) in days with Level 3 flow conditions when compared to the Existing Pumping (2041-2071 climate).

There are very few differences between water use scenarios and the frequency of a Level 1 low water condition. Compared to the Baseline Climate (1971-2000), all scenarios exhibit an increase in the frequency of a Level 1 condition occurring. This increase is most noticeable in the spring/early summer and fall.

Of particular note, the No Pumping scenario for the worst-case future climate condition has a significantly increased number of days below the Level 3 threshold than the Baseline Climate (1971-2000), with Existing Pumping scenario. While the assessment found that water withdrawals were responsible for Level 3 flow conditions under existing climate conditions, this finding suggests that a future climate will be predominantly responsible for an increased frequency of Level 3 flow conditions. This calls into question Innisfil Creek's ability to reliably supply water for either irrigation purposes or instream flow needs under a future climate condition.

Similar to Level 1 low water conditions, the change in the frequency of a Level 2 low water condition occurring is more impacted by the change in future climate than the change in irrigation practices. The results are very similar between different irrigation scenarios under the worst-case future climate. The Max Irrigation Area scenario has a slightly higher frequency of experiencing a Level 2 before June 1. Comparing Baseline Climate (1971-2000) with Existing Pumping, there is approximately a 60% increase in the number of days with a Level 2 condition under the worst-case future climate scenario, while irrigation scenarios increase the number of days by only 3%.

Under the worst-case future climate scenario, Level 3 low water conditions occur earlier (May) and last later into the year (December). In contrast to Level 1 and Level 2 conditions, the frequency of Level 3 conditions diverges between the evaluated scenarios, in particular the Max Irrigation Area and 1/3 Max Irrigation Area scenarios. However, the majority of this divergence is found early in the irrigation season (i.e., June). During the peak of irrigation season (July and August), between 70% and 80% of all days are expected to have flows below the Level 3 threshold under the worst-case future climate condition.

In summary, all global climate models project an increase in temperature, and while most predict an increase in mean annual precipitation, three scenarios predict a decrease. Resulting changes in streamflow are strongly correlated to whether a particular scenario was wetter or drier than baseline. For those future climate scenarios that were wetter, extreme low flows (flows that are exceeding 95% of the time) were not increased to the same degree as the more frequently observed flows; rather they remained similar to those simulated under the Baseline Climate (1971-2000). Alternatively, those future climate scenarios that were drier resulted in significantly reduced extreme low flows (flows that are exceeding 95% of the time).

The composition of streamflow, in terms of overland flow, interflow, and baseflow, remains the same as under baseline conditions, with the Innisfil Creek watershed being a runoff-dominated system. The timing of when streamflow is generated will be shifted. More streamflow will be generated during the winter months, and the spring freshet will be reduced and will occur earlier.

Total irrigation was simulated to significantly increase (40% to 90%), for all future climate conditions due to increasing temperature and evapotranspiration. While some future climate conditions resulted in a reduction in low water days, the majority of future climate scenarios indicate an increase, in particular the number of days with streamflow conditions that are below a Level 3 threshold.

When evaluating the water use scenarios under a changed climate, it is apparent that the most significant factor resulting in an increase in low water days is not the water use scenarios themselves, but the expected change in climate. This change will not occur immediately, but will require constant adaptation to a gradually warming climate. For the most extreme climate projection, under the No Pumping scenario, the number of days below a Level 3 flow condition is expected to increase by 180% from Baseline Climate (1971-2000) with the Existing Pumping scenario. If the most extreme climate projection occurs, what is now considered to be extreme low flow would become the new normal. This modification to the hydrologic regime of Innisfil Creek is so significant that without significant adaptation measures the creek may not be considered a reliable source of water to meet irrigation demands.

7.3.2.2 Population Growth

The population in the Innisfil Creek watershed region is experiencing a growth surge reflecting ongoing regional growth. From 2006 to 2011, the Town of Bradford West Gwillimbury grew at 3 times the provincial rate and the Town of New Tecumseth, which includes Alliston, grew by 23% or almost four times the provincial average. In keeping with this rapid growth and bordered by large population centres, the Toronto/Barrie Highway 400 corridor and the Ontario Greenbelt, the watershed has seen intense land speculation and planning for new housing developments in communities such as Cookstown, Beeton, and Tottenham (Matrix and BluMetric, 2017).

The top five sectors by employment (Manufacturing, Retail Trade, Construction, Health Care and Social Assistance, and Educational Services) account for 51% of jobs in the region. The number of jobs in Manufacturing declined by 15% between 2006 and 2011, while job growth has been seen in the Retail sector, (Matrix and BluMetric, 2017). Despite Manufacturing job losses, the sector is becoming more focussed in the automotive industry.

Although the local economy is still specialized in Agriculture, it is becoming less so. Agricultural jobs declined 21% between 2006 and 2011. The number of farms declined by 26% from 410 to 304 farms between 1991 and 2011, while total farmland area fell 25% from 32,325 hectares to 24,003 hectares, the highest rate of loss of any subwatershed in the Nottawasaga watershed, (Matrix and BluMetric, 2017).

Farm irrigation is also declining. Since 1991, the irrigated area fell 55% from 1,387 hectares to 626 hectares. Between 1991 and 2011, the area in root crop production (including potatoes and sugar beets) in the Innisfil Creek watershed declined by 60% from a high of 944 hectares in 2001 to 379 hectares in 2011 while the area reported in sod production for the same period declined by 95% from 1,603 hectares to 75 hectares. Some of this variation may of course reflect ongoing annual fluctuations of crop activities in response to growing conditions, markets, and the need to rotate crops, (Matrix and BluMetric, 2017).

Other significant agricultural trends include increasing average farm size and increased reliance on rented cropland. From 1991 to 2011, the proportion of rented farmland in Innisfil Creek watershed increased from 43% to 52%. This increase in rented farmland decreases commitment to irrigation infrastructure and affordable rents are an important determinant of long-term commitments to farming in the region.

According to the County of Simcoe's Official Plan, the County is expected to continue to experience population and employment growth over the next twenty years. To help plan for the expected growth, the County of Simcoe completed a Water and Wastewater Visioning Strategy (Greenland Consulting Engineers, 2012) which includes background information and a water and wastewater servicing gap analysis. Many of the municipalities in the County, including those in the WQSA, will be augmenting their current groundwater supplies with surface water from outside the watershed (Matrix and BluMetric, 2017).

7.3.2.3 Cumulative Effects

As described in Section 7.3.2.1, the predicted impact of five different water use scenarios under Climate Change conditions have been examined. The scenarios include an increase in taking and a change in climate.

The following is a summary of the analysis:

- The flow conditions between no withdrawal and change of source, i.e. moving from a surface water source to a groundwater source, are very similar.
- Comparing flow conditions between existing withdrawals and no withdrawals indicates the following:
    - Current withdrawals **do not** result in a significant increase in the number of days with streamflow below Level 1 and Level 2 low water thresholds.
    - Current withdrawals result in a significant increase in the number of days with streamflow below the Level 3 low water threshold.
- The Max Irrigation Area and 1/3 Max Irrigation Area scenarios greatly increase the number of days below the Level 3 low water threshold, when compared to the existing withdrawals.
- When compared to the existing withdrawals, groundwater levels show a slight decrease (~ 1 m) under the change of source scenario, but appear to be stable.
- Scenarios with increased takings (Max Irrigation Area and 1/3 Max Irrigation Area scenarios) show significant decreases in groundwater levels (up to 15 m), and appear not to be sustainable for certain wells.

Ecologic

From a hydraulic point of view, the limiting factor associated with aquatic ecology is likely a suitable habitat for adult fish populations. The use of adult fish populations as an ecological indicator of the effects of direct pumping from the creek can also be used to represent the ecological suitability for other stages in the species life cycle within the same aquatic ecosystem.

Habitat has been assessed as having a low suitability for adult fish under the Existing Pumping scenario, which is 16% less than the No Pumping scenario. Innisfil Creek has been assessed as having a low suitability under the No Pumping scenario as well. This suggests that hydrologic regime of Innsifil Creek, without any water withdrawals, is not conducive to a thriving coldwater fishery.

Habitat suitability for both the young-of-the-year (YOY)/juvenile and adult life cycles is similar between the No Pumping and Groundwater scenarios.

Scenarios with an increase in water withdrawals (Max Irrigation Area and 1/3 Max Irrigation Area) show a significant decrease in habitat suitability for both life cycles; however, the adult life cycle is impacted to a greater degree.

Economic

The following is a summary of a more detailed economic assessment completed as part of the Drought Management Plan Pilot for the WQSA (Matrix and BluMetric, 2017). Full details and documentation on this approach is provided in Appendix D of Matrix and BluMetric (2017).
The use of water is a critical component to the following economic activities:

- Agricultural crops: Annual value is approximately $35 million (Appendix B of Matrix and BluMetric, 2017). A significant component is associated with potatoes and turf production.
- Golf courses: Annual value is approximately $11 million.
- Municipal and private water supplies: Annual value is approximately $19.7 million.
- Recreational fishing: Annual value is approximately $20,000.

Assuming that water restrictions are put in place after 5 consecutive days of a Level 3 flow condition, annualized crop losses due to drought is estimated at $1.9 million per year. The timeline of 5 consecutive days is based on a reasonable estimate of the length of time it would take to measure, analyze and declare a Level 3 flow condition. Five days is also within the unit of measure for the amount of water irrigators have reported demand, typically 0.02 to 0.25 m of irrigation per week. These values are based on a hypothetical scenario used in a sensitivity analysis, and do not necessarily represent current regulatory practices (Matrix and BluMetric, 2017).

If water restrictions are put in place after 10 consecutive days of a Level 3 flow condition, annualized crop losses due to drought is estimated at $1 million per year.

The economic case for converting water sources from surface to groundwater depends on how quickly water restrictions are implemented during a Level 3 flow condition. If water restrictions are quickly implemented (5 days or fewer), then the cost of conversion has a positive rate of return. Should water restrictions be implemented greater than 5 days after a Level 3 flow condition is encountered, the conversion does not have a positive rate of return.

Multiple Takers

The cumulative impact as result of multiple takers is most notable in areas where surface water takers are concentrated in a given area. Within the Innisfil WQSA, the ongoing demand on surface water for the purpose of agricultural irrigation together with climate variability in terms of timing and amount of precipitation between May and September contributes to persistent low water conditions in Innisfil Creek. Surface water shortages resulting from these types of conditions were particularly pronounced in 2007, 2012 and 2016. The combination of high demand in a clustered area, and climate variability causing drought suggest that cumulative impacts have affected some areas of Innisfil Creek subwatershed.

No cumulative impacts as a result of multiple groundwater takers have been noted in the Innisfil WQSA.

7.3.2.4 Environmental Flow Needs

The previous section has investigated the change in streamflow, as a function of the number of days below low water response thresholds, as well as change in groundwater levels. While understanding the impact of the investigated scenarios on streamflow volume is a critical first step, it does not inform on the potential changes to instream habitat that are associated with those scenarios.

To understand the changes in instream habitat that may result from the changed hydrologic regime, habitat suitability modelling was completed by Matrix and BluMetric (2017). Habitat suitability modelling relates hydraulic parameters (e.g., depth and velocity) to fish species preferences, at various points in a species life cycle. A two dimensional (2D) hydraulic model was utilized to quantify depth and velocity, under a specified flow condition, for a specific reach. The gridded velocity and depth values were subsequently linked to habitat preferences, resulting in an overall habitat suitability index for that reach. This approach allows multiple flow regimes to be investigated, determining the effect (e.g., worsened or improved habitat) for each scenario. Full details and documentation on this approach is provided in Appendix E of Matrix and BluMetric (2017).

To support this analysis, a 2D hydraulic model was developed for each of the eight reaches identified as "warm water with potential for coldwater habitat." For each of the identified reaches, a detailed geomorphic survey was completed (Appendix F of Matrix and BluMetric (2017): Field Summaries), which focussed on capturing cross-section geometries within the low-flow channel. A map of the eight reaches can be found in Appendix F of Matrix and

BluMetric (2017). From this information, the hydraulic models were developed. The hydraulic models are able to produce gridded values of depth and velocity for all areas within the modelled reach.

As described above, the habitat suitability modelling used flow conditions output from each of the scenarios simulated by the MIKE SHE model. Typically, a habitat suitability assessment would consider changes in critical flows throughout the year (e.g., channel forming flows, flows during spawning conditions, summer low flow). However, as the investigated scenarios would only affect summer low flows, the habitat suitability assessment focussed on these flow conditions.

Generally, the habitat suitability relationships were defined for various species identified during the NVCA ecologic assessment (Section 2.7). This group of species included Rainbow Trout, Sculpin, Common Shiner, Hornyhead Chub, Johnny Darter, and Pumpkinseed. In developing the suitability relationships, it was determined that the majority of the hydraulic preferences (e.g., velocity and depth) were similar between species, but were significantly different for life cycle stage. As a result, the assessment considered YOY/juvenile and adult life stages separately. The hydraulic models were run for different flow conditions, which produced velocity and depth fields for all considered flows. Applying the suitability preferences resulted in suitability indices for both the YOY/juvenile and adult life stages.

In summary, the suitability assessment concluded that Innsifil Creek can be considered poor to moderate for YOY/juvenile and poor for adults for the No Pumping scenario. While the YOY/juvenile life cycle is not affected to the same degree, it is recognized that without a successful adult life cycle, there will not be a YOY/juvenile life cycle. The Existing Pumping scenarios did show minor decreases in suitability from the No Pumping scenario; however, these decreases are so minor, it is not expected to materially affect the overall suitability of Innisfil Creek. By transitioning water withdrawals from surface water in the Innisfil Creek watershed to groundwater sources, the analysis indicates that habitat suitability would approximately equal conditions found under the No Pumping conditions. None of the scenarios investigated would result in optimum habitat for the species investigated.

The final two scenarios, Max Irrigation Area and 1/3 Max Irrigation Area, resulted in significant decreases in habitat suitability for all life cycles for the majority of reaches. Some reaches did illustrate an improvement associated with the YOY/juvenile life cycle for these scenarios. This was primarily due to an increase in slower moving, shallower waters that are associated with habitats that would be preferred by young fish. Habitat suitability for the adult life cycle was significantly affected by these scenarios, with the average habitat suitability being decreased by 22%. Based on habitat suitability related to hydraulic parameters and fish species preferences at various points in a species life cycle, the Innisfil Creek watershed under existing conditions is considered impaired during low flow conditions, typically July and August. Efforts should therefore be taken to limit further degradation of aquatic habitat suitability under these low flow conditions. This would include limiting additional seasonal (summer) withdrawals from watercourses. The impact of water quality as it related to the degradation on Innisfil Creek and its tributaries has not been assessed as part of this review.

7.3.3 Conclusions

In the Innisfil WQSA, low water conditions experienced within the WQSA are primarily related to surface water resources (Section 7.3.1.1). Specifically, the ongoing demand on surface water for the purpose of agricultural irrigation together with climate variability in terms of timing and amount of precipitation between May and September contributes to persistent low water conditions in Innisfil Creek. BluMetric had not identified nor been made aware of any recently reported interference issues between permitted and non-permitted water takings.

There is a moderate density of permitted takers in the Innisfil WQSA, with the majority of the takings being seasonal in nature (irrigation) (Section 7.2.6.1 and Figure 7-11). The ongoing demand on surface water for irrigation as a result of drought conditions is one of the major contributors to persistent low water conditions in Innisfil Creek (Section 7.3.1.1). Agriculture and municipal water supply account for approximately 58% (49.4 million m^3) and 24% (20.44 million m^3) of the total permitted taking in the WQSA. The remainder of the permitted water takings are attributed to commercial, industrial and recreational uses (Section 7.2.6.1).

Impacts of water takings on the natural functions of the ecosystem do not appear to have been directly monitored or reported. However, habitat suitability modelling was completed for Innisfil Creek in order to determine the effects of pumping on instream habitat and the resulting habitat's suitability for various fish species and life stages (Section 7.3.2.4). The results indicate that, based on habitat suitability related to hydraulic parameters and fish species preferences by life cycle, the Innisfil Creek watershed, under existing conditions, is considered impaired during low flow conditions, typically July and August.

No significant declines in hydraulic head have been identified. Based on the hydrographs of the six PGMN wells in the WQSA for which the trend analysis was determined to be reliable, regional water levels in the complex overburden aquifer system appear to not be impacted by any water takings or climate stress (Section 7.3.1).

Review of the OLWR database indicates that the NVCA found it necessary to declare a Level 2 Low Water Condition Alert on one occasion for the Innisfil Creek subwatershed. No Level 3 Low Water Condition Alerts have been declared. No specific trends can be discerned in the frequency of Low Water Condition Alerts or OLWR notifications, and therefore do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends.

In addition to existing pressure on surface water resources, the Innisfil WQSA is an area where cumulative effects may continue to present a concern in the future for surface water. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a Medium percent water use based upon both the Average Annual and Summer Low Flow (Section 7.3.1). The extent to which cumulative effects may become a concern on groundwater resources is less clear: a groundwater Tier 2 Stress Assessment, covering the northern portion of the preliminary WQSA, concluded that there is a "Low Potential" for stress on municipal groundwater supplies both with average and maximum demand. However, in a drought evaluation completed as part of the Tier 2 Stress Assessment, all creeks in the study area were shown to experience reduction in baseflow during the simulated drought period.

The major contributors to surface water shortage have already been identified as the ongoing demand for irrigation combined with climate variability (Section 7.3.1.1), and therefore further evaluation of the cumulative effects of multiple takers was not necessary to substantiate the reasons for water shortages. Numeric modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

In summary, the sustainability of the water resources in the Innisfil WQSA under current and future conditions is as follows:

Groundwater Under Current Conditions

- **Regional scale** – the groundwater resources are sustainable in the broader WQSA under current conditions.
- **Local scale** – the groundwater resources are locally sustainable under current conditions, with no interference issues noted.

Groundwater Under Future Conditions

- **Regional scale** – the groundwater resources are sustainable into the future, however, PGMN monitoring would be advisable for early detection purposes since this conclusion is based on modelling and there is an inherent uncertainty with modelling.
- **Local scale** – the groundwater resources are sustainable into the future, however, PGMN monitoring would be advisable for early detection purposes since this conclusion is based on modelling and there is an inherent uncertainty with modelling.

Surface Water Under Current Conditions

- **Regional scale** – the surface water resources are sustainable if the current degraded condition of the resource is considered acceptable. The natural state of the resource is highly dependent on precipitation (as discussed in Section 7.3.1.2).
- **Local scale** – the surface water resources are sustainable under current conditions. Coordinated takings ensure no interference issues occur.

Surface Water Resources Under Future Conditions

- **Regional scale** – surface water resources are unsustainable into the future based on modelling.
- **Local scale** – surface water resources are unsustainable into the future based on modelling.

7.4 WATER MANAGEMENT APPROACHES AND CHALLENGES

A combination of available reports and communication with Water Managers from the NVCA and MECP knowledgeable of local water use/issues in the Innisfil WQSA was used to summarize approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in Section 7.6 of this report, what, if any, new management tools are needed in the Innisfil WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches. y.

Current Approaches

MECP's Central regional office manages the PTTW program in the Innisfil WQSA and responds to well water and drought complaints. However, it should be noted that the NVCA is a key partner and data and information coordinating agency for water management in the Innisfil WQSA. For example, Water Managers at the NVCA have pursued and obtained funding to complete several studies related to understanding and managing water resource on a watershed scale including the most recent Drought Management Plan Pilot (Matrix and BluMetric, 2017) which has been heavily relied upon in this study.

The approach for managing water quantity in the Innisfil WQSA relies on the policies of the South Georgian Bay Lake Simcoe Source Protection Plan. This primarily involves the requirement for new developments to maintain predevelopment groundwater recharge through the use of Low Impact Development options or other best management practices. The municipalities also promote water conservation.

The NVCA relies heavily on the PGMN network of wells within the WQSA to assess and evaluate the sustainability of the groundwater resource.

The approach to water resource management in the Innisfil WQSA is largely driven by the primary issue described above, namely noted shortages of surface water resources during low flow periods in the watershed. To help manage this issue, several initiatives and studies have been completed locally, including the establishment of a local stakeholder group called the Innisfil Creek Water Users Association (ICWUA). This is a group largely comprised of farmers that irrigate but also seeks input from municipal water managers and local golf courses. The ICWUA relies heavily on the administrative and technical capacity and support of the NVCA as well as the province (MECP, OMAFRA and MNRF). For example, the NVCA website maintains an on-line Low Water Status gauge as per the Ontario Low Water Response program. In addition, NVCA has helped to coordinate meetings for consultation and project development for the ICWUA. One key initiative of the ICWUA has been the coordination of permitted water taking from the creeks within the WQSA during Low Flow periods. The ICWUA together with the NVCA have hosted a number of farm tours for Ministry staff and other interested parties seeking to better understand the coordinated management of the water resources in the WQSA.

The value of the working relationship between the ICWUA and the NVCA is considered high. It is considered high because cooperation between the local water users and the regulatory body managing the local Low Water Response can in part help to avoid the need to declare a Level 3 through efforts to coordinate surface water taking schedules. A positive relationship between these two groups also helps to ensure best management practices are used to enhance water conservation in the watershed. Accordingly, there is a need to maintain the momentum the stakeholder group garnered since it was established in 2008. The effort requires resources from the NVCA and strong local stakeholder leadership between times of low flow conditions.

The involvement and support of Ministry staff (MECP, OMAFRA and MNRF) has also been very valuable as it has enhanced the water users understanding of the PTTW program and a level of trust has been established between permitted water users and the MECP in terms of there being a common language and understanding of normal irrigation practices in the WQSA and the mandate of the MECP with respect to managing Ontario's water resources and the objective of the PTTW program.

Challenges

The information summarized in Section 7.1 and 7.2 provides insight on the main challenges related to the management of water resources in the WQSA. These challenges include data gaps in PGMN data (e.g. of the 15 PGMN wells within and surrounding the Innisfil WQSA, trend analysis was determined to be reliable for only 6 PGMN wells), the ongoing support needed to maintain the relationship between the ICWUA and the NVCA, the unpredictability of climate change on a local scale in terms of timing and amount of precipitation during the summer months, water withdrawal effects to the frequency of the more extreme Level 3 flow conditions, and the expected increase of low flow periods during the summer months under climate change conditions. According to the NVCA, the Drought Management Plan Pilot study provided the technical understanding of the flow system in the WQSA to help support future initiatives for maintenance of the environmental flow needs within Innisfil Creek.

Since the Drought Management Plan Pilot was completed, the Hydrologic Function assessment as described above was completed, where one identified challenge was the limited amount of temporal data from the PGMN wells and the delay in when the data is available for public use. Data ranges between 2001 and 2017, with some wells containing years without recorded data. These data gaps create outliers and inconsistencies in data and therefore the wells are deemed unreliable.

The unpredictable nature of climate as it relates to precipitation is directly correlated to determining the need for irrigation. A great deal of variability in precipitation patterns within the WQSA has been noted in previous studies and recommendations have been made to increase the number of climate stations within the WQSA. These studies also recommended that flow gauges in key reaches within WQSA also be installed.

As per Section 7.2.6 and 7.3.2.2, irrigation and agriculture in general appear to be declining throughout the Innisfil Creek watershed. This should be an important consideration when reviewing permit renewals. In addition, there is a need to ensure the WTRS data is current and accurate in terms of assessing actual takings versus total permitted takings.

Due to the heavy dependence on surface water in the WQSA for irrigation by agriculture, the economic impacts of water restrictions can have a significant weight on water management decisions and approaches as discussed in Section 7.3.2.3. This is especially true in the administration of the OLWR program.

Based on modelling, it does not appear that surface water withdrawals are increasing the frequency of Level 1 and Level 2 low water conditions. These low water conditions are largely a product of climate variability alone. However, water withdrawals do affect the frequency of the more extreme Level 3 flow conditions.

To date, water withdrawal plans have not been restricted in times of a Level 3 occurrence.

One of the potential opportunities to mitigate chronic surface water shortages locally could be to move to a groundwater source. However, under the PTTW program guidelines, a technical assessment to determine if there are any potential interference issues with other groundwater users or a reduction in base flow of a nearby surface water feature is needed. The applicant is often required to incur a significant cost to install a well and undertake a technical study which may or may not result in a permitted groundwater taking. The current PTTW program as administered cannot guarantee upfront that an applicant moving from a surface water source to a more secure groundwater source will obtain a PTTW even if regional studies indicate that local water groundwater supplies are sustainable.

Climate change projections indicate that irrigation requirements, if existing agricultural land use remains essentially unchanged, will increase by 50% to 100% (depending on the future climate scenario selected). This increase in irrigation demand, coupled with reduced streamflow conditions will increase the frequency of Level 3 low water conditions by up to 180%. As a result of the changed climate, the hydrologic regime will be modified, resulting in higher streamflows through the winter months, and a spring freshet that occurs earlier and has a smaller magnitude than under existing climate conditions. Summer low flows will be reached earlier in the year and will last later into the fall.

Evaluation of how water management concerns are considered in water management decisions

As noted in *Challenges* above, the over reliance on surface water in the summer resulted in significant decreases in water levels, particularly during drought years. To help alleviate these pressures, efforts are being made to move agricultural irrigation from a surface water source onto groundwater wells. This effort however has had limited success due to the uncertainty associated with obtaining a PTTW for the groundwater source.

In addition, the establishment of the Innisfil Creek Water Users Association (ICWUA) and implementation of a coordinated irrigation strategy in the WQSA has provided an opportunity for water managers at the NVCA and irrigators to collaboratively develop tools and Best Management Practices (BMP) for managing water use and improving drought preparedness (Matrix and BluMetric, 2017).

The farmer-led ICWUA together with technical and financial support from the NVCA, MECP, OMAFRA and MNRF has proven a successful model in managing a limited resource that experiences frequent stress associated with climate conditions. The ICWUA forum offers training, education workshops, and guidelines to committee members and the wider irrigation community to promote fair and responsible agricultural water use. These locally lead initiatives are typically very effective and there is local accountability and local understanding.

Consideration of key topics in water management decisions

The following points describe if and how key topics are considered in water management decisions in the Innisfil WQSA.

- Climate change: efforts have been made to predict the potential effects of climate change on groundwater and surface water resources through the use of climate change modelling scenarios (Section 7.3.2.1). Based on the information reviewed as part of this study, there do not appear to be formal policies in place for considering the effects of climate change in water management decisions;
- Adaptive/alternative management: no policies and approaches were identified in the Innsifil WQSA that explicitly address the use of adaptive or alternative management. However, the province's PTTW program allows for the use of adaptive/alternative management, as one of the principles of the program is that the MECP "will employ adaptive management to better respond to evolving environmental conditions" (Permit to Take Water Manual, 2005). For example, the Ministry has the authority to limit, alter or stop a water taking that is considered to cause an unacceptable impact, even after a permit has been issued;
- Municipal growth: in the Innisfil WQSA, to help plan for the expected growth, the County of Simcoe completed a Water and Wastewater Visioning Strategy (Greenland Consulting Engineers, 2012) which includes background information and a water and wastewater servicing gap analysis. Many of the municipalities in the County, including those in the WQSA, will be augmenting their current groundwater supplies with surface water from outside the watershed (Section 7.3.2.2). Based on the information reviewed as part of this study, there do not appear to be formal policies in place for considering the effects of population growth in water management decisions;
- Drought: the Drought Management Pilot was completed to assist water managers and irrigators in the management of their water use and to improve drought preparedness. When evaluating the water use scenarios under a changed climate, it is apparent that the most significant factor resulting in an increase in low water days is not the water use scenarios themselves, but the expected change in climate. If the most extreme climate projection occurs, what is now considered to be extreme low flow would become the new normal. This modification to the hydrologic regime of Innisfil Creek is so significant that without significant adaptation measures the creek may not be considered a reliable source of water to meet irrigation demands (Sections 7.3.2.1);

- Natural function/EFN: the importance of EFN and aquatic habitat in Innisfil Creek has been investigated (Section 7.3.2.4). However, impacts of water takings on the natural functions of the ecosystem do not appear to have been directly monitored or reported. However, habitat suitability modelling was completed for Innisfil Creek in order to determine the effects of pumping on instream habitat and the resulting habitat's suitability for various fish species and life stages (Section 7.3.2.4). The results indicate that, based on habitat suitability related to hydraulic parameters and fish species preferences by life cycle, the Innisfil Creek watershed, under existing conditions, is considered impaired during low flow conditions, typically July and August. The study did not result in the establishment of EFN thresholds, and there is no indication that EFN are currently being taken into consideration in water management decisions in the WQSA. There is also a general lack of information on EFN in other surface water bodies in the WQSA.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

A collaborative effort together with the ICWUA could be initiated with the aim of ensuring that EFN thresholds be established for Innisfil Creek and its tributaries. The objective would be to ensure EFN are met during periods of high irrigation demand in particularly sensitive reaches of the watershed. The development of water management measures by the irrigators themselves will help ensure the measures are feasible and may help encourage compliance with the proposed approaches. A key challenge is that participation would be voluntary, and as such enforcement will be difficult, if not impossible. The collaborative effort should consider making the EFN thresholds adaptive in that they should have a three to five year review period. The challenge would be to account for expected natural impact of climate change.

7.5 IDENTIFIED DATA GAPS

The sections above have characterized, quantified and assessed both the hydrologic and economic conditions of the Innisfil WQSA based on previous studies. This section summarizes the identified data gaps noted in the preceding sections.

As described above, Innisfil Creek is largely a runoff-driven system. Compared to other watersheds within the NVCA's jurisdiction, Innisfil Creek has a low proportion of baseflow, relative to total streamflow. This results in inconsistent streamflow during periods of dry weather. Some of these inconsistencies could possibly be mitigated if additional streamflow gauges were part of the ongoing monitoring network since this would assist local water users in determining a more timely irrigation schedule in some of the reaches of the watershed that are more significantly impacted by reduced precipitation.

While surficial sands are present throughout the central portion of Innisfil Creek, these are thin deposits, which are underlain by thick glaciolacustrine deposits. There is limited groundwater resources associated with these surficial sands; shallow groundwater wells or dugout ponds would likely be insufficient to meet irrigation needs. However, there is evidence of a viable aquifer beneath the glaciolacustrine aquitard in the coarse-grained valley fill deposits that appears to be able to support large-scale withdrawals. Additional, subsurface investigation are needed on a subwatershed or local scale to better understand if there are sustainable groundwater resource alternatives in areas where limited surface water resources exist or where the impact of climate change may be most significant.

Since irrigators are currently being encouraged to transition to groundwater supplies for the purpose of gaining long term water security the need for additional subwatershed scale hydrogeological investigations is warranted. It should be noted that based on the economic analysis completed as part of the Drought Management Plan Pilot (Matrix and BluMetric, 2017) this may not return the anticipated economic results in the short term for the irrigator based on estimated capital costs associated with accessing a deep groundwater resource. Furthermore, many irrigators rent land in the watershed and much of the watershed is slated for development thus making it unlikely that irrigators would invest in the installation of deep wells to secure water on land they do not own or are not likely to farm in the long term. Therefore, additional subsurface investigations that could be used by the permitted irrigators in the PTTW application would be helpful.

A pre-screening process could be implemented for new PTTW applications seeking to replace a vulnerable surface water source with a more secure groundwater water source. The pre-screening process could make use of the model results from the Drought Management Plan Pilot study (Matrix and BluMetric, 2017) and possibly result in a greater rate of irrigators transitioning from using a surface water resources that is vulnerable to climate change to a more secure groundwater resource.

Finally, as noted above the NVCA identified the challenge of a limited amount of temporal data from the PGMN wells. In addition, the delay in when the data is available for public use is also a challenge with respect to timely assessment of seasonal impacts on groundwater resources.

7.6 RECOMMENDATIONS

Based on the available reports and communication with Water Managers knowledgeable of local water use/issues in the Innsifil WQSA, the following recommendations are provided as possible mitigative measure to address the identified gaps related to water quantity management, and help in avoiding potential future water quantity issues.

- Current irrigation estimates were completed using 2012 WTRS data. Given the expected decline in demand on surface water for the purpose of agricultural irrigation, it is recommended that the irrigation estimates be updated using the most recent data and projections;
- In the short to near term, the Ministry should help to maintain the momentum the stakeholder group (ICWUA) garnered since it was established in 2008 by remaining available to participate in organized tours and understanding the dynamic nature of irrigated agriculture. The effort requires resources from the NVCA and strong local stakeholder leadership between times of low flow conditions. The value of the local stakeholder group (ICWUA) is rooted in the maintenance of a cooperative relationship between the local water users and the regulatory body managing the Low Water Response program. A cooperative relationship can help to avoid the need to declare a Level 3 through efforts to coordinate surface water taking scheduled. A positive relationship between these two groups also helps to ensure best management practices are used to enhance water conservation in the watershed. In addition, the ICWUA could become a critical partner in the establishment of EFN thresholds within the Innisfil WQSA;
- Given the impaired nature of the Innisfil Creek watershed under existing conditions, efforts should be taken to limit further degradation of aquatic habitat suitability. This would include limiting additional withdrawals from watercourses. In addition, new PTTW applications to access surface water resources for irrigation purposes should be discouraged for water security reasons since climate change projections indicate that surface water resources will be increasingly unreliable as an irrigation source;
- Continue to use or consider using ecologically-based instream flow management, such as the LPRCA Instream Flow Management Framework. As noted above, the ICWUA could become a critical partner in the establishment of EFN thresholds within the Innisfil WQSA ;

- Encourage increased utilization of groundwater obtained from deeper aquifers in the aquifer complex to meet increased population demands. Seek out ways to coordinate additional subwatershed scale investigations into deeper aquifers. This would help to characterize and assess the potential yield of water quantity and quality to meet increased longer term demand;
- Ongoing monitoring of water levels in all overburden PGMN wells is strongly advisable so that reliable trends can be determine, which in turn will ensure any early detection of declining regional groundwater resources;
- Consider increasing stream monitoring data for all tributaries by adding additional hydrometric gauges. There have been issues with channel slump impacting the Water Survey of Canada Innisfil Creek gauge. For this reason, flow information for Innisfil Creek has not always been available or reliable, and as a result specific declarations for Innisfil Creek have not been considered in the past few years.

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8 WHITEMANS CREEK WQSA

The preliminary boundary of the Whitemans Creek WQSA, as provided by the MECP, is shown on Figure 8-1. The preliminary WQSA is approximately 550 km^2 and overlaps multiple municipal boundaries, including the Township of Perth East, Township of Wilmot, Township of Blandford-Blenheim, Country of Brant, Township of Norwich, City of Woodstock, and the Township of Zorra–Tavistock. The WQSA partially or fully encompasses multiple watersheds and Conservation Authorities, including Grand River (GRCA), Upper Thames River (UTRCA), and a minor portion of the Long Point Region (LPRCA).

In the Whitemans Creek WQSA, both groundwater and surface water resources are used dominantly for the purpose of agricultural irrigation, with some water supply and commercial uses. This WQSA was selected by the MECP because it lacks resiliency for drought, has been subject to frequent Low Water Response declarations, was identified as being potentially stressed under the source protection Tier 2 water budget, and demand challenges associated with multiple takings. The objectives of this section are to provide characterization of the Whitemans Creek WQSA in the context of the major (most used) surface water and groundwater resources, to refine the WQSA boundary based on the physical characterization, to summarize and evaluate the demands on water resources in the WQSA, and to determine the possible impact of projected changes in population, land use, and climate change on the quantity of the local resources and future security and sustainability of the water resources in the WQSA based on these changes.

8.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives for the WQSA described above and the preliminary WQSA boundary provided by the MECP.

A groundwater Tier 2 Water Quantity Stress Assessment as outlined in the Province's Guidance Module for Water Budget and Water Quantity Risk Assessment (MNR and MOE, 2011) was previously completed for the Grand River watershed and included the Whitemans Creek subwatershed, which comprises most of the WQSA (AquaResource, 2009a and 2009b). Based on the assessment, the Whitemans Creek subwatershed has a moderate potential for stress from a surface water perspective under current water demands.

The classification as moderate stress under the Tier 2 assessment prompted a Tier 3 Local Area Water Budget and Risk Assessment (Tier 3 Assessment) for the groundwater municipal supplies operated by County of Oxford in the Village of Bright and the Bethel Road wellfield servicing the Town of Paris. While the main purpose of the assessment was to determine the sustainability of these two water supplies (Figure 8-1), the assessment included groundwater and surface water models that cover a large portion of the WQSA. In conjunction with assessing the sustainability of the water supply in the area, the Tier 3 Assessment also attempted to understand the long-term sustainability of groundwater and surface water resources in the local area surrounding the municipal supply wells in the Whitemans Creek subwatershed, agricultural water use, and low-water mitigation strategies within the Whitemans Creek subwatershed.

Table 8-1 includes the reports used as the primary basis for the WQSA characterization and assessment. These reports were confirmed as being key sources of insight by local water managers. In addition to the reports noted in the table below, available databases (e.g. WWIS, PTTW, WTRS) provided by MECP, were also used to characterize and assess the WQSA. Each resource was categorized in terms of the main type of information presented within. It should be noted that a complete list of references used to characterize and assess this WQSA is provided at the end of this chapter and that the references noted in the table are the primary sources of information.

Table 8-1: Creek Key Reports and Information Sources for Whitemans Creek WQSA

Resource Reference	Type	Categories
Earthfx Inc., 2018. Whitemans Creek Tier Three Local Area Water Budget and Risk Assessment	Report	PC, GWQ, SWQ
Shifflett, S., 2014a. Climate Change Scenario Modelling. Grand River Water Management Plan	Report	CC, SWQ, GWQ
Etienne, J., 2014. Water Demand Management; Meeting Water Needs in the Grand River Watershed. Grand River Water Management Plan	Report	CU, SWQ, GWQ, CC
Wong, A.W. & Boyd, D., 2014. Environmental Flow Requirements in the Grand River Watershed. Grand River Water Management Plan	Report	EFN, SWQ, GWQ,

Categories:

PC – Physical Characterization
GWQ – Groundwater Quantity
SWQ – Surface Water Quantity
CU – Current Water Users
CC – Climate Change
EFN – Environmental Flow Needs

8.2 WATER RESOURCES SETTING /CHARACTERIZATION

8.2.1 Land Cover and Use Setting

Land cover in the Whitemans Creek WQSA (Figure 8-2) is predominantly agriculture with significant portions of swamp in the central area east of Innerkip and Woodstock. Community/Infrastructure comprises a minor portion of land use scattered among the villages and towns within the WQSA.

8.2.2 Population

Populations in urban centers with municipal water supplies located in watersheds which fall within or make up part of the WQSA are summarized using the most recently available population information in Table 8-2:

Table 8-2: Summary of Population Statistics and Water Supply Source in Whitemans Creek WQSA

Subwatershed	County	Population Centre	Water Source	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percentage Change (%)
Whitemans Creek	Oxford	Bright	Groundwater	ND	437 [1]	ND
Whitemans Creek	Brant	Bethel Road (Town of Paris) [2]	Groundwater	11,722	12,310	5.0%
South Thames River above Pittock Reservoir [3]	Perth	Shakespeare	Groundwater	519	530	2.1%
South Thames River above Pittock Reservoir	Oxford	Innerkip	Groundwater	935[4]	960[4] (1,290[5)]	2.7%

[1] From Oxford County (2018) (http://www.oxfordcounty.ca)

[2] Although the Town of Paris is located outside the WQSA, the Bethel Road wellfield supplying the town is located within the boundaries of the WQSA; therefore the population statistics for Paris are included here.

[3] The subwatershed is referred to as the "North Woodstock watershed" by the Upper Thames River Conservation Authority for the purpose of watershed monitoring (e.g. UTRCA, 2018), and as the "South Thames River above Pittock Reservoir" by the Thames-Sydenham and Region Source Protection Committee for the purpose of source protection planning (TSRSPC, 2015). The name "South Thames River above Pittock Reservoir" is used throughout this chapter.

[4] Based on the 2011 and 2016 Annual Drinking Water System Summary Reports (http://www.oxfordcounty.ca)

[5] Population for Innerkip is an estimate made by Oxford County based on the 2016 Census (http://www.oxfordcounty.ca)

Innerkip is the largest population centre within the WQSA, followed in size by the population centres of Shakespeare and Bright. Innerkip has seen a slightly greater population growth (2.7%) between 2011 and 2016 than Shakespeare, however it should be noted that the population estimate used to determine population growth for Innerkip is based on the estimated number of people the water supply system services versus a census population estimate used to calculate Shakespeare's population growth. Finally, the Bethel Road wellfield is located in the south eastern portion of the WQSA and is part of the Town of Paris water supply system, connected to the town via water pipeline. The Town of Paris is not within the preliminary WQSA boundaries.

8.2.3 Physiographic Setting

8.2.3.1 Physiography

Physiographic regions within the WQSA as defined by the OGS are illustrated on Figure 8-3. The WQSA area can roughly be described as an "L" shape, with the vertical potion of the "L" oriented between Shakespeare and the northeast tip of Woodstock (Horner Creek corridor), and the horizontal portion of the WQSA, which includes a 9 km wide area oriented between the area east of Woodstock and west of Brantford (Kenny Creek and Whitemans Creek corridor).

The vertical portion of the WQSA area is composed dominantly of either Till Plains (both drumlinized and undrumlinized) or Till Moraine in the north, with sections of Beaches and Drumlins oriented northeast-southwest in the south. The Whitemans Creek Tier Three Assessment (Earthfx Inc., 2018) refers to these regions as the Upper Whitemans Till Plains, and the Central Whitemans Outwash Area, respectively. This central region of Beaches and Drumlins is associated with multiple permitted agricultural takings from groundwater, surface water or both.

The horizontal portion of the WQSA area is composed of Till Plains and Till Moraines in the west and Sand Plains, Beaches, and Till Moraines in the east. The Whitemans Creek Tier Three Assessment refers to this region as the Lower Whitemans Sand Plain. The area of Sand Plains, Beaches, and Till Moraines in the southeastern portion of the WQSA is associated with multiple permitted agricultural takings from groundwater, surface water or both.

8.2.3.2 Topography

Broadly speaking, topography in the Whitemans Creek WQSA (Figure 8-4) gently slopes from topographic highs in the north and west portion of the WQSA to topographic lows located south and east. Locally, topography slopes toward the main creek systems. In the northern part of the WQSA, topography slopes toward Horner Creek within the Whitemans Creek subwatershed, and the Thames River within the South Thames subwatershed. In the Southern portion of the WQSA, topography slopes toward Kenny Creek and Whitemans Creek.

8.2.3.3 Climate

Winter is generally considered to have temperatures lower than 0 °C, beginning in December and lasting until late February or early March. Spring usually lasts two months, followed by four months (June to September) of summer and two months of autumn. Average annual precipitation varies from 950 mm in the northwest of the study area to 850 mm in the southeast around Brantford (southeastern portion of WQSA) (Earthfx, 2018). Approximately 88% of the average annual precipitation in the region arrives in the form of rain, as measured at the Woodstock and the "Brantford MOE" weather stations, located approximately 3.5 km west and 8.9 km east of the WQSA, respectively (Government of Canada, 2018). Monthly total precipitation is relatively lower in the winter compared to the remainder of the year, reaching its minimum in February (60.0 mm and 51.5 mm in Woodstock and Brantford, respectively), and peaking in July (103.8 mm and 95.0 mm in Woodstock and Brantford, respectively). In addition, at least half of the monthly total precipitation in the winter months is attributed to rainfall, with the remainder being attributed to snowfall.

Evapotranspiration ranges from 500-600 mm/year (AquaResource, 2009). Annually averaged daily temperature ranges between approximately 7 °C in the northern portion of the WQSA and approximately 8 °C in the southeast portion of the WQSA. Seven historical weather stations are located in the WQSA (Figure 8-5); however, none have operated since the early 1970s.

8.2.3.4 Surface Water Hydrology

The WQSA overlaps with two major watersheds: the South Thames River watershed, located in the western portion of the WQSA, and the watershed of the Grand River, which occupies the eastern and southern portions of the WQSA (Figure 8-14). The major water bodies located within the boundaries of the WQSA include the Thames River (from a point near the Town of Tavistock down to the City of Woodstock), the Pittock Reservoir (located on the Thames River at the western boundary of the WQSA, in the City of Woodstock), Horner Creek and Kenny Creek (tributaries to Whitemans Creek), and Whitemans Creek proper (a tributary to the Grand River); available data on streamflow in the major water bodies are presented in Section 8.3.1. The WQSA encompasses almost the entire Whitemans Creek subwatershed, from the headwaters of Horner Creek in its northern portion, to the confluence between Whitemans Creek and the Grand River at the southeastern boundary of the WQSA. General information regarding the two subwatersheds is provided in Table 8-3.

Table 8-3: Summary of Subwatersheds in Whitemans Creek WQSA

Region	Main Watershed	Subwatershed	Drainage Area [A] (km^2)	Surface Water (SW) Municipal Systems/Sources in WQSA
Oxford, Brant	Grand River	Whitemans Creek	404	None. Closest municipal SW intake is located 6.8 km downstream of the confluence between Whitemans Creek and the Grand River, in the City of Brantford.
Oxford	Thames River	South Thames River above Pittock Reservoir	273.6	None. No municipal SW intakes in the vicinity (< 10 km) of the WQSA.

[A] The entire drainage area of the subwatershed is reported here, not only the portion of the subwatershed located within the boundaries of the WQSA.
Source: LERSPC (2015), TSR (2010).

8.2.4 Aquatic Habitat and Species

Whitemans Creek, including Horner Creek, is characterized by a coldwater thermal regime, while Kenny Creek (tributary to Whitemans Creek) and the Thames River and its tributaries have a warm water thermal regime (Figure 8-6). Whitemans Creek flows through a large groundwater discharge zone, and as a result, supports a resident coldwater fishery and a migratory coldwater fishery (GRSPA, 2015). The downstream portion of the creek is reported to support populations of brown trout and rainbow trout, and the upstream portions support populations of northern pike and smallmouth bass (AquaResource, 2009).

The South Thames River above Pittock Reservoir subwatershed supports 33 fish species, including two gamefish species, the smallmouth bass and the largemouth bass (UTRCA, 2018). The dam at the Pittock Reservoir (located on the Thames River at the western boundary of the WQSA) is reported to be a barrier to fish movement (UTRCA, 2018).

Among the aquatic species at risk (SAR) listed under the federal *Species at Risk Act* and the provincial *Endangered Species Act*, only the silver shiner (species of Special Concern in Ontario) is confirmed to be present in the Whitemans Creek subwatershed (GRSPA, 2015; DFO, 2015). The following aquatic SAR are identified as being present within the broader Grand River watershed (GRSPA, 2015; GRCA, 2018):

- Eastern sand darter (Endangered provincially, Threatened federally);

- Redside dace (Endangered provincially and federally);
- Northern brook lamprey (Special Concern federally and provincially);
- Black redhorse (Threatened provincially);
- Mapleleaf mussel (Endangered provincially, Threatened federally);
- Fawnsfoot (Endangered provincially);
- Rainbow mussel (Endangered federally and provincially); and
- Pygmy pocket moss (Special Concern in Ontario).

Within the portion of the Thames River watershed overlapping with the WQSA, the rainbow mussel (Endangered federally and provincially) is reported to be present (UTRCA, 2018). In addition to the rainbow mussel, the following aquatic species are listed as being found or potentially found (DFO, 2018):

- Round Pigtoe mussel (Endangered federally and provincially); and
- Spotted sucker (Special Concern federally and provincially).

8.2.5 Geology

The Whitemans Creek WQSA is underlain by a series of gently westward dipping Silurian and Devonian age carbonates. These rocks are overlain by unconsolidated Quaternary-aged sediments of variable thickness that were laid down after the last glaciation. Surficial and bedrock geology of the Whitemans Creek WQSA are presented on Figures 8-7 and 8-8, respectively, and are described below.

8.2.5.1 Surficial Geology

Overburden deposits in the Whitemans Creek area date back to the Wisconsinan glaciation of the Pleistocene Epoch. The surficial geology of the WQSA loosely correlates with the physiographic regions. In general, surficial geology appears to correlate with the number of permitted groundwater takings (i.e. permitted takings are concentrated in areas with sand and gravel deposits, and are limited in areas dominated by till). Utilization of overburden groundwater resources is discussed in detail in section 8.2.5.1.

In the north, the surficial geology is characterized as silty to sand tills. These tills have relatively low permeability and are associated with very few permitted groundwater or surface water takings.

In the central area, the surficial geology is characterized by sandy and glaciofluvial deposits that comprise a shallow aquifer. This area is associated with several permitted shallow groundwater takings and surface water takings from Upper Horner Creek. The south-central area is characterized by silty to clayey till with very few permitted groundwater or surface water takings. These tills have relatively low permeability.

The southeastern portion of the WQSA is characterized by coarse textured glaciolacustrine deposits which represent the northern extension of the Norfolk Sandplain (the Whitemans Creek Tier Three Assessment refers to this region as the Lower Whitemans Sand Plain). This area contains numerous permitted takers which draw from shallow groundwater as well as surface water from Whitemans Creek.

8.2.5.2 Bedrock Geology

Silurian and Devonian carbonate and shale bedrock unconformably underlays the overburden deposits within the WQSA (see Figure 8-8). Striking north, dipping west, the sequence of bedrock formations exposed at bedrock surface (east to west) include the Salina, Bass Island, Bois Blanc, and the Onondaga Formations. In general, the Salina formation hosts a poor water quality aquifer, while the Bass Island, Bois Blanc or Onondaga Formations hosts good water quality aquifers (discussed in detail in 8.2.5.2 Bedrock Aquifers).

8.2.6 Hydrogeology

The conceptual hydrogeology of the Whitemans Creek WQSA is summarized in Table 8-4 and was adapted from the Tier Three Assessment.

Table 8-4: Conceptual Hydrostratigraphy in Whitemans Creek WQSA (modified from Earthfx Inc., 2018)

North	Central	Southeast
Upper Whitemans Till Plains	**Central Whitemans Outwash Area**	**Lower Whitemans Sandplain**
Poorly drained till plains due to low permeability aquitards at surface.	Complex system of moraines, outwash deposits and till plains. Northern portion of area contains the shallow unconfined aquifer. This aquifer extends southwest, however is confined by surficial tills in the south.	Extensive and thick (up to 65 m) glaciolacustrine and outwash sand deposits form regional unconfined water table aquifer.
Underlain by sequences of thick, continuous till aquitards, which are separated by relatively thin, discontinuous sand aquifer units. Underlain by a largely uninterrupted sequence of till aquitards down to bedrock.		Underlain by largely uninterrupted sequence of till aquitards down to bedrock.
Regionally confined bedrock aquifer system, except locally where rivers or outwash channels have scoured through drift deposits (e.g., bottom of Whitemans Creek, Thames River near Woodstock). The southwestern part of the study area is underlain by productive Devonian limestone aquifers (the Onondaga limestone aquifers). The northeastern half of study area is underlain by the poorer quality Salina Formation aquifer.		

Regionally, groundwater in the unconfined overburden and confined bedrock flows from north to south towards Lake Erie. Locally, the water table of the unconfined overburden may follow the surficial topography (Earthfx Inc., 2018). Figure 8-9 displays a north-southeast cross-section through the WQSA and illustrates the location and thicknesses of various aquifers and aquitards. Figure 8-10 illustrates the location of all overburden and bedrock water supply wells in the WQSA.

8.2.6.1 Overburden Aquifers

In the northern portion of the WQSA, limited overburden aquifers are present, as the Port Stanley, Tavistock Till, Maryhill Till, and Catfish Creek Till aquitards dominate the overburden sequence. The Post and Pre Catfish aquifers are sporadically present in this area, but their presence is thin and localized and therefore the overburden in this area can likely not be relied upon to support significant water takings. This observation is consistent with very few permitted shallow groundwater takings in the area (Figure 8-11). Several non-permitted domestic wells exist in the area suggesting that overburden water bearing units can be found and used for low volume use.

Within the north-central portion of the WQSA, a significant outwash deposit exists at surface. This deposit is the southwest extension of the Waterloo Moraine aquifer, which provides water for the Community of Bright Municipal Water Supply System, and also for multiple permitted (Figure 8-11) and non-permitted water users. A 2015 report on the Bright Municipal Water Supply System noted that the system is not capable of producing at its maximum permitted rate, and that exploratory investigations were needed to locate a nearby aquifer with acceptable water quantity and quality. The findings of the report are discussed further in Section 8.3.1.1. The Whitemans Creek Tier Three study suggests well capacity issues are due to well efficiency problems, rather than a poor yielding aquifer. In the south-central portion of the WQSA, the Waterloo Moraine sand aquifer is confined by the Port Stanley and Tavistock Tills. Underlying the Waterloo Moraine, down to bedrock, is a significant sequence of aquitards with no notable aquifers above bedrock.

In the southeast area of the WQSA, a broadly unconfined sand and outwash aquifer is present and widespread, and is considered the northern portion of the Norfolk Sandplain. The unit is up to 65 m thick in some areas. With the exception of a few local areas where the Tavistock Till confines the Norfolk Sandplain, the aquifer is unconfined and receives significant recharge accordingly. This aquifer supports a significant volume of groundwater extraction from permitted (Figure 8-11) and non-permitted users. As stated in Table 8-4 and displayed on Figure 8-9, the Norfolk Sandplain aquifer is underlain mainly by a sequence of aquitards down to bedrock, with the exception of the far eastern part of the WQSA where the Waterloo Moraine aquifer is present (between the Port Stanley Till and bedrock) and supplies water to the Bethel Road wellfield (Town of Paris Water Supply System).

8.2.6.2 Bedrock Aquifer

The Salina Formation is exposed at bedrock surface across much of the WQSA, with the Bass Island, Bois Blanc and the Onondaga Formations exposed at surface in the far west of the WQSA. The Salina Formation is regionally known to have naturally poor water quality because of highly mineralized water. For much of the central and eastern portions of the WQSA, attempting to utilize bedrock, where overburden aquifers are limited, may not be worthwhile giving the documented poor water quality in the Salina Formation.

The community of Shakespeare and the Town of Innerkip are the only municipal water supply systems in the WQSA to draw from bedrock. Given their longitudinal position within the WQSA, it is likely that they draw water from either the Bass Island, Bois Blanc or Onondaga Formations (Earthx Inc., 2018). Despite few permitted takings in the western part of the WQSA (Figure 8-11), bedrock aquifers support a significant number of domestic wells, and water supply wells for the City of Woodstock just west of the WQSA (Figure 8-10).

8.2.6.3 Groundwater Surface Water Interaction

Aquatic thermal regions for the surface water in the WQSA are mapped and illustrated on Figure 8-6. Coldwater surface water features are confined to the southeastern portion of the WQSA in Whitemans Creek. Significant groundwater discharge to surface water features is expected in areas with shallow unconfined aquifers such as the Norfolk Sandplain.

The Tier Three Assessment for Whitemans Creek subwatershed (Earthfx Inc., 2018) included an evaluation of water levels in shallow drive point piezometers across the WQSA to assess groundwater–surface water interaction. While most piezometers showed seasonal water level variation (high during spring melt, lower in the fall), piezometers located in the southeastern sandplain area were particularly sensitive to precipitation events, illustrating the potential for rapid recharge conditions, but also the ability for shallow groundwater takings to effect discharge to surface water features, such as Whitemans Creek.

As part of the Tier Three Assessment, three of the shallow drive point piezometers (RA-1, RA-2, RA-3) were installed and monitored as a perpendicular transect to Whitemans Creek to monitor the impact of the creek water levels on shallow unconfined aquifer levels. RA-1 was immediately next to the creek, while RA-3 was installed the furthest away (distance not stated). RA-1 water levels responded significantly to creek water levels, while the response in RA-3 was significantly dampened. These results suggest that shallow groundwater close to Whitemans Creek interacts significantly with the surface water; however, the creek has significantly less impact on shallow groundwater further from the creek. While no specific distance away from the creek was suggested for shallow groundwater use, 90 m has been suggested in the Norfolk Sandplain area which is in a similar shallow aquifer system that interacts readily with surface water features (Schroeter and Associates, 2002).

Communication with GRCA water managers determined that while it is widely known that the shallow overburden aquifer in the southern portion of the WQSA interacts readily with surface water features such as the Whitemans Creek system, the spatial variation of the interaction is not well understood.

8.2.7 Overview of Water Takings within WQSA

8.2.7.1 Permitted Takings

Water takings at a rate of over 50,000 litres per day are governed under the MECP Permit To Take Water program. Water takings in Ontario are governed by the OWRA and the Water Taking Regulation (O. Reg. 387/04) a regulation under the Act. Section 34 of the OWRA requires anyone taking more than a total of 50,000 litres of water in a day, with some exceptions, to obtain a Permit from a Director appointed by the Minister for the purposes of Section 34. The purpose of the PTTW program is to ensure the conservation, protection and wise use and management of the waters of the province. Permits are controlled, and not issued if the taking of more water in a given area would adversely affect existing users or the environment.

This section summarizes and reviews the reported takings in the WQSA based on the 2017 WTRS data collected by the MECP and water use data from the Tier Three Assessment (Earthfx, 2018) for the Whitemans Creek subwatershed. This annual snapshot data constitutes the most recent available information on actual water takings, and within the scope of the project are considered the most accurate description of the actual water use in the WQSA. The total permitted volume for all purposes in 2017 was 3.1 x 10^7 m^3 annually, while total reported volume taken was 1.8 x 10^6 m^3, or 5.7 % of the total permitted volume.

Permitted takings in the Whitemans Creek WQSA are dominated by agriculture. In 2017, agricultural takings accounted for approximately 80% of the total volume taken and 83% of the total permitted volume. The remaining 20% of the total volume taken in 2017 and 17% of the total volume permitted was used for the purposes of water supply (dominantly municipal), commercial (golf course irrigation), and recreation.

Figure 8-11 shows a map of the active surface and groundwater permitted takings within the Whitemans Creek WQSA, categorized by purpose. Percentages and values in the following paragraphs used to characterize water demands by purpose and specific purpose were compiled from the 2017 WTRS data.

Agriculture

According to WTRS data from 2017, the total agricultural reported water takings amounted to 1.4×10^6 m^3, which represent 80% of the total volume of water taken in the WQSA from all sources. Of the 80%, 67% was from groundwater, 7% was from surface water, and 6% was from "surface and groundwater" sources.

The majority of al agricultural takings occur in the southeast portion of the WQSA in the fertile soils of the Norfolk Sandplain area. Multiple takings also occur in the north-central part of the WQSA along the Highway 401 corridor.

All surface water takings are for agricultural irrigation, with the heavy demand for irrigation contributing to the surface water quantity stress in the subwatershed (AquaTerra, 2009b). Agricultural surface water takings from Whitemans Creek and its tributaries in 2017, as reported in the WTRS, totaled approximately 41,808 m^3 for the year, while the cumulative, maximum permitted surface water taking from these sources is significantly higher at approximately 1.6 million m^3/year. The cumulative, maximum daily surface water taking from these sources is approximately 31,377 m^3/day (note: the maximum number of taking days are generally less than 180 days/year, and none of the takings are permitted year-round). The average summer low flow in Whitemans Creek is reported to be 138,240 m^3/day (Wong, 2011) therefore the cumulative, maximum daily permitted taking represents approximately 23% of the average summer low flow in Whitemans Creek.

The water stress caused by agricultural irrigation is cited as the primary reason why the Ontario Low Water Response program is active in the Whitemans Creek subwatershed (AquaTerra, 2009a). The competing demands for surface water further prompted the implementation of the Whitemans Creek Subwatershed Drought Contingency Project, in which water managers and irrigators collaboratively developed tools and Best Management Practices (BMP) for managing water use and improving drought preparedness (Etienne, 2014).

In the South Thames River above the Pittock Reservoir subwatershed, surface water usage is estimated at 2,265 m^3/day, of which 256 m^3/day is for agriculture, 818 m^3/day is for industrial uses, 331 m^3/day is for miscellaneous permitted uses, and 860 m^3/day is for unspecified non-permitted uses (TSRSPC, 2015). The South Thames River above the Pittock Reservoir subwatershed was assigned a surface water potential stress classification of low. Further, no information was identified by BluMetric in the background reports and information sources about water stress in the subwatershed.

There are no municipal surface water intakes within the boundaries of the WQSA. The closest surface water intake is located 6.8 km downstream of the confluence between Whitemans Creek and the Grand River (at the southeastern boundary of the WQSA), in the City of Brantford. The lower portion of Whitemans Creek is within the "Zone 2" Intake Protection Zone (IPZ-2) of the Brantford intake; although the IPZ-2 delineation is intended for the protection of water quality, the "Zone 2" designation gives an indication of its proximity to the intake, namely that it is within a 2-hour time of travel of the intake.

Comparing current agricultural water takings in the 2017 WTRS data set to historical takings (based on estimates and studies discussed above) would be useful to determine water use trends (both the amount and source), however given the current configuration of the WTRS database, this is not possible within WTRS. Particularly problematic within the WTRS database is the use of the classification field "Groundwater and Surface Water" used to identify the source of the water taking. As discussed above, The Tier Three Assessment assumes assumed this field refers to dugout ponds, which are ponds dug to the water table that are fed by groundwater and surface water runoff. However, communication with MECP (January 7, 2019) determined that the same Groundwater and Surface Water classification is also used for permits that have multiple takings that include groundwater and surface water sources. The usage of the classification "Groundwater and Surface Water" makes identifying the origin of the water takings under this classification ambiguous and difficult, and the dual usage of the classification compounds the issue. In the Whitemans Creek WQSA, 2017 water takings under this classification make up a significant portion of all takings (i.e., 12.5 percent of 2017 water takings). Permitted takings from the Groundwater and Surface Water classification account for a larger total permitted volume than surface water permits. A summary of permitted versus reported takings is shown in Table 8-5.

Table 8-5: Volume of Reported Water Takings vs Maximum Permitted Volume of Surface and Groundwater in Whitemans Creek WQSA (2017 WTRS)

Sector	Type	Volume of Reported Water Takings (m^3/yr)	Percent of WQSA Total Reported Water Takings (%)	Maximum Permitted Volume (m^3/yr)	Permit Utilization (reported takings/ maximum permitted volume) (%)
Agriculture	Groundwater	1,173,266	67.0	20,242,733	5.80
	Surface and Groundwater	97,233	5.5	2,862,792	3.40
	Surface Water	128,427	7.3	2,410,222	5.33
Commercial	Groundwater	1,027	0.1	389,636	0.26
	Surface and Groundwater	122,231	7.0	1,330,315	9.19
Water Supply	Groundwater	230,005	13.1	3,538,295	6.50
	Surface and Groundwater	0	0.0	2,725	0.00
Total	All Sources	1,752,189	100.0	30,776,718	5.7

Water Supply

Reported water takings for water supply purposes (all groundwater) in 2017 amounted to 2.3 x 10^5 m^3 and represented roughly 13% of the total reported water takings in the WQSA (all groundwater) and 12% of total volume permitted. These Water Supply takings are dominantly for municipal purposes from the Community of Shakespeare, the Community of Bright, the Town of Innerkip, and the Bethel Road wellfield (located within the WQSA) which feeds into the Town of Paris water supply system (located east of the WQSA).

Water Supply PTTWs allow for water taking 365 days per year, as the communities reliant on water supply systems require access to potable water year around.

Municipal takings

Multiple municipal water supply takings were reviewed and summarized within the Whitemans Creek subwatershed, and the Tier Three study area boundary which envelopes the WQSA. The Tier Three Assessment reviewed and averaged the takings between 2012 and 2014. The municipal water supply takings that fall within the WQSA are summarized below and incorporate water taking data from the 2017 WTRS dataset.

The Community of Shakespeare draws water from the Onondaga Formations (bedrock) at an average taking volume of 58 m^3 per day, while the permitted rate is 546 m^3 per day (Earthfx Inc., 2018). No water quantity issues associated with this taking were reported in the Tier Three Assessment.

The Community of Bright located in the central-north area of the WQSA has two operating wells (4A and 5) and one non-operational well (4). Wells 4A and 5 are interpreted to be screened in the Waterloo Moraine aquifer and the screen bottoms of each well are located at 26 and 25 meters below ground surface (mbgs), respectively. A 2015 report reviewing well performance (www.oxfordcounty.ca/drinkingwater) found that the system, which is mainly reliant on 4A, was not capable of pumping at its permitted rate of 327 m^3/day, and that a maximum rate of 286 m^3/day is more realistic. The Community of Bright is in the process of conducting exploratory investigations to locate a nearby aquifer with acceptable water quantity and quality to supplement Wells 4A and 5. Impact of pumping from the municipal wells is limited to the immediate vicinity of the supply wells, with little to no observable impact to water levels in the neighboring monitoring wells MW-1D and MW-1S (monitoring well nest is located 20 m from 4A and 85 m from 5). No reduction to any surface water feature greater than one litre per second is expected to occur as a result of pumping from the Bright wellfield under future conditions.

The Innerkip water supply system consists of two bedrock wells (Well 1 and Well 2) located 1.8 km southwest of the town. Well 1 is cased to a depth of approximately 19 m bgs with an open hole in the bedrock to a depth of 34 m. Well 2 is cased to a depth of approximately 16 m with an open hole in the bedrock to a depth of 35 m. According to the 2017 WTRS data, the average daily combined taking from the wells was 296 m^3/day, while the daily combined permitted rate for all wells is 1,728 m^3/day.

The Bethel Road Wellfield has four water supply wells (TW1/05, PW1/12, PW2/12 and PW4/12) located in the southeast end of the WQSA and is connected to the Town of Paris water supply system to support businesses in the south end of the Town. These wells are interpreted to be screened within a portion of the Waterloo Moraine aquifer in the far eastern end of the WQSA, with bottom of screens ranging between 22 and 33 mbgs. According to the 2017 WTRS data, the average daily combined taking from the four wells was 280 m^3/day, while the daily combined permitted rate for all four wells is 3,240 m^3/day. The taking from the Bethel Road Wellfield between 2012 and 2017 varied between 1.2% and 9.2% of the permitted taking, based on annual average.

Commercial

All commercial permits in the WQSA are for the specific purpose of golf course irrigation. Takings in 2017 amounted to 123,259 m^3 representing 7% of total reported takings in the WQSA. All commercial permits are water taking from either groundwater or dugout ponds.

8.2.7.2 Non-Permitted Takings

Non-permitted takings represent water takings for domestic use and some agricultural uses including livestock watering. To determine the domestic water supply demand, the Tier 3 Assessment used the following assumptions to determine the domestic water supply demand: estimated that based on 1,258 wells with primary or secondary purpose designated as "domestic water supply" and using an assumed rate of 0.9 m^3/day (based on a Canadian historical estimate of per-capita water use (347 L/d per person), and the Ontario average of 2.6 people per dwelling). The Tier Three study then applied a consumptive factor of 0.2 (assumes that 80% of the water is returned to the ground through septic beds). Based on these assumptions, which determined that domestic wells in the model area represented a mean daily consumptive taking of approximately 226 m^3/day (1,258 x by 0.9 m^3/day x 0.2). The Tier Three Assessment estimated that livestock watering accounted for a mean daily consumptive taking of 1,470 m^3/day.

8.2.8 Recommended WQSA Boundaries for Data Review

The current WQSA boundary for Whitemans Creek loosely encompasses the established boundaries of Whitemans Creek subwatershed, within the Grand River watershed.

Given that the WQSA encompasses nearly the entire watershed, the current boundaries are sufficient for evaluating the state of surface water resources in the area. From a groundwater perspective, the southeast area of the WQSA hosts the northern portion of the Norfolk Sandplain, which extends beyond the WQSA boundary to the south. As the Sandplain's shallow unconfined aquifer supports multiple takers within the WQSA and beyond its southern boundary, it may be useful to look at the whole Norfolk Sandplain when considering the impacts of water management decisions. Given that the Norfolk WQSA (which was also reviewed as part of this study) boundary is just to the south of the Whitemans Creek southern WQSA boundary, these study areas should be considered simultaneously when reviewing water management issues in either the northern section of the Norfolk WQSA or the southeast portion of the Whitemans Creek WQSA.

The Tier Three Assessment for Whitemans Creek subwatershed focused on the subwatershed boundary; however the study area was significantly larger to account for groundwater and surface water modelling requirements. It may be useful for the WQSA to adopt the Tier Three study area boundary, which envelopes the current WQSA, to make use of the existing groundwater modelling results and analysis. Files needed to create a figure using the Whitemans Creek Tier Three Assessment boundaries were unavailable at the time of writing as the Assessment was recently completed in 2018, therefore no figure (expected to be Figure 8-12) outlining recommended boundary changes is provided at this time.

8.3 RESOURCE SUSTAINABILITY

8.3.1 Data Review and State of Water Resources

Available information on the sustainability of water resources in the Whitemans Creek WQSA has been reviewed and summarized. The key reports relied upon for the evaluation are listed in Table 8-1. Hydrographs from Provincial Groundwater Monitoring Network (PGMN) within the WQSA were also reviewed, and conclusions were made based on the general findings of studies/reports/data conducted and collected in the Whitemans Creek WQSA.

High Use Watershed Classification

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Whitemans Creek WQSA lies within a watershed that is classified as having a high percent water use based upon both the Average Annual and Summer Low Flow.

8.3.1.1 Groundwater

PGMN Hydrographs

The MECP provided hydrographs and a statistical analysis of water levels for all PGMN wells in all WQSAs. In the Whitemans Creek WQSA hydrographs and a statistical analysis of water levels were provided for seven PGMN wells located within and surrounding the Whitemans Creek WQSA, including Mann Kendall (MK) and Seasonal Mann Kendall (SK) monotonic trend analyses (i.e. consistently increases or decreases through time) between 2001-2017. These wells are summarized in Table 8-6 and shown on Figure 8-10. The methodology for the analysis is forthcoming from the MECP; however the results are relied upon here to summarize water level trends in the Whitemans Creek WQSA. The statistical analyses were performed using robust and defensible methodologies to look for longer-term trends in groundwater levels. An overall objective is to determine if there is enough data to support the presence of a widespread decrease in groundwater availability. Shorter trends within the PGMN data record (e.g. lasting for a few years) were not considered and the causes of any trends that were identified were not investigated. Both the data plots and preliminary findings for PGMN well locations within the Whiteman's Creek WQSA were shared by the ministry and are presented and relied on herein. The data plots indicate data available for the well at the time of the assessment. Further, the MECP has indicated that the methodologies used require that certain values be dropped from the data set if the month/year in question does not have a sufficient number of data points. The release of a final report that details the methodology and results from the PGMN data trends analysis is forthcoming from the ministry (MECP, 2018).

There are four PGMN wells within the Whitemans Creek WQSA, and three immediately outside the northern tip (Figure 8-10). The PGMN wells within the WQSA include W0000065-4, W0000477-1, W0000180-1, and W0000478-1. There are also three wells immediately outside the WQSA, north of the community of Shakespeare, which have also been included in this assessment due to their proximity to the Shakespeare water supply wells. These wells are labeled W0000218-3, W0000218-4, and W0000218-5. Plots of available data from all wells are provided in Appendix C and PGMN well information is summarized in Table 8-6.

Table 8-6: PGMN Wells in Whitemans Creek WQSA

PGMN Well ID	Water Well Record ID	Screened Interval (mbgs)	Lithology of Aquifer
W0000065-4[1]	1305684	Screen: 18.3 m-21.3 m	Gravel
W0000180-1	4708277	Open Hole: 16.2 m- 41.9 m	Limestone
W0000218-3	5005359	Screen: 3.6 m-6.7 m	Silty Sand
W0000218-4	5005359	Screen: 21.0 m-24.1 m	Sand
W0000218-5	5005360	Open Hole: 60.1 m-60.9 m	Limestone
W0000477-1	7052790	Screen: 14.9 m-17.9 m	Sand
W0000478-1	7052789	Screen: 14.0 m-17.0 m	Sand, Silt

[1] Relied heavily upon by GRCA due to the length of historical record (Verbal Communication)

The Mann Kendall analysis, which looks at the year over year water levels, determined that of the seven wells reviewed, six had no trend, while one well (W0000180-1) had a downward trend. The Seasonal Mann Kendall analysis, which determines the trend from season to season (i.e., Spring 2010 to Spring 2011) and then adds the sum of each seasonal analysis together, established that three of the seven wells had downward trends (W0000180-1, W0000477-1 and W0000478-1), three wells had no trend (W0000218-3, W0000218-4 and W0000218-5), and one well had an upward trend (W0000065-4).

Wells W0000065-4 and W0000477-1 are located in the southeast portion of the WQSA within 5 km of each other, and based on similar screen depth and lithology; both wells are interpreted to be screened within the shallow unconfined overburden associated with the Norfolk Sandplain. Communication with GRCA water managers determined that data for W000065-4 from 2010 to present exists and that the PGMN well is heavily relied upon by the GRCA due to the length of historical record (2002-present). However, the trend analysis provided by the MECP for well W0000065-4 only uses monitoring years of 2002 to 2010 (rationale unknown). During this period, the PGMN well exhibits a significant upward water level trend; however, given that the analysis does not reflect the past eight years, this trend cannot be relied upon to make relevant conclusions about regional water levels in this part of the WQSA. Well W0000477-1 exhibits a downward trend within the available monitoring years of 2010 and 2017.

Well W0000180-1, located in the far west of the WQSA shows a downward trend within the available monitoring years of 2003 and 2012. This well is an open hole in bedrock down to 42 mbgs. The well is within 300 m of the Innerkip water supply bedrock wells. As the water level trends in the Innerkip supply wells are unknown at the time of writing, it is unknown if the downward trend observed in the PGMN well (W0000180-1) correlates with water levels in the supply wells. Similar to well W0000065-4, no monitoring data for well W0000180-1 is available for the past six years. As such, this trend is not reflective of current groundwater level conditions in the bedrock within the area around well W0000180-1.

Well W0000478-1, located in the central-north part of the WQSA shows a downward trend within the available monitoring years of 2009 and 2017. Based on the depth and lithology of this well, it is interpreted to be screened within the Waterloo Moraine aquifer. The nearest permitted groundwater taking is over 900 m from the PGMN well (W0000478-1), and there are few domestic wells in the immediate vicinity of the well; therefore, groundwater takings are unlikely to explain the downward water level trend and therefore may reflect ambient conditions between 2009 and 2017.

Wells W0000218-3, W0000218-4, and W0000218-5 are located 1.1 km north of the Community of Shakespeare's water supply wells (bedrock) which are located at the northern tip of the WQSA. Based on the screen depth and lithology (3.6-6.7 mbgs/silty sand, 21.0-24.1 mbgs/sand, and 60.1-60.9 mbgs/bedrock respectively), the wells are interpreted to be screened within the shallow Waterloo Moraine aquifer, the Post Catfish aquifer, and the Bois Blanc or Onondaga bedrock aquifer. All three PGMN wells have water level data for between 2003 and 2015, with the exception of well W0000218-5, which has no data for 2010-2012. Annual maximum and minimum groundwater levels do vary over this time period; however no trends were determined by the Mann Kendall or Seasonal Mann Kendall analysis.

Whitemans Creek Tier Three Water Budget Stress Assessment and Risk Assessment

A Tier Three Assessment was triggered by the findings of the Tier Two study in the Whitemans Creek subwatershed. The Tier Two study determined that under drought conditions, the water level drawdown at municipal Well 4 in Bright would be approximately 7 m, which would fall below the top of the well screen, potentially leading to operational issues. Because of the results of this scenario, the Whitemans Creek subwatershed potential for stress classification is Moderate, thus triggering the need for a Tier Three Assessment. Due to the complexity of the groundwater-surface water interactions in the watershed, the Tier Three water budget used a fully integrated surface and groundwater model developed to allow additional drought (Earthfx, 2018). Additionally, the fully integrated model can potentially be used for future drought studies within the model domain.

Stress Assessment

A Stress Assessment was conducted as part of the Tier Two study. However, as the Bright and Bethel wellfield underwent operational changes after the Tier Two study was completed, a Water Budget and Stress Assessment were recalculated as part of the Whitemans Creek Tier 3 Assessment (Earthfx, 2018). The results of Tier Three Stress Assessment represent the most up to date Stress Assessment values for the two municipal groundwater supplies located in the subwatershed and are discussed below. The purpose of the stress assessment is to determine potential for stress under existing and planned (accounting for increased demand) conditions. The results of the stress assessment are expressed as "percent water demand", which is calculated using the following equation:

% Demand = Total Demand (takings)/(Total Supply[recharge]-Reserve[10% of discharge])

Percent demand was calculated on an annual and monthly basis to account for demand varying throughout the year, with the highest demand occurring in July, primarily due to agricultural irrigation. Under existing water demand conditions, the annual average and maximum monthly percentage of water demand in the Whitemans Creek Subwatershed is 2.8% and 11.1%, respectively. Under planned conditions (accounting for population and economic growth), the annual average and maximum monthly percent water demand in the Whitemans Creek Subwatershed is 3.4% and 11.6% respectively.

The MECP Guidelines for Stress Assessments states that an annual average and maximum monthly percent water demand below 10% and 25% respectively is considered low. Therefore, results from the stress assessment suggest that the municipal groundwater supply within the Whitemans Creek Subwatershed is under low stress on an average and monthly basis. This was expected, as the Tier Two study determined the Whitemans Creek subwatershed was considered to have a low potential for stress. It should be noted that for the watershed wide stress assessment described here, the planned percent water demand incorporates projected changes in demand (potential increased water takings), however it does not factor in potential land use changes or the most detrimental impacts of climate change scenarios on groundwater, such as prolonged periods of drought, which could decrease recharge rates and affect percent water demand results.

Risk Assessments

As part of the Tier Three Study, local area risk assessments are conducted around water supply pumping wells. They involve modelling the water taking under future scenarios which consider how population/economic growth, land use and climate changes may impact the potentiometric surface in the area. The outcomes of the risk assessment typically determined if the supply well is expected to exceed safe available drawn down (SAAD) which is based on the geology and well construction of each well. SAAD is defined as the difference (measured in meters) between the average water level in a pumping well under pumping conditions, and a point in the well typically 1 m above the screen or the lowest possible pump intake. If the modelled drawdown in the well under future conditions does not exceed the SAAD, the taking may be considered sustainable from a water supply perspective. The modelled outcome of the local area risk assessment for the Bright and Bethel wellfield is discussed below. The local area risk assessment predicts drawdown under the most extreme scenario, one which incorporates expected demand in 2031, drought conditions, and the implementation of all planned land use changes. The results for each of these parameters were applied to the wellfields in isolation in order to estimate the impact of each of the considerations. These are discussed in more detail in 8.3.2 – Assessment of Sustainability.

Bright

The modelled drawdown based on most extreme scenarios described above was 1.33 m in well 4A (SAAD of 7.0 m) and 1.25 m in well 5 (SAAD of 12.5 m). During the time between when the Tier Two study was completed, and the Tier Three study was conducted, well 4A replaced well 4, the well responsible for initiating the Whitemans Creek Tier Three study, was taken out of service. The drawdown of 1.33 m in 4A is significantly less than what was originally modelled in well 4 in the Tier Two study, which suggested that well 4 could see up to 7 m of drawdown under drought conditions.

Baseflow reduction simulations in the risk assessment use scenarios that consider future demand and land use plans, but not drought conditions (as per MECP Technical Guidelines). Baseflow reduction of 10% or more is considered significant. All surface water features in the assessment area were predicted to have less than 10% reduction as per modelled scenarios under future conditions and therefore not considered significant.

Bethel wellfield

The modelled outcome of the local area risk assessment for the Bright wellfield determined that drawdown under the most extreme scenario, one which incorporates expected demand in 2031, drought conditions, and the implementation of all planned land use changes, was 16.22 m in well TW1/05 (SAAD of 14.7 m), 14.23 m in well PW1/12 (SAAD of 9.4 m), 12.73 m in PW2/12 (SAAD of 9.5 m) and 12.35 m in PW4/12 (SAAD of 8.9 m). The results indicate that the Bethel wellfield has a high risk of not being able to meet the system demands under future pumping and land use during drought conditions.

Baseflow reduction under modelled scenarios of future conditions was minimal. Landon's Creek, located 4 km west of the Bethel wellfield is expected to experience a 2.4% decline in baseflow, which is not considered significant (less than 10%).

8.3.1.2 Surface Water

WSC Gauge Hydrographs

WSC gauges located within the boundaries of the WQSA include: 02GD021 (Thames River at Innerkip), 02GB006 (Horner Creek near Princeton), 02GB009 (Kenny Creek near Burford), and 02GB008 (Whitemans Creek near Mount Vernon). The locations of the WSC gauges are illustrated on Figure 8-5, and general information about the stations and flow data are summarized in Table 8-7.

Table 8-7: Water Survey of Canada stream gauges in Whitemans Creek WQSA

Station No.	Main Watershed	Years	Data Availability	Drainage Area (km^2)	Mean annual flow (m^3/day)
02GD021 (Thames River at Innerkip)	Thames River	1978 – present	Flow and level	149	164,160
02GB006 (Horner Creek near Princeton)	Grand River	1983 – present	Flow and level	150	164,160
02GB009 (Kenny Creek near Burford)	Grand River	1961 – 1991	Flow	91.9	86,400
02GB008 (Whitemans Creek near Mount Vernon)	Grand River	1961 – present	Flow and level	386	380,160

Source: WSC (2018)

Streamflow at the four WSC stations in Table 8-5 all exhibit similar seasonal patterns, with the highest flows being associated with the spring snowmelt, peaking around April, and seasonal low flow occurring in the summer, typically reaching its lowest point around August. Hydrographs for the four WSC stations are provided on Figure 8-13 to 8-16.

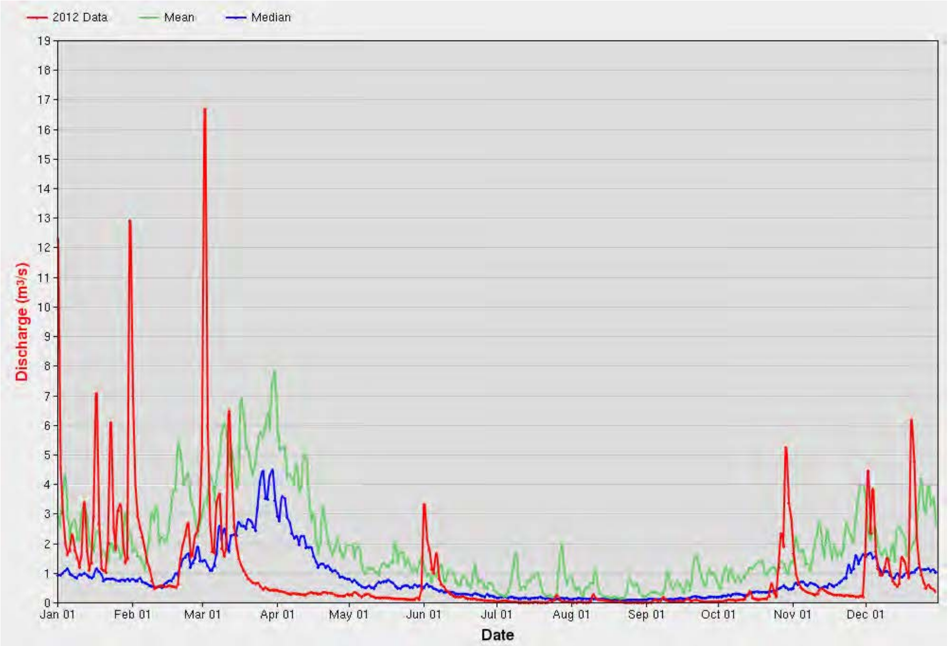

Figure 8-13. Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GB021 (Thames River at Innerkip). (Source: WSC, 2018).

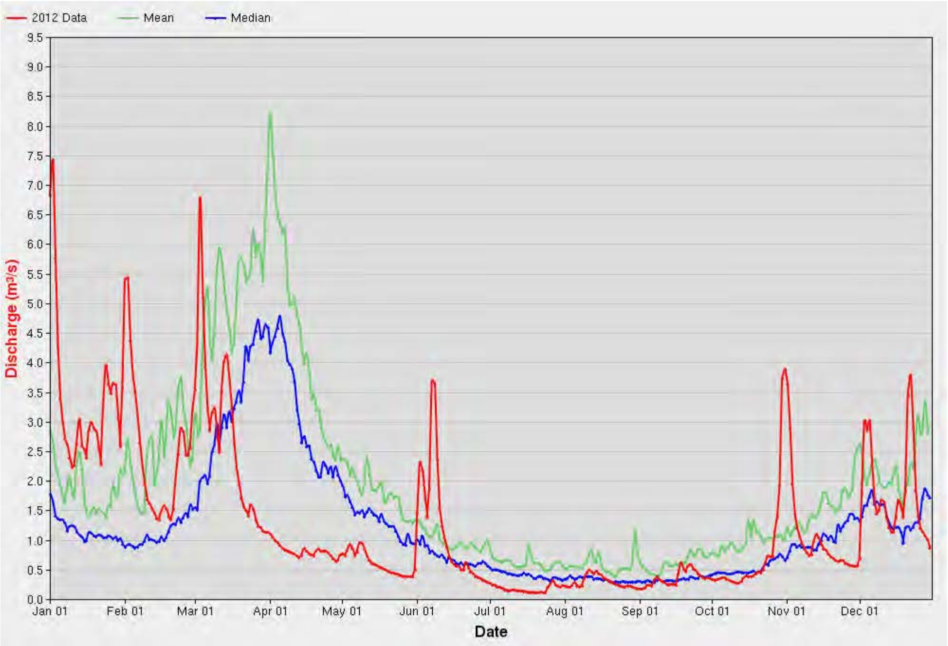

Figure 8-14: Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GB006 (Horner Creek near Princeton). (Source: WSC, 2018).

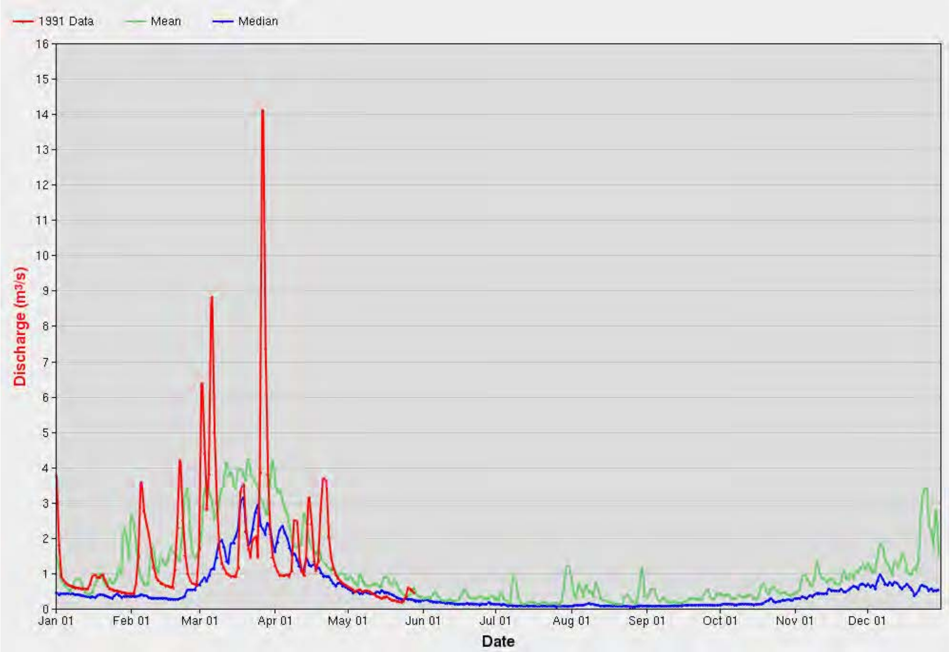

Figure 8-15: Mean daily streamflow (green line), median daily streamflow (blue line) and 1991 (last year on record) daily streamflow (red line) at 02GB009 (Kenny Creek near Burford). (Source: WSC, 2018).

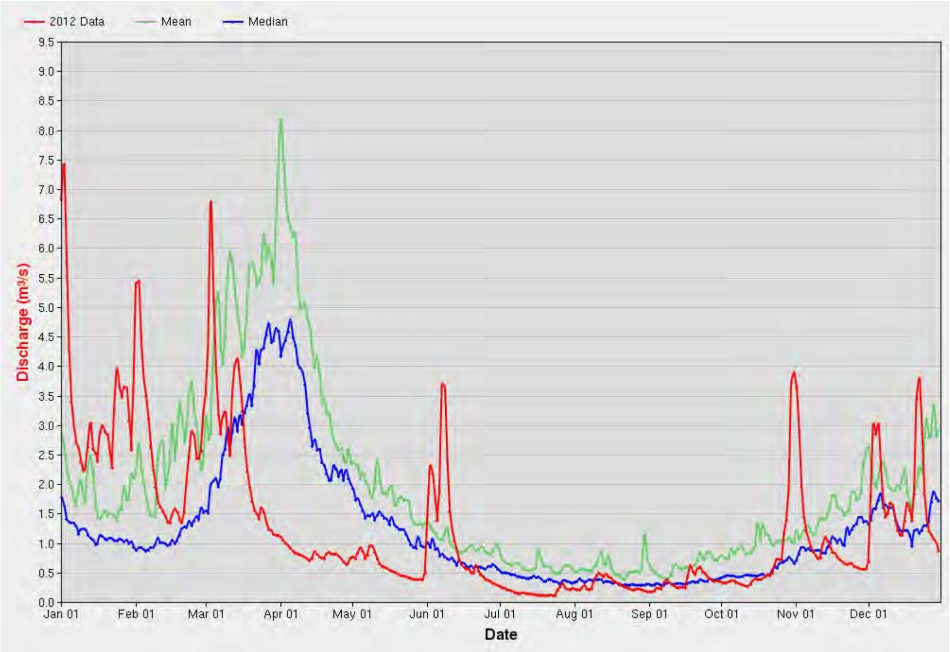

Figure 8-16: Mean daily streamflow (green line), median daily streamflow (blue line) and 2012 (drought year) daily streamflow (red line) at 02GB008 (Whitemans Creek near Mount Vernon). (Source: WSC, 2018).

Surface Water Budget – Whitemans Creek Subwatershed

The surface water budget components for the Whitemans Creek Subwatershed were calculated as part of the Drinking Water Source Protection studies for the Grand River Source Protection Area. Findings from the surface water budget study are summarized in the Assessment Report (GRSPA, 2015), and discussed below.

Precipitation inputs in the subwatershed were estimated to be approximately 1,046,000 m^3/day (945 mm/year); of this, 566,800 m^3/day (512 mm/year) is lost to evapotranspiration, 195,300 m^3/day (176 mm/year) is transported as runoff, and 284,300 m^3/day (257 mm/year) goes towards recharging the aquifers. Due to the highly permeable materials in the middle and lower reaches of the subwatershed, runoff is lower than the Grand River watershed average (176 vs. 266 mm/year), and groundwater recharge is higher than the watershed average (257 vs. 176 mm/year).

The total monthly consumptive demand of surface water in the subwatershed, calculated as part of a Tier Two Water Quantity Stress Assessment, ranges from 0.004 m^3/s (from October through to May), increasing significantly in the summer months to a peak of 0.218 m^3/s in July.

Due to the reduced surface water flow during the summer months, the percent water demand in the subwatershed ranges from 7 – 38% in the summer months (peaking in July), whereas the percent water demand is estimated at 0% for the remainder of the year.

Due to the high percent water demand in the summer, the Whitemans Creek Subwatershed was assigned a surface water potential stress classification of Moderate. However, there are no existing or planned municipal surface water supply system located within the subwatershed, therefore a Tier Three Water Quantity Stress Assessment on the surface water resource specifically was not completed, so future demand and drought scenarios were not evaluated beyond the Tier Three modelling completed for the two groundwater systems (Bright and Bethel) discussed above.

Surface Water Budget – South Thames River above Pittock Reservoir Subwatershed

The water budget components for the South Thames River above Pittock Reservoir subwatershed were calculated as part of the Drinking Water Source Protection Studies of the Upper Thames River Source Protection Area. Findings from the surface water budget study are summarized in the Assessment Report (TSRSPC, 2015), and discussed below.

Precipitation inputs for the subwatershed were estimated at 600,867 m^3/day; losses to evapotranspiration and surface water outflows were estimated at 354,842 m^3/day and 244,672 m^3/day, respectively. The remaining 1,353 m^3/day is inferred to go towards groundwater recharge.

The total monthly consumptive demand in surface water in the subwatershed, calculated as part of a Tier One Water Budget (TSR, 2010), ranges from 1.719×10^8 m^3/day (from October through to May), increasing in the summer months to a peak of 3.097×10^8 m^3/day in July and August. The percent water demand is at or below 2% from September to April, increasing sharply in July to 13%. As the percent water demand is consistently below 20%, the subwatershed was assigned a surface water potential stress classification of low, and therefore a Tier Two assessment was not required.

Ontario Low Water Response Program

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater level elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR program submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%;
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the WQSA.

In the Whitemans Creek subwatershed, triggers for the GRCA to post Low Water Condition Alerts are based on flows in the Whitemans Creek (Shifflett, 2014b). The triggers for Level 1, Level 2 and Level 3 occur when the 7-day average flow drops to 86,400 m^3/day, 69,120 m^3/day and 38,880 m^3/day, respectively. The trigger flows are intended in part to be representative of flow conditions under which fish migration is compromised (Shifflett, 2014b).

A review of the OLWR database indicates that, within the Whitemans Creek subwatershed, a total of one Level 1 notification (in late April 2012), and no Level 2 notifications, were sent to the GRCA by the MNRF between 2000 and August 2018; for the Grand River watershed as a whole, a total of 22 Level 1 notifications, three Level 2 notifications and one Level 3 notification were issued between 2000 and August 2018. Instances when more than one notification was issued for the watershed as a whole in the same calendar year occurred in 2000 (three Level 1 notifications), 2001 (two Level 1 notifications), 2004 (two Level 1 and one Level 2 notifications), 2005 (two Level 1 notifications), 2010 (four Level 1 notifications), 2012 (two Level 1 notifications), 2015 (three Level 1 notifications), 2016 (one Level 1, one Level 2 and one Level 3 notifications) and 2017 (two Level 1 notifications).

The GRCA, unprompted by the MNRF, posted Level 1 and/or Level 2 Low Water Condition Alerts every year except in 2000, 2001, 2009, 2010, 2014 and 2017. Level 2 Low Water Condition Alerts were posted in 2002 (July and September), 2003 (early September), 2005 (July to October), July 2007 through to February 2008, 2012 (July to August), 2015 (September to November) and 2016 (July to October). The only time of year when no Low Water Condition Alerts were ever posted from 2000 to 2018 is from late March to mid-June.

The OLWR Program is currently implemented for the UTRCA, but unlike the GRCA, not at the scale of individual subwatersheds. A review of the OLWR database indicates that, for the Conservation Authority as a whole, Level 1 and/or Level 2 notifications were sent to the UTRCA every year between 2000 and August 2018, except in 2008, 2014 and 2018. A total of 15 Level 1 notifications, eight Level 2 notifications, and one Level 3 notification (in July 2012) were issued between 2000 and August 2018. Instances where three or more notifications were issued in a year include 2000 (three Level 1 notifications), 2004 (six Level 1 notifications), 2005 (two Level 1 and three Level 2 notifications), 2012 (one Level 1, one Level 2 and one Level 3 notifications), 2015 (three Level 1 notifications), and 2016 (one Level 1 and two Level 2 notifications). The UTRCA posted Level 1 and/or Level 2 Low Water Condition Alerts every year except in 2000, 2001, 2004, 2011 and 2014. The Low Water Condition Alerts were posted for three months or more, with the longest-running Low Water Condition Alert occurring from late March 2012 to May 2013 (starting as a Level 1, then raised to a Level 2 in May 2012, then lowered back to Level 1 in March 2013). For the period of record, Low Water Condition Alerts were posted the least frequently in late spring, and the most frequently in the fall and winter.

Review of the OLWR database indicates that the Grand River CA and the Upper Thames River CA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts. No specific trends can be discerned in the frequency of Low Water Condition Alerts for the Grand River CA, nor in the frequency of OLWR notifications for either CA. Overall, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends. As notifications and alerts are on a watershed scale rather than subwatershed scale, the relevance to specific subwatersheds within the WQSA cannot be readily determined from the available posted data.

8.3.1.3 Water Shortages

At present, reported water shortages are associated with surface water. During summer months when precipitation can be minimal and irrigation demand is significant (particularly in drought years), shortages in Whitemans Creek have been reported, including anecdotal reports of the creek drying up in areas (source: Water Manager correspondence, but no specific areas or year of occurrences accompanied the anecdotal reports).

At present, groundwater shortages are not an issue, however, based on modelling conducted for the municipal water supply systems in the Whitemans Creek Tier Three Assessment that considered drought, land use change and population growth, the Bethel Road wellfield may be at risk of potential shortages under future conditions.

As per Section 8.2.6 – Hydrogeology, the aquifer systems within the Whitemans Creek WQSA are a result of a complex combination of different depositional environments and therefore have very different thicknesses, extents and properties. The aquifer systems in the WQSA range from a set of limited and relatively thin discontinuous confined aquifer units at depth in the north, to a shallow unconfined aquifer in the north-central portion which becomes confined in the south-central portion of the WQSA and a regional unconfined water table aquifer which is considered to be the northern portion of the Norfolk Sandplain in the southeast. Assessing the occurrence or potential for groundwater shortages outside the municipal areas where extensive modelling has not been conducted is difficult as one can only rely on PGMN well water levels to make conclusions about regional water levels, and/or well owners reporting water shortages to the MECP or Conservation Authorities.

8.3.2 Assessment of Sustainability of Water Resources

8.3.2.1 Climate Change

Groundwater

Modelling by the GRCA (GRCA, 2014a) looked at ten different predicted future climate scenarios that may occur in the future in each of the subwatersheds in the Grand River watershed, including Whitemans Creek. The ten simulations modelled a combination of potential precipitation and temperature scenarios that may occur in the future due to climate change. In five of the scenarios, groundwater recharge decreased slightly, in three it increased, and two remained similar to baseline conditions. Baseline recharge in the subwatershed is estimated to be 218 mm/year. Averaging all ten scenarios, recharge is expected to decrease by 3 mm to 215 mm/year. A groundwater stress assessment for Whitemans Creek subwatershed based on the outcomes of the ten climate change scenarios showed the subwatershed remaining within the "low stress" classification for groundwater.

As part of the Whitemans Creek Tier Three Assessment, Local Area Risk Assessments were conducted in the areas surrounding municipal water takings including the Community of Bright and the Bethel wellfield. The Local Area Risk assessments assess the potential for risk to the municipal water supply by modelling multiple scenarios which incorporate multiple factors including: potential climate change, expected land use changes, and projected water demand increases based on population and economic growth as discussed in detail in 8.3.1 – Risk Assessments.

The effect of prolonged drought conditions on groundwater levels represents the most detrimental effect climate change may have on groundwater resources. One modelled scenario in the risk assessment attempted to predict the effects of a 10 year drought (using 1956-1966 climate conditions for the Whitemans Creek area), under existing water demands and current land use. Under these conditions, water levels in the Bright and Bethel Road water supply systems were only marginally impacted which suggest that the current operating conditions for the Bright and Bethel Road water supply systems are sustainable during a drought.

Surface Water

In the early 2010s, climate change scenario modelling was implemented for select subwatersheds in the Grand River basin, including the Whitemans Creek subwatershed, in order to model future (2050s) streamflow conditions (Shifflett, 2014a). The modelling involved the use of ten climate change scenarios in order to predict changes in annual streamflow; the scenarios differed from one another in terms of the relative change in mean annual precipitation and in mean annual temperature. Changes in mean annual precipitation represented by the ten scenarios ranged from an approximate 5% decrease to a 13% increase, while increases in mean annual temperature ranged from approximately 1.8°C to 4°C.

The projected changes in monthly median flow in Whitemans Creek under the ten climate change scenarios are illustrated on Figure 8-17. The implications of the projected changes are discussed further below.

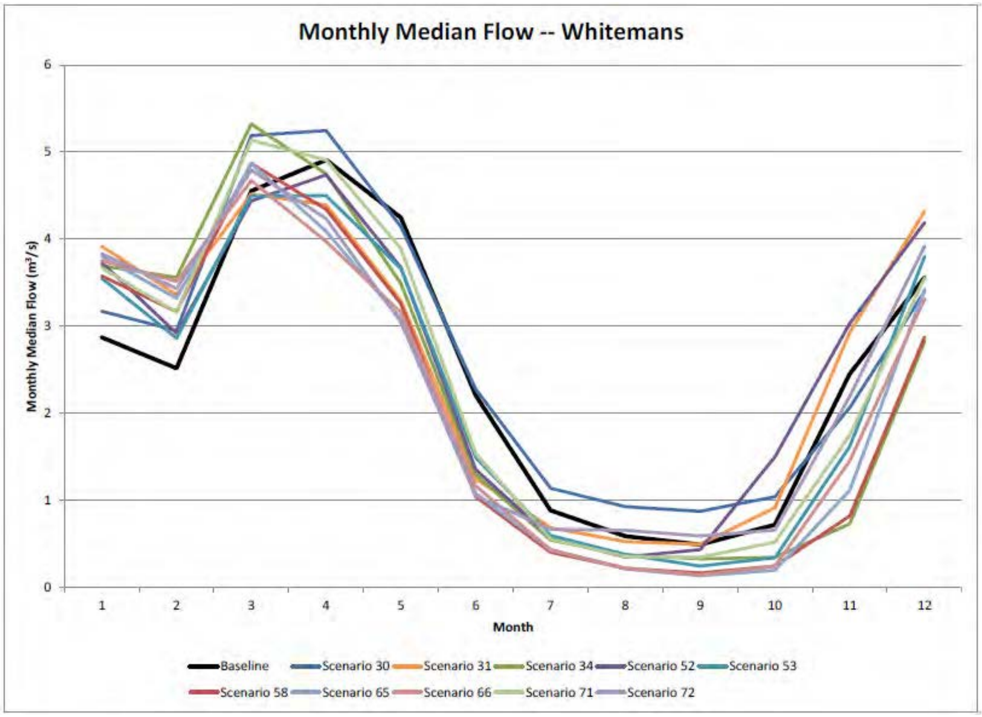

Figure 8-17. Projected monthly median flows for Whitemans Creek at Mt. Vernon (WSC gauge 02GB008) under ten climate change scenarios. (Source: Shifflett, 2014a).

The findings of the modelling indicated the Whitemans Creek subwatershed only had two scenarios that resulted in increased flow, whereas six scenarios resulted in decreased flows, and two scenarios resulted in flows similar to baseline conditions. Of interest, is the fact that the modelled responses of the subwatersheds to a given climate change scenario were sometimes in opposite directions: for example, under "Scenario 34", which involved an increase in precipitation and the largest temperature increase of the ten scenarios, streamflow in Whitemans Creek was projected to decrease due to an increase in evapotranspiration, whereas the "Conestogo Above Dam" subwatershed (one of the northernmost subwatersheds of the Grand River watershed) was projected to experience an increase in streamflow.

Other model findings for the Whitemans Creek subwatershed included:

- Baseline data indicates that 56% of Whitemans Creek's flow comes from runoff, with the remaining 44% coming from groundwater discharge. Under the modelled scenarios of climate change, runoff was projected to account for only 41 – 44% of the average annual flow, and groundwater discharge was projected to account for 56 – 59% of the average annual flow;
- Under baseline conditions, the subwatershed has a moderate potential for surface water stress. Under 9 of the 10 scenarios, the subwatershed was projected to develop a significant potential for surface water stress. Under the scenario with the highest precipitation increase, the stress level remained unchanged;
- With regards to median monthly streamflow:
    - Under all scenarios, winter flows in January and February were higher compared to baseline conditions, and December median flows had the most variability across all the scenarios;
    - In 9 of 10 scenarios, the highest median monthly flow was projected to occur about a month earlier compared to baseline conditions (March instead of April);
    - Except under the high precipitation scenario, the May-June period was projected to see lower flows under all scenarios, resulting in the low flow season starting 1-2 months earlier compared to baseline conditions;
    - Summer flows were decreased under all scenarios, except in the scenario with the highest precipitation increase.

The results of the climate change scenario modelling indicate that surface water resources in the Whitemans Creek WQSA may be negatively affected by climate change, except in the scenario where there is a relatively large increase in precipitation. The results indicate a greater likelihood of decreased flows, as well as a greater likelihood that the subwatershed would develop a significant potential for surface water stress. Summer low flows were projected to decrease and begin earlier in the year, which may further increase competition between ecosystem needs and human use in the watershed.

8.3.2.2 Population Growth

Population growth in the context of increased demand on municipal water supply systems was considered and modelled in the Local Area Risk Assessments for the Community of Bright and the Bethel wellfield. The increased demand is based on the allocated projected demand for the water supply system in 2031. This assessment on the impact of population growth focuses on municipal well fields and represents the only known assessment of impacts of population growth on water resources in the WQSA.

Modelling for allocated demand (expected usage in 2031) under normal climate scenarios and existing land use conditions had minimal effect on water level at the Bright wells. However, modelled water level drawdown in the Bethel Road wellfield consumed most of the SAAD, although did not exceed it. Population growth is expected to present the single most significant stressor on the Bethel wellfield water levels, while land use change and climate change are expected to have less significant effects.

As noted in Table 8-2 the largest population centre (Innerkip) had a slight population growth of 2.7% between 2011 and 2016. This is based on the estimated number of people the water supply system services. The largest population growth associated with a water supply in the WQSA is 5.0% for the Town of Paris which draws groundwater from the Bethel Road wellfield located in the south eastern portion of the WQSA. However, the Town of Paris is not within the WQSA boundaries. Furthermore, given the relatively modest population growth in these two main population centres, it is unlikely that groundwater resources would be stressed in the WQSA as a whole based solely on an increase in population. However, as noted above, local area impacts from population growth associated with the Bethel Road wellfield is a significant stressor on the local resource. It is not possible to assess the impact of population growth alone in a different local area within the WQSA based on the information available at the time of this study. There are no other areas predicted to experience population growth.

8.3.2.3 Cumulative Effects

In the Whitemans Creek WQSA, reported water shortages appear to be limited to surface water, and not groundwater (Section 8.3.1.1). As part of a Tier Two Water Quantity Stress Assessment, the Whitemans Creek subwatershed was assigned a surface water potential stress classification of moderate (Section 8.3.1.2), whereas the results from the Tier Three Assessment indicate that the municipal groundwater supply within the Whitemans Creek subwatershed is under low stress on an average and monthly basis (Section 8.3.1.1). Climate conditions and drought appear to be a major contributor to these reported surface water shortages, as such shortages generally occur during summer months when precipitation can be minimal and irrigation demand is significant, particularly in drought years (Section 8.3.1.1). BluMetric was not made aware of any reported interference issues between permitted and non-permitted water takings.

There is a moderate density of permitted takers in the Whitemans Creek WQSA, with most of the takings concentrated in the southeastern portion of the WQSA (Figure 8-11). All surface water takings are for agricultural irrigation, with the heavy demand for irrigation contributing to the surface water quantity stress in the subwatershed (AquaTerra, 2009b). In 2017, agricultural takings accounted for approximately 80% of the total volume taken and 83% of the total permitted volume. The remaining 20% of the total volume taken in 2017 and 17% of the total volume permitted was used for the purposes of water supply (dominantly municipal), commercial (golf course irrigation), and recreation (Section 8.2.7.1).

The ecosystem in Whitemans Creek has already been observed to experience significant stress during drought conditions. For example, during a drought in 2012, when flows in the creek fell below levels required to maintain the hydraulic connectivity for fish movement (Section 8.3.2.4). Wong & Boyd (2014) argued that agricultural water takings in the summer months may be unsustainable from an ecological perspective, and a potential for conflict and constraint exists.

There are four PGMN wells within the Whitemans Creek WQSA, and three immediately outside the northern tip (Section 8.3.1.1). Year over year and seasonal water levels at the wells do not indicate regional declines in hydraulic head. The absence of an observable downward trend across the PGMN wells indicates it is unlikely that the water takings in the WQSA are resulting in regional scale impacts.

Review of the OLWR database indicates that the Grand River CA and the Upper Thames River CA have found it necessary to declare Level 1 and Level 2 Low Water Condition Alerts (Section 8.3.1.2). No specific trends can be discerned in the frequency of Low Water Condition Alerts for the Grand River CA, nor in the frequency of OLWR notifications for either CA. Overall, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor of any specific climate change trends.

In addition to existing pressures on surface water resources, the Whitemans Creek WQSA is an area where cumulative effects may potentially become a concern in the future for both surface water and groundwater resources. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Whitemans Creek WQSA lies within a watershed that is classified as having a high percent water use based upon both the Average Annual and Summer Low Flow (Section 8.3.1). In addition, based on modelling conducted for the municipal water supply systems in the Whitemans Creek Tier Three Assessment that considered drought, land use change and population growth, the Bethel Road wellfield may be at risk of potential shortages under future conditions (Section 8.3.1.1).

The large number of agricultural takings has already been identified in previous studies as the major contributor to surface water shortages (AquaTerra 2009b, Wong & Boyd, 2014). Numerical modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

8.3.2.4 Environmental Flow Needs

Several studies of EFN for Whitemans Creek were conducted by GRCA (Wong & Boyd, 2014), and are summarized below. No similar study was identified for the South Thames River above Pittock Reservoir North Woodstock (Thames River) subwatershed in the western portion of the WQSA.

In a 2005 EFN study (GRCA, 2005), it was determined that empirical methods (e.g. Tennant, Tessmann) are not suitable for Ontario and the Grand River, as the landforms and fish assemblages are not comparable to those in Montana's mountain stream ecology, where the thresholds were developed. It was further noted that for the Grand River watershed, and particularly the Whitemans Creek subwatershed, statistical analyses of historic streamflow data (long impacted by agricultural water takings) is not a suitable approach for characterizing EFNs. The use of the hydraulic/geomorphic assessments was considered more suitable in these locations.

Through the use of hydraulic modelling, GRCA (2005) estimated that hydraulic connectivity for fish migration along the creek can be maintained down to a flow of 86,400 m^3/day, as this was estimated to be the flow at which a minimum flow depth of 20 cm can be maintained over riffles (the high points in the bed of the river). Significant loss to the hydraulic connectivity was estimated to occur at a flow of 69,120 m^3/day, at which point fish are prevented from moving from pool to pool to avoid predation, find refuge and select suitable habitat. Flows of 86,400 m^3/day and 69,120 m^3/day were recommended as the key EFN threshold and the significant loss EFN threshold, respectively.

A drought occurred in 2012, which presented an opportunity for the GRCA to verify the effects of low flow conditions in Whitemans Creek on fish. Flows in the creek fell to 86,400 m^3/day by June 21, then to 69,120 m^3/day by July 1, and were observed to have dropped to as low as 38,880 m^3/day on July 18. Field observations confirmed that certain riffles had flow depths below the 20 cm hydraulic connectivity threshold when flows were at 44,064 m^3/day. Fish were observed to exhibit severe stress behavior, and some mortality had been reported.

Wong & Boyd (2014) compared the key EFN threshold of 86,400 m^3/day to the values used in the Tier Two Water Quantity Stress Assessment (AquaResource, 2009b) for determining the potential for water quantity stress. They noted that the supply flow (equivalent to the median flow) and the reserve flow (equivalent to the 90th percentile flow) were calculated based on historical flows that were already heavily influenced by agricultural water takings in the summer, and therefore the statistically-derived reserve flow is not comparable to the actual flow needs of the stream ecosystem. In fact, the key EFN threshold of 86,400 m^3/day generally exceeds the supply flow in the months of July and August. Wong & Boyd (2014) observed that if the key EFN threshold is used in lieu of the reserve flow in estimating the percent water demand, there would be a deficit for supply in July and August. If the significant loss EFN threshold (69,120 m^3/day) is used, only July is in deficit, but very little water would be available in August. The authors argued that this suggests agricultural water takings in the summer months may be unsustainable from an ecological perspective, and a potential for conflict and constraint exists.

It was concluded that the EFN required in Whitemans Creek to sustain flow connectivity between the pools in the creek is 86,400 m^3/day, which, if maintained as a minimum for short periods of time, should support a healthy coldwater fishery in the creek. It was also concluded that a minimum flow of 69,120 m^3/day is required to avoid impairment of aquatic life during extreme low flow periods, and this flow should be used to inform the development of a drought management plan to deal with extreme low flow events.

8.3.3 Conclusions

Groundwater

Given the available Water Budget Stress Assessments, PGMN well hydrographs, and climate change assessment reports, groundwater resources in the WQSA appear to be sustainable in the present and in the future. However, making sustainability projections for water resources are inherently uncertain; recommendations are offered later in this report for gaining confidence in understanding and more accurately predicting water resource sustainability in the WQSA.

In the Grand River Tier Two Water Quantity Stress Assessment, the Whitemans Creek subwatershed initially received a stress assessment classification of low, however based on drought simulation results at Well 4A in the village of Bright which showed potential for drawdown exceeding SAAD, the classification was moved to moderate. As a result, the Tier Three Stress Assessment was triggered, and ultimately determined that the Bright wellfield was at a low risk for stress while the Bethel wellfield was at a high risk for stress. Given that if the Bright municipal supply Well 4 was excluded from the Tier Two Stress Assessment, the classification is low, it would suggest that the broader groundwater resource is sustainable.

The PGMN network includes four wells in the WQSA and shows a combination of upward and downward trends with no correlation between bedrock or overburden aquifers, making it difficult to make conclusions about the overall water level trends. This is compounded by several years of data missing from PGMN hydrographs (Appendix C). It is the opinion of the

GRCA water managers, who have had access to data missing from PGMN hydrographs, that groundwater levels in the PGMN wells have been reasonably stable and in general do not show any significant trends. This indicates that currently the resource is not stressed in the areas and aquifers monitored by the PGMN wells.

In general, the Whitemans Creek subwatershed is predicted to be largely resilient to the predicted effects of climate change. Modelling by the GRCA (GRCA, 2014a) looked at ten different climate scenarios that may occur in the future in each of the subwatersheds in the Grand River watershed, including Whitemans Creek. Averaging all ten scenarios, recharge is expected to decrease by 3 mm to 215 mm/year. A groundwater stress assessment for Whitemans Creek subwatershed based on the outcomes of the ten climate change scenarios showed the subwatershed remaining within the "low stress" classification for groundwater.

Surface Water

Evidence from EFN studies (discussed in Section 8.3.2.4) suggests that surface water resources in the WQSA, particularly in Whitemans Creek, are currently unsustainable, and will remain as such until the demand for surface water (particularly during dry summers) is more strictly controlled to ensure EFN thresholds are met whenever possible. The heavy demand for surface water for irrigation, particularly in the summer, contributes to the surface water quantity stress in the subwatershed, which was categorized as moderate based on a Tier Two Water Quantity Stress Assessment. Extreme low flow events have been observed in Whitemans Creek, such as during the summer of 2012, when fish were observed to exhibit severe stress behavior (including some mortality) as a result of low flow depths and a loss of hydraulic connectivity along the river. The contribution of surface water takings to extreme low flow events have not been directly quantified; however, an assessment of water taking data indicated that the cumulative, maximum daily permitted surface water taking represents approximately 23% of the average summer low flow in Whitemans Creek.

The projected effects of population growth on water resources have focused on municipal groundwater supply (Section 8.3.2.2), so there is a lack of information of the potential effects (if any) of population growth on surface water resources. As municipal water demand will likely continue to be met through groundwater extraction, it is BluMetric's opinion that population growth will not have any direct impact on surface water resources in the Whitemans Creek WQSA.

With respect to climate change, in 9 of the 10 climate change scenarios that were modelled for Whitemans Creek, the subwatershed was projected to develop a significant potential for surface water stress. The modelled scenarios also projected that the relative contribution of runoff to the flow in Whitemans Creek will decrease, and the groundwater discharge contribution will increase. Due to the surface water stress that is currently observed in Whitemans Creek, BluMetric agrees with the observations of Wong & Boyd (2014) that agricultural water takings in the summer months are likely not ecologically sustainable and present a risk for conflict and constraints.

In summary, the sustainability of the water resources in the Whitemans Creek WQSA under current and future conditions is as follows:

<u>Groundwater Under Current Conditions</u>

- **Regional scale** - sustainability of the groundwater resources under current conditions at a regional scale has a degree of uncertainty due primarily to the fact that the aquifer systems within the Whitemans Creek WQSA are a result of a complex combination of different depositional environments, resulting in a number of different hydrogeological terrains. However, the absence of an observable downward trend across the PGMN wells within the WQSA indicates it is likely that the groundwater is sustainable under current conditions in the WQSA. With the exception of the municipal areas, Tier Three modelling has not been completed for the broader WQSA so one should only rely on PGMN well water level trends to make definitive conclusions about the sustainability of groundwater resources on a regional scale. Conclusions about groundwater sustainability are therefore better considered and summarized on a local scale.
- **Local scale** - the sustainability of the shallow unconfined overburden aquifer (Norfolk Sandplain) in the southeast and the bedrock aquifer in the far west is uncertain under current conditions primarily due to the absence of recent water level data and/or trend analysis for the PGMN wells located in the southeast and far west portions of the WQSA. In contrast, the sustainability of the shallow overburden aquifer in the Waterloo Moraine and the bedrock aquifer in the central-north and northern part of the WQSA is considered sustainable under current conditions based primarily on the fact that there is no trend observed in the overburden PGMN wells north of the community of Shakespeare. In addition, the Tier Two stress assessment results support the conclusion that the broader groundwater resource in the WQSA is sustainable.

Groundwater Under Future Conditions

- **Regional scale** – the broader groundwater resources in the WQSA is considered sustainable in the future based on future climate change conditions, expected land use changes and expected low population growth rate.
- **Local scale** – Based on the results of the Tier Three stress assessment, the groundwater resources at the Bethel wellfield is unsustainable based primarily on expected population growth and related demand. With the exception of the municipal areas, Tier Three modelling has not been completed for the broader WQSA, however the Tier Two model results indicate that the other groundwater resources in the WQSA will be sustainable under future conditions, and this is consistent with the conclusions about future sustainability of groundwater resources in the nearby Norfolk WQSA.

Surface Water Under Current Conditions

- **Regional scale** –the surface water resources are unsustainable during the summer months under current conditions based on environmental flow needs in Whitemans Creek as determined by hydraulic/geomorphic assessments.
- **Local scale** – the surface water resources are unsustainable under current conditions.

Surface Water Under Future Conditions

- **Regional scale** – the surface water resources are unsustainable until the demand for surface water (particularly during dry summers) is more strictly controlled to ensure EFN thresholds are met whenever possible. This is partly based on modelled climate change scenarios which project that the relative contribution of runoff to the flow in Whitemans Creek will decrease, although it is noted that groundwater discharge contribution will increase. However, due to the surface water stress that is currently observed in Whitemans Creek, agricultural water takings in the summer month in the future are unsustainable.
- **Local scale** –the surface water resources are unsustainable under future conditions.

8.4 WATER MANAGEMENT APPROACHES AND CHALLENGES

A combination of available reports and communication with Water Managers from the GRCA and MECP knowledgeable of local water use/issues in the Whitemans Creek area were used to summarize current approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in Section 8.6 of this report, what, if any, new management tools are needed in Whitemans Creek WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches.

Current Approaches

MECP's West Central regional office manages the PTTW program in the Whitemans Creek area and the local district office responds to well water and drought complaints.

The approach for managing water quantity in the Whitemans Creek WQSA largely relies on the regional and provincial-level policies, such as the Grand River and Thames Sydenham Source Protection Plans, combined with Provincial mechanisms of the Permit to Take Water program (O. Reg. 387/04) and the OLWR program.

WQSA-specific management approaches currently appear to be limited to the Whitemans Creek Subwatershed Drought Contingency Project, in which water managers and irrigators collaboratively developed tools and Best Management Practices (BMP) for managing water use and improving drought preparedness (Etienne, 2014). One of the key strengths of the project is that the drought management measures are tailored to the hydrological and hydrogeological context of the Whitemans Creek WQSA, being based on the actual experiences of irrigators in the area. The project also aimed to be feasible and practical, recognizing the realities of farming (e.g. financial pressures, weather dependence). However, little information is currently available about the effects and long term success of the project, and whether any disadvantages or weaknesses have been identified.

Challenges

The following water management concerns were identified through the review of existing documentation and through communication with Water Managers in the Whitemans Creek WQSA:

Reported impacts on surface water

Historically it was reported that, water levels were significantly decreased such that downstream users and ecosystems were impacted on a seasonal basis, and there have been anecdotal reports of the creek drying up completely. However, no evidence was identified during this review (e.g. in the WSC stream gauge data provided in Section 8.3.1.2) to confirm these reports. Water shortages were reported to generally occur during the growing seasons, specifically in the summer months when less precipitation occurs and there is a higher demand for irrigation. Reducing direct takings from surface water can help mitigate impacts; unfortunately, this means impacting agricultural takers as they are the dominant water takers in this watershed.

Maintaining Environmental Flow Needs in Whitemans Creek

As noted above, aquatic ecosystems have reportedly been impacted by the heavy usage of surface water in Whitemans Creek. The supply flow (equivalent to the median flow) and the reserve flow (equivalent to the 90th percentile flow) that were calculated for the Tier Two Water Quantity Stress Assessment (AquaResource, 2009b) were based on historical flows that were already heavily influenced by agricultural water takings in the summer, and therefore the statistically-derived reserve flow is not comparable to the actual flow needs of the stream ecosystem. Wong & Boyd (2014) argued that agricultural water takings in the summer months may be unsustainable from an ecological perspective, and a potential for conflict and constraint exists.

Limited collaboration between the GRCA and the MECP

In communications with the GRCA, they noted that there appeared to be a reduction in the number of permits being issued in the WQSA, and they suspected that there is an increase in the number of non-permitted takings. The GRCA further noted that involvement and participation from the MECP in local studies and initiatives would help address existing and potential usage conflicts. As the CA is not a regulator, they have limited power in intervening and resolving such disputes.

Evaluation of how water management concerns are considered in water management decisions

As noted in *Challenges* above, anecdotal reports from local water managers suggest an over reliance on surface water in the summer may have contributed to significant decreases in water levels, particularly during drought years. To help alleviate these reported pressures, efforts have been made to move agricultural irrigation off of Whitemans Creek and onto groundwater wells or offline/dugout ponds. This may have contributed to a reduction in the number of complaints to the ministry. It should be noted that the decrease in the number of complaints may also have resulted from changes in crop types (e.g. transition to less water-intensive crops), and the fact that 2017 was a relatively wet year, such that demand for irrigation was reduced.

In addition, the development and implementation of the Whitemans Creek Subwatershed Drought Contingency Project, provided an opportunity for water managers and irrigators to collaboratively develop tools and Best Management Practices (BMP) for managing water use and improving drought preparedness (Etienne, 2014).

The Brant Federation of Agriculture and the GRCA have also worked together to support farmer-led 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 (MECP communication). These locally lead initiatives are typically very effective and there is local accountability and local understanding.

Consideration of key topics in water management decisions

The following points describe if and how key topics are considered in water management decisions in the Whitemans Creek WQSA.

- Climate change: efforts have been made to predict the potential effects of climate change on groundwater and surface water resources through the use of climate change modelling scenarios (Section 5.3.2.1). Based on the information reviewed as part of this study, there do not appear to be formal policies in place for considering the effects of climate change in water management decisions;

- Adaptive/alternative management: no policies and approaches were identified in the Whitemans Creek WQSA that explicitly address the use of adaptive or alternative management. However, the province's PTTW program allows for the use of adaptive/alternative management, as one of the principles of the program is that the MECP "will employ adaptive management to better respond to evolving environmental conditions" (Permit to Take Water Manual, 2005). For example, the Ministry has the authority to limit, alter or stop a water taking that is considered to cause an unacceptable impact, even after a permit has been issued;
- Municipal growth: in the Whitemans Creek WQSA, efforts have been made to predict the effects of municipal growth on groundwater and surface water uses by modelling for allocated demand in Local Area Risk Assessments (Section 8.3.2.2). Based on the information reviewed as part of this study, there do not appear to be formal policies in place for considering the effects of population growth in water management decisions;
- Drought: the Whitemans Creek Subwatershed Drought Contingency Project was implemented to assist water managers and irrigators in the management of their water use and to improve drought preparedness. The effects of drought have also been explored as part of the Tier Three Assessment (Sections 8.3.2.1 and 8.3.1.1);
- Natural function/EFN: the importance of EFN and aquatic habitat in Whitemans Creek has been recognized, and EFN thresholds have been quantified and proposed (Section 8.3.2.4), although there is no indication that the thresholds are currently being taken into consideration in water management decisions in the WQSA. There is also a general lack of information on EFN in other surface water bodies in the WQSA.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

Local water managers, including the local CAs, MNRF, MECP and municipalities, working in collaboration with irrigators, should establish a framework for considering EFN thresholds in Whitemans Creek, to ensure that these thresholds are met during periods of high irrigation demand. The development of water management measures by the irrigators themselves will help ensure the measures are feasible and may help encourage compliance with the proposed approaches. A key challenge is that participation would be voluntary, and as such enforcement will be difficult, if not impossible.

The GRCA and MECP could work collaboratively to investigate the apparent reduction in permitted takers within the WQSA. This could involve the MECP reviewing current and historical PTTWs for the area to determine whether there has been a reduction in the number of issued permits, and the GRCA providing local knowledge to MECP, including the identification of specific sites that warrant follow-up. A challenge in implementing this approach will be the potential associated costs (time and manpower), the types of data to be shared (e.g. preliminary data or only final, quality-controlled data) and the relative level of effort expected from, and required, by each party.

8.5 IDENTIFIED DATA GAPS

PGMN Wells Regional Monitoring Well Network

While four PGMN wells are located within the WQSA, only two have recent data (W0000477-1 and W0000478-1), which makes it difficult to accurately assess the conditions of regional water levels and the sustainability of groundwater resources. In the southeast portion of the WQSA where there are several permitted groundwater takings, it may be useful to add additional PGMN monitoring wells on the periphery (i.e. just beyond the zone of influence) of the areas of water takings, to determine the sustainability of the resource in the area, confirm that any adverse effects from permitted/non-permitted takers are not extending further than anticipated, and verify that the takings are not impacting groundwater resources at a regional level. Particularly useful would be well nests which can profile water levels in a given area (from shallow unconfined aquifer to deep possibly confined aquifers) to help determine the extent of hydraulic connectivity between aquifers, and potentially also inform the understanding of groundwater discharge and recharge in the WQSA. While not reviewed in this study, using water level data from appropriate municipal monitoring wells in addition to PGMN wells may assist in the regional assessment of groundwater levels.

WTRS Improvements

As discussed in Section 8.2.7.1, the current use of the classification "Groundwater and Surface water" in the WTRS database makes it difficult to determine if an individual source is groundwater, surface water, or both. There is also no column in the WTRS that identifies the individual classification (groundwater, surface water, or both) for each source. The use of the "Groundwater and Surface water" classification in the WTRS currently contributes to a lack of confidence when attempting to sum total taking volumes from Surface Water, or Groundwater sources in the WQSA.

WSC Gauges

Based on the assessment above, there are currently only two active WSC gauges within the WQSA, which may limit the ability to accurately characterize flow within the main creeks of the watershed. Additional flow data at several locations in the creek system would help strengthen decisions by local water managers by providing additional data to assess sustainability.

Horner Creek

As displayed on Figure 8-5, the WSC gauge on Horner Creek at Princeton is the most northern gauge in the WQSA. Several surface water takings occur upstream (north) of the gauge; therefore, the ability for the gauge to accurately discern the impact of surface water takings on the flow observed in the gauge is limited. Having a gauge (or multiple gauges) upstream of the majority of surface water takings would enhance the understanding of the impacts of water takings on flow in the creek.

Whitemans Creek

Similarly, there is roughly 20 km of creek between the Horner Creek at Princeton gauge and the Whiteman Creek at Mount Vernon gauge, which limits the ability of the gauge to accurately discern the impact of surface water takings on the flow observed in the gauge. Several surface water takings occur between the two gauges; however, based on mapping, several tributaries also join Whitemans Creek (likely intermittently), including Kenny Creek. Based on these conditions, it is possible for a scenario to arise where EFN thresholds are exceeded due to takings within gauge intervals; however, due to tributary contribution below the taking area, the closest downstream gauge (Whiteman Creek at Mount Vernon) does not capture EFN threshold exceedances. The addition of a gauge (or gauges) within the area of concentrated takings would help to better characterize the flow regime and understand the impacts of takings in Whitemans Creek between the Horner Creek at Princeton gauge and the Whiteman Creek at Mount Vernon gauge.

8.6 RECOMMENDATIONS

Based on the available reports and communication with Water Managers knowledgeable of local water use/issues in the Whitemans Creek WQSA, the following recommendations are provided as possible mitigative measures to address the identified gaps related to water quantity management, and help in avoiding potential future water quantity issues.

1. For agricultural takers, continue to promote the transition from surface water takings to groundwater wells or offline/dugout ponds. The WTRS database documents 21 Surface Water permits (plus 8 Groundwater and Surface Water permits that draw from the Horner, Kenny, or Whitemans Creek). Promoting the transition of these relatively few surface water permits to groundwater takings, may significantly enhance the health of the surface water creek system in the WQSA. Additionally, it should be noted that based on Figure 8-11, while permitted surface water taking locations along creeks often occur as clusters, their general location is not isolated from permitted groundwater takings. This suggests that moving irrigation reliance from surface water to groundwater sources to mitigate surface water shortages may be a viable option as groundwater appears to generally be available where permitted surface water takings occur.
2. Review the use of Groundwater and Surface Water classification in the WTRS to describe the origin of the permitted takings. Under its current use, it leads to confusion when attempting to identify the actual source of the water taking.
3. Improve the ability of the PTTW to address Cumulative Effects through working to clarify operational guidelines for internal MECP staff and external public on what constitute cumulative impacts and how they should be assessed in the context of the management of the water resources and PTTW program.
4. Consider the addition of more flow gauges to accurately characterize flow regimes in the Whitemans Creek WQSA and enhance the understanding of the impacts of water takings on flow throughout the creek. A higher resolution of flow data will help manage water level conditions in the Whitemans Creek system in an attempt to maintain EFN thresholds.
5. Reactivate water level monitoring in PGMN wells not currently monitored and possibly consider the addition of more PGMN wells in the shallow overburden of the southeast part of the WQSA to monitor regional ambient groundwater level trends. As well, using water level data from appropriate municipal monitoring wells in addition to PGMN wells may assist in the regional assessment of groundwater levels.

6. In areas with noted groundwater-surface water interaction (Section 8.2.5.3), any change in source from a surface water source to a groundwater source (i.e., well or dugout pond) should be located a reasonable distance from the creek (90 m has been suggested in the Norfolk Sandplain area which has a similar shallow aquifer system which interacts readily with surface water features (Schroeter and Associates, 2002)). This would limit impacts to surface water flow because as previously discussed creek-groundwater interaction decrease as a function of distance from the creek.
7. Given the Whitemans Creek WQSA proximity to the Norfolk WQSA, both areas should be studied in tandem when considering the impacts of water resource management.

8.7 REFERENCES

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9 QUINTE WQSA

The preliminary boundary of the Quinte WQSA, as provided by the MECP, is shown on Figure 9-1. The preliminary WQSA overlaps multiple counties and encompasses a number of population centers along the northern shore of Lake Ontario. The WQSA partially or fully encompasses multiple watersheds and CAs, including Cataraqui Region, Quinte, Lower Trent Region, Crowe Valley, Rideau Valley and Mississippi Valley.

In the Quinte WQSA, both groundwater and surface water resources are utilized for domestic, agricultural, commercial and industrial uses. This WQSA was selected by the MECP based on recommendations from the external working group broaden the scope covered by WQSA's to include the presence of First Nations, in this case, the Mohawks of the Bay of Quinte (MBQ), and represent a greater diversity of geography, geology, location and diversity of development conditions. There are also known or potential issues associated with increasing water demand and recent impacts from periodic droughts potentially leading to water supply shortages which may be exacerbated in the future as a result of Climate Change. The objectives of this section are: to provide a characterization of the Quinte WQSA in the context of the major (most used) surface water and groundwater resources; refine the WQSA boundary based on the physical characterization; summarize and evaluate the demands on water resources in the WQSA; and, determine to what extent the impact of projected changes in population, land use, and climate will have on the future security and sustainability in the WQSA in the context of drought risk.

9.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives for the WQSA noted above and the preliminary WQSA boundary provided by the MECP. The Quinte CA comprised of the Quinte watershed including the Mora River, Salmon River and Napanee subwatersheds, makes up the majority of the preliminary WQSA and was therefore the focus of the literature review. The watersheds within the WQSA intersect the main municipal areas of Belleville, Tweed, Odessa, Kingston, Loyalist Township, Quinte West and Madoc. Based on the review and input provided by water managers within the WQSA, the reports listed below, as well as available databases provided by MECP, were used as the primary basis for the WQSA characterization and assessment presented in the following sections. The reports listed in Table 9-1 are the key resources references and each key resource was categorized in terms of the information presented within. However, all the references reviewed are listed in the Reference section at the end of the chapter.

Table 9-1: Summary of Key Resources for Quinte WQSA

Resource Reference	Type	Categories
Quinte Region Source Protection Committee (QRSPC), 2014. Approved Quinte Region Assessment Report Version 5.0.	Report	PC, SWQ, GWQ, CU, FC, CC
Quinte Conservation, 2010. Tier 2 Water Budget Village of Madoc Quinte Source Protection Region	Report	GWQ, CU, FC
Morrison Environmental Limited. 2004. Trent Conservation Coalition Municipal Groundwater Study Paleozoic Area Volume 1 - Aquifer Characterization	Report	PC, GWQ
Dillion Consulting Ltd. Golder Associates Ltd., Lissom Earth Sciences, Ainly Group and Agricultural Watersheds Associates. 2004. Quinte Regional Groundwater Study	Report	PC, GWQ
Quinte Conservation, 2018. 2016 Quinte Region Low Water Report	Draft Report	GWQ, SWQ, CU
Quinte Conservation, 2010. Climate Change Monitoring Report	Report	GWQ, SWQ, CU, FC, CC

Categories:

PC – Physical Characterization
GWQ – Groundwater Quantity
SWQ – Surface Water Quantity
CU – Current Water Users
FC – Future Conditions
CC – Climate Change

It was not possible to consult Mohawks of the Bay of Quinte as part of the current study due to the time available for the study and the timing of the government change in Ontario.

9.2 WATER RESOURCES SETTING /CHARACTERIZATION

9.2.1 Land Cover and Use Setting

Land cover in the Quinte WQSA (Figure 9-2) is predominantly Agricultural and Undifferentiated Rural Land with areas of mixed treed and a few urban centers. The north and northeast parts of the WQSA consist mostly of deciduous, coniferous and mixed trees, as well as pockets of exposed bedrock.

Under the CLI, agricultural lands in the WQSA are primarily Class 6 (Perennial Crops Only) and Class 7 (No Capability for Crop Use) with the exception of lands along the shore of Lake Ontario which are Class 2 (Moderate limitations, moderate conservation practices required) and isolated small pockets of Class 3 (Moderately severe limitations, special conservation practices) located throughout the WQSA (CLI, 1978).

9.2.2 Population

Populations in urban centers with municipal water supplies, located in watersheds which fall within or make up part of the WQSA, are summarized in Table 9-2 using the most recently available population information:

Table 9-2: Summary of Population Statistics and Water Supply Source in Quinte WQSA

Watershed/S.P.A	County	Municipality	Water Source	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percentage Change 2011 to 2016 (%)
Cataraqui	Frontenac	Kingston	SW – Lake Ontario	123,363	123,798	0.4
Quinte	Hastings	Belleville	SW – Bay of Quinte	49,454	50,716	2.6
Quinte	Hastings	Village of Madoc	GW	2,166	2,078	-4.1
Quinte	Hastings	Village of Tweed	GW	6,057	6,044	-0.2
Quinte	Lennox and Addington	Town of Napanee	SW – Lake Ontario	7,134	7,439	4.3
Lower Trent	Hastings	Quinte West	SW – Trent River; GW	43,086	43,577	1.1
Quinte	Hastings	Town of Deseronto	SW – Bay of Quinte	1,835	1,774	-3.3
Quinte	Lennox and Addington	Loyalist Township	SW – Lake Ontario	16,221	16,971	4.6
Quinte	Hastings	Tyendinaga	SW; GW	4,150	4,297	3.5
Cataraqui	Frontenac	South Frontenac	SW; GW	18,113	18,646	2.9

According to data available through Statistics Canada, the total population of Frontenac County, which falls along the eastern portion of the WQSA, was 150,475 in 2016. Hastings County, which makes up the largest area in the WQSA, had 136,445. The populations of the adjacent counties of Lennox and Addington County and Northumberland County were 42,888 and 85,598, respectively, in 2016. A small portion of the total population in the WQSA is in sparsely populated rural areas which are not serviced by municipal water supplies.

9.2.3 Physiographic Setting

The preliminary Quinte WQSA is located in southeastern Ontario along the northern shore of Lake Ontario between Trent Hills in the west and Canadian Forces Base Kingston in the east. The preliminary boundary extends north to Central Frontenac and south to the northern tip of Prince Edward County. The two major CAs which comprise the preliminary Quinte WQSA are Quinte and Cataraqui Region. Combined, these two watersheds cover an area of approximately 9,322 km^2 with 5,929 km^2 attributed to Quinte and 3,363 km^2 attributed to Cataraqui Region. The adjacent Lower Trent Region and Crowe Valley CAs, which are partially intersected by the WQSA, cover areas of 453 km^2 and 2006 km^2, respectively. The northeast border of the WQSA intersects small areas of the Mississippi Valley and Rideau Valley, with areas of 3,750 km^2 and 4,000km^2, respectively.

9.2.3.1 Physiography

The Quinte WQSA is made up of a diverse physical landscape and features that can be grouped into distinct physiographic regions. The northern areas are rugged and form part of the Precambrian shield which underlies approximately 50 percent of the area. South of the Precambrian Shield, the area is underlain by Paleozoic limestone bedrock with large areas of thin soil cover as well as some areas of significant soil depth. In total there are seven main different physiographic regions found in the Quinte WQSA, as shown on Figure 9-3.

Algonquin Highlands: Covers the northern Precambrian Shield with rugged topography, shallow soil, numerous lakes and large forested regions.

Georgian Bay Fringe: Borders the Algonquin Highlands, and has similar characteristics, but with rolling to moderately rugged topography.

Napanee Plain: Covers the southern portion of the Napanee watershed and is comprised of flat to undulating topography with thin soil over limestone bedrock.

Peterborough Drumlin Field

The Peterborough Drumlin Field covers much of the southeastern portion of the preliminary WQSA. There are thousands of drumlins and drumlinoid shaped hills in the area, most of which are oriented from northeast to southwest. The drumlins are located in the upland areas and in areas that were immersed by glacial meltwater, where changing water levels, wave action and other processes formed them. In many parts of the Peterborough Drumlin Field, clayey soils can be found in the lowlands between the drumlins. These fine-textured soils influence local drainage by limiting infiltration and promoting runoff in the low-lying areas between the hills. The presence of the steep-sided drumlins and the clayey soil in the intervening areas has resulted in surface water drainage courses between the drumlins (Morrison, 2004).

The drumlins are made of a calcareous till, differing with local variations in the till composition. Where the till thins and immediately overlies bedrock, it tends to contain larger amounts of angular limestone rubble. In areas where the number of boulders increases the composition becomes more variable. Eskers also form throughout the Peterborough Drumlin Field. These sand and gravel ridges are valuable aggregate resources and also have the potential to form valuable aquifers (SWP, 2007). The largest is reportedly the esker that extends from Frankford to Marlbank, a distance of about 80 km (Chapman and Putnam, 1984). The Peterborough Drumlin Field has hydrogeological significance since run-off from precipitation tends to accumulate in the inter-drumlin areas and enhance groundwater recharge (TCCSWP, 2007).

Iroquois Plain

As the last glacial ice was receding, the lowland areas adjacent to the current Lake Ontario were inundated by former glacial Lake Iroquois. The old shorelines, beaches and other lacustrine features are easily identified because they contrast sharply with the undulating till plain to the north. The Iroquois Plain is up to 9.5 km in width and encompasses a south sloping sand plain, steep wave-cut shore cliffs, and terraces (Morrison, 2004).

Dummer Moraines

The Dummer Moraine soils contain Paleozoic and Precambrian rock fragments and the area is characterized as having rough topography with low moraine ridges comprised of generally angular fragments and blocks of limestone combined with many Precambrian rocks fragments.

The surface is extremely rough, even though most of the morainic ridges are quite low, (SWP, 2007). Several streams cross the moraine and flow southward toward the Trent River System. Many of these streams are associated with deep bedrock valleys. In some areas, the valleys became sediment blocked, forming long narrow lakes such as the Kawartha Lakes (Chapman and Putnam, 1984).

The Oak Ridges Moraine

The Oak Ridges Moraine (ORM) is a regional extensive upland granular deposit extending from the west WQSA boundary to the Trent River. A model for the origin of the Oak Ridges Moraine is based on the recognition that the moraine is built on a high-relief, erosional surface (unconformity) consisting of drumlin uplands and a network of deep, steep-walled, interconnected valleys (tunnel channels). The development of the moraine is thought to have occurred in four stages: I) subglacial sedimentation; II) subaqueous fan sedimentation; III,) fan to delta sedimentation; and IV) ice-marginal sedimentation. The model traces the transition from subglacial to proglacial conditions during moraine formation and examines the order and timing of sedimentation, (TCCSWP, 2007).

9.2.3.2 Topography

The topography of the Quinte Region is variable, ranging from the rocky highlands of the Precambrian Shield at the north to the more subdued relief of the limestone plains at the south along the shores of the Bay of Quinte and Lake Ontario. In the north, the predominant topographic gradient is to the south–southwest with elevations ranging from a high of 400 ms above sea level (masl) in the north to approximately 80 masl at the south along the Bay of Quinte, (QRSPC, 2014) (Figure 9-4).

The present day ground surface topography in the WQSA evolved from erosional and depositional processes that occurred during glacial and post-glacial periods. Valleys created by tributaries and rises characteristic of glacial drumlin features are the dominant topographic features throughout the WQSA. Ground surface lower elevations range from about 140 masl at the north end of the study area along the Trent waterway to an elevation of about 75 masl, showing that the ground surface generally slopes southward to Lake Ontario. Regionally, the ground surface slopes southward from the Trent Waterway toward Lake Ontario. However, relief varies significantly on a local scale, with some drumlins having side slopes in the 20-25% range and some plains having less than a 5% overall slope. At the northern end of the study area, the regional ground surface slope is in the 4-9% range, (Morrison, 2004).

9.2.3.3 Climate

In the Trent River Watershed, temperature decreases from south to north due to increases in latitude, altitude, and distance from the moderating influences of Lake Ontario. The temperature gradient is steepest in the winter, when the moderating effect of Lake Ontario is greatest, (TCCSWP, 2007).

The majority of the WQSA has low latitude and elevation compared to other parts of eastern Ontario, has a moderate temperate climate with moderate, even precipitation throughout the year and temperatures ranging from warm to hot and humid in summers to below freezing in winter. Winters are mild compared to the rest of Ontario. With Lake Ontario to the south, winds coming across the lake are warmer in winter and cooler in summer than the land, thereby moderating air temperatures over the WQSA. Winter is generally considered to have temperatures lower than 0°C, beginning in December and lasting until late February or early March. Spring usually lasts two months, followed by four months (June to September) of summer and two months of autumn. There is no rainy season in this region; precipitation is fairly evenly distributed throughout the year, however, in summer many of the rainfall events are intense with short durations. The duration of events, coupled with the high evapotranspiration rates between events, leaves an impression of less rain than in other seasons in terms of frequency of rain-created runoff and recharge. In winter most of the precipitation is rain. Even in January, the coldest month, more than half the precipitation is rain. Figure 9-5 displays the weather stations in the WQSA.

Provincial estimates of mean annual evapotranspiration have been documented within the Water Quantity Resources of Ontario (MNR, 1984), by subtracting mean annual streamflow from mean annual precipitation. Over the long term, the difference between annual streamflow and precipitation equals annual evapotranspiration (assuming negligible net groundwater outflow/inflow from the watershed). It is important to consider that in eastern Ontario, evapotranspiration totals for a particular year are dependent on the amount of water that is available to be evaporated. Areas with an unlimited supply of water will evaporate at the potential evapotranspiration rate. Areas that have a limited supply of water, and rely on precipitation events to replenish the soil water supply, will evaporate water at an actual evapotranspiration rate that is less than the potential rate for that type of surface when fully wetted. The difference can be very significant in years of drought, where very little soil water is replenished due to the reduced precipitation.

The Ontario Ministry of Natural Resources published a report in 2007 identifying the key impacts Climate Change would have in the Quinte region. These impacts include warmer temperatures, decreased precipitation, increased evapotranspiration, less snow/ice cover, increase in extreme weather events, change in distribution of flows in surface water, less groundwater recharge, and less baseflow, (MNR, 2007).

9.2.3.4 Surface Water Hydrology

The Quinte Region is known for its many significant surface water features which include the Napanee, Salmon, and Moira Rivers draining the northern Precambrian shield into the Bay of Quinte and further into Lake Ontario in the south. Surface water, sourced from Lake Ontario, is an important drinking water resource and provides supply to approximately 50 percent of the residents. The majority of these residents are located in the larger urban centres of the watershed such as Belleville, Napanee, and Deseronto (QRSPC, 2014). Watersheds draining into the Bay of Quinte from the north include the three largest rivers, Moira, Salmon, and Napanee and several smaller creeks. Figure 9-6 shows the Aquatic thermal regions of surface water in the Quinte WQSA, showing predominantly warm waters, with some cool areas towards the northwest corner of the study area.

The Moira River is the largest river draining over 2,700 km^2 of land and has two major tributaries, the Black and Skootamatta Rivers. This area in the Canadian Shield is dominated by forest cover with several large lakes and a large number of wetlands. Smaller tributaries to the Moira include the Clare River and Parks Creek which drain about 20 percent of the system. There are six operating stream gauges on the Moira River or its tributaries as of 2014 (QRSPC, 2014).

The Salmon River has just over 900 km^2 of drainage area. The northern headwaters are also in the Canadian Shield, while the southern half drains the limestone plains. Several large lakes are found in the headwaters including the Kennebec, Big Clear and Hungry Lakes. In the southern portion there are fewer and smaller lakes with the exception of two large lakes, Beaver and White Lakes. Drainage through the plains is more defined and the river is not slowed by any further online lakes and drains directly into the Bay of Quinte. Two streamflow gauges are present on the Salmon River; one is located in the Village of Tamworth downstream of Beaver Lake and the other is near the river mouth in Shannonville.

Similar to the Salmon River, the Napanee River also originates in the Canadian Shield. There are many large lakes and wetlands in the upper portion and only two large lakes (Varty Lake and Camden Lake) in the lower reaches. These lakes are shallow offline lakes with little drainage area. The Napanee River has two major tributaries, Hardwood Creek and Depot Creek that meet in the Cameron Swamp. Depot Creek is gauged at Bellrock and the only other stream gauge is located on the Napanee River near Camden East.

Table 9-3: Summary of Subwatersheds in Quinte WQSA

Region	Main Watershed	Subwatershed	Drainage Area (km^2)	Municipal Systems/Sources
Quinte	Quinte	Potter Creek	31	Bellville
	Quinte	Moira River	2735	Tweed
	Quinte	Bell Creek	23	Bellville
	Quinte	Blessington Creek	66	Bellville
	Quinte	Salmon Creek	915	Shannonville
	Quinte	Marysville Creek	52	Shannonville and Tyendinaga Mohawk Territory
	Quinte	Selby Creek	130	Deseronto
	Quinte	Napanee	818	Napanee
Cataraqui	Cataraqui	Bay Of Quinte	300	Fredericksburg, Harrowsmith
	Cataraqui	Millhaven Creek	235	South Frontenac, Loyalist, Millhaven
	Cataraqui	Collins Creek	165	Latimer, Westbrook
	Cataraqui	Little Catarqui River	77	Kingston
	Cataraqui	Great Cataraqui River		
Trent River	Lower Trent	Rawdon Creek	68	Stirling, Center Hastings
	Lower Trent	Squires Creek	188	Bonarlaw
	Lower Trent	Trent River Corridor Tributaries	560	Campbellford, Frankford, Battawa, Anson
	Lower Trent	Bay of Quinte Tributaries	150	Canadian Forces Base Trenton
Crowe Valley	Crowe Valley	Beaver Creek	460	
		Crowe River		Marmora
Rideau Valley	Rideau Valley	Tay River	800	Parham, Tichborne
Mississippi	Mississippi	Upper Mississippi	515	Central Frontenac

Sources: AR (2014) and QRSPC (2014)

9.2.4 Geology

The geology of the Quinte Region is predominantly controlled by shallow soil over bedrock divided into two main types – Precambrian and Paleozoic. The Precambrian rock is found in the north and the Paleozoic in the south. The shallow soils throughout are a direct result of glacial activity which resulted in the scraping and removal of soil. However, the same glacial activity deposited significant amounts of soils in other areas in the form of till in drumlins as well as eskers, and a moraine.

According to the geological survey conducted by Chapman and Putnam (1984), the WQSA is underlain by a series of gently dipping Neo-to Mesoproterozoic rocks consisting of felsic plutonic rocks interbedded with clastic metasedimentary rocks. Precambrian strata occur in two inliers, or monadnocks, both within 3 km northwest of Shannonville. The northernmost consists of fine crystalline dolomite and the southernmost is composed of both red and maroon granite and conglomerate. The inliers indicate a varied lithology of the Precambrian rocks underlying the Ordovician rock cover. The Ordovician layer contains middle and upper members. The upper member includes the Moore Hill and Chaumont units. The formation has been mapped near Foxboro, along the valley of the Salmon River, and at Point Anne. The middle member is composed of brown and grey limestones of various textures and bed thicknesses. Included are fine-grained argillaceous limestone; fine, medium, and coarse granular limestones; fragmental and bioclastic limestones; and, fine to medium crystalline, sublithographic and lithographic limestones. Beds are generally between 0.1 and 0.7 feet thick but some are 2 to 3 feet thick. The upper member is composed of brown lithographic, sublithographic, and admixed fine granular limestone (calcarenite) and sublithographic limestone. Fine and medium granular (calcarenitic) limestone may also be present. This member weathers into both thin (0.1 foot) and thick beds. Nodules of black chert occur throughout the upper member.

9.2.4.1 Surficial Geology

The Quinte WQSA is dominated by depositional features from the most recent glacial period (ending approximately 10,000 years ago), including till (deposits of sediment left behind as glaciers melted) and ice carved landforms. Significant features such as eskers, moraines and drumlins are evident throughout the Quinte Region; however, for most of the area a thin layer of sediment overlies bedrock that was exposed by glaciation. The Precambrian bedrock is overlain by stony, sandy silt to silty sand-textured till on Paleozoic terrain.

Quaternary overburden sediments in the WQSA were also described by Chapman and Putnam (1984). These sediments were deposited during the glacial and interglacial events that occurred as part of the Wisconsinan Glaciation (115 to 7 ka before present) and consist of glaciomarine deposits, glaciofluvial outwash deposits and tills, as shown on Figure 9-7. The predominant surficial deposits (shown in yellow) are composed of glaciomarine sand, gravelly sand and gravel nearshore beach deposits which make up the Quinte physiographic region.

9.2.4.2 Bedrock Geology

In the absence of significant soil deposits, the bedrock geology has a large influence on the physical landscape and flow of water in the Quinte Region. The bedrock found in this area consists of both Precambrian and Paleozoic formations with the Precambrian rock in the northern area and Paleozoic at the south, as shown on Figure 9-8. A generalized regional cross section of the study area is shown on Figure 9-9. The Precambrian rocks, the oldest in the area, underlie the entire region and are exposed near the surface in the Northern area. This rock is comprised of igneous and metamorphic rock that was later heated and reformed while still below the surface. The northern area may be described as the rocky highlands of the region containing the head waters of the Moira, Napanee, and Salmon Rivers. This area is characterized by steep to rolling topography, Precambrian bedrock outcrops, numerous lakes and forested lands.

The Paleozoic rocks, found throughout the southern area of the Limestone Terrane are above the Precambrian bedrock at depths of as much as 60 m in the extreme south and tapering to zero at the north, and can be described as an area of more subdued topography, greater soil depth and fertile agricultural land (TCCSWP, 2007). This zone extends to the south along the shore of the Bay of Quinte and encompasses numerous glacial soil deposits in the form of drumlins, eskers, and a large kame moraine, interpreted as an extension of the Oak Ridges Moraine. The soils in some of these landforms have been reported as extending to depths in excess of 60 m; however, the majority of this region exhibits shallow soil over limestone bedrock (QRSPC, 2014). The limestone rocks are predominantly flat-lying with the surface sloping in a southerly direction similar to the overall trend of the rugged Precambrian rock. The slope of the bedrock surface (both types) serves to direct the regional flow of both ground and surface water in a southerly direction.

The Palaeozoic rocks of the region are primarily Ordovician aged limestones of the Simcoe Group underlain by the Shadow Lake Formation of the Basal Group (collectively called the Ottawa group). The Simcoe Group is comprised of four distinct limestone formations: Lindsay Formation; Verulam Formation; Bobcaygeon Formation; and, Gull River Formation. The thickness of the limestone units increases in a southerly direction reaching depths of up to 300 m to the south of the WQSA in southern Prince Edward County (as identified through oil and gas exploration wells) where the younger Lindsay and Verulam formations can be found (Quinte Conservation, 2006).

9.2.5 Hydrogeology

Groundwater resources are found in both overburden and bedrock aquifers in the Quinte WQSA. Figure 9-10 illustrates defined wellhead protection areas (WHPA) along with all overburden and bedrock wells in the WQSA, including Provincial Groundwater Monitoring Network (PGMN) wells, discussed in more detail in Section 9.3.1. The aquifers of the Quinte Region are a direct reflection of the geology of the area which is predominantly bedrock with thin soil cover. Given these conditions the majority of wells obtain supply from fractured bedrock aquifers, as shown on Figure 9-10.

The bedrock is typically heavily fractured in the upper 10 to 30 m and overlain by a thin layer of soils. Delineation of Highly Vulnerable Aquifers in the Quinte CA resulted in characterizing most of the watershed as highly vulnerable. This is based on a series of variables including depth to bedrock, permeability/ fractures of the aquifers, and lack of aquitard layer preventing surface water contamination (QRSPC, 2014). The high vulnerability was due primarily to shallow depth of the water table (with a mean depth of 4.3 mbgs) and in many areas lack of significant depth of soil (less than 1.5 m). Some areas, particularly in the southern portion of the Moira watershed, have greater soil depth locally, with soils extending up to depths of 50 m; however, in those areas the thickness and relative high permeability of these soils do not provide significant protection.

9.2.5.1 Overburden Aquifers

The Quaternary overburden aquifer occupies much of the same area which is underlain by the Paleozoic bedrock. While the aquifer is thin near the bedrock transition zone to the north, to the south it is thick, approximately 40 m near the lake, saturated sand and gravel deposits which support a productive water table aquifer for local water supplies. The Quaternary aquifer, where sufficiently thick, provides the greatest volume of groundwater storage, as overburden deposits typically are able to store more water than fractured bedrock.

In the highland areas (crest of moraines, drumlins, etc.), the groundwater surface is deeper than in the lowland areas, where the groundwater surface is close to the ground surface or discharging (Morrison 2004). These upland glacial deposits allow for large areas of recharge for local aquifers. An unconfined aquifer exists in the upper sediments with the fine sediment 'Newmarket Till' being the separating aquitard, where it exists. Below the till, a deep confined aquifer exists above the bedrock (Sharpe et al., 1999).

Groundwater within the overburden aquifer primarily flows south towards Lake Ontario, following the slope of the underlying Paleozoic bedrock. Overburden aquifers in the study area are highly variable in location and composition. Typically, they are located in the sand and gravel filled bedrock valleys, buried channels and outwash deposits (QRSPC, 2014).

Overburden aquifers are not extensive throughout the region but are present where there is sufficient depth of sand and gravel. Such conditions exist in the southwestern portion of the Moira watershed, in the vicinity of a kame moraine formation. These aquifers are relatively isolated but are interpreted as being connected with the underlying bedrock aquifers, and serve as storage reservoirs providing significant volumes of recharge.

Yield from the Quinte Region aquifers is typically low to moderate and considered adequate for meeting most domestic and agricultural needs. The exceptions are some areas of the Precambrian Shield where the fractures in the bedrock are not well developed and it is difficult to find adequate quantities of water. The opposite is also true of other areas where, because of significant fracture openings, large quantities of water can be found as evidenced by the wells providing municipal supply to the Villages of Deloro, Madoc and Tweed as well as the Peats Point subdivision (QRSPC, 2014).

9.2.5.2 Bedrock Aquifer

The Precambrian Bedrock Aquifer Area is located to the north and is characterized by thin overburden, causing the groundwater surface to be shallow and close to the bedrock surface. The water supply in this area is mostly derived from fractured rocks of Precambrian age. The Trent River Watershed is comprised mainly of Precambrian rock outcrops with shallow overburden deposits infilling the rock valleys. Deep bedrock groundwater is supplied by fractures and faults in the Precambrian area and no large deep regional bedrock aquifer has been identified (Morrison, 2004).

Located south of the Precambrian area to Lake Ontario is a region of Paleozoic-aged limestone which is overlain by Quaternary-aged overburden material. In this area two aquifers coexist; the Paleozoic bedrock aquifer, where water is derived from fractures in bedrock, and the overlying Quaternary overburden aquifer, where water is supplied from sand and gravel deposits. Overburden in this area is relatively thin especially near the transition to the underlying northern Precambrian-aged bedrock. Often the bedrock at the bedrock–overburden interface is highly fractured and weathered and forms a preferential groundwater flow path (i.e. bedrock surface interflow), (QRSPC, 2014). Regional groundwater quality in both the overburden and the bedrock is reportedly good. However there are areas where salty, sulphurous and mineralized water is commonly found. These areas tend to be located close to the Paleozoic/Precambrian boundary, (Morrison, 2004).

For the most part, these fractured bedrock aquifers are considered to be unconfined. Precipitation (rain or melted snow) can move easily from the ground surface into the aquifer. However, in the deep zones of the bedrock the number and density of fractures decreases and are not as well connected to the surface. Since these fractures are the flow path through which water moves, precipitation does not move as easily into these zones. Under these conditions the aquifer is considered to be semi confined or confined.

Fractured bedrock aquifers have limited storage capacity. For example, as a result of much lower primary porosity in fractured bedrock, the volume of water stored in fractured bedrock aquifers is typically orders of magnitude less than in overburden aquifers. This means that pumping from bedrock supply wells may draw water from greater distances and that there is limited supply for sustained removal of groundwater. As a result, fractured bedrock aquifers are more prone to well interference and groundwater mining (unsustainable taking) (Crowe et al., 2003). This also makes these aquifers sensitive to recharge conditions. During periods of drought, the storage of water in fractured bedrock aquifers can be depleted relatively quickly and significant decreases in water levels and availability can occur.

The quality of supply from the aquifers is normally good with fresh water reported on well records. However, the water is often hard and in some areas natural water quality problems may be experienced due to mineralization, gas and sulphur. These natural water quality problems are typically encountered when wells are drilled too deep (i.e. depths of greater than 30 m in limestone bedrock) or in areas of groundwater discharge, (QRSPC, 2014).

9.2.5.3 Groundwater-Surface Water Interaction

In the Quinte watershed, there is significant interaction between surface water and groundwater. Mapping has illustrated that groundwater flows toward, and discharges to, surface water features. Through analysis of groundwater and surface water hydrographs, it was also found that groundwater and surface water features respond in similar fashion to rainfall events with increases in levels observed in each due to precipitation events. The quick response of the groundwater to precipitation recharge is an indication of the unconfined nature and vulnerability of the aquifers in the Quinte WQSA (QRSPC, 2014).

The development of marshes and wetlands appears to be more influenced by surface drainage through much of the northern part of the study area than in the southern part. In the south, where the overburden is thicker, topography appears to strongly influence the location of discharge areas.

9.2.6 Overview of Water Takings within WQSA

9.2.6.1 Permitted Takings

Figure 9-11 shows a map of the active surface water and groundwater permitted takings within the Quinte WQSA, categorized by purpose. Percentages and values in the following paragraphs used to characterize water demands by Purpose and Specific Purpose were derived from 2017 PTTW and WTRS data.

Water is used in the Quinte CA watershed for potable supply to municipalities and private homes as well as for irrigation (golf courses), agriculture, industry, hydroelectric generation and manufacturing. A review of PTTW and WTRS indicates that approximately 80% of the allocated takings are designated to Dams and Reservoirs, at approximately 1.1 billion m^3 of surface water. Power Production made up for 92% of the permitted volume of water taken in 2017, all surface water, extracted from Crowe River and Lake Ontario. For the purpose of the analysis below, water used for hydroelectricity will not be used as it is mostly reintroduced back into the surface water system. A summary of permitted versus actual takings can be found in Table 9-4.

Table 9-4: **Volume of Reported Water Takings vs Maximum Permitted Volume of Surface and Groundwater in Quinte WQSA (2017 WTRS)**

Sector	Type	Volume of Reported Takings (m^3/yr)	Percent of WQSA Total Reported Takings (%)	Maximum Permitted Volume (m^3/yr)	Permit Utilization (reported takings/ maximum permitted volume) (%)
Agriculture	Surface and Groundwater	0	0.0	11,808	0
	Surface Water	3,883	0.0	527,466	0.74
Commercial	Groundwater	209,867	0.5	1,703,218	12
	Surface and Groundwater	189,669	0.5	1,745,163	11
	Surface Water	154,700	0.4	3,476,331	4.5
Dewatering	Groundwater	408,484	1.0	10,350,332	3.9
	Surface and Groundwater	2,900,590	7.4	30,708,901	9.4
Industrial	Groundwater	27,326	0.1	9,220,800	0.30
	Surface and Groundwater	3,187	0.0	15,413,893	0.021
	Surface Water	1,581,798	4.0	5,064,872	31
Miscellaneous	Groundwater	5,850	0.0	563,230	1.0
	Surface and Groundwater	0	0.0	7,884,000	0.00
	Surface Water	10,937	0.0	24,090	45
Recreational	Surface and Groundwater	974	0.0	125,000	0.78
	Surface Water	409	0.0	138,240	0.30
Remediation	Groundwater	430,912	1.1	2,439,046	18
	Surface and Groundwater	144,190	0.4	92,792,959	0.16
	Surface Water	339	0.0	2,400	14
Water Supply	Groundwater	597,839	1.5	3,877,211	15
	Surface and Groundwater	740	0.0	109,644	0.67
	Surface Water	32,440,870	82.9	93,560,384	35
Total	All Sources	39,112,564	100.0	238,679,755	16

Water Supply

Permitted takings for water supply represent roughly 84.4% of the total volume of the permitted takings in the WQSA, representing the largest category of water withdrawal, (1.5% groundwater, 82.9% surface water, 0.002% both). Within the Water Supply category, Municipalities are the dominant takers for the specific purpose of municipal water systems. Municipal takings comprise over 84% of total permitted water supply takings, while the remaining water supply specific purpose takings (Campground, Communal, and Other) make up roughly 0.02% of the total takings. Water supply permit holders utilized approximately 34% of their total permitted amount in 2017.

Given the nature of water use in municipalities, permitted water takings allow for water taking year round. With the exception of one irrigation well using a water supply PTTW, nearly all water supply PTTWs allow for water taking 365 days per year (366 on leap years).

Municipalities within the Quinte WQSA that rely on groundwater sources include the towns and villages of Madoc, Marmora, Stirling-Rawdon, Tweed and Tyendinaga (except for those on the municipal water supply from the neighboring Town of Deseronto) as well as rural populations in all of the Townships. Communities located adjacent to Lake Ontario use the lake itself for municipal water. Communities reliant on Lake Ontario with permits to take water include Kingston, Belleville, Napanee, Deseronto, and Loyalist. Some communities rely on both groundwater and surface water, such as South Frontenac and Quinte West. Permits to take water are not required for takings less than 50,000 litres per day. Since some rural communities in the Quinte WQSA have small populations, it's likely that they do not meet the threshold for a permit to take water as they use private wells and septic systems. These small amounts of water are therefore not accounted for in the PTTW or WTRS databases.

Agriculture

Permitted surface and groundwater takings for the purpose of agriculture represents the smallest group of users by volume of water taken in the WQSA at approximately 0.01% of total takings in the WQSA, (0% groundwater, 0.01% surface water, 0% both). Permits for agricultural purposes represent 0.02% of active PTTWs in the WQSA.

Reported water taking volumes for agricultural permits are highly variable between years due to climate, and the type of crop being grown. In 2017, less than 1% of the permitted water was used (approximately 3,884 m^3 of water). While this suggests a low utilization rate, a review of daily or monthly taking rates would be useful to determine if during a particular month during irrigation season the permitted volume utilization becomes much higher than 1%. For agriculture permits, maximum days per year that water can be taken range from 15 to 120; however, in 2017 only 4 days were noted as having reported water taking.

Commercial

Water used by commerce and industry varies with the product being manufactured or the commercial activity. The main industrial activities in the study area are related to small manufacturing operations. Commercial water use includes groundwater extraction for water bottling facilities, the operation of retail bait operations (where unchlorinated water is needed), resorts, hotels, motels; sport fishing/hunting camps, and golf courses. Commercial groundwater use occurs throughout the study area and many operations do not take sufficient water to require a PTTW. In many cases the activity is focused on the fringe of settlements in tourist areas and near major waterways.

Commercial PTTWs make up 1.4% of total volume taken in the Quinte WQSA (0.5% groundwater, 0.4% surface water, 0.5% both). Within the Specific Purpose category golf course irrigation is the dominant taker, using 0.82% of the total volume taken in WQSA, followed by snowmaking using 0.11%. Aquaculture, bottled water and other commercial uses make up 0.47% of the total.

The range of taking days per year for golf course irrigation permits is between 0 and 365 days per year, spanning the golf season. The number of days utilized ranges from 0 to 235. Golf course takings represent 57.7% of commercial takings in 2017. Utilization of actual water takings vs the permitted volume is 5.6% for all golf course takings. Again, while this suggests a low utilization rate, a review of daily or monthly taking rates would be useful to determine if during a particular time period in the irrigation season the permitted volume utilization becomes much higher. Snowmaking had 75 permitted days, however only reported water takings on 112 days according to the 2017 WTRS data.

Aquaculture takings from groundwater are permitted for 365 days per year however takings were only reported on one day, when 40% of their total permitted volume was taken. This is the highest rate of any category for the purpose of commercial uses. However, this only represents 0.45% of the total permitted volume taken in WQSA.

Dewatering

Dewatering PTTWs make up 8.45% of total volume taken in the Quinte WQSA (1.05% groundwater, 0% surface water, 7.4% both). Within the Specific Purpose category pits and quarries are the dominant takers, using 3.9% of the total volume taken in the WQSA, taking both groundwater, as well as a combination of both groundwater and surface water. These specific purposes of extractions are for sumps and ponds. Quarries took 6.3% of their permitted volume in 2017. These permits allocate a range from 60 to 365 days a year for water extraction. Other Dewatering permits are also linked to quarries and excavations, with permits ranging from 260 to 365 days a year and utilizing 10.5% of permitted water.

Industrial

Industrial related permitted takings represent approximately 4.25% of the total permitted volume taken in 2017 in the WQSA, (0.2% groundwater, 4.04% surface water, 0.01% both). Of the Specific Purpose categories within the Industrial category of permits, other permits took 2.11%, while manufacturing took 2.03%, aggregate washing took 0.07%, and pipeline testing took 0.02% of the permitted volumes.

The range of allowable taking days per year for the Industrial category of permits is between 9 and 365 days per year. Actual days when water was taken ranged from 0 to 335 in 2017. The percentage of taking is 52% of the permitted taking for all industrial takings.

Remediation, Recreational and Miscellaneous

In the Quinte WQSA ,the Remediation, Recreation and Miscellaneous categories of permitted takings account for approximately 1.5% of the total volume taken in 2017 (1.1% groundwater, 0.03% surface water, 0.37% both). Specific purpose for use within these categories include: pumping tests, recreational, as well as groundwater and surface water remediation. The total taking as a percentage of the permitted takings for the categories of Remediation, Recreation and Miscellaneous are 60%, 52%, and 20% respectively.

The primary remediation project is the Deloro mine cleanup on the Moira River. The Village of Deloro, with a population 160, sits next to the 202-hectare mine site, in between the municipalities of Marmora and Madoc. The Moira River runs through the mine site and flows into the Bay of Quinte on Lake Ontario. The cleanup plan includes: building two large engineered covers and one engineered containment cell, directing rain and melting snow away from the engineered covers to keep water from getting to the contaminated material; and, ongoing operation of an arsenic treatment plant pumping and treating contaminated groundwater (Ontario Government, 2014). There are several remediation PTTWs in the vicinity of the Deloro mine.

Mohawks of the Bay of Quinte

The Mohawks of the Bay of Quinte control the Tyendinaga Mohawk Territory, a 73 km^2 First Nation on the Bay of Quinte, immediately to the west of Deseronto. Residents rely on groundwater for water supply. Constraints prevented consulting with the First Nation to obtain water supply information as part of this project.

9.2.6.2 Non-Permitted Takings

Private water supplies are a concern in the Quinte WQSA. Many residents rely on private water supplies including a number that rely on shore wells as their drinking water source. Private wells are not monitored stringently, creating vulnerability to availability in times of drought. There are also a large number of private septic systems in this area and potential for impact to groundwater and private supplies. Water supply information for some areas, such as Mohawks of the Bay of Quinte, creates gaps in water taking volumes. These takings are not accounted for in the PTTW or WTRS databases.

9.2.7 Recommended WQSA Boundaries for Data Review

The Quinte CA, including the Moira River, Salmon River, and Napanee Watersheds, makes up the majority of the preliminary WQSA. The preliminary WQSA also includes small parts of a number of adjacent CAs including Cataraqui Region, Lower Trent Region, Crowe Valley, Rideau Valley and Mississippi Valley. As the majority of groundwater and surface water studies, as well as water management strategies, are based on watershed boundaries (which typically correspond with CA boundaries), the recommended refined Quinte WQSA focusses on the Quinte CA area within the preliminary WQSA, and also incorporates the northern portion of the Quinte CA, in order to include the upper reaches of the Moira River and Salmon River Watersheds. The new boundary excludes the municipal supply wells belonging to the Town of Stirling-Rawdon, which have undergone significant study already as part of the Lower Trent Source Protection studies.

The refined Quinte WQSA, an area of approximately 4,900 km^2, is shown on Figure 9-12. While some differences exist between locales, the refined area can be considered as representative of other areas in Eastern Ontario when it comes to resource sustainability and water quantity management. These are discussed in the following sections based upon our review of the existing information, including feedback from local water managers and MECP contacts that have firsthand knowledge of the water quantity issues and concerns in the refined Quinte WQSA.

9.3 RESOURCE SUSTAINABILITY

9.3.1 Data Review and State of Water Resources

Available information on the sustainability of water resources within the recommended Quinte WQSA has been reviewed and summarized. They key reports relied upon for the evaluation are listed in Table 9-1. Hydrographs from the PGMN within the WQSA were also reviewed, and conclusions were made based on the general findings of studies/reports/data conducted and collected in the Quinte WQSA. Additionally, information and feedback were collected from local water managers and other key contacts.

High Use Watershed Classification

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a Low percent water use based upon the Average Annual Flow and Medium percent water use based upon Summer Low Flow.

9.3.1.1 Groundwater

PGMN Hydrographs

In the Quinte WQSA hydrographs and a statistical analysis of water levels were provided for seven PGMN wells located within and surrounding the Quinte WQSA, including Mann Kendall (MK) and Seasonal Mann Kendall (SK) monotonic trend analyses (i.e. consistently increases or decreases through time) between 2001 and 2017. These wells are summarized in Table 9-5 and shown on Figure 9-11. The methodology for the analysis is forthcoming from the MECP; however the results are relied upon here to summarize water level trends in the Quinte WQSA. An overall objective is to determine if there is enough data to support the presence of a widespread decrease in groundwater availability. Shorter trends within the PGMN data record (e.g. lasting for a few years) were not considered and the causes of any trends that were identified were not investigated. Both the data plots and preliminary findings for PGMN well locations within the Quinte WQSA were shared by the ministry and are presented and relied on herein. The data plots indicate data available for the well at the time of the assessment. Further, the MECP has indicated that the methodologies used require that certain values be dropped from the data set if the month/year in question does not have a sufficient number of data points. The release of a final report that details the methodology and results from the PGMN data trends analysis is forthcoming from the ministry (MECP, 2018).

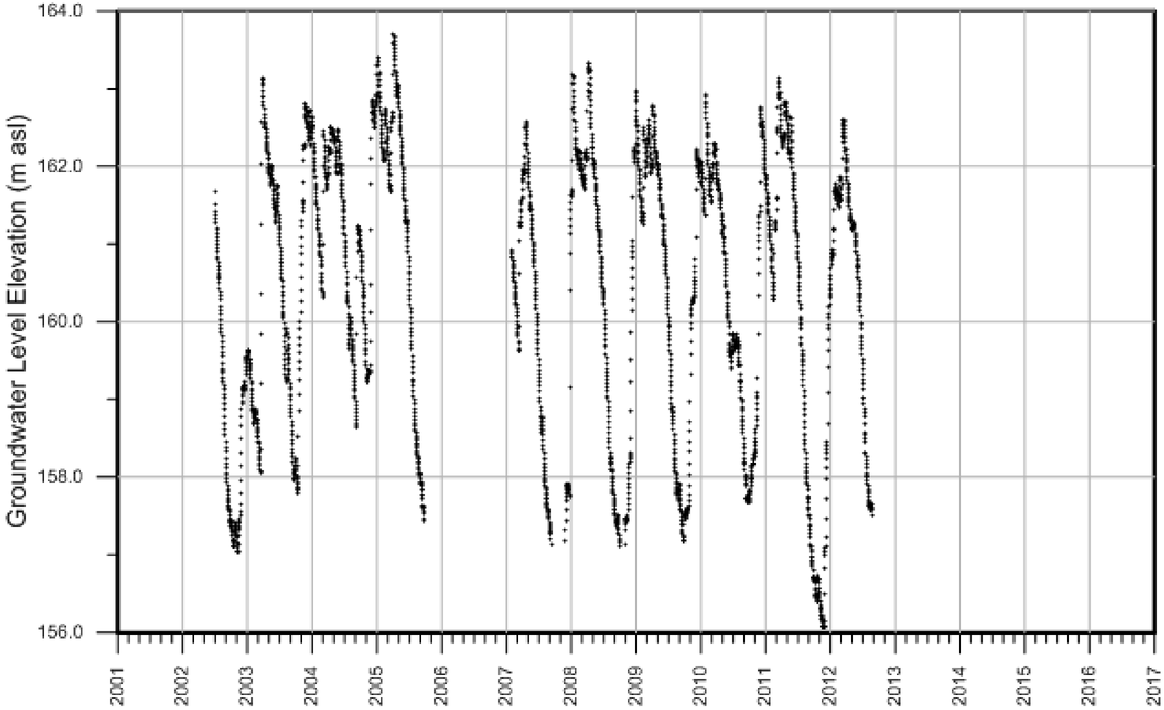
There are 17 PGMN wells within the Quinte CA (Figure 9-11). Plots of available data from all wells are provided in Appendix C. PGMN well information is summarized in Table 9-5.

Table 9-5: PGMN Wells in Quinte WQSA

PGMN Well ID	Water Well Record ID	Screened Interval (mbgs)	Ground Elevation (masl)	Lithology of Aquifer
W0000127-1	2900519	Open Hole: 5.2 m-18.05 m	130.64	Limestone
W0000129-1	N/A	Open Hole: 52.9 m- 58.6 m	118.58	Interbedded Limestone and Shale
W0000132-1	2909393	Screen: 13.7 m- 17.0 m	122.58	Brown Sand and Gravel /Limestone
W0000133-1	2206051	Open Hole: 6.7 m- 20.3 m	145.26	Black Granite
W0000134-1	2207642	Open Hole: 7.9 m- 27.4 m	190.98	Limestone
W0000148-1	2905484	Open Hole : 10.6 m- 21.9 m	139.2	Limestone
W0000152-1	3709584	Open Hole: 6.7 m- 24.7 m	167.13	Limestone, Sandstone, Granite
W0000153-1	2217749	Open Hole: 6.7 m- 63.7 m	172.7	Grey and Black Granite
W0000154-1	3709581	Open Hole: 6.42 m- 9.82 m	122.19	Grey Limestone
W0000155-1	2919757	Open Hole: 6.7 m- 43.6 m	160.51	Grey and Green Limestone
W0000212-1	2919766	Open Hole: 13.4 m- 15.3 m	158.83	Limestone
W0000213-1[1]	2919771	Open hole at end of casing	198.6	Gravel
W0000222-1[1]	2200184	Open Hole: 3.0 m- 26.37 m	177.99	Granite
W0000331-1	N/A	Open Hole: 7.01 m- 73.2 m	210.15	Granite
W0000365-1	3709714	Open Hole: 5.8 m- 19.8 m	97.28	Grey Limestone
W0000380-1	2920022	Screen: 35.7 m- 41.8 m	183.34	Grey Clay, Sand and Gravel
W0000383-1	3709737	Open Hole: 16.2 m- 18 m	78.28	Shaley Limestone

[1] Ministry staff noted the data for trend analysis purposes is deemed unreliable

The Mann Kendall analysis, which looks at year over year water levels, determined that water levels in PGMN wells within the Quinte WQSA showed no increasing or decreasing trends for the period between mid-2002 and mid-2012. The Seasonal Mann Kendall analysis, which determines the trend from season to season (e.g., between Spring 2010 and Spring 2011) and then adds the sum of each seasonal analysis together, established that PGMN wells within the Quinte WQSA had either an upward trend, or no trend, with the exception of one well, W0000152-1, which has exhibited a downward trend in water levels (Text Figure 9-13).



Text Figure 9-13. Groundwater Level Elevations (2001 to 2012) for PGMN Well W0000152-1

Well W0000152-1 is located in the central portion of the WQSA, near the small community of Tamworth. The trend analysis provided by the MECP only uses monitoring years of 2002 to 2005 and 2007 to 2012 (rational unknown). Given that the analysis does not reflect the past five years, this trend cannot be relied upon to make relevant conclusions about regional water levels in this part of the WQSA.

W0000213-1 is located to in the western portion of the WQSA, and is deemed unreliable by Ministry Staff. Several PTTW with significant takings are located west of the PGMN well within 1.5 km and may affect its water levels, making them not representative of regional conditions.

Because of the relatively limited number of PGMN wells within the WQSA and short period of data record, conclusions cannot be drawn about the long term presence of actual trends, and/or significance on water resource sustainability of these apparent temporal trends. Acquired water levels constitute a good baseline dataset.

Water Budgets

Tier 1 water budgets were completed for the entire Quinte CA for both current and future (25 year) water use projections (QRSPC, 2014). The Tier 1 water budgets indicated that all subwatersheds in the study area are considered to have Low stress levels for surface water, with the exception of one subwatershed in the study area, the Parks subwatershed in the Moira region, which was found to have a Moderate stress level for surface water. The Parks subwatershed did not progress to a Tier 2 water budget as it does not have a municipal surface water intake. All subwatersheds within the Quinte Region were assigned a Low stress level for groundwater. A Tier 2 water budget was completed on the Tweed subwatershed, containing the village of Madoc. This assignment was not a result of stress calculations, but because of water shortage problems experienced in the summer of 2007 when one of the municipal wells (the Rollins Well) was pumped dry on several occasions (Quinte Conservation, 2010). Tier 2 work confirmed the Low subwatershed stress level identified at the Tier 1 level; however, it indicated a potential for increased contribution from nearby surface water to maintain pumping at the wells. The Tier 2 work also revealed that the water shortage problems at Madoc in the summer of 2007 were a result of increased water use at one of the wells due to operational problems as opposed to the source water supply. This was attributed to increased demand on the Rollins Well as a result of taking the other well (Whytock Well) offline due to a water quality problem, and a problem with the water treatment system at the Rollins Well which allowed significant volumes of water to be pumped to waste.

As will be discussed later, strong groundwater / surface water interactions exist across the WQSA, as a result of the hydrogeological setting (thin soils overlying fractured bedrock aquifer), and it has been suggested by a local water manager, that the methodology applied (water budget Technical Rules), where aquifer recharge is applied equally throughout the year, may have underestimated the stress level in some parts of the WQSA.

9.3.1.2 Surface Water

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification.

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the WQSA.

A general review of the OLWR database indicates that a total of 20 Level 1 notifications and five Level 2 notifications were sent to Quinte Conservation between 2000 and August 2018. Instances when notifications were issued occurred in 2000 (six Level 1 notifications), 2001 (two Level 1 notifications), 2002 (one Level 1 notification), 2005 (three Level 1 and two Level 2 notifications), 2006 (two Level 1 notifications), 2010 (three Level 1 notifications), 2011 (one Level 1 and one Level 2 notifications), 2012 (one Level 1 and one Level 2 notifications), and 2017 (one Level 1 notification).

Quinte Conservation posted Low Water Condition Alerts on eight occasions:

- July 2001 to mid-May 2002: a Level 1 Low Water Condition Alert was posted in July 2001, which was raised to a Level 2 in early August, and lowered back down to a Level 1 in mid-December. The Low Water Condition Alert was removed entirely in mid-May 2002;

- Mid-November 2002 to mid-December 2003: a Level 1 Low Water Condition Alert was posted, and remained in effect for over a year;
- Mid-August 2005 to mid-December 2005: a Level 1 Low Water Condition Alert was posted;
- Mid-September 2007 to mid-January 2008: a Level 1 Low Water Condition Alert was posted in mid-September 2007, which was raised to a Level 2 in mid-October, and lowered back down to a Level 1 in mid-December. The Low Water Condition Alert was removed entirely in mid-January 2008;
- Mid-August 2011 to mid-December 2011: a Level 1 Low Water Condition Alert was posted in mid-August 2011, which was raised to a Level 2 in mid-September, and lowered back down to a Level 1 in early December. The Low Water Condition Alert was removed entirely in mid-December 2011;
- Mid-April 2012 to mid-October 2012: a Level 1 Low Water Condition Alert was posted in mid-April 2012, which was raised to a Level 2 in late July, and lowered back down to a Level 1 in late September. The Low Water Condition Alert was removed entirely in mid-October;
- June 2016 to early January 2017: a Level 1 Low Water Condition Alert was posted in June 2016, which was raised to a Level 2 in mid-July and then to a Level 3 in early August. The Low Water Condition Alert was lowered back down to a Level 2 in mid-December. The Low Water Condition Alert was removed in early January 2017; and,
- Mid-July 2018 to end of August 2018: a Level 1 Low Water Condition Alert was posted in mid-July 2018, and was raised to a Level 2 in mid-August. The Low Water Condition Alert was removed entirely at the end of August 2018.

During the Level 3 low water condition in 2016, Quite Conservation had to stop generating hydroelectric power at the McLeod Dam due to low flows in the Moira River (Quinte Conservation, 2018). And, although the low water warning was lifted in early 2017, water supply levels had still not returned to normal for all residents within the watershed, with reports from some residents that their wells were dry or extremely low.

During drought conditions, some water courses within the study area go completely dry (i.e. the Salmon River). The Second and Third Depot Lakes Dams and associated reservoir system were built for water supply issues experienced by the Town of Napanee in the 1950s (the town has since relocated their water intake to Lake Ontario).

During drought conditions, particularly the prolonged Level 3 drought in 2016, Quinte CA received many complaints from residents on private groundwater supply wells reporting that their wells had gone dry. In some cases, certain private supply wells went dry while neighbouring wells did not experience any water shortages issues, which led to additional questions and concerns from residents to local water managers. This is likely because of two main factors: 1) the spatial variability of water bearing fracture zones in bedrock aquifers means that the amount of water storage is highly variable in any given location, and 2) shallow bedrock wells will receive relatively rapid recharge as they are more impacted by groundwater-surface water interaction (which can also make them more impacted by drought), while deeper bedrock wells have limited connection to surface conditions, receiving slower recharge, however potentially being more resilient to drought. The physical properties of bedrock aquifers in the WQSA are discussed in detail in Section 9.2.5.2. This is a problem particularly in Prince Edward County which is just outside of the refined WQSA but in a similar geological environment (fractured limestone bedrock) as the southern portions of the WQSA, and similar complaints were received from areas within the WQSA as well, for example from residents in the Township of Tyendinaga.

Overall, the OLWR database indicates that the CA has found it necessary to declare Level 1, 2 and 3 Low Water Condition Alerts for the area. A Level 3 Low Water Condition Alert was declared once, in 2016, but beyond that, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor does the data indicate any specific climate change trends.

9.3.1.3 Water Shortages

Stress on water quantity in the Quinte CA, particularly from groundwater sources, tends to be seasonal. In the usually dry months of summer and early fall, the aquifers may become stressed but have typically rebounded almost immediately, once precipitation increased or snow melted (QRSPC, 2014). In recent years, however, droughts have become more severe.

9.3.2 Assessment of Sustainability of Water Resources

9.3.2.1 Climate Change

Quinte CA undertook a review of potential effects of climate change on the region with the assistance of a Quinte Region GAWSER model (QRSPC, 2014). The model was prepared to simulate average conditions, 2-year and 10-year drought conditions for each of three scenarios: 1) current meteorological conditions; 2) conditions in 2050; and, 3) conditions in 2090. The work made use of a Canadian Centre for Climate modelling and analysis (CCCma) gridded model output for southern Ontario.

The conceptual water budget for the watersheds of the Quinte CA identified that about two thirds of the water coming into the collective watersheds of the Quinte QA is lost through evaporation and transpiration. Evapotranspiration is expected to increase significantly by 2050 and more so by 2090 as a result of predicted climate change.

Model results generally show peak streamflows are experienced earlier in the spring and summer flows are lower. The current conditions show a large peak runoff in April. This peak is predicted to be reduced in 2050 and 2090, and also takes place earlier in the year. Annual baseflows are expected to remain generally unchanged, but seasonally summer baseflows are anticipated to diminish. The projected temperature increase and earlier spring runoff would have the following impacts on water quantity:

- Less water available for surface storage (lake and wetlands), flow augmentation, etc. and consequently less supply for surface water drinking water sources;
- Further, the overall demand for all uses is expected to increase, given the longer warm and dry periods;
- Lower lake levels in summer, wetlands dry up, recreational challenges (boating, swimming, etc.);
- Less water recharging into the ground, lower groundwater levels, dry groundwater fed streams/lakes; and,
- More rain vs. snow, earlier freshet, less water to ground during snow melt, but more during traditional winter periods.

The effects of climate change are expected to be more pronounced seasonally.

Sensitivity of groundwater to climate change was assessed through a review of Ontario Water Well Record data for wells that may be vulnerable to changes in recharge (Quinte, 2010). As discussed in Section 9.2.5.3, the aquifer supplying several of the wells within the WQSA is dependent on direct discharge from precipitation and therefore water levels would be impacted by a decrease in precipitation. The baseflow index was also used as an indication of the volume of groundwater that discharges to local surface water bodies. Potential impacts from climate change could result in decreased groundwater recharge (which can ultimately decrease groundwater discharge) and deterioration of areas already experiencing low flow conditions. Overall, the majority of subwatersheds in the Quinte WQSA were determined to have low vulnerability to climate change; however, two subwatersheds in the southern portion of the WSQA were assigned a moderate vulnerability to climate change (and subwatersheds within the Prince Edward County Region immediately south of the WQSA were assigned moderate to high vulnerability values to climate change). The factors identified as representing the highest sensitivity to climate change within the Quinte WQSA were low water (drought) conditions and reduced groundwater discharge/baseflow as a result of the local hydrogeological conditions and the lack of resilience within the groundwater and surface water resources.

9.3.2.2 Population growth

The Quinte WSQA lies within the Counties of Frontenac, Lennox and Addington, and Hastings. Statistics Canada has estimated that these counties will grow by about 11% between 2017 and 2041 (0.5% annual growth). Despite relatively modest population growth projections, as noted in Section 9.3.2.1, the sustainability of the local water resources is anticipated to be affected in the future within the Quinte WQSA due primarily to the impact of climate change. In particular, some municipalities are entirely reliant on groundwater for water supply and do not have alternative surface water supply sources locally that can be used to compensate during water shortages (e.g., Tyendinaga Township, Stone Mills, etc.). Water supply information for some areas, such as Mohawks of the Bay of Quinte, creates gaps in water taking volumes. These takings are not accounted for in the PTTW or WTRS databases, and therefore as their population grows the increase in water takings is not documented. Water level data from PGMN wells and potential temporal trends may provide useful information with respect to water resources in areas where population growth pressures are expected; however, greater data density may be required.

9.3.2.3 Cumulative Effects

In the Quinte WQSA, water quantity stress and shortages have been reported for both surface water and groundwater resources (Section 9.3.1). Aquifers in the WQSA sometimes become stressed in the dry months of summer and early fall, but the aquifers typically rebound quickly once precipitation increases or upon snowmelt. During drought conditions, some water courses (e.g. the Salmon River) have been reported to go completely dry. In addition, during drought conditions, the Quinte CA received many complaints from residents on private groundwater supply wells reporting that their wells had gone dry; this was especially so during the prolonged Level 3 drought in 2016. Droughts have become more severe in recent years. BluMetric was not made aware of any reported interference issues between permitted and non-permitted water takings.

In contrast, Tier 1 water budgets for the Quinte CA indicated that all but one subwatershed in the WQSA are considered to have Low stress levels for surface water, and all subwatersheds within the WQSA were assigned a Low stress level for groundwater (Section 9.3.1). The Parks subwatershed was found to have a moderate stress level for surface water, but did not progress to a Tier 2 water budget as it does not have a municipal surface water intake. A Tier 2 water budget was completed for the Tweed subwatershed, containing the Village of Madoc, due to water shortage problems experienced in the summer of 2007, when one of the municipal wells was pumped dry on several occasions. The Tier 2 work confirmed the results of the Tier 1 water budget, which assigned a low stress level for the Tweed subwatershed, and also revealed that the water shortage problems at Madoc in 2007 were caused by operational problems rather than the issues with the source water supply.

There is a relatively low density of permitted takers in the Quinte WQSA (Figure 9-11). Permitted takings for water supply represent roughly 84.4% of the total volume of the permitted takings in the WQSA, representing the largest category of water withdrawal (1.5% from groundwater, 82.9% from surface water, 0.002% from both groundwater and surface water). Municipal takings comprise over 84% of the total permitted water supply takings. The remainder of water takings are attributed to irrigation (golf courses), agriculture, industry, hydroelectric generation and manufacturing (Section 9.2.6.1).

Based on the information reviewed as part of this study, no direct evidence of impacts to the natural functions of the ecosystem was identified. However, there have been reports of water courses sometimes drying up during drought conditions (Section 9.3.1), which would be expected to impact the natural functions of the ecosystem in question.

No significant declines in hydraulic head have been identified. The majority of PGMN historical hydrographs in the WQSA have either an upward or no trend in water levels, with only one well showing a downward season-to-season trend (Section 9.3.1). The absence of an observable, regional downward trend across the PGMN wells indicates it is unlikely that the groundwater takings in the WQSA are resulting in regional scale impacts.

Review of the OLWR database indicates that Quinte Conservation has found it necessary to declare Level 1, 2 and 3 Low Water Condition Alerts for the area (Section 9.3.1). A Level 3 Low Water Condition Alert was declared once, in 2016, but beyond that, the frequency of OLWR notifications and alerts do not provide any clear indication of a decreasing trend in the availability of surface water (and possibly shallow groundwater) in the area, nor does the data indicate any specific climate change trends.

In addition to the existing pressures on groundwater and surface water resources, the Quinte WQSA is in an area where cumulative effects may potentially become a concern in the future. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the Quinte WQSA lies within a tertiary watershed that is classified as having a Low percent water use based upon the Average Annual Flow, but with a Medium percent water use based upon Summer Low Flow conditions (Section 9.3.1).

The water shortages described above have been attributed to climate conditions/droughts. Numerical modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

9.3.2.4 Environmental Flow Needs

The 7Q20 flow is being used as a minimum flow target for surface water systems within Quinte CA at gauged streams, established by Quinte CA based on the OLWR document (MNR et al., 2010). Quinte CA would like to expand this analysis to undertake a comprehensive study to evaluate Environmental Flow Needs for other surface water bodies, but have not had adequate resources to do so. Data collection (e.g., stream temperature, conductivity, streamflow, etc.) has been ongoing through local initiatives to develop baseline dataset, but technical direction and/or help from subject matter experts is needed to evaluate and interpret the results, and determine Environmental Flow Needs, identify sensitive areas, and develop mitigative measures as appropriate in order to maintain adequate water levels and baseflow. PGMN trend analysis results should also be used as part of this evaluation, in particular considering the groundwater / surface water interactions, known to be significant in the Quinte WQSA.

9.3.3 Conclusions

Water budget work conducted in the Quinte WQSA generally indicated low stress under current climate and water use conditions, which suggests that broadly, the water resource is sustainable. However, geologic variability on a local scale within the WQSA may be exacerbated by potential climate change impacts, such as reduced recharge, and may lead to local water security issues. Local water managers indicate that many private wells run dry during the summer months, particularly during periods of drought. This is in part due to the intrinsic properties of fractured bedrock aquifers which have highly variable water storage capacities, which in some cases are very low. The sustainability of local water resources is anticipated to be affected in the future due primarily to the impact of climate change. Two subwatersheds in the southern portion of the WSQA were assigned a moderate vulnerability to climate change (and subwatersheds within the Prince Edward County Region immediately south of the WQSA were assigned moderate to high vulnerability values to climate change. The factors identified as representing the highest sensitivity to climate change within the Quinte WQSA were low water (drought) conditions and groundwater discharge/baseflow. Water level data from PGMN wells may provide useful information with respect to water resources in areas where population growth pressures are expected; however, greater data density may be required. Technical direction from the Province is required to determine Environmental Flow Needs, identify sensitive areas, and develop mitigative measures as appropriate in order to maintain adequate water levels and baseflow.

In summary, the sustainability of the water resources in the Quinte WQSA under current and future conditions is as follows:

Groundwater Under Current Conditions

- **Regional Scale –** the groundwater resources are sustainable in the broader WQSA under current conditions based on water level trends in the PGMN wells.
- **Local Scale** – the groundwater resources are unsustainable in some parts of the WQSA under current conditions due to the lack of resilience to extreme drought within the groundwater and surface water resources.

Groundwater Under Future Conditions

- **Regional Scale** - the groundwater resources are unsustainable under future conditions based on the modelled effects of climate change (QRSPC, 2014) and the lack of resilience within the groundwater and surface water resources.
- **Local Scale** - the groundwater resources are unsustainable under future conditions based on the modelled effects of climate change (QRSPC, 2014) and the lack of resilience within the groundwater and surface water resources.

Surface Water Under Current Conditions

- **Regional Scale –** the surface water resources are sustainable under current conditions based on the Tier One and Tier Two water budgets, a review of the OLWR data and trends and the fact that no direct evidence of impacts to the natural functions of the ecosystem was identified. However, there are some local exceptions based on seasonal (summer) shortages caused by extreme drought conditions and the fact that a Level 3 Low Water Condition Alert was declared once, in 2016.
- **Local Scale –** the surface water resource in some local areas are unsustainable based on a review of OLWR data although no trend was determined recurring extreme drought conditions are noted as being provincially significant (Level 3 Low Water Condition Alert was declared once, in 2016). The Quinte WQSA lies within a tertiary watershed that is classified as having Medium percent water use based upon Summer Low Flow conditions. As an example, the Salmon River is not sustainable under extreme drought conditions.

Surface Water Under Future Conditions

- **Regional Scale** – the surface water resources are unsustainable under future conditions based on the modelled effects of climate change (QRSPC, 2014).
- **Local Scale** - the surface water resources are unsustainable under future conditions based on the modelled effects of climate change (QRSPC, 2014) and the lack of resilience within the groundwater and surface water resources.

9.4 WATER MANAGEMENT APPROACHES AND CHALLENGES

A combination of available reports (Table 9-1) and communication with Water Managers knowledgeable of local water use/issues in the Quinte area was used to summarize current approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in Section 9.6 of this report, what, if any, new management tools are needed in Quinte WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches. Water managers from Quinte CA and the MECP were contacted to provide input to this study. Responses were received from the water resource manager, the GIS/database specialist and hydrogeologist at Quinte CA.

Current Approaches

The approach for managing water quantity in the Quinte WQSA relies on the policies of the Quinte Region Source Protection Plan, combined with Provincial mechanisms of the PTTW program (O. Reg. 387/04) and the OLWR program. MECP's Eastern Region office manages the PTTW program in the Quinte area and responds to well water and drought complaints.

The following specific water management approaches relating to water quantity are used by Quinte CA:

- Operation and maintenance of 39 water control structures, several of which provide low flow augmentation and local water supply;

- Coordination of the local Low Water Response Team that provides information, leadership and preparedness in the event of a drought;
- Technical advice to municipalities, landowners, lawyers and developers, and review of development proposals in regulated areas;
- Support for the development of the Quinte Region Source Protection Plan to protect sources of municipal drinking water;
- Stream gauge monitoring as part of the Water Survey of Canada; and,
- Well monitoring as part of the Ontario PGMN program.

Municipalities within the WQSA are encouraged to promote voluntary action to protect sources of drinking water and water conservation measures such as water saving fixtures, tips on how to save water in the house, and water conserving appliances (Policy G-1; QRSPC, 2014) .

It was not possible to consult water managers from the Mohawks of the Bay of Quinte as part of the current study due to the time available for the study and the timing of the government change in Ontario. In future, they should be engaged to obtain information about the state and management of the water resources in the Quinte WQSA.

Challenges

The following water management challenges were identified through the review of existing documentation and through communication with local water managers at Quinte CA:

- Seasonal shortage of groundwater in some areas;
- Some municipalities are entirely reliant on groundwater and do not have access to surface water sources so a better understanding of groundwater trends is needed;
- Water conservation measures within the CA are voluntary, there is no way to enforce reductions on takers not requiring a permit;
- There is not an abundant supply of groundwater for rural development;
- There is a lack of water supply information for some areas, such as Mohawks of the Bay of Quinte;
- There is a lack of resources to properly assess cumulative effects and EFNs (discussed in more detail below);
- Many subwatersheds have no stream gauge data (see Section 9.5);
- There is a lack of lake level gauges data (see Section 9.5); and
- Additional groundwater monitoring locations are required.

Other challenges identified, not specific to the sustainable provision of water, include risks associated with the hauling of water during periods of water shortages and real estate market declines.

Evaluation of how water management concerns are considered in water management decisions

Seasonal stresses on water quantity (for aquifers in particular) was not reflected in the prescribed Tier 1 water budget methodology which generally indicated consistent low monthly stress throughout the year (QRSPC, 2014). Since there were no identified water quantity threats at any municipal water sources, there was no legislative authority for water quantity policies in the Quinte Region Source Protection Plan. However, local water managers indicate that many private wells run dry during the summer months, and water shortage issues are more severe and last longer during periods of naturally occurring low water conditions due to drought (e.g., 2016). Residents, homeowners and rural businesses are all affected. Bulk water sales from water treatment plants in the region indicate that this occurs throughout the region (QRSPC, 2014). Since water conservation measures are voluntary, there is no way to enforce reductions on takers not requiring a permit (unless individual municipalities pass water conservation by-laws). Therefore, municipalities within the WQSA are encouraged to promote voluntary action to protect sources of drinking water and water conservation measures. Municipal water managers should be encouraged to ensure that water resources are considered in the rural development approval process in order to avoid future water security issues with respect to rural non-permitted water demands.

Local water managers have indicated that there is not an abundant supply of groundwater for rural development due to the low yield and/or naturally poor groundwater quality from many wells in fractured carbonate bedrock aquifers in this part of the province. This has impeded development in the area, particularly in the Prince Edward County region located just south of the WQSA, but also in the southern portion of the Quinte WQSA. Whether there are Official Plan restrictions around rural development in sensitive water quantity areas has not been investigated as part of this study.

Consideration of key topics in water management decisions

Local water managers (Conservation Authority and MECP) have indicated that support, including funding, additional staff and available/appropriate methodologies and tools, are required to monitor groundwater and surface water levels and flows, predict impacts and identify early warning triggers to initiate drought management, properly assess cumulative effects (i.e. impact from Climate Change) and EFNs within local watersheds. Quinte CA has some data such as data on benthic populations, surface water flows and water quality but needs support to compile and analyze the data.

Although access to the Great Lakes water supply (and large water treatment plants) has helped to alleviate the impacts of drought within the WQSA, should low water conditions occur more frequently in the future, challenges, according to local water managers may include:

- Need for drought planning and preparedness;
- Adequate water for municipalities (such as the Township of Tyendinaga, Stone Mills and several others in the northern portion of the WQSA) which are entirely reliant on groundwater and do not have access to surface water sources;
- Potential for exposure to contamination due to improperly securing an alternate water supply from an untreated source; and,
- Access to a nearby safe alternate water supply for existing populations during times of extended drought. This population is vulnerable due to having shallow supply wells constructed in areas that are less resilient to drought conditions. Identifying a nearby safe alternative water supply may be a related challenge since areas that are less resilient than other parts of the WQSA may be spatially extensive.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

Local water managers have indicated a need for hydrologic modelling and detailed guidance on how to optimize dam operations for low flow augmentation during droughts and to sustain EFNs. In addition, initiating a dialogue process between key informants (local water managers) and stakeholders to develop a collaborative and proactive regional scale drought management plan should be encouraged.

9.5 IDENTIFIED DATA GAPS

Data gaps identified during water budget investigations and through communications with local water managers include:

- Additional stream gauges (many subwatersheds have no steam gauge data and water availability has to be estimated) at the following locations:
    - Moira River at Stoco Lake outlet, Tweed
    - Potter Creek, Belleville
    - Bell Creek, Belleville
    - Marysville Creek, Tyendinaga;
- Lake level gauges to assess the potential for low flow augmentation and the effects of drought at the following locations:
    - Moira Lake, Moira River
    - Stoco Lake, Moira River
    - Deerock Lake, Moira River
    - Skootamatta Lake, Moira River
    - Lingham Lake, Moira River
    - Kennebec Lake, Salmon River
    - Upper Arden Dam (Big Clear Lake), Salmon River
    - Beaver Lake (Laraby Rapids Dam), Salmon River
    - Horseshoe Lake, Salmon River
    - James Lazier Dam, Salmon River
    - Third Depot Lake Dam, Napanee River
    - 13 Island Lake Dam, Napanee River
    - Verona, Napanee River
    - Varty Lake, Napanee River;
- Additional groundwater monitoring locations to improve the temporal and spatial resolution of locally limited groundwater resources;
- It is unknown whether there are Official Plan restrictions around rural development in sensitive water quantity areas; and,
- Water supply information for some areas, such as Mohawks of the Bay of Quinte, creates gaps in water taking volumes in the PTTW or WTRS databases.

Local water managers have also indicated a need for hydrologic modelling and detailed guidance on how to optimize dam operations for low flow augmentation during droughts and to sustain EFNs. Assistance from subject matter experts is needed in the analysis and interpretation of baseline monitoring data (e.g. PGMN) that have been ongoing within the WQSA.

It was not possible to consult water managers from the Mohawks of the Bay of Quinte as part of the current study due to the time available for the study and the timing of the government change in Ontario. In future, they should be engaged to identify any concerns they may have with respect to water quantity data needed to manage water resources in the Quinte WQSA.

9.6 RECOMMENDATIONS

Based on the reports and data reviewed and communication with Water Managers knowledgeable of local water use/issues in the Quinte WQSA, the following recommendations are provided as possible mitigative measures to address the identified gaps related to water quantity management, and help in avoiding potential future water quantity issues.

Future water budget work should look at improving the study methodology to identify areas that may be impacted more severely by seasonal changes under Climate Change conditions. For areas where water shortages have been reported (i.e. southern portion of the WQSA) a water use survey could be conducted to obtain actual water use data from non-permitted takers in these areas (instead of using estimated rate of 525 L/well/day).

More consideration should also be given to communities and rural areas that are dependent on groundwater as a drinking water supply but do not have a municipal drinking water system. If a subwatershed determined as exhibiting moderate to significant hydrologic stress in private water systems since there are no municipal systems consideration should be given to developing a water budget process similar to those completed under SWP initiatives for municipally serviced areas.

Water quantity management should be linked to land use planning decisions. Official Plans should include policies to protect groundwater resources and homeowners on private wells (i.e. development should be limited in privately serviced areas where groundwater supply is determined to be limited or potentially impacted by Climate Change in the future).

Due to the fact that there are a significant number of non-municipal and not permitted water takings in the Quinte WQSA, more temporal and spatial groundwater level data is required within the Quinte CA to support land use planning decisions and evaluate potential long-term trends; the PGMN does not provide sufficient water level monitoring data for the area and SWP delineation and assessment is limited to municipal drinking water systems. Additional PGMN wells could be installed or alternately, routine submission of water level data could be required for sites with PTTWs and/or dataloggers could be installed in domestic or other wells in sensitive areas.

Additional surface water monitoring locations are recommended for ungauged subwatersheds (such as Lower Moira, Lower Salmon and Lower Napanee), as well as lake level gauges as described in Section 9.5.

Local water managers should be provided with more support in terms of drought preparedness and management. For example, water managers should be encouraged to initiating a dialogue process between key informants (local water managers) and stakeholders to develop a collaborative and proactive regional scale drought management plan. Detailed guidance from other parts of the province should be provided for identifying and preparing for drought conditions and addressing water supply needs for private as well as municipal takers in times of drought. Detailed guidance should also be provided on how to optimize dam operations for low flow augmentation during droughts. Finally, PTTW conditions could require mandatory reductions in takings during periods of low water/drought in certain circumstances.

Local water managers should be provided with support (including funding, additional staff and available/appropriate methodologies and tools) for evaluating cumulative effects and sustaining EFNs.

Whether there are Official Plan restrictions around rural development in sensitive water quantity areas should be investigated.

Water Managers from the Mohawks of the Bay of Quinte should be engaged regarding the state of water resources, data needs and management of water quantity in the WQSA and asked for their input regarding current and future water management practices.

Climate Change assessments should be reviewed with updated regional modelling as it becomes available to provide improved projections on potential impacts. The modelling completed in the Quinte WQSA lacks groundwater or surface water monitoring data in several subwatersheds (i.e. Lower Moira, Lower Salmon and Lower Napanee). This could in part be addressed through adding wells to the existing PGMN or monitoring of additional wells to increase data density, as discussed above. This would in turn add greater confidence to model calibration and the results (QRSPC, 2014). Potential changes in evapotranspiration could also be better evaluated with improved local data of projected changes in cloud cover, solar radiation and wind speed to support Climate Change assessment.

9.7 REFERENCES

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10 CHAPLEAU WQSA

The preliminary boundary of the Chapleau WQSA, as provided by the MECP, is shown on Figure 10-1. The preliminary WQSA is located approximately 250 km northwest of Sudbury, northeast of Lake Superior. The WQSA is comprised primarily of the Upper Kapuskasing watershed; it is not part of a Conservation Authority and outside of a source protection area.

In the Chapleau WQSA surface water resources are used for industrial, and municipal and private water supply; and, groundwater is used for mine dewatering and private water supply. The Chapleau WQSA was selected for geographic diversity (representative of Northern Ontario setting with sensitive water systems located on Canadian Shield bedrock), and to include stakeholders from First Nations communities (Indigenous concerns and involvement). The Chapleau WQSA includes Chapleau Cree, Brunswick House, and Chapleau Ojibway communities.

The objectives of this section are: to provide a characterization of the Chapleau WQSA in the context of the major (most used) surface water and groundwater resources; refine the WQSA boundary based on the physical characterization; summarize and evaluate the demands on water resources in the WQSA; and determine the possible impact of projected changes in population, land use, and climate on the quantity of the local resources and the future security and sustainability of the water resources in the WQSA based on these changes.

10.1 AVAILABLE STUDIES, MODELS AND DATA

Available information was reviewed in the context of the defined objectives for the WQSA noted above and the preliminary WQSA boundary provided by the MECP. The Chapleau WQSA does not have a Conservation Authority, and includes lakes such as Borden Lake, Missinaibi Lake, Nemegosenda Lake and Kapuskasing Lake. The area intersects several Provincial Parks, including Wenebegon River along the south border, Ivanhoe Lake along the west border, Missinaibi along the Northeast border, and Chapleau-Nemegosenda River which is fully encompassed by the WQSA. The main municipal areas of the WQSA include the communities of Chapleau, Nemegos, Elsas, and Peterbell. The WQSA also includes several First Nations lands; Chapleau(61A, 61, 74, 74A and 75 Reserves, Chapleau Cree Fox Lake Reserve, Mounbatten 76A Reserve and Duck Lake 76B Reserve. Based on the review and input provided by Water Managers within the WQSA, the reports listed below (Table 10-1), as well as available databases provided by MECP, were used as the primary basis for the WQSA characterization and assessment presented in the following sections. Each resource was categorized in terms of the information presented within.

Table 10-1: Summary of Key Sources for Chapleau WQSA

Resource Reference	Type	Categories
Ontario Clean Water Agency (OCWA). 2017. Chapleau Drinking Water System 2017 Annual Report.	Report	SWQ, GWQ, CU
Boissonneau, A .N. 1968. Glacial history of northeastern Ontario II. The Timiskaming- Algoma area. Canadian J. Earth Sci., Vol. 5, p. 97-109.	Report	PC
Evans, L.J. and Cameron, B.H. 1984. *Reconnaissance Soil Survey of the CHAPLEAU-FOLEYET AREA Northern Ontario*. Ontario Ministry of Natural Resources.	Report	PC
Thurston, P C, G M. Siragusa, and R P. Sage. 1977. *Geology of the Chapleau Area, Districts of Algoma, Sudbury, and Cochrane*. Toronto: Ontario Division of Mines.	Report	PC

Categories:

PC – Physical Characterization
GWQ – Groundwater quantity
SWQ – Surface water quantity
CU – Current water users

It was not possible to consult First Nations communities as part of the current study due to the time available for the study and the timing of the government change in Ontario.

10.2 WATER RESOURCES SETTING /CHARACTERIZATION

10.2.1 Land Cover and Use Setting

Land cover in the Chapleau WQSA (Figure 10-2) is predominantly Deciduous Treed, Mixed Treed, and Coniferous Treed Land with pockets of Sand/Gravel/Mine Tailings/Extraction in the north and south parts of the WSQA as well as a few small urban centers of Community/Infrastructure. There are also pockets of disturbed land throughout the largely undeveloped study area, including mining east of the Township of Chapleau and lumber harvesting north of Peterbell.

The WQSA is located beyond the limits of the CLI of agricultural lands.

10.2.2 Population

Populations in urban centers with municipal water supplies located in watersheds which fall within or make up part of the WQSA are summarized using the most recently available population information in Table 10-2.

Table 10-2: Summary of Population Statistics and Water Supply Source in Chapleau WQSA

Watershed/ S.P.A	County	Municipality	Water Source	2011 Population (Statistics Canada)	2016 Population (Statistics Canada)	Percentage Change 2011 to 2016 (%)
Upper Kapuskasing Watershed/ No SPA	Sudbury District	Chapleau	Kebsquasheshing River (Chapleau River)	1,226	1,964	-4.6

The total population of the District of Sudbury was 21,546 in 2016 according to data available through Statistics Canada. The District of Sudbury encompasses the bottom two thirds of the WQSA, and the north area of the WQSA is in the District of Algoma. Most of the population in the WQSA is in sparsely populated rural areas which are not serviced by municipal water supplies.

10.2.3 Physiographic Setting

The Chapleau WQSA is located in northeastern Ontario, north of Lake Huron and east of Lake Superior. The preliminary WQSA boundary provided by the MECP extends north to the tip of Mons Lake, west to Missinaibi Provincial Park, east to the eastern border of Mountbatten First Nations lands, and south to Wenebegon River Provincial Park.

10.2.3.1 Physiography

The physiography of the Chapleau WQSA is shown on Figure 10-3. The study area predominately consists of ground (MG) and hummocky (MH) moraines with ice contact deltas (GD), eskers (GE), kame (GK) and outwash plains (GO) to the south, exposed bedrock in the central region, and organics (OT) to the north.

The most extensive deposit in the area is sandy glacial moraine till, generally occurring as ground moraines (basal till), but also in the form of recessional moraines. Sandy till in hummocky terrain, formed by the mass disintegration of glacial ice, may be up to 30 m in thickness. The till is generally considerably thinner in areas of frequent bedrock exposure, (Evans and Cameron, 1984), and is described in further detail in section 10.2.4.1.

A stony, bouldery sand till is the most widely distributed surficial material of the ground moraine in the study area. This till mantle is thin, shallow, and discontinuous; exposures of bedrock are abundant. In places the till is overlain by younger morainic outwash or lacustrine deposits; in other places the tills were eroded by wave action of glacial lakes, exposing extensive areas of bare, polished bedrock surfaces (Boissonneau, 1968).

The glaciofluvial outwash deposits are found throughout the entire WQSA, and are particularly extensive in the Chapleau area. They are believed to have been laid down by slowly running water (Boissonneau, 1968). These deposits generally consist of fine to coarse sands up to 2 m in thickness underlain by gravel, and are often associated with eskers (Evans and Cameron, 1984).

10.2.3.2 Topography

The WQSA lies across the divide separating the Atlantic Ocean and Arctic Ocean watersheds. To the north of the divide the land slopes rather gently to the shores of Hudson Bay and James Bay, while to the south the slope decreases more steeply to the shores of Lake Superior and Lake Huron. The divide is often referred to as the Height of Land. Elevations along the divide are generally between 500 to 540 masl, although individual hills, particularly in the rugged terrain in the south of the Town of Chapleau, rise to between 650 and 725 m. To the north the topography is generally flat but gently sloping, with elevations between 360 and 300 m (Evans and Cameron, 1984). The topography of the area is shown on Figure 10-4.

10.2.3.3 Climate

The climate of northern Ontario is classified as modified continental, the modification resulting mainly from the Great Lakes to the south and, to a lesser extent, from Hudson Bay to the north (Chapman and Thomas, 1968). A pattern of lower winter and higher summer precipitation occurs, where in the winter the cold polar air masses produce dry, clear conditions that persist for considerable periods of time. In the summer, a continuing succession of cyclonic storms sweep over the area and warm, humid air masses from the south alternate with cooler and drier air from the north (Evans and Cameron, 1984). This alternation of air masses gives a few days of fine weather followed by more humid weather and changeable winds and rain. The Chapleau area occurs principally in the climatic region known as the Height of Land (Chapman and Thomas, 1968).

Mean annual air temperatures range from 0.9 to 2.2°C for the two weather stations (Figure 10-5) within the preliminary WQSA with total precipitations from 688 to 901 mm. January is the coldest month with daily temperatures averaging -16°C and July is the warmest month with an average daily temperature of 17°C (Evans and Cameron, 1984). Temperatures in winter however often fall below -40°C and summer temperatures rise to over 30°C. Approximately 30% of precipitation falls as snow.

10.2.3.4 Surface Water Hydrology

In the Arctic Ocean watershed there are a number of major rivers that flow north, over the relatively flat plain, into James Bay. In the eastern and central parts of the Chapleau WQSA (Figure 10-4), the Kapuskasing and Groundhog Rivers drain the Kebsquasheshing (Chapleau), Nemegosenda and Ivanhoe Rivers and they themselves flow into the Mattagami River. From the west the Missinaibi River and its tributary, the Fire River, join the Mattagami River in the Moose River basin. The resulting Moose River enters James Bay at Moosonee (Evans and Cameron, 1984). Waterbodies within the Atlantic Ocean watershed run southward towards Lake Huron. There are several existing or proposed hydropower facilities within the WQSA; however, they are not within the scope of this report.

The Aquatic Thermal Regions can be seen on Figure 10-6, from GIS shapefiles provided by the MECP. In the Chapleau WQSA, most rivers and some bodies of water are cold, while most bodies of water are cool. A very small percentage of surface water courses are categorized as warm.

Major surface water bodies used for water takings within the WQSA include the Kebsquasheshing (Chapleau) River and Borden Lake. As decribed above, the Kebsquasheshing (Chapleau) River flows north to the Kapuskasing River. Water from Borden Lake flows in a northerly direction to the Borden River through a small dam maintained by the Ministry of Natural Resources and Forestry (MNRF). The watershed area of the Borden River, inclusive of Borden Lake, is approximately 11,457 ha (Amec Foster Wheeler, 2016). The Borden River flows in a northeasterly direction before flowing into the Nemegosenda River at Lake Nemegosenda.

Available data from 2006 to 2014 from the WSC Nemegosenda River HYDAT station (04LE002), the only HYDAT station in the WQSA, indicate that the greatest monthly average flow rates occur in the spring, in April and May, coinciding with the snow melt period (Amec Foster Wheeler, 2016). Lowest flows recorded are shown to occur during the mid-winter months

(January through March), when precipitation is accumulated and held as snow and ice, and in mid to late summer. Flow records for this area have been evaluated for the Borden Lake Gold project which has active surface water and groundwater PTTWs.

10.2.4 Geology

The geology of the Chapleau Region predominantly consists of shallow soil over bedrock. Surficial and bedrock geology in the Chapleau WQSA is described in the following sections.

10.2.4.1 Surficial Geology

The most extensive type of surficial deposit in the Chapleau WQSA is Precambrian bedrock (discussed in more detail in Section 10.2.4.2) exposed at surface or covered by a discontinuous, thin layer of till as shown on Figure 10-7. The till is typically undifferentiated, fine-grained (predominantly silty clay to silt), and clast poor, with a high matrix carbonate content. The till is associated with large areas of bedrock outcrops and is often drumlinized. In most of the Chapleau WSQA, the till varies in depth from 1 to 7 m, with a low to moderate undulating to slightly knobby landform (Roed and Hallet, 1979).

The next major surficial material found in the WQSA consists of glaciofluvial outwash and ice-contact deposits. While they are found in patches throughout the WQSA, glaciofluvial outwash sands and gravels are found primarily in the central and southern portions of the WQSA, as shown on Figure 10-7. The glaciofluvial outwash sands and gravels are often associated with eskers. Eskers in the area range in height from 15 to 60 m. Kame deposits also occur, particularly around the Township of Chapleau. The glaciofluvial ice-contact deposits are present throughout the WQSA, consisting of gravel, sand and minor till, and forming esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits.

Glaciomarine deposits, found in the central and southern areas of the WQSA, consist of sand, gravelly sand and gravel nearshore and beach deposits, and are assumed to have been laid down by slowly running water, in what was termed Lake Sultan by Boissonneau (1968). Thicknesses of up to 40 m have been inferred by Roed and Hallett (1979). These deposits are generally composed of fine to coarse-grained sands, are up to 2 m thick, and are underlain by gravel.

Organic deposits, composed mainly of sphagnum moss, occur throughout the area in poorly drained depressions or flat low lying terrain. They are commonly found associated with glaciomarine deposits, but extensive areas also occur along rivers and around lakes in much of the area, (Evans and Cameron, 1984). In the Chapleau WQSA, areas of organic deposits occur along the Abinette Riversouth of the township of Chapleau, adjacent to Highway 129, and in small sections in the northern part of the WQSA.

10.2.4.2 Bedrock Geology

According to the OGS Report 157, all the bedrock found in the Chapleau WQSA, with the exception of some Mesozoic lamprophyre dykes, is Precambrian in age and belongs to the Superior Province. The bedrock consists predominantly of tonalite to granodiorite, which is foliated to gneissic with minor supracrustal inclusions or foliated to massive as seen in the north, as shown on Figure 10-8. In the central and eastern areas of the WQSA, metavolcanic rocks, minor metasedimentary rocks, mafic gneisses of uncertain protolith, granitic gneisses and anorthosite, form a portion of a 'greenstone' belt characteristic of Archean age rocks present in the Canadian Shield, (Thurston et al, 1977). Three of the structural subprovinces of the Canadian Shield recognized by Stockwell (1970) are found within the WQSA (the Wawa Subprovince, the Abitibi Subprovince and the Kapuskasing Structural Zone*)*, and are further described in a Soil Survey completed by Evans and Cameron 1984:

> *The Wawa and Abitibi Subprovinces include extensive metavolcanic - metasedimentary belts surrounded by granitic rocks, and the Kapuskasing Structural Zone contains highly metamorphosed sediments with scattered occurrences of mafic intrusive rocks. The major bedrock of the area is a mixture of intrusive granitic and migmatite rock. These rocks cover approximately three quarters of the Chapleau-Foleyet area. The southern part of the region is dominated by felsic igneous rocks composed of massive to foliated coarse grained quartz monzonite and granodiorite, pink to red in colour. The granitic rocks of the northern part of the area consist of a broad band of dominantly metamorphosed gneissic trondhjemites and quartz diorites west of the south end of the Kapuskasing Structural Zone, and a weakly defined zone of trondhjemitic and granodioritic rocks around Missinaibi Lake. Plagioclase feldspar, quartz and potassium feldspar dominate mineralogically in varying proportions, with hornblende and biotite occurring as the major mafic minerals.*

10.2.5 Hydrogeology

Hydrogeological data are very limited for this area, despite extensive literature and internet searches, well records and consultation with local water managers and key contacts. It can be assumed that in areas where extensive bedrock deformation occurs, groundwater in the fractures associated with the bedrock could be sources for water, as described in well records near Peterbell, Borden Lake and Minnipuka. Areas with shallow weathering or structurally deformed bedrock at surface will be expected to have relatively good recharge/infiltration from precipitation and will be good sources of groundwater especially for domestic use. The overburden deposits distribution in the area can be used in identifying areas where groundwater resources are likely to occur, such as the thick overburden layers typical of moraines indicated in well records around Racine Lake with a thickness greater than 30 m.

The hydrogeologic system at the Borden Gold Project site, located approximately 11 km northeast of Chapleau (Figure 10-9), consists of bedrock with various degrees of fracturing and faulting, overlain by a relatively thin veneer of primarily sandy sediments (Amec Foster Wheeler, 2016). This site is located in the township of Borden, where several smaller communities, such as The Brunswick House First Nations Community, rely on surface water takings and groundwater-surface water interaction could have an effect on the local community. Data collected at this site suggests that there is a lack of large seasonal variation in the groundwater levels in some areas, likely reflecting a good hydraulic connection between Borden Lake and the shallow groundwater flow system in this area; however, in other areas of the site, large seasonal variations likely reflect a much poorer hydraulic connection to the lake, as described by Amec Foster Wheeler, (2016).

Figure 10-9 shows water wells from the Water Well Information System (WWIS). These are installed in both overburden and bedrock, with the majority of bedrock wells situated near small municipalities such as Chapleau, Elsas, Peterbell and Devon.

10.2.6 Overview of Water Takings within WQSA

10.2.6.1 Permitted Takings

Figure 10-10 shows the location of the four active permitted takings within the Chapleau WQSA, categorized by purpose. Table 10-3 summarizes the details of these permits. Percentages and values in the following paragraphs used to characterize water demands by Purpose and Specific Purpose were obtained using MECP provided 2017 Active PTTW and WTRS data.

Water is used in the Chapleau region for three main purposes by permitted takers: water supply, industrial, and dewatering uses. The permitted takers are discussed in more detail below. Groundwater taking represents 4.5% of the permitted volume and 6% of the volume taken within the WQSA for 2017. Surface water makes up the remaining 95.5% and 94%, respectively.

Table 10-3: Summary of Active Permitted Takings in Chapleau WQSA

Permit No	Issue Date	Expiry Date	Purpose	Specific Purpose	Source	Source Specifics	Permitted Taking (L/year)	Actual Takings (L/year)
1548-7PMKA4	2009/02/26	2019/03/31	Water Supply	Municipal	Surface Water	Kebsquasheshing River	1,606,000,000	438,843,000
4045-ANAL37 (formerly 5688-A2MJWQ*)	2017/06/20	2027/06/20	Industrial	Other Industrial	Surface Water	Intake 3	73,000,000	0
						Intake 4	73,000,000	0
						Intake 2	73,000,000	0
						Intake 5	73,000,000	1,469,600
						Intake 6	73,000,000	0
						Intake 1	73,000,000	0
7743-AMAH6G	2017/07/04	2022/07/04	Dewatering	Other - Dewatering	Ground Water	Exploration Ramp	27,249,900	912,500,000
98-P-6015	1998/03/31	2018/03/31	Industrial	Power Production	Surface Water	Steam Production	49,778,700	0
						Condenser	16,924,758,000	8,123,145

*Please note that water withdrawals were documented in the WTRS under the expired permit 5688-A2MJWQ; these volumes were not included in the assessment.

Water Supply

The preliminary boundary of the WQSA is outside of a source protection area. None of the source protection studies identified in other WQSAs, including a Tier 1 water budget, have therefore been completed. Permitted water supply takings represent roughly 91.8% of the total volume from permitted takings in the WQSA, by far the largest area for water withdrawal (91.8% surface water). The municipality of Chapleau is the only municipality with a permit to take water, as shown in the table above. Chapleau has obtained municipal water from Kebsquasheshing River since 1975. In 2017, Chapleau extracted approximately 27.3% of their total permitted volume. Given the nature of water use in municipalities, water takings are permitted year round. Chapleau reported takings on 363 days in 2017.

Dewatering

Dewatering permits make up 5.7% of the total volume of permitted water taken in the Chapleau WQSA (5.7% groundwater). Only 1 permit within the WQSA was issued for dewatering. This permit is used for mining exploration activities, specifically dewatering an exploration ramp at the Borden Gold Project. This permit allocates 365 days a year for water extraction; however water taking was only reported on 177 days in 2017. Based on the water taking records, only 3% of the permitted taking was used.

Industrial

Industrial related permitted takings represent approximately 2.55% of the total permitted volume taken in 2017 from within the WQSA (2.55% surface water), between two permit holders. Considering the specific purpose category on these PTTWs, 0.77% of the water taken was for the purpose of other industrial uses (i.e., mining), while 1.7% was for power production. The Borden Gold Project industrial permit (PPTW #4045-ANAL37) extracts water from Lake Borden, near Chapleau, from 6 individual intakes. These sources are described above in Table 10-3.

The second industrial permit holder is Rayonier A.M. Canada (formally Tembec GP). Surface water is taken from the Kebsquasheshing (Chapleau) River for steam production for their facility. They are located on the north side of the river upstream of the Town of Chapleau municipal taking.

The allowable water taking days for industrial permit withdrawals is up to 365 days per year. Actual number of days when water was taken ranged from 0 to 359 days in 2017. Less than 2.34% of the volume permitted for industrial taking was actually utilized taken in 2017.

10.2.6.2 Non-Permitted Takings

The Brunswick House First Nation community is located approximately 7 km southwest of the Borden Gold project site. The community (about 200 people) relies on Borden Lake as the source of its water supply and maintains a water treatment plant in the community. It is estimated that the community uses approximately 130 m^3/day of water based on a conversation with the plant operator (Amec Foster Wheeler, 2016).

Bedrock wells are used in some communities, such as Peterbell, Borden Lake and Minnipuka, whereas other communities around Racine Lake depend on overburden deposits for water withdrawal.

10.2.7 Recommended WQSA Boundaries for Data Review

Given the reliance on surface water, it is recommended that the boundary of the Chapleau WQSA be refined to coincide with the Upper Kapuskasing watershed boundary as shown on Figure 10-11. The Upper Kapuskasing watershed boundary encompasses the majority of the preliminary WQSA boundary and can be considered as representative of other areas in Northern Ontario when it comes to resource sustainability and water quantity management.

10.3 RESOURCE SUSTAINABILITY

10.3.1 Data Review and State of Water Resources

There is very limited information on the sustainability of water resources in the Chapleau WQSA. The following review is based on communication with the MECP Regional Surface Water Specialist and Regional Hydrogeologist, supporting studies for PTTW applications and some regional studies. The key reports relied upon for the evaluation are listed in Table 10-1.

High Use Watershed Classification

As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a Low percent water use based upon both the Average Annual and Summer Low Flow.

10.3.1.1 Groundwater

There is minimal groundwater taking in the Chapleau WQSA. The main taking is for mining exploration activities at the Borden Gold Project with withdrawals permitted throughout the year (PTTW #7743-AMAH6G). The closest private well is not within the predicted zone of influence (ZOI) of dewatering activities (Amec Foster Wheeler, 2016). Some small creeks within the ZOI are expected to experience some reductions in groundwater contributions from bedrock; however, it is unlikely that these reductions will represent a measurable reduction in flow as flow in these features is dominated by surface water runoff events (Amec Foster Wheeler, 2016). On a watershed scale, dewatering will remove water from the Borden Lake watershed and transfer it to the Borden River. The highest steady state dewatering rate of 1,175 m^3/d, when divided by the area of the lake (8,432 ha), represents a less than 1 cm per year reduction in lake level. Lake levels are expected to fully replenish each spring and fall; therefore, this reduction will not have a cumulative effect from year to year (Amec Foster Wheeler, 2016).

10.3.1.2 Surface Water

The Borden Gold Project also has surface water takings associated with exploration drilling activities (PTTW #4045-ANAL37). Water is obtained from Borden Lake at six individual intake locations. The range of flows in the Borden River was evaluated by continuous monitoring of water levels within the Borden River between October 2012 and August 2013. The maximum water-taking limit represents 0.25% of the average Borden River flow (and approximately 8% of the minimum flow) (AECOM, 2014). This is considered conservative, as it assumes that water-taking is 100% consumption, when in practice water that is pumping from the lake will be largely recycled through the drilling process in a closed-loop system. With respect to Borden Lake levels, conservatively assuming zero recharge into Borden Lake, the daily maximum permitted water taking of 200,000 L/day would result in a decrease in water levels of 0.012 mm/day based on the total surface water area of the lake (AECOM, 2014). This minor change in lake level is not expected to impact other surface water intakes from Borden Lake.

There are two permitted surface water takers from the Kebsquasheshing (Chapleau) River: the municipal water supply for Chapleau (PTTW #1548-7PMKA4); and, an industrial plant operated by Rayonier Advanced Materials (formerly Tembec) (PTTW #98-P-6015). There have been no reported concerns regarding water quantity within the Kebsquasheshing River.

10.3.1.3 Water Shortages

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification.

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the Site.

A general review of the OLWR database indicates that a total of 15 Level 1 notifications were sent to the Township of Chapleau between 2000 and August 2018. Instances when notifications were issued occurred in 2001 (one Level 1 notification), 2004 (one Level 1 notification), 2005 (three Level 1 notifications), 2010 (seven Level 1 notifications) and 2011 (three Level 1 notifications). The Township of Chapleau has not issued any Low Water Condition Alerts.

Given no history of Low Water Condition Alerts within the Township of Chapleau, and the absence of any specific trends in the frequency of OLWR notifications, the watershed would not appear to have a history of water scarcity.

10.3.2 Assessment of Sustainability of Water Resources

Considering that much of the Chapleau WQSA, typical of much of the Northern Region Ontario, is characterized by thin soils over bedrock, it can be expected that groundwater-surface water interactions are spatially variable depending on the nature and thickness of overburden materials and bedrock weathering and fracturing. However, no studies have been identified to verify groundwater-surface water interactions or their potential influence on surface water baseflow for the Chapleau WQSA.

10.3.2.1 Climate Change

Based on projected changes in climate by 2050s (relative to 1986-2005) under the Business as Usual Emission Scenario, precipitation is predicted to increase by up to 35% in winter in Northern Ontario (compared to an average annual increase of 9% province-wide). Northern Ontario is also expected to experience the greatest warming compared to the rest of the province, in particular during winter months when more precipitation will likely fall as rain. While the exact impact has not been investigated for the Chapleau WQSA, these changes to climate will probably influence water resources, in particular possible groundwater-surface water interactions resulting from the typically thin soils present across the WQSA. For example, the intensity, timing and duration of frost and snow melt periods can be expected to affect groundwater recharge and/or surface water runoff as a result of predicted climate change. A more detailed climate change assessment, utilizing the Chapleau WQSA as a pilot area, would provide a better understanding of potential impacts on surface water supplies and EFNs.

10.3.2.2 Population Growth

Population growth is not expected to be a stress on water resources in the Chapleau WQSA. The population of Chapleau decreased by 4.6% between 2011 and 2016 (StatsCan).

10.3.2.3 Cumulative Effects

Based on the information reviewed as part of this study, no evidence was identified of water shortages or interference between permitted and non-permitted users in the Chapleau WQSA.

There are currently only four active permitted takings within the Chapleau WQSA (see Section 10.2.6.1 and Figure 10-10). Water uses under the permitted takings are for three main purposes: water supply, industrial and dewatering uses. Groundwater and surface water takings represent 4.5% and 95.5%, respectively, of the permitted volume within the WQSA in 2017, and 6% and 94% of the reported water takings in 2017, respectively.

Based on the information reviewed as part of this study, no direct evidence of impacts to the natural functions of the ecosystem was identified. Environmental flow needs have not been considered extensively in the Chapleau WQSA.

No PGMN wells are present in the Chapleau WQSA; therefore no information is available about any observable, regional downward trends in hydraulic head.

Review of the OLWR database indicates that a total of 15 Level 1 notifications were sent to the Township of Chapleau between 2000 and August 2018. However, the Township of Chapleau does not appear to have ever declared any Low Water Condition Alerts. Given no history of Low Water Condition Alerts within the Township of Chapleau, and the absence of any specific trends in the frequency of OLWR notifications, the watershed would not appear to have a history of water scarcity.

The Chapleau WQSA does not appear to be in an area where cumulative effects may potentially become a concern in the future for surface or groundwater resources. As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map) for tertiary watersheds, the WQSA lies within a tertiary watershed that is classified as having a Low percent water use based upon both the Average Annual and Summer Low Flow (Section 10.3.1). In addition, population growth is not expected to result in stress to water resources; with the population of Chapleau having decreased by 4.6% between 2011 and 2016 (Section 10.3.2.2). As the WQSA is located outside of any source protection areas, no source protection studies, such as Tier 1 water budgets, have been completed within the Chapleau WQSA (Section 10.2.6.1).

Due to the remote nature of the Chapleau WQSA, the cumulative impacts of multiple takers is not a significant concern, however in the past, one permitted user, Tembec was required to demonstrate that they would not impact the Chapleau municipal supply as a result of their takings. During the PTTW renewal process, Tembec (now Rayonier Advanced Materials) was ask to demonstrate that their surface water taking did not impact the downstream Chapleau municipal water source. Based on the size of the watershed, the associated river flows, the water taking volumes, and a lack of operational concerns (no interference complaints) during the several years that both takings have been occurring, interference between the two sources is not expected (Pinchin, 2017).

Numerical modelling and predictions of future climate scenarios have inherent uncertainties associated with them, however, there is likely no further risk that may arise from not conducting a more robust assessment of cumulative effects.

10.3.2.4 Environmental Flow Needs

Environmental Flow Needs (EFN) has not been considered extensively in the Chapleau WQSA. This is discussed at greater detail in Section 10.5.

10.3.3 Conclusions

Based on the information reviewed, no stress concerns were identified for the sustainability of regional water quantity resources under current climate and water use conditions and population growth is not expected to be a stress on water resources in the future either. A more detailed Climate Change assessment, utilizing the Chapleau WQSA as a pilot area, would provide a better understanding of potential impacts on surface water supplies and EFNs.

In summary, the sustainability of the water resources in the Chapleau WQSA under current and future conditions is as follows:

<u>Groundwater Under Current Conditions</u>

- **Regional Scale –** the groundwater resources are sustainable under current conditions based on the fact that there are minimal groundwater takings and no water shortages have been reported.
- **Local Scale** – the groundwater resources are sustainable under current conditions based on the fact that there are minimal groundwater takings and no water shortages have been reported.

Groundwater Under Future Conditions

- **Regional Scale** – the groundwater resources are sustainable under future conditions based on a declining population and projected climate change conditions.
- **Local Scale** – the groundwater resources are sustainable under future conditions based on a declining population and projected climate change conditions.

Surface Water Under Current Conditions

- **Regional Scale –** the surface water resources are sustainable under current conditions based on there being no history of Low Water Condition Alerts within the Township of Chapleau, and the absence of any specific trends in the frequency of OLWR notifications.
- **Local Scale –** the surface water resources are sustainable under current conditions based on there being no history of Low Water Condition Alerts within the Township of Chapleau, and the absence of any specific trends in the frequency of OLWR notifications.

Surface Water Under Future Conditions

- **Regional Scale** – the surface water resources are sustainable under future conditions based on a declining population and projected climate change conditions.
- **Local Scale** – the surface water resources are sustainable under future conditions based on a declining population and projected climate change conditions.

10.4 WATER MANAGEMENT APPROACHES AND CHALLENGES

A combination of available reports and communication with those knowledgeable of local water use/issues in the Chapleau area (Table 3.1) were used to summarize current approaches to water management and current challenges in the WQSA; evaluate how water management concerns are considered in water management decisions; summarize how natural function/ecological needs, adaptive/alternative management, municipal growth, drought management, and climate change are considered in water management decisions; and determine if additional water monitoring data would strengthen water management decisions. Also, to identify in Section 10.6 of this report, what, if any, new management tools are needed in Chapleau WQSA beyond what is currently enabled or applied by the province along with a discussion of advantages and challenges of possible approaches. Water managers from the Town of Chapleau, Ontario Clean Water Agency (OCWA) and the MECP were contacted to provide input to this study. Responses were received from the OCWA, and MECP regional surface water specialist and regional hydrogeologist.

Current Approaches

The approach for managing water quantity in the Chapleau WQSA relies on the policies of the PTTW program (O. Reg. 387/04). MECP's Northern regional office manages the PTTW program in the Chapleau area.

As part of the Category 3 PTTW application for the Borden Gold groundwater taking (the only active groundwater PTTW in the Chapleau WQSA), a detailed hydrogeological report was submitted which included the following:

- Results and interpretation of hydrological testing including packer testing, slug tests and short-term pumping tests;
- Numerical groundwater flow modelling;
- Predicted zone of influence (ZOI) as a result of dewatering; and,
- An evaluation of impacts to other water users, surface water features and habitat.

In order to confirm the impacts related to the proposed taking are consistent with the predictions made in the hydrogeological report, and to provide groundwater level monitoring data that might be used to support future updates of the groundwater model for the Borden Gold Project, a comprehensive monitoring program was developed for the site including:

- Groundwater level monitoring of site monitoring wells;
- Water levels of Borden River;
- Mini-piezometers near unnamed Tributary 1 and Tributary 2; and,
- Water levels in Borden Lake.

An interpretation of the monitoring data is required on an annual basis by the PTTW to determine the impact of mining related dewatering on water levels and flows, and assess the need for flow supplementation. The company was also required to develop trigger values that when exceeded will trigger the need to implement a flow supplementation program.

Water conservation measures have been incorporated where possible into operations with active surface water PTTWs. For example, water used from Borden Lake for exploration drilling at the Borden Gold Project, will be captured and pumped to a sediment filter shack where it will progress through a hopper and a series of settling tanks to separate the sediment from the water and the filtered water will be pumped back to be used again in the drilling process. Therefore, it is a predominantly closed-loop system with surface water drawn from the lake as a make-up source to supplement and refresh water in the recycling process as opposed to a continuous pumping activity. At the Rayonier Advanced Materials site, all water is returned to the river after being used for industrial cooling purposes.

It was not possible to consult water managers from the First Nations Communities in the Chapleau WQSA as part of the current study due to the time available for the study and the timing of the government change in Ontario. In future, they should be engaged to obtain information about the state and management of the water resources in the WQSA.

Challenges

The following water management challenges were identified through the review of existing documentation and through communication with the regional surface water specialist and regional hydrogeologist with the MECP:

- Limited hydrologic and hydrogeological information and data in general for the WQSA;
- No clear guidance is available outlining MECP's requirement for minimum EFNs and other related flow criteria (e.g. ramping rates); and
- Limited guidance on how to address the issues associated with large hydropower facilities.

Evaluation of how water management concerns are considered in water management decisions

Due to the limited amount of data and limited water quantity management issues in the WQSA, water management decisions typically only rely on data collected by PTTW applicants.

Consideration of key topics in water management decisions

Local water managers have indicated that there is limited to no guidance on MECP's requirement for minimum Environmental Flow Needs and other related flow criteria (e.g. ramping rates). Although the ministry's mandate includes maintaining the natural function of aquatic ecosystems, there is not clear guidance on what constitutes the minimum flows required to achieve this protection. As such, minimum flows associated with certain takings are considered on a case by case basis, often relying on guidance obtained from MNRF or DFO (see references). Despite this, there is often disagreement between the MECP, MNRF, and DFO on the requirements for minimum environmental flows that are protective of the natural functions of aquatic ecosystems.

Given that large waterpower facilities are generally unique to Northern Region, little guidance has been provided to date on how to address the issues associated with these large water takings from a provincial perspective, or to the minimum flow requirements associated with them.

Possible New or Enhanced Approaches to Address Water Management Concerns Identified by Water Managers

No new or enhanced approaches to address water management challenges were identified due to the fact that there were limited to no water quantity challenges noted within the Chapleau WQSA.

10.5 IDENTIFIED DATA GAPS

Presently there is not a significant reliance on groundwater resources within the Chapleau WQSA. Should there be increased reliance on this resource in the future, additional information on regional hydrogeology, and installation of a PGMN well in the area may be warranted.

Similarly, there are currently no reported stresses on surface water resources in the Chapleau WQSA. Should issues arise in the future, such as low water conditions due to resource development or climate change, additional resources to monitor low flow conditions, such as additional HYDAT stations, may be necessary.

Local water managers have indicated that there is limited guidance on MECP's requirement for minimum EFNs and other related flow criteria. This has led to inconsistencies between the MECP, MNRF, and DFO on the requirements for minimum environmental flows that are protective of the natural functions of aquatic ecosystems.

It was not possible to consult First Nations communities within the Chapleau WQSA as part of the current study due to the time available for the study and the timing of the government change in Ontario. In future, they should be engaged to identify any concerns they may have with respect to water quantity data needed to manage water resources in this WQSA.

10.6 RECOMMENDATIONS

Provincial guidance should be developed in regards to the following key issues potentially impacting future water quantity in the Chapleau WQSA and most of them to northern Ontario, in general:

- Cumulative effects assessments of multiple or competing water takings; and,
- Ecological flow requirements to ensure the protection of the natural functions of aquatic ecosystems.

The Province should consider expanding the PGMN to cover areas in the north with population centres and municipal water supplies. A streamflow gauge should also be considered for the Chapleau River to confirm that the municipal water taking is not having a negative impact on water levels. Establishing baseline groundwater and surface water levels in the area will make it possible to evaluate future potential effects of Climate Change.

A more detailed Climate Change assessment, utilizing the Chapleau WQSA as a pilot area, would provide a better understanding of potential impacts on surface water supplies and EFNs.

It is BluMetric's conclusion that detailed source protection assessments are not required for the Chapleau WQSA at this time given that there is not a significant reliance on groundwater and there are no reported stresses on surface water resources. This conclusion should be reviewed if a detailed Climate Change assessment is conducted.

Water Managers from the First Nations communities in the Chapleau WQSA should be engaged regarding the state of water resources, data needs and management of water quantity within the WQSA and asked for their input regarding current and future water management practices.

10.7 REFERENCES

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11 SUMMARY – SUSTAINABILITY, GAPS AND RECOMMENDATIONS

The seven WQSA are diverse in terms of scale, amount of available information/data, water resources of concern and reported water quantity issues. For example, two of the WQSAs are largely at a municipal/urban scale (Orangeville and Guelph) with a significant amount and spatial coverage of relevant information available for review through Source Water Protection. Four WQSAs are primarily rural settings (Norfolk Sand Plain, Innisfil, Whitemans Creek and Quinte) with varying amounts and spatial coverage of relevant information available for review and one is large, largely remote, sparsely populated, northern setting (Chapleau) with limited to no relevant information available for review. The areas range in size from 140 km^2 (Orangeville) to 6,600 km^2 (Chapleau) and one WQSA (Guelph) includes watersheds that lie within the jurisdiction of four different Conservation Authorities while another WQSA (Chapleau) is in an area without a Conservation Authority. Two WQSAs (Guelph and Orangeville) had groundwater identified in the RFB as being the water resource of concern, four WQSAs (Norfolk Sand Plain, Whitemans Creek, Quinte and Chapleau) had both surface water and groundwater identified in the RFB as being the water resources of concern and one WQSA (Innisfil) had surface water identified in the RFB as being the water resource of concern. The majority, five of seven WQSA are located in tertiary watersheds classified as either High or Medium Average Annual Percent Water Use Watersheds while six out of seven are located in tertiary watersheds classified as either High or Medium Summer Percent Water Use Watershed as defined by O. Reg. 387/04 Water Taking and Transfer. Two WQSA (Norfolk Sand Plain and Whitemans Creek) are located in tertiary watersheds classified as both High Average Annual Percent and Summer Percent Water Use Watersheds.

The purpose of this final section is to summarize: the overall conclusions about sustainability of the water resources, based on the findings of the seven WQSA assessments, and the gaps and recommendations that apply more broadly based on BluMetric's assessment and review process.

Conclusions regarding the sustainability of the water resource in each WQSA and the management and data gaps and recommendations identified for each WQSA are reported in the WQSA specific sections.

Table 11-1 (Appendix D) provides a summary of the assessment of each WQSA including general information, resource sustainability now and in the future, water management, gaps and recommendations associated with each WQSA. Table 11-2 (Appendix D) provides a summary of the assessment of the three WBSAs in the Guelph WQSA: Aquaterra (Hillsburgh) (Appendix A), and Nestlé (Erin) (Appendix B) and Nestlé (Aberfoyle) (Section 4, Appendix C).

The content of Table 11-1 and Table 11-2 is based on the review and analysis contained in this report, and as such, should only be read and used in conjunction with the relevant WQSA chapters and appendices.

11.1 SUMMARY OF ASSESSMENT OF SUSTAINABILITY OF WATER RESOURCES

Under current climate and water use conditions, based on this review, Ontario's groundwater and surface water resources in the seven Water Quantity Areas appear to be sustainable with minor exceptions. Local concerns related to drought and/or conflicting seasonal usage is observed in some watersheds and where groundwater supply is naturally limited. In the longer term, continued science and enhanced management may be required in some areas to ensure water resources can meet the needs of the environment and future generations, in light of growth, land use changes, drought and adaptation to a changing climate.

The following paragraphs provide some commonalties related to areas where there is some concern or uncertainty. It is important to note that because Ontario's PTTW program focuses on assessment at the site/ local scale it is easiest to conclude that water resources in the WQSAs are considered largely sustainable on a local scale under current conditions. Source Protection water budgets and models provide information that supports a more regional approach to assessing current sustainability. Future sustainability conditions (i.e., growth and/or effects of climate change) is largely made on previous assessments related to municipal supplies under Source Water Protection (e.g. Guelph and Orangeville) and/or modelling potential impacts from Climate Change (e.g. Quinte).

Current stainability concerns are primarily surface water related and include Whitemans Creek and local reaches in the Norfolk Sand Plain and Innisfil WQSAs. These are typically due to over allocation of surface water resources under significant drought conditions (i.e. summer months) in WQSAs where a significant number of PTTWs have been issued for agricultural irrigation.

Without restrictions or interventions through local collaborative efforts, these local scale surface water reaches may not currently be sustainable.

Current groundwater sustainability concerns are limited to local scale shallower groundwater resources which tend to be closely linked to surface water bodies. This is observed in Quinte WQSA, where there is a lack of intrinsic resilience to drought conditions, and locally in shallow groundwater in the Norfolk Sand Plain (Norfolk Sand Plain WQSA and the southern part of the Whitemans Creek WQSA).

In WQSAs where only part of the area has been assessed as part of a municipal supply (e.g. Norfolk Sand Plain and Whitemans Creek), there is uncertainty associated with determining the future sustainability of the groundwater and surface water resources on a regional scale.

Recent assessments in the vicinities of the Innisfil and Quinte WQSAs helped to support the future sustainability assessments for these areas. In the Innisfil WQSA case, the NVCA, with provincial funding, commissioned a pilot project to develop a proactive drought management plan which took into consideration climate change and ecosystem health and flow needs in the Innisfil WQSA. Similarly, Quinte WQSA has recently (2014) modelled the impact of climate change on a regional scale and determined that both groundwater and surface water are largely unsustainable under future conditions and that it is largely related to a general lack of intrinsic resiliency to extreme drought conditions.

11.2 GENERAL GAPS IN WATER QUANTITY MANAGEMENT POLICY, PROGRAM OR SCIENCE IN ONTARIO

Ontario's water resource science, assessment approaches and practices are generally consistent with best science and best practices in other jurisdictions, as documented in BluMetric's Task 1 report titled Management Framework: Science Review Report (2018) and the Task 3 report titled "Water Quantity Management Framework: Water Managers Workshops Report (2018). However, as identified through these reviews there is always room for improvement.

Information gaps and recommendations for potential enhancements to water quantity management in Ontario as determined through the sustainability assessments of the water resources in the seven WQSAs are summarized below and in Section 9.3 respectively. These are in addition to the gaps that are more specific to each WQSA, as discussed in Sections 4 to 10.

- MECP currently relies on shortage complaints as a measure of sustainability, but this is not an effective tool, particularly when people do not necessarily report all shortage issues, in particular with respect to surface water resources to the ministry.
- The process of assessing the sustainability of the water resources in the WQSAs was significantly challenged by the fact that data and information resides with a significant number of different agencies. In addition, the quality and timeliness of the data varied between WQSAs.
- The PTTW program has limited guidance on what specific triggers are needed for regional scale assessment and management approaches and there is limited to no direction or guidance provided for a method to undertake a regional assessment such as for Cumulative Effects or for the development of a management strategy beyond a Cumulative Effects assessment. For example, when considering how to address Cumulative Effects on a regional scale, there is no guidance on how to determine the appropriate assessment scale or how to establish what the Environmental Flow Needs (EFN) should be. BluMetric notes that the data needed to support EFN assessments are often available from other agencies (e.g. Conservation Authorities) but may not be packaged in a manner that would easily support undertaking such assessments.
- The OLWR program primarily reflects shortages with respect to surface water resources. However, there is uncertainty among water managers as to what extent water managers can determine locally appropriate declarations and reductions. For example, when does a Level 1 and Level 2 alert or declaration pertains to surface water only and when may it apply to both surface water and shallow groundwater. Often voluntary or mandatory reductions do not identify which takings should be reduced but rather that all water takings should be reduced.

- WTRS data is self-reported and may be estimated based on pump run time and capacity. This is typical of most agricultural PTTWs in the province. In addition, the current use of the source type "Groundwater and Surface water" in the WTRS database makes it difficult to query the WTRS to determine total surface water takings in watersheds. This is important in areas with a significant number of permits classified as groundwater and surface water permits. The uncertainty of this data represents a gap in understanding water taking demand and a gap in being able to differentiate and quantify surface water takings and/or groundwater takings.

11.3 RECOMMENDATIONS TO ENHANCE WATER QUANTITY MANAGEMENT IN ONTARIO

Recommendations for potential enhancements to water quantity management in Ontario as determined through the sustainability assessments of the water resources in the seven WQSAs are summarized below. These are in addition to the recommendations that are more specific to each WQSA, as discussed in Sections 4 to 10.

- To address the challenges posed by multiple datasets hosted at multiple agencies, efforts should be made to centralize and present the data in usable forms for assessment purposes through a universally accessible portal. For example, static water levels within key regional aquifers, flow in priority creeks and rivers, climate data, reported water takings and well records could be shared online through aggregate analysis.
- Data that can support EFN assessments should be more generally accessible and more broadly shared between agencies and the ministry for consideration in the preparation and review of PTTW applications. This type of information is needed when considering what conditions may need to be required in a PTTW, e.g. the development of trigger levels and consideration of how often they should be reviewed. Such conditions could be established and used in the development of an adaptive management plan.
- Climate Change assessments should be reviewed with updated regional modelling as it becomes available to provide improved projections on potential impacts to water resources.

Recommendations for all WBSAs

Based on the assessment of water takings at bottling facilities assessed in BluMetric's Task 7 report titled Water Bottling Study Areas Report (2019) and this report, recommendations relating to all of the water bottling takings reviewed, and in fact could pertain to any taking, not just those related to water bottling, were identified:

1. The presentation of hydrographs with long-term water level data (e.g. groundwater level and surface water level data collected over many years) was identified in the present study and in BluMetric Task 1 report (2018) as the best available science in assessing whether steady state conditions exist and for addressing sustainability of the water taking.
2. During the completion of the file review, it was apparent that most documentation for the WBSAs, and therefore it can be supposed likely most permit files, remains in hard copy only. Hard copy documentation storage and file management poses a number of challenges and risks. Challenges are associated with access to files that get moved from desk to desk. Risks are associated with the potential misplacement of files and the potential loss of hard copy documents to fire or other forms of damage. Consequently, transitioning file management to an e-based system is recommended.
3. The WWIS should be cross-referenced against ground-truthed data from water well surveys (where available), and updated/revised where applicable.

Opportunities for Improving Provincial Instruments and Tools

OLWR Program Database

The OLWR Program uses high quality, real time surface water monitoring data collected from the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. However, the program datasets are poorly maintained and therefore the intrinsic value of the raw data is lost which greatly limits further analysis beyond the originally intended purpose of the OLWR program. It is recommended that the OLWR Program database be reviewed to identify improvements that will enhance the use of OLWR 'Notifications' as a tool for assessing trends in the availability of surface water, and possibly shallow groundwater resources. Developing and implementing shallow groundwater triggers into the OLWR program would provide further enhancement of the program by providing a monthly status of shallow groundwater levels within the watershed. Timely release of the integrated data would allow for timely response to Alert conditions.

PGMN Database

It was noted that data records for many PGMN wells have not been updated in many years (some wells not since 2010). It is understood that the current method of data management requires multiple tiers of data review before data is released. It is also understood that the smaller CAs generally do not have the resources to maintain the PGMN network stations and complete a timely review of the PGMN data. The current system of data management for the PGMN network should be reviewed to create a system that will ensure the timely release of data.

PTTW Program

The PTTW program lacks guidance on how to assess Cumulative Effects in a regional context. While there is some provincial level guidance on the need to consider Cumulative Effects and Environmental Flow Needs (EFN), the PTTW program itself does not currently provide adequate guidance for internal staff and the public for evaluating Cumulative Effects and EFN. Providing additional technical guidance on how to conduct Cumulative Effects assessments and how to study and establish EFN would be beneficial.

WTRS Database

The self-reported actual water taking data that was collected in Ontario since 2006 should be made universally available. WTRS should be updated to include all information from Table A of each individual PTTW. Occasional audits of the reported takings would reduce the uncertainty associated with self-reported data. The inclusion of this additional information would help clarify which source(s) on each PTTW is/are groundwater or surface water. The current use of the source type "Groundwater and Surface water" in the WTRS database makes it difficult to query the WTRS to determine total surface water takings in watersheds. This is important in areas with a significant number of permits classified as groundwater and surface water permits.

High Use Watersheds

High Use Watersheds, as originally recommended, should be regularly re-assessed to account for changing conditions including Climate Change. The original approach for developing the High Use Watershed Maps used a GIS based low flow estimation tool (OFAT) and information from existing PTTWs to estimate the percent water use for each tertiary watershed across the province. This simplified water budget was useful at the time as a screening tool to evaluate whether further development of water resources should be allowed in the watersheds. However, the maps require updating as the stream flow data used in the analysis is now more than 30 years old and did not include stream gauges that have been established since the late 1980's. Methods for calculating and estimating low flows and GIS capabilities have also improved and need to be updated. To update the High Use Watershed Map, information on key low flow stream indicators such as annual and monthly flow duration rates and extreme/low flows of various recurrence intervals is needed. In addition to supporting a reassessment of the High Use Watershed maps, this updated information could be used to support a range of water resources management decisions from water taking proposals to assessing the effects of droughts and climate change effects on water bodies.

Information and Data Management

During the completion of the review and sustainability assessments of the different WQSAs, it was apparent that the necessary information and data resides in a number of different agencies, ministries, branches or divisions. In addition, the data quality and currency varied significantly. An enhanced level of coordination between agencies through the use of an on-line portal where all applicable data and regional watershed and subwatershed reports can be stored would assist in meeting this gap/ challenge.

Northern Ontario

Recommendations identified in Section 10.6 of this report (Chapleau WQSA), should be considered for addressing issues potentially impacting future water quantity in most of the rest of northern Ontario.

Respectfully submitted,

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12 GENERAL REFERENCES

Key references were provided at the end of each of the WQSA sections (Sections 4 to 10) and are not reproduced here. Other documents referenced in other parts of this report are provided below.

AquaResource Inc., 2005. A Method for Assessing Water Use in Ontario Watersheds.

BluMetric Environmental Inc., 2018. Assessment of Water Resources to Support a Review of Ontario's Water Quantity Management Framework: Water Managers Workshops Report.

BluMetric Environmental Inc., 2019. A Review of Ontario's Water Quantity Management Framework – Water Bottling Study Areas Report

Ministry of the Environment, Conservation and Parks (MECP), 2017: Assessment of Water Resources to Support a Review of Ontario's Water Quantity Management Framework, Request for Bids (RFB) #6792.

APPENDIX A

Main Figures

APPENDIX A posted separately for internet access in 4 sections.

APPENDIX A - PART 1

- FIGURES for Guelph – Centre Wellington, Orangeville and Norfolk Sand Plain Water Quantity Study Areas

APPENDIX A - PART 2

- FIGURES for Innisfil And Whitemans Creek Water Quantity Study Areas

APPENDIX A - PART 3

- FIGURES for Quinte Water Quantity Study Area

APPENDIX A - PART 4

- FIGURES for Chapleau Water Quantity Study Area

(Inserted by the Ministry of the Environment and Climate Change, June 2020)

APPENDIX B

Correspondence with Local Water Managers

Appendix B has been removed from the posted report in accordance with privacy requirements.

(Inserted by the Ministry of the Environment, Conservation and Parks, June 2020)

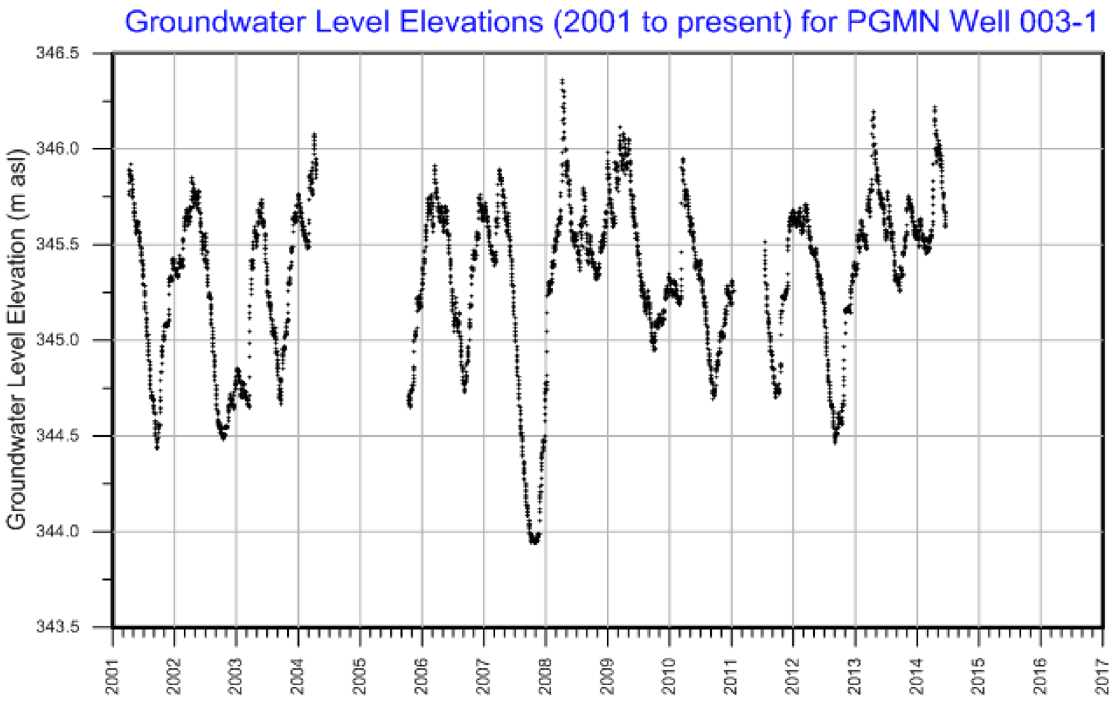
APPENDIX C

Provincial Groundwater Monitoring Network (PGMN) Hydrographs

PGMN Well Hydrographs

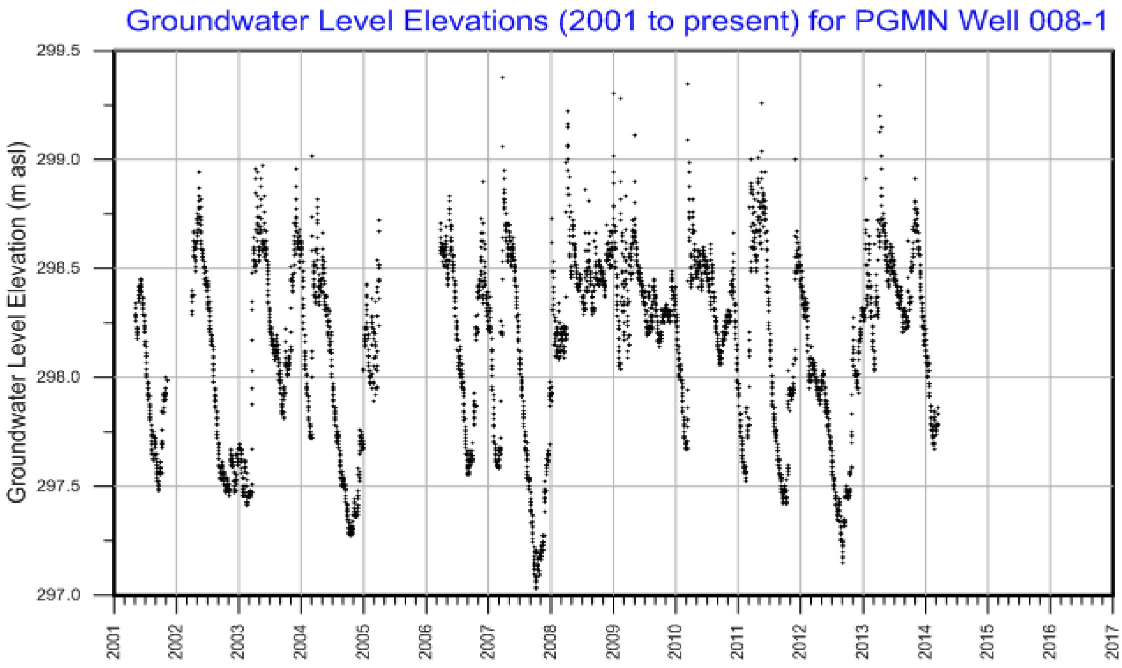
Chapter 4 Guelph-Wellington

W0000003-1


Groundwater Level Elevations (2001 to present) for PGMN Well 003-1

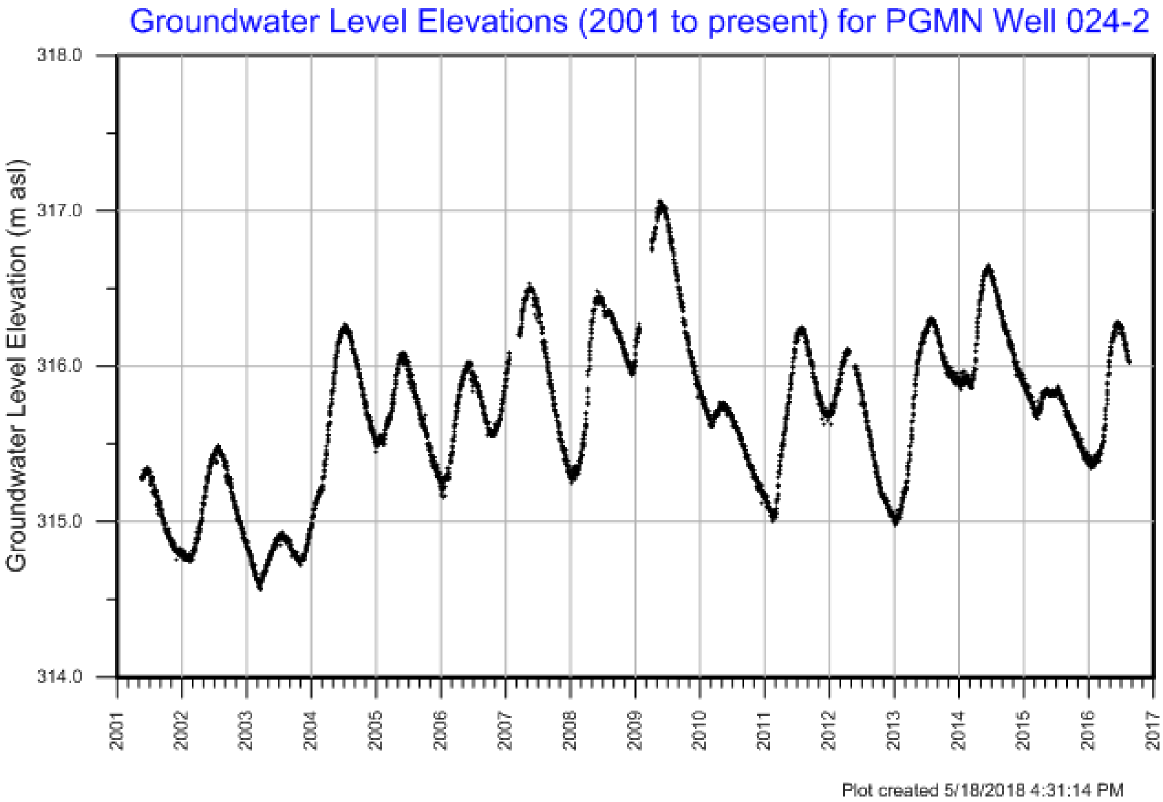
Plot created 5/18/2018 4:27:26 PM

W0000008-1


Groundwater Level Elevations (2001 to present) for PGMN Well 008-1

Plot created 5/18/2018 4:28:23 PM

W0000024-2



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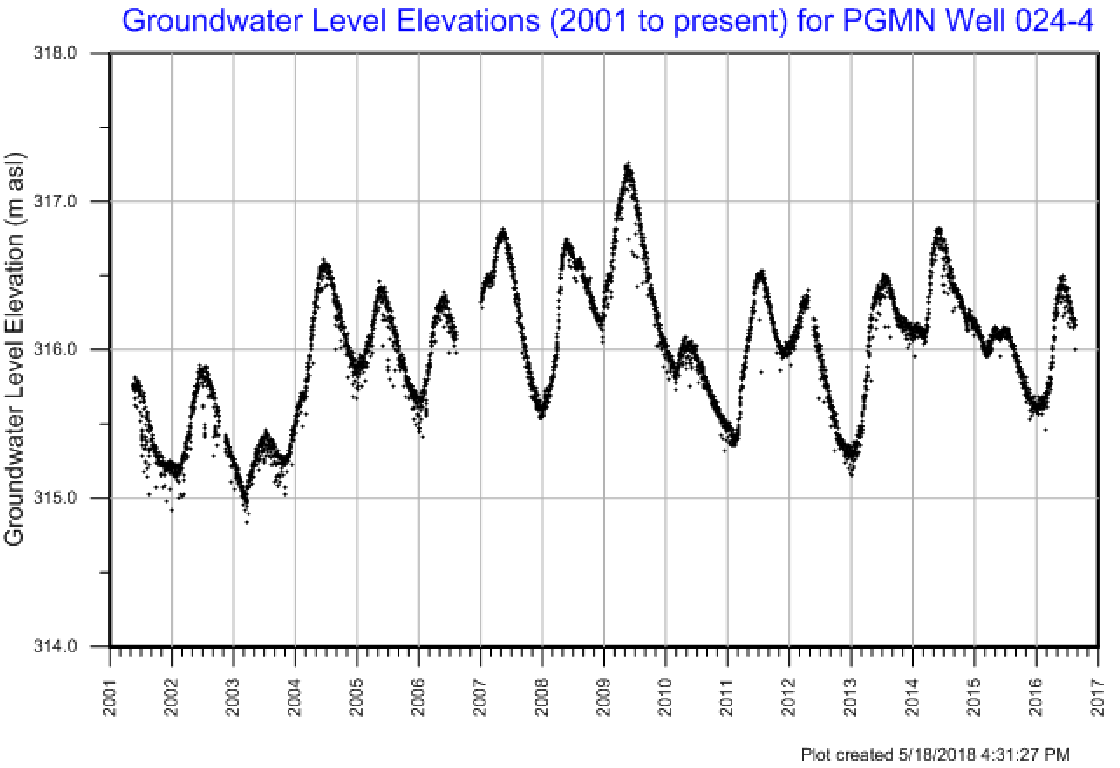

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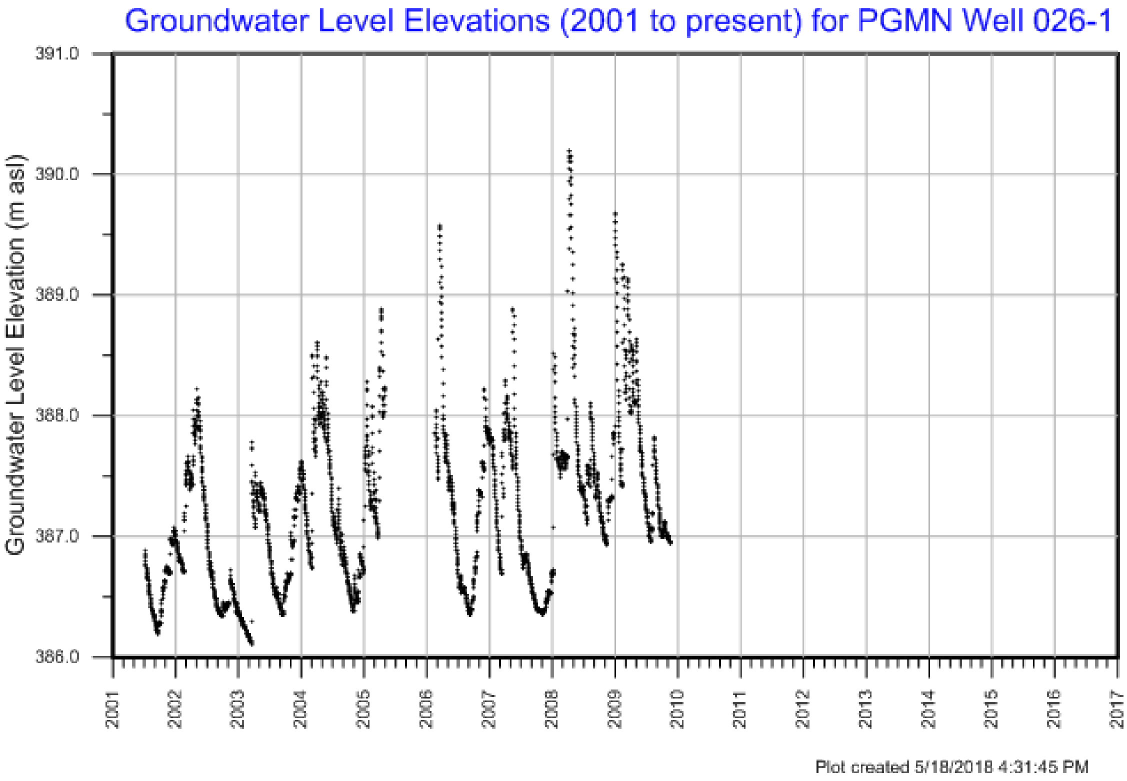

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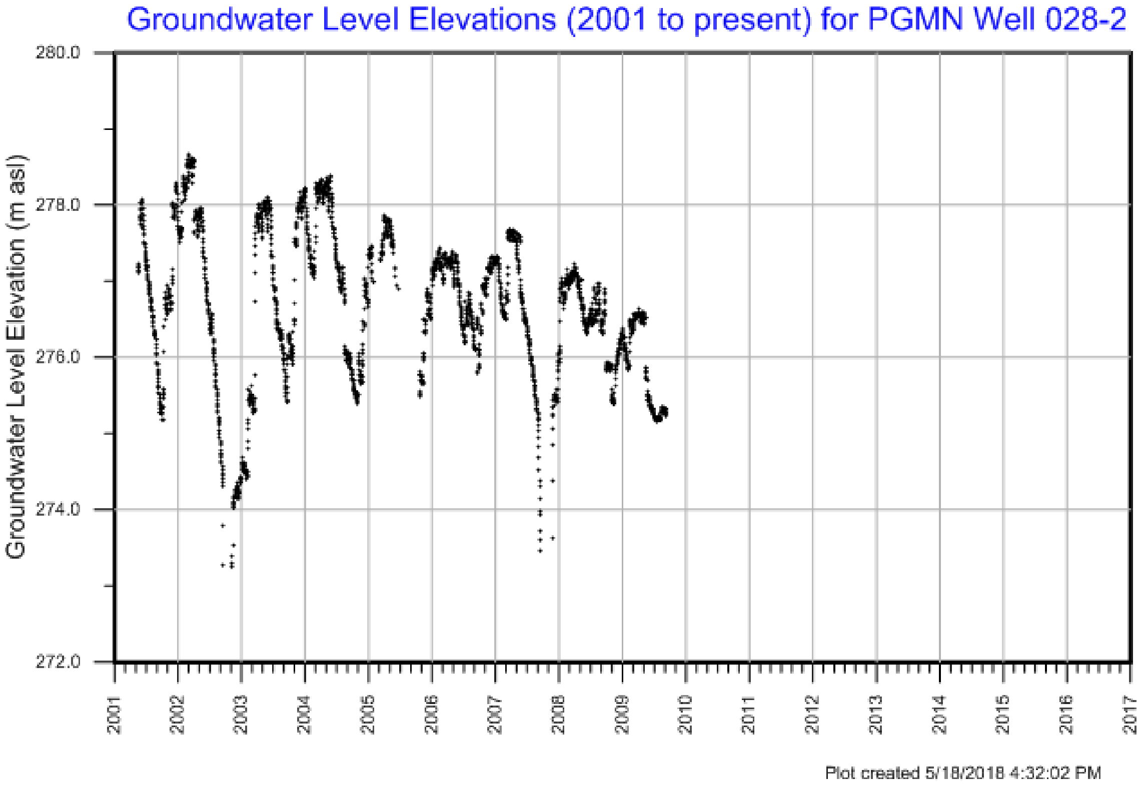

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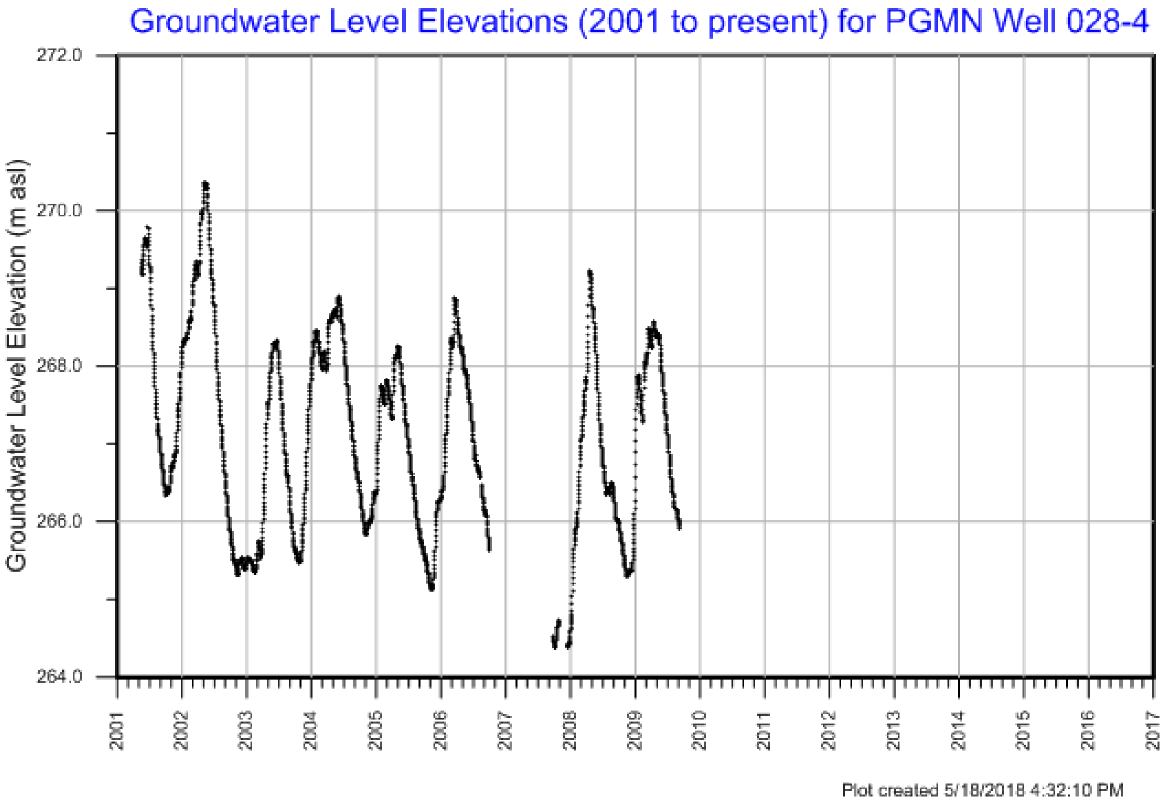

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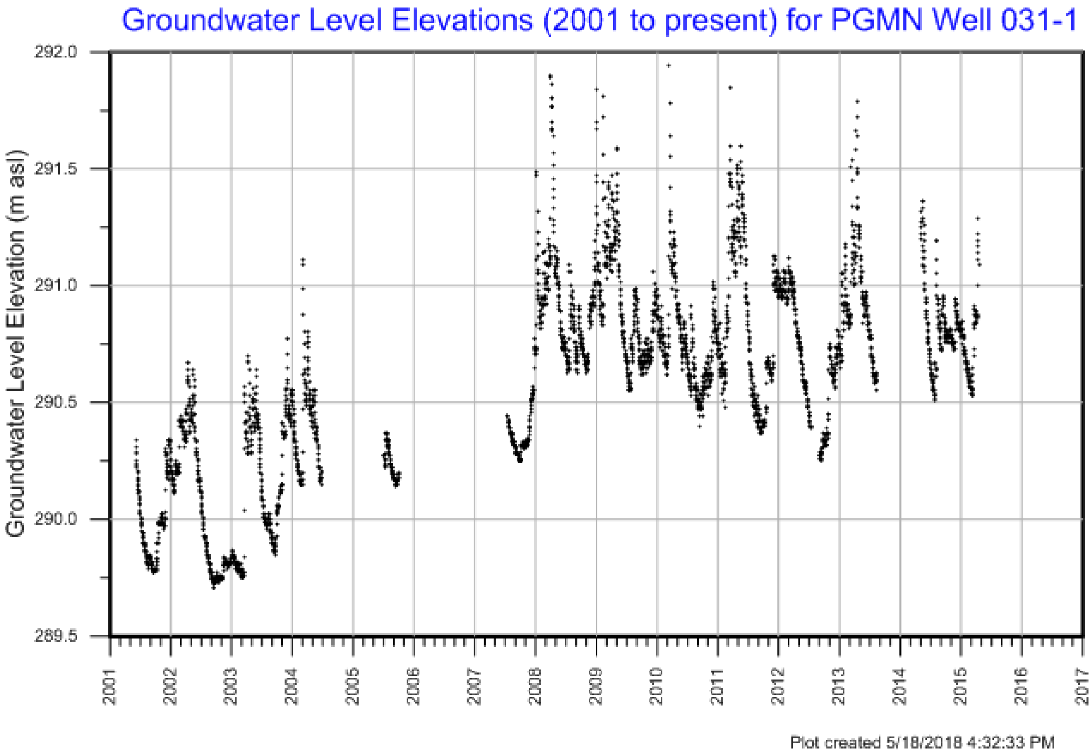

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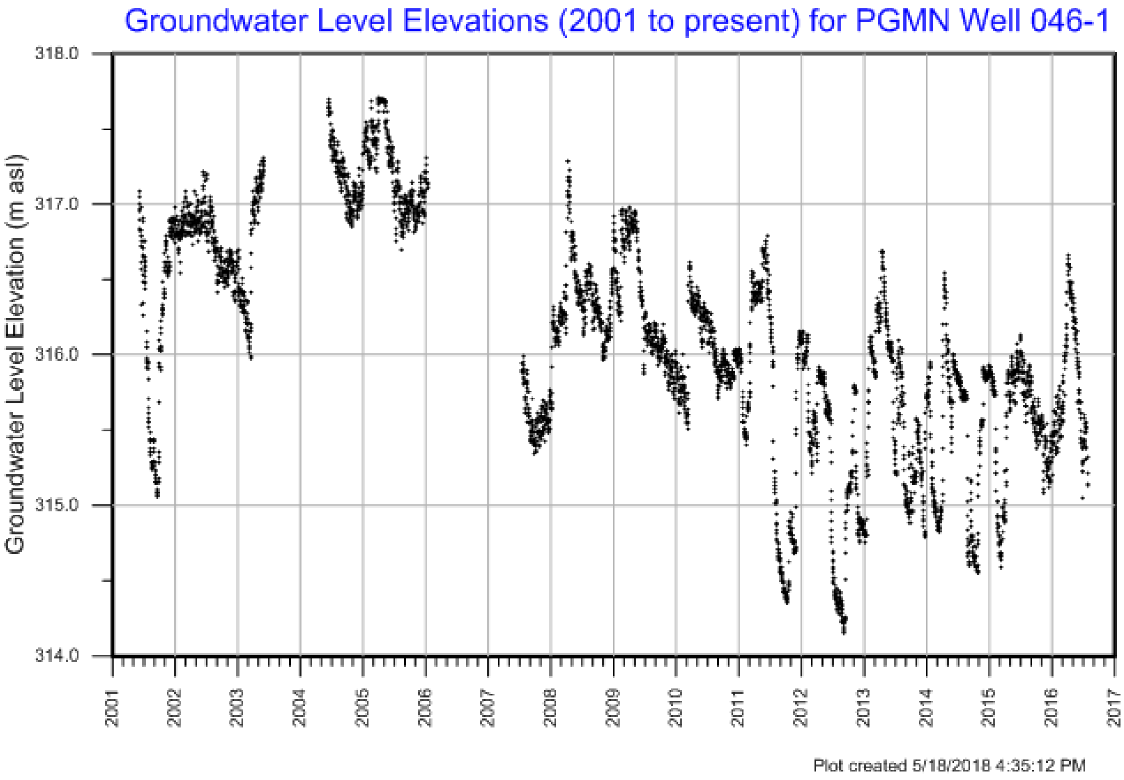

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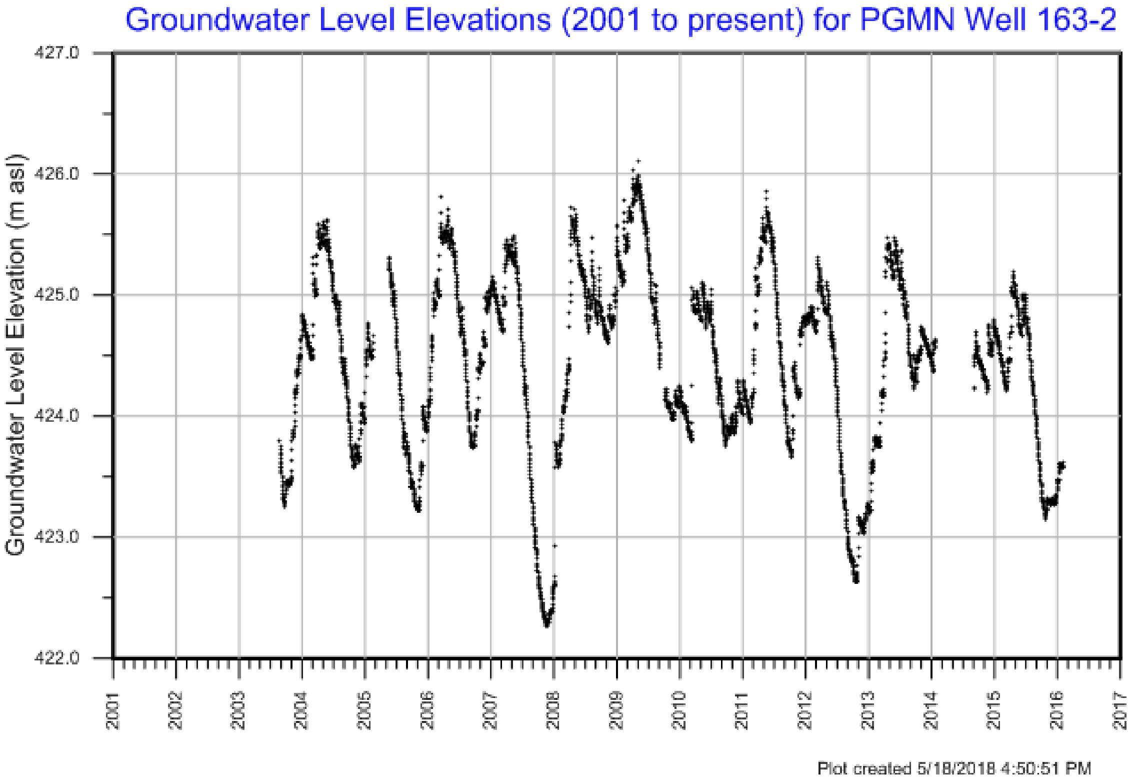

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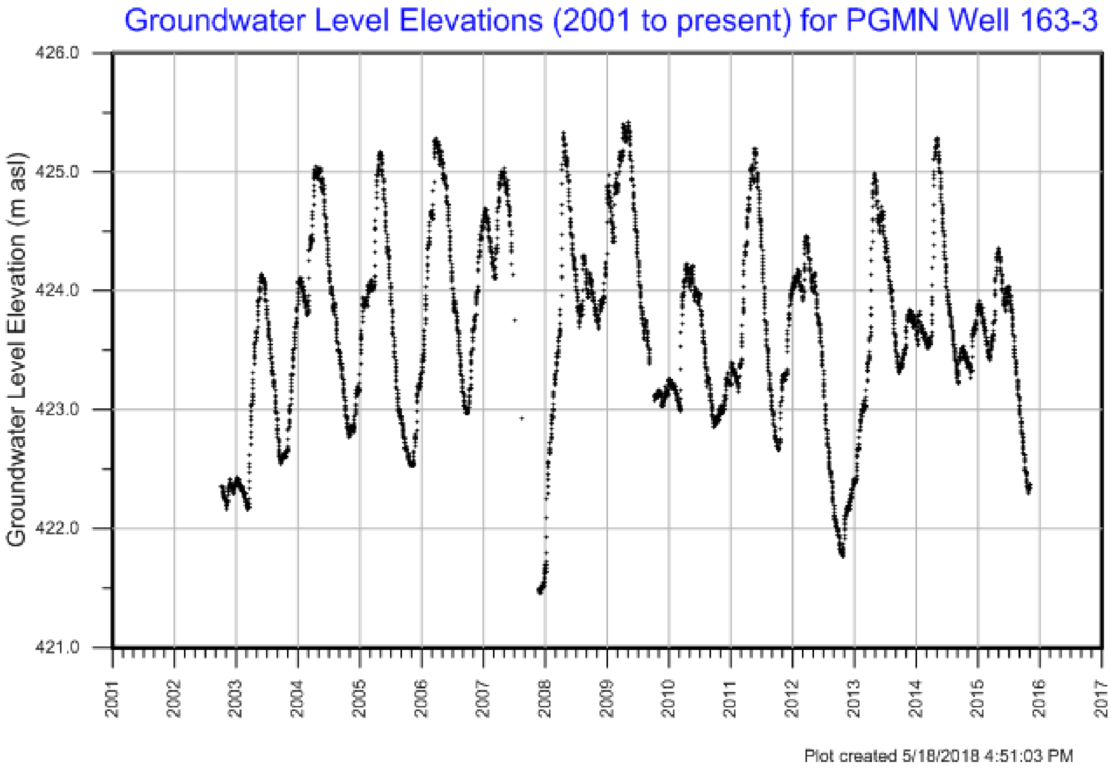

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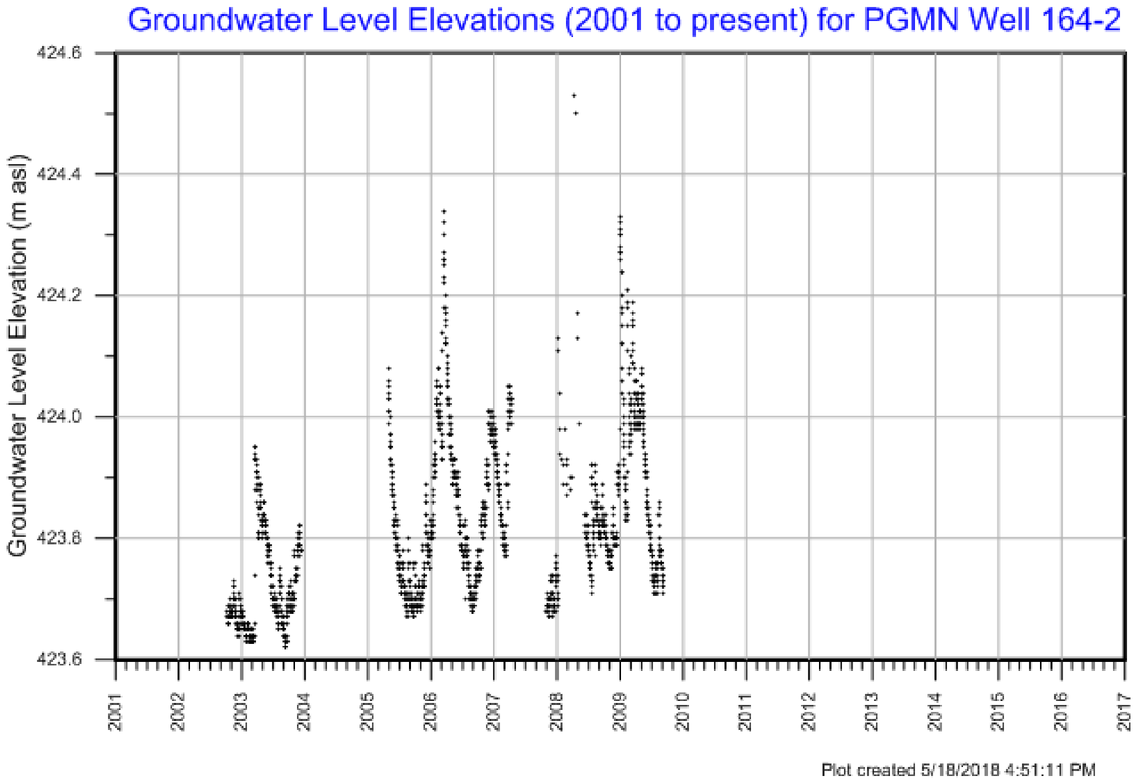

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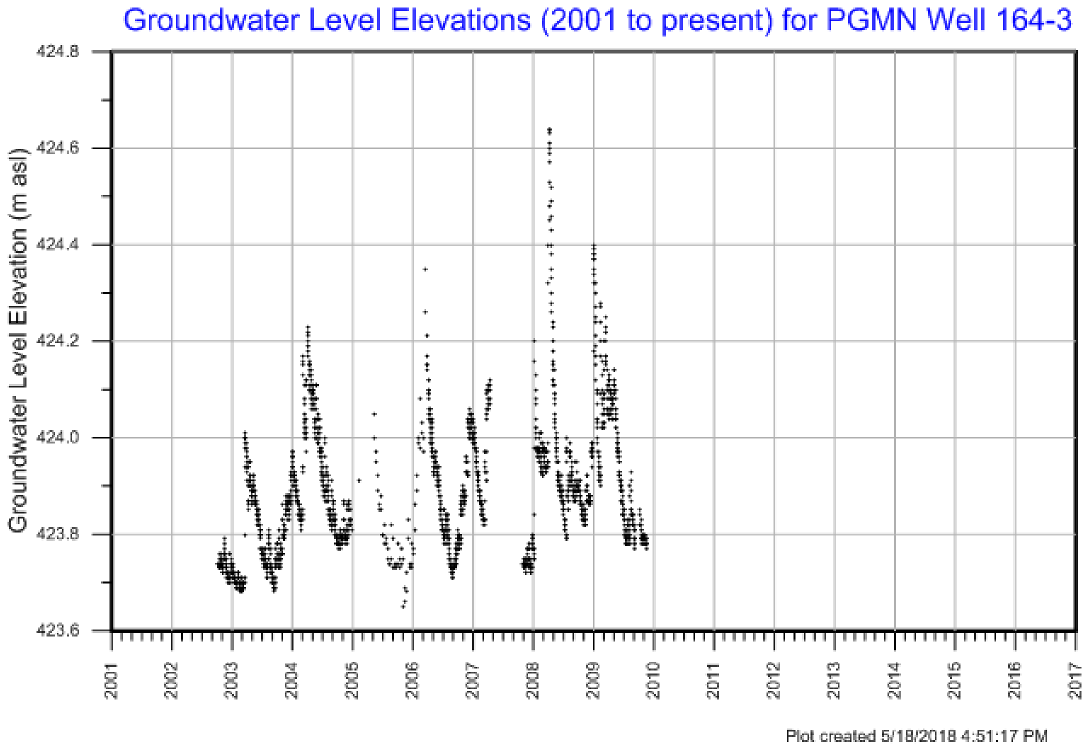

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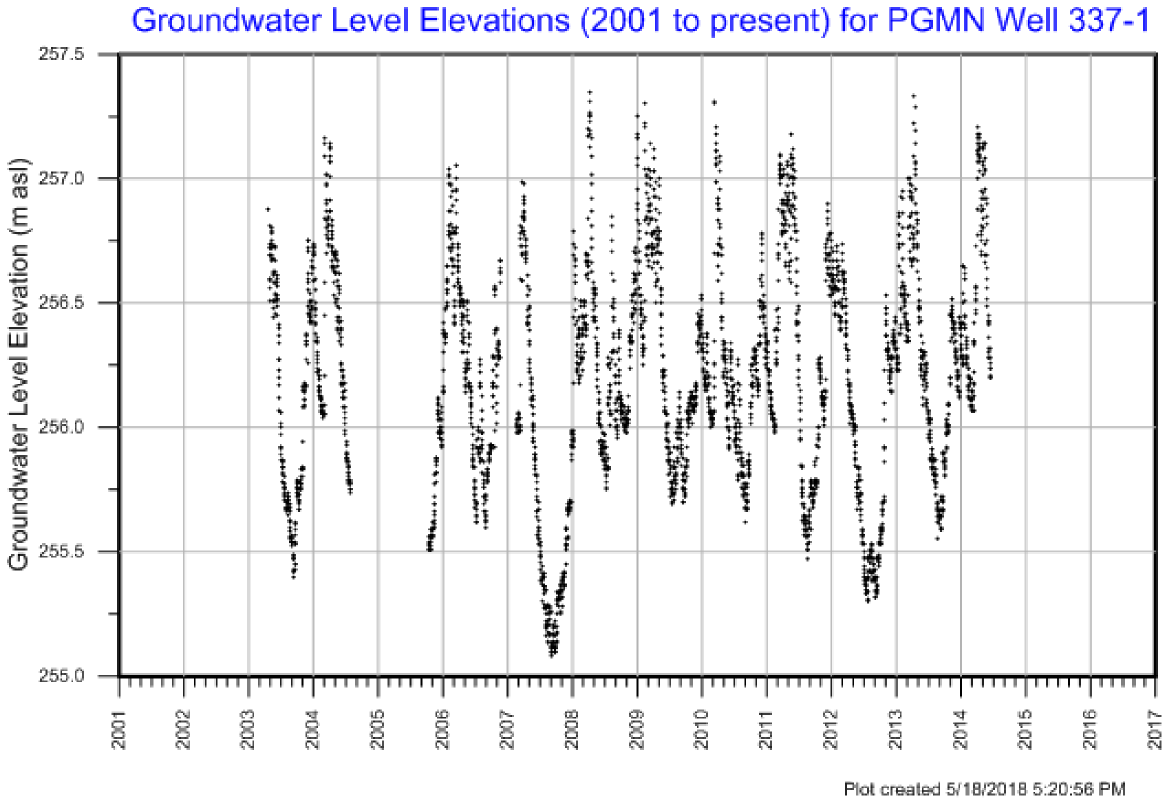
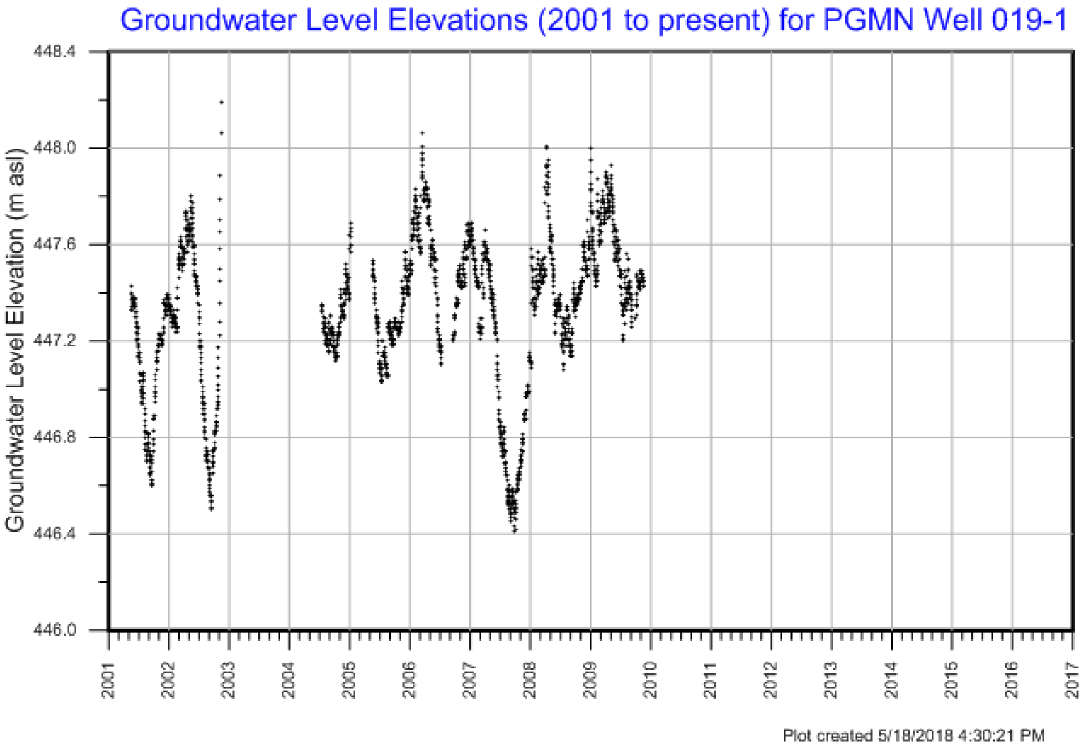


PGMN Well Hydrographs

Chapter 5 Orangeville

W0000019-1



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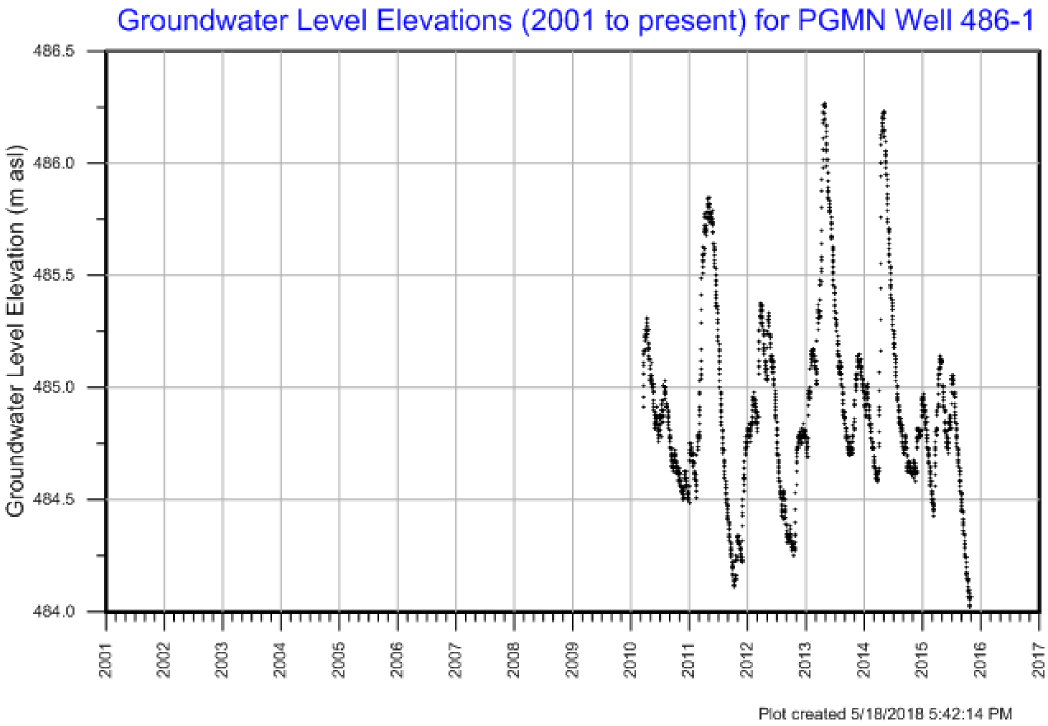
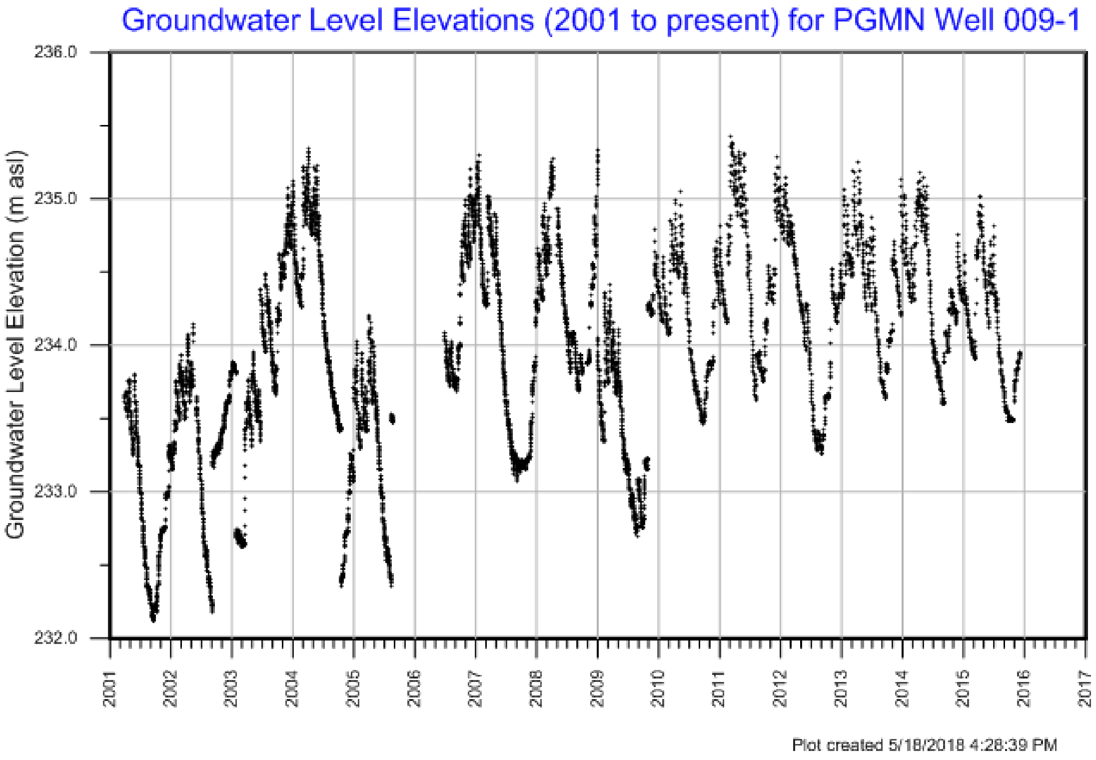


PGMN Well Hydrographs

Chapter 6 Norfolk

W0000009-1



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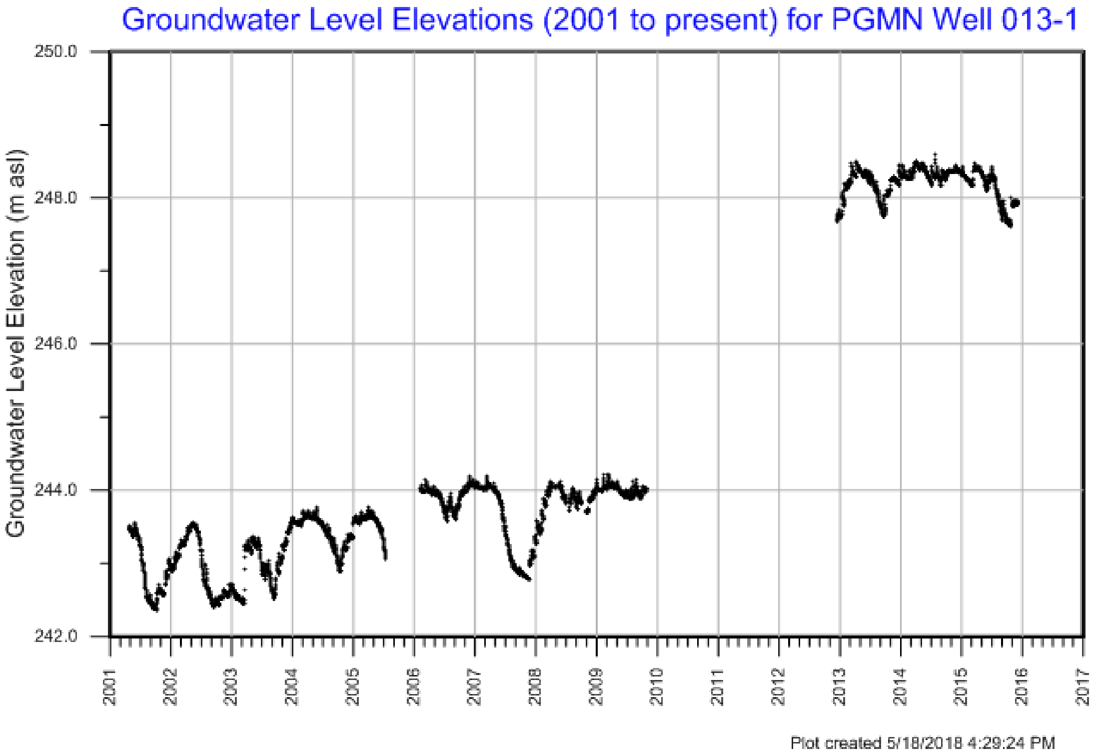

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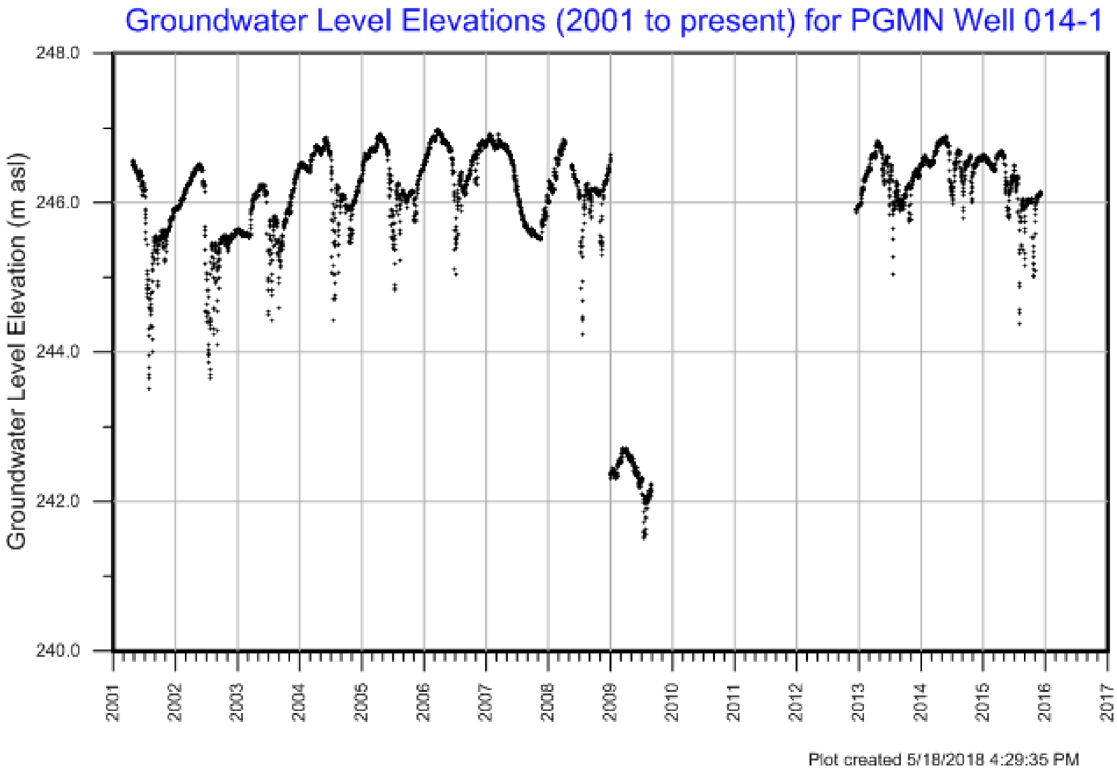

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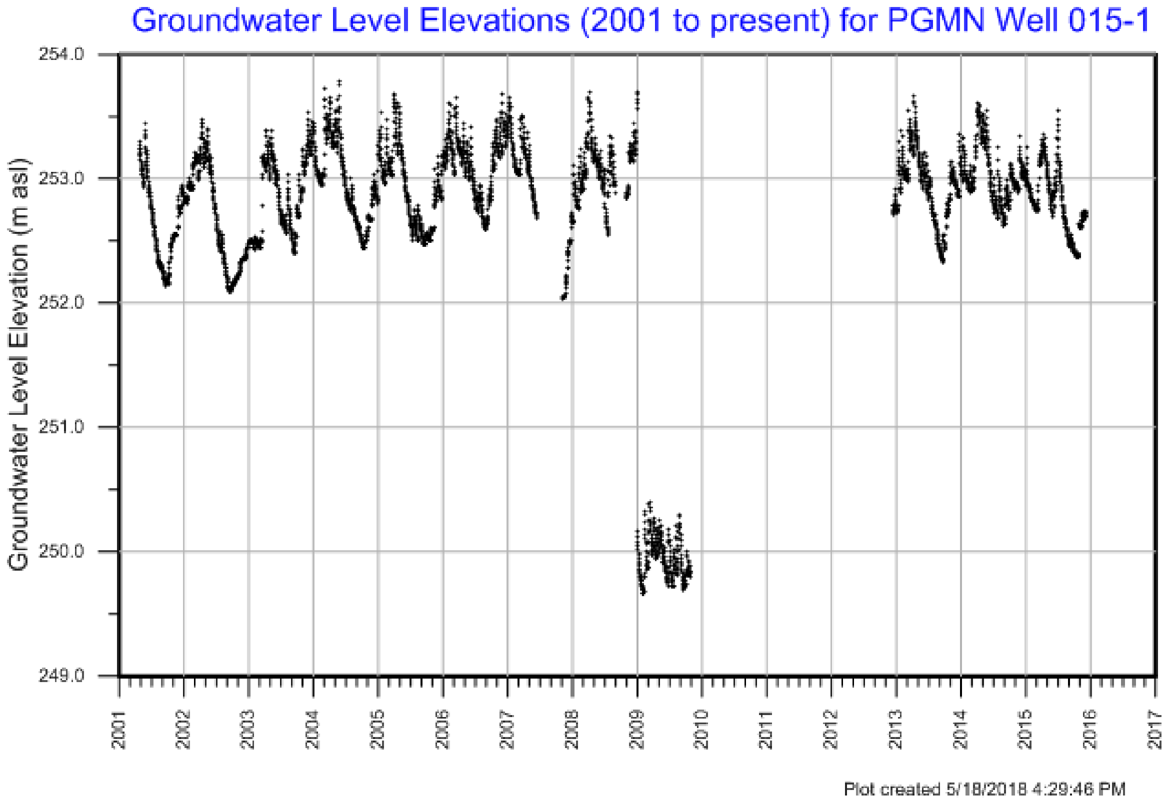

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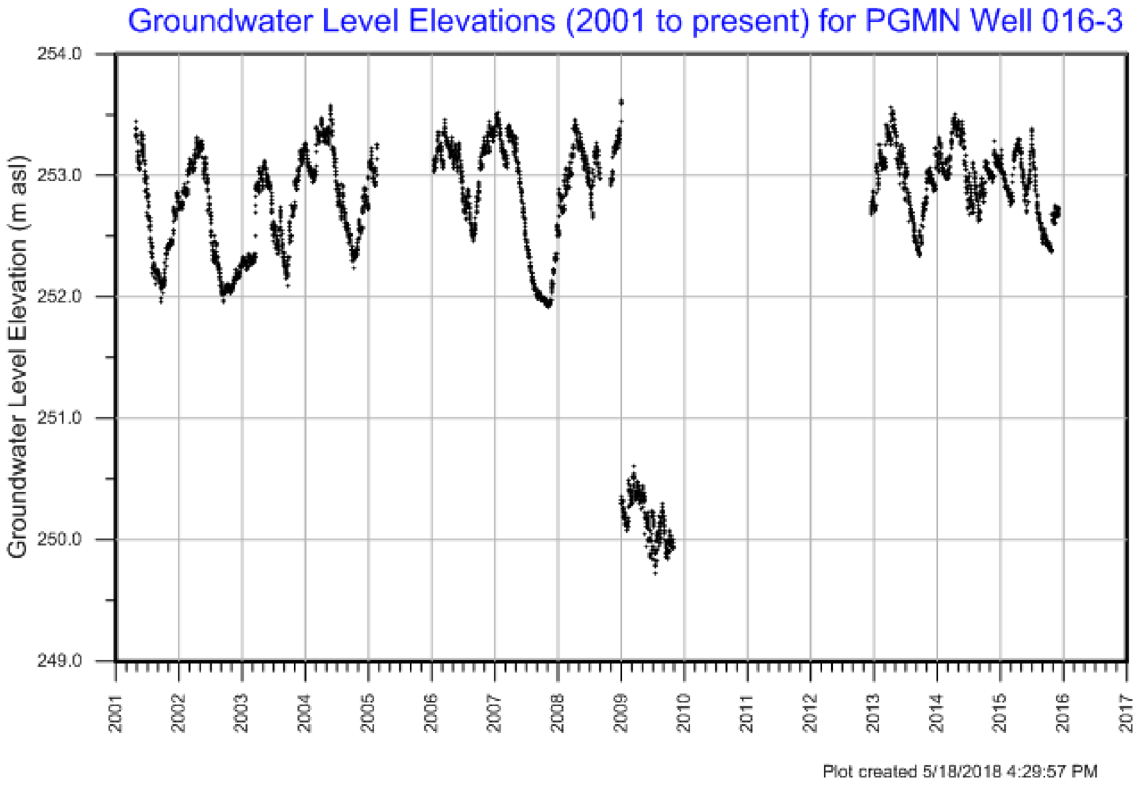

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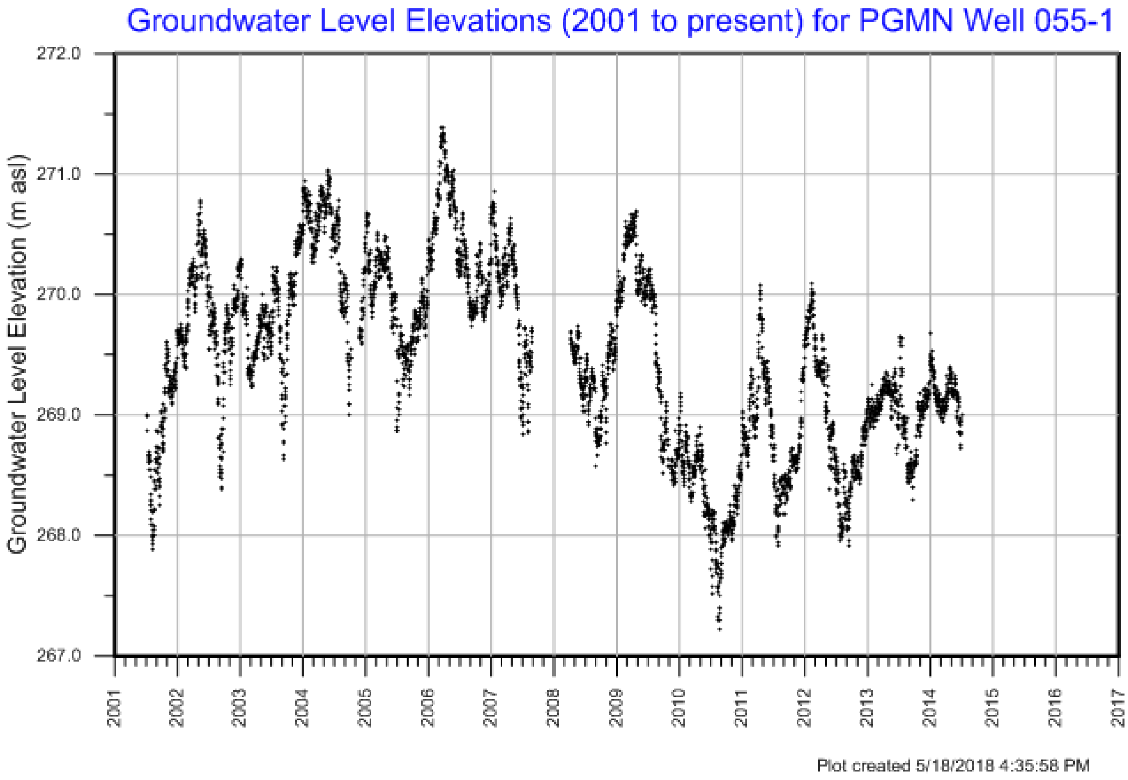

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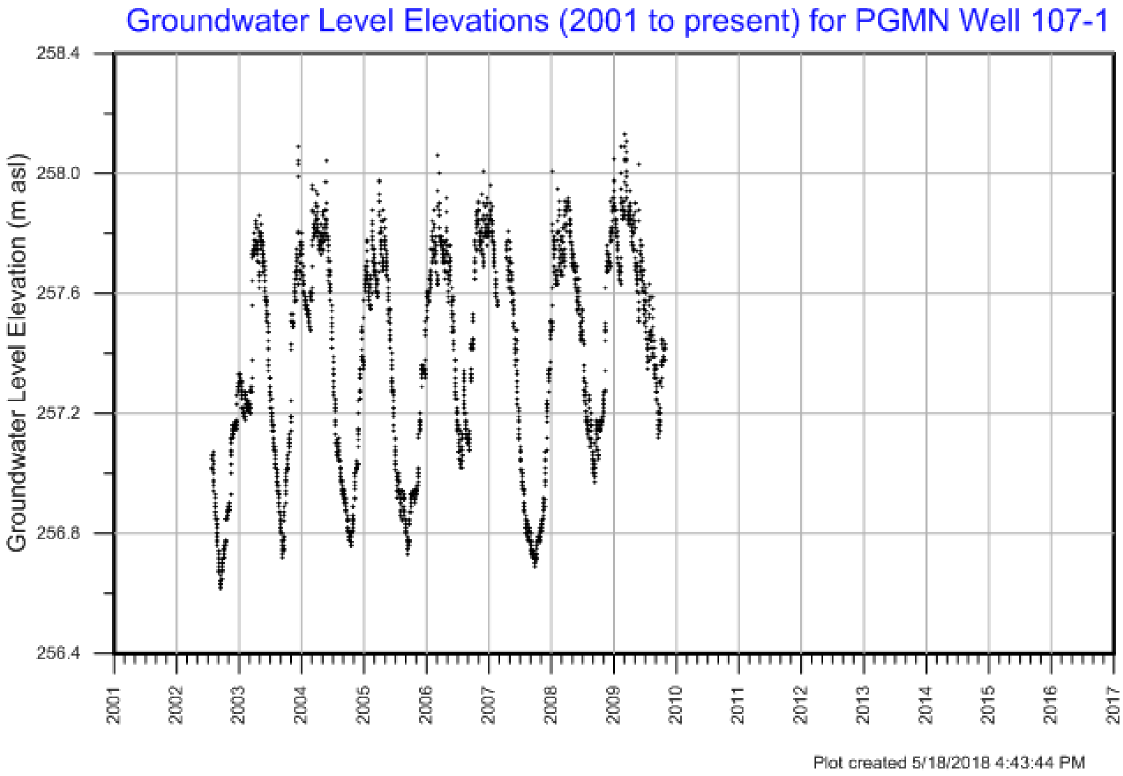

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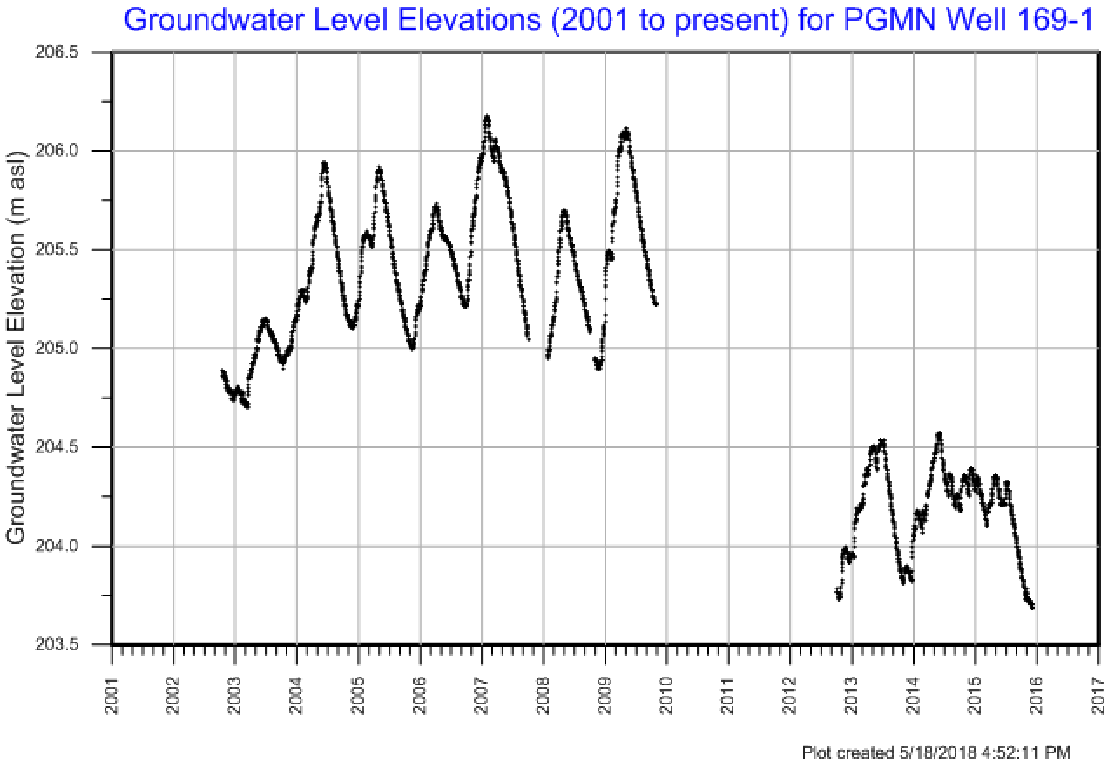

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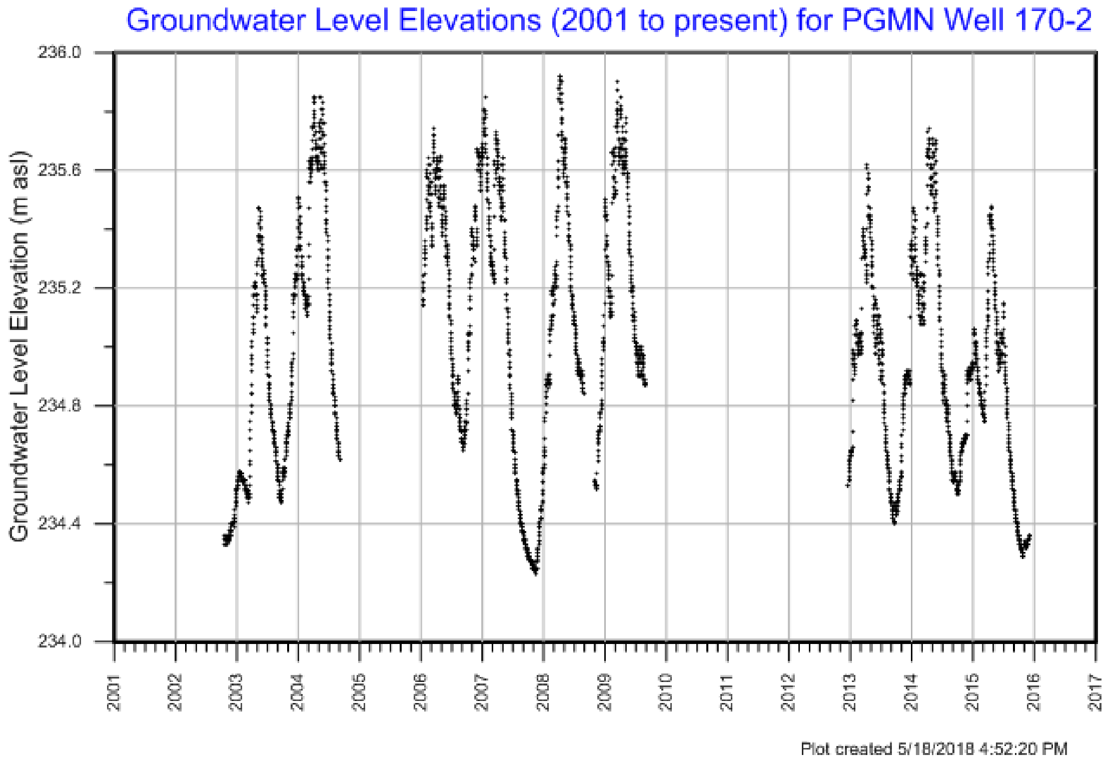

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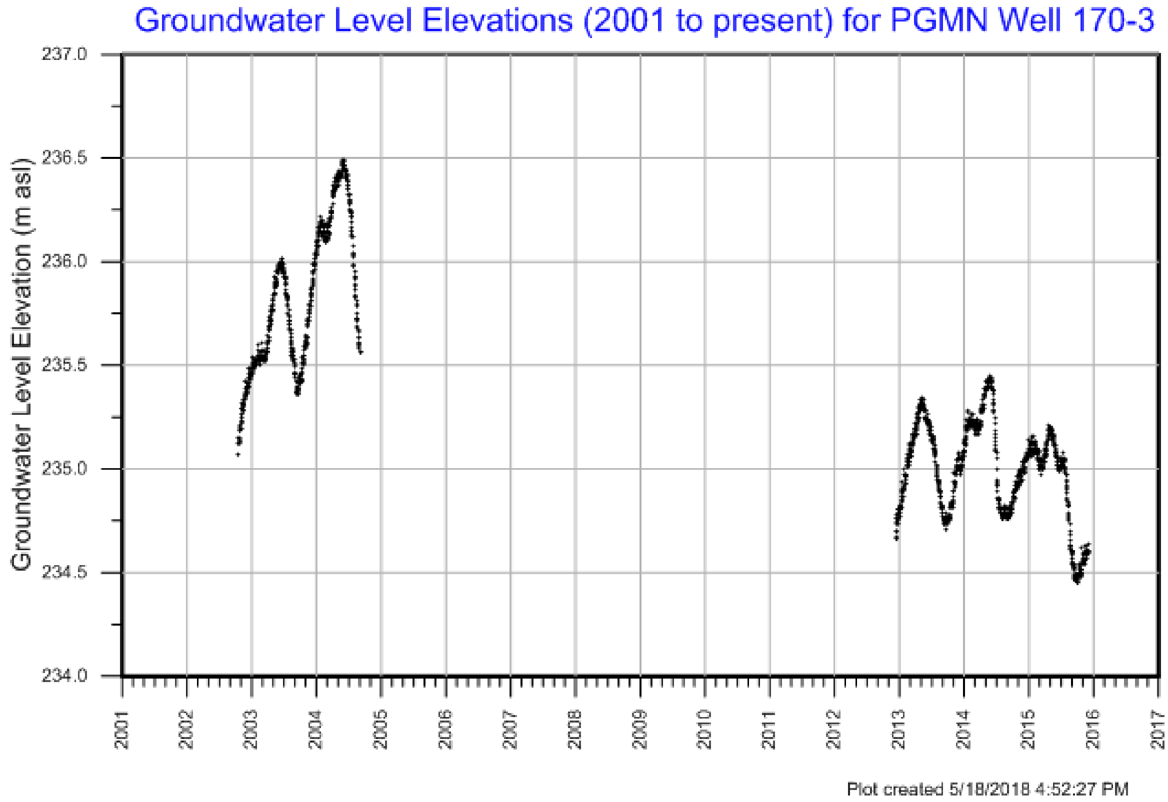

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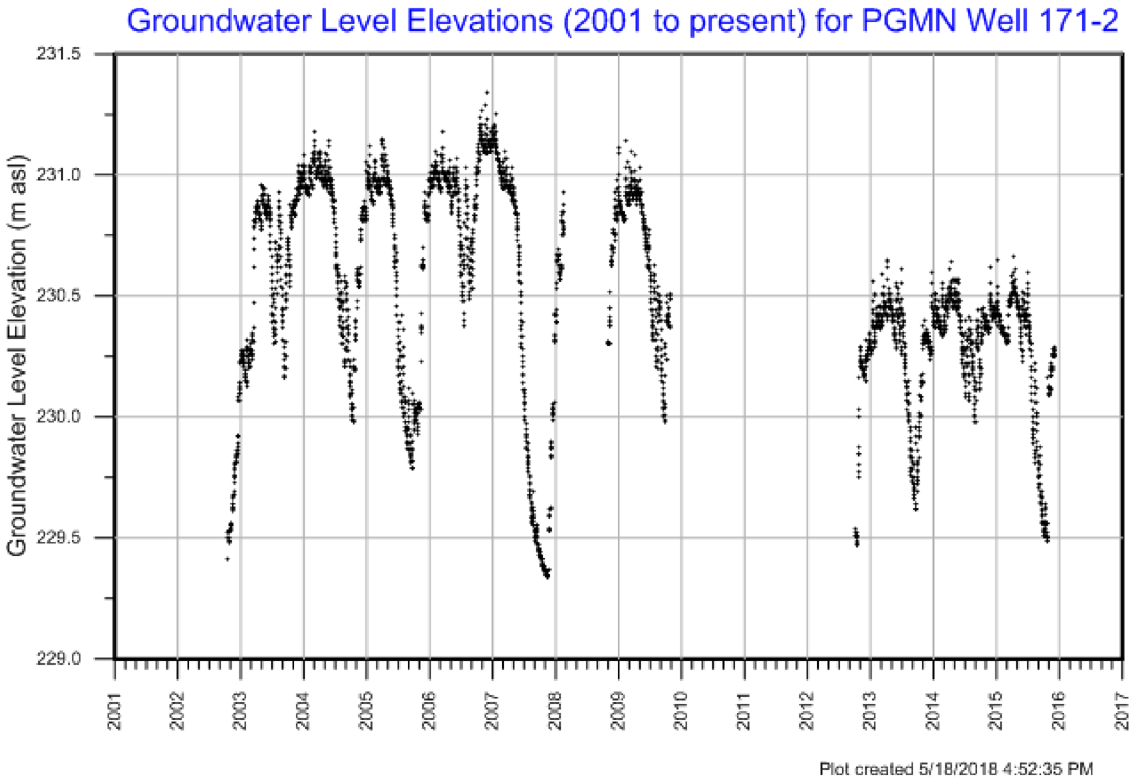

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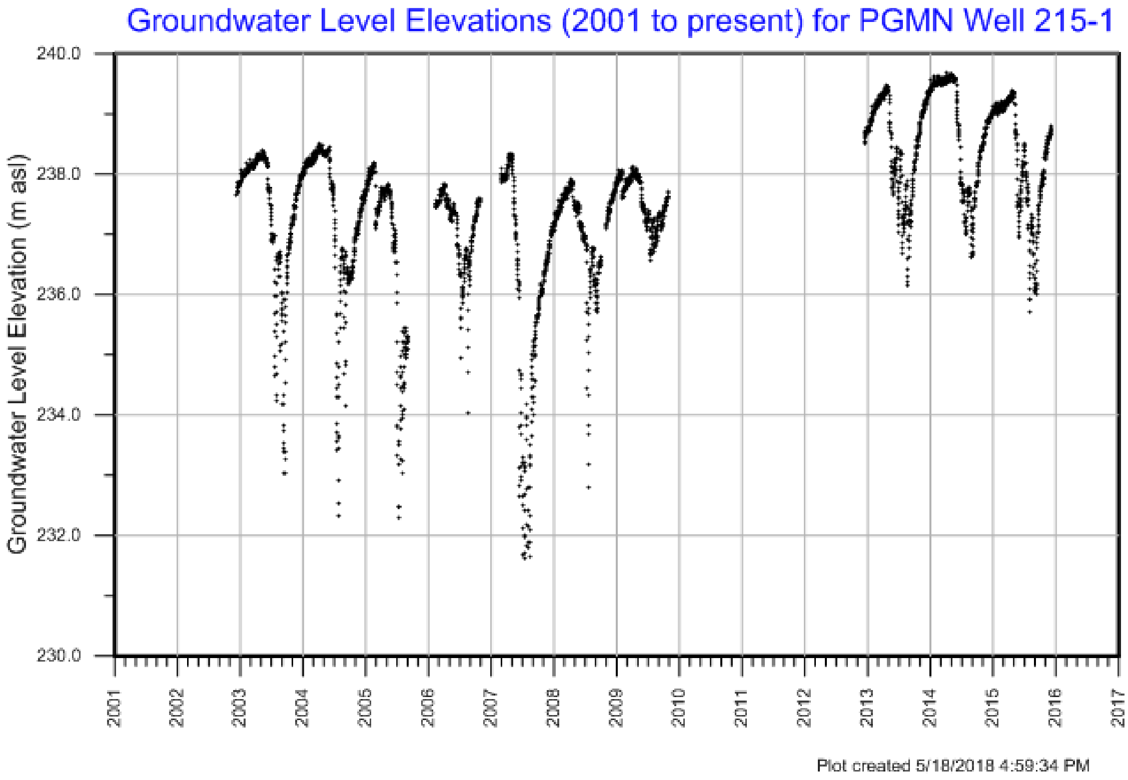

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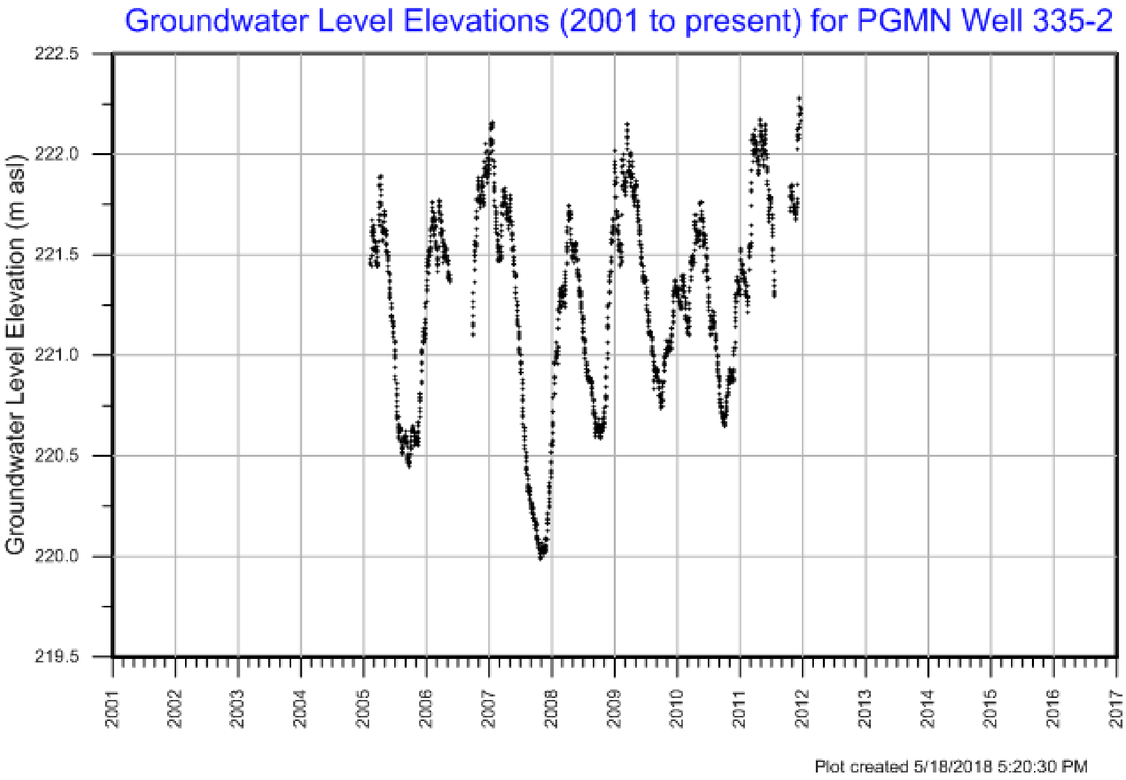

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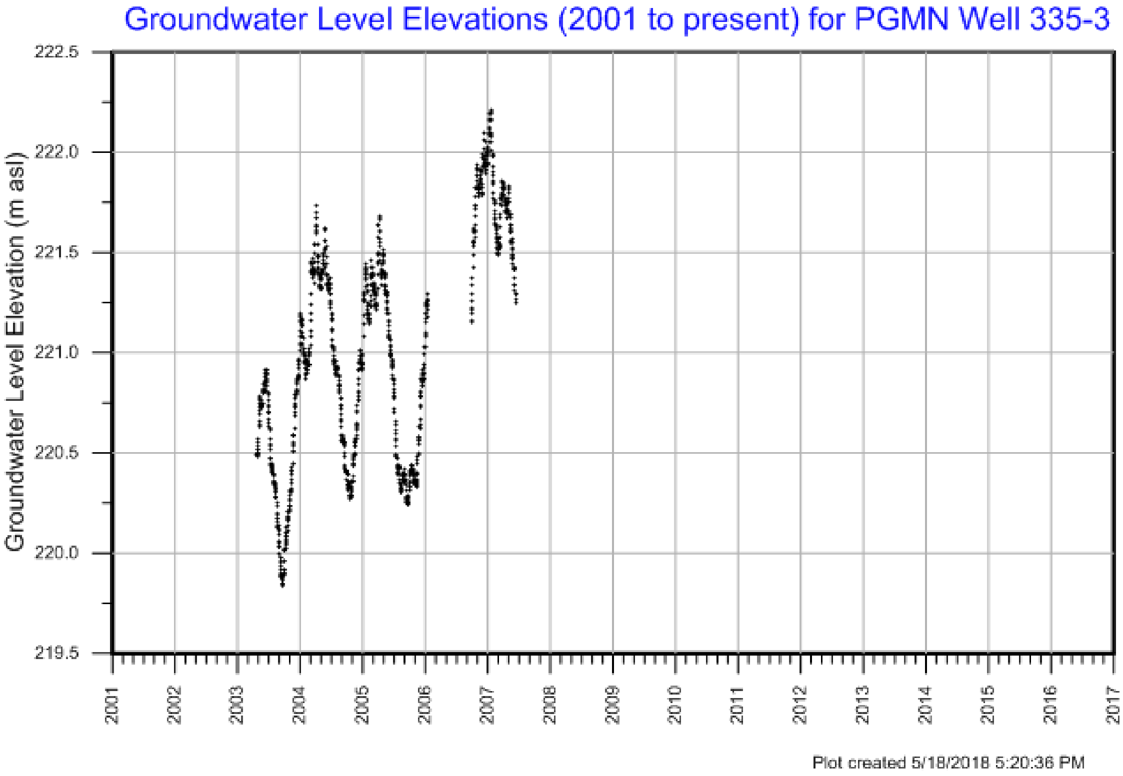

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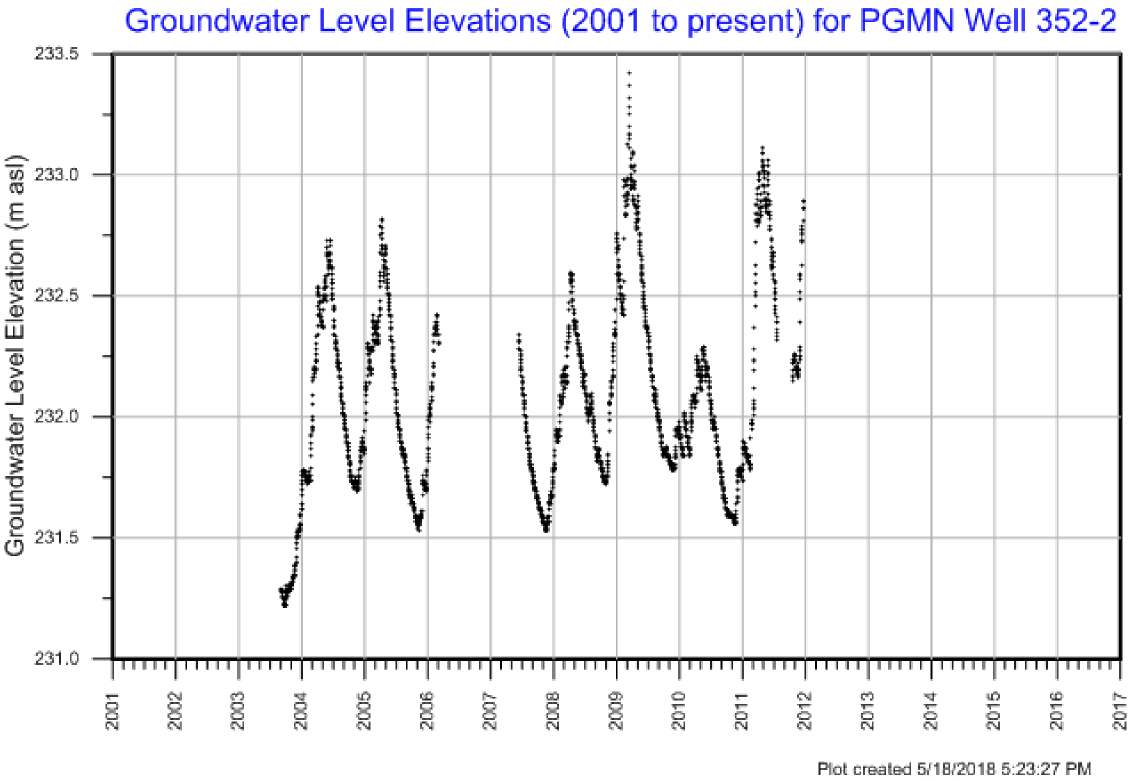

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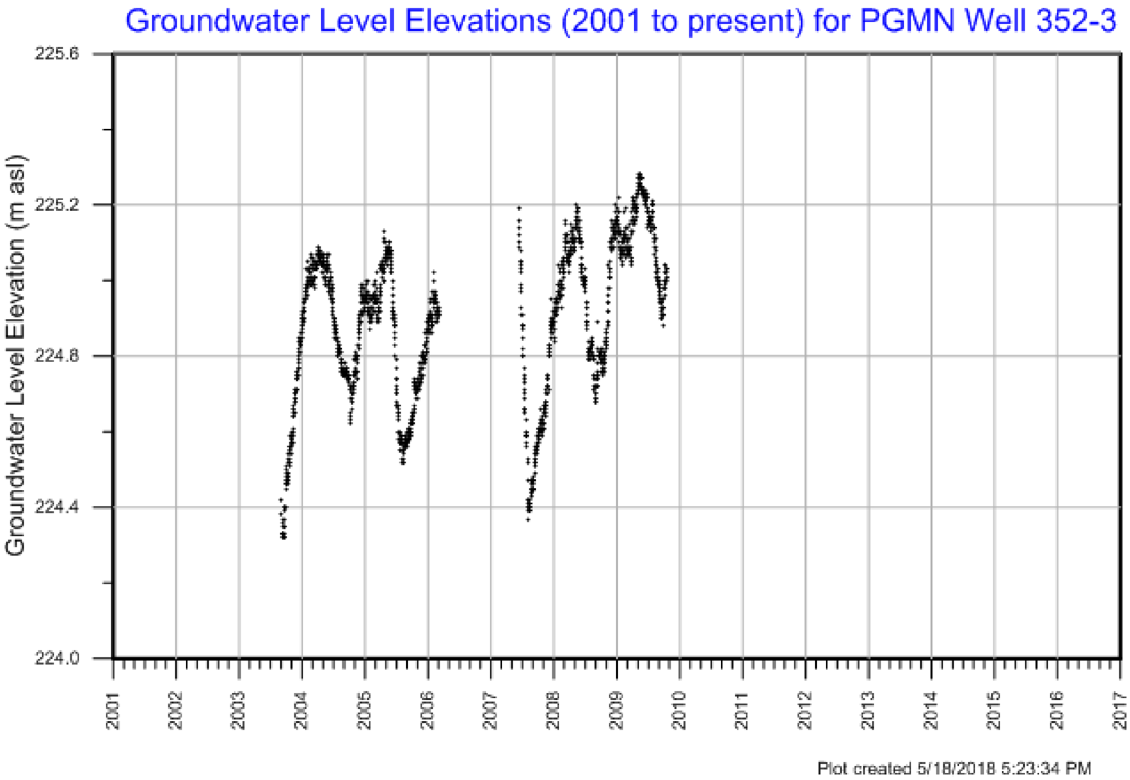

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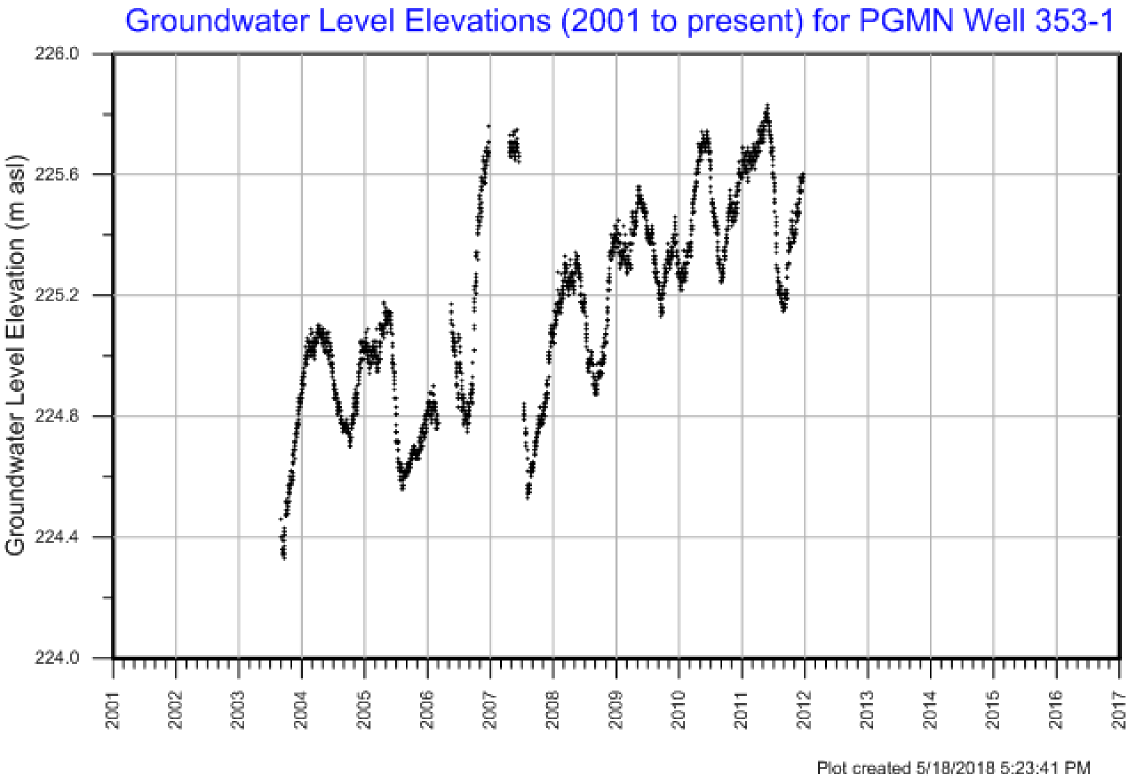

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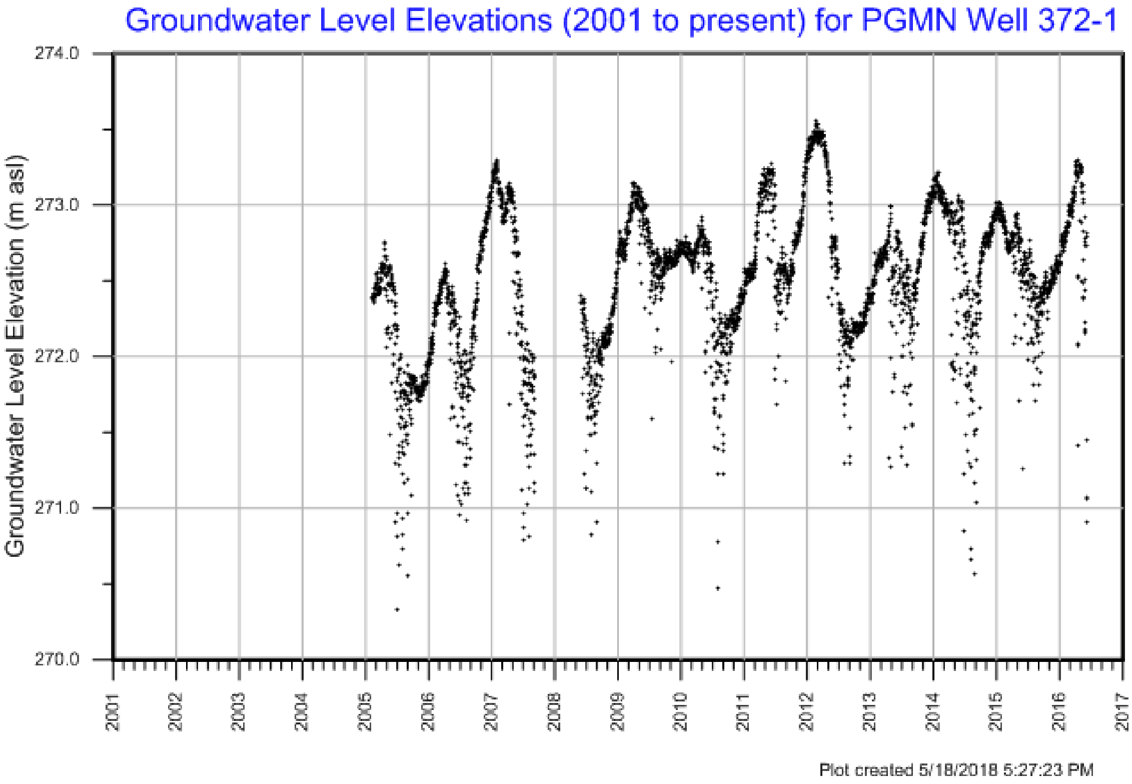

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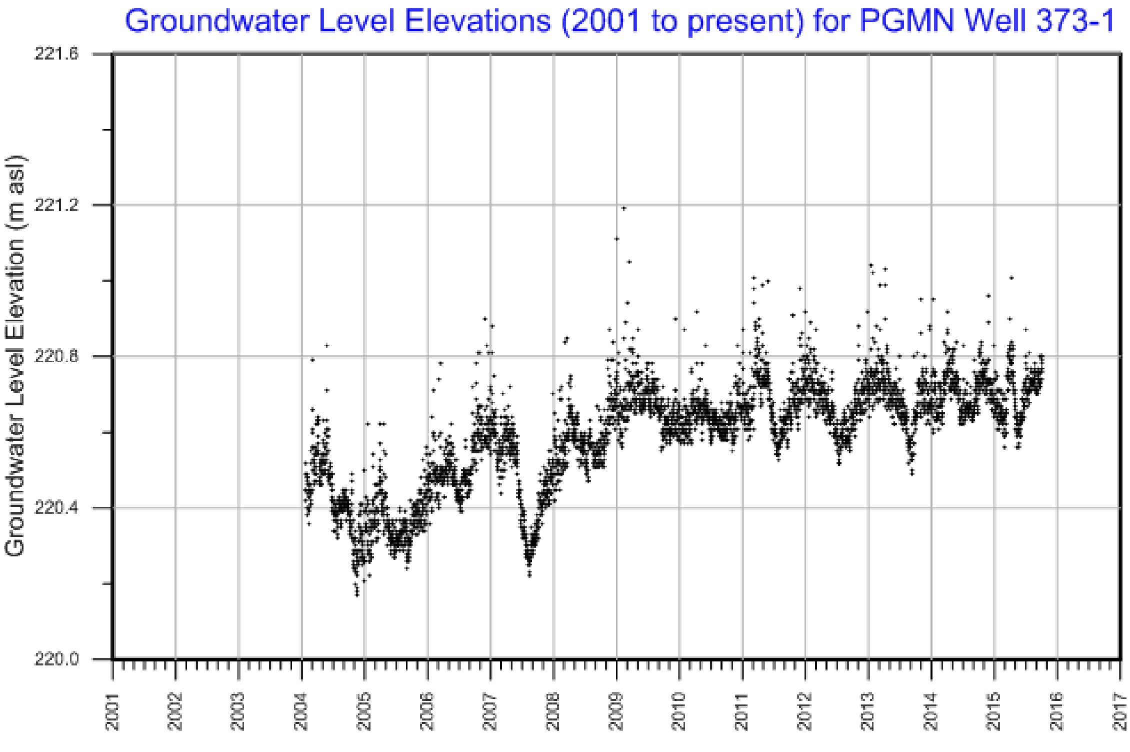

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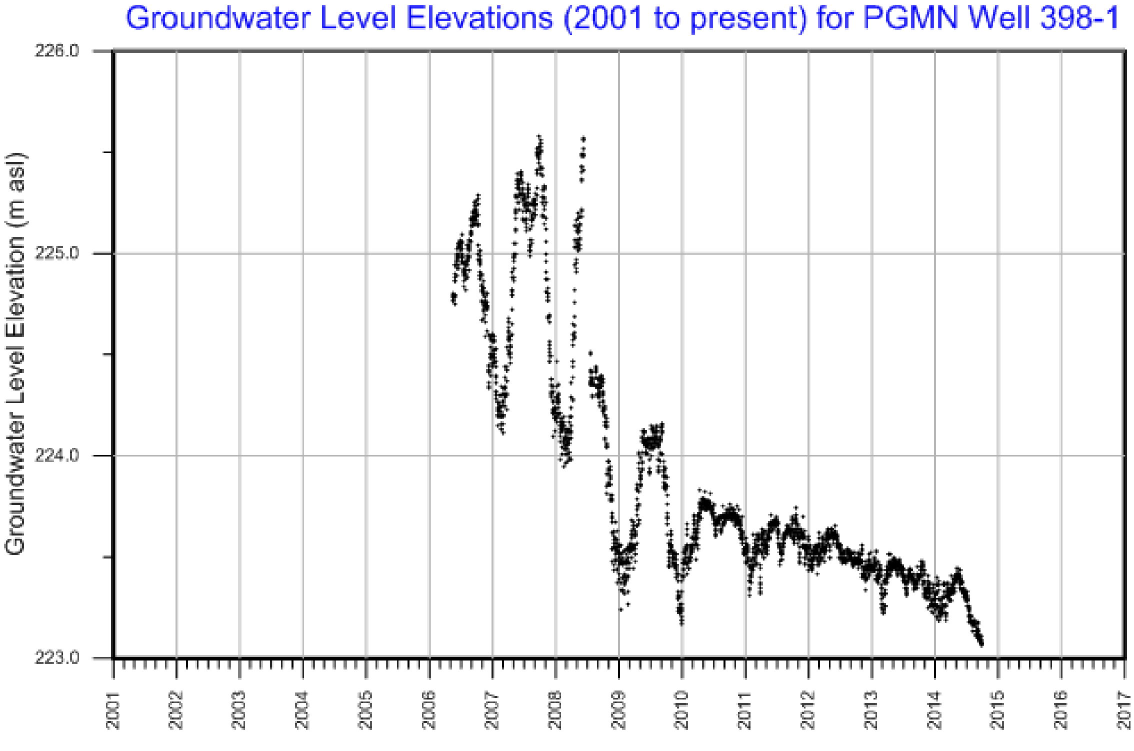

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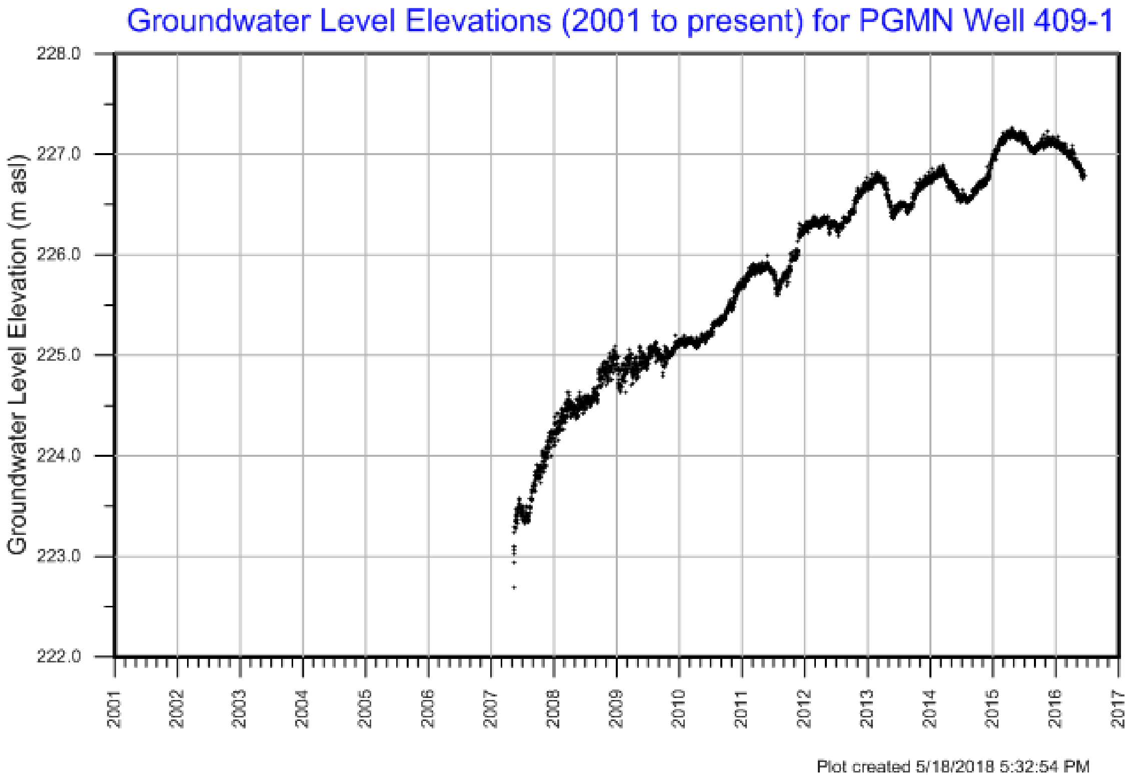

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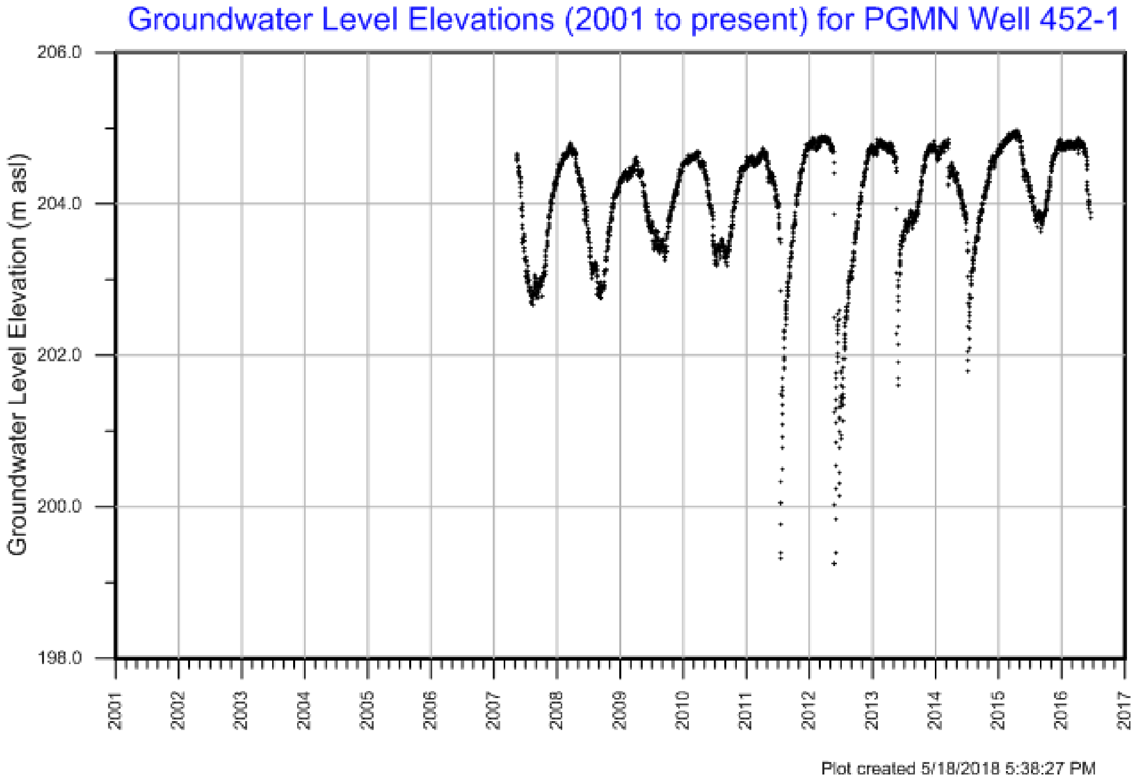

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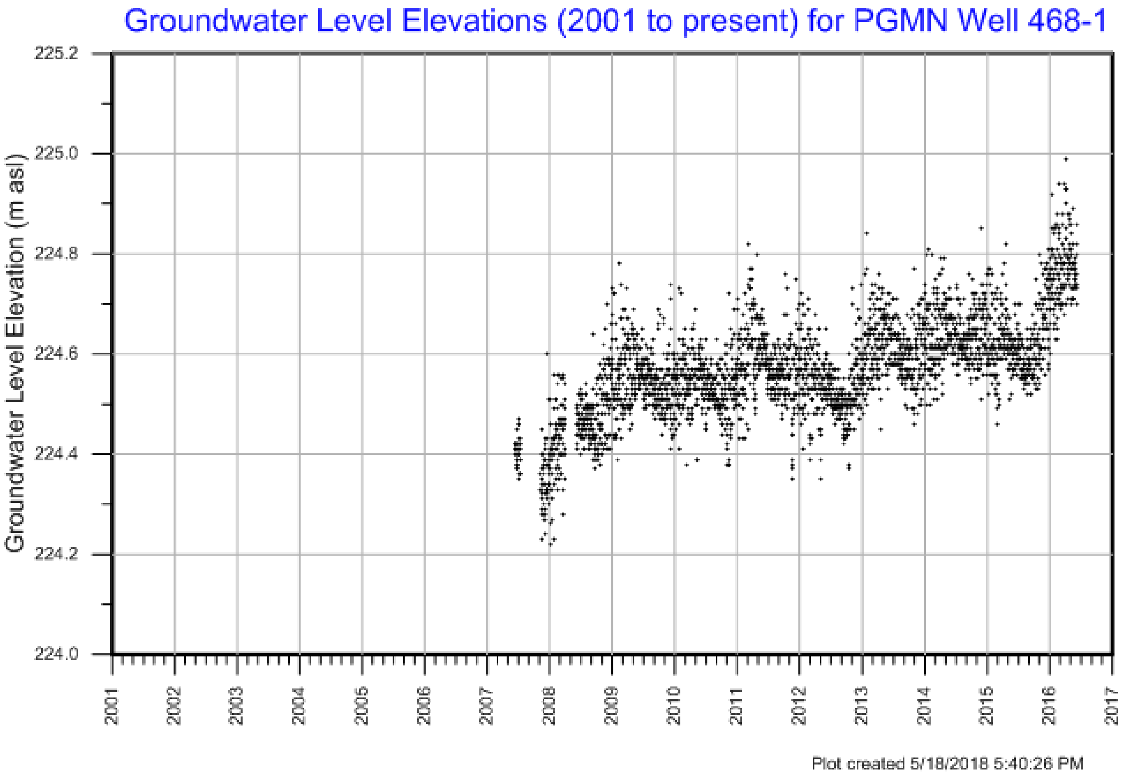
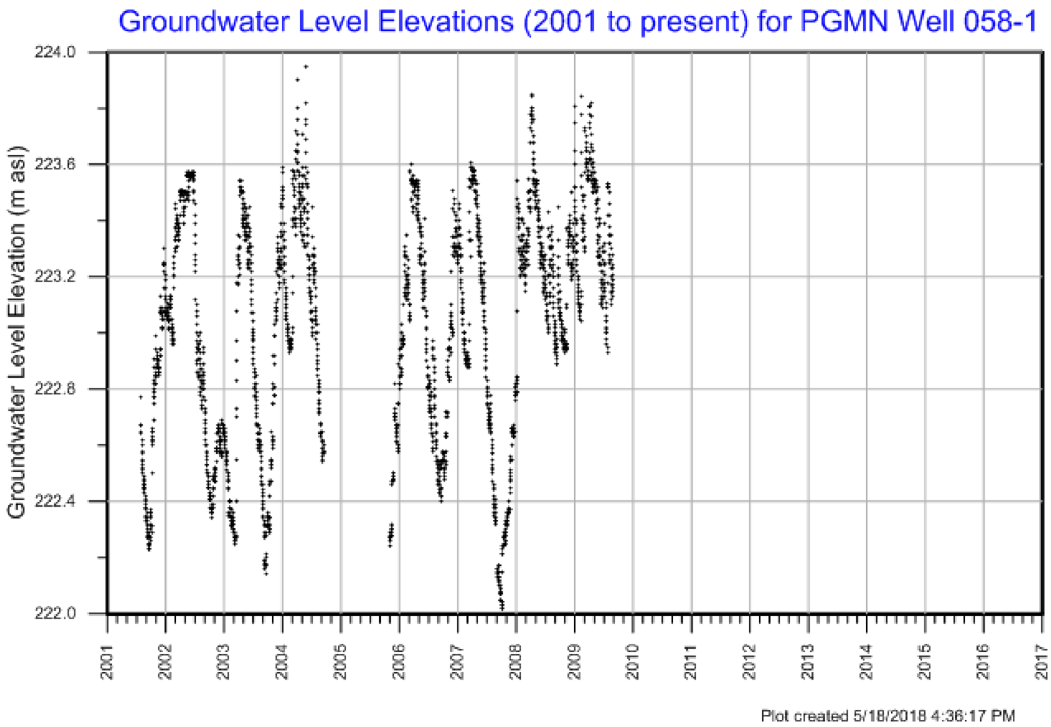

Groundwater Level Elevations (2001 to present) for PGMN Well 468-1
Groundwater Level Elevation (m asl)
225.2
225.0
224.8
224.6
224.4
224.2
224.0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Plot created 5/18/2018 5:40:26 PM

PGMN Well Hydrographs

Chapter 7 Innisfil

W0000058-1



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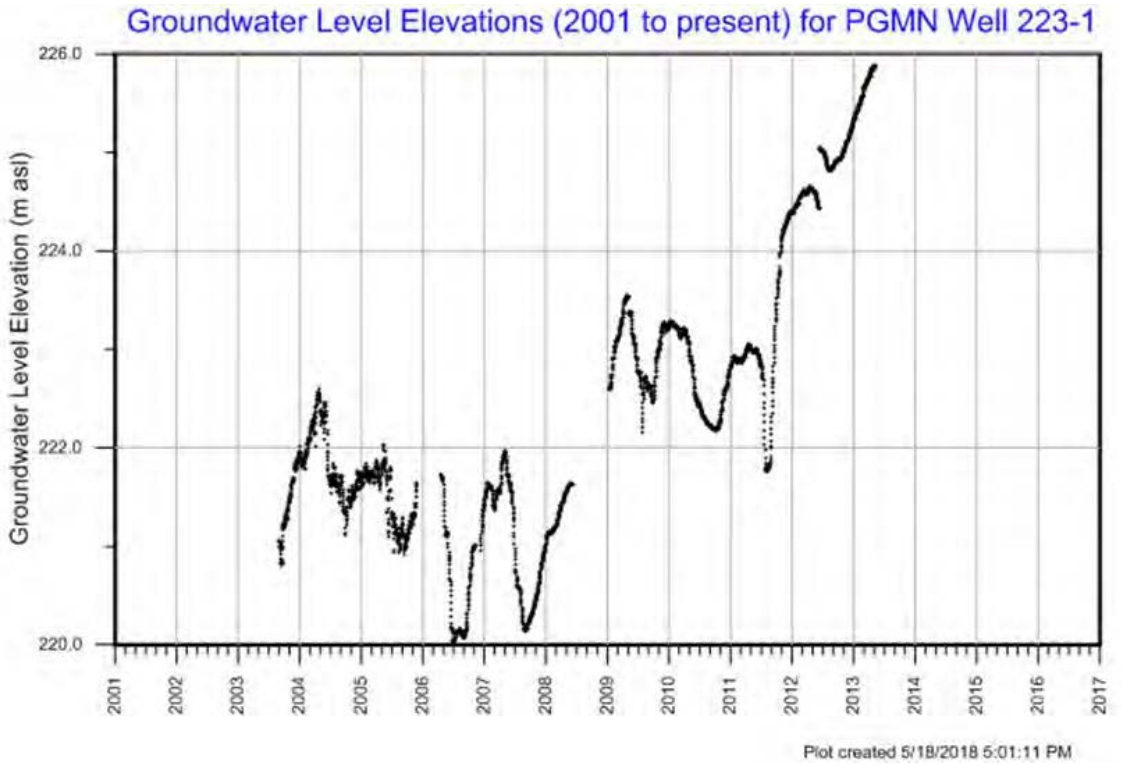

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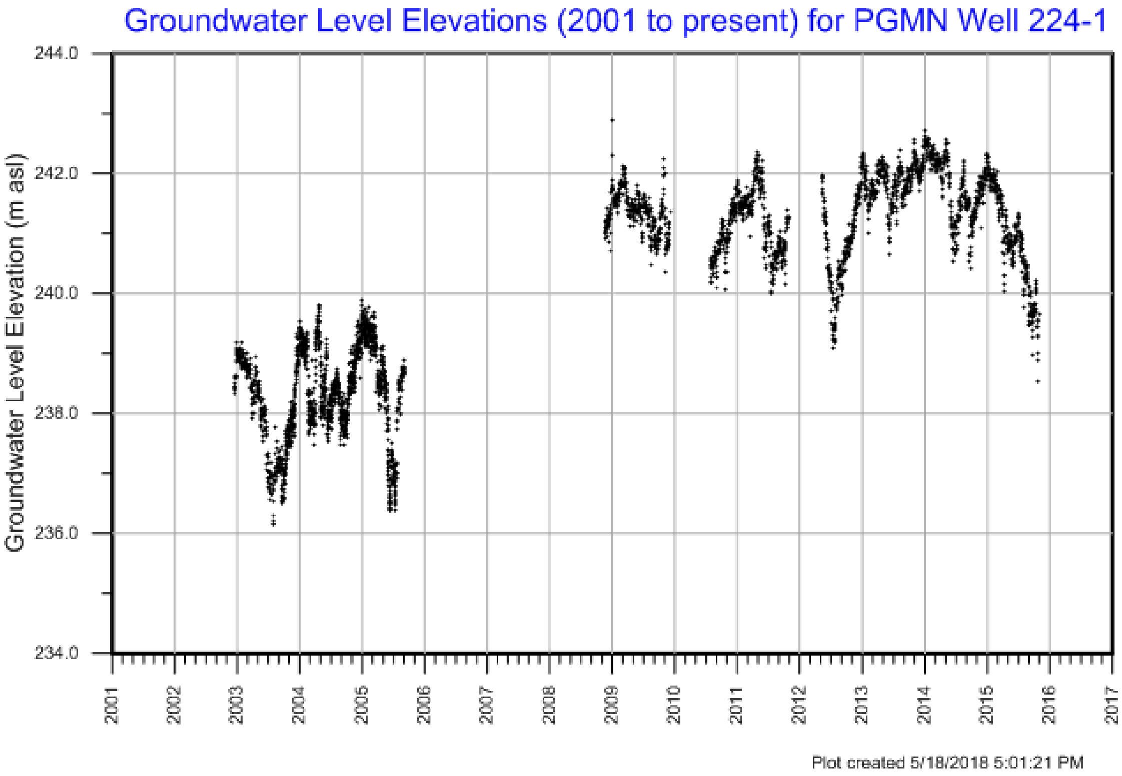

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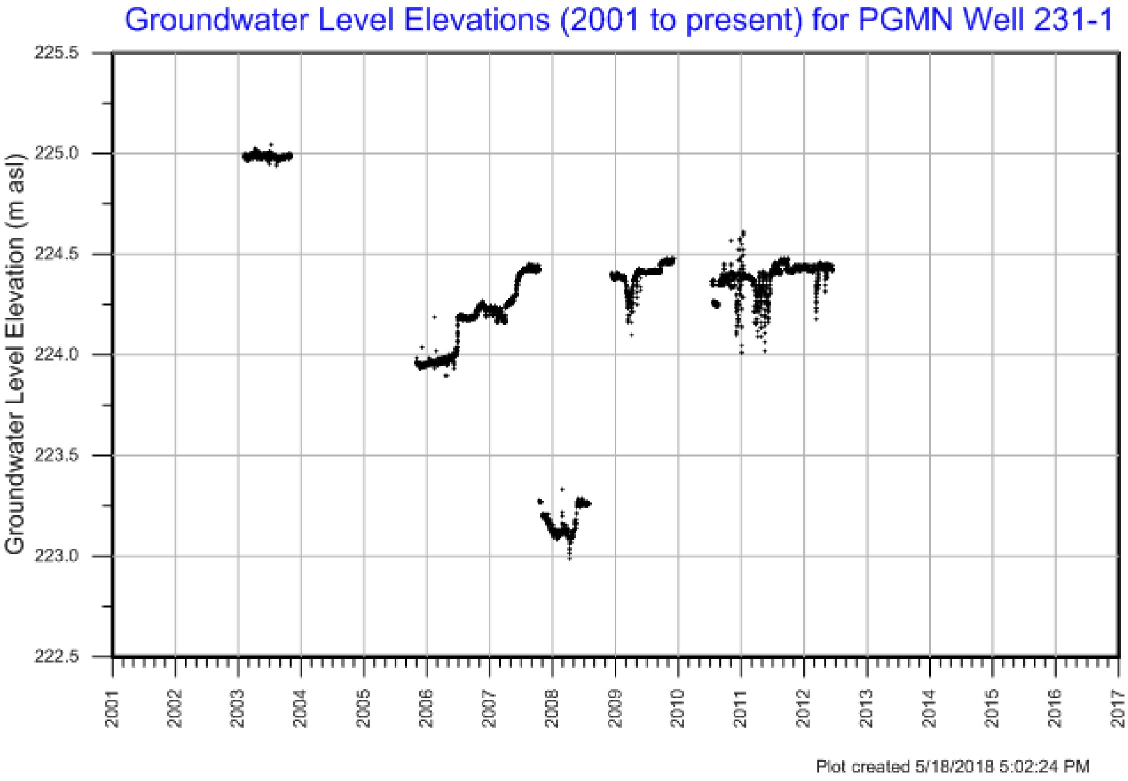

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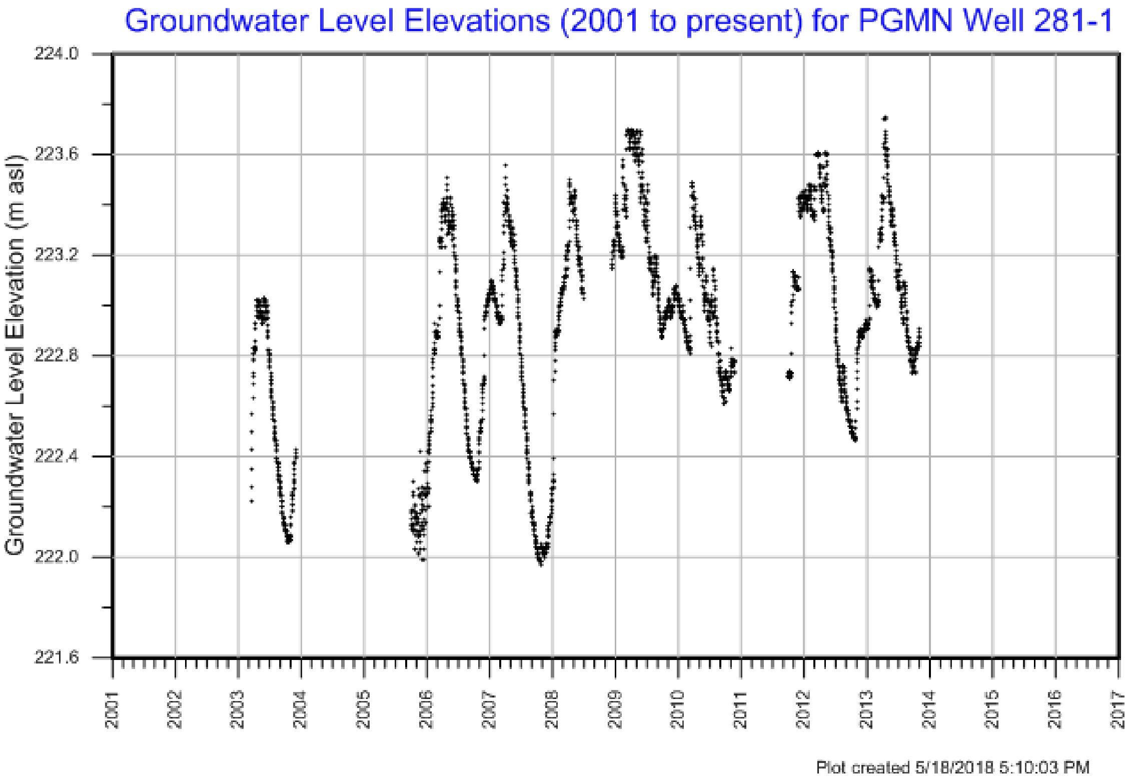

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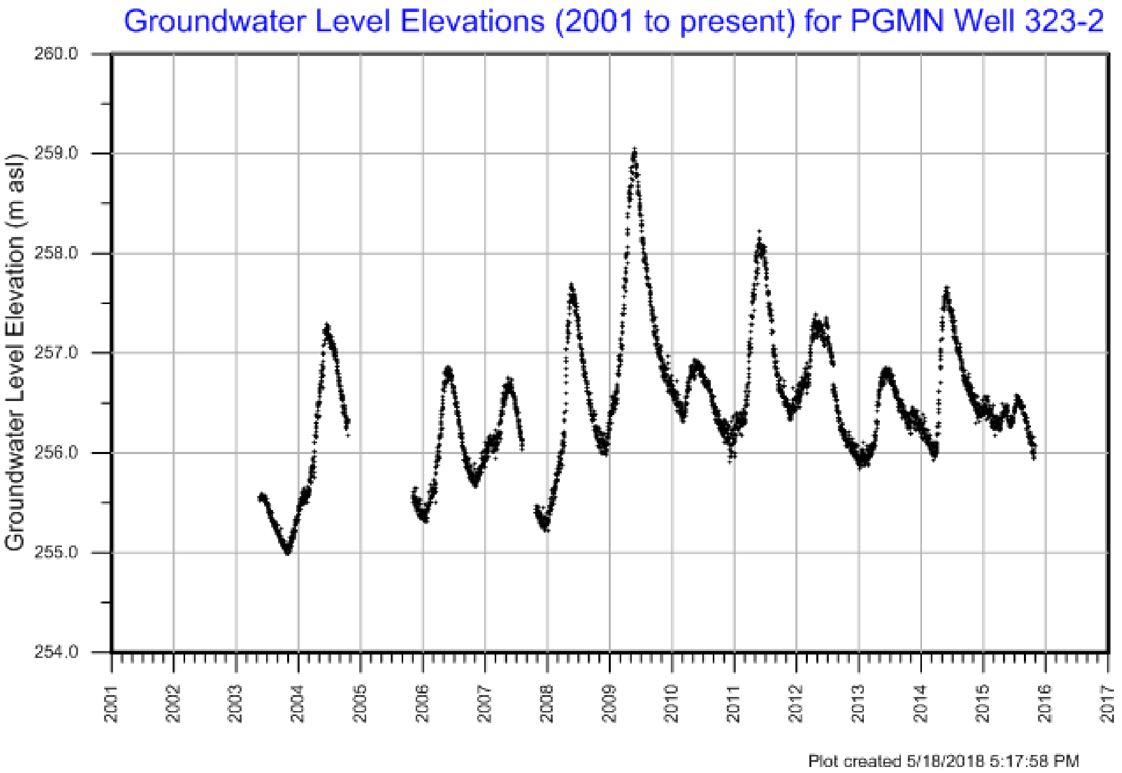

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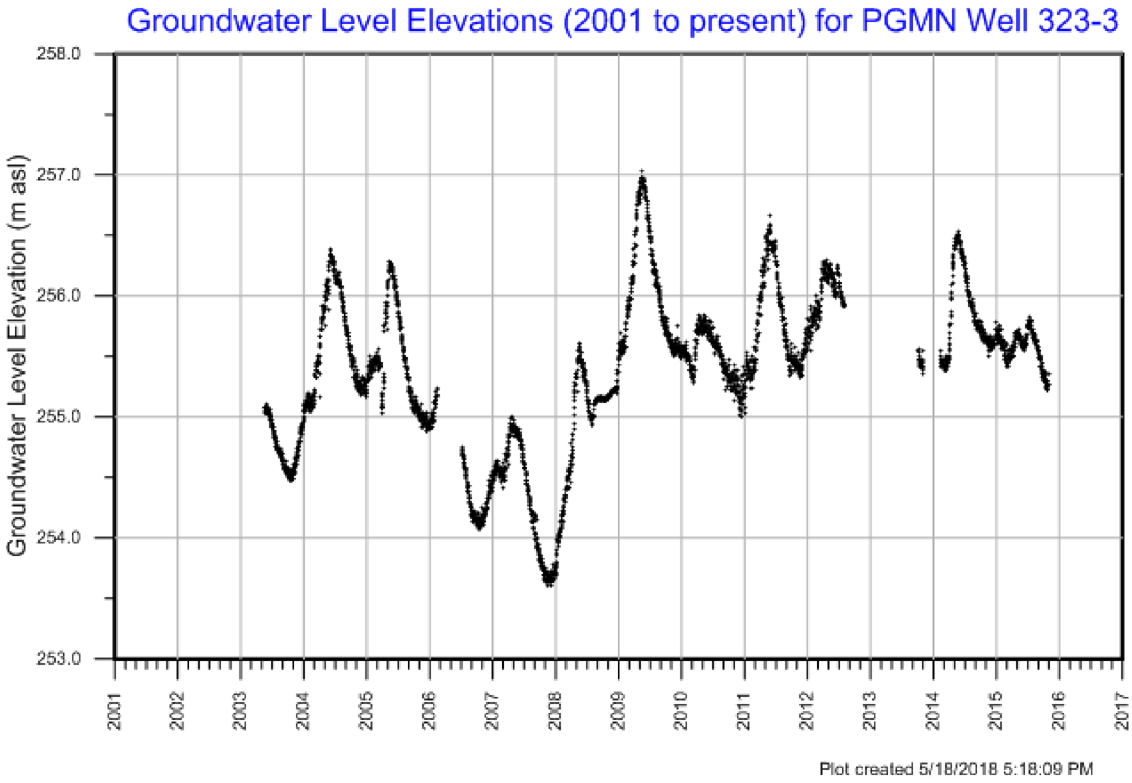

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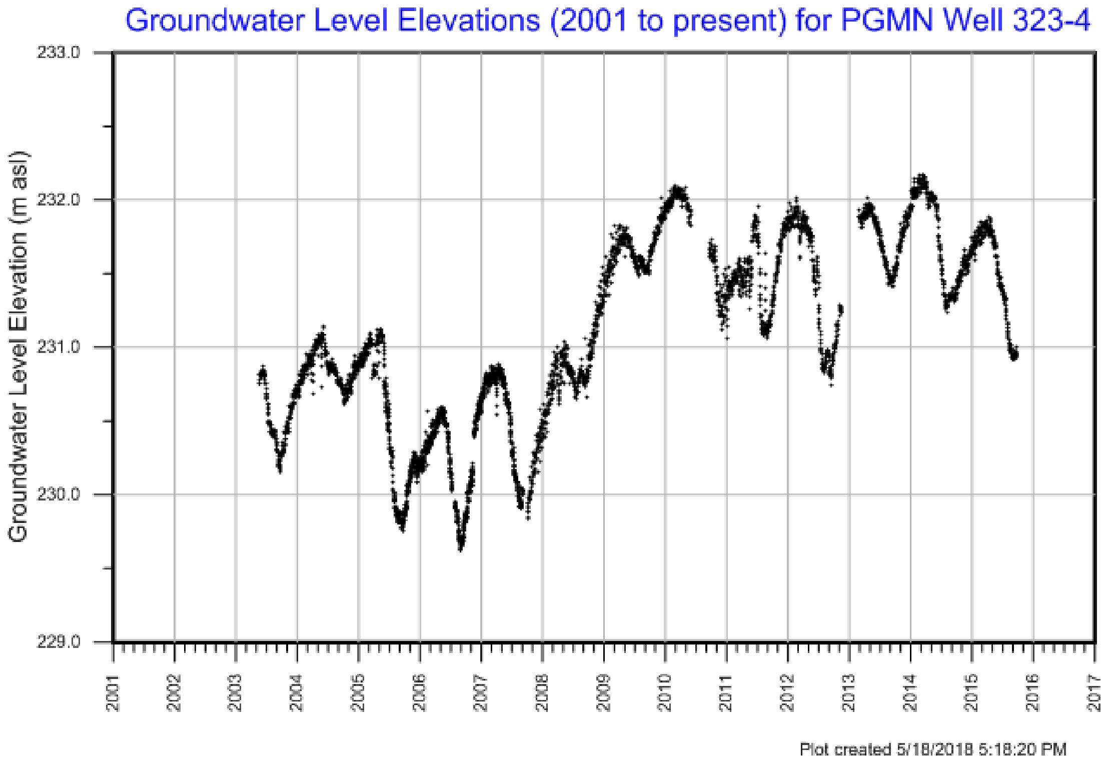

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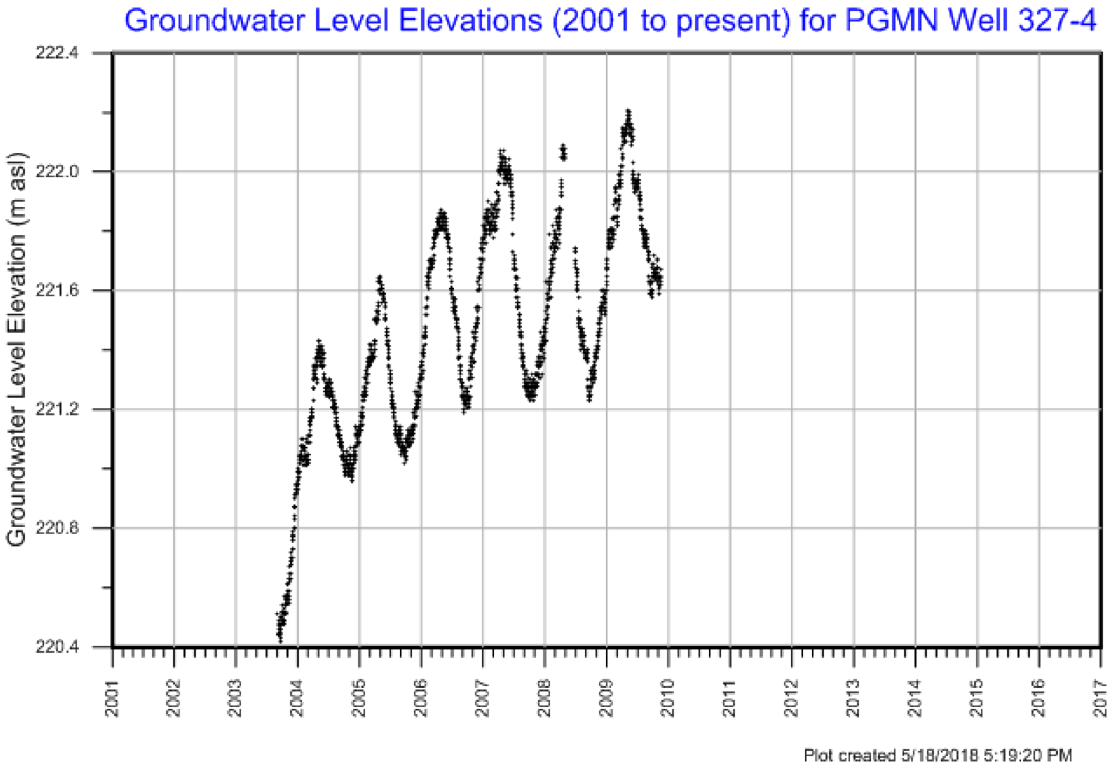

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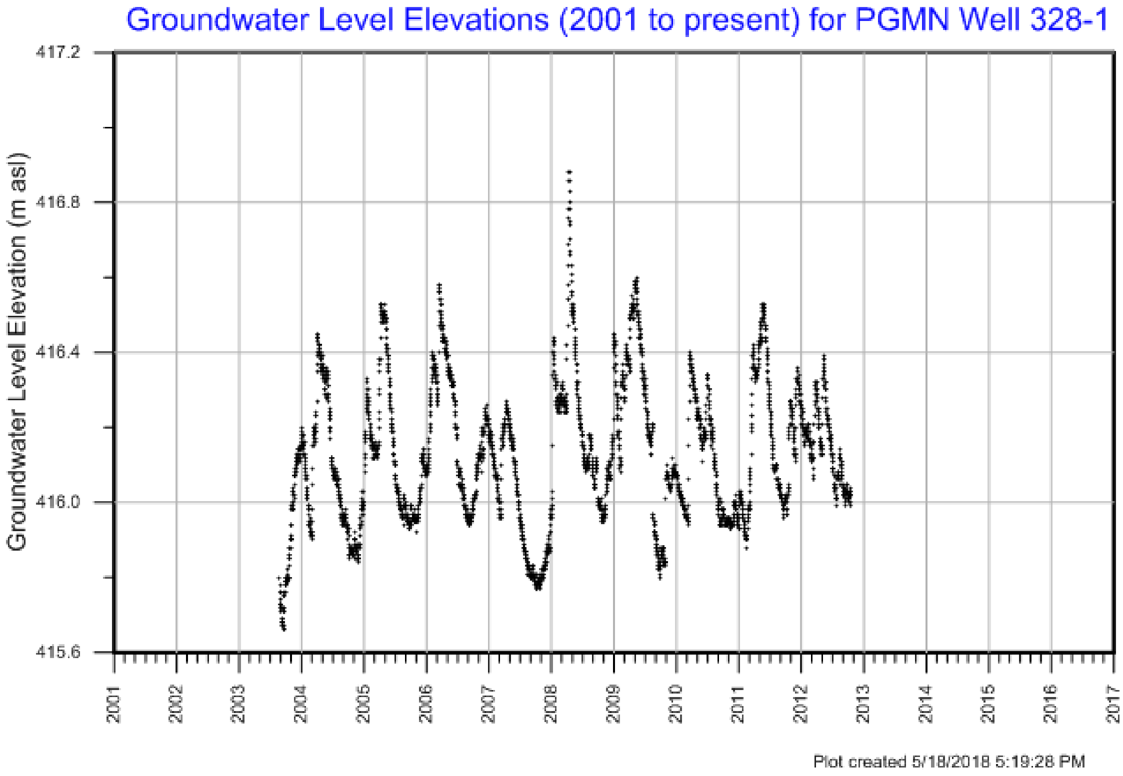

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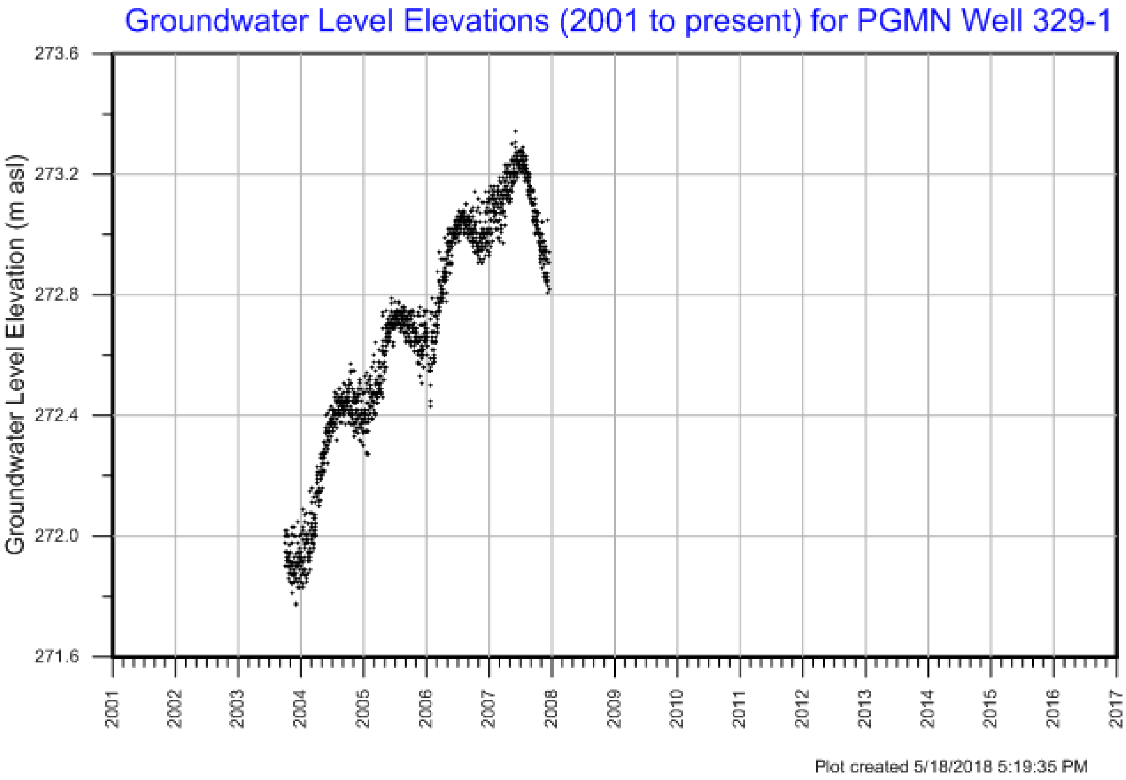

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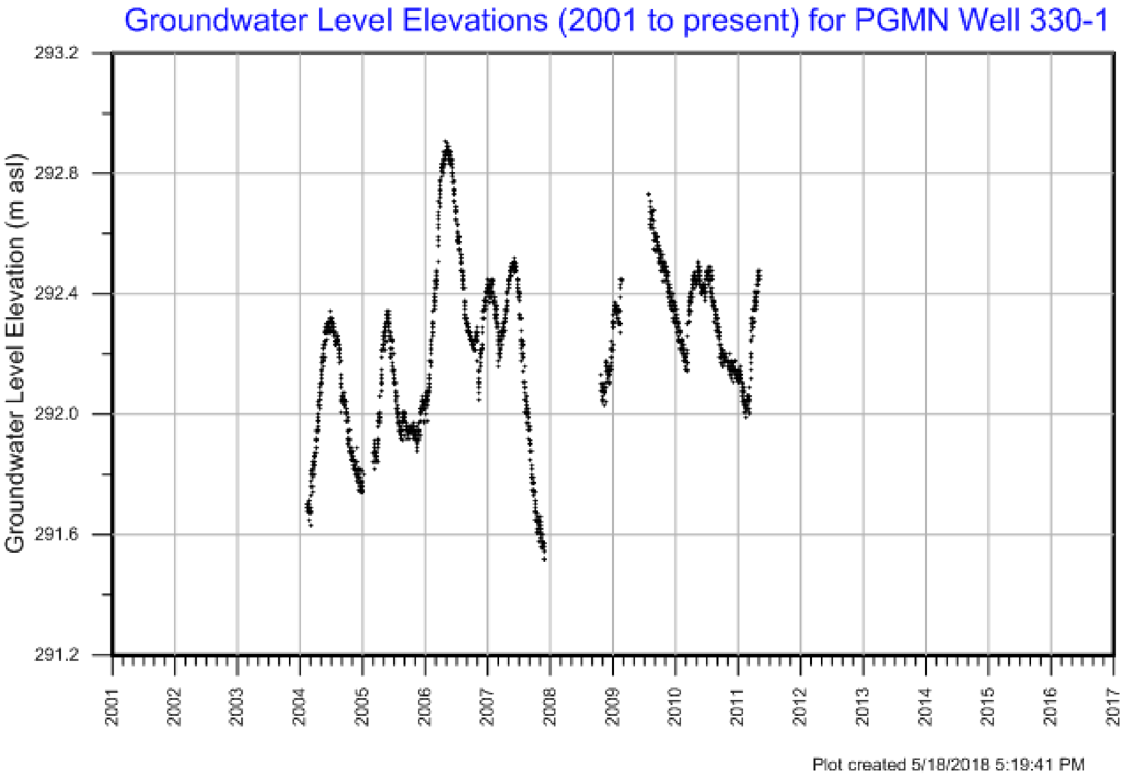

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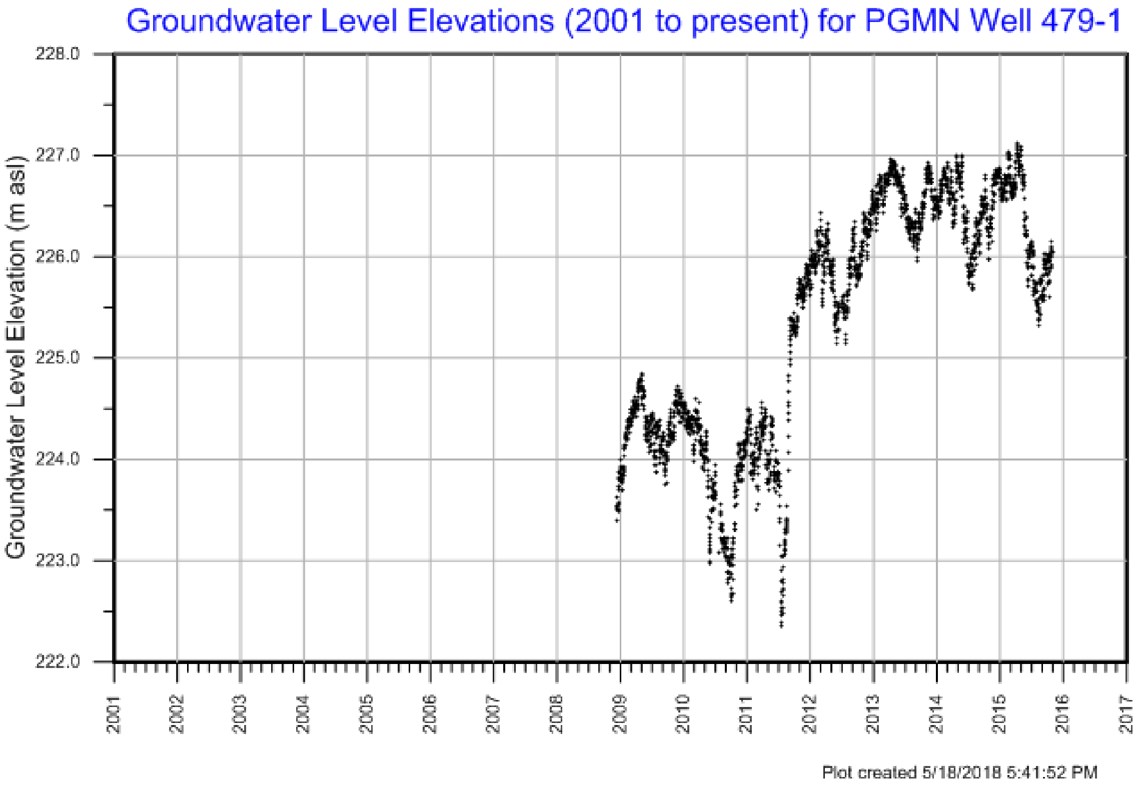

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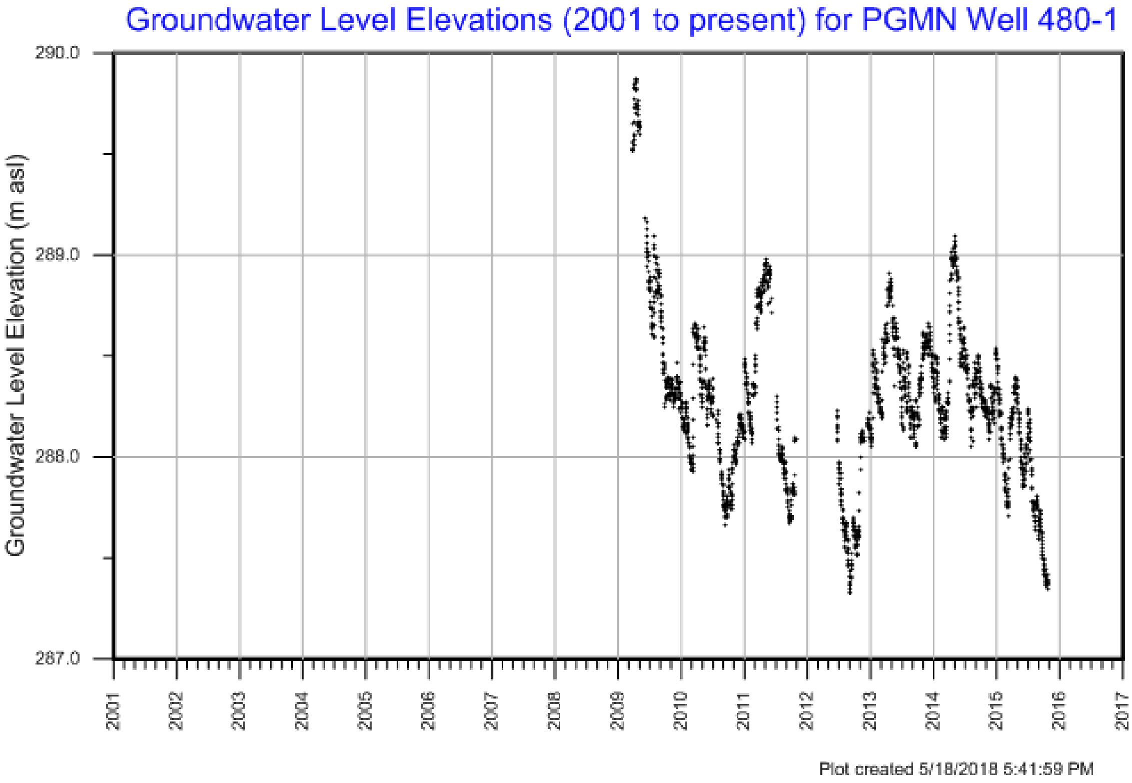

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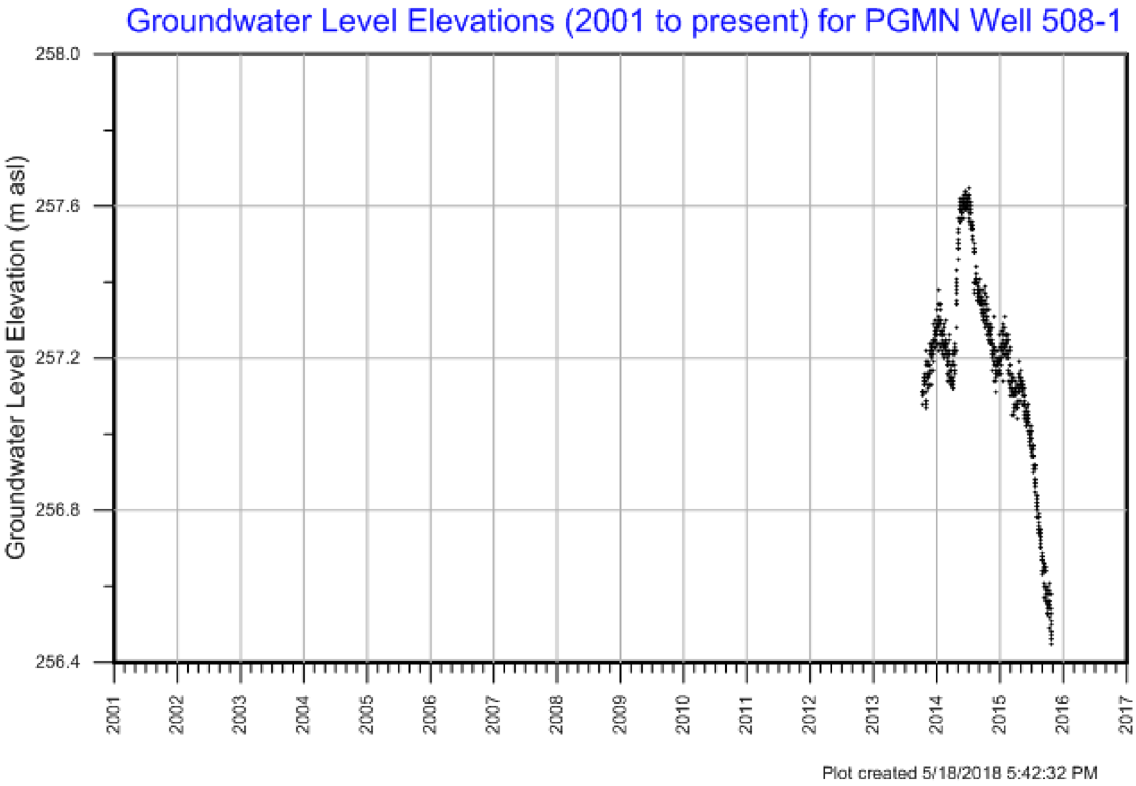
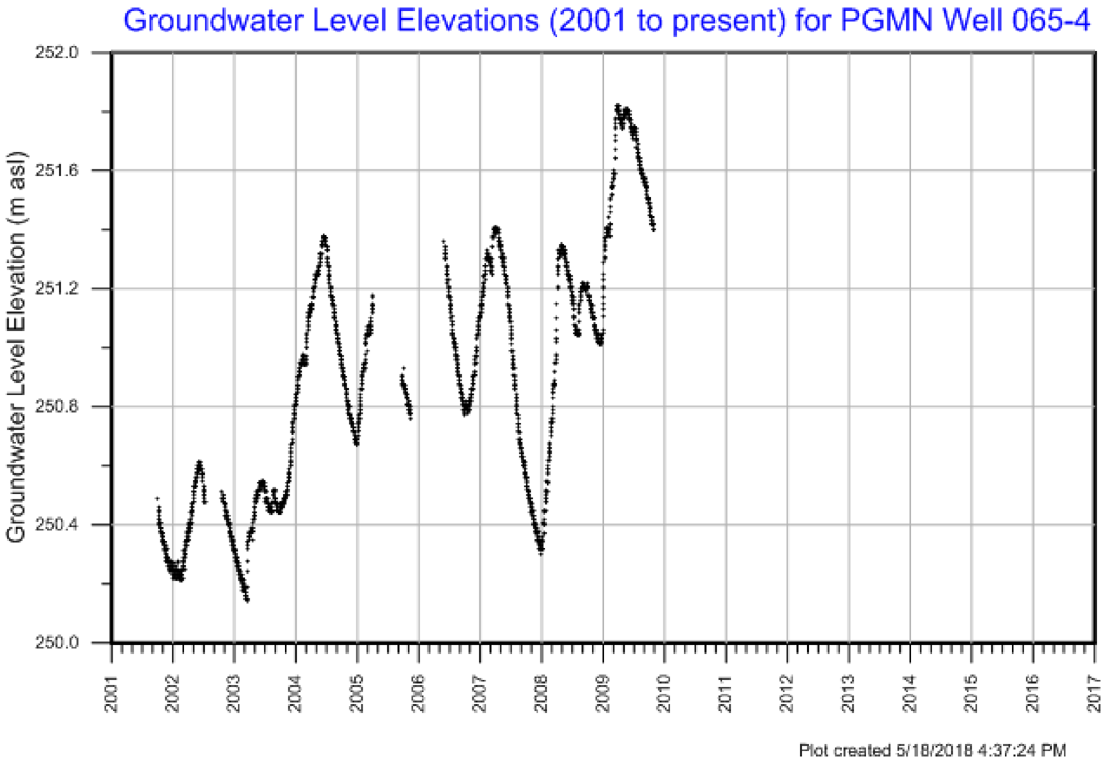

Groundwater Level Elevations (2001 to present) for PGMN Well 508-1
Groundwater Level Elevation (m asl)
258.0
257.6
257.2
256.8
256.4
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Plot created 5/18/2018 5:42:32 PM

PGMN Well Hydrographs

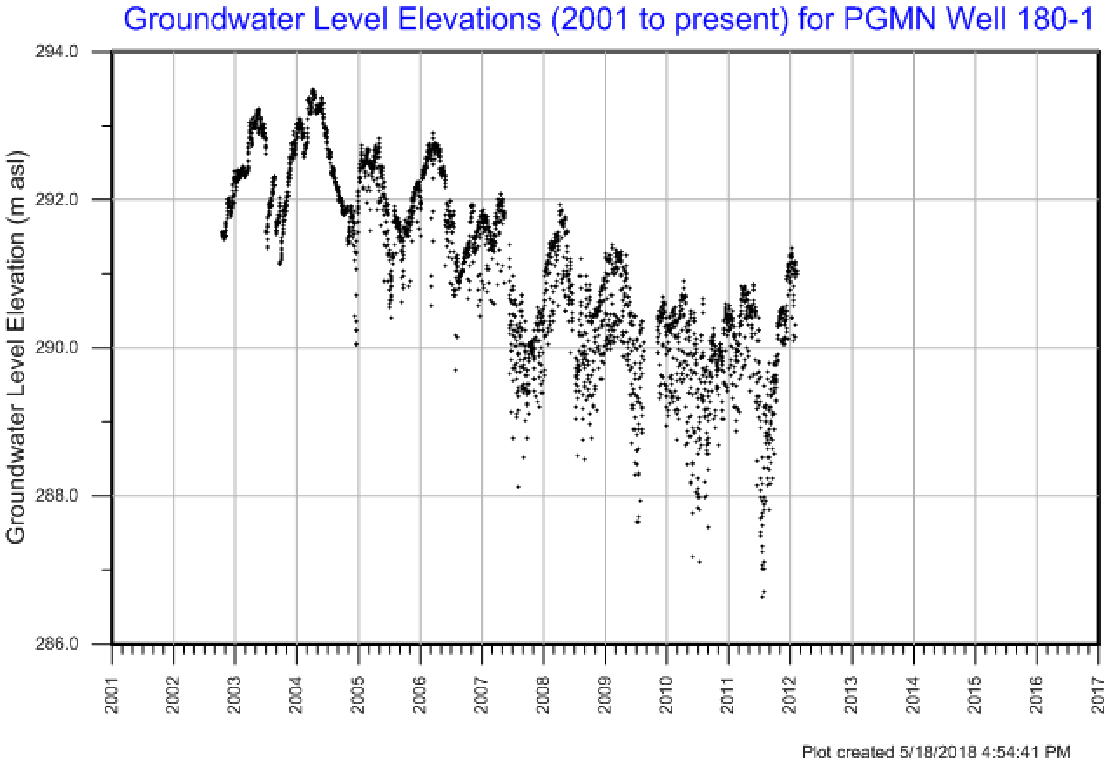
Chapter 8 Whiteman's Creek

W0000065-4


Groundwater Level Elevations (2001 to present) for PGMN Well 065-4

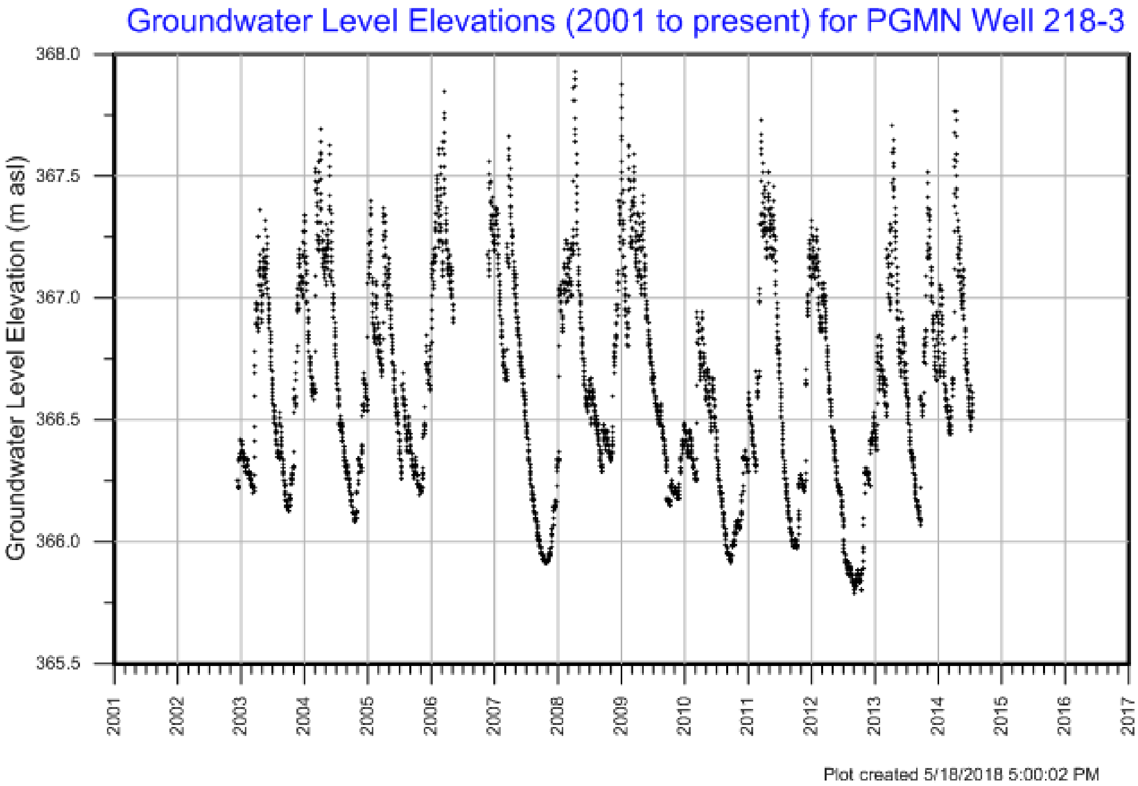
Plot created 5/18/2018 4:37:24 PM

W0000180-1

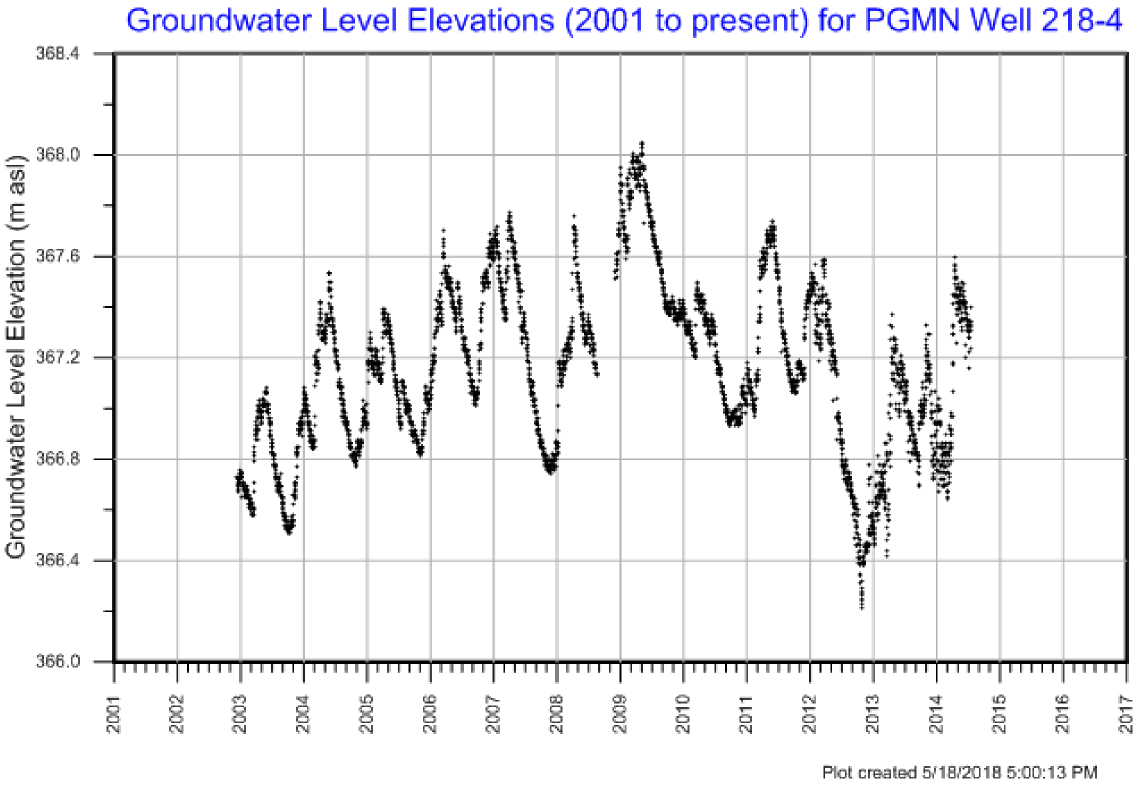

Groundwater Level Elevations (2001 to present) for PGMN Well 180-1

Plot created 5/18/2018 4:54:41 PM

W0000218-3



W0000218-4



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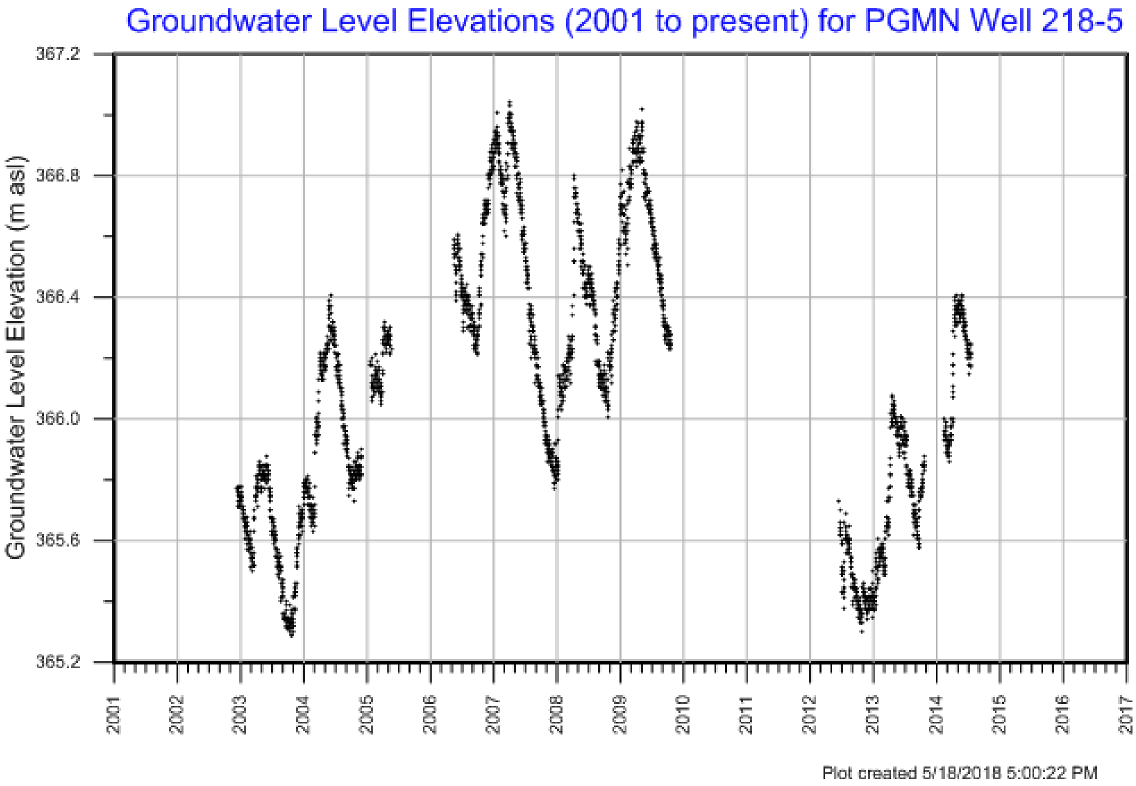

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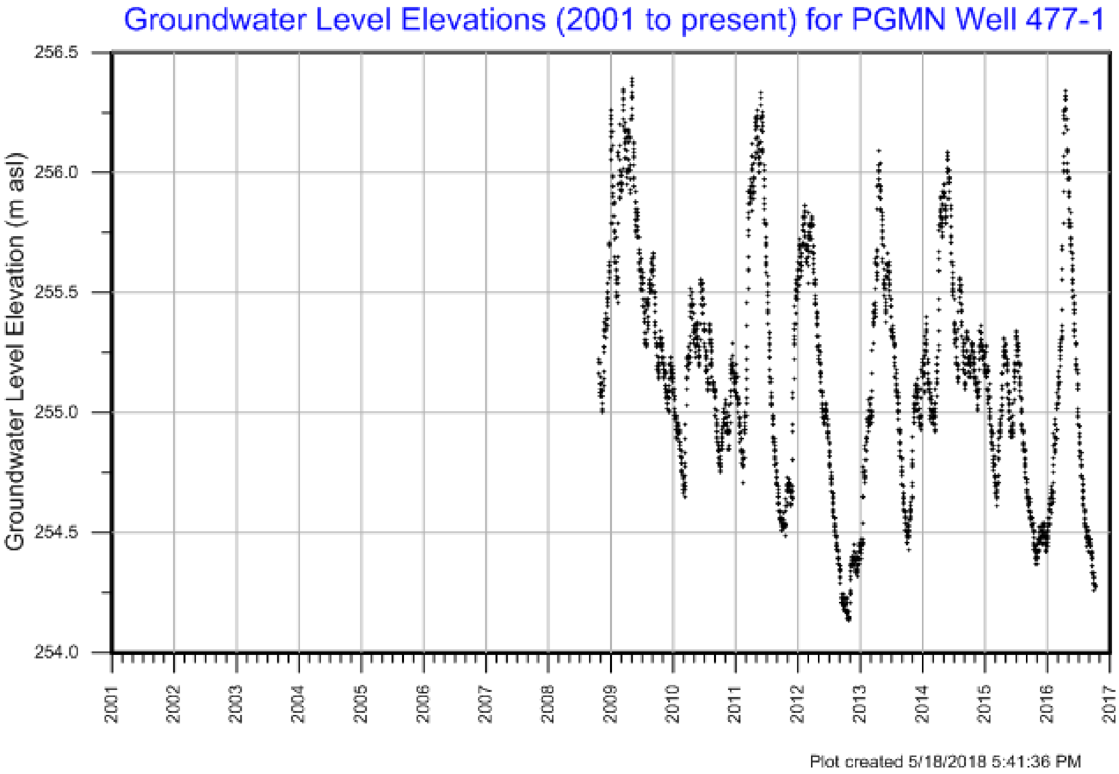

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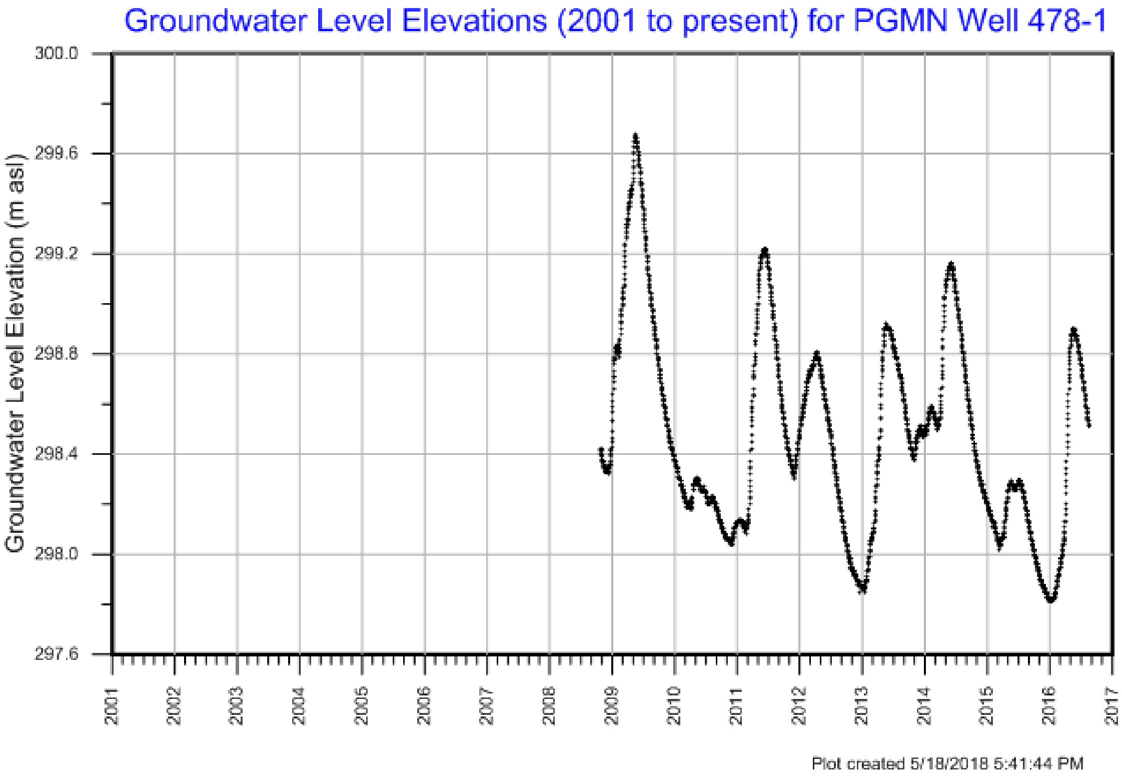
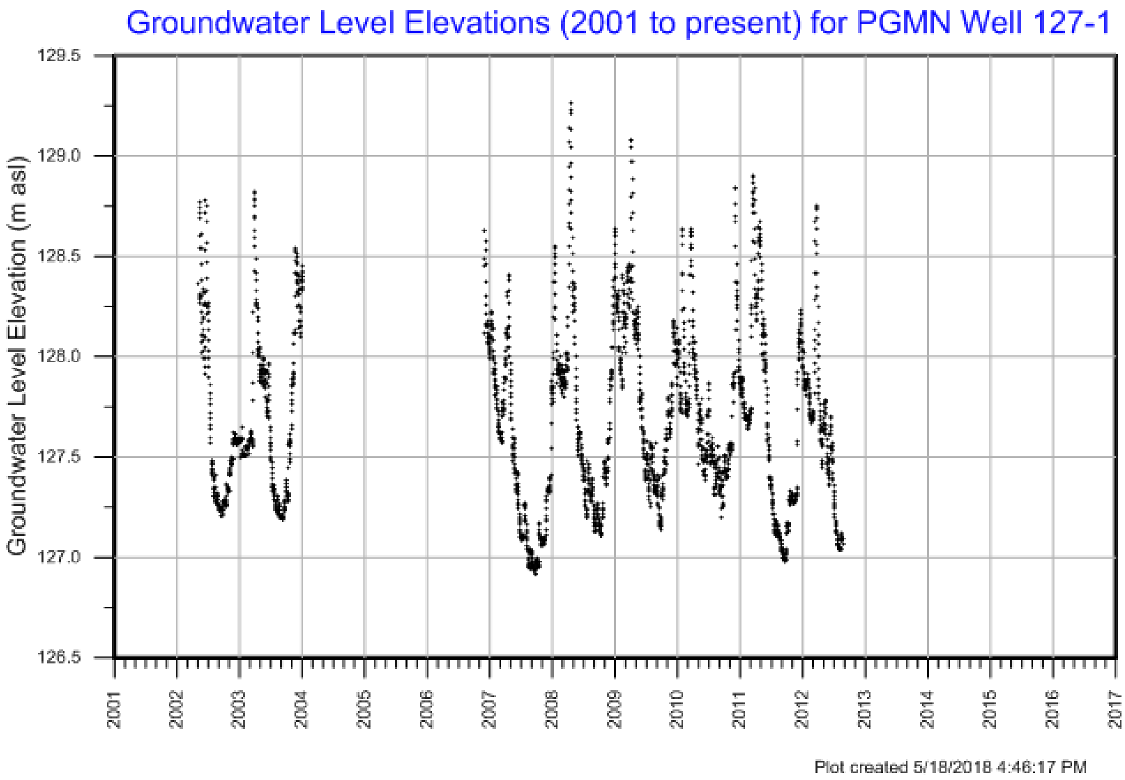

Groundwater Level Elevations (2001 to present) for PGMN Well 478-1
Groundwater Level Elevation (m asl)
300.0
299.6
299.2
298.8
298.4
298.0
297.6
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Plot created 5/18/2018 5:41:44 PM

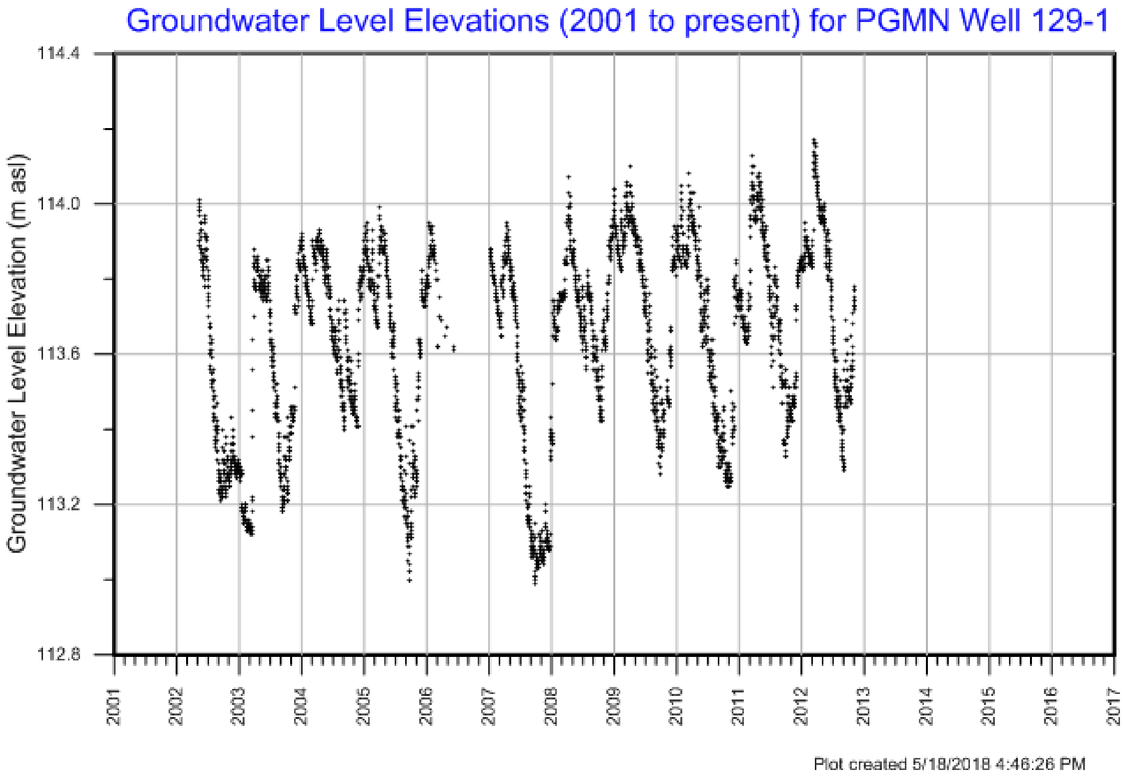
PGMN Well Hydrographs

Chapter 9 Quinte

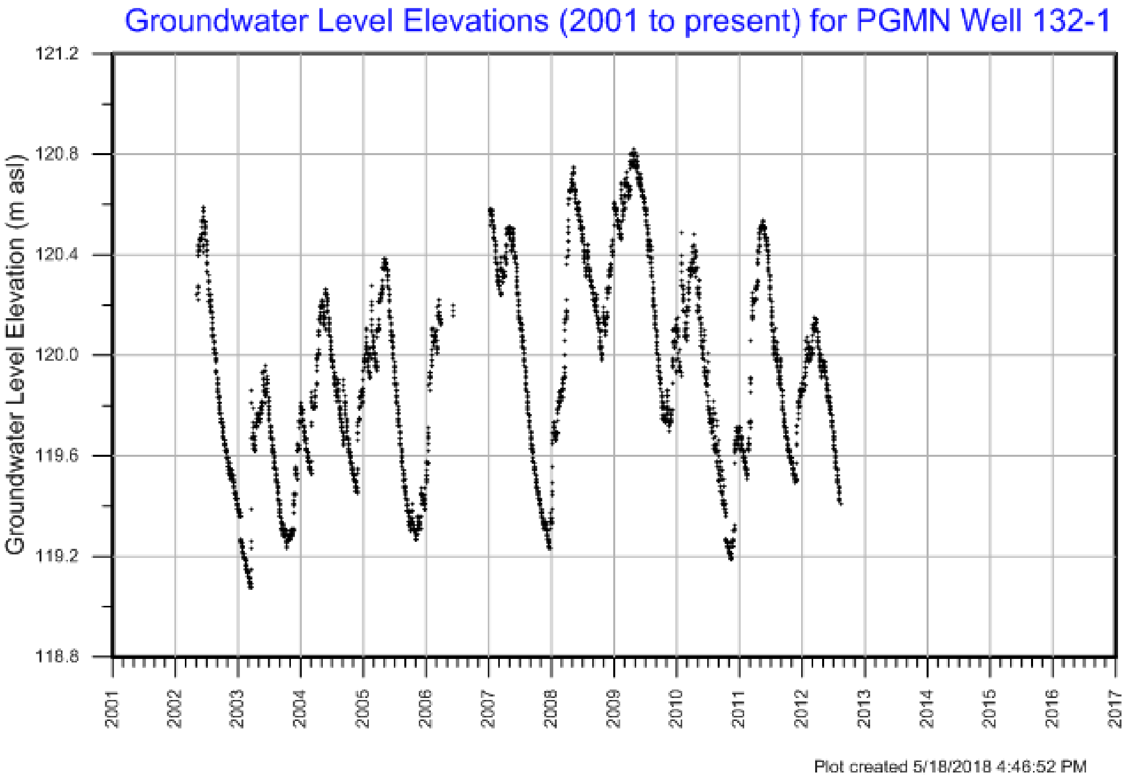
W0000127-1



W0000129-1



W0000132-1


Groundwater Level Elevations (2001 to present) for PGMN Well 132-1

Plot created 5/18/2018 4:46:52 PM

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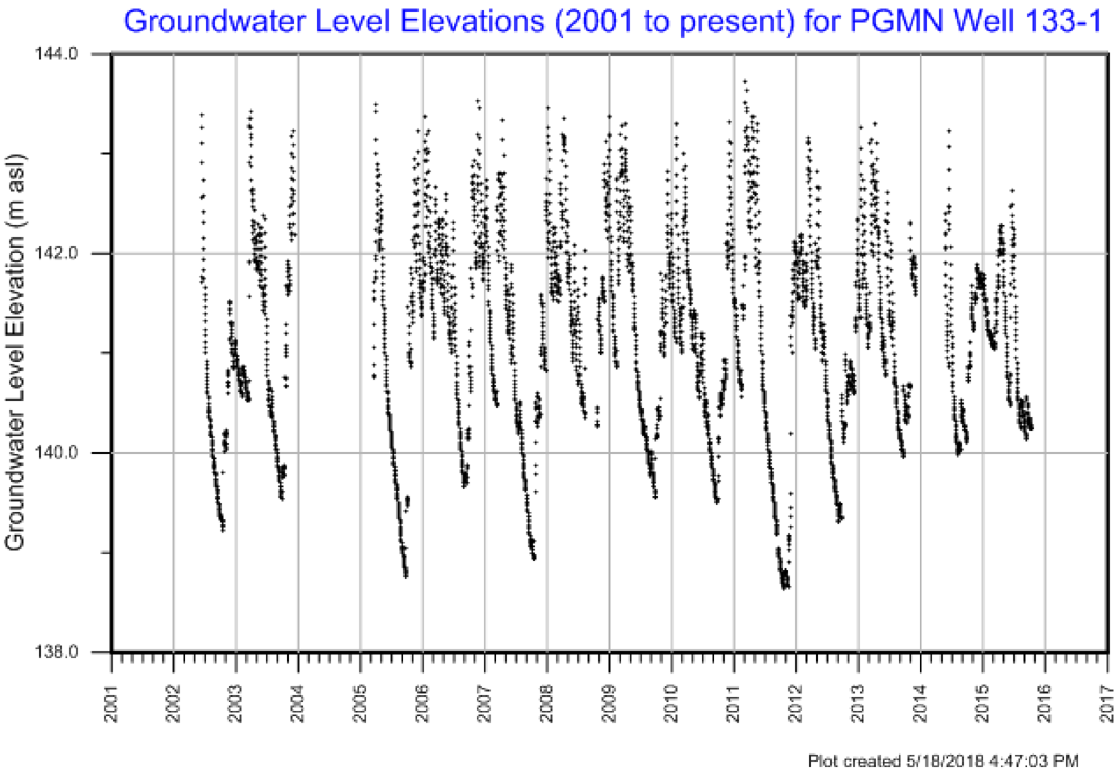
Groundwater Level Elevations (2001 to present) for PGMN Well 133-1

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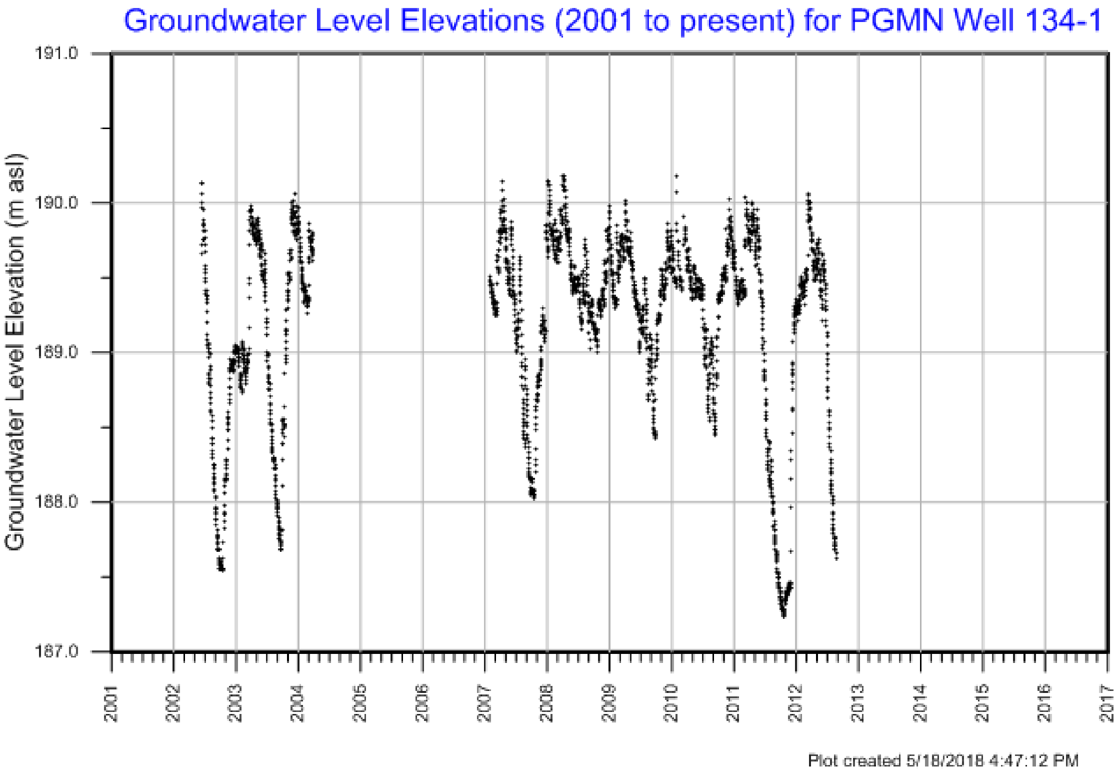

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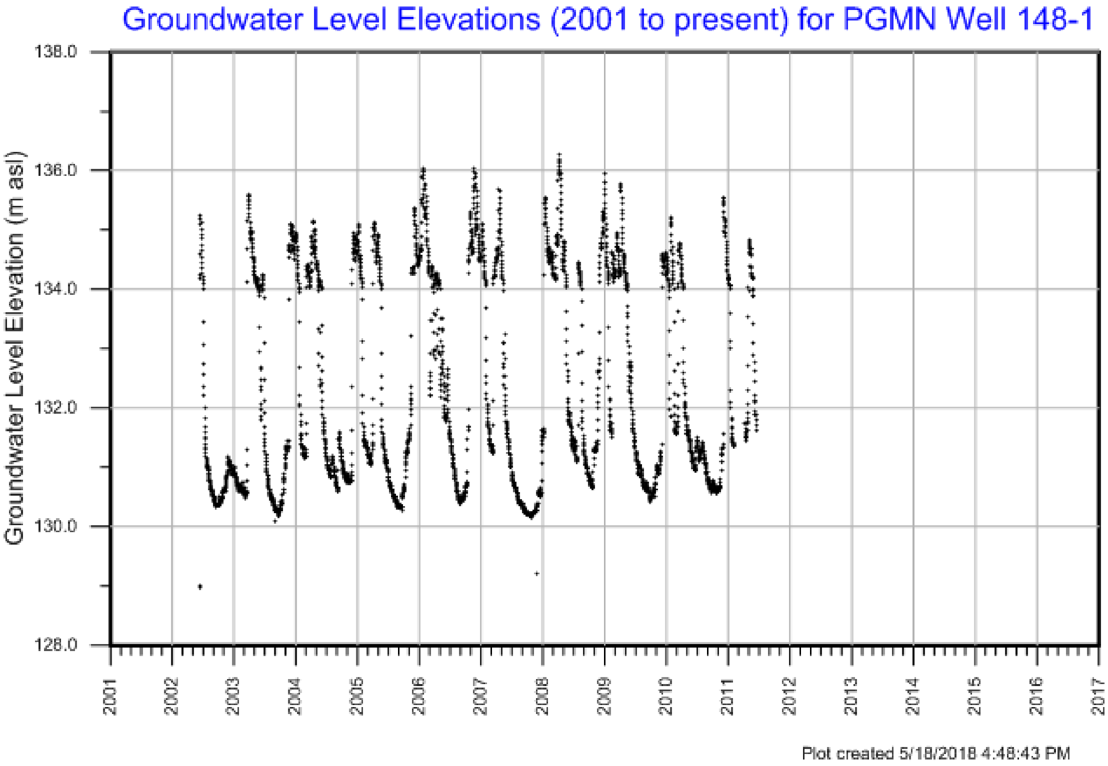

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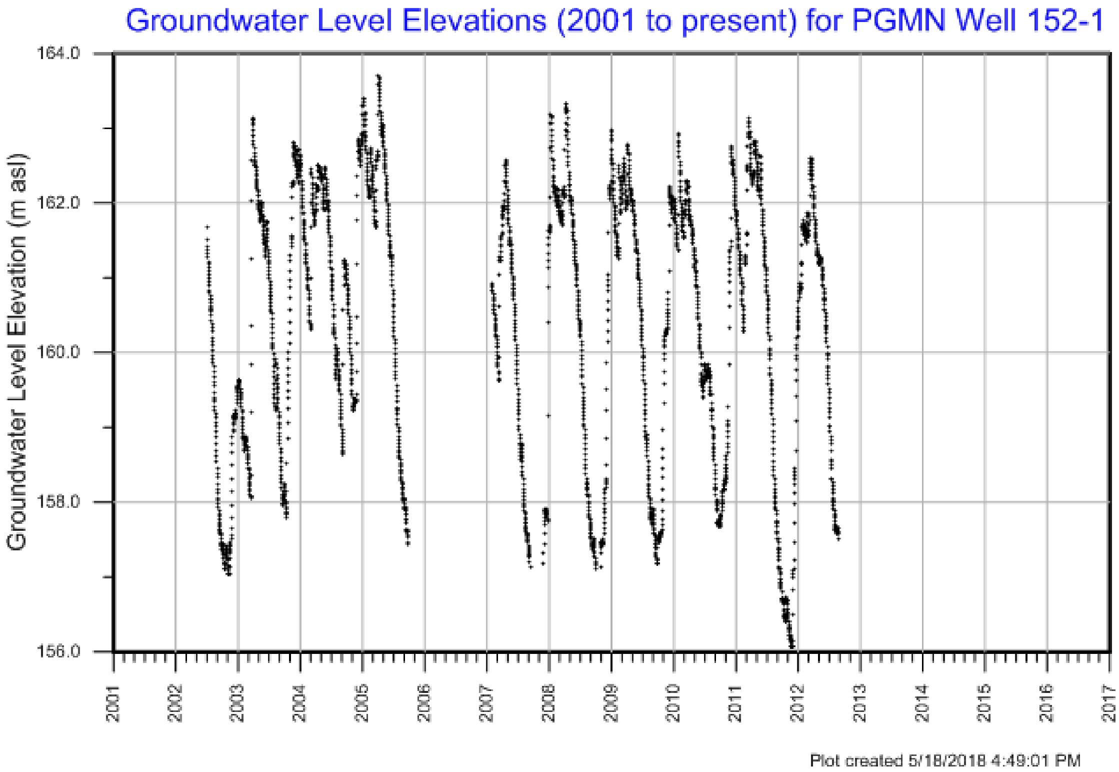

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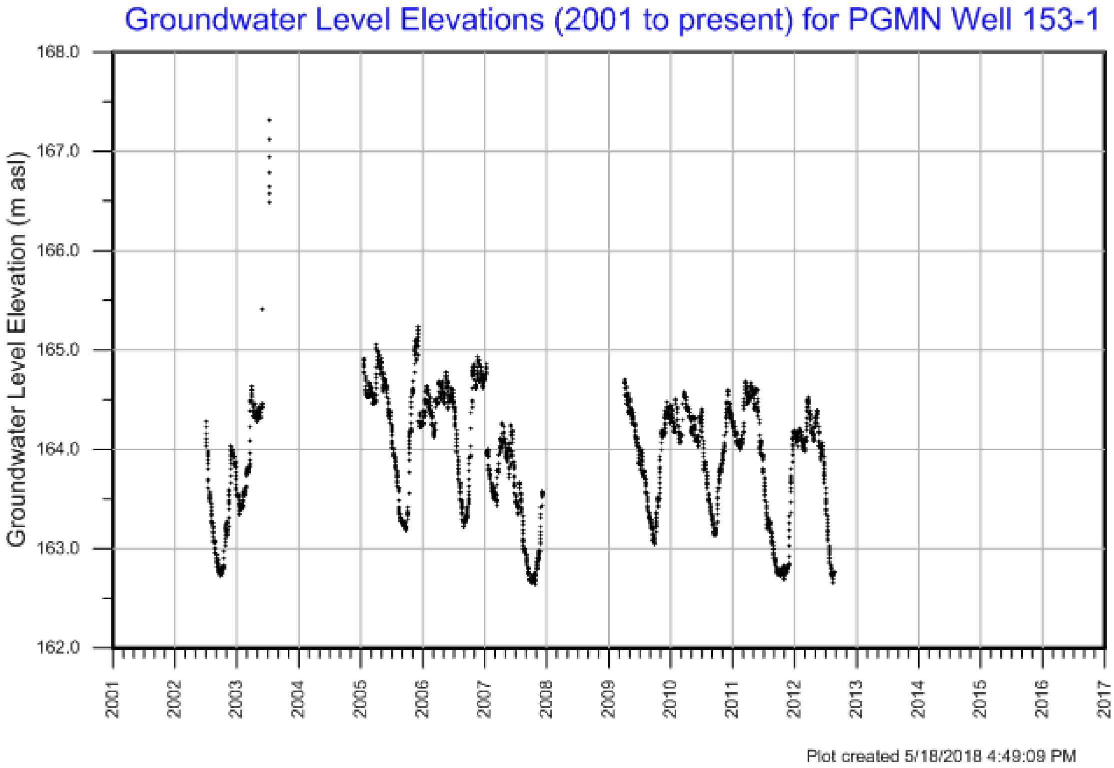

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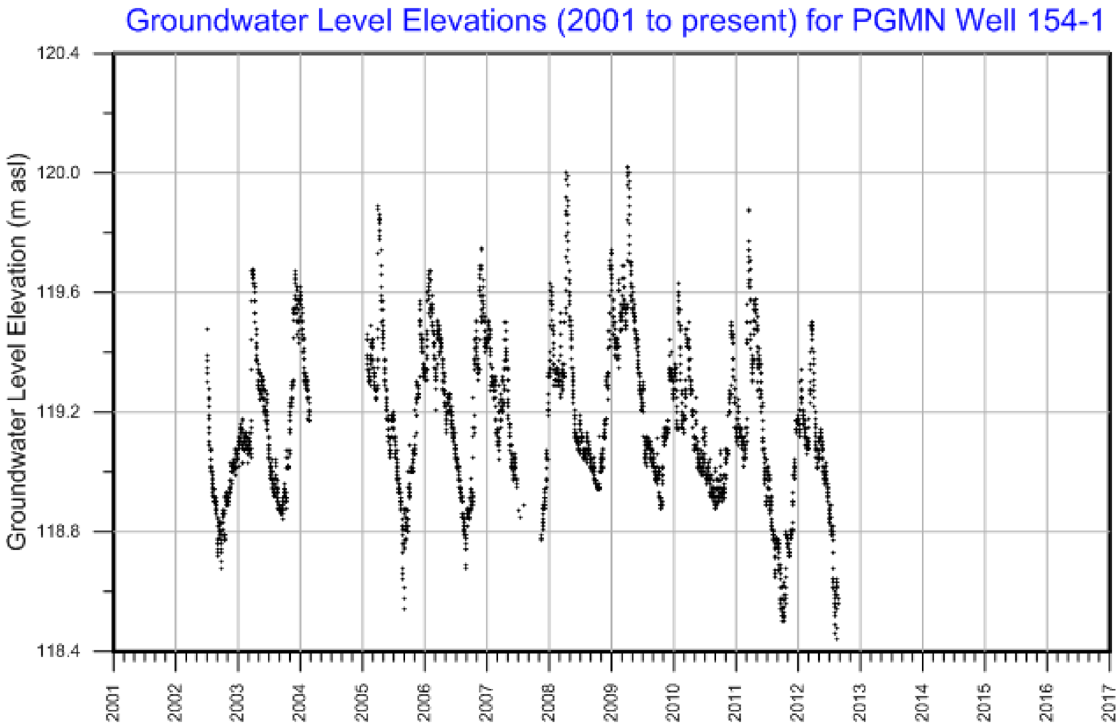

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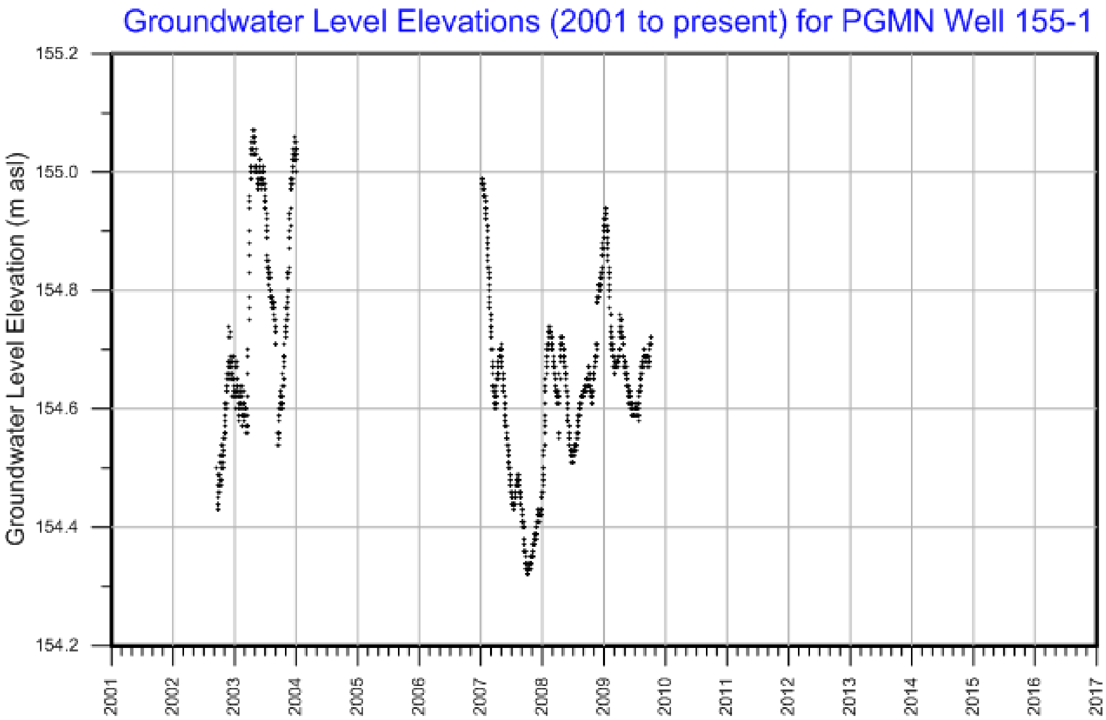

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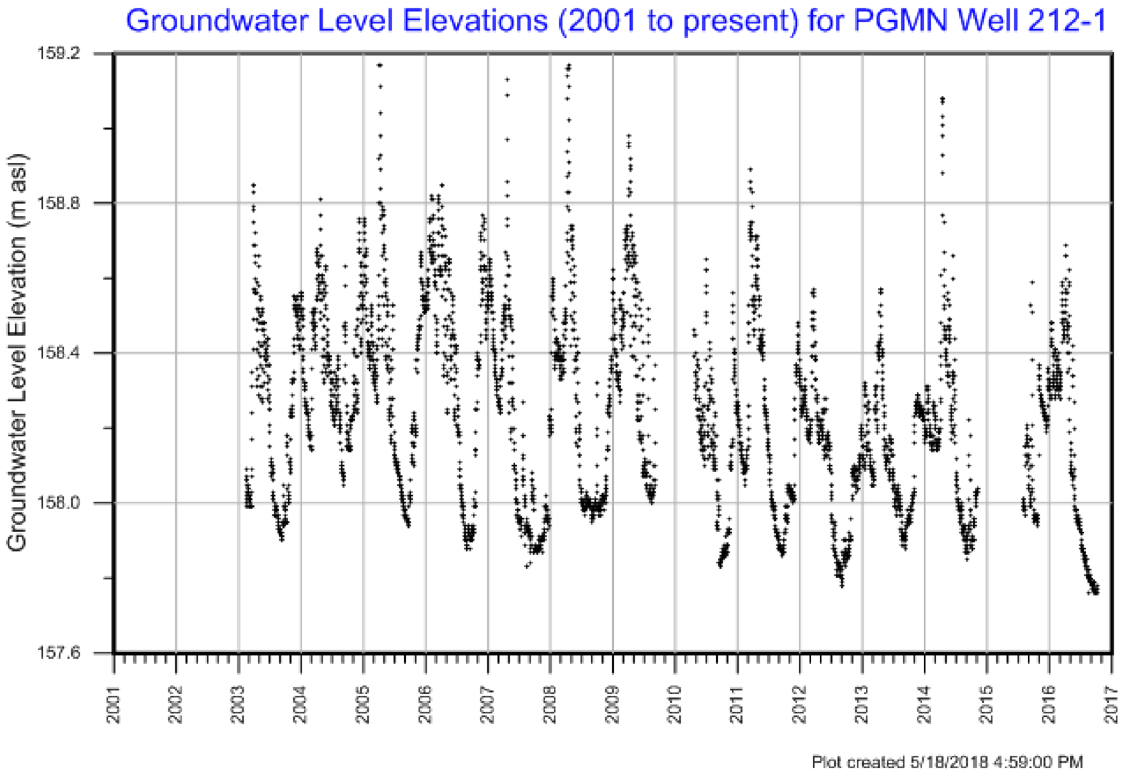

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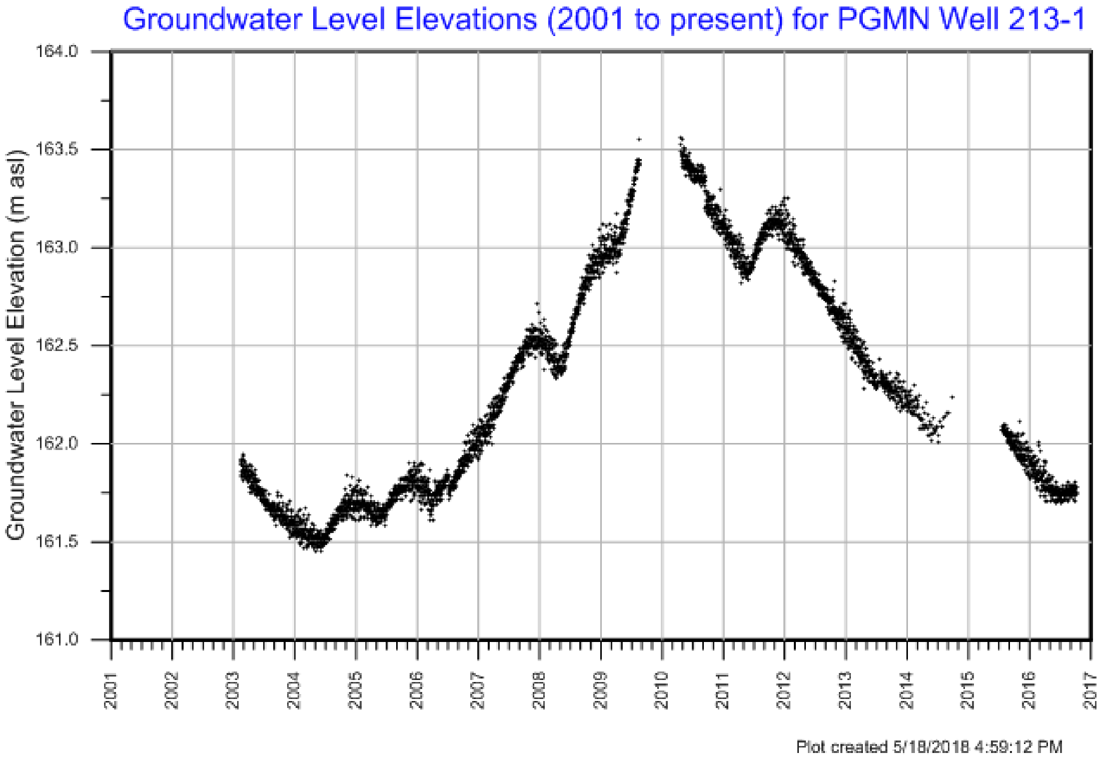

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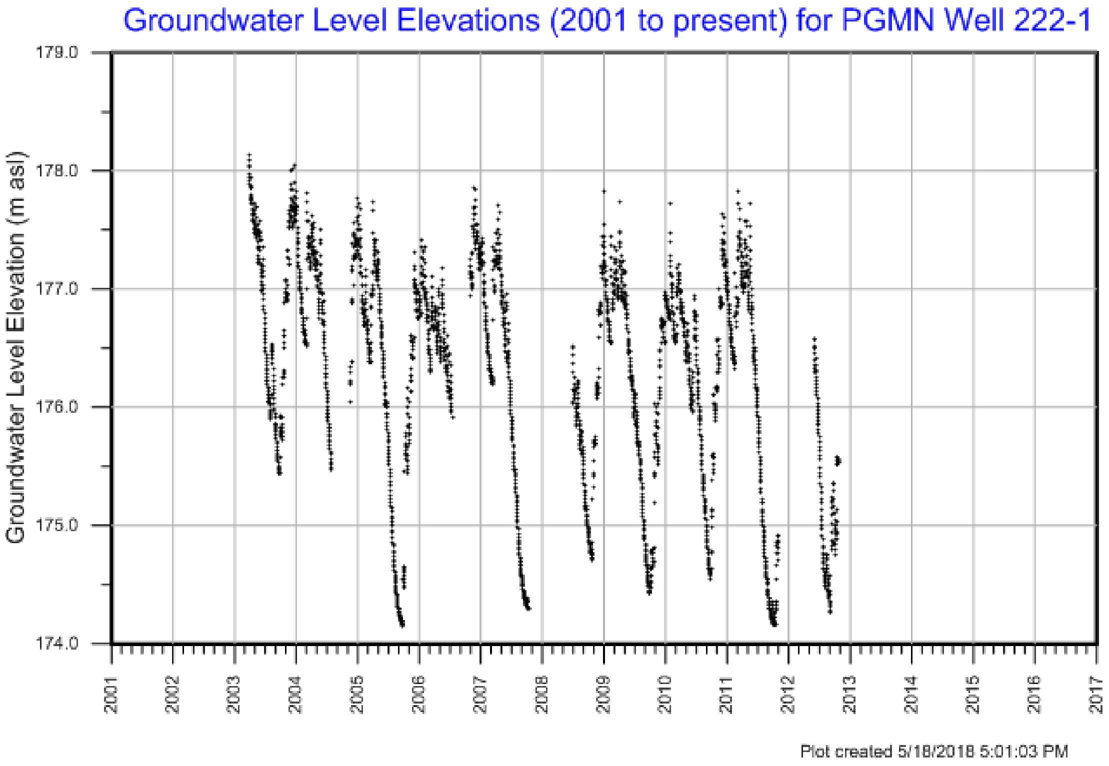

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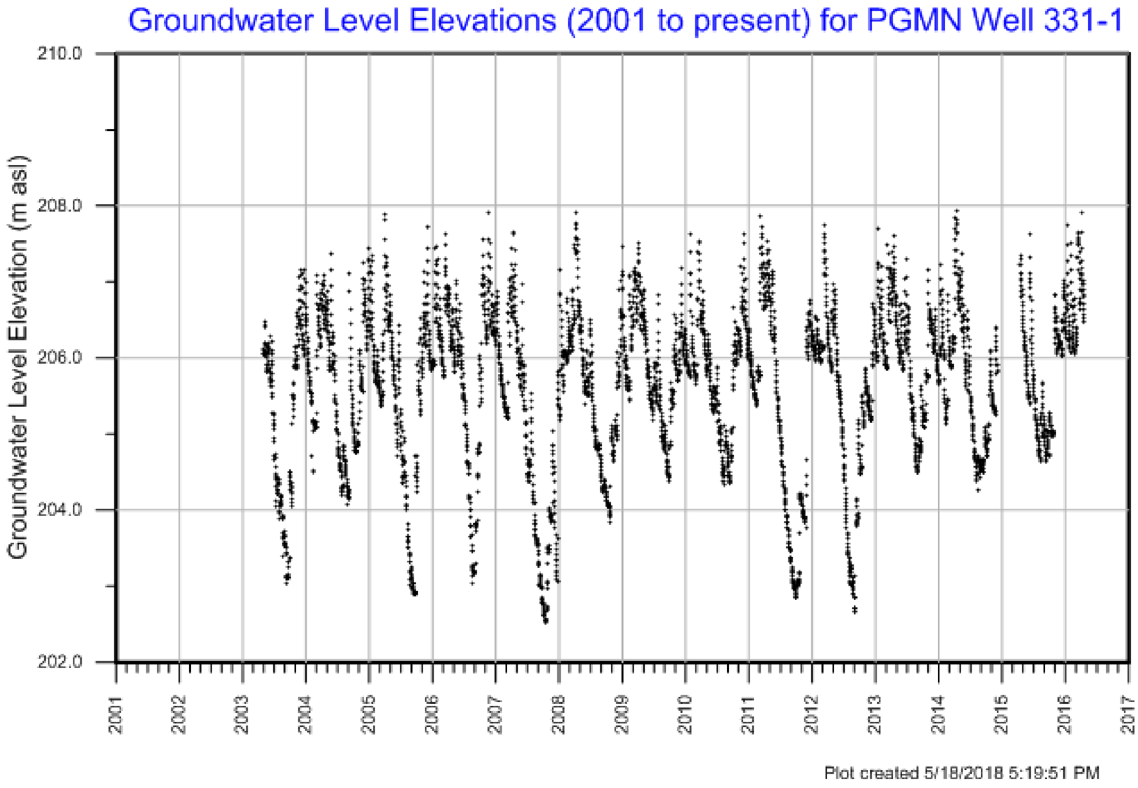

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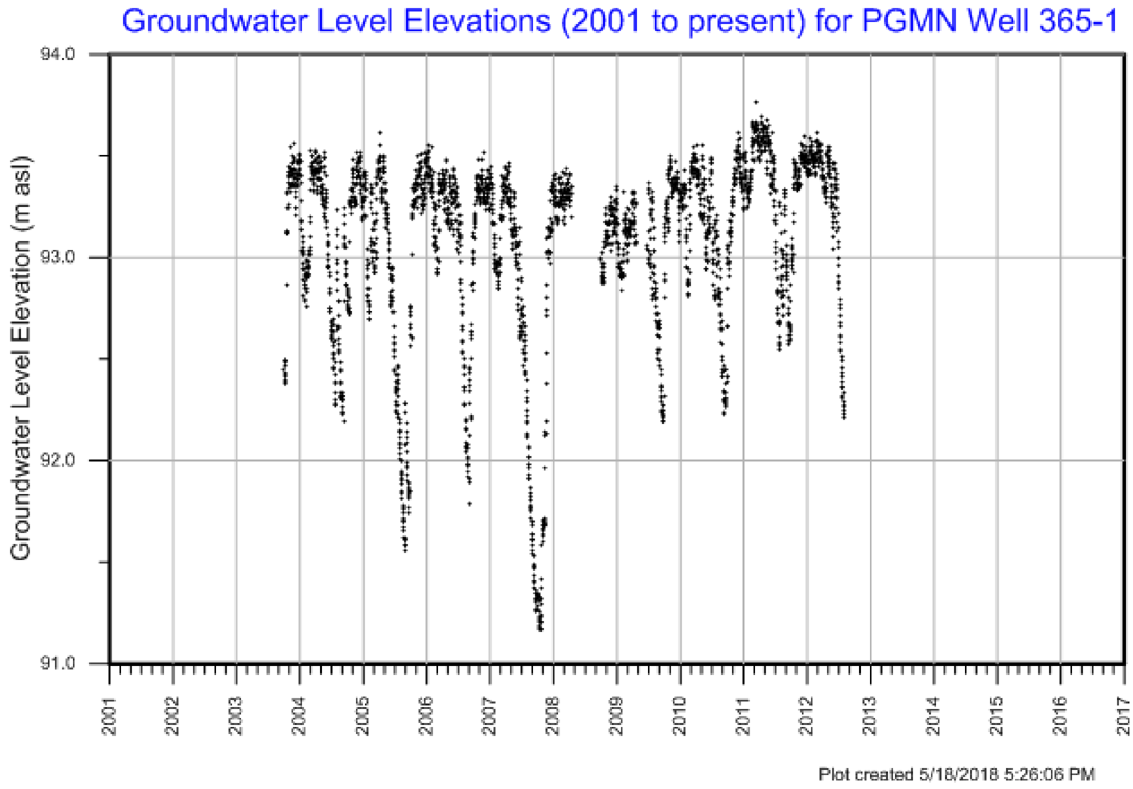

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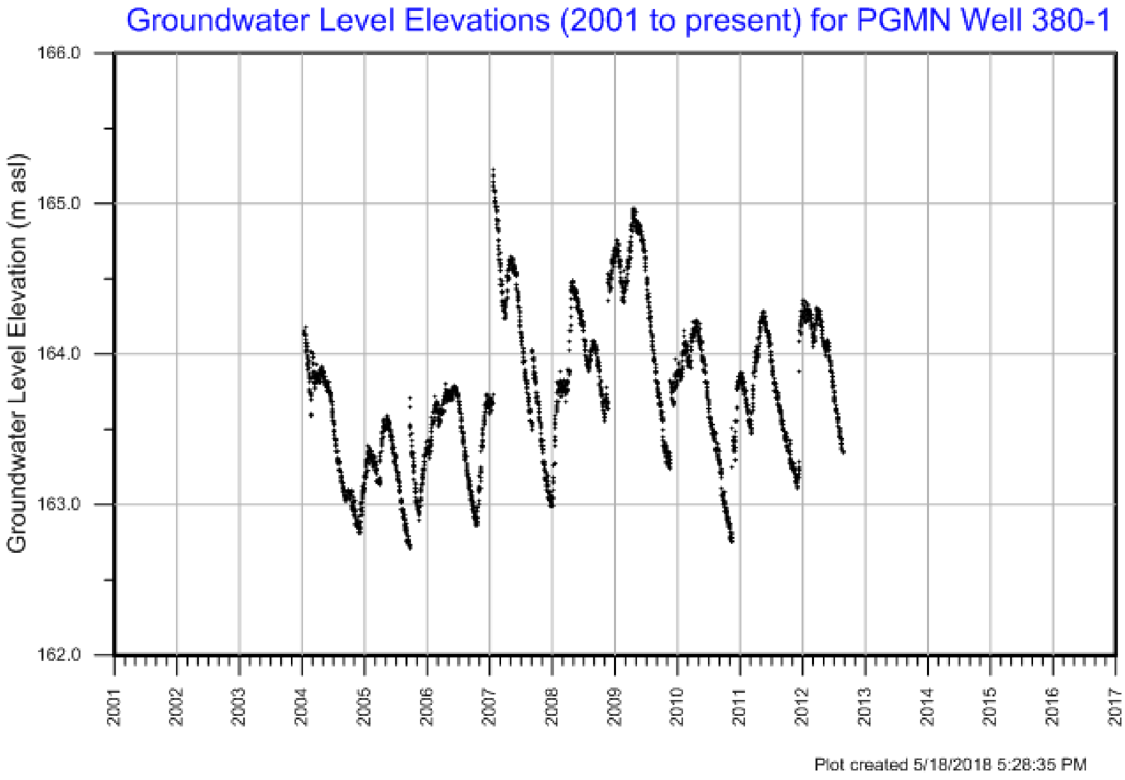

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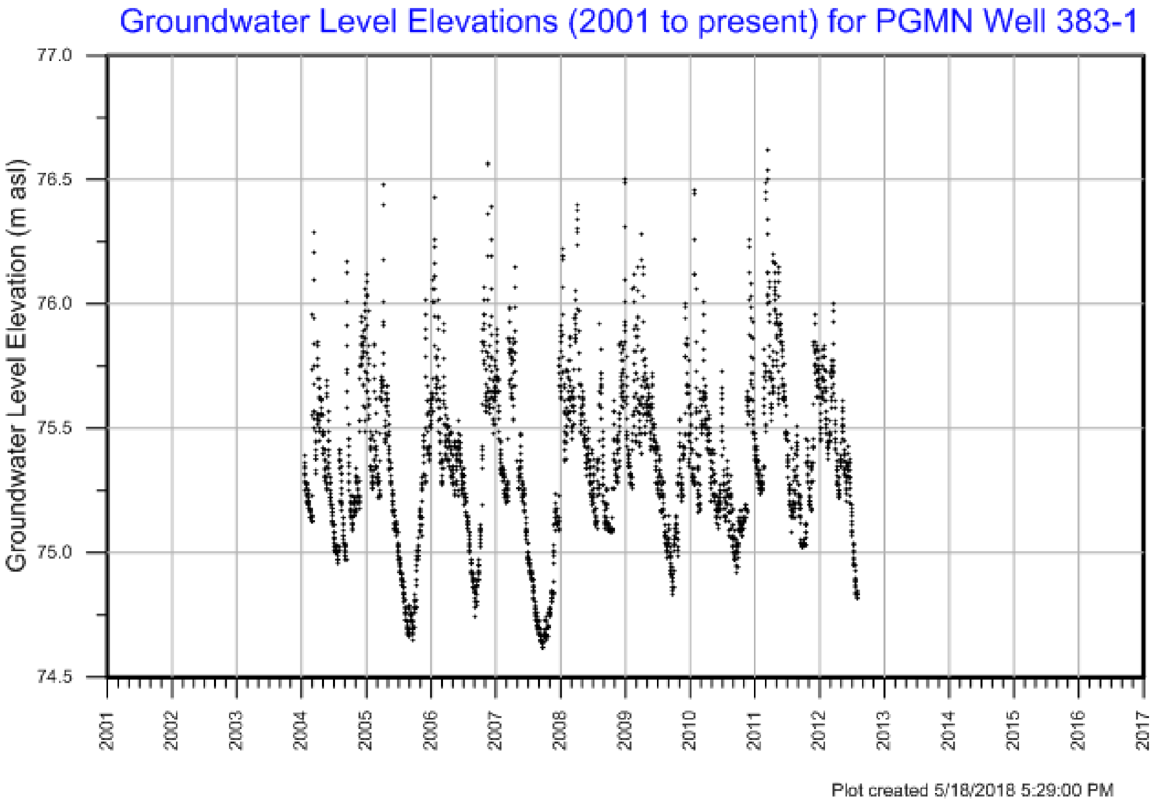
Groundwater Level Elevations (2001 to present) for PGMN Well 383-1
Groundwater Level Elevation (m asl)
77.0
76.5
76.0
75.5
75.0
74.5
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
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APPENDIX D

Table 11-1 Water Quantity Study Areas Report – Summary of Findings, Information Gaps and Recommendations

Table 11-2 Water Bottling Study Areas – Summary of Findings, Information Gaps and Recommendations

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

		Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]								
RFB Water Resource(s) of Concern		Groundwater	Groundwater	Surface Water and Groundwater	Surface Water	Surface Water and Groundwater	Surface Water and Groundwater	Surface Water and Groundwater
RFB Reason for Selection		Growth	Growth	Demand, Drought	Demand, Drought	Demand, Drought	Eastern Ontario, Low Drought Resilience, Indigenous Community (Mohawks of the Bay of Quinte)	Northern Ontario, Canadian Shield environment, Indigenous communities
RFB Water Managers	**Province**	West Central Region Technical Support of the Ministry Source Protection Program Branch Ministry of Northern Development and Mines	West Central Region Technical Support of the Ministry Source Protection Program Branch Ministry of Northern Development and Mines	West Central Region Technical Support of the Ministry Source Protection Program Branch Ministry of Northern Development and Mines	Central Region Technical Support of the Ministry Ministry of Natural Resources and Forestry Ministry of Northern Development and Mines	West Central Region Technical Support of the Ministry Source Protection Program Branch Ministry of Northern Development and Mines	Eastern Region Technical Support of the Ministry Source Protection Program Branch Northern Development and Mines Natural Resources, Agriculture and Rural Affairs	Northern Region Technical Support of the Ministry Northern Development and Mines Natural Resources
	Conservation Authority	Grand River	Credit Valley	Long Point Region, Grand River	Nottawasaga Valley, Lake Simcoe Region	Grand River	Quinte, Lower Trent	None
	Municipality	Guelph, Guelph-Eramosa Centre Wellington, Puslinch	Orangeville, Amaranth, Mono	County of Norfolk, Town of Simcoe	County of Simcoe	Oxford, Brant	Stirling, Marmora and Lake, Deloro, Centre Hastings, Madoc, Tweed, Belleville, Point Anne, Deseronto, Greater Napanee	Chapleau
Total Area		2,000 km^2	140 km^2	3,900 km^2	1,200 km^2	560 km^2	5,800 km^2	6,600 km^2
Source Protection Area(s)[3]		Grand River SPA	Credit Valley SPA	Long Point Region SPA	Nottawasaga Valley SPA	Grand River SPA	Quinte Conservation SPA	None
Source Protection Region(s)		Lake Erie SPR	Credit Valley-Toronto and Region-Central Lake Ontario (CTC) SPR	Lake Erie SPR	South Georgian Bay-Lake Simcoe SPR	Lake Erie SPR	Quinte SPR	None
Lead Source Protection Authority		Grand River Conservation Authority	Toronto and Region Conservation Authority	Grand River Conservation Authority	Lake Simcoe Region Conservation Authority	Grand River Conservation Authority	Quinte Conservation	None
Source Protection Tiered Water Budget Assessment		A Tier Three Water Budget and Local Area Risk Assessment was completed for the City of Guelph and the Township of Guelph/Eramosa, as their municipal water supplies are located in areas determined to have a Moderate level of surface and groundwater potential stress. An intake in the Eramosa River conveys water to a pond and trench-based recharge system, which recharges the shallow overburden aquifer supplying the Glen Collector. An IPZ-Q was delineated for the Eramosa River intake. The GGET Tier Three Assessment determined a moderate to significant potential for water quantity stress to the Guelph municipal supply under future demand, land use and drought conditions. Increased demand on the municipal systems, driven by population and economic growth, is the most significant cause of potential for water quantity risk. Four WHPA-Q were delineated around municipal wells in the City of Guelph and the Township of Guelph/Eramosa.	A Tier Three Water Budget and Local Area Risk Assessment was completed for Orangeville, Amaranth, and Mono, which is roughly equivalent to the preliminary Orangeville WQSA. The findings of the Assessment suggest that the area is not currently facing water quantity issues; however, given projected population growth and planned land use development, the study found that a significant water quantity risk level exists within a portion of the study area called Local Area A (including much of the Town of Orangeville, and the area immediately to the west).	A Tier 3 Local Area Risk Assessment was completed for the municipal drinking water systems of the Towns of Waterford, Delhi and Simcoe. The assessment determined that Local Area A in the Town of Simcoe was considered a Significant Water Quantity Risk Level for groundwater, while the other municipal supplies in the Tier 3 study were considered to be at a low level of risk. It was also determined that there is a Low Risk Level associated with the operation of the Town of Delhi's surface water intake in the Lehman Reservoir.	A Tier 2 Stress Assessment for groundwater in the north part of the preliminary WQSA concluded that there is a "Low Potential" for stress on municipal groundwater supplies both with maximum and average demand. No Tier 3 Water Budget Assessment completed for the water resources of concern in the WQSA. However, portions of two Tier 3 Water Budget Assessments lie within the WQSA; Barrie in the northern portion of the WQSA and York along the eastern and southern boundary of the WQSA. In addition, a detailed water budget assessment including consideration of climate change scenarios was completed for the Innisfil Creek watershed, including the water resources of concern in the WQSA, as part of a Pilot Drought Management Plan.	A Tier 2 Water Quantity Stress Assessment was completed for the Whitemans Creek subwatershed for both surface water and groundwater resources. A Tier 3 Local Area Water Budget and Risk Assessment was completed for groundwater. The stress assessment was re-calculated in order to account for substantial changes that had occurred to the municipal water supply over time. A Tier 3 assessment was not completed for surface water resources, as there are no existing or planned surface water municipal water supply systems in the subwatershed.	Tier 1 water budget completed for entire Quinte CA. A Tier 2 water balance was completed for the Tweed subwatershed, not as a result of stress calculations, but because of water shortage problems experienced in the summer of 2007 when one of the municipal wells was pumped dry on several occasions. Tier 2 work confirmed Low subwatershed stress level and revealed water shortage problems were a result of increased water use at one of the wells due to operational problems as opposed to source water supply. No Tier 3 water budgets completed within the WQSA.	None
Conservation Authority(ies)		Grand River/ Credit Valley/ Hamilton Region/ Halton Region	Credit Valley/ Grand River/ Nottawasaga Valley	Long Point Region/ Upper Thames River/ Grand River	Nottawasaga Valley/ Lake Simcoe Region/ Toronto and Region	Grand River/ Upper Thames River	Quinte Conservation	None

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

		Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]								
MECP Regional Office Consultation and Review		Hamilton (West Central)	Hamilton (West Central)	Hamilton (West Central)/ London (Southwest)	Toronto (Central)	Hamilton (West Central)	Kingston (Eastern)	Sault Ste Marie (Northern)
Water Resources	Groundwater (overburden)	Major moraine systems, including the Orangeville, Waterloo, Paris and Galt, are found in the Grand River watershed, and are comprised of extensive sand and gravel units, and provide significant amounts of groundwater for municipal and private use across the watershed. A number of aquifers situated within the Waterloo moraine are used by the Region of Waterloo for municipal drinking water supply.	Overburden aquifers used for municipal water supply and some residential water supply include the Intermediate Aquifer (Upper Sands) and the Lower Aquifer (Lower Sands). Within the WQSA, two municipal supply wells draw from the Intermediate Aquifer (Upper Sands) and three municipal wells obtain groundwater from the Lower Sands overburden aquifer. All other municipal supply wells in the WQSA draw water from the bedrock aquifers.	The upper, shallow overburden aquifer is unconfined and consists of sand and gravel deposits associated with the Norfolk Sand Plain; it supports municipal wells for a number of communities and is the primary groundwater resource in the Long Point, Catfish Creek and Kettle Creek watersheds. Throughout much of the WQSA, the unconfined aquifer is underlain by an aquitard consisting of sandy silt and clay glaciolacustrine deposits. Below the aquitard is a discontinuous intermediate aquifer. Deeper overburden aquifers, generally located at depths greater than 20 m, are reportedly present in both the Catfish Creek and Kettle Creek Watersheds within the basal portions of the Port Stanley Till and the underlying Catfish Creek Till where discontinuous sand and gravel lenses exist; they have also been identified in isolated locations in the Long Point Watershed.	The aquifer system is generally described as containing four major sand and gravel aquifer units. Shallow Unconfined - Lake Algonquin Sand Aquifer (most upper, shallow sand and gravel deposits) and Thornton Sand Aquifer (between 2 and 30 m thick surficial sand, limited groundwater resource). Deep Confined - Innisfil Valley Aquifer (deep, highly transmissive aquifer under central portion of the Innisfil Creek valley within the tunnel channel deposits associated with the lowland area) and Laurentian Valley Aquifer (coarse-grained valley fill deposits at the base of the Laurentian Valley). These lower aquifer units tend to host significant groundwater resources, and a connection of the two systems would present a regionally extensive, highly transmissive aquifer.	In the northern portion of the WQSA, limited overburden aquifers are present, as till aquitards dominate the overburden sequence; aquifers are sporadically present, but they are thin and localized. Within the north-central portion of the WQSA, a significant outwash deposit (the southwest extension of the Waterloo Moraine aquifer) exists at surface. In the south-central portion of the WQSA, the Waterloo Moraine sand aquifer is confined by tills; underlying the moraine is a significant sequence of aquitards with no notable aquifers above bedrock. In the southeast area of the WQSA, a broadly unconfined sand and outwash aquifer is present and widespread, and is considered the northern portion of the Norfolk Sandplain; the aquifer receives significant recharge and supports a significant volume of groundwater extraction. Regional groundwater flow is in a general southward direction towards Lake Erie.	The Quaternary overburden aquifer occupies much of the same area which is underlain by the Paleozoic bedrock. While the aquifer is thin near the bedrock transition zone to the north, to the south it is thick, approximately 40 m near the lake, saturated sand and gravel deposits which support a productive water table aquifer for local water supplies. The Quaternary aquifer, where sufficiently thick, provides the greatest volume of groundwater storage, as overburden deposits typically are able to store more water than fractured bedrock.	Hydrogeological data are very limited for this area. The overburden deposit distribution in the area could be used in identifying areas where groundwater resources are likely to occur, such as the thick overburden layers typical of moraines indicated in well records around Racine Lake with a thickness greater than 30 m.
	Groundwater (bedrock)	The municipal supplies for Guelph, Cambridge, Rockwood, Fergus and Elora rely on the Gasport and Guelph Formation units for the majority of their potable drinking water supplies. The Gasport Formation represents the most common aquifer used for groundwater supply within the WQSA due to the transmissive nature of the limestone unit.	The Guelph and Amabel Formations represent the main bedrock aquifers used for water supply within the WQSA. Of the two, the Amabel is particularly productive, exhibiting high secondary porosity. Stratigraphically, the Eramosa member of the Amabel Formation overlies the aquifer portion of the Amabel, separating it from the overlying Guelph Formation. While the Eramosa is known to act as a good aquitard where present, its spatial continuity is poorly understood due to a lack of deep, good quality boreholes in the WQSA.	Domestic bedrock wells within Long Point Region are typically completed into the upper 10 to 30 m of the Dundee Formation. In other areas, including the Norwich municipal wells, the bedrock wells are interpreted as having been completed in the Detroit River Group. Regional groundwater flow in the bedrock is in a general southerly direction towards Lake Erie. Under the Norfolk Sand Plain area, there is generally an upward gradient from the lower aquifer/bedrock into the overlying overburden units.	Limited use. The valley fill aquifers may also be connected to aquifers associated with the Thorncliffe Formation. Few bedrock wells are concentrated along the south-west region of the WQSA.	The Salina formation is exposed at bedrock surface across much of the WQSA, with the Bass Island, Bois Blanc and the Onondaga Formations exposed at surface in the far west of the WQSA. The Salina formation is regionally known to have naturally poor water quality because of highly mineralized water. The community of Shakespeare and the Town of Innerkip are the only municipal water supply systems in the WQSA to draw from bedrock; it is likely that they draw water from either the Bass Island, Bois Blanc or Onondaga Formations. Despite few permitted takings in the western part of the WQSA, bedrock aquifers support a significant amount of domestic wells, and water supply wells for the City of Woodstock just west of the WQSA. Regional groundwater flow is in a general southward direction towards Lake Erie.	The Precambrian Bedrock Aquifer Area is located to the north and is characterized by thin overburden, causing the groundwater surface to be shallow and close to the bedrock surface. The water supply in this area is mostly derived from fractured rocks of Precambrian age. Located south of the Precambrian area to Lake Ontario is a region of Paleozoic-aged limestone Paleozoic bedrock aquifer, where water is derived from fractures in the bedrock. For the most part, these fractured bedrock aquifers are considered to be unconfined. Precipitation can move easily from the ground surface into the aquifer. Fractured bedrock aquifers have limited storage capacity.	It is assumed that in areas where extensive bedrock deformation occurs, groundwater in the fractures associated with the bedrock could be sources for water, as described in well records near Peterbell, Borden Lake and Minnipuka. Areas with shallow weathering or structurally deformed bedrock at surface are expected to have relatively good recharge/infiltration from precipitation and would be good sources of groundwater especially for domestic use.
	Surface Water	The WQSA overlaps with the watersheds of the Grand River, Credit River, Bronte Creek, Sixteen Mile Creek and Spencer Creek. The majority of the WQSA is occupied by the Grand River watershed, including the subwatersheds of the Speed River, Mill Creek, and Eramosa River. With the exception of Puslinch Lake in the southern portion of the WQSA, there are no large natural surface water bodies in the WQSA. The majority of the water bodies in the WQSA are characterized by cold or cool water regimes; warmwater bodies are largely confined to the southwestern portion of the WQSA, in the lower Speed River and its tributaries.	The headwaters of two significant river systems, the Credit and the Nottawasaga Rivers, lie within the Orangeville WQSA. The Island Lake Reservoir is situated on the northeast margin of the Town of Orangeville and feeds both river systems. Two main creek systems, the Monora and Eastern Tributaries, provide all of the inflow to the Island Lake Reservoir. The Orangeville Wetland Complex, a Provincially Significant Wetland, is approximately 340 ha in area and includes wetlands that surround the Island Lake Reservoir, the Credit River, North Branch of Lower Monora Creek, Middle Monora Creek, the eastern portion of Upper Monora Creek, and the riverine wetlands south of Island Lake that support coldwater fish communities.	The WQSA overlaps with the watersheds of the Long Point Region, Thames River, Catfish Creek, Kettle Creek, and a small portion of the Grand River. The majority of the WQSA is occupied by the watersheds of the Long Point Region, which is drained by more than 30 creeks and tributaries. Most of the water bodies in the Long Point Region watershed are characterized as cold water habitat, though the subwatersheds draining the clay plain in the eastern portion of the watershed tend to have warm water habitats.	The WQSA contains a mix of cool and cold streams throughout the study area; however most stream temperatures are unknown and/or have not been reported. Innisfil Creek subwatershed is drained by five main creek systems: Innisfil, Bailey, Beeton, Cookstown, and Penville creeks. Innisfil Creek originates in the uplands region and drains the northern portion of the subwatershed as it passes through the lowlands. Innisfil Creek enters the Nottawasaga River south of Alliston. Bailey Creek begins on the Oak Ridges Moraine and drains the southwestern portion of the watershed as it flows northeast through an agricultural and forested area to join Innisfil Creek.	The WQSA overlaps with the watersheds of the South Thames River above Pittock Reservoir, and of the Grand River (including almost the entirety of the Whitemans Creek subwatershed). The major water bodies located within the boundaries of the WQSA include the Thames River, the Pittock Reservoir, Horner Creek, Kenny Creek and Whitemans Creek. Whitemans Creek, including Horner Creek, is characterized by a coldwater thermal regime, while Kenny Creek (tributary to Whitemans Creek) and the Thames River and its tributaries have a warm water thermal regime.	Significant surface water features include the Napanee, Salmon, and Moira Rivers draining the northern Precambrian shield into the Bay of Quinte and further into Lake Ontario in the south. Surface water sourced from Lake Ontario is an important drinking water resource and provides supply to approximately 50 percent of the residents. Surface water in the Quinte WQSA is predominantly warm water, with some cool areas towards the northwest corner of the study area.	In the eastern and central parts of the WQSA, the Kapuskasing and Groundhog Rivers drain the Kebsquasheshing (Chapleau), Nemegosenda and Ivanhoe Rivers and they themselves flow into the Mattagami River. From the west, the Missinaibi River and its tributary, the Fire River, join the Mattagami River in the Moose River basin. Major surface water bodies used for water takings within the WQSA include the Kebsquasheshing (Chapleau) River and Borden Lake. Most rivers and some bodies of water in the WQSA are cold, while most bodies of water are cool. A very small percentage of surface water courses are categorized as warm.
	Groundwater/ Surface Water Interaction	In general, the groundwater divide in the Gasport Formation aquifer appears to coincide with the surface water divide between the Grand River and Credit River watersheds. Deep aquifers are influenced by some of the regional groundwater discharge features (i.e., the Eramosa River and Blue Springs Creek) where ground surface topography is incised into the deeper bedrock system. The smaller streams have very little influence on the deep groundwater flow system. There is limited interaction between the deep aquifer and surface water bodies, although interaction can be seen along the Eramosa River upstream of Eden Mills near Rockwood and along Blue Springs Creek.	With the exception of the Island Lake Reservoir, nearly the entire WQSA is mapped as cold water or unknown thermal status. This suggests that groundwater discharge to surface water is significant in the WQSA. Groundwater recharge is highly variable within the WQSA. In topographically high areas with coarse glaciofluvial sediments, such as the Orangeville Moraine (Kame Moraine), recharge can be as high as 320 mm/year, while in low lying saturated wetlands (typically areas where groundwater is discharging), recharge can be 0 mm/year.	Interactions between groundwater and surface water are known to be more significant in areas where surficial materials are comprised of medium and coarse grained sands and gravels of the Norfolk Sand Plain, and where typically cooler surface water temperatures indicate groundwater discharge to the creeks and streams. The interactions are generally limited in areas where surficial materials are comprised of fine grained clays and till material (i.e. Haldimand and Ekfrind clay plains and tills that comprise the Horseshoe Moraines and Mount Elgin Ridges); water courses in these areas are generally run-off driven with little baseflow provided by groundwater discharge.	Limited. The majority of groundwater discharge occurs at the physiographic boundary between the uplands and lowlands within the WQSA. Areas of high groundwater recharge include granular deposits within the Oak Ridges Moraine as well as the surficial sand deposits in the lowlands. Due to the thick glaciolacustrine deposits underlying the surficial sands in the lowlands, much of this groundwater recharge results in quickly responding interflow that does not sustain streamflows during extended dry periods. MIKE SHE found that the majority of streamflow for the Innisfil Creek watershed is associated with direct overland runoff or quickly responding interflow. Groundwater discharge is estimated to be less than 15% of total streamflow.	Significant groundwater discharge to surface water features is expected in areas with shallow unconfined aquifers such as the Norfolk Sandplain. Piezometric monitoring results indicated the potential for rapid recharge conditions in the southeastern sandplain area, but also the ability for shallow groundwater takings to affect discharge to surface water features. Piezometric monitoring near Whitemans Creek also indicated that shallow groundwater close to the creek interacts significantly with the surface water; however, the creek has significantly less impact on shallow groundwater further from the creek.	There is significant interaction between surface water and groundwater. Mapping has illustrated that groundwater flows toward, and discharges to, surface water features. Through analysis of groundwater and surface water hydrographs, it was also found that groundwater and surface water features respond in similar fashion to rainfall events with increases in levels observed in each due to precipitation events. The quick response of the groundwater to precipitation recharge is an indication of the unconfined nature and vulnerability of the aquifers in the Quinte WQSA.	Considering that much of the Chapleau WQSA is characterized by thin soils over bedrock, it can be expected that groundwater-surface water interactions are significant, and that baseflow in smaller surface water courses may be more susceptible to potential reductions in recharge from groundwater in periods of drought. However, no studies have been identified to verify this for the Chapleau WQSA.

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

		Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]								
Overview of Water Takings	Total Number of PTTW in 2017	346	39	1,976	224	173	181	4
	Total Permitted Volume (m^3/yr)	43,613,808	181,863,557	280,330,189	85,184,567	30,776,721	238,679,760	19,045,786
	Total Permitted Water Supply (m^3/yr)	208,805,544	10,116,383	46,177,838	27,084,312	3,541,020	97,547,240	1,606,000
	2017 WTRS - Water Supply Usage (m^3/yr)	35,696,541	3,708,899	8,177,786	3,254,611	230,004	33,039,450	438,843
	Total Permitted Commercial (m^3/yr)	39,651,842	1,251,857	45,023,255	5,961,397	1,719,952	6,924,713	N/A
	2017 WTRS - Commercial Usage (m^3/yr)	7,547,640	285,631	14,874,213	499,991	123,258	554,237	N/A
	Total Permitted Agriculture (m^3/yr)	4,272,238	11,784	174,146,915	49,956,748	123,258	539,274	N/A
	2017 WTRS - Agriculture Usage (m^3/yr)	71,167	0	17,360,030	613,072	1,398,928	3,884	N/A
	Non-Permitted Takings (m^3/yr)	<138,335	N/A	N/A	120,000	N/A	N/A	N/A
Land Cover and Use Setting		A mixture of agriculture, forest and built-up areas (residential/commercial/industrial). The largest urban centre in the WQSA is the City of Guelph. Most of the smaller urban centres in the WQSA are surrounded by rural areas consisting mainly of agricultural land use.	A community/infrastructure core surrounded by predominantly agricultural and other rural land with pockets of mixed trees, swamps and bogs.	Predominantly agricultural and undifferentiated rural lands with pockets of mixed treed areas and a few small urban commercial, industrial and residential centres surrounded by less-populated rural land used for intensive agricultural production.	Predominantly agricultural and undifferentiated rural land with pockets of swamp areas and a few small urban commercial, industrial and residential centers surrounded by less-populated rural land used for intensive agricultural production.	Predominantly agricultural, with significant portions of swamp in the central area east of Innerkip and Woodstock. Community/Infrastructure comprises a minor portion of land use scattered among the villages and towns within the WQSA.	Predominantly Agricultural and Undifferentiated Rural Land with areas of mixed treed and a few small urban centers.	Predominantly Deciduous Treed, Mixed Treed, and Coniferous Treed Land with pockets of Sand/Gravel/Mine Tailings/Extraction as well as a few small urban centers of Community/Infrastructure.
Recommended WQSA Boundary for Data Review		Tier Three Study Area for the City of Guelph and Township of Guelph/Eramosa	Tier 3 Study Area for Orangeville, Amaranth and Mono	Kettle Creek, Catfish Creek and Long Point Region Watersheds	Innisfil Creek Watershed	Whitemans Creek Tier 3 Assessment Study Area	Moira River, Salmon River and Napanee River Watersheds	Upper Kapuskasing Watershed
RESOURCE SUSTAINABILITY								
Groundwater	**Under Current Conditions**	Sustainable	Sustainable	Sustainable	Sustainable	Sustainable on a regional scale based on trend across the PGMN wells within the WQSA and Tier Two Stress Assessment. However, sustainability is uncertain in the Norfolk Sand Plain but sustainable in the Waterloo Moraine and bedrock aquifer in the central-north and north part of the WQSA.	Sustainable on a regional scale but unsustainable in some parts of the WQSA due to the lack of resilience to extreme drought.	Sustainable
	Under Future Conditions	Uncertain in some parts of the WQSA. Unsustainable in some part of the WQSA.	Unsustainable unless normal climate conditions exist.	Sustainable	Sustainable	Sustainable on a regional scale but unsustainable based on Tier Three Stress Assessment for the Bethel wellfield.	Unsustainable based on the modelled effects of climate change and a lack of resilience to extreme drought.	Sustainable
Surface Water	**Under Current Conditions**	Sustainable	Uncertain	Sustainable but may be at risk of becoming unsustainable during dry years.	Sustainable if current degraded condition of the resource is acceptable. The natural state of the resource is highly dependent on precipitation.	Unsustainable during the summer months.	Sustainable on a regional scale based on modelling but unsustainable in some parts of the WQSA under extreme drought conditions.	Sustainable
	Under Future Conditions	Unsustainable without restrictions.	Unsustainable based on modelling.	Uncertain	Unsustainable based on modelling.	Unsustainable during the summer months.	Unsustainable based on the modelled effects of climate change and a lack of resilience to extreme drought.	Sustainable
PGMN (Groundwater)	Total number of hydrographs from PGMN wells	11	2	18	15	7	11	0
	Mann Kendall and Seasonal Mann Kendall trend analyses	The Mann Kendall analysis determined that 10 out of 11 wells had no trend in water levels year over year, while one had a downward trend. The Seasonal Mann Kendall analysis was completed for 10 of the wells in the WQSA, in which it was determined that seven of the wells had upward trends, two wells had no trend, and one well had a downward trend.	The Mann Kendall analysis determined that both wells had no trend. The Seasonal Mann Kendall analysis established that one well (W0000486-1) had an upward water level trend, while the other had no trend.	The Mann Kendall analysis determined that 16 of the 18 wells had no trends in water levels year over year, while two wells had upward trends. The Seasonal Mann Kendall analysis determined that 13 wells had upward water level trends, three had no trend, and two had a downward trend.	All PGMN wells are overburden wells. Four wells W0000323-2, W0000323-3, W0000323-4 and W0000224-1 had an upward water level trend, one (W0000480-1) had no seasonal trend and one (W0000508-1) had a downward seasonal trend. The rest were determined to be unreliable.	The Mann Kendall analysis determined that 6 of the 7 wells had no trends in water levels year over year, and one had a downward trend. The Seasonal Mann Kendall analysis determined that 3 of the wells had downward water level trends, 3 wells had no trends, and one well had an upward trend.	The Mann Kendall analysis showed no increasing or decreasing trends. The Seasonal Mann Kendall analysis established that wells had either an upward trend, or no trend, with the exception of W0000152-1, which has exhibited a downward trend in water levels.	N/A
Stream Flow (HYDAT and other)		Water Survey of Canada (WSC) gauges are present within the WQSA in the watersheds of the Grand River, Credit River and Bronte River; no gauges are present in the Sixteen Mile Creek and Spencer Creek subwatersheds within the boundaries of the WQSA. Hydrographs for the available gauges show that the rivers all exhibit similar seasonal patterns, with the highest flows being associated with the spring snowmelt, peaking around April, and seasonal low flow occurring in the summer, typically reaching its lowest point around August.	There is one Water Survey of Canada (WSC) gauge located within the WQSA. Continuous and spot flow measurements are recorded in Mill Creek and Monora Creek, respectively, as per the town's PTTW monitoring program.	Twenty-seven Water Survey of Canada (WSC) gauges are located within the boundaries of the WQSA; no gauges are located in the Kettle Creek or Grand River watersheds within the boundaries of the WQSA. Hydrographs for the available gauges show that the rivers all exhibit similar seasonal patterns, with the highest flows being associated with the spring snowmelt, peaking around March-April, and seasonal low flow occurring in the summer, typically reaching its lowest point around August-September.	Eight stream gauges, four operated by the Water Survey of Canada (WSC), and four operated by NVCA. Two of the WSC stream gauges have complete datasets to be able to assess annual streamflow from 2000 to 2012. In recent years (>2007), annual streamflow yield has become more variable than observed in the early 2000s. A slight increasing trend in overall streamflow yield; although due to the relatively short time frame, it cannot be determined if this is part of a longer term trend or normal climate variability. It has been noted that since 2016, there have been issues with channel slump impacting the Water Survey of Canada Innisfil Creek gauge. For this reason, flow information for Innisfil Creek has not always been available or reliable, and as a result specific declarations for Innisfil Creek have not been considered in the past few years.	Four Water Survey of Canada (WSC) gauges are located within the boundaries of the WQSA. Hydrographs for the available gauges show that the rivers all exhibit similar seasonal patterns, with the highest flows being associated with the spring snowmelt, peaking around April, and seasonal low flow occurring in the summer, typically reaching its lowest point around August.	There are 12 (ten active) Water Survey of Canada (WSC) gauges located within the boundaries of the WQSA.	Available data from 2006 to 2014 from the WSC Nemegosenda River HYDAT station (04LE002), the only HYDAT station in the WQSA, indicate that the greatest monthly average flow rates occur in April and May, coinciding with the snow melt period. Lowest flows recorded are shown to occur during the mid-winter months (January through March), when precipitation is accumulated and held as snow and ice, and in mid to late summer.

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

		Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]								
Stress Assessment[4]		A Tier Three Water Budget and Local Area Risk Assessment was completed for the City of Guelph and the Township of Guelph/Eramosa, for the Eramosa River intake and Glen Collector (infiltration system feeding the aquifer supplying the City of Guelph).	A Tier Three Water Budget and Local Area Risk Assessment found that a significant water quantity risk level under projected future conditions exists within a portion of the study area called Local Area A (including much of the Town of Orangeville, and the area immediately to the west).	A Tier 3 Water Budget and Local Area Risk Assessment was completed for the municipal drinking water systems of the Towns of Waterford (groundwater), Delhi (groundwater and surface water), and Simcoe (groundwater). Local Area A in the Town of Simcoe was determined to have a Significant Water Quantity Risk Level, while the other municipal supplies in the Tier 3 study were considered to be at a low level of risk.	No Tier 3 Water Budget Assessment, however a water budget stress assessment was completed as part of the Pilot Drought Management Plan project.	The Bethel Road Wellfield Local Area was determined to have a significant risk level, as modelling results indicate the wells will be unable to meet future pumping demands under drought conditions. Surface water in the Whitemans Creek subwatershed has a moderate potential for stress due to the high percent water demand in the summer.	Tier 1 water budget indicated that all subwatersheds have Low stress levels for surface water, with the exception of the Parks subwatershed, which was found to have a Moderate stress level. All subwatersheds were assigned a Low stress level for groundwater.	N/A
High Use Watershed (HUW)[5]	Average Annual Percent Water Use	Medium	Medium	High	Medium	High	Low	Low
	Summer Percent Water Use	Medium	Medium	High	Medium	High	Medium	Low
Ontario Low Water Response (OLWR) Conditions	**Level 1 (year:days)**	For the GRCA as a whole: 2002:115; 2003:181; 2004:184; 2005:86; 2006:52; 2007:91; 2008:94; 2009:21;2010:56; 2011:98; 2012:72; 2013:57; 2015:121; 2016:37; 2017:99; 2018:51	For the Credit Valley: 2012:154; 2016:138; 2017:38	For the Long Point Region as a whole: 2001:60; 2002:54; 2003:221; 2004:92; 2005:223; 2007:202; 2008:35; 2011:62; 2012:76; 2016:177; 2017:128	2007:74; 2011:47; 2012:67; 2016:126	2002:100; 2003:97; 2004:7; 2005:51; 2006:46; 2007:28; 2008:23; 2011:11; 2012:14; 2013:57; 2015:28; 2016:16; 2018:38	2001:47; 2002:176; 2003:353; 2005:119; 2007:46; 2008:11; 2011:39; 2012:120; 2016:40; 2018:28	No Level 1 Low Water Condition Alerts were posted. However, Level 1 Notifications were sent to the municipality in 2001, 2004, 2005, 2010 and 2011.
	Level 2 (year:days)	For the GRCA as a whole: 2003:21; 2005:96; 2007:98; 2008:57; 2012:119; 2016:149; 2017:12	For the Credit Valley: 2016:41	For the Long Point Region as a whole: 2001:101; 2002:88; 2012:105	2007:+81	2002:61; 2003:5; 2005:96; 2007:160; 2008:60; 2012:55; 2015:69; 2016:99	2001:137; 2007:58; 2012:60; 2016:40; 2017:7; 2018:15	N/A
Climate Change	**How has Climate Change been considered in the context of water resource management in the WQSA?**	In the early 2010s, modelling was implemented for the individual subwatersheds in the Grand River watershed, in order to model potential changes to annual precipitation, evapotranspiration, runoff and groundwater recharge and discharge under future (2050s) climate change scenarios.	Climate change modelling utilized ten possible climate change scenarios based on the Ontario Ministry of Natural Resources and Forestry (MNRF) Future Climate Data Application. The period 1961 to 1990 was used as the baseline and weather data taken from the Orangeville weather station and 2011 to 2040 was used for the future time period. The scenarios included a variety of projected climate patterns that included a range of average annual temperature increases, and a range of average annual precipitation increases, with the exception of one scenario which projected decreased precipitation.	Climate change has been considered extensively in the Grand River watershed (in the northeast corner of the WQSA), and an assessment of the influence of climate change on irrigation water demand in the Long Point Region was conducted as part of the Tier 2 water budget.	The Innisfil Creek Watershed Drought Management Plan Pilot incorporates ten different Climate Change Scenarios. Overall climate change will have a marked impact on the surface water resources in the WQSA rendering them unreliable as a water resource for irrigation purposes.	Climate change scenario modelling was implemented for Whitemans Creek in order to model future streamflow conditions under ten different climate change scenarios. A similar modelling exercise does not appear to have been implemented for groundwater resources in the WQSA; however, as part of the Tier 3 Local Area Water Budget and Risk Assessment, potential water levels in the Bright and Bethel Road groundwater supply systems were modelled under different scenarios, including one simulating a 10-year drought.	Sensitivity of groundwater to climate change was assessed through a review of Ontario Water Well Record data for wells that may be vulnerable to changes in recharge. The majority of subwatersheds in the Quinte WQSA were determined to have low vulnerability to climate change; however, two subwatersheds in the southern portion of the WQSA were assigned a moderate vulnerability to climate change. The factors identified as representing the highest sensitivity to climate change within the Quinte WQSA were low water (drought) conditions and groundwater discharge/baseflow.	No climate change assessments have been completed for areas within the Chapleau WQSA.
	Has Climate Change been adequately considered in the context of water resource management in the WQSA?	No, the extent to which the effects of climate change have actually been incorporated into water resource management in the WQSA is not apparent.	Yes, the effects of climate change were modelled in conjunction with the most advanced Risk Mitigation Management option implemented to determine the "best case scenario" (i.e. what effects climate change may have on water quantity issues if the most advanced mitigative and adaptive policies are employed).	No, the extent to which the effects of climate change have actually been incorporated into water resource management in the WQSA is not apparent.	Yes, the Climate Change Assessment was consistent with the 2010 Guide for Assessment of Hydrologic Effects of Climate Change in Ontario.	Limited modelling of the effects of climate change on groundwater resources appears to have been implemented.	No, the extent to which the effects of climate change have actually been incorporated into water resource management in the WQSA is not apparent.	No climate change assessments have been completed for areas within the Chapleau WQSA.
Cumulative Effects/ Impacts	**Have there been documented well interference impacts?**	No	No	Yes. Since approximately 2012, the two municipal supply wells in the community of Springford have been taken offline due to low groundwater levels in the summer months. There are indications that private water supply wells in the area may also be impacted by the seasonal drop in groundwater levels. The MECP is working with local PTTW holders, including the agricultural community, municipalities and OMAFRA, to develop a long-term solution to manage the groundwater resource in this area. In 2016, the MECP was contacted by representatives of the County of Oxford regarding groundwater level interference that was causing operational issues for the Mt. Elgin supply well, which was subsequently determined to be caused by another nearby PTTW holder drawing water from the same confined bedrock aquifer. The interference problem was resolved by reducing the pumping rate for the PTTW holder that was causing the interference.	No	No	Quinte CA has received complaints from rural residents who claim that their wells have been impacted by neighbouring private wells, as well as industrial and agricultural water takings, particularly in times of drought; however, these reported effects have not been quantified.	No
	Has there been documented interference between permitted surface water takings?	No	No	No	The Innisfil Creek Watershed was selected as a site to complete a Drought Management Plan Pilot in part due to the fact that there are noted regular cumulative impacts on surface water resources of concern, resulting in interference between permitted users of the same resource, further compromising Environmental Flow Needs.	Interference between permitted takings is inferred, but not directly confirmed, to occur. Shortages of surface water in Whitemans Creek have been reported during summer months, particularly during drought years, when precipitation can be minimal and irrigation demand is significant. The creek has reportedly dried up in certain areas (years and locations unconfirmed).	No	No

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

		Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]								
Environmental Flow Needs (EFN)	**Is there Groundwater/Surface Water Interaction related to the resources of concern in the WQSA?**	Groundwater discharge to surface water bodies occurs in areas where the ground surface topography is incised into the deeper bedrock system (e.g. along the Eramosa River upstream of Eden Mills near Rockwood, and along Blue Springs Creek).	Yes	Yes, interaction is significant in the areas occupied by the Norfolk Sand Plan, but generally limited in the Haldimand and Ekfrind clay plains.	Based on the information reviewed there is limited to no groundwater/ surface water interaction related to the resources of concern in the WQSA.	Significant groundwater discharge to surface water features is expected in areas with shallow unconfined aquifers such as the Norfolk Sandplain.	Groundwater/ surface water interactions are significant in the Quinte WQSA	N/A
	Has an Ecosystem Study been done?	Yes, hydraulic modelling was used to determine EFNs for the Speed River at Guelph and the Eramosa River above Guelph.	In conjunction with the Tier Three study, Monora Creek was selected for a site specific ecological flow needs assessment.	Within the WQSA, assessing EFN has currently only focused around the Big Creek watershed.	Yes, EFN were assessed as part of the Drought Management Plan Pilot.	Several studies of EFNs were conducted for Whitemans Creek. It was determined that empirical methods are generally not suitable for Ontario rivers, as the landforms and fish assemblages are not comparable to those in Montana's mountain stream ecology, where the thresholds were developed. For the Whitemans Creek, hydraulic modelling was used to identify the minimum flows required to ensure the hydraulic connectivity of the creek's length for fish migration.	No	No
	Is there On-going Ecosystem Monitoring?	Ongoing monitoring in the Eramosa River at the intake where water is pumped from the river to recharge the shallow overburden aquifer supplying the Glen Collector (City of Guelph water supply system). The City of Guelph cannot pump water from the river when flows in the river fall below 0.42 m^3/s.	Yes, as per the Town of Orangeville's PTTW, Monora and Mill Creeks are routinely monitored for flow conditions and fishery. These are the only two surface water locations in the WQSA where groundwater takings are known to limit baseflow.	No on-going monitoring identified.	Only flow monitoring through stream gauge data as it relates to the Low Water Response program.	No on-going monitoring identified.	7Q20 flow is being used as a minimum flow target for surface water systems within Quinte CA at gauged streams.	No
Population Growth[6] between 2011 and 2016 (%)		-0.6% to 34%	2.9% to 14.1%	1.6% to 14%	3.5% to 25.8%	2.1 to 5.0%	0.5% to 2.6%	-4.6%
Stress Review and Reported Water Shortages[7]	**If a Water Budget Assessment has been completed for the WQSA, what does it indicate about existing or future stress on the water resources of concern in the WQSA?**	It was estimated that the total potential influence of municipal and non-municipal takings on streamflow in the Eramosa River at WSC stream gauge 02GA029 is a reduction in streamflow of 0.287 m^3/s, equivalent to approximately 12% of the mean annual flow (2.3 m^3/s). The City of Guelph's Arkell wells have an estimated influence of 0.148 m^3/s on baseflow in the Eramosa River. It was recommended that the city maintain its current groundwater and surface water monitoring program to ensure that the hydrologic regime in the Eramosa River is maintained in accordance with the requirements of its PTTW.	A Tier Three Water Budget and Local Area Risk Assessment were completed for Orangeville, Amaranth and Mono. The findings of the Assessment suggest that the area is not currently facing water quantity issues; however, given projected population growth and planned land use development, the study found that a significant water quantity risk level exists within a portion of the study area called Local Area A (including much of the Town of Orangeville, and the area immediately to the west).	Based on the results of Tier 2 stress assessments, certain subwatersheds (e.g. Big Creek) may be prone to water quantity issues when maximum demand scenarios occur. The Tier 3 Water Budget and Local Area Risk Assessment for the Long Point Region determined that, with the exception of Local Area A in the Town of Simcoe well field, the predominantly groundwater-based municipal water supplies are likely sustainable when considering population growth in the municipalities.	Shortages related to surface water resources heavily relied upon by seasonal takings for agricultural (irrigation) purposes. Seasonal takings are inversely correlated with the amount and timing of precipitation between May and September and therefore water shortages are typically reported in years with below average amounts of precipitation in June, July and August. No groundwater shortages noted.	The Tier 3 groundwater stress assessment determined that the groundwater supply in the Whitemans Creek subwatershed is under low stress on an average and monthly basis. However, the Bethel Road Wellfield Local Area was determined to have a significant risk level due to the wells' inability to meet future pumping demands under projects population growth, drought, and land use conditions. For surface water, the Tier 2 assessment assigned the subwatershed a potential stress classification of Moderate, due to the high percent water demand in the summer. As a surface water municipal water supply system is not located within the subwatershed, a Tier 3 Water Quantity Stress Assessment was not required to be completed. There are also no planned municipal systems, so future demand and drought scenarios were not evaluated.	Tier 1 and 2 water budget results indicate generally low stress on water resources; however, local water managers indicate that many private wells run dry during the dry summer months, and water shortage issues are more severe and last over a longer time period under drought conditions.	N/A
	Are there reported population growth pressures?	No	Not currently; however, the area is subject to conditions in the Places to Grow Act of 2005, and Tier 3 modelling scenarios suggest population growth-related pressures are likely to occur in the future.	Current population projections for the WQSA suggest that the area is not expected to have significant population growth pressures. The Long Point Tier 3 study determined that the total allocated demand, which combines committed demand (accounts for expected population growth) and existing demand, will remain well below the current total permitted rates.	The population growth pressures are noted for urban centres in the WQSA. The increase in population will be reliant on groundwater resources which are not expected to be stressed based on the Water Budget Assessment and Climate Change Scenarios considered.	None identified.	Local water managers have indicated that there is not an abundant supply of groundwater for rural development due to the low yield from many wells in fractured bedrock. This has impeded development in the southern portion of the Quinte WQSA.	No
	Was there an overall decreasing water level trends detected in the PGMN wells?	In the Grand River watershed, for 17 of the 19 years of record, at least one Low Water Notification and/or Alert was issued/posted per year. No trends in the frequency or duration of the Notifications and/or Alerts are evident.	No	The Mann Kendall analysis showed 16 of 18 PGMN wells showed neither upward or downward trends, while two showed upward trends. And, The Mann Kendall Seasonal analysis showed 13 of the 18 wells had upward water level trends, three had no trend, and two had a downward trend.	The PGMN wells considered reliable for trend analysis are all completed in the overburden. Overall the trend analysis indicates an increasing trend.	Only 1 of the 7 PGMN wells exhibited downward trends in water levels, both annually and season to season.	Only 1 of 11 wells demonstrated a decreasing water level trend.	N/A
	OLWR: What trends were identified for 'Notifications' and 'Declared Alerts"?	In the Grand River watershed, for 17 of the 19 years of record, at least one Low Water Notification and/or Alert was issued/posted per year. No trends in the frequency or duration of the Notifications and/or Alerts are evident.	In the Credit Valley watershed, for 10 of the 19 years of record, at least one Low Water Notification and/or Alert was issued/posted per year. No trends in the frequency or duration of the Notifications and/or Alerts are evident.	In the Long Point Region watershed, for 13 of the 19 years of record, at least one Low Water Notification and/or Alert was issued/posted per year. No trends in the frequency or duration of the Notifications and/or Alerts are evident.	Through collaboration Level 2 Declarations have been to some extent avoided. No Level 3 Declarations have been made.	For 13 of the 19 years of record, Level 1 and/or Level 2 Low Water Condition Alerts were posted for the Whitemans Creek subwatershed (Low Water Notifications are generally not issued at the subwatershed scale). No trends are evident in the frequency or duration of the Alerts.	For 14 of the 19 years of record, at least one Low Water Notification and/or Alert was issued/posted per year. No trends in the frequency or duration of the Notifications and/or Alerts are evident.	Only Level 1 Notifications were ever issued; no Low Water Condition Alerts have ever been posted. No trends in the frequency of the Level 1 Notifications are evident.
	Have Level 2 or Level 3 Low Water Conditions Alerts been Declared in the WQSA?	For the GRCA as a whole, Level 2 Low Water Condition Alerts were declared in 2003, 2005, 2007, 2008, 2012, 2016 and 2017.	A Level 2 Low Water Condition Alert was declared in the Credit Valley in 2016.	For the Long Point Region as a whole, Level 2 Low Water Condition Alerts were declared in 2001, 2002 and 2012.	No	Level 2 Low Water Condition Alerts were posted in 2002, 2003, 2005, 2007, 2008, 2012, 2015 and 2016.	Level 2 Low Water Conditions Alerts were declared in 2001, 2007, 2012, 2016, 2017 and 2018. A Level 3 Alert was declared in 2016 (August to mid-December).	No

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

	Guelph-Wellington	**Orangeville**	**Norfolk Sand Plain**	**Innisfil**	**Whitemans Creek**	**Quinte[2]**	**Chapleau[2]**
WQSA GENERAL INFORMATION SUMMARY[1]							
WATER MANAGEMENT							
Current Approaches	• MECP's West Central regional office manages the PTTW program in the Guelph WQSA and the local district office responds to well water and drought complaints. • The technical studies relating to water quantity, as completed under the requirements of Source Water Protection (SWP), largely inform water quantity management decisions within the Guelph WQSA. • Approaches have been significantly shaped by a number of different water management tools used under Ontario's legislative and regulatory framework. • The source protection process, specifically the implication of the Tier Three model results, is culminating in policies that will direct the assessment of sustainability of the resource. • Based on BluMetric's review, Water Managers appear to be seeking solutions on how to sustainably manage the resources in the WQSA based on regional scale assessments and information but only having site scale instruments such as the PTTW program available to do so.	• MECP's West Central regional office delivers the PTTW program in the Orangeville WQSA and responds to well water and drought complaints. • The approach in the Town of Orangeville is largely based on the policies of the CTC Source Protection Plan (SPP). Of note, is the requirement for new developments to maintain predevelopment groundwater recharge through the use of Low Impact Development options or other best management practices, particularly in the urban part of the WQSA. This is the only policy in the SPP to be made into an actual requirement in the Town of Orangeville. The Town also promotes water conservation with a toilet rebate program for residents who replace old high volume flush toilets with new low or dual flush toilets. • Another policy implemented from the CTC SPP requires a joint municipal approach to managing the groundwater resources across multiple administrative districts including town (or townships) Orangeville, Mono, Amaranth and East Garafraxa. • In accordance with the conditions of the consolidated PTTW for the Town of Orangeville's water supply wells, the Town is required to conduct environmental monitoring as per their Environmental Monitoring Plan. • Water quantity management in the WQSA also relies on the Provincial mechanisms of the PTTW program (O. Reg. 387) and the Ontario Low Water Response (OLWR) program. • The Town of Orangeville is currently investigating if the Pullen well located in the Township of Amaranth could be added to their water supply system.	• MECP's West Central regional office delivers the PTTW program in the Norfolk WQSA and responds to well water and drought complaints. • Generally, water quantity is managed though the Ontario Water Resources Act and O. Reg. 387/04. • In 2005, the MECP designated the Long Point, Kettle Creek, and Catfish Creek watersheds (which make up much of the WQSA) as a High Use Watershed based on a preliminary regional assessment. This designation places significant restrictions on obtaining PTTWs for most Purposes. • Local municipalities have water use bylaws in place, e.g. the Watering Restriction By-Law in Norfolk County, which restricts the external use of water. • A variety of programs, projects and studies have been conducted in the WQSA (drought contingency projects, water supply expansion projects, irrigation advisory committees, etc.). • Stakeholders working collaboratively on a case by case basis to solve water quantity issues have produced successful results in some areas. E.g., the MECP has worked with local PTTW holders and other stakeholders in Springford Mt. Elgin to resolve local water quantity issues.	• MECP's Central regional office manages the PTTW program in the Innisfil WQSA and responds to well water and drought complaints. • NVCA is a key partner and data and information coordinating agency for water management in the Innisfil WQSA. • Water quantity management relies on the policies of the South Georgian Bay Lake Simcoe Source Protection Plan. • The NVCA relies heavily on the PGMN network of wells within the WQSA to assess and evaluate the sustainability of the groundwater resource. • To help manage the issue of surface water shortages, a local stakeholder group was formed (the Innisfil Creek Water Users Association (ICWUA)), consisting largely of irrigation farmers, but also seeking input from municipal water managers and local golf courses. One key initiative of the ICWUA has been the coordination of water taking from the creeks within the WQSA during Low Flow periods.	• MECP's West Central regional office manages the PTTW program in the Whitemans Creek area and the local district office responds to well water and drought complaints. • The approach for managing water quantity in the Whitemans Creek WQSA largely relies on the regional and provincial-level policies, such as the Grand River and Thames Sydenham Source Protection Plans, combined with Provincial mechanisms of the Permit to Take Water program (O. Reg. 387/04) and the OLWR program. • WQSA-specific management approaches currently appear to be limited to the Whitemans Creek Subwatershed Drought Contingency Project, in which water managers and irrigators collaboratively developed tools and Best Management Practices (BMP) for managing water use and improving drought preparedness.	• MECP's Eastern Region office manages the PTTW program in the Quinte area and responds to well water and drought complaints. • Water quantity management relies on the policies of the Quinte Region Source Protection Plan, combined with Provincial mechanisms of the Permit to Take Water program (O. Reg. 387) and the Ontario Low Water Response (OLWR) program. • Quinte CA operates and maintains 39 water control structures, several of which provide low flow augmentation and local water supply. • Quinte CA also provides technical advice to municipalities, landowners, lawyers and developers, and review of development proposals in regulated areas. • Municipalities within the WQSA are encouraged to promote voluntary action to protect sources of drinking water and water conservation measures such as water saving fixtures, tips on how to save water in the house, and water conserving appliances.	• MECP's Northern regional office manages the PTTW program in the Chapleau area. • Water quantity management relies on the Provincial Permit to Take Water program. There is no CA or source protection committee for this WQSA.
Challenges	• Assessing cumulative effects and sustainability on a regional scale • Meeting future water demand in the City of Guelph • Water supplies for the City of Guelph are limited to its municipal boundaries • Limited collaboration between the GRCA and the MECP	• Identifying additional water supply sources • Determining efficacy of surface water monitoring programs • Getting municipalities to accept a shared-resource management approach to groundwater resources • If the Official Plan undergoes changes or expansion in the future, and includes more or less development, groundwater modelling may have to be calibrated to account for the changes.	• Quantifying demand: maximum permitted volumes are not reflective of the actual water use, which can be relatively low and/or sporadic (e.g. episodic periods of intense irrigation). WTRS data is self-reported, and often estimated based on pump run time and capacity; it is possible that the reported amounts may not accurately reflect the actual amounts being pumped. • Degradation of Groundwater-Fed Irrigation Ponds and Switching to Less Stressed Sources • Underutilization of Deeper Aquifers • High Use Watershed Designation places significant restrictions on obtaining PTTWs for most Purposes and limits development in Norfolk County.	• Data gaps in PGMN data, delay in the data becoming publicly available. • Ongoing support needed to maintain the relationship between the ICWUA and the NVCA. • The unpredictability of climate change on a local scale in terms of timing and amount of precipitation during the summer months, water withdrawal effects the frequency of the more extreme Level 3 flow conditions, and the expected increase of low flow periods during the summer months under climate change conditions. • Transitioning from surface water to groundwater supplies in the short term to help avoid constraints during Level 3 flow conditions may not return the anticipated economic results needed in the short term.	• Historically it was reported that water levels were significantly decreased such that downstream users and ecosystems were impacted on a seasonal basis, and there have been anecdotal reports of the creek drying up completely. However, no evidence was identified during this review (e.g. in the WSC stream gauge data) to confirm these reports. • Aquatic ecosystems have reportedly been impacted by the heavy usage of surface water in Whitemans Creek. Agricultural water takings in the summer months may not be sustainable from an ecological perspective, and a potential for conflict and constraint exists. • Limited collaboration between the GRCA and the MECP	• Seasonal shortage of groundwater in some areas; • Some municipalities are entirely reliant on groundwater and do not have access to surface water sources so a better understanding of groundwater trends is needed; • Water conservation measures within the CA are voluntary, there is no way to enforce reductions on takers not requiring a permit; • There is not an abundant supply of groundwater for rural development; • There is a lack of water supply information for some areas, such as Mohawks of the Bay of Quinte; • There is a lack of resources to properly assess cumulative effects and EFNs; • Many subwatersheds have no stream gauge data; • There is a lack of lake level gauges data; and • Additional groundwater monitoring locations are required.	• Limited hydrologic and hydrogeological information and data in general for the WQSA; • No clear guidance is available outlining MECP's requirement for minimum EFNs and other related flow criteria (e.g. ramping rates); and • Limited guidance on how to address the issues associated with large hydropower facilities.
Evaluation of how water management concerns are considered in water management decisions	• To help mitigate against its needs and projected shortfall in meeting Maximum Day Demand by 2023, the City of Guelph has implemented its Water Efficiency Strategy for demand management through conservation and efficiency programs and an Outside Water Use program for water conservation in times of low water and drought. • The City of Guelph has implemented an Environmental Monitoring Program to monitor groundwater in and around its wellfields. • The City, since 2007, has implemented a number of programs and studies to maintain and optimize existing supply facilities and infrastructure • The WSMP Update reports that the short to mid-term implementation strategy also included the initiation of various hydrogeological investigations, the purpose of which was to explore the potential for new water supplies. • Regional studies and plans were also initiated to ensure the protection and long term sustainability of the existing water supply system • The 2014 WSMP Update (AECOM and Golder Associates, May 2014) summarized the water supply alternatives considered to address the noted shortfall between the Current Water Supply Capacity and the projected Maximum Day Demand.	• A series of Risk Management Measures (RMM) (e.g. pump optimization, integrated municipal water supply systems) were applied to the Tier Three Assessment Water Budget groundwater model, and the results indicated that the measures may be effective in meeting pumping demands and reducing drawdown stress. Whether the RMM are or will be incorporated into water management decisions could not be confirmed as part of the present study. • The Town of Orangeville's current approach for managing water supply does, to a certain extent, attempt to reduce the overall demand on groundwater supplies by requiring the use of Low Impact Development options or other best management practices for new developments, and promoting water conservation measures for residents. • Under modelled growth and climate change scenarios, the Monora Creek System may potentially experience decreased groundwater discharge, which could limit its contribution to the Island Lake Reservoir in the future, and in turn may affect the ability for the reservoir's ability to provide assimilation capacity to the downstream Water Pollution Control Plant on the Credit River. How or whether water management decisions currently take this concern into consideration in unknown.	• The heavy demand for water is likely a key driver behind the Watering Restriction By-Law in Norfolk County that restricts the external use of water by premises served by Norfolk County owned water systems between May 15 and September 15 each year. • Programs and projects in the WQSA, such as the creation of irrigation advisory committees and water user associations, assist water users in managing water consumption effectively and in compliance with the requirements stemming from water management decisions.	• The over reliance on surface water in the summer resulted in significant decreases in water levels, particularly during drought years. To help alleviate these pressures, efforts are being made to move agricultural irrigation from a surface water source onto groundwater wells. This effort however has had limited success due to the uncertainty associated with obtaining a PTTW for the groundwater source. • The establishment of the Innisfil Creek Water Users Association (ICWUA) and implementation of a coordinated irrigation strategy in the WQSA has provided an opportunity for water managers at the NVCA and irrigators to collaboratively develop tools and Best Management Practices (BMP) for managing water use and improving drought preparedness.	• To help alleviate reported pressures on surface water, efforts have been made to move agricultural irrigation off of Whitemans Creek and onto groundwater wells or offline/dugout ponds. This may have contributed to a reduction in the number of complaints to the ministry. • The development and implementation of the Whitemans Creek Subwatershed Drought Contingency Project, provided an opportunity for water managers and irrigators to collaboratively develop tools and Best Management Practices (BMP) for managing water use and improving drought preparedness • The Brant Federation of Agriculture and the GRCA have also worked together to support farmer-led 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 (MECP communication). These locally lead initiatives are typically very effective and there is local accountability and local understanding.	• Municipalities within the WQSA are encouraged to promote voluntary action to protect sources of drinking water and water conservation measures.	• Due to the limited amount of data and limited water quantity management issues in the WQSA, water management decisions typically only rely on data collected by PTTW applicants.
Possible New or Enhanced Approaches to Address Water Management Concerns Identified by City of Guelph Water Managers	• Harmonization needs to happen between the legislated purpose and objectives of Source Water Protection under the Clean Water Act and the overarching policy of ensuring the fair sharing, conservation and sustainable use of the surface and groundwater in the province as per the requirements of the PTTW program. • Water management in the Guelph WQSA would benefit greatly from the broader use of the Tier Three groundwater model in the evaluation of PTTW applications as it would contribute to a more consistent way to evaluate and assess other proposed water takings in the WQSA.	• Continued efforts to find a regional, shared approach to water resource management should be encouraged. For example, a working group made up of key informants and stakeholders could be established to help develop a framework to manage an inter-jurisdictional water management plan.	• Multiple reports have recommended that water managers work to promote moving water users off of surface water supplies on to groundwater in areas where surface water is or may become stressed. • A number of case studies in the GRCA have also shown that restoration of groundwater-connected irrigation ponds to re-establish significant recharge is possible and can assist farmers to partially or wholly move away from on-line surface water irrigation sources.	• A collaborative effort together with the ICWUA could be initiated with the aim of ensuring that EFN thresholds be established for Innisfil Creek and its tributaries.	• Local water managers, including the local CAs, MNRF, MECP and municipalities, working in collaboration with irrigators, should establish a framework for considering EFN thresholds in Whitemans Creek, to ensure that these thresholds are met during periods of high irrigation demand. • The GRCA and MECP could work collaboratively to investigate the apparent reduction in permitted takers within the WQSA.	• Local water managers have indicated a need for hydrologic modelling and detailed guidance on how to optimize dam operations for low flow augmentation during droughts and to sustain EFNs. • Initiating a dialogue process between key informants (local water managers) and stakeholders to develop a collaborative and proactive regional scale drought management plan should be encouraged.	• No new or enhanced approaches to address water management challenges were identified due to the fact that there were limited to no water quantity challenges noted within the Chapleau WQSA.

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

	Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]							
WQSA-SPECIFIC GAPS							
Identified Data Gaps	• No identified data gaps that precluded an assessment of the sustainability of water resources, but more data will always strengthen management decisions. • According to municipal water managers in Centre-Wellington, overall ecosystem and water resource monitoring is best completed by either the Province through MECP or the conservation authorities. • Additional stress and climate change assessments centred on non-municipal water takings would address issues of uncertainty with respect to future non-municipal groundwater demand and including consideration of climate change conditions.	• Perform downhole geophysical well log surveys in existing production and monitoring wells within the WQSA to assist with the search for additional water supply sources.	• The Tier Three study does not speak to the possibility of increased takings within the study area for agricultural, commercial or industrial purposes, nor does it speak to the possibility of land use changes reducing recharge to the shallow overburden aquifer. Limited information is available for areas in the WQSA outside the municipal systems subject to Tier Three assessments. The lack of scenario modelling for other areas (outside of the Town of Delhi) in the WQSA with high surface water use represents a gap in understanding of the sustainability of surface water resources at a regional scale. • EFN thresholds are not well characterized in areas outside of the Big Creek Watershed. • There is a lack of information on the nature and occurrence of water shortages outside of municipal water supply systems. • There is a discrepancy between the Tier Two water budget groundwater annual taking values and the actual annual taking values based on WTRS data, which constitutes a gap in understanding or the intrinsic uncertainty and variability of annual climate conditions relating to precipitation and recharge.	• There is inconsistent streamflow in Innisfil Creek during periods of dry weather, some of which could possibly be mitigated if additional streamflow gauges were installed. • In the central portion of Innisfil Creek, there is evidence of a viable aquifer beneath the glaciolacustrine aquitard in the coarse-grained valley fill deposits that appears to be able to support large scale withdrawals. This should be explored to a greater extent. • Irrigators should be encouraged to transition to groundwater supplies for the purpose of gaining long term water security. • A pre-screening process could be implemented for new PTTW applications seeking to replace a vulnerable surface water source with a more secure groundwater water source. • There is a limited amount of temporal data from PGMN wells. The delay with PGMN data being available for public use is a challenge/gap for the timely assessment of seasonal impacts on groundwater resources.	• Only 2 of the 4 PGMN wells have recent data, making it difficult to accurately assess the conditions of regional water levels and the sustainability of groundwater resources. • The current use of the classification "Groundwater and Surface water" in the WTRS database makes it difficult to determine if an individual source is groundwater, surface water, or both. There is also no column in the WTRS that identifies the individual classification (groundwater, surface water, or both) for each source. The use of the "Groundwater and Surface water" classification in the WTRS currently contributes to a lack of confidence when attempting to sum total taking volumes from Surface Water, or Groundwater sources in the WQSA. • There are currently only two active Water Survey of Canada gauges within the Whitemans Creek subwatershed, which may limit the ability to accurately characterize flow.	• Need additional stream gauges; • Need additional lake level gauges to assess the potential for low flow augmentation and the effects of drought; • Need additional groundwater monitoring locations; • It is unknown whether there are Official Plan restrictions around rural development in sensitive water quantity areas; • Need hydrologic modelling and detailed guidance on how to optimize dam operations for low flow augmentation during droughts and to sustain environmental flow needs; • Assistance in the analysis and interpretation of baseline monitoring data (e.g. PGMN); • Water supply information for some areas, such as Mohawks of the Bay of Quinte, creates gaps in water taking volumes in the PTTW or WTRS databases.	• Presently there is not a significant reliance on groundwater resources within the Chapleau WQSA. Should there be increased reliance on this resource in the future, additional information on regional hydrogeology, and installation of a PGMN well in the area may be warranted. • Similarly, there are currently no reported stresses on surface water resources in the Chapleau WQSA. Should issues arise in the future, such as low water conditions due to resource development or climate change, additional resources to monitor low flow conditions may be necessary.
WQSA-SPECIFIC RECOMMENDATIONS							
	• The province should consider amending or enhancing the PTTW program to incorporate additional guidance and methodology describing under what circumstances a beyond local or regional scale assessment of cumulative effects and environmental flow needs are required. In BluMetric's opinion, this guidance should be harmonized with the guidance provided under Source Water Protection and the related process of the development of a Source Protection Plan (SPP), as it relates to water quantity risk.	• The province should ensure that the municipalities in the Orangeville WQSA identify in their servicing master plans and Official Plans prospective water supply sources capable of supporting any planned growth.	• Where appropriate, the Province should encourage permitted takings for the purpose of irrigation to move away from surface water reliance to groundwater, particularly when irrigating 100 m beyond surface water sources as water taking from such a distance is unlikely to cause a significant effect on baseflow contribution. • Cost sharing programs for the restoration of groundwater-connected irrigation ponds to re-establish significant recharge could be considered as a management approach to decreasing agricultural reliance on surface water.	• Current irrigation estimates were completed using 2012 WTRS data. Given the expected decline in demand on surface water for the purpose of agricultural irrigation, it is recommended that the irrigation estimates be updated using the most recent data and projections.	• For agricultural takers, continue to promote the transition from surface water takings to groundwater takings.	• Future water balance work should look at improving the study methodology to identify areas that may be impacted more severely by seasonal changes under Climate Change conditions. More consideration should also be given to communities and rural areas that are dependent on groundwater as a drinking water supply but do not have a municipal drinking water system.	• Provincial guidance should be developed in regards to the following key issues potentially impacting future water quantity in the Chapleau WQSA and most of them to northern Ontario, in general: • Cumulative effects assessments of multiple or competing water takings; and, • Ecological flow requirements to ensure the protection of the natural functions of aquatic ecosystems.
	• Developing a system or protocol that allows for the existing Tier 3 model groundwater model to be used by permit holders/applicants in areas where the MECP is concerned about the particular taking may be useful to predict the impacts of the existing/potential taking and develop or issue the permit accordingly.	• There are conflicting findings from separate technical studies about whether pumping at the Town of Orangeville's water supply wells is impacting local surface water. The additional study being completed by the town's consultant, expected in 2019, should be reviewed by the province to determine whether the discrepancy has been resolved, or whether additional study is required.	• Consideration should be given to the development of Environmental Flow Needs thresholds for instream flow management in areas that are or have the potential to become stressed.	• The Ministry should help to maintain the momentum the stakeholder group (ICWUA) garnered since it was established in 2008 by remaining available to participate in organized tours and understanding the dynamic nature of irrigated agriculture.	• Review the use of Groundwater and Surface Water classification in the WTRS to describe the origin of the permitted takings.	• Water quality management should be linked to land use planning decisions. Official Plans should include policies to protect groundwater resources and homeowners (i.e. development should be limited in privately serviced areas where groundwater supply is limited).	• First Nations should be consulted regarding the state of water supply within their communities and asked for their input regarding current and future water management practices.
	• The province should consider encouraging and, as appropriate, assisting neighbouring municipalities in developing shared water management strategies.	• The local source protection plan policies direct local water managers to manage groundwater as a shared resource, but achieving consensus among the Town of Orangeville and the Townships of Mono, Amaranth and East Garafraxa on a joint approach has been challenging. The province should investigate what is needed to develop an effective shared integrated water resource management strategy that would be accepted by all parties. The potential need for provincial facilitation should be recognized.	• Where appropriate, consider increased utilization of the bedrock aquifer, including deeper aquifers. Subwatershed scale investigations into bedrock aquifers would help to characterize and assess the potential yield of water quantity and quality.	• Given the impaired nature of the Innisfil Creek watershed, efforts should be taken to limit further degradation of aquatic habitat suitability, including limiting additional withdrawals from watercourses. In addition, new PTTW applications to access surface water resources for irrigation purposes should be discouraged as climate change projections indicate that surface water resources will be increasingly unreliable as an irrigation source.	• Improve the ability of the PTTW to address Cumulative Effects through working to clarify operational guidelines for internal MECP staff and external public on what constitute cumulative impacts and how they should be assessed in the context of the management of the water resources and PTTW program.	• More groundwater level data is required within the Quinte CA to support land use planning decisions and evaluate potential long-term trends.	• A more detailed Climate Change assessment, utilizing the Chapleau WQSA as a pilot area, would provide a better understanding of potential impacts on surface water supplies and EFNs.
	• Coordination between public agencies and adjacent jurisdictions (municipal) with respect to sharing data and the PTTW review process would be beneficial, especially when assessing Cumulative Effects and related environmental flow needs on a regional scale.		• A detailed analysis of the PTTW and WTRS is warranted given that the Long Point Region has among the highest number of permitted surface and groundwater users of any area in Southern Ontario.	• Continue to use or consider using ecologically-based instream flow management, such as the LPRCA Instream Flow Management Framework.	• Consider the addition of more flow gauges to accurately characterize flow regimes in the WQSA and enhance the understanding of the impacts of water takings on flow throughout the creek.	• Local water managers should be provided with more support in terms of drought preparedness and management. Detailed guidance should be provided on how to optimize dam operations for low flow augmentation during droughts.	• Consider expanding the PGMN to cover areas in the north with population centres and municipal water supplies. A stream flow gauge should also be considered for the Chapleau River to confirm that the municipal water taking is not having a negative impact on water levels. Establishing baseline groundwater and surface water levels in the area will make it possible to evaluate future potential effects of climate change.
	• In order to allow for broader use of the Tier Three groundwater model to evaluate PTTW applications, an online portal could be developed in a similar manner to the tool used for water management in the area of the Oak Ridges Moraine.		• The MECP has worked with local PTTW holders and other stakeholders in Springford Mt. Elgin to resolve local water quantity issues. A similar approach may be useful in the future for specific, localized issues in other part of the WQSA.	• Encourage increased utilization of groundwater obtained from deeper aquifers in the aquifer complex to meet increased population demands. Subwatershed scale investigations into deeper aquifers would help to characterize and assess the potential yield of water quantity and quality to meet increased demand.	• Reactivate water level monitoring in PGMN wells not currently monitored and possibly consider the addition of more PGMN wells in the shallow overburden of the southeast part of the WQSA to monitor regional groundwater level trends.	• Additional surface water monitoring locations are recommended for ungauged subwatersheds (Lower Moira, Lower Salmon and Lower Napanee), as well as lake level gauges	

Table 11-1: Water Quantity Study Areas Report - Summary of Findings, Information Gaps and Recommendations

	Guelph-Wellington	Orangeville	Norfolk Sand Plain	Innisfil	Whitemans Creek	Quinte[2]	Chapleau[2]
WQSA GENERAL INFORMATION SUMMARY[1]							
			• Consider implementing a method of recording water shortages reported by a permit holder and validated by an MECP officer into a database connected with the PTTW, WTRS and WWIS system.	• Ongoing monitoring of water levels in all overburden PGMN wells is strongly advised so that reliable trends can be determined, which in turn will ensure any early detection of declining regional groundwater resources.	• In areas with noted groundwater-surface water interaction, any change in source from a surface water source to a groundwater source (i.e., well or dugout pond) should be located a reasonable distance from the creek.	• Local water managers should be provided with support (including funding, additional staff and available/appropriate methodologies and tools) for evaluating cumulative effects and sustaining Environmental Flow Needs.	
			• Given the Norfolk WQSA proximity to the Whitemans Creek WQSA, both areas should be studied in tandem when considering the impacts water resource management.	• Consider increasing stream monitoring data for all tributaries by adding additional hydrometric gauges.	• Given the Norfolk WQSA proximity to the Whitemans Creek WQSA, both areas should be studied in tandem when considering water resource management.	• Water Managers from the Mohawks of the Bay of Quinte should be engaged regarding the state of water supply within their communities and asked for their input regarding current and future water management practices.	
			• Due to the gaps in information associated with cumulative effects, particularly outside of municipal water supply areas (as noted in Section 6.5), consider expanding the Tier Three Local Area Risk Assessment approach.			• Climate Change assessments should be reviewed with updated regional modelling as it becomes available to provide improved projections on potential impacts. The modelling completed in the Quinte WQSA lacked groundwater or surface water monitoring data in several subwatersheds.	
			• The High Use Watershed Designation places significant restrictions on obtaining PTTWs for most purposes. The designation should be reviewed to determine if the regulation and the designation should be revisited, and a determination made if the requirements attached to that designation, through the regulation and other guidance, are warranted, and if so where within the watershed specifically.			• Whether there are Official Plan restrictions around rural development in sensitive water quantity areas should be investigated.	

GAPS / RECOMMENDATIONS FOR ALL WQSAs TO ENHANCE THE WATER QUANTITY MANAGEMENT FRAMEWORK	
Gaps	• MECP currently relies on shortage complaints as a measure of sustainability, but this is not an effective tool, particularly when people do not necessarily report all shortage issues, in particular with respect to surface water resources to the ministry.
	• The process of assessing the sustainability of the water resources in the WQSAs was significantly challenged by the fact that data and information resides with a significant number of different agencies. In addition, the quality and timeliness of the data varied between WQSAs.
	• The PTTW program has limited guidance on what specific triggers are needed for regional scale assessment and management approaches and there is limited to no direction or guidance provided for a method to undertake a regional assessment such as for Cumulative Effects or for the development of a management strategy beyond a Cumulative Effects assessment.
	• The OLWR program primarily reflects shortages with respect to surface water resources. However, there is uncertainty among water managers as to what extent water managers can determine locally appropriate declarations and reductions.
	• WTRS data is self-reported and may be estimated based on pump run time and capacity. This is typical of most agricultural PTTWs in the province. In addition, the current use of the source type "Groundwater and Surface water" in the WTRS database makes it difficult to query the WTRS to determine total surface water takings in watersheds. The uncertainty of this data represents a gap in understanding water taking demand and a gap in being able to differentiate and quantify surface water takings and/or groundwater takings.
Recommendations	Information and Data Management - During the completion of the review and sustainability assessments of the different WQSAs, it was apparent that the necessary information and data resides in a number of different agencies, ministries, branches or divisions. In addition, the data quality and currency varied significantly. An enhanced level of coordination between agencies through the use of an on-line portal where all applicable data and regional watershed and subwatershed reports can be stored would assist in meeting this gap/ challenge.
	EFN (Environmental Flow Needs) - Data that can support EFN assessments should be more generally accessible and more broadly shared between agencies and the ministry for consideration in the preparation and review of PTTW applications. This type of information is needed when considering what conditions may need to be required in a PTTW, e.g. the development of trigger levels and consideration of how often they should be reviewed. Such conditions could be established and used in the development of an adaptive management plan.
	Climate Change - Assessments should be reviewed with updated regional modelling as it becomes available to provide improved projections on potential impacts to water resources.
	OLWR Program Database - the program datasets are poorly maintained and therefore the intrinsic value of the raw data is lost which greatly limits further analysis beyond the originally intended purpose of the OLWR program. It is recommended that the OLWR Program database be reviewed to identify improvements that will enhance the use of OLWR 'Notifications' as a tool for assessing trends in the availability of surface water, and possibly shallow groundwater resources.
	PGMN Database - It was noted that data records for many PGMN wells have not been updated in many years (some wells not since 2010). It is understood that the current method of data management requires multiple tiers of data review before data is released. It is also understood that the smaller CAs generally do not have the resources to maintain the PGMN network stations and complete a timely review of the PGMN data. The current system of data management for the PGMN network should be reviewed to create a system that will ensure the timely release of data.
	PTTW Program - The PTTW program lacks guidance on how to assess Cumulative Effects in a regional context. While there is some provincial level guidance on the need to consider Cumulative Effects and EFN, the PTTW program itself does not currently provide adequate guidance for internal staff and the public for evaluating Cumulative Effects and EFN. Providing additional technical guidance on how to conduct Cumulative Effects assessments and how to study and establish EFN would be beneficial.
	WTRS Database - The self-reported actual water taking data that was collected in Ontario since 2006 should be made universally available. WTRS should be updated to include all information from Table A of each individual PTTW. Occasional audits of the reported takings would reduce the uncertainty associated with self-reported data. The inclusion of this additional information would help clarify which source(s) on each PTTW is/are groundwater or surface water. The current use of the source type "Groundwater and Surface water" in the WTRS database makes it difficult to query the WTRS to determine total surface water takings in watersheds. This is important in areas with a significant number of permits classified as groundwater and surface water permits.
	High Use Watersheds - High Use Watersheds should be regularly re-assessed to account for changing conditions including Climate Change. The maps require updating as the stream flow data used in the analysis is now more than 30 years old and did not include stream gauges that have been established since the late 1980's. Methods for calculating and estimating low flows and GIS capabilities have also improved and need to be updated. To update the High Use Watershed Map, information on key low flow stream indicators such as annual and monthly flow duration rates and extreme/low flows of various recurrence intervals is needed. In addition to supporting a reassessment of the High Use Watershed maps, this updated information could be used to support a range of water resources management decisions from water taking proposals to assessing the effects of droughts and climate change effects on water bodies.
	Northern Ontario - Recommendations identified in Section 10.6 of this report (Chapleau WQSA), should be considered for addressing issues potentially impacting future water quantity in most of the rest of northern Ontario.

Notes:

1 Initial WQSA
2 WQSA as per Amendment No 1.
3 Primary SPA
4 As completed through Source Protection and/or Tier 3 Water Budget Assessment
5 As per O. Reg. 387/04 Water Taking and Transfer (as shown on the Average Annual Flow Map, Summer Low Flow Map)
6 Statistics Canada (2011 and 2016) Closest Representative Census Subdivisions (Municipalities)
7 Noted water shortages as reported by Water Managers

Table 11-2: Water Bottling Study Areas - Summary of Findings, Information Gaps and Recommendations

		Aquaterra Hillsburgh **Appendix 4-A**	**Nestlé Erin** **Appendix 4-B**	**Nestlé Aberfoyle** **Appendix 4-C**
PTTW INFORMATION SUMMARY				
Municipality		Erin	Erin	Puslinch
Conservation Authority		Credit Valley CA	Grand River and Credit Valley CA	Grand River CA
MECP District Office / Regional Office		Guelph / Hamilton (West Central)	Guelph / Hamilton (West Central)	Guelph / Hamilton (West Central)
PTTW Number		8664-75QJ2J	3716-8UZMCU	1381-95ATPY
PTTW Issue Date (month/day/year)		08/21/2007	09/28/2012	12/19/2013
PTTW Expiry Date (month/day/year)		07/31/2017	08/31/2017	07/31/2016
Source Description		1 limestone **bedrock well** (53.6 m deep)	1 limestone **bedrock well** (39.01m deep; screened from 21.79m - 39.01m)	1 dolostone **bedrock well** (31.1 m deep; screened from 28.4 to 31 m) for water bottling. 1 dolostone **bedrock well** (58 m deep, screening from 31.7 to 58 m) for firefighting purposes only.
Annual Amount Permitted by the PTTW (Million Litres)		58.5	406.25	1,314
Max. Taken per Day (Litres)		225,000	1,113,000	3,600,000
WTRS Amount Taken in 2017 (% of PTTW)		19.0%	16%	58%
How Long Have Current Water Taking Limits Been in Effect?		Since 1988	Since 2001	Since 2005
How Long Has there Been a Water Taking at the Site?		Since 1981 (for fish farm as per well record)	Since 1989; since 2000 for water bottling	Since 1980 (fish hatchery); since at least 1994 for water bottling
PTTW Monitoring Requirements	**At Taking Sources:**	Hourly: pressure head monitoring Daily: date, taking volume of each container load, start and end time of water taking, destination of each container. Annual: WTRS	Daily: date, time, total daily taking volume Monthly: Letter reports to the Director and Town of Erin Annual: WTRS	Daily: date, total daily taking volume, taking rate Monthly: total monthly taking volume; if monthly volume > 83.7 million L, multi-level piezometer data is to be submitted in a letter report to the Director. Continuous WL @ each taking well (transducer) Annual: WTRS
	Groundwater:	None	Continuous WL @ 6 bedrock and 6 overburden MWs; Monthly WL @ 10 bedrock and 4 overburden MWs; Continuous WL and vertical hydraulic gradients @ 7 piezometers MWs	Continuous WL @ 41 on-site wells Monthly WL @ 11 off-site private wells
	Surface Water:	None	Continuous WL @ 6 monitoring stations Monthly WL @ 3 monitoring stations	Continuous WL, monthly monitoring of flows, and development of stage-discharge curves @ 2 on-site locations on Aberfoyle Creek Continuous WL @ multi-level piezometers along Aberfoyle Creek Continuous temperature at 6 on-site locations on Aberfoyle Creek Monthly WL @ 3 off-site locations on Aberfoyle Creek and in 2 off-site ponds
	Ecosystem Monitoring:	None	None	Aquatic characterization and monitoring Vegetation characterization and monitoring Wildlife monitoring and surveys
	Other:	None	For the purpose of sanitization of the well, the maximum pumping rate is 1,040 L/min.	None
	Reporting of Monitoring Data:	Annual Monitoring Reports to the MECP	Annual Monitoring Reports available on request by MECP	Annually - Name & Location of facilities to which water is delivered in bulk containers >20 L Size of containers Total volume transported to facilities
ASSESSMENT FINDINGS				
Completeness of Site Characterization	**Are construction records available for all source wells and monitoring wells?**	Yes	Yes	Yes
	Are Site boundaries well defined?	Yes	Yes	Yes
	Are all monitoring locations indicated on Site Drawings and Tables?	Yes	Yes	Yes
	Have cross sections been prepared for the Site?	Yes	Yes	Yes
	Have the main hydrostratigraphical units been characterized for the Site?	Yes	Yes	Yes
	Is there aquifer testing data and analysis for all sources?	Yes	Yes	Yes
	Has the Zone of Influence been determined?	Source is artesian. The radius of influence could reach 5 km at a pumping rate of 1,600 L/min (TDM, 1991).	Yes - zone of influence (area with a predicted drawdown of 0.1 m) identified as 1 km from the well to the west, north and east. To the south and southwest it was determined to be greater than 0.7 km (CRA, 2014).	Yes - zone of influence (area with a predicted drawdown of 1 m or more) in each bedrock unit was interpreted to be: in the Amabel about 1,725 m to the north, about 1,200 m to the northeast and about 1,000 m to the south; and, in the Guelph about 650 m to the north, about 100 m to the south and a maximum of 200 m to the west and east (CRA, 2012).
	Overall, is there adequate information to assess the sustainability of the water taking?	Yes	Yes	Yes

Table 11-2: Water Bottling Study Areas - Summary of Findings, Information Gaps and Recommendations

		Aquaterra Hillsburgh Appendix 4-A	Nestlé Erin Appendix 4-B	Nestlé Aberfoyle Appendix 4-C
ASSESSMENT FINDINGS				
Stress Review	**Has A Water Budget Been Completed for the Watershed/ Subwatershed?**	Yes - West Credit River subwatershed	Yes - West Credit River subwatershed and the Eramosa River subwatershed	Yes - Mill Creek subwatershed
	Tier 1 Groundwater	Moderate Stress Potential (Credit River)	Moderate Stress Potential (Credit River)	Not Done
	Tier 1 Surface Water	Moderate Stress Potential (Credit River)	Moderate Stress Potential (Credit River)	Not Done
	Tier 2 Groundwater	Low Stress Potential (Credit River)	Low Stress Potential (Credit River and Eramosa River)	Moderate Stress Potential (Tier 3 Not Recm., however using Guelph Tier 3 Model evaluation underway, expected completion is March 2019)
	Tier 2 Surface Water	Low Stress Potential (Credit River)	Low Stress Potential (Credit River). Moderate Stress Potential (Eramosa River)	Low Stress Potential (Tier 3 Not Recm., however using Guelph Tier 3 Model evaluation underway, expected completion is March 2019)
	Are there Population Growth Pressures?	Per the Town of Erin's Official Plan (2012), anticipated population growth from 2016 to 2031 is 42% for the Village of Erin and 50% for the village of Hillsburgh.	Per the Town of Erin's Official Plan (2012), anticipated population growth from 2016 to 2031 is 42% for the Village of Erin and 50% for the village of Hillsburgh.	No, however the City of Guelph north of the WBSA does have population growth pressures.
	PGMN Wells (Distance) Type	W0000164-2 (2.7 km) Overburden W0000164-3 (2.7 km) Overburden W0000026-1 (3.6 km) Bedrock W0000163-2 (8 km) Overburden W0000163-3 (8 km) Overburden W0000019-1 (13.5 km) Overburden W0000028-2 (18.6 km) Overburden W0000028-4 (18.6 km) Overburden	W0000026-1 (6.8 km) Bedrock W0000164-2 (1.4 km) Overburden W0000164-3 (1.4 km) Overburden	W0000003-1 (8.6 km) Overburden W0000008-1 (8.8 km) Bedrock W0000024-2 (5.8 km) Overburden W0000024-4 (5.8 km) Bedrock W0000031-1 (5.9 km) Bedrock W0000046-1 (9.4 km) Bedrock
	Were Decreasing Water Level Trends Detected for PGMN Wells?	One shallow overburden well showed downward seasonal trends; one deeper overburden well at the same location also showed downward seasonal trends.	No	One deep bedrock well showed downward year to year and seasonal trends.
	OLWR: What trends were identified for 'Notifications' and 'Declared Alerts'?	On an occasional seasonal basis (summer months) for notifications and alerts.	None	None
	Have Level 2 or Level 3 Low Water Conditions Alerts Been Declared for the Watershed and When?	Yes - Level 2 Alert in 2012 and 2016	Yes - Level 2 Alerts were declared in 2002, 2003, 2005 and 2007, 2012, 2016.	Yes - Level 2 Alerts in 2002, 2003, 2007, 2008, 2012, and 2016.
	Overall Findings of Stress Review	Based on the information reviewed, no stress concerns were identified for the sustainability of regional water quantity resources at current water taking quantities. A climate change modelling assessment for the City of Guelph and the Guelph/Eramosa Township determined that no impact to the sustainability of the municipal supply wells is anticipated, suggesting that there may also be no impact on regional groundwater resources.	Based on the information reviewed, no stress concerns were identified for the sustainability of groundwater resources, though the potential for moderate surface water stress was identified. A climate change modelling assessment for the City of Guelph and the Guelph/Eramosa Township determined that no impact to the sustainability of the municipal supply wells is anticipated, suggesting that there may also be no impact on regional groundwater resources.	Based on the information reviewed, no stress concerns were identified for the sustainability of regional surface water quantity resources, but the potential for moderate stress concerns for groundwater was identified. In a Risk Management Measures Evaluation Process that was completed for the City of Guelph and the Township of Guelph/Eramosa, the water taking at the Nestlé (Aberfoyle) Site was ranked as having a relatively low level of threat compared to the other consumptive water demands in the groundwater Vulnerable Area, with a predicted maximum percent impact of 1% on the municipal wells. A climate change modelling assessment for the City of Guelph and the Guelph/Eramosa Township determined that no impact to the sustainability of the municipal supply wells is anticipated, suggesting that there may also be no impact on regional groundwater resources.
Cumulative Effects/Impacts	**Have there been documented well interference impacts?**	No	No	None at the current level of taking.
	Has there been a documented decline in groundwater Levels for the Site?	No	No	No
	Other Large Water Takings of Potential Interest	PTTW No. 8112-9CPNNW (Erin Municipal Wells) @ 1.5 km; PTTW No. 7370-A8YL4P (Derrydale Golf Course) @ 1.8 km; PTTW No. 5227-ABYPXB (Remediation) @ 2.9 km; PTTW No. 3716-8UZMCU (Nestlé Water Bottling) @ 3.7 km; PTTW No. 7740-A9ZNTP (Erin Municipal Supply) @ 3.7 km; PTTW No. 6131-AL5QJ9 (Silvercreek Aquaculture) @ 4.2 km; PTTW No. 6306-8X5KRY (Erin Municipal Wells) @ 4.4 km; 8548-6SBGWC (3.9/Water Supply).	7740-A9ZNTP (The Corporation of the Town of Erin) @1.3 km; 6306-8X5KRY (The Corporation of the Town of Erin) @ 1.5 km; 8548-6SBGWC (The Corporation of the Town of Erin) @ 1.6 km; 0834-ASYKZU and 5200-7VSP2M (Mimosa Springs Trout Farm Ltd.) @ 3.5 km; 8664-75QJ2J (Aquaterra Corp. Ltd. [water bottling]) @ 3.7 km; 7436-A6ZSZA (Harlan James and Delphine Taylor) @ 4.6 km.	5626-7WLQ3W & 2003-AQWHTC (Wellington Vacant Land Condo Corp. No. 147 [communal water supply]) @ 0.69 km; 3331-73RKYV & 7137-AG7SV2 (Wellington Common Elements Condo Corp. No.214 [communal water supply]) @ 1.8 km.
	Has a potential for unacceptable well interference been identified?	The general assessment of potential water quantity interference with existing or planned municipal water supply systems did not identify any potential for unacceptable well interference and/or impediment to future expansion of existing municipal groundwater systems.	The general assessment of potential water quantity interference with existing or planned municipal water supply systems did not identify any potential for unacceptable well interference and/or impediment to future expansion of existing municipal groundwater systems.	The general assessment of potential water quantity interference with existing or planned municipal water supply systems did not identify any potential for unacceptable well interference and/or impediment to future expansion of existing municipal groundwater systems.

Table 11-2: Water Bottling Study Areas - Summary of Findings, Information Gaps and Recommendations

		Aquaterra Hillsburgh Appendix 4-A	Nestlé Erin Appendix 4-B	Nestlé Aberfoyle Appendix 4-C
ASSESSMENT FINDINGS				
Ecosystem and Environmental Flow Needs Assessment	**Is there Groundwater/Surface Water Interaction at the Site?**	Yes - artesian flow to the Credit River located to the south of the Site (TDM, 1991)	No - the bedrock and overburden aquifers are not observed to be hydraulically connected.	Yes
	Has an Ecosystem Study been done?	No	Yes - 2012 Terrestrial Monitoring Program	Yes
	Is there On-going Ecosystem Monitoring?	No	No	Yes - biological assessments completed on an annual basis.
	Are Ecosystem and/or Environmental Flow Needs (EFN) Assessments Warranted?	The current water taking amounts appear to be adequately protective of the ecosystem and EFN. Completion of an ecosystem assessment is considered necessary in support of any proposed increase to the Permit water taking quantities, or if any complaints or concerns are raised about ecosystem impacts.	The current limit appears to be adequately protective of ecosystem and EFN. Completion of an ecosystem assessment is considered necessary in support of any proposed increase to the Permit water taking limits, or if any complaints or concerns are raised about ecosystem impacts.	Ecosystem assessments have been undertaken for the Site. Continued water takings at the permitted water taking levels are not expected to impact surface water and natural functions of the ecosystem. The existing monitoring program in place serves to identify any possible changes to these features.
Sustainability	**Are Regional Water Resources Sustainable?**	Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater and surface water resources appear to be sustainable under existing conditions. However, groundwater resources may become unsustainable in the future due to population growth and the associated increase in water demand, and increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs.	Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater and surface water resources appear to be sustainable under existing conditions. However, groundwater resources may become unsustainable in the future due to population growth and the associated increase in water demand, and increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs.	Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater and surface water resources appear to be sustainable under existing conditions. However, groundwater resources may become unsustainable in the future due to population growth and the associated increase in water demand, and increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs.
	Are the PTTW Water Taking Limits Sustainable?	Based on the information reviewed, there are no indicators of the Aquaterra Hillsburgh water taking having an impact on the sustainability of existing and future water resources at the current levels of taking. Consequently, it is BluMetric's opinion that the water taking is being managed sustainably. There are uncertainties around the future sustainability of the taking if the maximum allowed taking were taken over maximum allowed pumping duration. Further work, such as modelling, would be required to determine the potential impacts on the municipal water supplies from the pumping of the Hillsburgh well at the maximum permitted rate.	Based on the information reviewed, there are no indications that the Nestlé (Erin) water taking is having an impact on the sustainability of existing and future water resources at the current or permitted levels of taking. Consequently, it is BluMetric's opinion that the water taking is being managed sustainably.	Based on the information reviewed, there are no indicators of the Nestlé (Aberfoyle) water taking having an impact on the sustainability of existing and future water resources at the current levels of taking; the water taking was determined to have a predicted maximum percent impact of 1% on municipal wells in the area. Consequently, it is BluMetric's opinion that the water taking is sustainable under current conditions. Additional insight on the sustainability of the groundwater resource under future climate scenarios will be possible based on the additional Tier Three Modelling when completed.
	Are PTTW Monitoring Conditions Adequate to Ensure Sustainability?	Monitoring/reporting conditions under the PTTW are considered adequate. The monitoring program provides a measure of security in ensuring the water taking remains sustainable in the future.	Monitoring/reporting conditions under the PTTW are considered adequate. The monitoring program provides a measure of security in ensuring the water taking remains sustainable in the future.	Monitoring/reporting conditions under the PTTW are considered adequate. The monitoring program provides a measure of security in ensuring the water taking remains sustainable in the future.
GAPS & RECOMMENDATIONS				
Site Specific Information Gaps and Recommendations for the Water Quantity Management Framework		There are uncertainties around the future sustainability of the taking if the maximum allowed taking were taken over the maximum allowed pumping duration. Further work, such as modelling, would be required to determine the potential impacts on the municipal water supplies from the pumping of the Hillsburgh well at the maximum permitted rate.		The results of the Risk Management Measures Evaluation Process for the City of Guelph and the Township of Guelph/Eramosa, as well as the additional Tier 3 modelling currently underway by Nestlé, S.S. Papadopulos & Associates Inc. and Matrix Solutions Inc., should be considered as part of future assessments of water takings at the Nestlé (Aberfoyle) Site.
				The integrity of the Eramosa as an aquitard has been questioned in some parts of the WQSA in which this WBSA is located. Further review and testing to determine the hydraulic properties of the unit should be conducted. Nestlé should use this review to determine the implications (if any) to the water taking at the Nestlé (Aberfoyle) Site.

Table 11-2: Water Bottling Study Areas - Summary of Findings, Information Gaps and Recommendations

	Aquaterra Hillsburgh **Appendix 4-A**	**Nestlé Erin** **Appendix 4-B**	**Nestlé Aberfoyle** **Appendix 4-C**
ASSESSMENT FINDINGS			
Gaps / Recommendations for All Sites to Enhance the Water Quantity Management Framework	Data Availability to Assess Sustainability - The presentation of hydrographs with long term water level data (e.g. groundwater level and surface water level data collected over many years) was identified in the present study and in BluMetric (2019) as the best available science in assessing whether steady state conditions exist and for addressing sustainability of the water taking. Consequently, on-going monitoring and the presentation of long term monitoring data as hydrographs is recommended for all water bottler water takings to establish that the water taking is sustainable.		
	OLWR Program Database - It is recommended that the OLWR Program database be reviewed to identify improvements that will enhance the use of OLWR 'Notifications' (that are based on surface water trigger levels) as a tool for assessing trends in the availability of surface water, and possibly shallow groundwater resources. Integration of PGMN groundwater level data into the OLWR Program would provide a further enhancement by providing a monthly status of groundwater levels within the watershed. Timely release of the integrated data would allow for timely response.		
	PGMN Database - It was noted that data for many PGMN wells has not been updated in many years (some wells not since 2010). The current system of data management for the PGMN network should be revised to ensure the timely release of data so that the data can compliment other background monitoring well data. It should be determined whether any PGMN wells are installed within the same aquifers as nearby municipal water supply wells, water bottling operations, and other major consumptive water uses. The PGMN wells have the potential to be used for long-term monitoring of potential groundwater impacts resulting from or affecting such water takings.		
	File Management - During the completion of the file review it was apparent that most documentation for the WBSAs remain in hard copy only. Hard copy documentation storage and file management poses a number of challenges and risks. Challenges are associated with access to files that get moved from desk to desk. Risks are associated with the potential misplacement of files and the potential loss of hard copy documents to fire or other forms of damage. Consequently, transitioning file management to an e-based system is recommended.		
	WWIS Database - The WWIS should be cross-referenced against ground-truthed data from water well surveys (where available), and updated/revised where applicable.		

Notes:

GW	Groundwater
MW	Monitoring Well
WL	Water Level

APPENDIX 4-A

(Aquaterra Corporation Ltd., Hillsburgh WBSA)

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4A. AQUATERRA CORPORATION LTD HILLSBURGH SITE

4A.1 BACKGROUND AND HISTORY

Aquaterra Corporation Ltd. ("Aquaterra") currently draws water from a single bedrock flowing artesian well identified as the Hillsburgh Well, located on the north side of Trafalgar Road N and west of Sideroad 17 in the Town of Erin, Ontario, herein referred to as the 'Site' or 'Aquaterra Hillsburgh Site'. The Site falls within the jurisdictions of the Ministry of the Environment, Conservation and Parks (MECP) Guelph District Office and Credit Valley Conservation (CVC). The Aquaterra Hillsburgh Site water source location and Site boundaries are indicated on Figure 4-A-1.

The Aquaterra Hillsburgh Site is located in a rural setting and is situated adjacent to both the Niagara Escarpment and the Credit River. The well record (# 6707549) from 1981 indicates that the well was originally drilled for a fish farm. The Site has been taking water for the purposes of water bottling since 1988. At that time, the well was owned and operated by the Spring Valley Water Company (SVW). The Site has changed ownership several times, but it is assumed that the Site was continuously used for groundwater taking to supply a water bottling plant in Mississauga, Ontario. An approximate timeline of events relevant to the PTTW history of the Aquaterra Hillsburgh Site is provided in Table 4-A-1.

Table 4-A-1: Aquaterra Corporation Ltd. Hillsburgh PTTW History Summary

Year	Event
1988	The Hillsburgh Well was constructed in April 1988 for a proposed fish farming operation. **PTTW 88-P-2002** issued to Spring Valley Water Company on March 1, 1988 for water taking from one well for bottled water purposes. Approved water taking amount is 900 L/minute and 225,000 L/day. The expiry date was March 1, 1998.
1996	Spring Valley Water Company was purchased by Aquaterra Corporation in June of 1996.
1998	**PTTW 98-P-2029** was issued to renew the 1988 PTTW and to change the name to Aquaterra Corporation. The water taking was permitted for the period between April 30, 1998 and March 31, 2000. The source is one well with a purpose of commercial – bottled water. The approved water taking amount is 900 L/minute and 225,000 L/day. The permit required submittal of the water taking records to the ministry annually by February 28 for the preceding calendar year.
2001	Renewal of **PTTW 98-P-2029** was issued to Aquaterra Corporation for commercial – bottled water on June 14, 2001 and was valid until March 31, 2003. The maximum rate and amount of taking were identical to the previous permit. The PTTW included the following conditions: • Identification of water features within 500 m of the source well (Condition 2). • Within 60 days of the issuance of the permit, complete a 12 hour aquifer test at the permitted rate of 900 L/min with a pressure head recovery of 95 %. Prior to the test, no flow conditions were to be implemented for a period of 24 hrs (Condition 3). On August 7, 2001, an amendment was issued for **PTTW 98-P-2029** for a name change to Danone Waters of North America as Aquaterra Corporation was now part of Danone Waters of North America. There were no other changes to the permit. This PTTW was the subject of an Appeal brought by the Town of Erin as per an EBR posting. The Environmental Review Tribunal found the test for leave to appeal under the EBR, was not met by the Applicant, the Town of Erin. Therefore, the Application by the Town of Erin in seeking leave to appeal a decision of the Director, Ministry of the Environment, to issue a Permit To Take Water No. 98-P-2009 to Aquaterra Corporation was denied. The decision was dated September 20, 2001.
2003	Notice of Denial of application dated February 28, 2003 to increase existing permitted water taking. The reason for the denial of the application was that the denial was in keeping with Ontario Regulation 434/03. As the moratorium only applied to new or increased rates and/or amounts, the ministry may have considered an application for renewal of the existing PTTW at the previously approved rates and amounts.
2004	Renewal of **PTTW 98-P-2029** was issued to Danone Waters of North America on May 23, 2004 for one well, with an expiry date of May 31, 2006. The maximum rate and amount of taking were identical to the previous permit. The PTTW included the following conditions: • Recording of daily water taking rate and amount. • Tabulation of the water taking data on an annual basis and submittal of the records to the ministry by February 28 for the preceding calendar year. • On February 28, 2005, the submittal of a report describing the extent of the water taking at this location including: o Discussion of whether artesian conditions exist at this site and whether or not they remain continuous throughout the year. o Discussion on what impact water taking under the authorization of this permit has on the artesian conditions. • Maintain a spreadsheet listing the amounts of each container load in litres and the times started and finished for all days water is taken.

Year	Event
2006	**PTTW 7670-6RLKS8** issued to Danone Waters of Canada Inc. on July 14, 2006, with an expiry date of July 31, 2016. The maximum rate and amount of taking were identical to the previous permit. Water could be taken for a maximum of 18 hours per day, and a maximum of 260 days per year. Permit conditions/requirements included: At Taking Source HW: • Pressure head monitoring at 15 minute intervals until September 30, 2007 and hourly thereafter (Condition 4.1). • Recording of the amounts of each container load, the times that each loading started and finished and the destination if each container. Submission of data by March 31 each year (Condition 4.2). Reporting: • Annual submission of a report detailing the following: o Discussion of seasonal variability of artesian conditions; and, o Discussion of the impact of the water taking on artesian conditions (Condition 4.3). • 2016 renewal application shall include an interpretive assessment of the impact of the water taking over the duration of the Permit, any groundwater trends and recommendations for changes to the monitoring program (Condition 4.4). A datalogger was installed in the source well to measure the pressure head.
2007	**PTTW 8664-75QJ2J** was issued to Aquaterra Corporation Ltd. on **August 21, 2007**, with an expiry date of July 31, 2017. The permit allowed water to be extracted from the Hillsburgh Well (HW) for the purpose of commercial water bottling. The maximum withdrawal rate and amount were identical to the previous permit. The permit conditions remained the same.
2017	An application to renew **PTTW 8664-75QJ2J** (expiry date of July 31, 2017) was submitted by Aquaterra Corporation in May 2017. As a decision on the application had not been made, and in accordance with Section 34.1(6) of the Ontario Water Resources Act, the PTTW is to remain in force until the Signing Director makes a decision to renew the permit or refuse the renewal.

General information about the source well (Hillsburgh Well) on the Aquaterra Hillsburgh Site is provided in Table 4-A-2.

Table 4-A-2: Summary of Water Taking Source

Source Name	Type/Date of Install	Well Record ID	Total Well Depth	Completion Unit	PTTW No. 8664-75QJ2J		
					Max. Taken Per Minute (L)	Max. Num. of Hours Taken per Day	Max. Taken Per Day (m^3)
Hillsburgh Well	Drilled Well/ January 19, 1981	6707549	53.6 m bgs	Bedrock - limestone	900	18	225

As indicated in Table 4-A-2 the Hillsburgh Well is completed in bedrock to a depth of 53.6 m. According to the well record, the well is an open hole in the bedrock from 16.15 to 53.6 m below ground surface (bgs). Further to above, the well record indicates 'water found' between 49.4 and 51.8 m depth. Overburden is reported in the well record as sand-gravel-clay from 0 to 5.5 m depth and clay-stones from 5.5 to 14.6 m depth where limestone bedrock was encountered. Water takings from the well are shipped by water tanker to the Canadian Springs bottling plant located in Mississauga, Ontario. The volume of water taken is recorded from the number of truckloads that are removed each day. Each truckload takes approximately one hour to load and is based on tank capacity which is 36,368 L. The only structures reported to be located on the Site are a locked, secure building that houses the Hillsburgh Well. Since the well is operated by artesian pressures, there is no electrical power provided to the building (i.e. no pumps). When not in use, the well remains capped except during winter months where the well maintains a constant drip to prevent freezing. The well casing was repaired in 2009 after it was noted to be leaking.

4A.2 PRIMARY INFORMATION SOURCES

The following records pertaining to the PTTW history were reviewed by BMEI.

- PTTW 8664-75QJ2J, Aquaterra Corporation Ltd., August 21, 2007.

The following key technical documents provided to the ministry by the proponent/Permit Holder were identified and reviewed herein.

- Hydrogeological Study Spring Valley Production Well Hillsburgh, Ontario. Trow, Dames & Moore, April 19, 1991 (TDM, 1991).
- Re: Renewal Application for Permit to Take Water #98-P-2029, Hillsburgh, Ontario. Gartner Lee Limited, September 18, 2001 (GLL, 2001).

- Canadian Springs Hillsburgh 2009 PTTW Annual Report. AECOM, March 2010 (AECOM, 2010).
- Canadian Springs Hillsburgh 2011 PTTW Annual Report. AECOM, March 2010 (AECOM, 2012).
- Canadian Springs Hillsburgh 2016 PTTW Annual Report. AECOM, March 2017 (AECOM, 2017).

Other information sources used in this assessment included:

- Approved Updated Assessment Report: Credit Valley Source Protection Area. Credit Valley Conservation Authority, July 27, 2015 (CVC, 2015).
- Town of Erin Zoning by-law No. 07-67.
- Wellington County Official Plan. May 2018.
- Public Works Department Website. Corporation of the Town of Erin. 2018. http://www.erin.ca/town-hall/public-works (Accessed on November 29, 2018). (Town of Erin, 2018).
- Brunton, F.R., 2009. Update of Revisions to the Early Silurian Stratigraphy of the Niagara Escarpment: Integration of Sequence Stratigraphy, Sedimentology and Hydrogeology to Delineate Hydrogeologic Units. In Summary of Field Work and Other Activities 2009, Ontario Geological Survey, Open File Report 6240, p.25-1 to 25-20 (Brunton, 2009).
- Matrix Solutions Inc. 2017. City of Guelph and Township of Guelph/Eramosa Tier Three Water Budget and Local Risk Assessment. Lake Erie Source Protection Region.
- Matrix Solutions Inc., 2018. Assessment of Climate Change and Assessment of Water Quantity Threats in the IPZ-Q in Support of the Guelph-Guelph/Eramosa Water Quantity Policy Study. Lake Erie Source Protection Region.
- BluMetric Environmental Inc., 2019. A Review of Ontario's Water Quantity Management Framework. Water Bottling Study Areas Report.
- Physiography of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228. Chapman, L.J. and Putnam, D.F. 2007. (Chapman and Putnam, 2007).
- Surficial Geology of Ontario; MNDM File - MRD128-REV. Ontario Geological Survey, 2010. (OGS, 2010).
- Bedrock Geology of Ontario; MNDM File - MRD126-REV1. Ontario Geological Survey, 2011. (OGS, 2011).
- MECP Water Well Information System (WWIS). Available at: https://www.ontario.ca/environment-and-energy/map-well-records.

- MECP on-line Provincial Groundwater Monitoring Network database. Available at https://www.ontario.ca/environment-and-energy/map-provincial-groundwater-monitoring-network.
- Groundwater Levels in Ontario: A Trends Analysis using the Provincial Groundwater Monitoring Network. MECP, Southwest Region. 2018 (MECP, 2018).
- MECP on-line Permit to Take Water database. Available at: https://www.ontario.ca/environment-and-energy/map-permits-take-water.
- MECP Water Taking Reporting System (WTRS) database (Confidential – Used with Permission from MECP).
- Ontario Low Water Response Program (OLWR) notifications and alert levels for Lower Trent Region Conservation Authority (2000 to 2018 data from MNRF).

Technical information sources referenced in other documentation but not reviewed by BMEI:

- 2001 Renewal Application for Permit to Take Water #98-P-2029, Hillsburgh, Ontario.
- 2004 PTTW Annual Report for the Canadian Springs Hillisburgh Site. Gartner Lee Limited, March 2005 (GLL, 2005).
- 2005 PTTW Annual Report for the Canadian Springs Hillisburgh Site. Gartner Lee Limited, March 2006 (GLL, 2006).
- 2006 PTTW Annual Report for the Canadian Springs Hillisburgh Site. Gartner Lee Limited, March 2007 (GLL, 2007).
- 2007 PTTW Annual Report for the Canadian Springs Hillisburgh Site. Gartner Lee Limited, March 2008 (GLL, 2008).
- Canadian Springs Hillsburgh 2010 PTTW Annual Report. AECOM, March 2010 (AECOM, 2011).
- Canadian Springs Hillsburgh 2012 PTTW Annual Report. AECOM, March 2010 (AECOM, 2013).
- Canadian Springs Hillsburgh 2013 PTTW Annual Report. AECOM, March 2010 (AECOM, 2014).
- Canadian Springs Hillsburgh 2014 PTTW Annual Report. AECOM, March 2010 (AECOM, 2015).
- Canadian Springs Hillsburgh 2015 PTTW Annual Report. AECOM, March 2010 (AECOM, 2016).

4A.3 CHARACTERIZATION OF STUDY AREA

The Aquaterra Hillsburgh Site is located at the north end of the Guelph-Wellington County Water Quantity Study Area ("Guelph WQSA") as defined in MECP RFB# 6792. As specified by the MECP, the water bottler has been investigated as part of the Guelph WQSA. Characterization of water quantity resources conditions on a regional scale is provided in the main body of the Guelph WQSA report. Figure 4-A-2 presents an area of approximately 20 km by 20 km centred over the Aquaterra water taking location. The 20 km by 20 km study area was selected to ensure the following were captured: the closest municipal groundwater system takings, Provincial Groundwater Monitoring Network (PGMN) wells, and Survey of Canada (WSC) hydrometric monitoring stations (HYDAT), and the radius of influence of the Aquaterra water taking (suggested by TDM (1991) to reach 5 km at a pumping rate of 1,600 L/minute, a higher rate of taking than the currently approved maximum taking rate of 900 L/minute; see Section 4A.3.4.3 for further discussion of the radius of influence).

The review of permitted water takings as reported within the Water Taking Reporting System (WTRS) database focused on 'municipal water supply system takings' located within a 20 km by 20 km area centred over the Aquaterra Hillsburgh water taking, and 'other' reported water takings located up to 5 km from the Site. Smaller assessment areas were used for the review of existing/planned land use and the review of water well information system (WWIS) records and are indicated herein.

The Aquaterra Hillsburgh Site is located between the Village of Erin and the Village of Hillsburgh municipal groundwater systems and is within the Credit Valley Source Protection Area (SPA). Of note, the Nestle Erin Spring (water bottler) water taking is located 3.7 km northwest of the Site and the Aquaterra Cataract (water bottler) water taking is located 8.4 km northeast of the Site.

4A.3.1 Land Use Setting

Existing Land use in the vicinity of the Aquaterra Hillsburgh Site, as per the County of Wellington Official Plan, is indicated on Figure 4-A-3. Local land use was assessed in consideration of existing and potential future land use/development activities that might contribute towards stress on groundwater resources.

The Aquaterra Hillsburgh Site is located in the Town of Erin. The Town of Erin is described as a rural community with agricultural activities being an important component of the Town's economy (Town of Erin, 2012). The Town of Erin has a 2016 census population of 12,490, and the population is forecast to rise to about 13,510 and then 15,530 by the years 2021 and 2031, respectively. The primary growth areas are designated to occur in Urban Centres, i.e. compact, well-integrated rural towns on full, piped water services. Within the Town of Erin there are separate Urban Centres for the Village of Erin and the Village of Hillsburgh, both are primarily residential areas. The Aquaterra Hillsburgh water taking location is situated between the two urban centres. The urban area boundary for the Town of Erin is located 800 m east of the Aquaterra Hillsburgh water taking location and the urban area for the Town of Hillsburgh is located approximately 2,500 m northwest of the water taking.

As indicated on Figure 4-A-3, land use within approximately 1000 m of the Aquaterra Hillsburgh Site, as per the County of Wellington Official Plan, consists of secondary agricultural land to the north, east and west, core greenlands (wetland/water body) to the north, east and south, and prime agricultural to the south and northeast. Land use zoning 'on' the Aquaterra Hillsburgh Site consists mainly of Greenlands (woodland). There is a small section of core Greenlands (wetland) indicated for the south and north side of the Site and a small section of secondary agricultural land use indicated on the north side of the Site. The Town of Erin Zoning by-law No. 07-67 indicates that the core Greenlands sections of the Hillsburgh Site are zoned as a Rural Environmental Protection (EP2) zone, placing restrictions on land development. The Ministry of Natural Resources and Forestry's (MNRF) Natural Heritage Areas mapping shows that the Environmental Protection zones on the Aquaterra Hillsburgh Site include non-provincially significant wetlands. Based on the land use assessment the potential for other high volume groundwater use activities, other than possibly for agriculture, appears to be low for the area.

4A.3.2 Physiographic Setting

The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of the regional physiographic setting. The Aquaterra (Hillsburgh) Site is located within the Hillsburg Sandhills physiographic region as identified by Chapman and Putnam, 1984.

Chapman and Putnam (1984) characterize the Hillsburg Sandhills region as being comprised of rough topography, sandy soils and swampy valleys. In the Township of East Garafraxa and the Town of Erin, the Hillsburg Sandhills form a natural boundary on the southeastern flank of the Dundalk and Stratford Till Plains. The sandhills have a minimum elevation of 425 masl with some ridges reaching elevations of 490 masl (Matrix Solutions Inc., 2017).

4A.3.3 Geologic Setting

A detailed discussion of the regional geologic setting of the Guelph WQSA is presented in Section 4 of the main report.

The surficial geology within the study area consists of unconsolidated glacial deposits. The Orangeville Moraine, consisting of ice-contact stratified drift (mainly sand and gravel), is located on the north and west sides of the study area. The Caledon meltwater channel to the east and south of the Hillsburgh Site consists of sand and gravel. A deposit of Port Stanley Till (sandy silt till) is mapped for the Aquaterra Hillsburgh Site, and identified as "CS" on Text Figure 4-A-4 (TDM, 1991). The Hillsburgh well is identified as "SVW" on Text Figure 4-A-4.

The bedrock formations mapped for the Hillsburgh area (including the Town of Erin) consist of Guelph (upper) and Amabel (lower) formations. The Guelph-Amabel formations in the Hillsburgh area have a combined thickness that ranges from approximately 60 to 120 m (TDM, 1991).

A brief description of each of these bedrock formations is provided below, as an excerpt from the City of Guelph Tier 3 Assessment (Matrix Solutions Inc., 2017):

> ***Gasport (Amabel) Formation***
> *The Gasport Formation is a cross-bedded crinoidal grainstone-packstone with sequences of reef mound and coquina (shell bed) lithofacies. This unit has commonly been referred to as the Amabel Formation in previous studies in the area. The Formation generally varies in thickness from about 25 to over 70 m, and the upper sections of the reef mounds, the crinoidal grainstones and the coquina shell beds make this formation highly transmissive, where they are present.*
>
> ***Guelph Formation***
> *The Guelph Formation consists of two members; the lower Hanlon Member and the upper Wellington Member. The Guelph Formation consists of medium to thickly bedded crinoidal grainstones and wackestones and reefal complexes (Brunton, 2008). The Guelph Formation is cream-coloured and fossiliferous and where present in the Cambridge and Guelph area it is most often the uppermost bedrock unit.*

4A.3.4 Hydrogeologic Setting

4A.3.4.1 Regional Hydrogeology

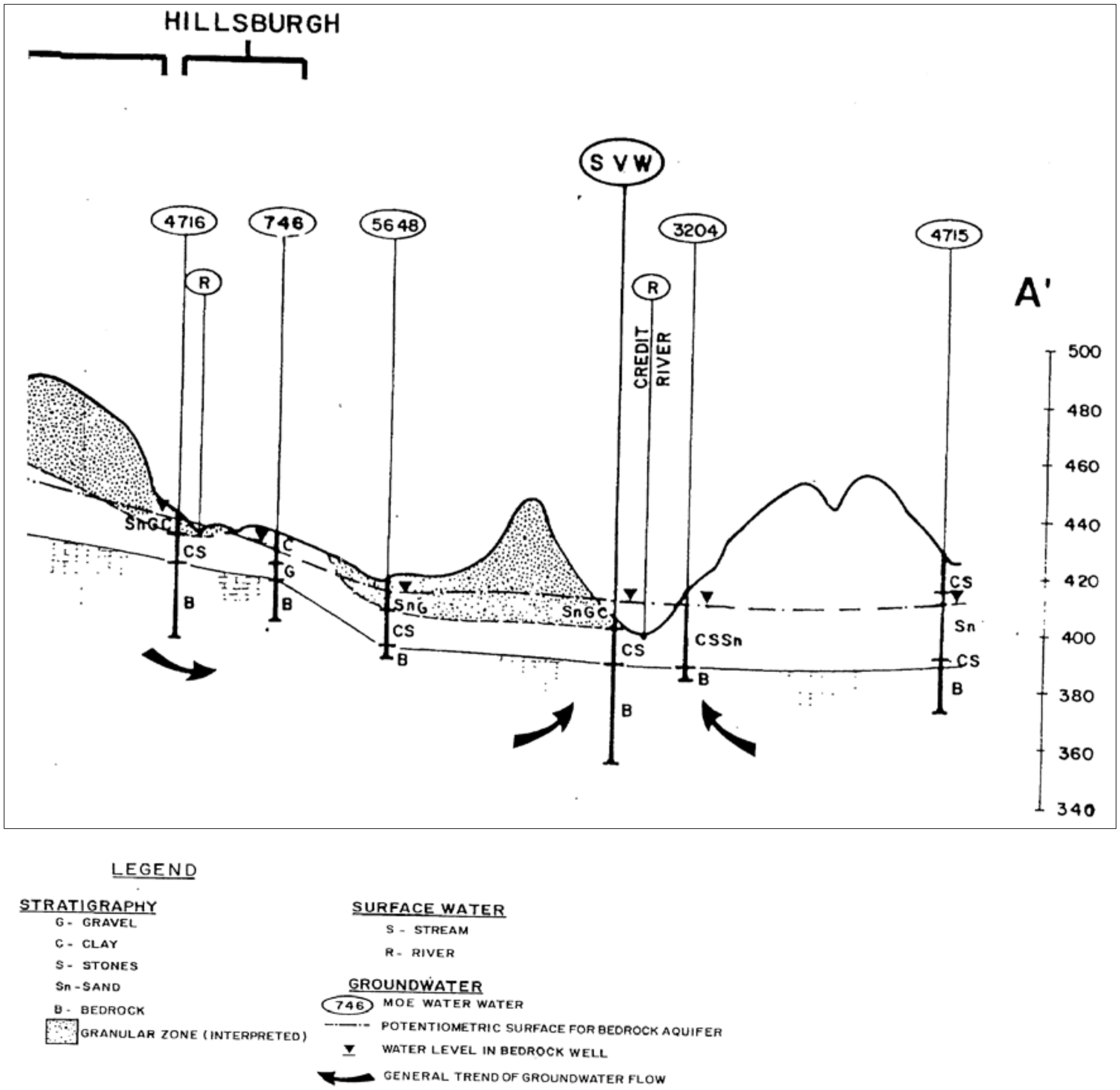
The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of the regional hydrogeologic setting of the Aquaterra (Hillsburgh) Site.

4A.3.4.2 Local Hydrogeology

TDM (1991) describe aquifers occurring in both the overburden and the bedrock within the Town of Erin area. The Orangeville Moraine and the Upper Credit and Caledon meltwater channels located to the northwest and southeast of the Site, respectively, contain overburden aquifers within their coarse-grained deposits. The Guelph and Amabel dolostone bedrock formations provide the bedrock aquifers supplying groundwater to the Town of Erin area. Based on the studies that have been completed, the Aquaterra Hillsburgh Well extracts groundwater from the Guelph-Amabel dolostone bedrock formations.

The Credit River flows through the southern section of the Aquaterra Hillsburgh property and the Aquaterra Hillsburgh production well (identified as SVW on the cross section below) is located approximately 130 m north of the river. In the vicinity of the Credit River, groundwater flow direction in the overburden and bedrock is towards the river. Water well record information for private water wells immediately northwest of the Aquaterra Hillsburgh Site indicate that bedrock rises sharply to the northwest and towards Hillsburgh (TDM, 1991). A northwest to southeast cross-section through the Site (TDM, 1991) is provided as Text Figure 4-A-4.

Text Figure 4-A-4: Northwest-Southeast Cross-Section



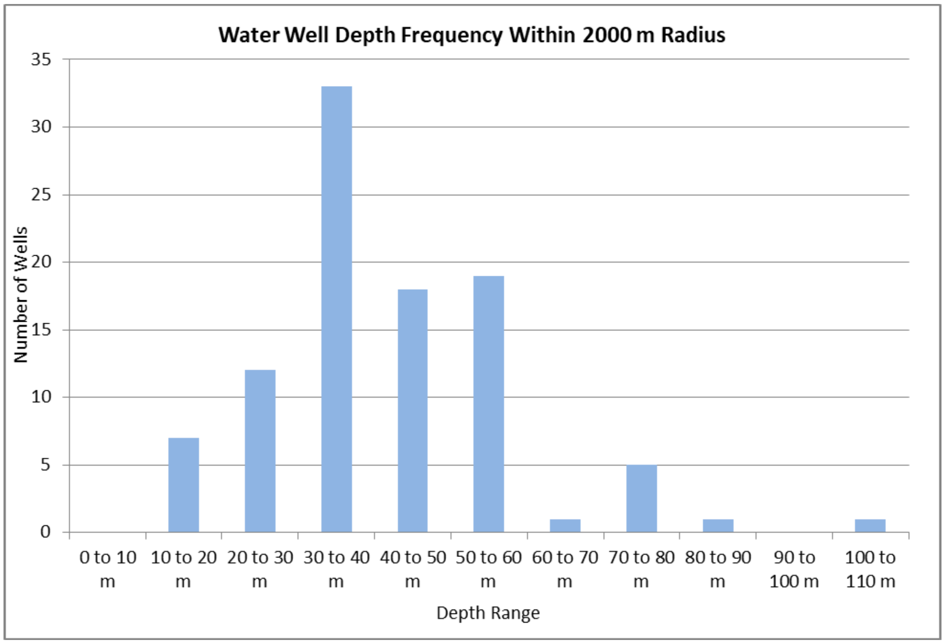
Source: Figure 4 of Hydrogeological Study Spring Valley Production Well Hillsburgh, Ontario. Trow, Dames & Moore, April 19, 1991 (TDM, 1991).

TDM (1991) indicates that the flowing artesian conditions for the Aquaterra Hillsburgh Well likely result from the presence of the low permeability Port Stanley Till (indicated as CS on Text Figure 4-A-4) that restricts the upward flow of groundwater from bedrock to the river. Also, the water table elevation in the Orangeville Moraine to the northwest of the Site provides an additional hydrostatic pressure that forces groundwater to the surface at the Site.

Properties in the Town of Erin are serviced by private water supply wells and municipal groundwater supply. The MECP WWIS database was reviewed for well locations situated within 2,000 m of the Aquaterra Hillsburgh Site production well. A 2,000 m search radius was considered appropriate based on the observed density for water well records in this search area while being representative of local conditions. Water well record locations as referenced in the WWIS are plotted on Figure 4-A-1. A total of 102 well construction records for supply wells were identified (i.e. monitoring wells and well abandonment records were omitted). The WWIS database indicates that 4 of the 102 wells are completed in overburden, 5 are of unknown type, and the remaining 93 are completed in bedrock. Of note, more than 5 well records were indicated as unknown type; however, upon review of the original well records, some of these wells were determined to be either a bedrock or an overburden well. The 4 overburden wells identified in the WWIS records are completed to depths ranging from 13.7 to 25.9 m while the 93 bedrock wells are completed to depths ranging from 12.8 to 109.7 m. Overburden materials are most commonly described in the well records as consisting of sand, clay and gravel. Reported static water level depths ranged from 0 m to 44.8 m and indicate that 8 of the 97 wells have flowing artesian conditions. These wells are located to the east, south, south east and north east of the Site and are typically located near the river. The depth of the flowing artesian wells ranges from 18.6 to 53.6 mbgs.

The frequency distribution in water well depths for the 2,000 m search radius is provided as a chart on Text Figure 4-A-5 (excludes wells of unknown type). The chart indicates that all but eight wells are between 10 and 60 m in depth, and the majority of wells (70 of 97 wells) are between 30 and 60 m in depth.

Text Figure 4-A-5: Distribution of Private Water Well Depths within a 2 km Radius of the Site



4A.3.4.3 Site Hydrogeology

Several technical reports were identified in MECP files providing hydrological and hydrogeological information for the Aquaterra Hillsburgh Site. Salient information derived from these reports and relating to water quantity assessment is summarized as follows.

<u>Hydrogeological Study Spring Valley Production Well Hillsburgh, Ontario. Trow, Dames & Moore, April 19, 1991 (TDM, 1991).</u>

The TDM, 1991 report was identified as the main technical report providing hydrogeological characterization of the Site. The information provided in the report that describes local geological/ hydrogeological conditions was summarized previously in Section A.3.4.2.

The TDM, 1991 hydrogeological evaluation was conducted for the Spring Valley Water Company (SVW) Site and includes aquifer testing of the production well. The purpose of the report was to determine the maximum safe sustainable yield for the well, determine the radius of influence of the well and establish a monitoring program. The production well is identified as a 6 inch nominal diameter artesian well with an excess pressure head of approximately 10 m above ground. Natural flow is used to fill tanker trucks.

A pumping test was conducted on September 8, 1990 to determine the specific capacity of the well and the appropriate long-term pumping rate. A 1,220 L/min constant rate pumping test was conducted for a 24-hr period and water levels were recorded at the production well and at a neighbouring artesian bedrock domestic water well (located approximately 200 m from the production well). The drawdown in the production well was observed to be approximately 15 m. The results of the pumping test data analysis indicated that the arithmetic mean of the estimated transmissivity of the bedrock aquifer is 101 m^2/day and the storativity is 6 x 10^{-6}. The low storativity value was considered typical of a bedrock aquifer. The report concluded that the bedrock acted as a leaky confined aquifer based on the hydraulic responses observed and the presence of low permeability Port Stanley Till above the bedrock that act as a confining layer. The safe drawdown for the production well was determined to be 18 m (75% of the total available drawdown) and the estimated flow of the well was estimated to range from 568 to 757 L/min. The report suggests that a reasonable, long-term pumping rate for the well is approximately 1,600 L/min.

The neighbouring bedrock well (approximately 200 m away, no MECP Well Record) had an observed maximum drawdown of 7.25 m as a result of the pumping of the production well. The report projected that if this pumping rate continued for a year, the neighbouring well drawdown would stabilize at 10 m. The report authors indicate that its real radius of influence cannot be calculated as a result of the aquifer leakage recharge, they suggest that the radius of influence could reach 5 km at the estimated sustainable rate of 1,600 L/min. Based on the PTTW history provided in Table 4-A-1, a maximum rate of 900 L/minute and 225,000 L/day was approved for the well.

2001 Renewal Application for Permit to Take Water #98-P-2029, Hillsburgh, Ontario. Gartner Lee Limited, September 18, 2001 (GLL, 2001).

In 2001, Gartner Lee Limited completed an assessment of the Hillsburgh well and physical environment of the surrounding area to satisfy conditions 2 and 3 of the existing PTTW (see Table 4-A-1). Static head conditions were attained following a 48 hour shut down of the Hillsburgh well, followed by a natural flow 12 hour pumping test.

A datalogger was installed in a neighbouring artesian residential well (approximately 200 m to the west, no MECP well record), the same well used in the 1991 study to monitor the drawdown during the pumping test. A second neighbouring residential well located to the north (approximately 440 m to the west, MECP well # 6712435) was also used as an observation well during the pumping test.

The static head above ground was reported to be 8.1 m with a measured flow of 643 L/min; both measurements were consistent with the 1991 hydrogeological report. Following the natural flow pumping test, the Hillsburgh well recovered to approximately 90% in less than 12 hours. During the filling of a tanker, a drawdown of up to 5 m was observed in the Hillsburgh well, while the closest neighbouring residential well (200 m to the west) was found to have a drawdown of less than 1 m. During the 12-hour pumping test on the Hillsburgh well, the neighbouring well located 440 m to the west (not reported as an artesian well) had a drawdown of 3 m, while the neighbouring well 200 m away had a drawdown of 3.25 m.

Based on the PTTW history provided in Table 4-A-1, the maximum taking rate for the well of 900 L/minute and 225,000 L/day remained unchanged following this testing program for the well.

Canadian Springs Hillsburgh PTTW Annual Reports AECOM – 2009, 2011, 2016

AECOM Canada Ltd. was retained by Aquaterra to prepare the annual PTTW monitoring reports for the Hillsburgh site. Due to the large volume of documentation on this file selected reports,the reports for the 2009, 2011 and 2016 reporting years were reviewed by BMEI, which briefly discuss historical trends. The reports provide a hydrograph of water levels for the Hillsburgh Well for the reporting year. However, no hydrographs indicating water levels over the long term (i.e. year over year) were provided. Evaluation of the sustainability of the water taking is provided in the reports using a table summary of historical static head levels and drawdown and the summary table from the AECOM, 2017 report is reproduced below in Table 4-A-3.

Table 4-A-3: Aquaterra Hillsburgh Well Static Hydraulic Heads and Drawdown

Year	Static Head (m above ground)	Drawdown (m above ground)
2001	8.1	4
2006	8 – 8.3	4
2007	8 – 8.5	4 – 5
2008	8 – 8.7	4.5 – 5
2009	7.4 – 7.6	4.0 – 4.6
2010	7.8 – 8.4	5 – 5.6
2011	7.1 – 7.5	4.5 – 5 (September Only)
2012	6.5*	N/A
2013	7.5 – 8	0
2014	7.6 – 8.4	0
2015	7.2 – 8.1	0
2016	7.3 – 8.3	0

Note: *transducer was moved higher when replaced in 2012

Source: Table 1 of Canadian Springs Hillsburgh 2016 PTTW Annual Report. AECOM, March 2010 (AECOM, 2017).

The only monitoring required by the PTTW is the static head of the production well. In comparison to the 2001 reported static head of 8.1 m above ground, the artesian conditions are reported to have been maintained from 2001 to 2005. For the annual monitoring period from 2006 to 2016, the static head ranged from 6.5 m to 8.3 m above ground and artesian conditions were maintained. The lower static head measurements were attributed to a leak in the well casing in 2009 and transducer malfunction in 2011. During water takings, a maximum drawdown to 4 m above ground was observed during the 2006 to 2012 monitoring period. The pressure head transducer was replaced in September 2012 and no recorded drawdown was reported following this event. AECOM suggests that this may be related to the reduction in the quantity of daily water taking volume which began in 2011.

Reportedly, seasonal variability of the artesian conditions exists and reflects seasonal climatic conditions, with data indicating that there is a higher pressure head during the spring months (April to May) and a slight decrease to December.

The reports indicate that data collected verifies that artesian conditions continue to exist at the production well and there are no lasting effects on neighbouring well. No recommendations are provided for modifications to the monitoring program. However, AECOM recommends maintaining 15 minute intervals for the recording of water levels in order to accurately capture the drawdown and rebound rates as a result of tanker fill ups. No well interference complaints are reported during the reporting periods and the reports state that the water takings from the Hillsburgh well are not expected to result in an adverse effect on the groundwater environment.

The pumping test and annual reports do not include surface water monitoring data for the nearby Credit River. Since the production well is completed in a confined aquifer and there is no evidence of hydraulic connections between surface water and groundwater at the site, monitoring of surface water would not be required.

4A.3.5 Hydrologic Setting

The Aquaterra (Hillsburgh) Site is located in the West Credit River subwatershed of the Credit River watershed. The subwatershed supports the provincially significant West Credit River Wetland Complex that extends through the villages of Hillsburgh and Erin, and which also overlaps with the southern corner and northern portion of the Aquaterra (Hillsburgh) Site. MNRF's Natural Heritage Areas mapping shows that the Aquaterra production well does not overlap with the wetland complex. The wetland is largely dominated by eastern white cedar and poplar swamps and is an important contributor to the self-sustaining heritage brook trout population native to the area (CVC, 2015).

The West Credit River overlaps with the southern property boundary of the Hillsburgh site, coming within 130 m of the Hillsburgh production well, and flows in a general west to east direction past the site. Several ponds are also present within 500 m of the production well and the Site itself contains a small pond within its boundaries. Many of the ponds in the area appear to be isolated and do not receive flow from or discharge to streams (GLL, 2001).

The effects of water taking at the production well on nearby surface water bodies, such as the nearby West Credit River, was not conducted as part of the historical pumping tests and annual reports. Monitoring of surface water is not required given the confined nature of the aquifer.

4A.4 DATA REVIEW AND STATE OF GROUNDWATER RESOURCES

The following section provides a review of Ontario's Water Quantity Management Framework (WQMF) data relevant to the Aquaterra Hillsburgh Site and available to MECP for consideration when making water management decisions.

4A.4.1 Water Taking Reporting System

The Water Taking Reporting System (WTRS) is the ministry's repository for water taking data for active Permits to Take Water (PTTW). As a requirement of each PTTW the water taking data must be reported on an annual basis and daily water taking data must be entered into the system. The WTRS is not publicly available, but is available for use by ministry staff when assessing the status of a PTTW or addressing potential issues associated with a PTTW. The WTRS data was provided by the ministry for use in the WBSA assessment to be inclusive of all information available to MECP for making water management decisions. Data on the volume of water taken per year and the number of water taking days per year for the Aquaterra Hillsburgh Site was obtained from the MECP WTRS for review. Table 4-A-4 below includes annual water taking data for the period from 2007 to 2017.

Table 4-A-4: Reported Water Takings – Aquaterra Hillsburgh Well

Permit Number	Year	Source Name	Annual amount permitted by the PTTW (Million L)	Permitted No. of Taking Days per Year	Reported No. of Days Taken per Year	Reported annual taking (Million L)	Reported annual taking (% of permitted amount)	Average volume taken per day (L/day)
7670-6RLKS8	2007	Hillsburgh Well	58.50	260	165	23.38	40%	141,725
8664-75QJ2J	2008	Hillsburgh Well	58.50	260	256	28.88	49%	122,799
8664-75QJ2J	2009	Hillsburgh Well	58.50	260	199	20.62	35%	103,621
8664-75QJ2J	2010	Hillsburgh Well	58.50	260	254	26.11	45%	225,000
8664-75QJ2J	2011	Hillsburgh Well	58.50	260	249	18.47	32%	74,160
8664-75QJ2J	2012	Hillsburgh Well	58.50	260	252	16.91	29%	67,108
8664-75QJ2J	2013	Hillsburgh Well	58.50	260	243	13.93	24%	57,321
8664-75QJ2J	2014	Hillsburgh Well	58.50	260	218	10.91	19%	50,048
8664-75QJ2J	2015	Hillsburgh Well	58.50	260	245	11.57	20%	47,204
8664-75QJ2J	2016	Hillsburgh Well	58.50	260	233	10.95	19%	46,982
8664-75QJ2J	2017	Hillsburgh Well	58.50	260	222	10.91	19%	49,146

As indicated in Table 4-A-4, the reported annual water takings during the 2007 to 2017 period varied from 19% to 49% of the PTTW limit, with a general decreasing trend in water taking quantities. In the last three years of reported data, the average volume taken per day has been less than the threshold value of 50,000 L/day that defines the requirement for a PTTW. The threshold value is exceeded when more than one tanker is filled in a day. The most recent available annual monitoring data (2016) indicates that more than one tanker was filled in a day approximately 30% of the time. Water taking volumes appeared to exceed 50,000 L/day most frequently in the summer months (June to September) for the 2016 reporting year.

The study area for review of other active PTTW was set at a 10 km radius for municipal water takings (Note: none identified between 5 and 10 km from the Site) and a 5 km radius of the Aquaterra Hillsburgh well (Figure 4-A-2) for other active water takings. The selected search radiuses were considered appropriate for review based on the density of active PTTW in the area, as a conservative distance for any potential contribution from the Site on the cumulative effects from multiple water takings and to be protective of any potential impacts to existing and proposed future municipal groundwater uses. A summary of the 2016 and 2017 WTRS data for these permits is provided in Table 4-A-5.

Table 4-A-5: Reported Water Takings – Neighbouring PTTWs

Permit Holder (Permit no.)	Issue Date	End Date	Source	Dist. from Hillsburgh Well (Km)	PTTW Limits			2016 WTRS Data		2017 WTRS Data	
					Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
8112-9CPNNW (The Corporation of the Town of Erin)	Oct. 31, 2013	Oct. 31, 2023	Erin Well E8	1.5	1.97	365	718	158	22%	150	21%
			Erin Well E7	1.7	2.16	365	788	123	16%	131	17%
			Bel-Erin Well BE1	4.2	0.66	365	239	0	0%	0	0%
			Bel-Erin Well BE2	4.2	0.66	365	239	0	0%	0	0%
7370-A8YL4P (Derrydale Golf Course Limited)	April 27, 2016	Feb. 28, 2026	Irrigation Pond	1.8	0.91	198	180	40	22%	21.9	12%
			Clubhouse Well	1.9	0.05	365	20	0	0%	0.75	4%
5227-ABYPXB (Budcan Holdings Inc., Remediation)	July 25, 2016	Aug. 31, 2026	GDCW1	2.9	0.32	365	117	14.9	13%	33	28%
			GDCW2	2.9	0.98	365	358	4.56	1%	0.04	0.01%
3716-8UZMCU (Nestle Canada Inc.)	Sept. 28, 2012	Aug. 31, 2017	TW1-88	3.7	1.11	365	406	82	20%	66	16%
7740-A9ZNTP (The Corporation of the Town of Erin)	May 18, 2016	May 31, 2026	Municipal Well H3	3.7	0.66	365	239	21	9%	38	16%

Permit Holder (Permit no.)	Issue Date	End Date	Source	Dist. from Hillsburgh Well (Km)	PTTW Limits			2016 WTRS Data		2017 WTRS Data	
					Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
8548-6SBGWC (The Corporation of the Town of Erin)	Aug. 29, 2006	Oct. 31, 2016	Hillsburgh Well #H3	3.9	0.66	365	239	11	5%	-	-
6131-AL5QJ9 (Silvercreek Aquaculture Inc.)	April 11, 2017	July 31, 2027	Spring #3	4.2	30.4	365	11,090	-	-	1201	11%
			Spring Pond	4.2	1.63	365	596	-	-	433	73%
			Spring #2	4.2	1.30	365	473	-	-	0	0%
			Spring #1	4.3	2.52	365	919	-	-	455	49%
6306-8X5KRY (The Corporation of the Town of Erin)	Aug. 13, 2012	July 31, 2022	Municipal Well H2	4.4	0.98	365	358	28	8%	27	8%

The closest active PTTW (no. 8112-9CPNNW) which consists of two wells located at a distance of 1.5 and 1.7 km from the Hillsburgh well, respectively, is associated with the Town of Erin's municipal groundwater supply system. The reported takings for this permit have been less than 25% of the maximum permitted annual amount for 2016 and 2017; however, annual takings for 2016 and 2017 are more than double the annual permitted amount for the Aquaterra Hillsburgh Site (58.5 million L/year). The next closest active PTTW (no. 7370-A8YL4P), located approximately 1.8 km from the Hillsburgh well, is held by Derrydale Golf Course Limited and is associated with irrigation activities for the golf course and water supply for the clubhouse. Reported takings for this permit are also well below permitted amounts (less than 13 %). The remaining active PTTWs are associated with municipal water supply, remediation and aquaculture activities. In addition, there is a PTTW for the Nestle Canada Inc. water bottling site located 3.7 km to the west of the Hillsburgh well.

4A.4.2 Provincial Groundwater Monitoring Network

The Provincial Groundwater Monitoring Network (PGMN) is a partnership program with all 36 CAs and 10 municipalities (in areas not covered by a conservation authority) to collect and manage ambient (baseline) groundwater level and quality information from key aquifers located across Ontario. During the spring and summer of 1999, low water conditions in many parts of southern Ontario prompted the formation of an inter-ministerial task force to assess drought conditions, determine trigger levels and develop a response strategy. The PGMN was approved in 2000 and there are currently more than 450 monitoring wells in the network.

The PGMN datasets report on ambient (baseline) groundwater level and chemistry conditions. The PGMN well locations are typically sited to be away from areas where there is a large density of permitted water takings. Consequently, the PGMN wells are typically far too distant from any permitted water taking to be used as an indicator of potential well interference impacts.

Water level data collected for the PGMN wells is of potential value in assessing regional groundwater level trends as an indicator of stress within the watershed/subwatershed. Data has been collected for the PGMN well network since 2001 though some wells were installed more recent than this. Also the data for some wells is not current to 2018. The Provincial Groundwater Monitoring Network database is made available by MECP on-line.

As a recent internal project the MECP has applied the Mann-Kendall (MK) and Seasonal Kendall (SK) tests to analyze the PGMN water level data for monotonic trends (i.e. consistently increases or decreases through time). The statistical analyses were performed using robust and defensible methodologies to look for longer-term trends in groundwater levels. An overall objective is to determine if there is enough data to support the presence of a widespread decrease in groundwater availability. Shorter trends within the PGMN data record (e.g. lasting for a few years) were not considered and the causes of any trends that were identified were not investigated. Both the data plots and preliminary findings for PGMN well locations nearest a WBSA were shared by the ministry and are presented and relied on herein. The data plots indicate data available for the well at the time of the assessment. Further, the MECP has indicated that the methodologies used require that certain values be dropped from the data set if the month/year in question does not have sufficient number of data points. The release of a final report that details the methodology and results from the PGMN data trends analysis is forthcoming from the ministry (MECP, 2018).

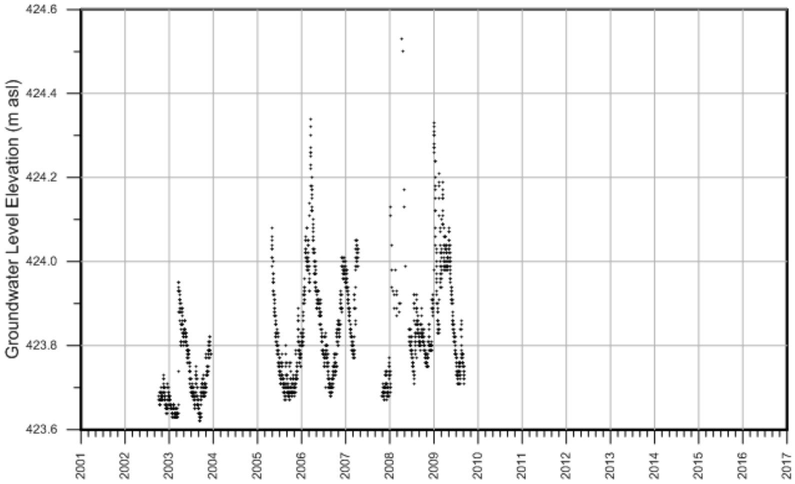
Eight PGMN wells are located within the study area for the Aquaterra Hillsburgh Site, as shown on Figure 4-A-2. The PGMN well information is summarized in Table 4-A-6 below.

Table 4-A-6: PGMN Wells Summary

PGMN Well ID	Water Well Record ID	Distance from Aquaterra Source Well (km)	Well Depth (m)	Ground Elevation (m asl)	Lithology of Aquifer
W0000164-2	6714839	2.7	7.9	427.76	Overburden (sand gravel, silty sand)
W0000164-3	6714839	2.7	12.8	427.76	Overburden (silty sand and gravel, sand)
W0000026-1	6713771	3.6	35.96	392.96	Bedrock (limestone)
W0000163-2	4909396	8.0	8.14	426.84	Overburden (silty sand, sandy silt)
W0000163-3	4909396	8.0	23.16	426.84	Overburden (gravel)
W0000019-1	1705664	13.5	19.2	448.85	Overburden (sand, gravel, clay)
W0000028-2	2808070	18.6	6.71	279.44	Overburden (gravel, sand)
W0000028-4	2808070	18.6	14.9	279.44	Overburden (gravel, sand)

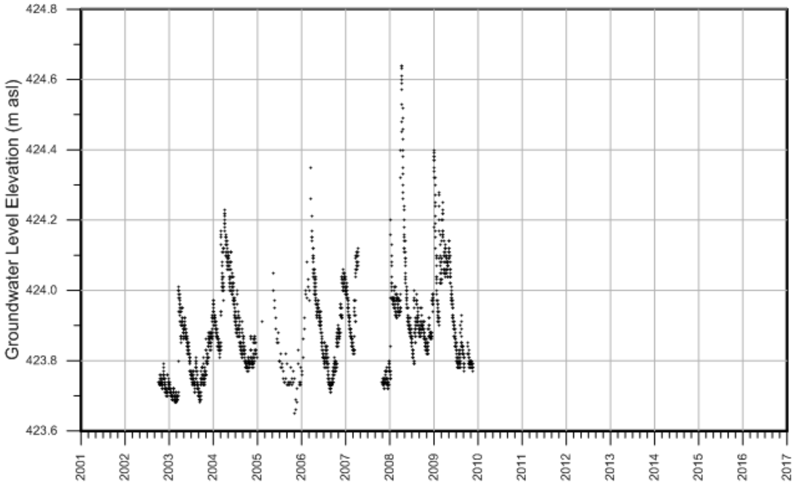
The majority of the PGMN wells are located with the overburden aquifer, while the supply wells in the vicinity of the Hillsburgh well are located within the bedrock aquifer. As a result, the trends inferred from the overburden PGMN well data are not expected to be relevant to the bedrock supply wells. The data plots and trend analyses for the 8 PGMN well installations within the study area of the Aquaterra Hillsburgh Site are provided on Text Figures 4-A-6a to 4-A-6h.

Text Figure 4-A-6a: Groundwater Elevations (2002 to 2010) for PGMN Well W0000164-2



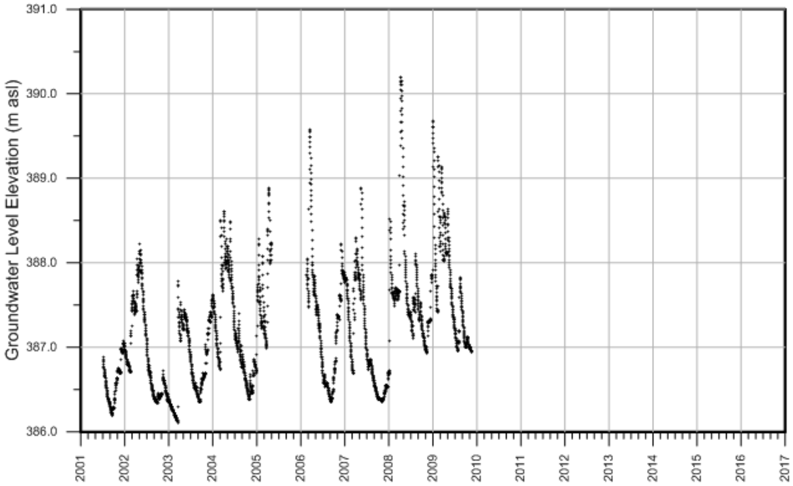
For PGMN well No. W0000164-2, the MK test did not detect a significant trend, using 3 years of data. The SK test detected an upward trend, based on 52 months of data.

Text Figure 4-A-6b: Groundwater Elevations (2002 to 2010) for PGMN Well W0000164-3



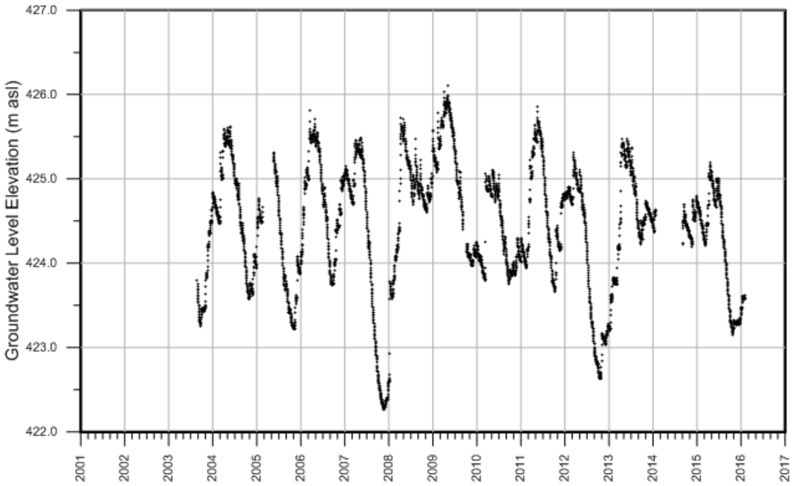
For PGMN well No. W0000164-3, the MK test did not detect a significant trend, using 5 years of data. The SK test detected an upward trend, based on 60 months of data.

Text Figure 4-A-6c: Groundwater Elevations (2001 to 2010) for PGMN Well W0000026-1



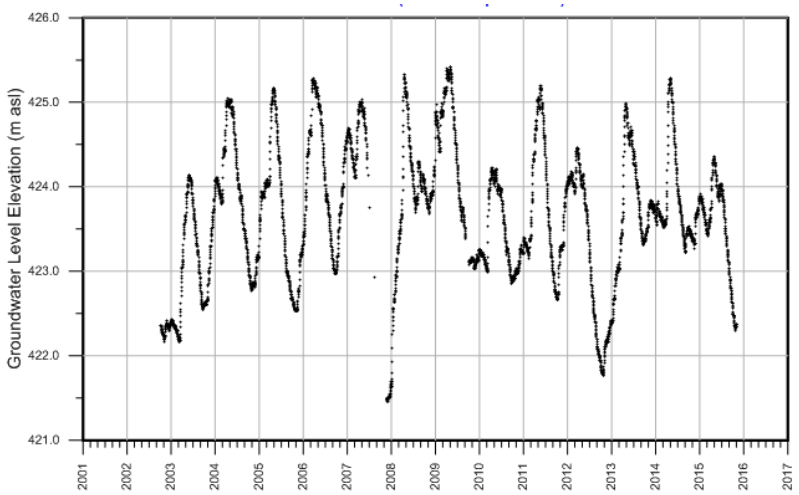
For PGMN well No. W0000026-1, the MK test did not detect a significant trend, using 6 years of data. The SK test detected an upward trend, based on 90 months of data.

Text Figure 4-A-6d: Groundwater Elevations (2003 to 2015) for PGMN Well W0000163-2



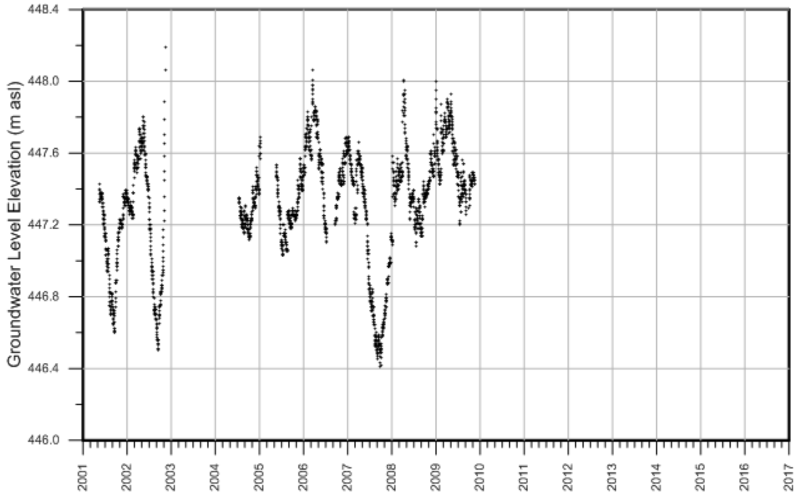
For PGMN well No. W0000163-2, the MK test did not detect a significant trend, using 10 years of data. The SK test also did not detect a significant trend, based on 136 months of data.

Text Figure 4-A-6e: Groundwater Elevations (2002 to 2015) for PGMN Well W0000163-3



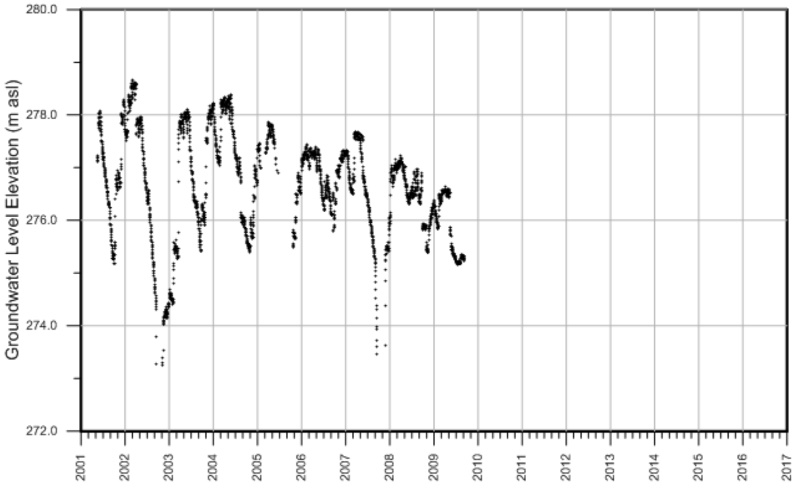
For PGMN well No. W0000163-3, the MK test did not detect a significant trend, using 11 years of data. The SK test also did not detect a significant trend, based on 149 months of data.

Text Figure 4-A-6f: Groundwater Elevations (2001 to 2010) for PGMN Well W0000019-1



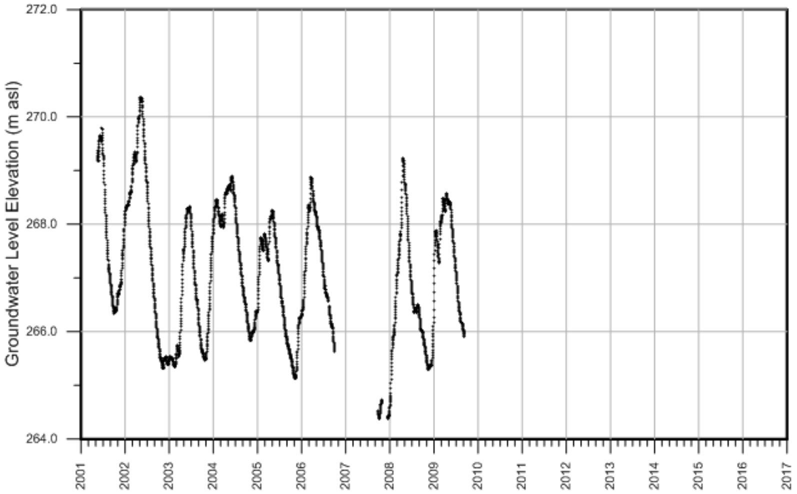
For PGMN well No. W0000019-1, the MK test did not detect a significant trend, using 3 years of data. The SK test detected an upward trend, based on 71 months of data.

Text Figure 4-A-6g: Groundwater Elevations (2001 to 2010) for PGMN Well W0000028-2



For PGMN well No. W0000028-2, the MK test did not detect a significant trend, using 5 years of data. The SK test detected a downward trend, based on 86 months of data.

Text Figure 4-A-6h: Groundwater Elevations (2001 to 2010) for PGMN Well W0000028-4



For PGMN well No. W0000028-4, the MK test did not detect a significant trend, using 6 years of data. The SK test detected a downward trend, based on 85 months of data.

Based on the PGMN data trend analyses provided by MECP, no data trends were identified that could be an indicator of groundwater stress. The trend data for the bedrock PGMN well (No. W0000026-1) showed no significant monotonic trend indicating no longer-term consistent trend in groundwater levels at this location. However, there was a seasonal upward trend in the groundwater elevation.

4A.4.3 Ontario Low Water Response (OLWR) Program

The OLWR program was initiated in 2000 and is managed by the Ministry of Natural Resources and Forestry (MNRF). The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the Water Survey of Canada (WSC) stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

> Note: Specific Permits to Take Water may have conditions requiring mandatory reductions of water takings during low water events. Upon renewal of their water bottling permit, the above decreases will be mandatory based on 3-month average actual flow as outlined in the guidance for bottled water renewals (MOECC, 2017).

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the Site. Further discussion on the OLWR Program is provided in the Guelph Water Quantity Study Area main report.

A review of the OLWR database indicates that a total of 11 Level 1 notifications and two Level 2 notifications were sent to the Credit Valley CA between 2000 and August 2018. Instances when more than one notification was issued in the same calendar year occurred in 2001 (two Level 1 notifications), 2012 (one level 1 and one Level 2 notifications), and 2018 (two Level 1 notifications). The Credit Valley CA posted Low Water Condition Alerts during two periods: a Level 1 Low Water Alert was posted from mid-May to mid-October 2012, and again from July 2016 to early February 2017 (this was raised to a Level 2 Low Water Alert between early August and mid-September 2016).

While the OLWR notifications do not indicate any specific long term trends, it is apparent that Level 1 and 2 Low Water Condition Alerts and Level 2 Notifications have been necessary within the boundaries of the CA on an occasional seasonal basis.

The OLWR is based on surface water indicators and is not a good tool for the assessment of drought conditions for confined bedrock aquifers, which is the case of the Hillsburgh site.

4A.4.4 Water Budget Analyses

Extensive water budget work had already been completed in the Credit Valley Source Protection Area (CVSPA) prior to the development of the Source Water Protection program in Ontario. As a result, the CVC was permitted to forego the requirement of undertaking conceptual and Tier 1 Water Budgets for the Assessment Report of the CVSPA (CVC, 2015). As moderate drinking water quantity stress had been identified in the early water budget work, CVSPA undertook a Tier 2 Water Budget.

In the "West Credit River" subwatershed, in which the Aquaterra Hillsburgh Site is located, it was determined through the Tier 2 water budget that the surface water and groundwater potential stress classifications were both low (CVC, 2015). Tier 3 Assessments are only conducted for subwatersheds which have been identified as having moderate or significant potential stress in the Tier 2 stress assessment, and have a municipal water supply system. Therefore, a Tier 3 assessment was not recommended for the municipal water supplies of Hillsburgh and Erin in "West Credit River" subwatershed. It should be noted that the Aquaterra Hillsburgh Site does not lie within the study area boundary/modelled area for the Guelph/Guelph Eramosa Tier 3 assessment.

In summary, based on the findings of the Tier 2 water budget, the Aquaterra Hillsburgh Site is not located in an area where hydrologic stress has been identified.

4A.5 IMPACT ASSESSMENT

The following section provides a general assessment of potential water quantity interference with other groundwater uses and the environment.

4A.5.1 Municipal Groundwater Use

The Town of Erin is serviced by two municipal groundwater systems located within 3.2 km of the Aquaterra Hillsburgh Site: the Erin Municipal Water system located in the village of Erin and the Hillsburgh Municipal Water System located in the village of Hillsburgh. The Erin municipal system services a population of approximately 2,500 residential and commercial customers. Connections include approximately 870 residences, 110 non-residential properties, 100 mobile homes and 10 cottages. The Hillsburgh system services a population of approximately 810, with 275 residential and 4 nonresidential properties connected (Town of Erin, 2018). Properties in the remainder of the town are serviced by private wells. Based on the 2016 Census Profile (StatCan, 2016) for Hillsburgh reporting a population of 1,124, a population of approximately 214 on private wells is indicated.

The water quality wellhead protection areas (as shown on Figure 4-A-2) associated with the Hillsburgh Village wells extend to the northwest, away from the Hillsburgh well, indicating that groundwater flow in the vicinity of the village is in a general northwest to southeast direction. The Aquaterra Hillsburgh well is located downgradient relative to the Hillsburgh Village municipal supply; thus, the Hillsburgh well has no impact on the available water for the

Hillsburgh Village municipal supply. The wellhead protection areas for the Erin Village wells, located over 1.5 km to the east of the site, extend northwest-southeast and southwest-northeast. The Hillsburgh well is therefore located outside of these wellhead protections areas, suggesting that the Hillsburgh well is not located hydraulically upgradient of the Erin Village wells, and therefore is unlikely to have an impact on the available water for the Erin Village municipal supply.

Per the Town of Erin's Official Plan (2012), anticipated population growth from 2016 to 2031 is 42% for the Village of Erin and 50% for the village of Hillsburgh. As presented earlier, the reported takings for the associated water taking permits have been less than 25% of the maximum permitted annual amounts for 2016 and 2017. Based on the information reviewed, no 'planned' new municipal groundwater supply systems are anticipated for the vicinity of the Site as the existing systems and currently approved maximum water taking volumes are anticipated to be able to support the projected population growth.

In summary, the general assessment of potential water quantity interference with existing or planned municipal water supply systems did not identify any potential for unacceptable impact/interference at the current rates of taking. Further work, such as modelling, would be required to determine the potential impacts on the municipal water supplies from the pumping of the Hillsburgh well at the maximum permitted rate.

4A.5.2 Well Interference Potential

Based on the studies that have been completed, the Hillsburgh Well extracts groundwater from the Guelph-Amabel dolostone bedrock formations. The Gartner Lee Limited, September 2001 report included an inventory of neighbouring well water supplies within 500 m of the Hillsburgh Well as required by a condition of the PTTW. Six domestic wells located within 500 m of the Hillsburgh Well were identified at this time, with the closest well located 200 m to the northwest. Based on well records, all neighbouring wells are located within the bedrock aquifer.

As discussed previously, an aquifer test was conducted in 1990 where the Hillsburgh Well was pumped continuously for 24 hours at a rate of 1,220 L/minute. The maximum drawdown of the Hillsburgh well was reported to be 15 m. The maximum drawdown measured at the neighbouring bedrock well, located approximately 200 m from the Hillsburgh Well, during the pumping test was 7.25 m. Following the pumping test, an 80% recovery of the production well and the neighbouring well was achieved within three hours.

A second pumping test at the Hillsburgh well was completed in 2001 where drawdown was observed at two neighbouring wells located 200 m and 440 m (not artesian) from the Hillsburgh Well. The static head above ground at the Hillsburgh well was reported to be 8.1 m with a measured flow of 643 L/min. After the 12-hour natural flow pumping test, the observed drawdown at the wells located 200 m and 440 m away from the Hillsburgh well were 3.25 m and 3 m, respectively. During water takings from the production well, a temporary drawdown of 0.5 m and less than 1 m were observed at the wells 200 m and 440 m away, respectively.

Continuous groundwater level monitoring for the years 2001 to 2016 resulted in a static head at the Hillsburgh well that ranged from 6.5 m to 8.3 m above ground. The lower static head measurements were attributed to a leak in the well casing in 2009 and transducer malfunction in 2011. For the monitoring period of 2006 to 2012, a maximum drawdown of 4 m above ground was observed in the Hillsburgh well. Although there has been no reported monitoring of neighbouring wells since the 2001 assessment, the maximum reported drawdown at the Hillsburgh well is less than the drawdown recorded during the 1990 and 2001 pumping tests. This indicates that the drawdown at the neighbouring wells are also less than the drawdowns recorded during the pumping tests. Furthermore, no documented well interference complaints/impacts were identified in the ministry files/reports provided for review.

The current PTTW No. 8664-75QJ2J water taking limit is 900 L/min (74% of the test rate in 1990) with a maximum number of hours of taking limited to 18 hours/day. In addition, the production taking rate (643 L/min) is less than the permitted amount and the permit conditions allow for recovery following water takings. Based on the information reviewed, a potential for unacceptable well interference impacts to neighbouring groundwater supplies has not been identified at the current permitted water taking rates and volumes.

No new high water use activities are apparent near the Aquaterra Hillsburgh Site. Any new neighbouring land development on private wells and/or any new PTTW of significant scale are expected to require a site specific hydrogeological study and well interference assessment in support of the proposed development/water taking. Continued use of the Aquaterra Hillsburgh Site well in accordance with the current PTTW conditions is not anticipated to cause detrimental impacts to private water wells.

4A.5.3 Impact to Surface Water and Natural Functions of the Ecosystem

Groundwater discharge contributes the majority of flow to the Credit River. The West Credit River subwatershed, in which the Aquaterra Hillsburgh Site is located, consists of the West Credit Wetland Complex that extends through the villages of Hillsburgh and Erin. The surface water and groundwater potential stress classifications within the West Credit River subwatershed were both low, as determined through the Tier 2 water budget (CVC, 2015).

Pumping tests completed at the Hillsburgh Well did not include monitoring of the neighbouring West Credit River or the West Credit River Wetland Complex; however, the presence of the confined aquifer suggests that the Hillsburgh Well is hydraulically isolated from nearby surface water features. Current water takings at the production well are not anticipated to impact surface water in the vicinity of the Site.

4A.6 SUSTAINABILITY OF WATER RESOURCES

Water resources are considered sustainable if the total amount of water entering, leaving, and being stored in the system meet existing needs without compromising the ability to meet the needs in the future. Typical indicators used to assess the sustainability of water quantity include Water Budgets completed at the watershed/subwatershed scale and/or for the specific water taking(s) and the evaluation of water level data for trends over time to ensure resources are remaining in a steady state. The following provides a general assessment of the sustainability of regional water resources and of the potential impact from the Aquaterra Hillsburgh water taking on sustainability, now and in the future.

Regional Water Resources

The characterization of the regional study area indicates that the Aquaterra Hillsburgh Site is located in the "West Credit River" subwatershed, where it was determined through the Tier Two Water Budget that the surface water and groundwater potential stress classifications were both low (CVC, 2015).

The OLWR Program uses real time surface water monitoring data collected from the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. BluMetric's review of the OLWR Program notification data (2000 to August 2018) for the Credit Valley CA did not identify any specific trends in the notification data indicating the depletion in the availability of surface water (and possibly shallow groundwater were directly connected to surface water) resources. While Level 1 and Level 2 Low Water Condition Alerts have been necessary within the boundaries of the CVCA, the information indicates these have been in response to extended dry seasonal conditions.

BluMetric's review of PGMN groundwater level data for 8 wells located within 10 km of the Hillsburgh Site water taking also did not identify any specific trends indicating a potential depletion in the availability of regional groundwater resources.

Because the Tier Two Water Budget determined that the surface water and groundwater potential stress classifications were both low in the watershed where the Aquaterra Hillsburgh Site is located (CVC, 2015), a Tier Three Water Budget and Stress Assessment has not been completed. However, immediately to the west of the site, the City of Guelph – Guelph Eramosa Township (GGET) completed a Tier Three Water Budget and Stress Assessment and a WHPA-Q (Groundwater Vulnerable Area) and IPZ-Q (Surface Water Vulnerable Area) have been delineated (Matrix, 2017). The Aquaterra Hillsburgh Site is located just east of the GGET Tier Three IPZ-Q. While not necessarily directly applicable to questions of sustainability with respect to regional water resources at the site, the regional context for the Guelph WQSA is summarized here for completeness and consideration.

The Tier Three Assessment Water Budget models were used to delineate the WHPA-Q and IPZ-Q. The WHPA-Q and IPZ-Q are the areas where the municipal drinking water systems could be affected by other existing, new, or expanded water takings (Matrix, 2017). Since delineation of the original WHPA-Q and IPZ-Q for the City of Guelph's water supply was initiated in 2008, it was recently determined that they should be re-delineated. This was completed to ensure that the Tier Three model reflected revised plans for future land development in 2017 as well as current, non-municipal permitted water use. These consumptive takings were later used as the starting point in the Risk Management Measures Evaluation Process (RMMEP) described in the Guelph – Guelph/ Eramosa Water Quantity Policy Development Study Threats Management Strategy (Matrix, June 2018). The threats identified as significant were assessed at progressively finer levels of detail in order to rank which threats have the greatest impact on municipal drinking water systems within the WHPA-Q or IPZ-Q. Based on the threat ranking process within the WHPA-Q, it was determined that among the group of 32 non-municipal, permitted takings assessed, Nestlé Waters Canada in Aberfoyle (discussed in Appendix 4-C) had a maximum percent impact of 1% on the Burke municipal well. In summary, the Tier Three Assessment scenarios predicted that the GGET municipal wells can meet current water demands, though the Tier Three model scenarios also predicted that the City's Queensdale municipal well may not be able to meet future needs under normal climate conditions and during prolonged drought (Matrix, 2017). The City's other wells and Guelph/Eramosa Township's (GET) wells were expected to meet future needs under all scenarios. However, the Tier Three Assessment indicated that there is a high level of uncertainty for the results of the City's Arkell Well 1. Of note, because water pumped from the Eramosa River intake is not pumped directly into the City of Guelph's drinking water system, and that the Glen Collector was included in the Risk Assessment for groundwater, a Risk Assessment for the surface water supply was not completed. However, to ensure the sustainability of the Glen Collector and the Eramosa intake, the IPZ-Q was assigned the same Risk Level (Significant) as the WHPA-Q, containing the Glen Collector. Furthermore, the Tier Three Assessment predicted that groundwater discharge into some coldwater streams may be reduced by 10% or more as municipal pumping is increased to future rates. This magnitude of impact resulted in a Moderate Risk Level being applied to the WHPA-Q; however, the Moderate Risk Level associated with the surface water impacts was superseded by the Significant Risk Level designation (Matrix, June 2018).

In addition, as a follow up to the GGET Tier Three Study, a Climate Change Assessment was conducted for the GGET WHPA-Q area by modelling predicted Climate Change scenarios to determine potential impacts on the sustainability of the groundwater and surface water resources (Matrix, 2018). Due to expected warmer temperatures and increased precipitation in the winter, the modelling exercise suggests a slight increase in recharge; thus, no impact to the sustainability of the groundwater resource is anticipated. Similarly, no stress concerns were identified for the sustainability of regional surface water quantity resources, which appear to be sustainable under current pumping conditions (Matrix, 2018). However, the risk ranking exercise for IPZ-Q threats has not been completed at this time. The net consumptive water use within the IPZ-Q is small as compared to the natural variability of flow of the Eramosa River at the intake; therefore, on an average basis, consumptive water taking threats are not expected to impact the municipal surface water intake's ability to pump. Further evaluation of the threats in the IPZ-Q will be completed as part of the Climate Change Assessment being carried out. In addition, assessments of environmental flow needs in the Guelph WQSA have focused on the Speed River and the Eramosa River. Target thresholds were quantified for the two rivers, and it was determined that flow requirements are generally achieved in most years. Matrix Solutions Inc. (2018) recommended that the City of Guelph maintain its current groundwater and surface water monitoring program to ensure that the hydrologic regime in the Eramosa River is maintained.

A moderate potential for groundwater stress exists for the sustainability of regional groundwater resources in the future under projected municipal groundwater demand. As discussed in Section 4.3.3 of the main report, available reports and communication with local Water Managers determined that, within the Guelph WQSA, the use of water resources is sustainable under existing population, land use and climate conditions. However, findings from the Local Area Risk Assessments indicate that population growth is the most significant stressor on the groundwater resources in general. In contrast, simulated recharge reduction due to land use changes had a near negligible effect on water levels in the Guelph municipal supply wells, indicating a minimal effect on the groundwater resources in general.

Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater and surface water resources appear to be sustainable under existing conditions. However, groundwater resources may become unsustainable in the future due to population growth and the associated increase in water demand, and increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs. The reader is referred the Guelph WQSA (Section 4 of the main report) for a more detailed discussion of regional groundwater and surface water resources.

Aquaterra Hillsburgh Water Taking

Historical information relating to the Aquaterra Hillsburgh Site indicates the groundwater resources with water withdrawals for commercial water bottling have been permitted since the late-1980s. The reported water taking amounts from 2007 to 2017 have consistently remained below 49% of the maximum permitted annual amount, and have generally decreased in recent years to approximately 20% of the permitted volume. The last annual monitoring report for 2016 did not identify any unacceptable impacts on groundwater from the water taking. No documented well interference complaints/impacts were identified in the ministry files/reports provided for review.

The last monitoring report, for 2016, included the monitoring of groundwater levels within the production well. Annual reports do not include monitoring of neighbouring wells or nearby surface water. While there is no long-term hydrograph available for the Site, the 2016 monitoring report presents a summary of historical static head levels and drawdown at the production well (refer to Text Table 4-A-1 in section A.3.4.3). Long-term monitoring of groundwater levels in the bedrock aquifer at the production well has not revealed any indications of stress to groundwater due to the water taking. Flowing artesian well conditions have been maintained at the production well since its construction.

The information review also did not identify any other planned water taking activities that might contribute to the overall cumulative effects/impacts on local groundwater resources.

Based on the information reviewed, there are no indicators of the Aquaterra Hillsburgh water taking having an impact on the sustainability of existing and future water resources at the current levels of taking. Current Permit requirements/conditions in place appear to be suitable in identifying potential issues should climate change and growth pressures become a larger factor in the sustainability of local water resources under current water taking quantities. Consequently, it is BluMetric's opinion that the water taking is being managed sustainably. There are uncertainties around the future sustainability of the taking if the maximum allowed taking were taken over the maximum allowed pumping duration. Further work, such as modelling, would be required to determine the potential impacts on the municipal water supplies from the pumping of the Hillsburgh well at the maximum permitted rate.

4A.7 GAPS AND RECOMMENDATIONS

A summary of information gaps and potential enhancements identified from the assessment of the Aquaterra (Hillsburgh) Site is provided as follows:

1. There are uncertainties around the future sustainability of the taking if the maximum allowed taking were taken over the maximum allowed pumping duration. Further work, such as modelling, would be required to determine the potential impacts on the municipal water supplies from the pumping of the Hillsburgh well at the maximum permitted rate.

Based on the assessment of water takings at the Aquaterra Hillsburgh Site, Nestlé (Erin) (Appendix B), and Nestlé (Aberfoyle) (Appendix C), and as well as at various other bottling facilities assessed in BluMetric (2019), gaps and recommendations relating to all water bottling facilities were identified. The reader is referred to Section 11 of the main report for a summary of the gaps and recommendations.

4A.8 FIGURES

Figures are provided in Appendix A of the main report.

APPENDIX 4-B

(Nestlé Canada Inc., Erin WBSA)

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4B. NESTLÉ WATERS CANADA ERIN SITE

4B.1 BACKGROUND AND HISTORY

Nestlé Waters Canada ("Nestlé") currently draws water from a single bedrock well located on Lot 24, Concession 7, Geographic Township of Erin, County of Wellington, Ontario, herein referred to as the 'Nestlé (Erin) Site'. The Site falls within the jurisdictions of the Ministry of the Environment, Conservation and Parks (MECP) Guelph District Office, the Grand River Conservation Authority (GRCA) and Credit Valley Conservation (CVC). The Nestlé (Erin) water source location and Site boundaries are indicated on Figures 4-B-1a and 4-B-1b.

The northern portion of the site is mainly within the Grand River watershed (Eramosa Above Guelph subwatershed) and the southern part of the site is mainly within the Credit River watershed (West Credit River subwatershed) as indicated on Figure 4-B-2. The site consists of an area of about 75.5 hectares. The production well (TW1-88) itself is located within the jurisdiction of the GRCA.

The Nestlé (Erin) Site is located in a rural setting and is situated adjacent to the Niagara Escarpment and at the headwaters of the Eramosa and Credit Rivers. The original well was drilled in 1988 and the initial Permit to Take Water (PTTW) No. 89-P-2018 was issued in 1989. Between 1989 and 1999, the well was in operation for one day. In 2000, Aberfoyle Springs Co. (Aberfoyle), a subsidiary of Nestlé Canada Inc., began pumping for water bottling purposes. An approximate timeline of events relevant to the PTTW history of the Nestlé (Erin) Site is provided in Table 4-B-1.

Table 4-B-1: Nestlé Waters Canada Erin PTTW History Summary

Year	Event
Aug 1988	Initial Well Drilled Name: TW1-88 Type: Drilled Well Record No: 7156653 Depth (m): 57.3 Completion Unit: Limestone
1989	Initial Application for **PTTW No. 89-P-2018** (not reviewed by BluMetric Environmental Inc. ("BluMetric")) under different ownership. A maximum of 1,112,860.8 L/day for 10 years. Reportedly, TW1-88 was only used for one day between 1989 and 1999.
1999	A 7-day pumping test was conducted from May 27 to June 2, 1999.
2000	Pumping for water bottling purposes began by Nestlé in 2000.
2001	**PTTW No. 01-P-2219** was issued to Aberfoyle Springs Co. (a subsidiary of Nestlé Canada Inc.) on **September 5, 2001**, with an expiry date of March 31, 2003. The permit allowed water to be taken from the same source (Well TW1-88). The maximum volume was 1,113,000 L/day (773 L/minute). • A groundwater and surface water monitoring program was a requirement of the permit
2005	**PTTW No. 3031-6BSK7E** was issued on **May 6, 2005**, with an expiry date of May 30, 2007. The PTTW allowed for the same taking volumes and rates from the same source and for the same purpose as PTTW No. 01-P-2219. • A groundwater and surface water monitoring program was a requirement of the permit
2005	**PTTW No. 7102-6CQKMQ** was issued on **May 30, 2005** for a pumping test on one well (TW1-88). The permit expired on July 15, 2005. The maximum rate was 1,800,000 L/day (1,250 L/min) for a maximum of 24 hours per day and for a 7-day period.
2005	**PTTW No. 8062-6FQQJD** was issued on **September 19, 2005** for a pumping test on one well (TW1-88). The permit expired on November 30, 2005. The maximum rate was 1,800,000 L/day (1,250 L/min) for a maximum of 24 hours per day and for a 7-day period.
2005 - 2007	Name change from Nestlé Waters Canada to Nestlé Canada Inc.
2007	The Ministry of the Environment (MOE), now the MECP, issued notice on May 31, 2007 to extend the expiry date of **PTTW 3031-6BSK7E** until a decision is rendered on the renewal application dated April 4, 2007. **PTTW No. 6480-74BKR4** was issued on **August 24, 2007** for the same source (TW1-88) and permitted volume. The Permit expired on August 12, 2012. • A groundwater and surface water monitoring program was a requirement of the permit
2010	In November 2010, the carbon steel well casing for well TW1-88 was overdrilled and replaced by a stainless steel well casing installed and grouted in place to 21.8 m depth (Well Tag No. A095193). In addition, since the lower portion of the well was a poor production zone, it was cement grouted from 57.3 to 39 m (188 to 128 feet), resulting in a well depth of 39.01 m (128 feet).

Year	Event
2012	**PTTW No. 3716-8UZMCU** was issued on **September 28, 2012**, with an expiry date of August 31, 2017. The maximum permitted water taking limits and source are consistent with the permit issued in 2007. A condition of the permit allowed an increase in the maximum daily limit to 1,362,240 L/day (946 L/min) between April 1 and September 30; however, the average daily limit during that period was restricted to the maximum daily limit of 1,113,000 L/day. The following conditions are included in the PTTW: If Grand River Low Water Response Team declares a Level 1 or Level 2 drought condition in the watershed, then the maximum daily taking permitted in Table A (i.e., 1,113,000 L/day) shall be reduced in accordance with the Ontario Low Water Response Protocol. If the Ontario Water Directors Committee declares a Level 3 drought condition in the watershed, the maximum daily water taking shall be reduced in accordance with the Level 3 declaration. • A groundwater and surface water monitoring program was a requirement of the permit.
2014	On **January 20, 2014**, the MOE issued a Notice to amend **PTTW No. 3716-8UZMCU** to add an additional condition (Condition 3.6). The notice permitted a short-term increase in the maximum pumping rate for a five-hour period for proper sanitization of the production well. A Notice to amend **PTTW No. 3716-8UZMCU** was issued on **February 25, 2014** to revoke and replace Condition 4.1 to reflect modifications to the monitoring locations. On April 28, 2014 a letter was issued from the MOE clarifying the reporting requirements of Condition 4.7 of **PTTW No. 3716-8UZMCU.** Condition 4.7 requires the Permit Holder to submit to the PTTW signing Director and the Town of Erin a report within 30 days of the end of each month where the water taking is in accordance with the increased volume permitted between April 1 and September 30. The clarification letter listed the results to include in the letter report.
2015	A Notice to amend **PTTW No. 3716-8UZMCU** was issued on February 5, 2015. The Notice amended the monitoring locations and well sanitation conditions. Condition 3.6 was replaced to increase the maximum pumping rate to 1,040 L/min for the purpose of sanitization of the well. • A groundwater and surface water monitoring program was a requirement of the permit. Reporting: - Annual submission of a report which presents and interprets the monitoring data to be collected under the Terms and Conditions of the Permit. - Monthly letter reports to the Director and Town of Erin with the pumped volumes and water level information
2017	A **Category 3 PTTW Renewal Application** was submitted to the MECP on May 18, 2017, more than 90 days before the expiry date (August 31, 2017). Per Section 34.1(6) of the Ontario Water Resources Act, the permit will continue to be in force until a decision is made on the permit renewal application. The Application was prepared by Golder Associates Ltd, dated May 2017. The applicant is requesting the same water taking amount as the current Permit (3716-8UZMCU), at a maximum rate of 1,113,000 L/day (773 L/min) for a maximum of 24 hours per day and for 365 days per year, and with additional flexibility to increase the rate to a maximum of 1,362,240 L/day (946 L/min) between April 1 and September 30.

General information about the source well (TW1-88) located on the Nestlé (Erin) Site is provided in Table 4-B-2.

Table 4-B-2: Summary of Water Taking Source

Source Name	Type/Date of Install	Well Record ID	Total Well Depth	Completion Unit	PTTW No. 3716-8UZMCU		
					Max. Taken Per Minute (L)	Max. Num. of Hours Taken per Day	Max. Taken Per Day (m^3)
TW1-88	Drilled Well/ August 1988	7156653	39.01 m	Bedrock – limestone	773	24	1,113

As indicated in Table 4-B-2, TW1-88 is completed in bedrock to a depth of 39.01 m. In November 2010, the original well casing was overdrilled and the lower portion of the well, between 39.01 and 57.3 meters below ground surface (mbgs), was sealed (CRA, 2011).

Prior to November 2001, tankers were filled directly from the well. Since November 2001, water is pumped to a stainless steel silo for storage prior to being loaded into a tanker and shipped to the Aberfoyle bottling plant located in Aberfoyle, Ontario.

Since 2000, the volume of water taken has been recorded using the following methods:

- March 2000 to May 2002: Number of truckloads received at Aberfoyle Plant;
- June 2002 to May 2003: Flow meter readings from the well head;
- June 2003 to December 2004: Flow meter readings from the loading station prior to pumping the water into the silo; and,
- Since July 2004: Data logger readings.

4B.2 PRIMARY INFORMATION SOURCES

The following key records were on file with the MECP documenting the PTTW history (note that the following is not an exhaustive list of all records on file with the ministry):

- PTTW No. 01-P-2219, Aberfoyle Springs Co. (a subsidiary of Nestlé Canada Inc.), September 5, 2001.
- Renewal Application PTTW No. 01-P-2219, Nestlé Waters Canada, March 14, 2003.
- PTTW No. 3031-6BSK7E, Nestlé Waters Canada, May 6, 2005.
- PTTW No. 7102-6CQKMQ, Nestlé Waters Canada, May 30, 2005.

- Amendment Application PTTW, Nestlé Waters Canada, July 15, 2005.
- PTTW No. 8062-6FQQJD, Nestlé Waters Canada, September 19, 2005.
- Renewal Application, Nestlé Waters Canada, April 4, 2007.
- Notice for PTTW No. 3031-6BSK7E, Nestlé Waters Canada, May 31, 2007.
- PTTW No. 6480-74-BKR4, Nestlé Canada Inc., August 24, 2007.
- Notice for PTTW No. 6480-74-BKR4, Nestlé Canada Inc., August 30, 2012.
- PTTW No. 3716-8UZMCU, Nestlé Canada Inc., September 12, 2012.
- Notice for PTTW No. 3716-8UZMCU, Nestlé Canada Inc., January 20, 2014.
- Notice for PTTW No. 3716-8UZMCU, Nestlé Canada Inc., February 25, 2014.
- Notice for PTTW No. 3716-8UZMCU, Nestlé Canada Inc., February 5, 2015.
- Renewal Application (Category 3) PTTW No. 3716-8UZMCU, Nestlé Canada Inc., May 2017.

The following key technical documents provided to the ministry by the proponent/Permit Holder were identified and reviewed herein.

- Nestlé Erin 2004 PTTW Annual Report. Conestoga-Rovers & Associates, March 2005 (CRA, 2005).
- Nestlé Erin 2005 PTTW Annual Report. Conestoga-Rovers & Associates, April 2006 (CRA, 2006).
- Nestlé Erin 2006 PTTW Annual Report. Conestoga-Rovers & Associates, April 2007 (CRA, 2007).
- Nestlé Erin 2007 PTTW Annual Report. Conestoga-Rovers & Associates, April 2008 (CRA, 2008).
- Nestlé Erin 2008 PTTW Annual Report. WESA Inc., April 2009 (WESA, 2009).
- Nestlé Erin 2009 PTTW Annual Report. Conestoga-Rovers & Associates, May 2010 (CRA, 2010).
- Nestlé Erin, TW1-99 Pumping Test. Schlumberger Water Services (Canada) Inc., July 2010
  (SWS, 2010).
- Nestlé Erin 2010 PTTW Annual Report. Conestoga-Rovers & Associates, April 2011 (CRA, 2011).
- Nestlé Erin 2011 PTTW Annual Report. Conestoga-Rovers & Associates, April 2012 (CRA, 2012).

- Nestlé Erin 2012 PTTW Annual Report. Conestoga-Rovers & Associates, April 2013 (CRA, 2013).
- Nestlé Erin 2013 PTTW Annual Report. Conestoga-Rovers & Associates, April 2014 (CRA, 2014).
- Nestlé Erin 2015 PTTW Annual Report. Golder Associates, April 2016 (Golder, 2016).
- Nestlé Erin 2016 PTTW Annual Report. Golder Associates, March 2017 (Golder, 2017).
- Nestlé Erin 2017 PTTW Annual Report. Golder Associates, March 2018 (Golder, 2018).

Other information sources used in this assessment included:

- Caledon Creek and Credit River Subwatershed Study (Subwatersheds 16 & 18). Phase I: Characterization Report. Blackport Hydrogeologic, Credit Valley Conservation, Environmental Water Resources Group, Water Systems Analysts and Parish Geomorphic, 1999 (Blackport Hydrogeologic et al., 1999).
- RE: Nestlé Waters Canada 2005 and 2006 Annual Monitoring Reports, Erin Source, MOE Memorandum from Technical Support Section, June 11, 2007.
- RE: Nestlé Waters Canada Erin PTTW 3031-6BSK7E Annual Report, MOE Memorandum from Technical Support Section, June 18, 2007.
- Grand River Watershed, Integrated Water Budget Report, AquaResource Inc., June 2009 (AquaResource Inc., 2009).
- Grand River Watershed, Tier 2 Water Quantity Stress Assessment Report, AquaResource Inc., December 2009 (AquaResource Inc., 2009).
- Blackport Hydrogeology Inc. and Golder Associates Ltd., 2010. Issues Evaluation and Threats Assessment, Town of Erin Municipal Wells, Final Report, prepared for the Town of Erin, June 2010. (Blackport, 2010)
- Blackport Hydrogeology Inc. and Golder Associates Ltd., 2010. WHPA Delineation and Vulnerability Assessment, Town of Erin Municipal Wells, Final Report, prepared for the Town of Erin and Credit Valley Conservation, April 2010.
- Approved Updated Assessment Report: Credit Valley Source Protection Area. Credit Valley Conservation, July 27, 2015 (CVC, 2015).
- Grand River Conservation Authority, Watershed Map, published February 2004 (version 2). https://www.grandriver.ca/en/our-watershed/Maps-and-data.aspx (Accessed on December 10, 2018).

- Approved Updated Assessment Report: Credit Valley Source Protection Area. Credit Valley Conservation, July 27, 2015 (CVC, 2015). Hydrogeological Impact Assessment. Aggregate License Application. Lots 11 – 13, Concession 6 West Side. Town of Caledon, Regional Municipality of Peel. (Harden Environmental Services Limited, December 16, 2016).
- Matrix Solutions Inc. 2017. City of Guelph and Township of Guelph/Eramosa Tier Three Water Budget and Local Risk Assessment. Lake Erie Source Protection Region.
- Matrix Solutions Inc., 2018. Assessment of Climate Change and Assessment of Water Quantity Threats in the IPZ-Q in Support of the Guelph-Guelph/Eramosa Water Quantity Policy Study. Lake Erie Source Protection Region.
- BluMetric Environmental Inc. ("BluMetric"), 2019. A Review of Ontario's Water Quantity Management Framework. Water Bottling Study Areas Report.
- Census Profile, 2016 Census. Statistics Canada website at https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm (StatCan, 2016).
- Wellington County Official Plan. May 2018.
- Town of Erin Zoning by-law No. 07-67.
- Public Works Department Website. Corporation of the Town of Erin. 2018. http://www.erin.ca/town-hall/public-works (Accessed on November 29, 2018). (Town of Erin, 2018).
- Ministry of the Environment and Climate Change (MOECC) Interim Procedural and Technical Guidance Document for Bottled Water Renewals: PTTW Applications and Hydrogeological Study Requirements, April 2017.
- MECP water well information system (WWIS) database. Available at: https://www.ontario.ca/environment-and-energy/map-well-records.
- MECP on-line Provincial Groundwater Monitoring Network (PGMN) database. Available at: https://www.ontario.ca/environment-and-energy/map-provincial-groundwater-monitoring-network.
- MECP on-line Permit to Take Water database. Available at: https://www.ontario.ca/environment-and-energy/map-permits-take-water.
- Ministry of Natural Resources and Forestry (MNRF) on-line Natural Heritage Areas mapping. Available at: https://www.ontario.ca/page/make-natural-heritage-area-map.
- MECP Water Taking Reporting System (WTRS) database (Confidential – Used with Permission from MECP).

- Ontario Low Water Response Program (OLWR) notifications and alert levels for Grand River Conservation (2000 to August 2018 data from the MNRF).
- Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario. Special Volume 2*. Ontario Geological Survey.

4B.3 CHARACTERIZATION OF STUDY AREA

The Nestlé (Erin) Site is located at the north end of the Guelph-Wellington County Water Quantity Study Area ("Guelph WQSA") as defined in MECP RFB# 6792. As specified by the MECP, the water bottler has been investigated as part of the Guelph WQSA. Characterization of water quantity resources conditions on a regional scale is provided in the main body of the Guelph WQSA report. Figure 4-B-2 presents an area of approximate 20 km by 20 km centred over the Nestlé (Erin) water taking location. The 20 km by 20 km study area was selected to ensure the following were captured: the closest municipal groundwater system takings, Provincial Groundwater Monitoring Network (PGMN) wells, and Survey of Canada (WSC) hydrometric monitoring stations (HYDAT), and the radius of influence of the Nestlé (Erin) water taking (associated with a predicted drawdown of 0.1 m, estimated to extend up to about 1 km from the production well (CRA, 2014); see Section 4B.3.4.3 for further discussion of the radius of influence).

The review of permitted water takings as reported within the WTRS database focused on 'municipal water supply system takings' located within a 20 km by 20 km area centred over the Nestlé (Erin) water taking, and 'other' reported water takings located up to 5 km from the Site. Smaller assessment areas were used for the review of existing/planned land use and WWIS records and are indicated herein.

The Nestlé (Erin) Site is located between the Village of Erin and the Village of Hillsburgh municipal groundwater systems and is within the Credit Valley Source Protection Area (CVSPA). Of note, the Aquaterra Hillsburgh (water bottler) water taking is located 3.7 km southeast of the Site and the Aquaterra Cataract (water bottler) water taking is located 10.8 km east-northeast of the Site.

4B.3.1 Land Use Setting

Land use within an approximate 500 m radius of the Nestlé (Erin) Site (Figure 4-B-3), as per the County of Wellington Official Plan, consists of Secondary Agricultural land to the north and west, Prime Agricultural to the south, Core Greenlands (wetland/water body) to the west and southeast, and Urban Centre to the northeast.

The Nestlé (Erin) Site is located in the Town of Erin (County of Wellington) just south of Hillsburgh. The Town is described as a rural community with agricultural activities being an important component of the Town's economy (Town of Erin, 2012). The Town of Erin had a 2016 census population of 12,490, and the population is forecast to rise to about 13,510 and then 15,530 by the years 2021 and 2031, respectively. The primary growth areas are designated to occur in urban centres, i.e. compact, well-integrated rural towns on full piped water services. Within the Town of Erin, the Urban Centres are the Village of Hillsburgh, located approximately 1 km to the north and the Village of Erin, located approximately 6 km to the east of the Nestlé (Erin) Site. The Aquaterra Hillsburgh Site, discussed in Appendix A, is located approximately 3.7 km to the southeast of the Nestlé (Erin) Site and is located within the jurisdiction of CVC.

The Town of Erin, as per zoning by-law No. 07-67, is characterized by large areas of agricultural and greenland uses with some environmental protection zones. Residential areas are located in the urban centres of the Villages of Erin and Hillsburgh. The majority of the land use on the Nestlé (Erin) Site is Secondary Agricultural land use, as per the County of Wellington Official Plan. There is a small section of Greenlands and Core Greenlands land use on the northwest and south side of the Site and a small section of Urban Centre land use on the northwest side of the Site. As per the Town of Erin zoning by-law No. 07-67, the Core Greenlands are zoned as a Rural Environmental Protection (EP2) zone.

The MNRF's Natural Heritage Areas mapping shows that the Environmental Protection zones on the Nestlé (Erin) Site include some provincially significant wetlands in the northwest and south of the Site, specifically the Speed-Lutteral-Swan Creek Wetland Complex and the West Credit River Swamp Complex.

4B.3.2 Physiographic Setting

The Nestlé (Erin) Site is located within the Hillsburgh Sandhills physiographic region as identified by Chapman and Putman (1984). The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of the regional physiographic setting.

4B.3.3 Geologic Setting

A detailed discussion of the regional geologic setting of the Guelph WQSA is presented in Section 4 of the main report.

The surficial geology of the Nestlé (Erin) Site is classified by stone-poor carbonate-derived silty to sandy till, glaciofluvial deposits, sandy deposits, ice-contact stratified deposits and the on-site wetland area consists of organic material (Golder, 2018). The source well (TW1-88) is interpreted to have been drilled through the surficial glaciofluvial sand and gravel layer, followed by a sandy silt/clay till and into the dolostone bedrock of the Guelph Formation.

The bedrock formations mapped for the Hillsburgh area (including the Town of Erin) consist of Guelph (upper) and Amabel (lower) formations. The Guelph-Amabel formations in the Hillsburgh area have a combined thickness that ranges from approximately 60 to 120 m (TDM, 1991).

A brief description of each of these bedrock formations is provided below, as an excerpt from the City of Guelph Tier Three Assessment (Matrix Solutions Inc., 2017):

> ***Gasport (Amabel) Formation***
> *The Gasport Formation is a cross-bedded crinoidal grainstone-packstone with sequences of reef mound and coquina (shell bed) lithofacies. This unit has commonly been referred to as the Amabel Formation in previous studies in the area. The Formation generally varies in thickness from about 25 to over 70 m, and the upper sections of the reef mounds, the crinoidal grainstones and the coquina shell beds make this formation highly transmissive, where they are present.*

> ***Guelph Formation***
> *The Guelph Formation consists of two members; the lower Hanlon Member and the upper Wellington Member. The Guelph Formation consists of medium to thickly bedded crinoidal grainstones and wackestones and reefal complexes (Brunton, 2008). The Guelph Formation is cream-coloured and fossiliferous and where present in the Cambridge and Guelph area it is most often the uppermost bedrock unit.*

4B.3.4 Hydrogeologic Setting

4B.3.4.1 Regional Hydrogeology

The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of the hydrogeologic setting of the Nestlé (Erin) Site.

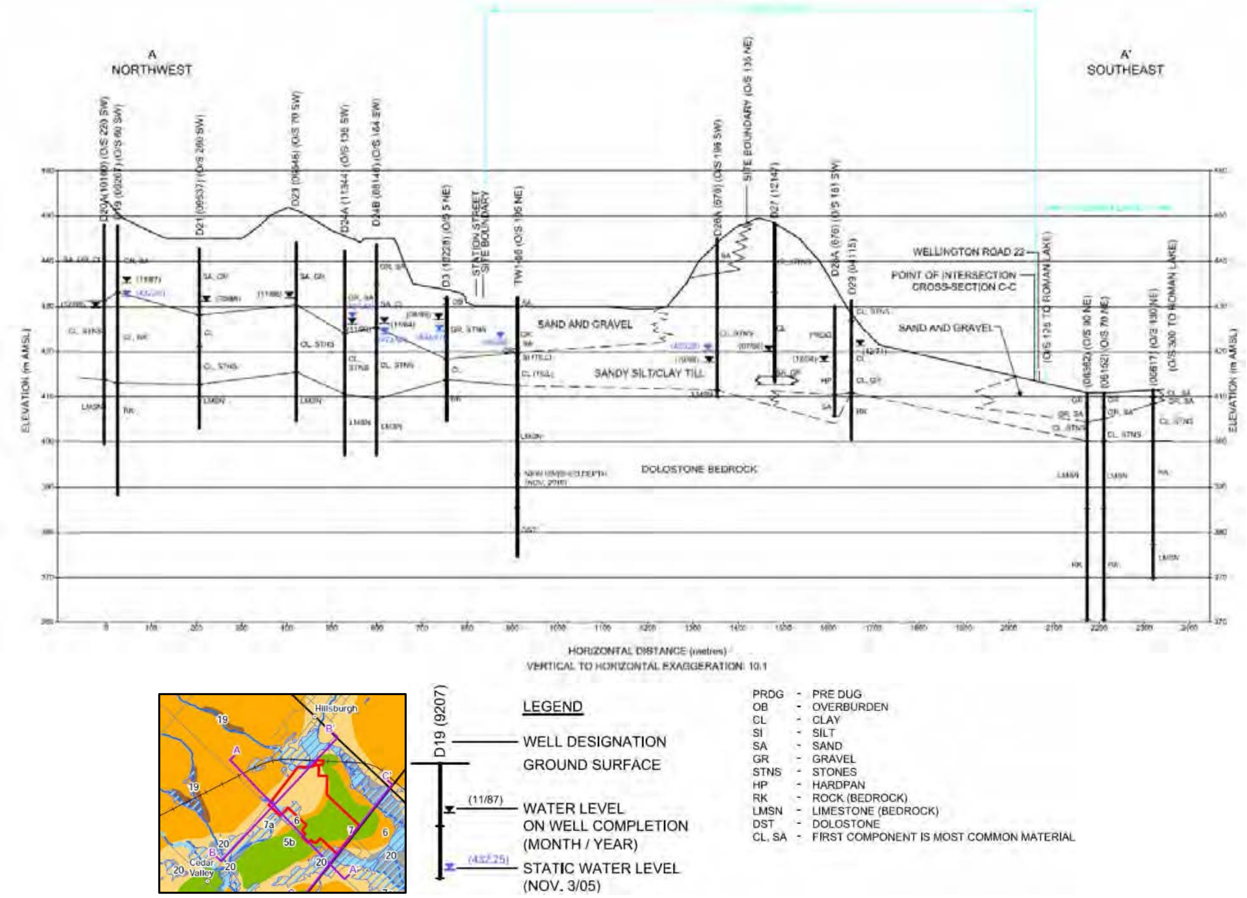
4B.3.4.2 Local Hydrogeology

The reported three hydrogeologic units at the Nestlé (Erin) Site and surrounding area are, from top to bottom (Golder, 2017):

- Sand and Gravel Aquifer. Consists of sand, gravel, or sand and gravel. The thickness of the layer is approximately 12 m at TW1-88, increases in thickness to the northwest of TW1-88 and is generally absent to the south, southeast, and east of TW1-88. The water levels are typically 1 to 2 m below ground surface.
- Sandy Silt/Clay Till Aquitard. The thickness of the till at TW1-88 is 7.3 m and ranges in thickness from about 5 m to 35 m within 1 km of TW1-88.
- Dolostone Bedrock Aquifer. Consists of light brown, fine to medium crystalline sucrosic dolostone. The Guelph Formation is located at the site and to the west, while the Amabel Formation is located to the east of the site. Under pumping and non-pumping conditions, a downward vertical gradient exists.

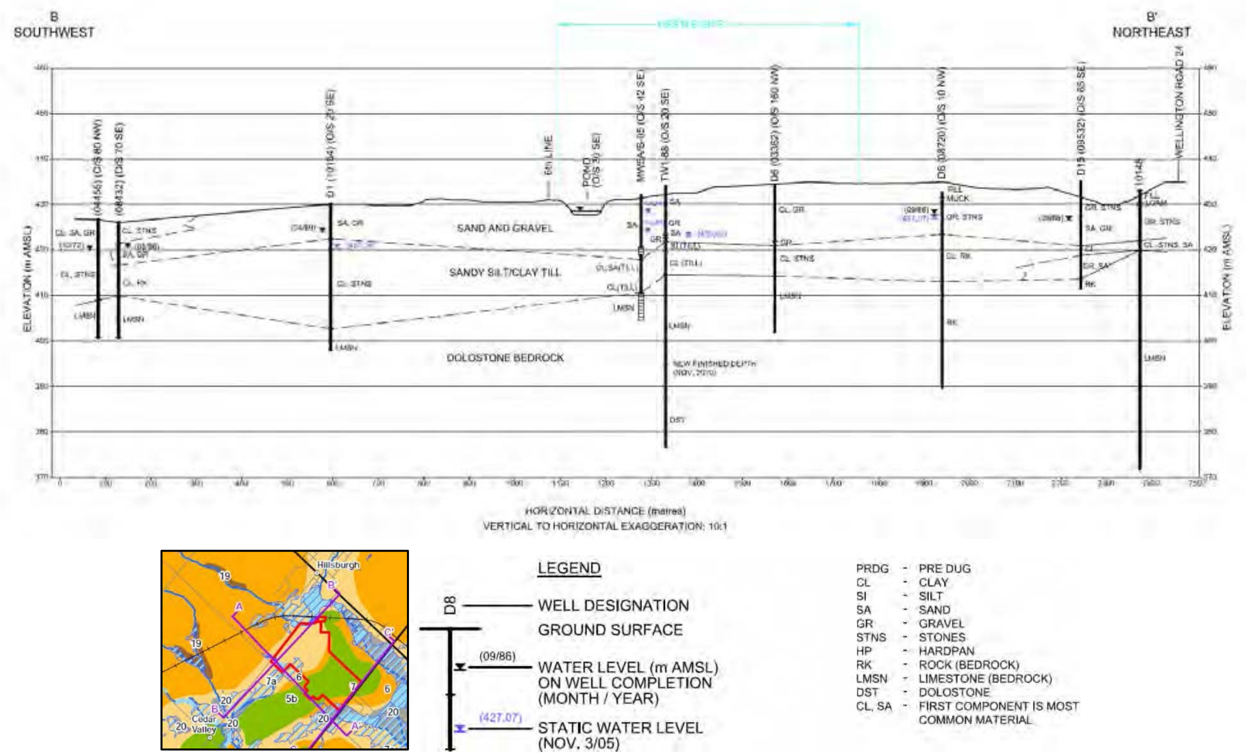
Perpendicular hydrogeological cross-sections through the Site from CRA (2014) are provided in Text Figures 4-B-4a and 4-B-4b.

Text Figure 4-B-4a: Northwest to Southeast Hydrogeological Cross-Section through TW1-88.



Source: CRA, 2014 (inset map: Golder Associates, 2018).

Text Figure 4-B-4b: Southwest to Northeast Hydrogeological Cross-Section through TW1-88.

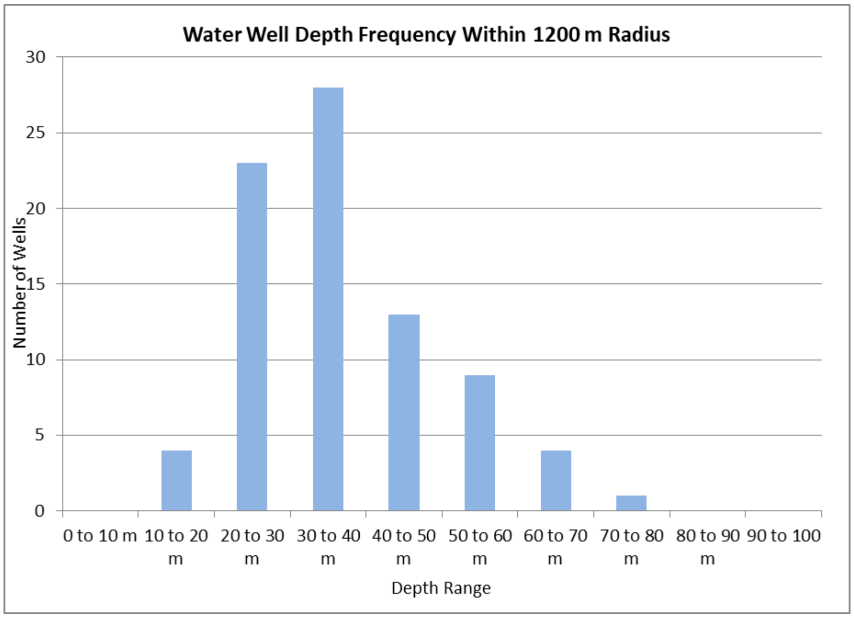


Source: CRA, 2014 (inset map: Golder Associates, 2018).

Properties in the Town of Erin are serviced by private well water supply and municipal groundwater supply. The MECP WWIS database was reviewed for well locations situated within 1,200 m of the Nestlé (Erin) Site production well. A 1,200 m search radius was considered appropriate based on the observed density for water well records in this search area while being representative of local conditions. Water well record locations as referenced in the WWIS are plotted on Figure 4-B-1a. A total of 82 well construction records for supply wells were identified (i.e. monitoring wells and well abandonment records were omitted). The reported well construction depths for the water supply wells range from 0 to 71.6 mbgs. The database indicates that the majority of supply wells are completed in bedrock. Under static conditions the groundwater flow direction within the upper bedrock is primarily to the south-southeast (Golder, 2018).

The frequency distribution in water well depths within the 1,200 m search radius is provided in the chart shown on Text Figure 4-B-5 (excluding the unknown well types), indicating that the majority of wells (73 of 82 wells) are between 20 and 60 m in depth.

Text Figure 4-B-5 Distribution of Private Water Well Depths within a 1,200 m Radius of the Site



The overburden wells are completed to depths ranging from 12.8 to 47.2 mbgs while bedrock wells are completed to depths ranging from 15.8 to 71.6 mbgs. Overburden materials are most commonly described in the well records as consisting of sand, gravel and clay. The two deepest wells within 1,200 m of the Nestlé (Erin) Well (well ID no. 6705975 and 6706342) with depths of 71.6 and 62.8 mbgs, respectively, are located adjacent to the southeast Nestlé (Erin) Site property boundary. Records for the two wells indicate that they are both used for domestic water supply. Reported static water levels within the search radius ranged from 0.6 to 31.4 mbgs.

4B.3.4.3 Site Hydrogeology

Several technical reports were identified in MECP files providing hydrological and hydrogeological information for the Nestlé (Erin) Site. Salient information derived from these reports and relating to water quantity assessment is summarized as follows.

2004 Annual Monitoring Report, Nestlé Erin Site (CRA 2005)

In 2000, pre-pumping water level data determined that the groundwater flow direction was to the southeast in the Guelph Amabel Aquifer with a hydraulic gradient of 0.01 m/m. Static water levels ranged from 6 to 16 mbgs and at TW1-88, the Erin Well, the static water level was about 10 mbgs.

2010 TW1-99 Pumping Test Observation Well Installation Field Report, Schlumberger Water Services (Canada) Inc. (Schlumberger, 2010)

A feasibility-level pumping test was conducted in the overburden aquifer using TW1-99 as the test well. TW1-99 was being considered to supplement the main supply well TW1-88. Four additional overburden monitoring wells and one bedrock well were installed to monitor the test and to determine any potential effects on the overburden or bedrock aquifers. The test confirmed the thickness of the overburden aquifer within the vicinity of TW1-99 (5 to 6 m thick) and at wells located to the west and northwest of TW1-99 (8 to 10 m thick). After drilling, the groundwater depths in the overburden wells stabilized after one day (ranging from 2.18 to 4.22 mbgs). The bedrock well observed flow rates of 1 to 5 L/s. The water level in the bedrock well was reported to be 5 m below the static water level in the overburden aquifer. The report did not conclude whether the utilization of the overburden well TW1-99 would be feasible or not. Since the pumping test in 2010, there has been no reported water taking from TW1-99.

2013 Annual Monitoring Report, Nestlé Erin Site (CRA 2014)

In 2001, a pumping test was conducted on TW1-88. TW1-88 was shut down and allowed to recover for about 36 hours prior to initiating pumping for 18 hours at a rate of 773 litres per minute (LPM) (i.e., the maximum permitted rate). The drawdown observed at TW1-88 was 8.1 m. The zone of influence based on a drawdown of 0.1 m was determined to be approximately 1,000 m from TW1-88 to the west, north and east. To the south and southwest it was determined to be greater than 700 m, based on a drawdown of 1.55 m at D2A. Drawdown at monitoring wells MW12A-08 and D15 was less than 0.3 m and these wells used to represent background conditions.

In 2005, another pump test was conducted on TW1-88. TW1-88 was shut down for 12.5 hours. It was noted that the groundwater flow within the bedrock was generally to the southeast. The horizontal gradient north of TW1-88 was about 0.017 m/m and the water level at TW1-88 was 423.5 masl, similar to pre-pumping values measured in January 2000.

Between April 1 and September 30 2013, TW1-88 operated at rates of up to 946 LPM in accordance with the permitted peak rate. A drawdown of about 1.5 m (from 8.0 to 9.5 mbgs) was observed during this period. In bedrock monitoring well MW5A-05, 70 m from the production well, a drawdown of 1.0 m (from 5.0 to 6.0 mbgs) was observed during this increased pumping period. Also the off-site domestic well (D3), located 220 m from TW1-88, had a 0.5 m drawdown from 3 to 3.5 mbgs. There was no measured influence on the overburden monitoring wells from the increased pumping.

Summary of Nestlé Erin PTTW Annual Reports 2004 to 2017

Conestoga-Rovers & Associates was retained by Nestlé to prepare the annual PTTW monitoring reports for the Erin site from 2004 to 2007 and 2009 to 2013. WESA Inc. completed the report for 2008, and Golder and Associates completed the 2015 to 2017 monitoring reports. The annual reports prior to 2004 and the reporting year 2014 were not available for review; however, the reviewed reports do briefly discuss historical trends.

General conclusions from the Annual Monitoring Reports (2004 to 2017) include:

- The results from the 2001 hydraulic monitoring indicate that the zone of influence within the bedrock aquifer as a result of pumping at TW1-88 extended about 1000 m to the west, north and east and was greater than 700 m to the south.
- The zone of influence when pumping at a rate of 773 LPM does not interfere with the Well Head Protection Area for the two Hillsburgh municipals wells, located in excess of 1.5 km from TW1-88.
- The static water levels in TW1-88 typically ranged from approximately 422.8 to 424 masl.
- The lower water levels under pumping conditions typically ranged from approximately 416 to 418 masl.
- Small upward vertical gradients were observed within the shallow overburden around TW1-88 indicating that shallow overburden groundwater is primarily discharging to surface water, with the exception of the Erin Branch of the Credit River which is a losing stream that typically shows a downward gradient.
- The vertical gradients within the shallow overburden underlying, or adjacent to, the surface water bodies in the area have remained relatively stable and do not appear to be influenced by pumping at TW1-88.
- Over the past five years water levels in the bedrock aquifer appear to be stable.
- The closest monitoring well downgradient and in the same aquifer as TW1-88 is MW5A-05 (located approximately 70 m southwest of TW1-88). The water levels have been reported as stable in the 2017 annual report.
- The fluctuations in water levels observed in the shallow overburden and surface water bodies seems to be a result of seasonal variations in precipitation and recharge, as opposed to water taking at the Site.

The reports indicate that the monitoring program has been on-going for more than 15 years and no impacts to private wells or to the surrounding aquifer have been noted. The 2017 annual monitoring report recommended discontinuing monitoring at the private wells with sufficient nearby monitoring wells and replacement of other private wells with dedicated monitoring wells. The reports state that the water takings from the Nestlé (Erin) well are not expected to result in an adverse effect on the groundwater environment.

In 2008, the owner of the closest off-site domestic bedrock well located at D3 (see well ID 6710228 on Figure 4-B-1a), raised a concern that the pond on their property had been impacted by pumping at TW1-88. Additional studies and assessments were completed and there was no evidence that there is any discernable impact to the owner's pond as a result of water taking at TW1-88 (WESA, 2009). In addition, the information collected from the monitoring program did not suggest an impact at D3. The results of studies and assessments of water levels in well D3 itself indicated there were observable, but not unacceptable impacts at D3 from pumping at TW1-88 (WESA, 2009). It was noted that well D3 appears to be used for heating purposes in winter months. The water levels were reported to be stable from 2013 to 2018, with a slight decrease in 2014 (see Text Figure 4-B-7d).

4B.3.5 Site Hydrology

The Erin Branch of the Credit River is located approximately 300 m northeast of the Nestlé (Erin) Site and flows in a southeasterly direction before discharging into the Credit River. In the vicinity of the Credit River, overburden and bedrock groundwater flow is towards the river. There are three large and several small on-line ponds located along the Erin Branch of the Credit River, situated approximately 1 km northeast of TW1-88. Additionally, Roman Lake, that is not part of the Credit River system, is located approximately 1.2 km southeast of TW1-88.

The provincially significant Speed-Lutteral-Swan Creek Wetland Complex is partially located on the Site. The wetland pond is located approximately 265 m south-southeast of TW1-88. Also, an on-site pond is located approximately 135 m southwest of TW1-88. Both ponds discharge into the unnamed drain that flows into the Eramosa River, located in the Grand River watershed.

Per the conditions of PTTW No. 3776-8UZMCU, water levels in mini-piezometers are continuously monitored in the shallow overburden underlying, or adjacent to, the surface water bodies of the area (and vertical hydraulic gradients calculated). Surface water levels are also measured at the on-site pond, the creek downstream of the on-site pond, the Erin Branch of the Credit River, in the stream flowing into Roman Lake, and in Roman Lake itself.

Pumping at TW1-88 does not appear to have an effect on vertical gradients in the shallow overburden near surface water features (Golder Associates, 2018). Small upward vertical hydraulic gradients are generally observed within the shallow overburden underlying, or adjacent to, the surface water bodies in the area, indicating that groundwater is primarily discharging to surface water. An exception is at the Erin Branch of the Credit River, which is a losing stream and therefore shows downward gradients.

Pumping at TW1-88 does not appear to have an effect on water levels or flows in the surface water features (Golder Associates, 2018). Rather, the surface water levels and flows appeared to be influenced by precipitation and/or snowmelt events.

4B.4 DATA REVIEW AND STATE OF GROUNDWATER RESOURCES

4B.4.1 Water Taking Reporting System

The WTRS is the ministry's repository for collection of water taking data for active PTTWs. As a requirement of each PTTW, the water taking data must be reported on an annual basis and daily water taking data must be entered into the system. The WTRS database containing the reported water taking data for all PTTWs is not publicly available, but is available for use by ministry staff when assessing the status of a PTTW or addressing issues potentially associated with one or more PTTW. The WTRS database was provided by the ministry for use in the Water Bottling Study Area (WBSA) assessment to be inclusive of all information available to MECP for making water management decisions.

Data on the volume of water taken per year and the number of water taking days per year for the Nestlé (Erin) well site was obtained from the WTRS for review. Table 4-B-3 below includes annual water taking data for the period from 2005 to 2017.

Table 4-B-3: Reported Water Takings – Nestlé (Erin)

Permit Number	Year	Source Name	Annual amount permitted by the PTTW (Million L)	Permitted No. of Taking Days per Year	Reported No. of Days Taken per Year	Reported annual taking (Million L)	Reported annual taking (% of permitted amount)	Average volume taken per day (L/day)
3031-6BSK7E	2005	TW1-88 Well	406.25	365	147	93.10	23%	633,356
3031-6BSK7E	2006	TW1-88 Well	406.25	365	327	145.03	36%	443,518
6480-74BKR4	2007	TW1-88 Well	406.25	365	128	21.81	5%	170,415
6480-74BKR4	2008	TW1-88 Well	406.25	365	355	96.25	24%	271,123
6480-74BKR4	2009	TW1-88 Well	406.25	365	362	132.72	33%	366,640
6480-74BKR4	2010	TW1-88 Well	406.25	365	348	157.86	39%	453,621
6480-74BKR4	2011	TW1-88 Well	406.25	365	350	162.77	40%	465,070
3716-8UZMCU	2012	TW1-88 Well	406.25	365	67	35.23	9%	525,882
3716-8UZMCU	2013	TW1-88 Well	406.25	365	355	223.70	55%	630,135
3716-8UZMCU	2014	TW1-88 Well	406.25	365	361	146.03	36%	404,516
3716-8UZMCU	2015	TW1-88 Well	406.25	365	342	78.49	19%	229,490
3716-8UZMCU	2016	TW1-88 Well	406.25	365	348	82.27	20%	236,406
3716-8UZMCU	2017	TW1-88 Well	406.25	365	317	66.07	16%	208,438

As indicated in Table 4-B-3, annual water takings during the 2005 to 2017 period varied from 5% to 55% of the PTTW limit, but were generally between 20 to 40%. The average volume taken per day was consistently far below the PTTW limit of 1,113,000 L/day.

The assessed study area for review of other active PTTWs was set at a 5 km radius of the Nestlé (Erin) well (Figure 4-B-2). The 5 km radius was considered appropriate for review based on the density of active PTTWs in the area and as a conservative distance for any potential contribution from the Site on the cumulative effects from multiple water takings. A summary of the 2016 and 2017 WTRS data for these permits is provided in Table 4-B-4.

Table 4-B-4: Reported Water Takings – Neighbouring PTTWs

Permit Holder (Permit no.)	Issue Date	End Date	Source	Dist. from Erin Well (Km)	PTTW Limits			2016 WTRS Data [1]		2017 WTRS Data [1]	
					Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
7740-A9ZNTP (The Corporation of the Town of Erin)	May 18, 2016	May 31, 2026	Municipal Well H3	1.3	0.66	365	239	21	9%	38	16%
6306-8X5KRY (The Corporation of the Town of Erin)	Aug. 13, 2012	July 31, 2022	Municipal Well H2	1.5	0.98	365	358	2	8%	27	8%
8548-6SBGWC (The Corporation of the Town of Erin)	Aug. 29, 2006	Oct. 31, 2016	Hillsburgh Well #H3	1.6	0.66	365	239	11	5%	-	-
7713-AMNK6P (St. Mary's Cement Inc.)	June 1, 2017	Aug. 31, 2020	Source Pond	3.4	12.7	304	3,874	-	-	484	12%
5001-AJVHXU (St. Mary's Cement Inc.)	May 25, 2017	Aug. 31, 2020	Source Pond	3.4	6.2	365	2,294	-	-	105	5%
8216-84XLZB (St. Mary's Cement Inc.)	May 25, 2010	Aug. 31, 2020	Source Pond	3.4	7.8	365	2,853	544	19%	24	1%

Permit Holder (Permit no.)	**Issue Date**	**End Date**	**Source**	**Dist. from Erin Well (Km)**	**PTTW Limits**			**2016 WTRS Data**		**2017 WTRS Data**	
					Max. taken per day (Million L)	**Taking Days per Year**	**Annual Taking (Million L)**	**Annual Reported Taking (Million L)**	**Annual Reported Taking (% of PTTW Limit)**	**Annual Reported Taking (Million L)**	**Annual Reported Taking (% of PTTW Limit)**
0834-ASYKZU (Mimosa Springs Trout Farm Ltd.)	Nov. 10, 2017	July 31, 2019	Pond	3.5	1.31	365	478	-	-	151.2	32%
			Well	3.6	0.654	365	239	-	-	0	0%
			Spring	3.6	2.62	365	956	-	-	39.5	4%
5200-7VSP2M (Mimosa Springs Trout Farm Ltd.)	Sept. 5, 2009	July 31, 2019	Pond	3.5	1.31	365	478	2,075	474%	2,399	502%
			Well	3.6	0.654	365	239	0	0%	0	0%
			Spring	3.6	2.62	365	956	691	72%	602	63%
0287-9ZXRAC (Strada Aggregates Inc.)	Oct. 19, 2015	Oct. 31, 2018	Washing Pond	3.6	2.4	240	576	193	34%	90	16%
			GW Pond	3.6	0.216	240	52	0	0%	0	0%
8664-75QJ2J (Aquaterra Corp. Ltd.)	Aug. 21, 2007	July 31, 2017	Hillsburgh Well (Water Bottling Facility)	3.7	0.225	260	58.5	10.9	19%	10.9	19%
7436-A6ZSZA (Harlan James and Delphine Taylor)	Feb. 11, 2016	Dec. 31, 2021	Wilson Well	4.6	1.21	100	121	22.8	19%	1.45	1%
			Wilson Dugout	4.6	3.24	100	324	0	0%	0	0%

[1] A hyphen (-) indicates that no taking was reported in the WTRS.

Note: Data accurate as of September 2018

The closest active PTTWs, no. 7740-A9ZNTP, 6306-8X5KRY and 8548-6SBGWC, approximately 1,300 to 1,600 m from the Nestlé (Erin) well, each consist of one well associated with the Town of Erin's municipal groundwater supply system. The reported water takings for each of these permits have been less than 17% of the maximum permitted annual amount for 2016 and 2017. The annual permitted amounts for the Town of Erin municipal wells range from 239 to 358 million L/year and 0.66 to 0.98 million L/day, which are lower than the permitted amounts for the Nestlé (Erin) Site (406 million L/year, 1.113 million L/day). The remaining active PTTWs are at least 3.4 km from the Nestlé (Erin) well and are associated with aggregate, aquaculture and water bottling operations. The permitted amounts for these active PTTW range from 52 to 3,874 million L/year and 0.2 to 12.7 million L/day. Among the permitted water users in the area, permitted water takings from surface water for aggregate operations are generally the largest. The water takings do not, however, take into account that much of the water used in aggregate washing is returned to the natural environment although details of the surface water and geological units associated with the ponds have not been determined as part of this report.

The anticipated radius of influence of the Nestlé well as stated in the annual reports is 1,000 m, excluding the southwest direction where the zone of influence was greater than 700 m. The Town of Erin municipal groundwater system, consisting of two wells drawing from a bedrock aquifer, is located about 1,500 m to northeast of the Nestlé (Erin) well and is outside of the reported radius of influence.

4B.4.2 Provincial Groundwater Monitoring Network

The PGMN is a partnership program with all 36 conservation authorities (CAs) and 10 municipalities (in areas not covered by a CA) to collect and manage ambient (baseline) groundwater level and quality information from key aquifers located across Ontario. During the spring and summer of 1999, low water conditions in many parts of southern Ontario prompted the formation of an inter-ministerial task force to assess drought conditions, determine trigger levels and develop a response strategy. The PGMN was approved in 2000 and there are currently more than 450 monitoring wells in the network.

The PGMN datasets report on ambient (baseline) groundwater level and chemistry conditions. The PGMN well locations are typically sited to be away from areas where there is a large density of permitted water takings. Consequently, the PGMN wells are typically far too distant from any permitted water taking to be used as an indicator of potential well interference impacts. Three PGMN wells are located within 10 km of the Nestlé (Erin) Site, as shown on Figure 4-B-2. The PGMN well information is summarized in Table 4-B-5 below.

Table 4-B-5: PGMN Well Summary

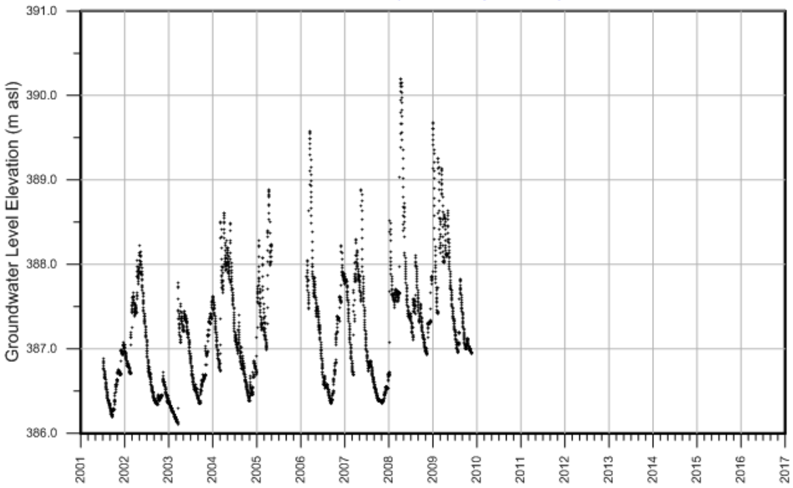
PGMN Well ID	Water Well Record ID	Distance from Nestlé (Erin) Well (km)	Well Depth (m)	Ground Elevation (m asl)	Lithology of Aquifer
W0000026-1	6713771	6.8	35.96	392.96	Bedrock (limestone)
W0000164-2	6714839	1.4	8.08	427.76	Overburden (silty sand, sandy silt, sand)
W0000164-3	6714839	1.4	12.8	427.76	Overburden (silty sand and gravel, sand)

Water level data collected for the PGMN wells is of potential value in assessing regional groundwater level trends and as a general indicator of stress within the watershed/subwatershed. Data has been collected for the PGMN well network since 2001 though some wells were installed more recently. Also the data for some wells is not current to 2018. The PGMN database is made available by MECP on-line.

As a recent internal project, the MECP has applied the Mann-Kendall (MK) and Seasonal Kendall (SK) tests to analyze the PGMN water level data for monotonic trends (i.e. consistent increases or decreases through time). The statistical analyses were performed using robust and defensible methodologies to look for longer-term trends in groundwater levels. An overall objective is to determine if there is enough data to support the presence of a widespread decrease in groundwater availability. Shorter trends within the PGMN data record (e.g. lasting for a few years) were not considered and the causes of any trends that were identified were not investigated. Both the data plots and preliminary findings for PGMN well locations nearest a WBSA were shared by the ministry and are presented and relied on herein. The data plots indicate data available for the well at the time of the assessment. Further, the MECP has indicated that the methodologies used require that certain values be dropped from the data set if the month/year in question does not have sufficient number of data points. The release of a final report that details the methodology and results from the PGMN data trends analysis is forthcoming from the ministry (MECP, 2018).

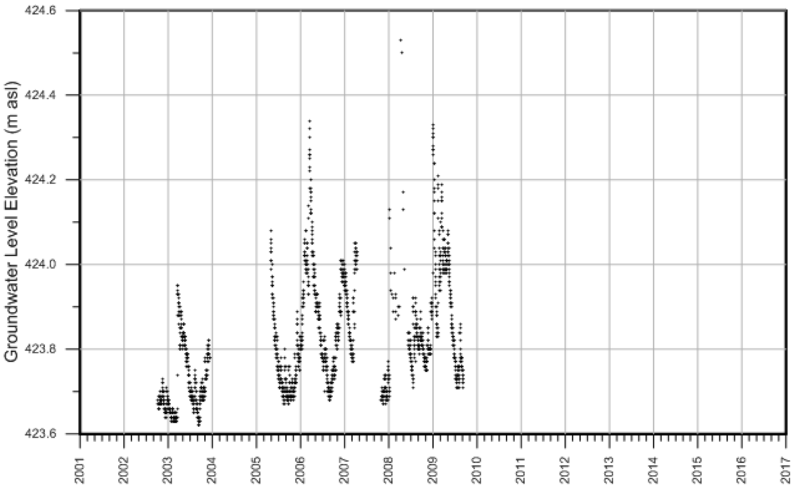
The data plot and trend analysis for the three PGMN well installations within 10 km of the Nestlé (Erin) Site are provided on Text Figures 4-B-6a to 4-B-6c.

Text Figure 4-B-6a: Groundwater Elevations (2001 to 2010) for PGMN Well W0000026-1



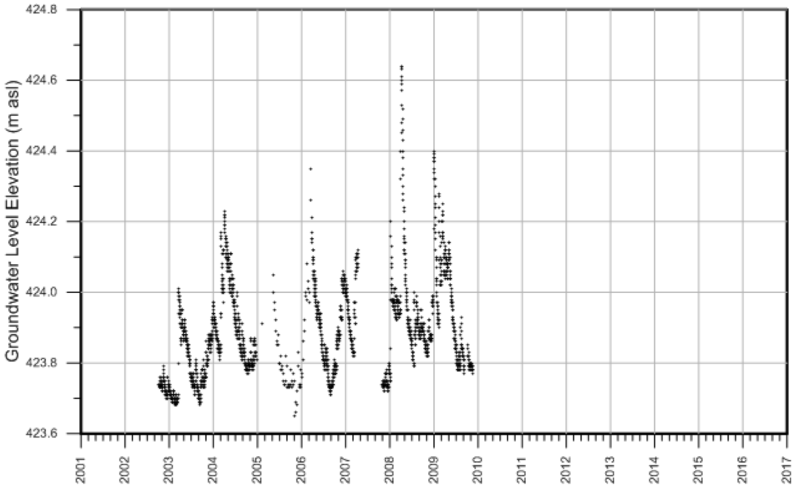
For PGMN well No. W0000026-1, the MK test did not detect a significant trend, using six years of data. The SK test detected an upward trend, based on 7.5 years of data.

Text Figure 4-B-6b: Groundwater Elevations (2002 to 2010) for PGMN Well W0000164-2



For PGMN well No. W0000164-2, the MK test did not detect a significant trend, using three years of data. The SK test detected an upward trend, based on 4.3 years of data.

Text Figure 4-B-6c: Groundwater Elevations (2002 to 2010) for PGMN Well W0000164-3



For PGMN well No. W0000164-3, the MK test did not detect a significant trend, using five years of data. The SK test detected an upward trend, based on five years of data.

Based on the PGMN data trend analyses provided by MECP for one bedrock PGMN well and two overburden PGMN wells located within 10 km of the Nestlé (Erin) Site water taking, no data trends were identified that would suggest a depletion in the availability of groundwater resources for this area. However, it should be noted that the most recent PGMN water level data used in the MECP assessment is for 2010. A summary of the PGMN data trend analyses for the regional study area is provided within Section 4 of the main report for the Guelph WQSA.

4B.4.3 Ontario Low Water Response Program

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

> Note: Specific PTTWs may have conditions requiring mandatory reductions of water takings during low water events. Upon renewal of their water bottling permit, the above decreases will be mandatory based on 3-month average actual flow as outlined in the guidance for bottled water renewals (MOECC, 2017).

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water (and possibly shallow groundwater where directly connected to surface water), and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the Site.

The OLWR database indicates the GRCA receives OLWR notification data for the CA as a whole along with separate notification data for each subwatershed. Since notification data for the subwatersheds is not reported for all years, only data for the CA as a whole is discussed herein. A general review of the OLWR database indicates that a total of 22 Level 1 notifications, three Level 2 notifications, and one Level 3 notification were sent to the GRCA between 2000 and

August 2018. Notifications were sent to the GRCA every year except in 2002, 2003, 2006 – 2008, 2011, 2013 and 2014. Instances when more than two notifications were issued in the same calendar year occurred in 2000 (three Level 1 notifications), 2004 (two Level 1 notifications and one Level 2 notification), 2010 (four Level 1 notifications), 2015 (three Level 1 notifications), and 2016 (one Level 1 notification, one Level 2 notification and one Level 3 notification). The only Level 3 notification to be issued between 2000 and August 2018 occurred in early December 2016. The OLWR notification database indicates the GRCA has declared Low Water Condition Alerts in 12 of 19 years with 'no Alerts' declared in 2004, 2006, 2010, 2011, 2013, 2014, and 2017. A summary of the 'declared Alerts' is as follows:

- Mid-July 2002 to late July 2003: a Level 1 Low Water Condition Alert was posted in mid-July 2002, which was raised to a Level 2 Low Water Condition Alert a week later, and lowered back down to a Level 1 in early October. The Low Water Condition Alert ended entirely in late July 2003 (although records indicate a Level 2 Low Water Condition Alert was later briefly posted on August 28, 2003, for less than one week);
- Mid-August to early December 2005: a Level 2 Low Water Condition Alert was posted in mid-August 2005, and was lowered to a Level 1 Low Water Condition Alert in mid-October. The Low Water Condition Alert ended entirely in early December 2005;
- Late August 2007 to late March 2008: a Level 1 Low Water Condition Alert was posted in late August 2007, which was raised to a Level 2 in late September 2007, and lowered back to a Level 1 at the beginning of March 2008. The Low Water Condition Alert ended entirely in late March 2008;
- Mid-September to early October 2009: a Level 1 Low Water Condition Alert was posted;
- Late June to late August 2012: a Level 1 Low Water Condition Alert was posted in late June 2012, which was raised to a Level 2 in early July. The Low Water Condition Alert ended entirely in late August 2012;
- August to mid-November 2015: a Level 1 Low Water Condition Alert was posted;
- July to late October 2016: a Level 1 Low Water Condition Alert was posted in July 2016, which was raised to a Level 2 in mid-August. The Low Water Condition Alert ended entirely in late October 2016; and,
- Late July to end of August 2018: a Level 1 Low Water Condition Alert was posted.

While the reporting of OLWR notifications does not indicate any specific long-term trends, it is apparent that the reporting of Level 1 and 2 Notifications and the declaration of Level 1 and 2 Low Water Condition Alerts has been necessary within the boundaries of the CAs and mostly on a seasonal (summer and early fall) basis.

4B.4.4 Water Budget Analyses

The water taking well and a portion of the Nestlé (Erin) Site are located in the Eramosa Above Guelph subwatershed, part of the Grand River watershed. A stress assessment was performed for both surface water and groundwater within the subwatershed. The Eramosa Above Guelph subwatershed was identified as having a moderate potential for surface water stress, based on a Tier 2 water budget assessment (AquaResource Inc., 2009). The potential for groundwater stress was assessed for an area enclosing the Eramosa River (including the water taking well and a portion of the Nestlé (Erin) Site and much of the Speed River. Under current demand, the area was determined to have a potential groundwater stress classification of low and moderate under maximum monthly demand and average demand, respectively. Based on the future demand, the stress classification was determined to be moderate under both average and maximum monthly water demand. The largest water use sector in the groundwater assessment area is municipal water supply (71% of average annual water demand) followed by quarry dewatering at 17% of the demand.

Within the CVSPA, the West Credit River subwatershed, in which part of the Nestlé (Erin) Site is located, it was determined through the Tier 2 water budget that the surface water and groundwater potential stress classifications were both low (CVC, 2015). Tier 3 Assessments are only conducted for subwatersheds which have been identified as having moderate or significant potential stress in the Tier 2 stress assessment, and have municipal water supply system. Therefore, a Tier 3 assessment was not recommended for the municipal water supplies of Hillsburgh and Erin in West Credit River subwatershed. It should be noted that the Nestlé (Erin) Site does lie within the study area boundary/modelled area for the Guelph/Guelph Eramosa Tier 3 assessment, however no specific information regarding water quantity in the West Credit River subwatershed was reported in the assessment.

In summary, based on the findings of the Tier 2 water budgets, the Nestlé (Erin) Site is located in an area where hydrologic stress has been identified as low to moderate.

4B.5 IMPACT ASSESSMENT

The following section provides a general assessment of the potential for water taking at the Nestlé (Erin) Site to result in water quantity interference with other groundwater uses and the natural environment.

4B.5.1 Municipal Groundwater Use

The Town of Erin is serviced by two municipal groundwater systems located within 6 km of the Nestlé (Erin) Site: the Erin Municipal Water system located in the village of Erin and the Hillsburgh Municipal Water System located in the village of Hillsburgh. The municipal wells are located within the jurisdiction of the CVC and obtain water from the bedrock aquifer (Blackport, 2010). The Erin system services a population of approximately 2,500 residential and commercial customers. Connections include approximately 870 residences, 110 non-residential properties, 100 mobile homes and 10 cottages. The Hillsburgh system services a population of approximately 810, with 275 residential and 4 non-residential properties connected (Town of Erin, 2018). Properties in the remainder of the town are serviced by private wells. Based on the 2016 Census Profile (StatCan, 2016), the village of Hillsburgh has a population of 1,124 with approximately 214 on private wells.

The bedrock groundwater flow direction in the area of the Nestlé (Erin) Site is to the south-southeast, towards the Credit River

The water quality wellhead protection areas for the Hillsburgh Village wells (as shown on Figure 4-B-2) extend to the northwest, indicating that groundwater flow in the vicinity of this village is in a general northwest-southeast direction. As the Nestlé (Erin) well is located south of the Hillsburgh Village, it is located downgradient of the Hillsburgh municipal wells; thus, obtaining groundwater that has moved passed the Hillsburgh municipal wells. The wellhead protection areas for the Erin Village wells, located approximately 5 km to the east of the Nestlé (Erin) well, extend northwest-southeast and southwest-northeast.

In 2005, modeling work was performed for Wellington County that indicated that the pumping from TW1-88 does not interfere with the wellhead protection area for the two Hillsburgh municipal wells located 1.5 km north-northeast of TW1-88 (Golder, 2017).

Per the Town of Erin's Official Plan (2012), anticipated population growth from 2016 to 2031 is 42% for the Village of Erin and 50% for the village of Hillsburgh. As presented earlier, the reported takings for the associated water taking permits have been less than 20% of the maximum permitted annual amounts for 2016 and 2017. Based on the information reviewed, no 'planned' new municipal groundwater supply systems are apparent for the vicinity of the Site as the existing systems with the currently approved water taking volumes are anticipated to be able to support the projected population growth.

In summary, the general assessment of potential water quantity interference with existing or planned municipal water supply systems did not identify any potential for unacceptable impact/interference.

4B.5.2 Well Interference Potential

Based on the studies reviewed, the Nestlé (Erin) well obtains water from the dolostone bedrock aquifer of the Guelph Formation. The majority of the private well water supply wells in the area are completed in the bedrock aquifer. There are four domestic wells located within 500 m of the Nestlé (Erin) well, with the closest well located approximately 220 m to the west. There have been no impacts to any private domestic wells over the last 15 years of monitoring.

Based on the short-term pumping test conducted in 2001, the zone of influence was determined to be approximately 1,000 m from TW1-88 to the west, north and east, and greater than 700 m to the south and southwest.

In 2013, the results of an increased rate from 773 to 946 LPM influenced the production well TW1-88, the on-site bedrock well MW5A-05 and the closest off-site domestic well (D3). At the bedrock monitoring well (MW5A-05) a drawdown of 1.0 m was observed. The recent annual report indicates that the water levels have been stable from 2013 to 2018, as shown in Text Figure 4-B-7c. The off-site domestic well (D3), located 220 m from TW1-88, exhibited a 0.5 m drawdown from the pumping. The recent annual report indicates that the water levels have been stable from 2013 to 2018, as shown in Text Figure 4-B-7d.

No new, high water use activities are apparent near the Nestlé (Erin) Site. Any new neighbouring land development on private wells and/or any new PTTW of significant scale are expected to require a site specific hydrogeological study and well interference assessment in support of the proposed development/water taking. Continued use of the Nestlé (Erin) Site well in accordance with the current PTTW conditions is not anticipated to cause detrimental impacts to private water wells.

4B.5.3 Impact to Surface Water and Natural Functions of the Ecosystem

The production well and part of the Nestlé (Erin) Site is located in the Eramosa Above Guelph subwatershed of the Grand River Watershed. The Speed-Lutteral-Swan Creek Wetland Complex is partially located on the Site and on-site ponds discharge into the unnamed drain that flows into the Eramosa River. It was determined through a Tier 2 water budget that the Eramosa Above Guelph subwatershed has a moderate potential for surface water stress, and the Upper Speed groundwater assessment area (in which the production well and part of the Nestlé (Erin) Site are located) has a moderate potential for groundwater stress under future demand (AquaResource Inc., 2009).

The vertical hydraulic gradients in the Erin Branch of the Credit River are generally downwards and therefore groundwater discharge to the Credit River is expected to be minimal. The West Credit River subwatershed, in which part of the Nestlé (Erin) Site is located, consists of the provincially significant West Credit Wetland Complex that extends through the villages of Hillsburgh and Erin. The Complex, largely dominated by eastern white cedar and poplar swamps, is an important contributor to the self-sustaining heritage brook trout population native to the area (CVC, 2015). It was determined through a Tier 2 water budget that the stress classifications within the West Credit River subwatershed for both surface and groundwater potential stress were low (CVC, 2015).

Per the conditions of PTTW 3716-8UZMCU on-site and off-site surface water levels, stream flow and water levels in nested mini-piezometers are monitored upstream and downstream of the Nestlé (Erin) Site. The water levels are monitored continuously at six monitoring locations and stream flows are monitored monthly at four locations. There are seven mini-piezometer locations that water levels are monitored continuously at shallow and deep monitors. The observed surface water data is relatively stable over time, with no observable increasing or decreasing trend.

Based on the findings of this review, continued water takings at the permitted water taking levels are not expected to impact surface water and natural functions of the ecosystem. The monitoring program currently in place serves to identify any possible changes to these features.

4B.6 SUSTAINABILITY OF WATER RESOURCES

Water resources are considered sustainable if the total amount of water entering, leaving, and being stored in the system meet existing needs without compromising the ability to meet the needs in the future. Typical indicators used to assess the sustainability of water quantity include Water Budgets completed at the watershed/subwatershed scale and/or for the specific water taking(s) and the evaluation of water level data for trends over time to ensure resources are remaining in a steady state. The following provides a general assessment of the sustainability of regional water resources and of the potential impact from the Nestlé (Erin) water taking on sustainability, now and in the future.

Regional Water Resources

The characterization of the regional study area indicates that the water taking well and a portion of the Nestlé (Erin) Site is located in the Eramosa Above Guelph subwatershed and a portion of the site is located within the West Credit River subwatershed. The Eramosa Above Guelph subwatershed was identified as a moderate stress for surface water, based on a Tier Two Water Budget Assessment. The Site is also located within the Upper Speed groundwater assessment area and based on future demand, the stress classification for the Upper Speed assessment area is moderate (AquaResource Inc., 2009). In the West Credit River subwatershed, in which part of the Nestlé (Erin) Site is located, it was determined through a Tier Two water budget that the surface water and groundwater potential stress classifications were both low (CVC, 2015). Consequently, stresses presented by existing and future demand are not an identified concern for the sustainability of water resources within the regional study area.

The OLWR Program uses real time surface water monitoring data collected from the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. BluMetric's review of the OLWR Program notification data (2000 to August 2018) for the GRCA did not identify any specific trends indicating the depletion in the availability of surface water (and possibly shallow groundwater where directly connected to surface water) resources. While Level 1 and Level 2 Low Water Condition Alerts have been necessary within the boundaries of the CVC, the information indicates these have been in response to extended dry seasonal conditions.

BluMetric's review of PGMN groundwater level data for three wells located within 10 km of the Nestlé (Erin) water taking also did not identify any specific trends indicating a potential depletion in the availability of regional groundwater resources.

The Tier Three Assessment Water Budget models were used to delineate the WHPA-Q (Groundwater Vulnerable Area) and IPZ-Q (Surface Water Vulnerable Area). The WHPA-Q and IPZ-Q are the areas where the municipal drinking water systems could be affected by other existing, new, or expanded water takings (Matrix, 2017). Since delineation of the original WHPA-Q and IPZ-Q for the City of Guelph's water supply was initiated in 2008, it was recently determined that they should be re-delineated. This was completed to ensure that the Tier Three model reflected revised plans for future land development in 2017 as well as current, non-municipal permitted water use including water taking at the Nestlé (Erin) Site. These consumptive takings were later used as the starting point in the Risk Management Measures Evaluation Process (RMMEP) described in the Guelph – Guelph/ Eramosa Water Quantity Policy Development Study Threats Management Strategy (Matrix, June 2018). The threats identified as significant were assessed at progressively finer levels of detail in order to rank which threats have the greatest impact on municipal drinking water systems within the WHPA-Q or IPZ-Q. In summary, the Tier Three Assessment scenarios predicted that the GGET municipal wells can meet current water demands; though the Tier Three model scenarios also predicted that the City's Queensdale municipal well may not be able to meet future needs under normal climate conditions and during prolonged drought (Matrix, 2017). The City's other wells and Guelph/Eramosa Township's (GET) wells were expected to meet future needs under all scenarios. However, the Tier Three Assessment indicated that there is a high level of uncertainty for the results of the City's Arkell Well 1. Of note, because water pumped from the Eramosa River intake is not pumped directly into the City of Guelph's drinking water system, and that the Glen Collector was included in the Risk Assessment for groundwater, a Risk Assessment for the surface water supply was not completed. However, to ensure the sustainability of the Glen Collector and the Eramosa intake, the IPZ-Q, in which the Nestlé (Erin) Site is located, was assigned the same Risk Level (Significant) as the WHPA-Q, containing the Glen Collector. Furthermore, the Tier Three Assessment predicted that groundwater discharge into some coldwater streams may be reduced by 10% or more as municipal pumping is increased to future rates. This magnitude of impact resulted in a Moderate Risk Level being applied to the WHPA-Q; however, the Moderate Risk Level associated with the surface water impacts was superseded by the Significant Risk Level designation (Matrix, June 2018).

In addition, as a follow up to the GGET Tier Three Study, a Climate Change Assessment was conducted for the GGET WHPA-Q area by modelling predicted Climate Change scenarios to determine potential impacts on the sustainability of the groundwater and surface water resources (Matrix, 2018). Due to expected warmer temperatures and increased precipitation in the winter, the modelling exercise suggests a slight increase in recharge; thus, no impact to the sustainability of the groundwater resource is anticipated. Similarly, no stress concerns were identified for the sustainability of regional surface water quantity resources, which appear to be sustainable under current pumping conditions (Matrix, 2018). However, the risk ranking exercise for IPZ-Q threats has not been completed at this time. The net consumptive water use within the IPZ-Q is small as compared to the natural variability of flow of the Eramosa River at the intake; therefore, on an average basis, consumptive water taking threats are not expected to impact the municipal surface water intake's ability to pump. Further evaluation of the threats in the IPZ-Q will be completed as part of the Climate Change Assessment being carried out. In addition, assessments of environmental flow needs in the Guelph WQSA have focused on the Speed River and the Eramosa River. Target thresholds were quantified for the two rivers, and it was determined that flow requirements are generally achieved in most years. Matrix Solutions Inc. (2018) recommended that the City of Guelph maintain its current groundwater and surface water monitoring program to ensure that the hydrologic regime in the Eramosa River is maintained.

A moderate potential for groundwater stress exists for the sustainability of regional groundwater resources in the future under projected municipal groundwater demand. As discussed in Section 4.3.3 of the main report, available reports and communication with local Water Managers determined that, within the Guelph WQSA, the use of water resources is sustainable under existing population, land use and climate conditions. However, findings from the Local Area Risk Assessments indicate that population growth is the most significant stressor on the groundwater resources in general. In contrast, simulated recharge reduction due to land use changes had a near negligible effect on water levels in the Guelph municipal supply wells, indicating a minimal effect on the groundwater resources in general.

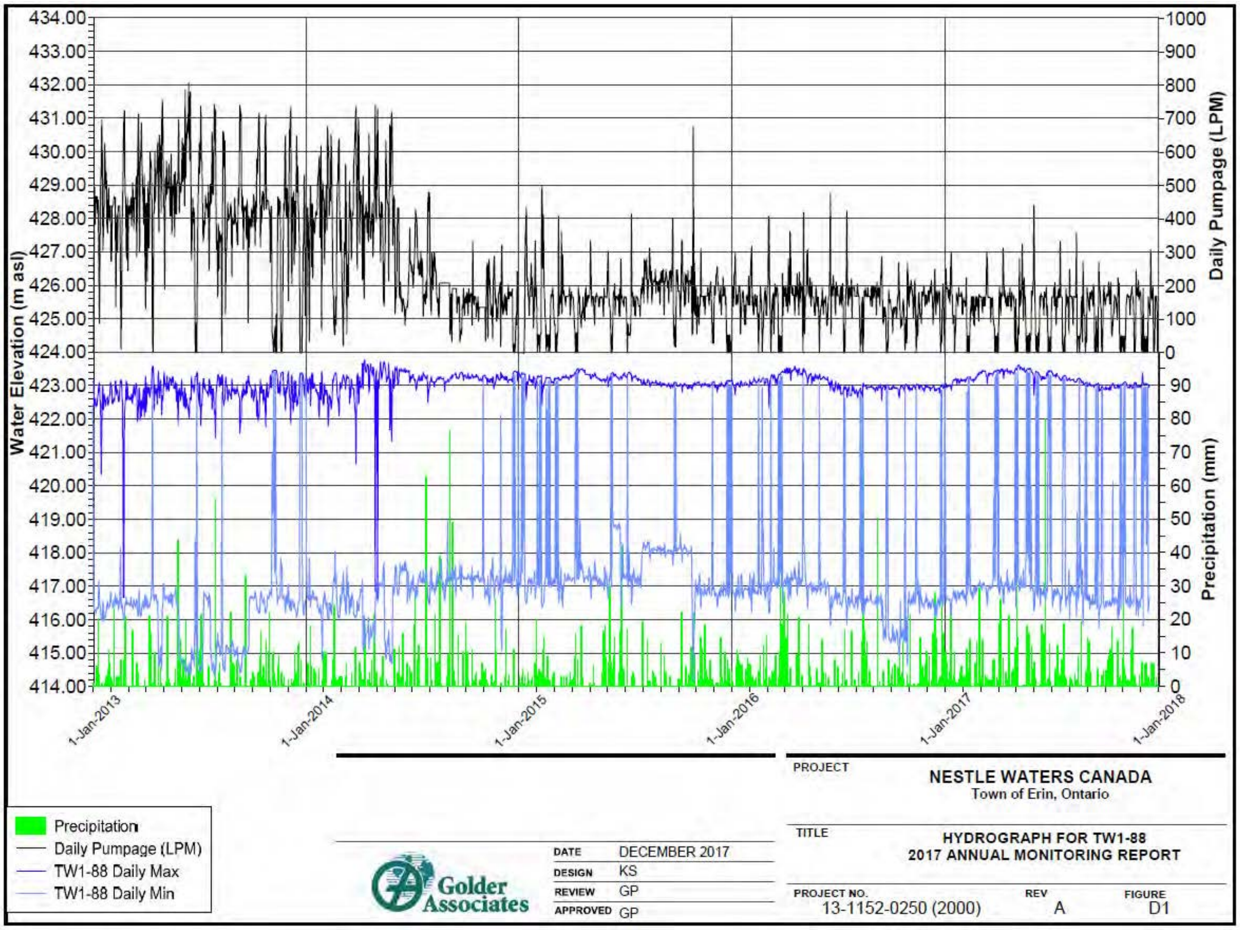
Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater and surface water resources appear to be sustainable under existing conditions. However, groundwater resources may become unsustainable in the future due to population growth and the associated increase in water demand, and increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs. The reader is referred the Guelph WQSA (Section 4 of the main report) for a more detailed discussion of regional groundwater and surface water resources.

Nestlé (Erin) Water Taking

Historical information relating to the Nestlé (Erin) Site indicates the groundwater resources have been used for commercial water bottling since 2000, and water takings have been permitted since the late-1980s. The reported water taking amounts from 2005 to 2017 have consistently remained below 55% of the maximum permitted annual amount. Maximum withdrawal rates and maximum annual withdrawal amounts through the PTTW have remained unchanged since 2005. No documented well interference complaints/impacts from the water taking were identified in the files provided for review.

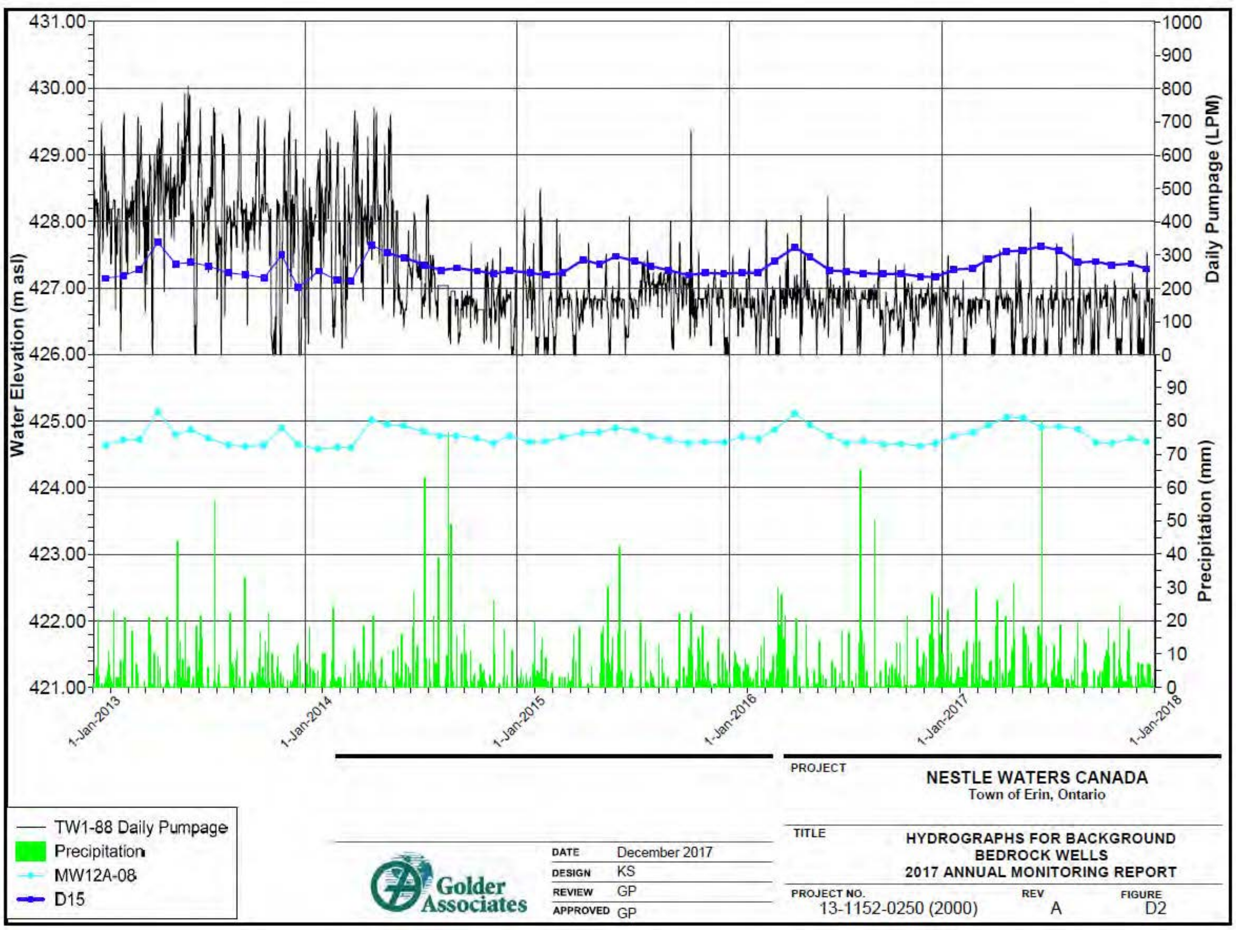
The 2017 annual monitoring report included monitoring of groundwater levels in the overburden and bedrock aquifers, as well as monitoring of stream flows, water levels and vertical gradients have not provided any indication of unacceptable or increasing stress to groundwater or surface water due to the water taking. The hydrograph for long-term groundwater elevation data from 2013 to 2018 for TW1-88 (water taking well), MW12A-08 and D15 (background bedrock wells), and MW5A-05 and D3 are reproduced below and do not indicate any decreasing trend in groundwater elevations.

Text Figure 4-B-7a: Groundwater Elevations (2013 to 2018) in TW1-88 (Bedrock Aquifer)



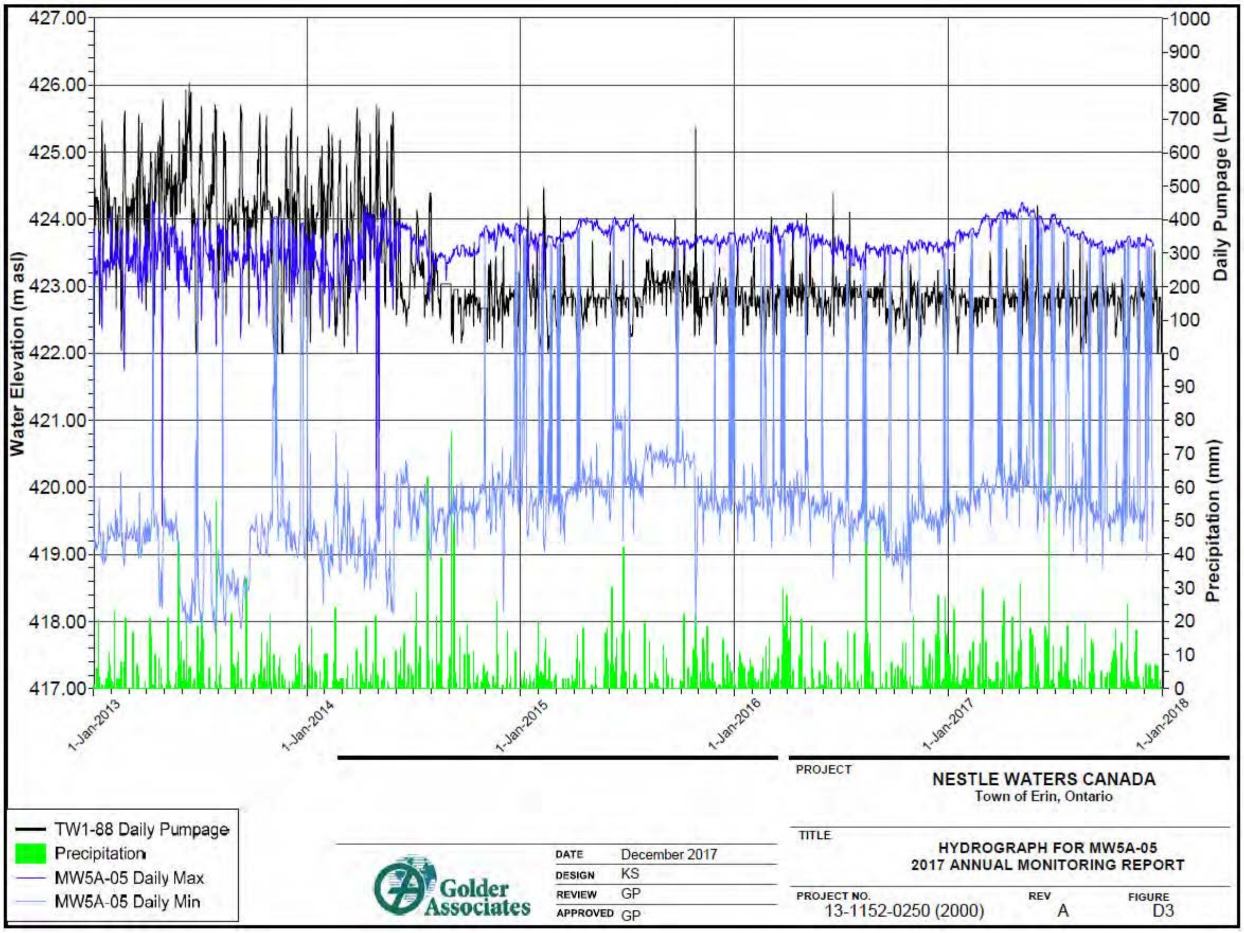
Source: Figure D1 of Golder, 2018

Text Figure 4-B-7b: Groundwater Elevations (2013 to 2018) in Background Bedrock Wells



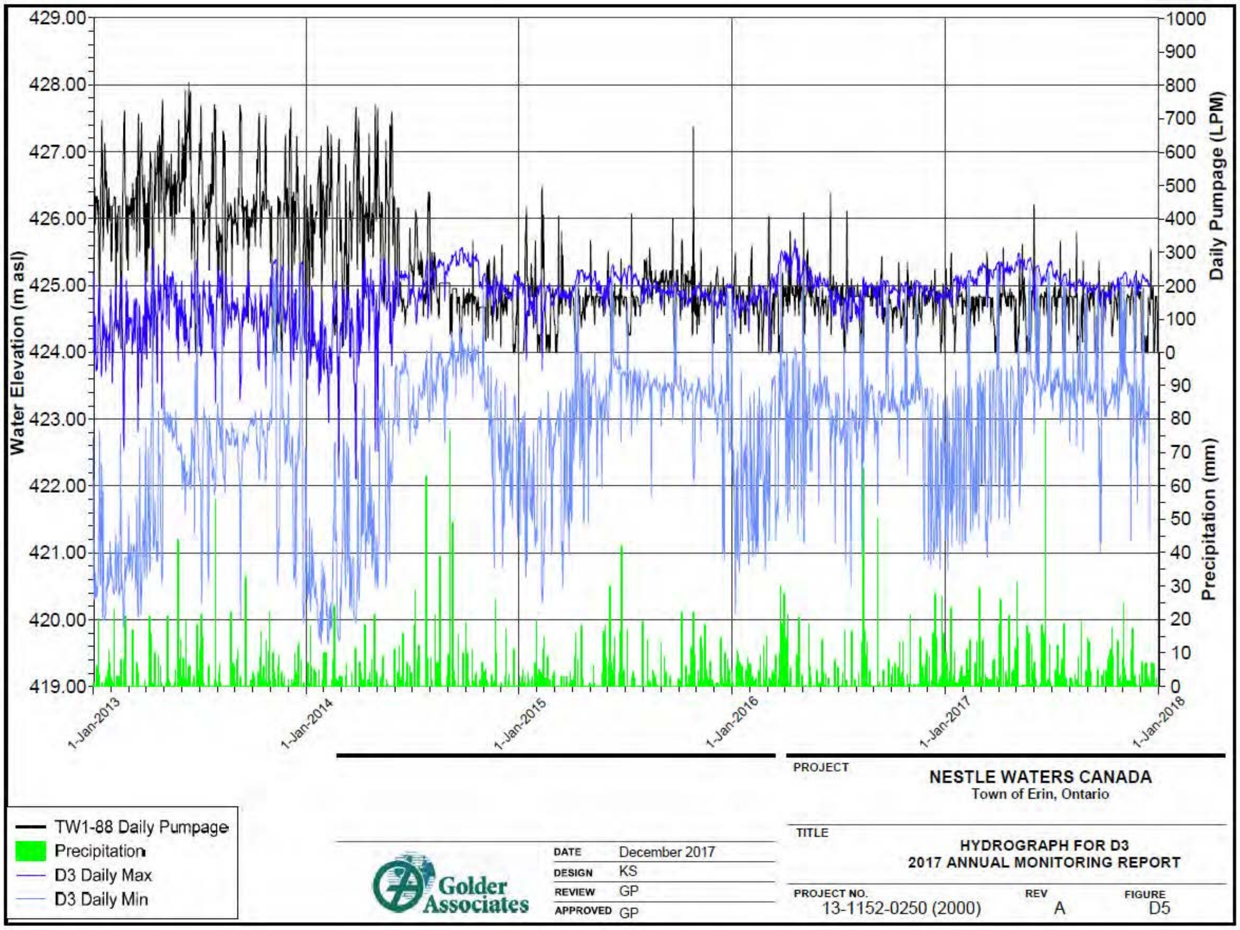
Source: Figure D2 of Golder, 2018

Text Figure 4-B-7c: Groundwater Elevations (2013 to 2018) in MW5A-05



Source: Figure D3 of Golder, 2018

Text Figure 4-B-7d: Groundwater Elevations (2013 to 2018) in D3



Source: Figure D5 of Golder, 2018

A review of the WTRS database did not identify any other high volume water taking activities within the study area. The information review also did not identify any other planned water taking activities that might contribute to the overall cumulative effects on local groundwater resources.

Based on the information reviewed, there are no indications that the Nestlé (Erin) water taking is having an impact on the sustainability of existing and future water resources at the current or permitted levels of taking. Consequently, it is BluMetric's opinion that the water taking is being managed sustainably. The permit requirements/conditions as summarized in Section B.1 are deemed adequate, with a monitoring program in place to identify any potential changes to Site conditions. Current permit requirements/conditions in place appear to be suitable in identifying potential issues should climate change and growth pressures become a larger factor in the sustainability of local water resources under current water taking quantities.

4B.7 GAPS AND RECOMMENDATIONS

The assessment of the Nestlé (Erin) Site indicated that there are no information gaps or site-specific recommendations.

Based on the assessment of water takings at Nestlé (Erin), Aquaterra (Hillsburgh) (Appendix A), and Nestlé (Aberfoyle) (Appendix C), as well as at various other bottling facilities assessed by BluMetric (2019). The reader is referred to Section 11 of the main report for a summary of the gaps and recommendations.

4B.8 FIGURES

Figures are provided in Appendix A of the main report.

APPENDIX 4-C

(Nestlé Canada Inc., Aberfoyle WBSA)

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4C. NESTLÉ WATERS CANADA – ABERFOYLE SITE

4C.1 BACKGROUND AND HISTORY

Nestlé Waters Canada ("Nestlé") currently draws water for water bottling purposes from a single bedrock well on Lot 23, Concession 7, in the community of Aberfoyle in the Township of Puslinch, Ontario, herein referred to as the Nestlé (Aberfoyle) Site. The Site has a civic address of 101 Brock Street South, Puslinch, ON, and falls within the jurisdictions of the Ministry of the Environment, Conservation and Parks (MECP) Guelph District Office and the Grand River Conservation Authority (GRCA). The Nestlé water source well location and Site boundaries are indicated on Figures 4-C-1a and 4-C-1b.

The Nestlé (Aberfoyle) Site is located at the southern boundary of the Hamlet of Aberfoyle. Aberfoyle Creek flows through the length of the Site, in a general northeast to southwest direction.

Ownership of the Site dates back to at least 1980, when well TW3-80 (the current source well) was constructed and a Permit to Take Water (PTTW) was issued for a fish hatchery operation. Sometime before 1993, Site ownership passed to Aberfoyle Springs Inc., a commercial water bottling operation. The Site and the commercial water bottling operation were purchased by Perrier Group of America, a Nestlé Company, in 2000. Water withdrawal for the purpose of commercial water bottling is known to have occurred continuously since at least 1994.

An approximate timeline of events relevant to the PTTW history of the Nestlé (Aberfoyle) Site is provided in Table 4-C-1.

Table 4-C-1: Nestlé Aberfoyle PTTW History Summary

Year	Event
1980	Well TW3-80 was constructed in April 1980 for a proposed fish farming operation by Aberfoyle Fisheries (a division of Custom Concrete). **PTTW 80-P-2038** (not reviewed by BluMetric Environmental Inc. ("BluMetric")) was issued to a fish hatchery operation (presumed to be Aberfoyle Fisheries) on **December 5, 1980**, with an expiry date of March 31, 1981. The PTTW allowed water to be pumped at a rate of 310 imperial gallons per minute (igpm) (1,409 L/minute) at well TW1-80, and at a rate of at least 780 igpm (3,546 L/minute) at well TW3-80.
1981	**PTTW 81-P-2013** was issued to Aberfoyle Fisheries on **March 31, 1981** for commercial fish farming, with an expiry date of March 31, 1986. The maximum rate and amount of taking were 1,100 igpm (5,000 L/min) or 1,577,000 igpd (7,169,184 L/day) from one or both wells (TW1-80 and TW3-80). The permit required monitoring of test wells and private wells to determine the extent and amount of interference with local wells. A report with the results of the monitoring was required to be submitted to the ministry at the time of permit renewal.
1986	**PTTW 81-P-2013** was renewed on **March 31, 1986**, with an expiry date of March 31, 1991. The PTTW was issued to Aberfoyle Fisheries for commercial fish farming. The maximum rate and amount of taking were identical to that previously authorized. The permit required monitoring of test wells and private wells to determine the extent and amount of interference with local wells. A report with the results of the monitoring was required to be submitted to the ministry at the time of permit renewal.
1993	Water well records for wells on the Site indicate that the Site was purchased by Aberfoyle Springs Inc. sometime before 1993.
1994	**PTTW 81-P-2013** was cancelled on December 28, 1994. **PTTW 94-P-2072** (not reviewed by BluMetric) was issued on **December 23, 1994** to Aberfoyle Springs Inc. for commercial water bottling, with an expiry date of January 31, 1997. The permit allowed water to be taken from TW1-80 at 3,637 L/minute or 5,236,992 L/day and TW3-80 at 114 L/minute or 163,656 L/day. The permit required monitoring of test wells and private wells to determine the extent and amount of interference with local wells. A report with the results of the monitoring was required to be submitted to the Ministry at the time of permit renewal. The permit also required an assessment by an aquatic biologist in the summer of 1995 of the tributary of Aberfoyle Creek beginning on-site and extending to the crossing at Regional Road 46. A report of this assessment had to be submitted to the ministry by January 31, 1996.
1995	TW1-80 was sealed and abandoned in November 1995.
1996	**PTTW No. 96-P-2036T** was issued to Aberfoyle Springs Co. on **August 9, 1996** for a pumping test. The expiry date of the permit was September 30, 1996. The permit allowed water to be taken from one drilled well at 455 L/min or 654,624 L/day.
1997	Aberfoyle Springs applied for a permit to take 800 igpm (3,637 L/minute), up to a maximum of 1,152,000 igpd (5,237,096 L/day). Aberfoyle Springs and the Ministry of the Environment (now the MECP) remained in negotiation over the application for the next 3 years (source: Environmental Registry record no. IA7E1487).

Year	Event
2000	**PTTW 00-P-2165** (not reviewed by BluMetric) was issued on **December 1, 2000**, with an expiry date of March 31, 2002, for the purpose of commercial water bottling. This PTTW replaced 94-P-2072. The PTTW allowed for the withdrawal of water from TW3-80 at a maximum withdrawal rate and withdrawal amount of 400 igpm (1,818 L/minute) and 576,000 igpd (2,618,500 L/day), respectively. The permit required monitoring of test wells and private wells to determine the extent and amount of interference with local wells. A report with the results of the monitoring was required to be submitted to the ministry at the time of permit renewal. In December 2000, the Site was purchased by the Perrier Group of America, a Nestlé Company.
2002	An application for a permit renewal was submitted on **February 28, 2002** (CRA, 2011). PTTW 00-P-2165 expired on March 31, 2002. Water takings continued until a new permit was obtained in 2003 (CRA, 2011).
2003	**PTTW 00-P-2165** was renewed on **April 30, 2003**, with an expiry date of May 31, 2005. The PTTW was issued to Nestlé Waters Canada Division of Nestlé Canada Inc. The PTTW allowed for a maximum withdrawal rate of 400 igpm (1,816 L/minute) and 576,000 igpd (2,618,000 L/day). The permit required monthly water level monitoring in selected overburden and bedrock wells and surface water locations. The permit also required the submittal of annual monitoring reports.
2004	**PTTW 2372-63WMFC** was issued to Nestlé Waters Canada on **August 27, 2004** for a pumping test, with an expiry date of October 31, 2004. The PTTW allowed for a 72-hour pumping test to be carried out at TW3-80 at a maximum rate of 800 igpm (3,637 L/minute) or 5.2 million L/day. The purpose of the pumping test was to evaluate the zone of influence for that well at a pumping rate higher than the existing permitted rate.
2005	**PTTW 6673-6CAJWK** was issued to Nestlé Waters Canada on **June 30, 2005**, with an expiry date of June 30, 2007. The PTTW allowed water to be withdrawn from well TW3-80 for the purpose of commercial water bottling, at a maximum withdrawal rate and amount of 2,500 L/minute and 3.6 million L/day, respectively. The PTTW included requirements for a monitoring program that included: • Continuous monitoring of groundwater levels in 4 on-site bedrock wells (including TW3-80) and 3 on-site overburden wells; • Monthly monitoring of groundwater levels at 12 off-site bedrock wells and 5 off-site overburden wells; • Monthly monitoring of water levels at two off-site ponds; • Monthly monitoring of water levels and monthly flow measurements in Aberfoyle Creek at SW1 (where it enters the Site) and SW2 (where it leaves the Site); and, • Continuous monitoring of water levels in a multi-level piezometer in Aberfoyle Creek. The PTTW also required the permit holder to identify, in consultation with the Ministry of Natural Resources (now the Ministry of Natural Resources and Forestry, MNRF), four locations in the portion of Aberfoyle Creek passing through the Site for continuous surface water temperature monitoring. Monitoring was to commence within 30 days of the issuance of the PTTW.
2008	**PTTW 7043-74BL3K** was issued to Nestlé Canada Inc. on **April 17, 2008**, with an expiry date of April 30, 2010. This PTTW cancelled and replaced PTTW 6673-6CAJWK, issued in 2005. The PTTW allowed water to be withdrawn from well TW3-80 for the purpose of commercial water bottling, at the same rates and amounts as in the previous permit (2,500 L/minute, 3.6 million L/day). The PTTW included requirements for a monitoring program that included: • Continuous monitoring of groundwater levels in 13 on-site bedrock wells (including TW3-80) and 11 on-site overburden wells; • Monthly monitoring of groundwater levels at 18 off-site, private bedrock wells and 2 off-site, private overburden wells; • Continuous monitoring of water levels in Aberfoyle Creek at SW1 and SW2; • Monthly monitoring of flows and the development of stage-discharge curves at SW1 and SW2;

Year	Event
	• Monthly monitoring of water levels in three off-site locations on Aberfoyle Creek, and in two off-site ponds; • Continuous monitoring of multi-level piezometers along Aberfoyle Creek; and, • Continuous monitoring of temperature at the sediment-water interface at 5 on-site stations along Aberforyle Creek. The PTTW also required the permit holder to: • Install an additional multi-level piezometer and continuous temperature monitor within Aberfoyle Creek at a location upstream near Brock Road (adjacent to the Site's northeastern boundary), within 30 days of issuance of the permit; • Determine vertical hydraulic conductivity at the locations of the multi-level piezometers, including the new multi-level piezometer (see previous bullet); • Conduct an extended pumping test during seasonal low surface and groundwater conditions, in order to determine equilibrium conditions at the monitored groundwater wells when TW3-80 is pumped at 95% to 100% of the permitted capacity; • Characterize the groundwater source, and assess the potential connection of the source groundwater with surface water, through the collection of groundwater samples and laboratory testing of the water's general chemistry and microbiology; • Define the full extent of the cone of influence to the northeast of TW3-80 and on the east side of Brock Road; • Complete a baseline biological inventory and provide recommendations for an ongoing biological monitoring program; and, • Prepare a plan for a stream habitat mapping survey of Aberfoyle Creek in the reach between Aberfoyle Mill Pond and the confluence with Mill Creek.
2009	An extension to **PTTW 7043-74BL3K** was granted on **October 30, 2009**, moving the expiry date back to April 30, 2011. The extension was granted in order to allow Nestlé Canada Inc. to meet the condition for conducting an extended pumping test during seasonal low surface water and groundwater conditions; the summers of 2008 and 2009 experienced significant and frequent precipitations events, such that appropriate low flow conditions were not established. The extended pumping test was ultimately completed between August 27 and October 12, 2010.
2011	Test well TW2-11 was completed on September 26, 2011, near the Site's southwestern boundary. The test well was constructed for use as a facility well, to supplement flow to a pond behind the plant for emergency fire flow purposes. **PTTW 1763-8FXR29** was issued to Nestlé Canada Inc. on **April 29, 2011**, with an expiry date of July 31, 2016. The PTTW allowed water to be withdrawn from well TW3-80 for the purpose of commercial water bottling, at the same rates and amounts as in the previous permit (2,500 L/minute, 3.6 million L/day). The monitoring program required as a condition of the permit was similar to the program outlined in the 2008 permit, with the following changes: • Addition of 10 new off-site bedrock wells for continuous monitoring of groundwater levels (bringing the total up to 23); • Replacement and removal of some of the off-site, private bedrock wells for monthly monitoring, reducing the list from 18 to 16 wells; • Replacement and removal of some of the on-site overburden wells for continuous monitoring of groundwater levels, reducing the list from 11 to 10 wells; • Removal of monthly monitoring of groundwater levels at the 2 off-site, private overburden wells; • Replacement and removal of some of the locations for continuous monitoring of multi-level piezometers, reducing the list from 7 to 6 locations; and, • Addition of a new location for continuous monitoring of temperature at the sediment-water

Year	Event
	interface along Aberfoyle Creek (increasing the total to 6). The PTTW also required the permit holder to: • Undertake wetland monitoring and redd (fish spawning nest) surveys; • Determine the total amount of water taken each month. If the monthly amount exceeded 83.7 million L, the permit holder was to submit multi-level piezometer data to the director within 30 days of the end of the calendar month; and, • Submit for review and approval a chemical isotopic analysis work plan for source water characterization of TW3-80 recharge.
2012	**PTTW 6763-8VFNDQ** was issued to Nestlé Canada Inc. on **August 20, 2012**, with an expiry date of July 31, 2013. The PTTW allowed water to be withdrawn from TW2-11 to conduct a pumping test at a maximum withdrawal rate and amount of 945 L/minute and 1,360,800 L/day, respectively, for up to 40 days. An amendment to this PTTW was issued on August 31, 2012, allowing the maximum rate of taking to be increased to 350 U.S. gpm (1,325 L/minute) during the pumping test, upon written approval from the Director.
2013	PTTW 1763-8FXR29 was amended with **PTTW 1381-95ATPY** on **December 19, 2013**, with an expiry date of July 31, 2016. The amendment allowed for a second bedrock well, TW2-11, without any change in the total daily rate or amount of taking. The taking from TW2-11 was limited to supplying water to the on-site pond for firefighting purposes, with a maximum withdrawal rate and amount of 475 L/minute and 684,000 L/day, respectively. The monitoring program requirements are summarized in Table 4-C-3.
2015	An amendment to the water taking limits of **PTTW 1381-95ATPY** was issued to Nestlé Canada Inc. on **February 5, 2015**. The amendment allowed for a short-term pumping rate increase to a maximum of 2,575 L/minute for the sole purpose of sanitization of the well. The maximum withdrawal amount remained at 3.6 million L/day.
2016	An application to renew PTTW 1381-95ATPY (expiry date of July 31, 2016) was submitted by Nestlé Canada Inc. in April 2016. As a decision on the application had not been made, and in accordance with Section 34.1(6) of the Ontario Water Resources Act, the existing PTTW is to remain in force until the Signing Director makes a decision to renew the permit or refuse the renewal.

General information about the source wells on the Nestlé (Aberfoyle) Site is provided in Table 4-C-2.

Table 4-C-2: Summary of Water Taking Sources

Source Name	Type/Date of Install	Well Record ID	Total Well Depth	Completion Unit	Screened Interval	PTTW No. 1381-95ATPY		
						Max. Taken Per Minute (L)	Max. Num. of Hours Taken per Day	Max. Taken Per Day (m^3)
TW3-80	Drilled Well/ Apr 14, 1980	6707290	Initially 42.4 m (139 ft); now 31.1 m (102 ft) [A]	Bedrock	Initially 15.2 to 42.4 m (50 to 139 ft); then 15.2 to 31 m (50 to 102 ft) in 1999; now 28.4 to 31 m (93 to 102 ft) [B]	2,500	24	3,600 [C]
TW2-11	Drilled Well/ Sept 26, 2011	7172966	57.9 m (190 ft)	Bedrock – Dolostone	31.7 to 58 m (104 to 190 ft)	475	24	684 [C]

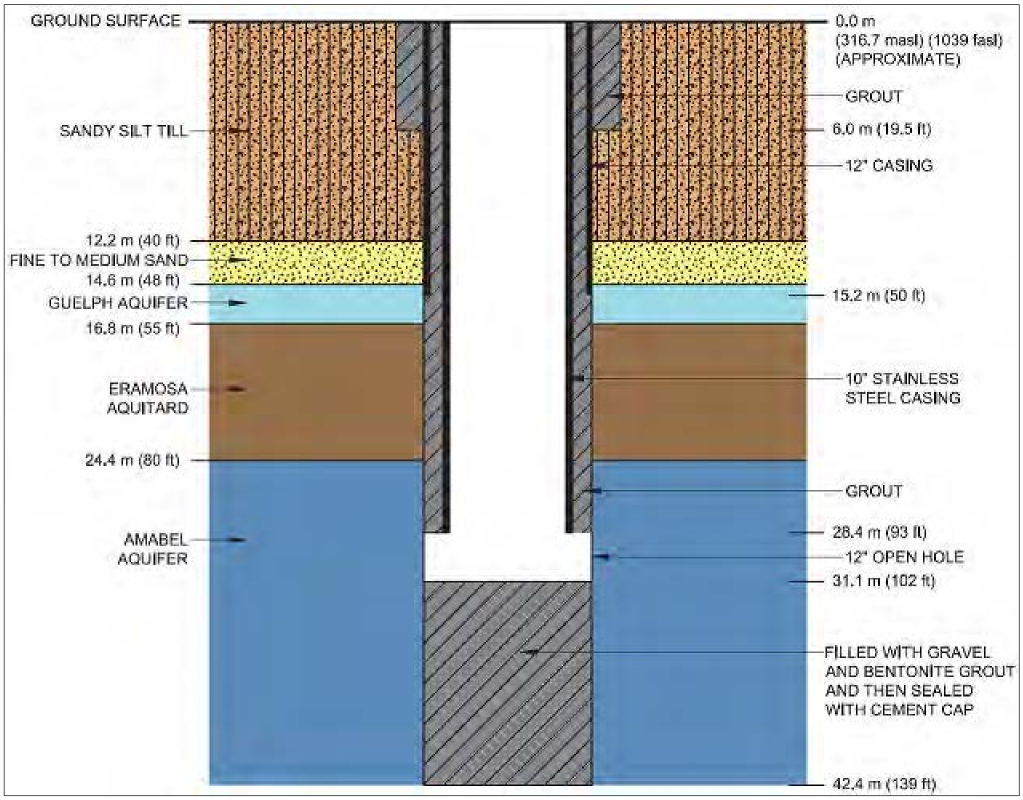
[A] In 1999, the lower 11.3 m of the well was filled and sealed in order to pump water with more favourable water quality from the Amabel Formation (Golder Associates, 2018).

[B] In 2002, in order to comply with Nestlé water well construction standards, a stainless steel liner was installed in the well casing and grouted in place to a depth of 28.4 m.

[C] The total amount of water taken from the two sources cannot exceed 3.6 million L/day.

Based on the established nomenclature at the time TW3-80 was drilled, the well is interpreted to be drilled through the Guelph Formation dolostone (from 14.6 to 24.4 meters below ground surface (mbgs)) and into the Amabel Formation (Eramosa Member and Unsubdivided Member (from 24.4 to 42.4 mbgs) (CRA, 2011)). Based on the revised bedrock nomenclature proposed by the Ontario Geological Survey, CRA (2011) interpreted the well to have been drilled through the Guelph, Eramosa and Goat Island Formations and possibly into the Gasport Formation. The existing well construction is illustrated in the schematic reproduced below in Text Figure 4-C-4. Based on the information from CRA (2011) and the schematic below, TW3-80 is inferred to be drawing water from the Amabel Formation (Goat Island Formation and possibly the Gasport Formation).

Text Figure 4-C-4: Schematic of production well TW3-80



Source: Golder Associates, 2018

Under the most recent PTTW 1381-95ATPY, the permit holder must implement a monitoring program incorporating groundwater monitoring, surface water monitoring, and biological assessments, in addition to the documentation of pumping records. The monitoring program is summarized in Table 4-C-3, and the locations of the different monitoring components are illustrated on Figure 4-C-1b.

Table 4-C-3: Summary of Monitoring Program Required under PTTW 1381-95ATPY

Location	Monitoring Completed	Monitoring Frequency
Groundwater Monitors		
Overburden monitors: TW1-93 (67-11283) TW1-99 (67-12929) MW-S/I PCC S/I MW2D/E-07 MW4C-07 MW10A-09	Water Level	Continuous
Bedrock Wells: TW3-80 (67-07290) MW2A/B/C-07 MW4A/B-07 Fire flow (67-14195) MW-D (67-11936) MW1A-04 PCC-D (67-11650) MW10B/C/D-09 MW6A/B-08 MW7A/B-08 MW8A/B-08 TW2-11 MW14A/B/C-11 MW15A/B-12 MW16A/B-12 MW17A/B-12 MW18A/B-12	Water Level	Continuous
Bedrock Wells (private): Private well MOE WWR #67-08740 Private well at 2 Brock Road Private well MOE WWR #67-07589 Private well MOE WWR #67-08317 (also known as 8 Maple Lane Well) Private well at 58 Brock Road Private well "B" Private well "M1" Private well "Y" MOE WWR #67-09669 Private well "J" Meadows of Aberfoyle well #PW5 (67-1197) Private Well "W2" (67-13335)	Water Level	Monthly

Location	Monitoring Completed	Monitoring Frequency
Surface Water Monitors		
SW1, SW2	Water Level	Continuous
SW3, SW4, SW5, SW9, SW10	Water Level	Monthly
SW1, SW2	Streamflow and development of a stage-discharge curve	Monthly
Multi-Level Piezometers: MP16S/D-08 MP6S-08/D -04 MP12S/D-04 MP14S/D-07 MP8S/D-04 MP11S-08/D-04 MP17S/D-12 MP18S/D-12 MP19S/D-12	Water Level	Continuous
Sediment-Water Interface Monitors		
ST6-08 ST1-05/AT-01 ST2-05 ST3-05 ST4-05 ST5-05	Temperature	Continuous
Biological Assessments		
Aberfoyle Creek, Nestlé (Aberfoyle) property	Type and frequency of biological monitoring is variable and is based on the recommendations provided in the previous year's annual monitoring report (Golder Associates, 2018). From 2007 to 2017, monitoring has included: • Aquatic characterization and monitoring (electrofishing, habitat characterization and spawning surveys); • Vegetation characterization and monitoring (Ecological Land Classification mapping, vegetation plot sampling, marsh surveys and invasive species mapping); • Wildlife monitoring and surveys (nocturnal amphibians, breeding birds, owls, basking turtles and odonates).	
Water Taking		
TW3-80, TW2-11	Pumping records	Downloaded monthly

4C.2 PRIMARY INFORMATION SOURCES

The following key records were on file with the MECP documenting the PTTW history (note that the following is not an exhaustive list of all records on file with the ministry):

- PTTW No. 00-P-2165, Nestlé Waters Canada Division of Nestlé Canada Inc., April 30, 2003.
- Temporary PTTW No. 2372-63WMFC, Nestlé Waters Canada, August 27, 2004.
- PTTW No. 6673-6CAJWK, Nestlé Waters Canada, June 30, 2005.
- PTTW No. 7043-74BL3K, Nestlé Canada Inc., April 17, 2008.
- PTTW No. 1763-8FXR29, Nestlé Canada Inc., April 29, 2011.
- PTTW No. 6763-8VFNDQ, Nestlé Canada Inc., August 20, 2012.
- PTTW No. 1381-95ATPY, Nestlé Canada Inc., December 19, 2013.
- Amendment to PTTW No. 1381-95ATPY, Nestlé Canada Inc., February 5, 2015.
- PTTW No. 1381-95ATPY Renewal Application, Nestlé Canada Inc., April 2016.

The following key technical documents provided to the ministry by the proponent/Permit Holder were identified and reviewed herein:

- Hydrogeological Investigation and Test Well Evaluations (Conestoga-Rovers and Associates (CRA), November 1980).
- Test Pumping Investigation. Supply Well TW3-80. Nestlé Waters Canada. Aberfoyle, Ontario (CRA, December 2004).
- Supplemental Hydrogeologic Investigation. Final Report. Nestlé Waters Canada. Guelph, Ontario (CRA, January 2008).
- Geochemical Evaluation of Water Sources for Well TW3-80 (S.S. Papadopulos & Associates, Inc., July 2012).
- Test Pumping Investigation for TW2-11. Prepared for Nestlé Waters Canada. Guelph, Ontario (CRA, December 2012).
- Various status reports submitted to the MECP for the monitoring program at the Nestlé (Aberfoyle) Site, for the years 2010 to 2017 (CRA, Golder), including, but not limited to:
    - 2010 Annual Monitoring Report. Nestlé Waters Canada (CRA, January 2011).
    - 2017 Annual Monitoring Report. Nestlé Waters Canada Aberfoyle Site (Golder Associates, March 2018).

Other information sources used in this assessment included:

- AquaResource Inc., 2010. City of Guelph Source Protection Project. Water Quality Threats Assessment Report. Draft.
- Matrix Solutions Inc., 2017. City of Guelph and Township of Guelph/Eramosa Tier Three Water Budget and Local Area Risk Assessment.
- Matrix Solutions Inc., 2018. Guelph-Guelph/Eramosa Water Quantity Policy Development Study: Threats Management Study.
- BluMetric Environmental Inc., 2019. A Review of Ontario's Water Quantity Management Framework. Water Bottling Study Areas Report.
- County of Wellington Official Plan. Office Consolidation, June 2018.
- Lake Erie Region Source Protection Committee (LERSPC), 2017. Grand River Source Protection Area. Approved Assessment Report.
- Statistics Canada, 2017. Puslinch, TP [Census subdivision], Ontario and Ontario [Province] (table). Census Profile. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017.
- Watson & Associates Economists Ltd., 2014. Township of Puslinch, 2014 Development Charges Background Study.
- Township of Puslinch Zoning By-Law 19/85. April 2018 Consolidation.
- Township of Puslinch, 2018. Feasibility Study for Municipal Water and Sewage Servicing. Available at: https://www.puslinch.ca/en/living-here/feasibility-study-for-municipal-water-and-sewage-servicing-.asp
- CIMA+, 2018. Feasibility Study Report: Feasibility Study for Municipal Water and Sewer Servicing in the Township of Puslinch. Available at: https://www.puslinch.ca/en/living-here/resources/T000866A-81-180508-FINAL-Feasibility-Study-Report-e02-with-Appendices-1.pdf
- The Corporation of the Township of Puslinch. Resolution 2018-212. Municipal Council. June 20, 2018. Available at: https://www.puslinch.ca/en/our-government/resources/3650_001.pdf.
- Ministry of the Environment and Climate Change (MOECC) Interim Procedural and Technical Guidance Document for Bottled Water Renewals: PTTW Applications and Hydrogeological Study Requirements, April 2017.
- MECP water well information system (WWIS) database. Available at: https://www.ontario.ca/environment-and-energy/map-well-records.

- MECP on-line Provincial Groundwater Monitoring Network (PGMN) database. Available at: https://www.ontario.ca/environment-and-energy/map-provincial-groundwater-monitoring-network.
- MECP on-line PTTW database. Available at: https://www.ontario.ca/environment-and-energy/map-permits-take-water.
- MECP on-line Source Protection Information Atlas. Available at: www.applications.ene.gov.on.ca/swp/en/index.php.
- MNRF on-line Natural Heritage Areas mapping. Available at: https://www.ontario.ca/page/make-natural-heritage-area-map.
- MECP Water Taking Reporting System (WTRS) database (Confidential – Used with Permission from MECP).
- Ontario Low Water Response Program (OLWR) notifications and alert levels for the GRCA (2000 to August 2018 data from MNRF).

4C.3 CHARACTERIZATION OF STUDY AREA

The Nestlé (Aberfoyle) Site is located at the south end of the Guelph-Wellington County Water Quantity Study Area ("Guelph WQSA") as defined in MECP RFB# 6792. As specified by the MECP, the water bottler has been investigated as part of the Guelph WQSA. Characterization of water quantity resource conditions on a regional scale is provided in the main body of the Guelph WQSA report. Figure 4-C-2 presents an area of approximate 20 km by 20 km centered over the Nestlé (Aberfoyle) water taking location. The 20 km by 20 km study area was selected to ensure the following were captured: the closest municipal groundwater system takings, Provincial Groundwater Monitoring Network (PGMN) wells, and Survey of Canada (WSC) hydrometric monitoring stations (HYDAT), and the radius of influence of the Nestlé (Aberfoyle) water taking (associated with a predicted drawdown of 0.1 m, estimated to extend up to about 1.725 km from the production well (CRA, 2012); see Section 4C.3.4.3 for further discussion of the radius of influence).

The review of permitted water takings as reported within the WTRS database focused on 'municipal water supply system takings' located within a 20 km by 20 km area centred over the Nestlé (Aberfoyle) water taking, and 'other' reported water takings located up to 5 km from the Site. Smaller assessment areas were used for the review of existing/planned land use and the review of WWIS records and are indicated herein.

The Nestlé (Aberfoyle) Site is located between the municipal groundwater systems of the community of Freelton (City of Hamilton) and the City of Guelph, and is within the Grand River Source Protection Area.

4C.3.1 Land Use Setting

The Nestlé (Aberfoyle) Site is located in the Township of Puslinch, at the southern boundary of the community of Aberfoyle. The Township is characterized by predominantly agricultural land use. In the vicinity of the Nestlé (Aberfoyle) Site, land uses include extractive industries to the southwest, south and southeast, undeveloped land to the northwest, and a mixture of agricultural, commercial and residential land uses to the north and northeast (County of Wellington, 2018; Figure 4-C-3). As per the Zoning By-Law No. 19/85 of the Township of Puslinch, the majority of the Site is zoned as Industrial Site-Specific (IND-5), which allows for a water bottling operation, a business office accessory to the main use, and accessory buildings and structures (Puslinch Township, 2018). The northern portion (encompassing Aberfoyle Creek) and the eastern portion of the Site are zoned as Natural Environment (NE). NE zones are intended to generally identify areas where, with specific exceptions, buildings and structures cannot be built due to potentially hazardous environmental features (e.g. flooding risk) (Puslinch Township, 2018).

The Township of Puslinch has a 2016 census population of 7,336 (Statistics Canada, 2017), and the population is forecast to increase to 8,564 by 2024, and 9,808 by 2034 (Watson & Associates Economists Ltd., 2014). To accommodate the forecasted population increase, 6% and 4% of the housing growth is assigned to the urban settlement areas of Aberfoyle and Morriston (the latter being located 2.7 km southeast of the Site), respectively, with the remaining 90% assigned to rural areas (Watson & Associates Economists Ltd., 2014).

No municipal water services were identified in the vicinity (< 2 km) of the Nestlé (Aberfoyle) Site; however, groundwater supply wells for communal water supply (condominium developments) are located approximately 690 m northeast and 1.8 km north-northeast of the Site (Figure 4-C-2). The closest municipal groundwater wells are the City of Guelph's Burke well and Downey well, located 6.9 km north-northwest and 8.4 km northwest of the Site, respectively.

No municipal water or wastewater services are currently available in the Township of Puslinch, although several water supply wells (the Carter well and Arkell wells) for the City of Guelph are located within the boundaries of the Township, approximately 9 to 10 km north-northwest and north of the Site (AquaResource, 2010). The Township recently commissioned a Feasibility Study to assess the viability of implementing municipal water and wastewater services within key areas of the township to the southeast of the City of Guelph and north of Highway 401 (Township of Puslinch, 2018). It was noted in the feasibility study that the township has a lot of potential for growth, due to it being within proximity to growing urban areas, its natural setting and accessibility to major markets, but opportunities for growth are limited by the lack of servicing (CIMA+, 2018). The two high-level options identified in the feasibility study included the development of a new water supply system and wastewater system to be owned and operated by the Township, or reliance on the City of Guelph's water and sewage system. Public consultation on the subject revealed that residential property owners were generally not in favour of municipal servicing due to the associated costs (CIMA+, 2018).

The MNRF Natural Heritage Areas mapping shows that the provincially significant Mill Creek Puslinch Wetland Complex extends into the northwestern portion of the Site, in the vegetated areas of the property.

4C.3.2 Physiographic Setting

The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of the regional physiographic setting. The physiography of the area in and around the Nestlé (Aberfoyle) Site is characterized by glacial spillways.

4C.3.3 Geologic Setting

A detailed discussion of the regional geologic setting of the Guelph WQSA is presented in Section 4 of the main report.

The surficial geology within the study area consists predominantly of stone-poor, carbonate-derived silty to sandy till, with areas of gravelly glaciofluvial deposits (at the location of the Nestlé (Aberfoyle) Site and towards the northeast and southwest), and pockets of organic deposits.

As noted in Section C.1, well TW3-80 is interpreted to have been drilled through the Guelph Formation dolostone and into the Amabel Formation (Eramosa Member and Unsubdivided Member), based on established nomenclature at the time the well was drilled. Based on the revised bedrock nomenclature proposed by the Ontario Geological Survey, the well is interpreted to have been drilled through the Guelph, Eramosa, and Goat Island Formations and possibly into the Gasport Formation.

A brief description of each of these bedrock formations is provided below, as an excerpt from the City of Guelph Tier Three Assessment (Matrix Solutions Inc., 2017):

> ***Gasport (Amabel) Formation***
>
> *The Gasport Formation is a cross-bedded crinoidal grainstone-packstone with sequences of reef mound and coquina (shell bed) lithofacies. This unit has commonly been referred to as the Amabel Formation in previous studies in the area. The Formation generally varies in thickness from about 25 to over 70 m, and the upper sections of the reef mounds, the crinoidal grainstones and the coquina shell beds make this formation highly transmissive, where they are present.*
>
> ***Goat Island Formation***
>
> *The Goat Island Formation consists of two members; the lower Niagara Falls Member and the upper Ancaster Member. The Niagara Falls Member is a finely crystalline and cross laminated crinoidal grainstone with small reef mounds. This unit is typically less than 10 m thick. The Ancaster Member is a chert rich, finely crystalline dolostone that is medium to ash grey in colour. This unit generally overlies the Niagara Falls Member although in some cases in the Cambridge and Guelph areas, these units are interfingered.*
>
> ***Eramosa Formation***
>
> *The Eramosa Formation consists of three members including, from oldest to youngest, the Vinemount Member, the Reformatory Quarry Member and the Stone Road Member. Both the Vinemount and Reformatory Quarry member can be seen in the cross section. The Vinemount Member is comprised of thinly bedded, fine crystalline dolostone with shaley beds that give off a distinctive petroliferous odour when broken (Brunton, 2008). This dark grey to black dolostone unit was commonly identified in water well records as 'black shale' and mapped in previous studies in the City of Guelph as the Eramosa Member. The shaley beds of this*

> *Formation significantly reduce the vertical permeability across this unit relative to the other Formations. The Eramosa Formation above the Vinemount Member is described by Brunton (2008) as light brown to cream coloured, pseudonodular, thickly bedded and coarsely crystalline dolostone. This unit is susceptible to karstification due to its uniform fine dolomite crystallinity (Brunton, 2008). This unit also often contains mud-rich and microbial matbearing lithofacies that may act as aquitard materials, reducing the vertical permeability across this unit. This unit was logged as either the Guelph Formation or Eramosa Member in previous studies within the City of Guelph. The Stone Road Member is cream coloured coarsely crystalline Upper Eramosa unit and can be difficult to distinguish from the Guelph Formation.*
>
> ***Guelph Formation***
>
> *The Guelph Formation consists of two members; the lower Hanlon Member and the upper Wellington Member. The Guelph Formation consists of medium to thickly bedded crinoidal grainstones and wackestones and reefal complexes (Brunton, 2008). The Guelph Formation is cream-coloured and fossiliferous and where present in the Cambridge and Guelph area it is most often the uppermost bedrock unit.*

CRA (2011) cross-sections (reproduced in Text Figures 4-C-5a and 4-C-5b) indicate a sandy silt till aquitard ranging in thickness from about 1 m to 13 m on the Nestlé (Aberfoyle) Site, underlain by the Guelph Aquifer (itself ranging from about 5 m to 14 m in thickness) and an approximately 10 m thick Eramosa Aquitard. Well TW3-80 pumps water from the Amabel Aquifer, underlying the Eramosa Aquitard. Based on the revised bedrock nomenclature proposed by the Ontario Geological Survey, well TW3-80 pumps water from the Goat Island Formation and possibly the Gasport Formation.

4C.3.4 Hydrogeologic Setting

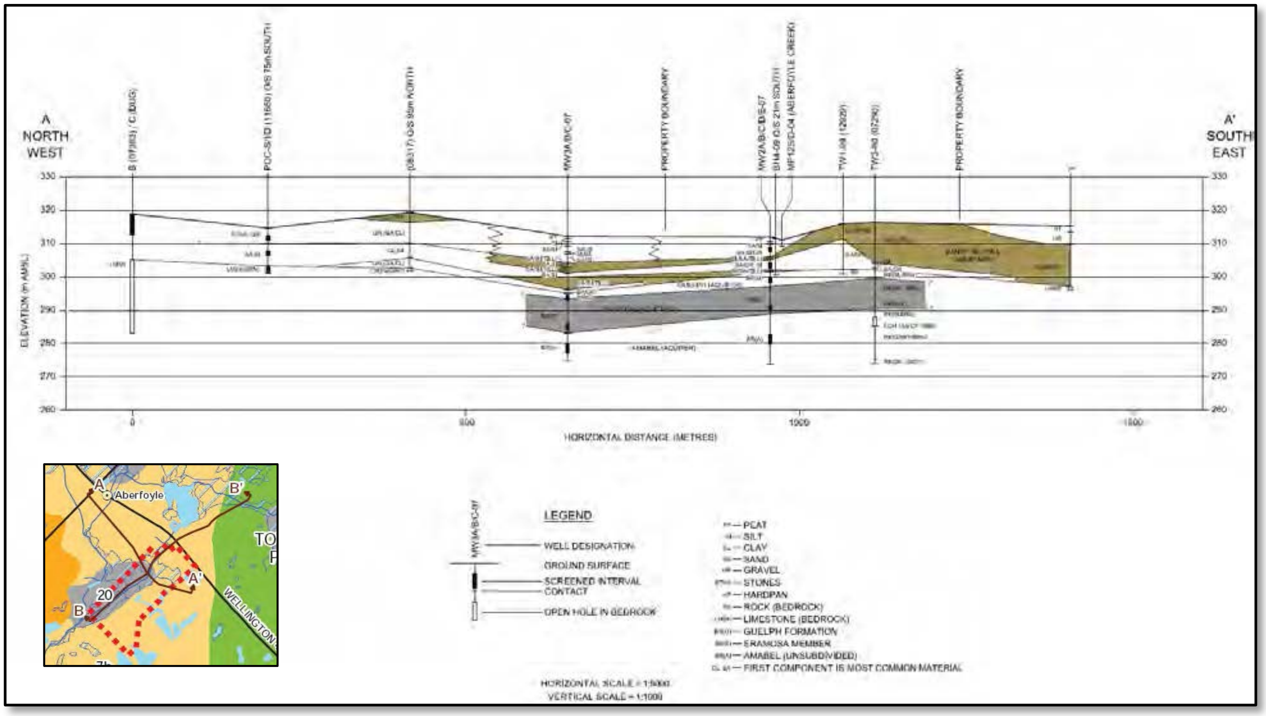
4C.3.4.1 Regional Hydrogeology

The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of the regional hydrogeologic setting of the Nestlé (Aberfoyle) Site.

4C.3.4.2 Local Hydrogeology

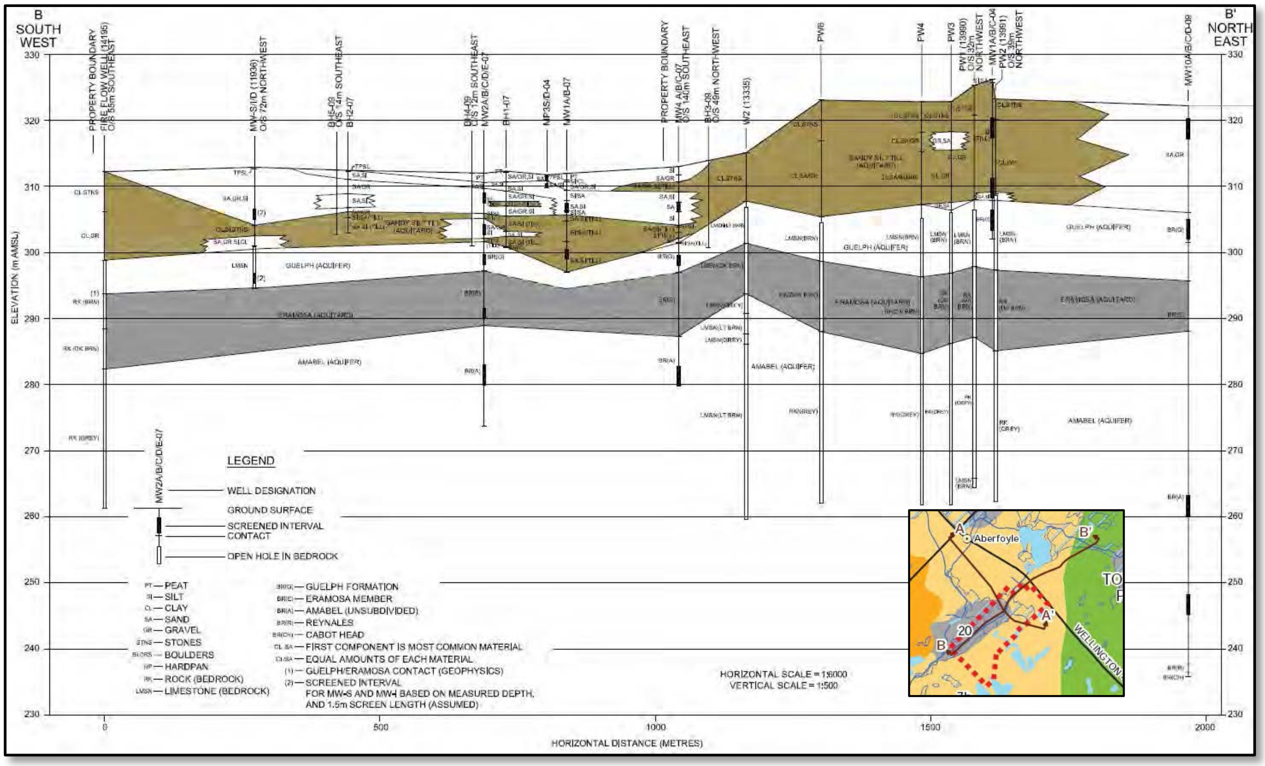
Hydrogeologic cross-sections of the area, crossing through the Nestlé (Aberfoyle) Site and well TW3-80, were developed by CRA (2011) based on water well records and on-site and off-site monitoring wells completed during the site-specific hydrogeological investigations. The cross-sections extend in a general northwest to southeast direction, and in a general southwest to northeast direction. The cross-sections are reproduced on Text Figures 4-C-5a and 4-C-5b.

Text Figure 4-C-5a: Nestlé (Aberfoyle) Site – Northwest-Southeast Cross-Section



Source: CRA, 2011 (inset map: Golder Associates, 2018)

Text Figure 4-C-5b: Nestlé (Aberfoyle) Site – Southwest-Northeast Cross-Section



Source: CRA, 2011 (inset map: Golder Associates, 2018)

Locally, within a 1 km radius around the Nestlé (Aberfoyle) Site, the overburden thickness typically ranges from 15 m to 20 m, and consists mainly of outwash gravel or ice-contact gravel deposits (Golder Associates, 2018). No bedrock outcrops are known to be present on or around the Site.

The bedrock hydrogeologic units underlying the Nestlé (Aberfoyle) Site and surrounding area are from top to bottom (Golder Associates, 2018):

- Guelph Aquifer, typically consisting of brown to grey dolostone. The thickness of the Guelph Aquifer ranges from about 15 m at a location approximately 3.2 km northeast of the Site, to as thick as 30 m at the western edge of Puslinch Township (more than 10 km west of the Site);

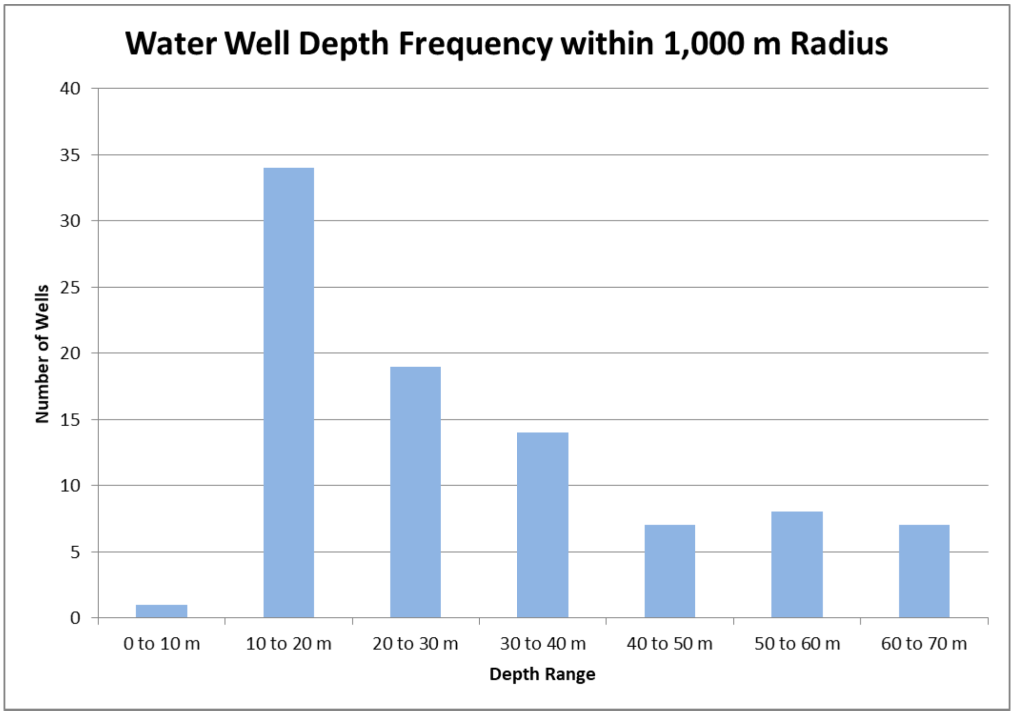
- Eramosa Aquitard, consisting of dark brown or black bituminous dolostone. The unit has low vertical hydraulic conductivity, so is recognized regionally as an aquitard. However, S.S. Papadopulos & Associates, Inc. (2012), suggests that locally at the Site, the hydraulic conductivity values may be higher and therefore it may not always act as true aquitard (See Section 4C.3.4.3). Any further detailed study, such as modelling, of the site should evaluate the effectiveness of the Eramosa as an aquitard;
- Amabel Aquifer, consisting of blue-grey to buff dolostone. Based on the proposed/revised nomenclature, the Amabel Aquifer generally corresponds (from top to bottom) to the Goat Island, Gasport and Irondequoit Formations. The thickness of the Amabel Aquifer is reported to be 35 m at a location 3.2 km northeast of the Site, and 30 – 35 m at a location 15 km southwest of the Site. Production Well TW3-80 does not penetrate the full thickness of the Amabel Aquifer, but based on the water well record for a now-abandoned well previously located 6.1 m northeast of TW3-80, its thickness is interpreted to be approximately 53.9 m; and,
- Cabot Head Formation composed of green and grey shale with interbedded limestone. The shales of the formation are generally accepted as an aquitard underlying the Amabel aquifer.

It was noted by CRA (2011) that some private wells within the monitoring program are open across multiple bedrock units, e.g. they may have a finished depth in the Amabel Formation, but are open across the Guelph Formation through to the Amabel Formation. In such cases, the wells were categorized according to the lowermost unit in which they were installed, but water levels measured in the wells represent a composite water level, influenced by hydrogeologic conditions in the various formations.

Properties in the Township of Puslinch are serviced by a mixture of private well water supply, and a few small and private communal water systems servicing individual developments (CIMA+, 2018). The MECP WWIS database was reviewed for well locations situated within 1,000 m of the Nestlé (Aberfoyle) Site production well. A 1,000 m search radius was considered appropriate based on the observed density of water well records in this search area and the local conditions. Water well record locations as referenced in the WWIS are plotted on Figure 4-C-1a. A total of 154 well records were identified, of which 90 records are for supply wells (the remainder being test holes, monitoring/observation wells, and abandonment records). The reported well construction depths for the water supply wells range from 7.3 to 61.3 m. The database indicates that 13 of the supply wells are completed in overburden, 72 are completed in bedrock, and 5 are of an unknown type. Upon review of the original well records, it was determined that three of the "overburden" wells and the five "unknown" type wells are all bedrock wells; as such, of the 90 water supply wells, 10 are completed in overburden, and 80 are completed in bedrock. The largest concentrations of water wells within 1,000 m of the Nestlé (Aberfoyle) Site occur along Brock Road (Wellington Road 46), and the residential area on the opposite side of Brock Road, across from the Site.

The frequency distribution in water well depths within the 1,000 m search radius is provided in the chart shown on Text Figure 4-C-6, indicating that the majority of the wells are between 10 and 40 m in depth and all but one are at least 10 m deep.

Text Figure 4-C-6: Distribution of Private Water Well Depths within a 1 km Radius of the Site



Overburden materials are most generally described in the well records as consisting of clay, sand and gravel. Golder (2018) indicates more specifically that the overburden consists mainly of outwash gravel or ice-contact gravel deposits. Reported static water level depths ranged from 0.3 m to 20.7 mbgs. Depth to bedrock ranges from 6.1 m to 24.1 mbgs.

4C.3.4.3 Site Hydrogeology

Six technical reports were identified in MECP files given to BluMetric providing hydrological and hydrogeological information related to the Nestlé (Aberfoyle) Site. Salient information derived from these reports and relating to the water quantity assessment is summarized as follows.

Hydrogeological Investigation and Test Well Evaluations (CRA, 1980)

Conestoga-Rovers & Associates (CRA) was commissioned in 1979 by Aberfoyle Fisheries to conduct a hydrological investigation in support of a proposed fish farming operation. No surface water data was collected as part of this investigation. Four test wells, including TW3-80 (the current production well for the Nestlé (Aberfoyle) Site) and TW1-80 (located roughly 150 m south of TW3-80), and two observation wells were installed on the subject property for the study. The four test wells and one of the observation wells were installed in bedrock; the other observation well was installed in overburden.

Multiple pumping tests were completed on all four test wells during the period February to June 1980. In addition to the wells installed for this study, several off-site private wells were monitored during the tests. Pumping test results indicate that test well TW1-80 could sustain a yield of 1,523 L/minute (335 igpm) without causing excessive drawdown in neighbouring wells. An approximate 1,300 feet (396 m) zone of influence was estimated. A sustained yield of 3,955 L/minute (870 igpm) was demonstrated at TW3-80, and the authors suggested that a yield of 5,455 L/minute (1,200 igpm) could be maintained without causing excessive drawdown in neighbouring wells, with drawdown expected to be less than 1 foot (0.30 m) at a distance of 2,500 feet (762 m) from the well. At a pumping rate of 5,455 L/minute (1,200 igpm), drawdown in TW3-80 was expected to stabilize at 42 feet (12.8 m). CRA noted that the yield from TW1-80 would be restricted if it was pumped simultaneously with TW3-80. The yield of TW2-80 and TW4-80 was less than 114 L/minute (25 igpm) each.

Test Pumping Investigation Supply Well TW3-80 (CRA, 2004)

In a summary of the Site history, CRA (2004) noted that a pumping test was performed on November 28, 1980, in which wells TW1-80 and TW3-80 were pumped at rates of 310 and 1,200 igpm (1,409 and 5,455 L/minute), respectively. Interference problems were reportedly experienced in the Village of Aberfoyle, and test pumping was terminated on November 29, 1980.

In 2004, CRA conducted a 72-hour pumping test of supply well TW3-80 to evaluate its zone of influence at a pumping rate higher than the existing permitted rate (1,818 L/minute, as per PTTW 00-P-2165).

The total drawdown in TW3-80 during the pumping test at 700 igpm (3,182 L/minute) was about 18.5 m. Water levels stabilized after approximately 19 hours, and 90% recovery was achieved 4 hours after pumping stopped. The area affected by the pumping test, based on a water level decline of 1.0 m or more in monitored bedrock wells, extended about 750 m to the southwest, 750 m to the southeast, 850 m to the northeast and on the order of 1,350 m to the northwest. There were no complaints of water loss during the test and no evidence to suggest that water levels in other private wells were lowered below the level of their respective pump intakes.

Shallow overburden water levels were affected by pumping at locations to the northwest, northeast and southeast of TW3-80, including locations on the opposite side of Aberfoyle Creek. The radius of influence due to pumping was on the order of 300 m. Surface water levels, flows and temperatures in Aberfoyle Creek did not appear to be influenced by pumping.

Supplemental Hydrogeologic Investigation Final Report (CRA, 2008)

CRA conducted an investigation to address comments that were made by the Ministry of the Environment (now the MECP) and other agencies on the 2006 Annual Monitoring Report and PTTW renewal application submitted on behalf of Nestlé Waters Canada.

As part of the investigation, a 31-day pumping test was conducted using supply well TW3-80, from November 9 to December 10, 2007. For the first seven days of the test, the well was pumped at a constant rate of 1,600 L/minute. The pumping rate was then increased to 2,470 L/minute for the next three weeks of the test before being reduced to 1,600 L/minute for the final three days of the test for recovery monitoring.

The net decline of water levels in supply well TW3-80 (completed in the unsubdivided Amabel Formation) due to increasing pumping from 1,600 to 2,470 L/minute after 21 days was 6.7 m. The water level stabilized after approximately 32 hours of pumping at the increased rate and remained stable for the remainder of the test. Water levels in monitored unsubdivided Amabel bedrock wells declined in response to pumping of TW3-80 at the increased rate, but stabilized after approximately 48 hours. The zone of influence for the Amabel is elongated toward the northwest.

The drawdown due to pumping of TW3-80 in the Guelph Formation was significantly smaller than in the Amabel. Water level changes in the Guelph Formation in response to pumping from the unsubdivided Amabel Formation are muted by the Eramosa Member of the Amabel Formation. Drawdown in the overburden due to pumping of TW3-80 was significantly smaller than in the bedrock. There were no complaints of water loss from private well owners during the tests and no evidence to suggest that water levels were sufficiently impacted to affect water use.

The calculated reduction in flow of Aberfoyle Creek due to increased pumping during the test is approximately 0.19 L/s, which represents less than one percent of the lowest flow rate historically measured in Aberfoyle Creek between December 2001 and December 2007. Surface water levels were not measurably influenced by increased pumping of TW3-80 during the test.

Based on laboratory analysis of groundwater quality samples collected from TW3-80 and various monitoring wells, the groundwater supplying TW3-80 was estimated to have a residence time of 35 to 45 years in the subsurface.

2010 Annual Monitoring Report (CRA, 2011) – Long-term Pumping Test of Well TW3-80

As required under Condition 4.8 of PTTW No. 7043-74BL3K (issued on April 17, 2008), a long-term pumping test for production well TW3-80 was completed over 46 days between August 27 and October 12, 2010. The test was to be conducted during seasonal low surface and groundwater conditions, in order to assess the impacts on groundwater levels, surface water levels, vertical gradients, surface water flow and surface water temperature when TW3-80 is pumped at 95% to 100% of the permitted capacity.

As agreed upon during a stakeholder meeting, the average summer low flow level of 500 L/s at the GRCA gauge station at Sideroad 10 station on Mill Creek (approximately 8.7 km southwest of TW3-80) was selected as an appropriate trigger to begin the pumping test.

The test was divided into three stages: a stabilization period, when water was pumped at 1,700 L/day for 3 days; a pumping period, when water was pumped at 2,460 L/day (equivalent to 98.4% of the permitted capacity) for 39.6 days; and, a recovery period, when water was not pumped for the last 3.4 days of the test.

Based on the recovery results, the non-pumping direction of groundwater flow is generally to the southwest, with local components of flow to the west and south toward Aberfoyle Creek. The flow pattern was similar to those that were observed during previous shutdowns in October 2004 and November 2006.

Based on the predicted drawdown at each location in the Amabel Formation production aquifer at the maximum permitted pumping rate of 2,500 L/minute, calculated using the recovery data, the zone of influence (with a predicted drawdown of 1 m or more) was estimated to extend about 1,400 m to the north-northwest, 1,100 m to the northeast and 800 m to the southwest of TW3-80.

The zone of influence in the Guelph Formation aquifer at the maximum permitted pumping rate was estimated to extend approximately 1,200 m to the north-northwest, a maximum distance of 550 m to the west, and 220 m to the east of TW3-80.

As the drawdown in overburden wells was observed/predicted to be less than 1 m, no zone of influence was delineated for the overburden.

Surface water levels and temperatures in Aberfoyle Creek were not measurably influenced by pumping at TW3-80 during the test, nor was there any measurable reduction in flow at the upstream and downstream property boundaries that was correlated with pumping.

Geochemical Evaluation of Water Sources for Well TW3-80 (S.S. Papadopulos & Associates, Inc., 2012)

S.S. Papadopulos & Associates, Inc. conducted a chemical isotope analysis for source characterization of TW3-80 recharge to satisfy condition 4.9 of PTTW No. 1763-8FXR29 (issued on April 29, 2011). The objectives of the study were to: 1) characterize the geochemical signatures of water obtained from TW3-80 and overlying units, and determine if groundwater from TW3-80 and other overlying units are of similar or different origins; and, 2) determine if the source and geochemical signature of the water at well TW3-80 changes under different pumping scenarios.

The results from the study indicate that groundwater from TW3-80 and nearby on-site monitoring wells in the Amabel, Eramosa and Guelph Formations and the overburden have a distinct geochemical signature from off-site background wells in these same hydrogeologic units. Groundwater from TW3-80 and nearby wells has higher relative concentrations of sodium and chloride and higher concentrations of total dissolved solids than background wells. The data from this study suggest a shallow source for sodium and chloride and downward migration of groundwater to the Amabel Formation as a result of downward hydraulic gradients in areas where the effective permeability of the Eramosa is relatively high.

Among the background wells, no unique geochemical signature was identified that would allow differentiation in groundwater from the different hydrogeologic units.

No significant change in the isotopic composition of groundwater from TW3-80 was observed that correlated with changes in pumping rates.

<u>Pumping Test Investigation for TW2-11 (CRA, 2012)</u>

CRA conducted a pumping test on test well TW2-11 for use as a facility well, to supplement flow to a pond behind the Nestlé plant for emergency fire flow purposes. Test well TW2-11 was completed in September 2011, with casing grouted in place through the Guelph Formation to the base of the Eramosa, and open hole in bedrock through a portion of the Amabel (i.e., entire Goat Island Formation and a portion of the Gasport Formation).

The pumping rate for TW2-11 was maintained at 940 L/minute for the duration of the 10.9-day pumping test. The pumping rate for existing supply well TW3-80 was set at 1,590 L/minute throughout the testing period; the rationale for selecting that rate was not explicitly stated, but may have been to keep the maximum, combined withdrawal rate of TW3-80 and TW2-11 (2,530 L/minute) at approximately the maximum permitted withdrawal rate of TW3-80 (2,500 L/minute). The zone of influence (area with a predicted drawdown of 1 m or more) in each bedrock unit was interpreted to be as follows: in the Amabel Formation about 1,725 m to the north, about 1,200 m to the northeast and about 1,000 m to the south; and, in the Guelph Formation about 650 m to the north, about 100 m to the south and a maximum of 200 m to the west and east. The magnitude of response in the Guelph Formation and in the overburden aquifers was notably dampened relative to the response in the Amabel Formation based on review of hydrographs for nested locations; therefore, CRA inferred that the Eramosa Member of the Amabel Formation acts as an aquitard, thus limiting the effect in overlying units. As noted in SSPA (2012), the Eramosa may not act as a true aquitard locally, so there appears to be a difference of opinion in the studies conducted to date at the site. CRA indicated that surface water flows in Aberfoyle/Mill Creek did not appear to be influenced by pumping at TW2-11.

<u>2017 Annual Monitoring Report – Nestlé Waters Canada Aberfoyle Site (Golder Associates, 2018)</u>

The 2017 annual monitoring report by Golder Associates was completed as required by the condition of PTTW 1381-95ATPY to report on water takings on an annual basis.

It was observed that, in general, water level trends in TW3-80 are correlated with the overall water taking from the well, i.e. with lower levels being observed during periods of relatively higher takings, and vice versa. In 2017, the water levels continued to respond to pumping as expected, and the ongoing taking at well TW3-80 has not resulted in a long-term declining trend in water levels in the well.

Water levels in the Amabel Aquifer are influenced by pumping at TW3-80 over the short term and the long term, and are also influenced by recharge (precipitation) over the long term. Water levels in the Amabel Aquifer in 2017 were within the range measured over the previous five years (see hydrographs in Section C.6). Water levels fluctuate in the short term in response to daily changes in pumping rates. The long-term influence of pumping is observed in the wells closer to TW3-80, where year-to-year variations in water levels correlate with the overall annual water taking. Water levels also appear to generally correlate with precipitation trends, with lower water levels and higher water levels being observed during periods of below and above average precipitation, respectively.

Water levels measured in the Eramosa Aquitard in 2017 were within the range measured over the previous five years, and year-to-year water levels generally follow a similar trend as those in the Amabel Aquifer (see hydrographs in Section C.6). Water levels in the aquitard were observed to respond to pumping at TW3-80, although the annual spring melt (recharge to the aquitard) was inferred to potentially have more of an effect on water levels than pumping.

Water levels in the Guelph Aquifer were observed to be influenced by pumping at TW3-80, indicating that there is a hydraulic connection between the Amabel Aquifer (pumped by TW3-80) and the Guelph Aquifer; however, the response in the Guelph Aquifer is dampened compared to the response of the Amabel Aquifer. Although the Guelph Aquifer is influenced by pumping, the long-term trends in water levels indicate that it is recharged by precipitation, as water levels typically increase or decrease during years of higher or lower than normal precipitation, respectively. Water levels in the Guelph Aquifer also exhibited seasonal influences, with an increase in levels during the spring. Water levels measured in the aquifer in 2017 were within the range measured over the previous five years (see hydrographs in Section C.6).

Water levels in the overburden were observed to be influenced by pumping at TW3-80, although the response to pumping was less compared to the response of the Amabel Aquifer; the response in the overburden appears to have been less than 1 m in nearby monitoring wells located approximately 150 m from TW3-80. Water levels measured in the overburden in 2017 were within the range observed over the previous five years, with no overall increasing or decreasing trend (see hydrographs in Section C.6). Water levels in the overburden were determined to be more influenced by precipitation than pumping.

Based on water levels measured in July 2017, during a period of relatively high pumping volumes, the regional potentiometric surfaces in the Amabel Aquifer, the Guelph Aquifer, and the overburden were established. In both the Amabel Aquifer and the Guelph Aquifer, groundwater is inferred to flow toward TW3-80 from the northeast, north and northwest. In the overburden, groundwater flow is inferred to generally be in a south to southwest direction, with potentially some flow towards Aberfoyle Creek. Both lateral and vertical flows were observed in the overburden.

Water levels measured in 2017 in the mini-piezometers located along Aberfoyle Creek were within the range measured over the previous five years, generally increasing in the spring and fall, and decreasing in the summer. No long-term changes or trends in the shallow gradients of the mini-piezometers were noted during the previous five years.

Surface water levels in Aberfoyle Creek and Mill Creek have been relatively stable over time, with no increasing or decreasing trend. The water levels exhibit seasonal trends, with higher levels in the spring and fall, and lower levels in the summer. Water levels were also measured in two ponds located on the neighbouring property (aggregate operations), in which overall declining trends were observed in 2014 and 2015, followed by a pattern of seasonal fluctuations (an increase during the spring followed by a decline in the summer/fall) in 2016 and 2017. The trends in water levels were believed to be the result of precipitation patterns combined with aggregate washing operations. Streamflow in Aberfoyle Creek, at the upstream and downstream limits of the Nestlé (Aberfoyle) Site, were observed to be within the range observed in the past, and appear to be influenced by precipitation events. Seasonal trends in stream temperature in 2017 were also observed to be similar to previous years and are relatively stable.

No significant changes were observed to the terrestrial and aquatic environment on the Site that would indicate altered hydrology. The species richness, abundance and distribution were determined to be generally within the range expected and attributable to natural variation and succession (Golder Associates, 2018).

4C.3.5 Hydrologic Setting

The Nestlé (Aberfoyle) Site is located in the Mill Creek subwatershed of the Grand River Watershed. Aberfoyle Creek, a tributary of Mill Creek, flows through the site in a general northeast to southwest direction, and converges with Mill Creek at a point approximately 100 m west of the Site. Aberfoyle Creek comes within 150 m (to the northwest) of the production well TW3-80. Several natural and man-made ponds are present within 1 km of the Site's boundaries; the Site itself contains a small number of small ponds within its boundaries. Aberfoyle Mill Pond is located approximately 250 m northeast of the Site's northernmost tip, and discharges water to Aberfoyle Creek; the relatively large and shallow pond is an important contributor to warm water conditions in the creek (see also the discussion on "Influence of Pumping at TW3-80 on Surface Water Temperature"). Many of the other ponds in the area appear to be man-made and are off-line (i.e., do not receive flow from or discharge to streams), and may have been the result of aggregate extraction below the water table (Golder Associates, 2018).

Several wetlands are present within a 1 km radius of the Site, most of which are considered part of the provincially significant Mill Creek Puslinch Wetland Complex. The Wetland Complex also extends into the northwest portion of the Site.

The effects of pumping on surface water flows and temperature, as determined during the 2010 pumping test (CRA, 2011), are discussed below.

Influence of Pumping at TW3-80 on Surface Water Flows

The influence of pumping on Aberfoyle Creek was estimated by quantifying the change in the vertical flux of shallow groundwater to surface water when the pumping rate was increased from 0 to 2,460 L/minute, and extrapolating the results to 2,500 L/minute.

The portion of Aberfoyle Creek that is influenced by changes in pumping rate at TW3-80 was determined to be bounded by multi-piezometers MP8 and MP16 (located near the southwestern (downstream) boundary and the northeastern (upstream) boundary of the Site, respectively; see Figure 4-C-1b), as no change in vertical gradients were observed at these locations. Between MP8 and MP16, a length of approximately 1,090 m of Aberfoyle Creek was estimated to be influenced by the change in pumping rate at TW3-80.

When TW3-80 was not pumping, the 1,090 m reach of Aberfoyle Creek was calculated to be gaining 1.53 L/s from groundwater upwelling. When TW3-80 was pumping at 2,460 L/minute, the reach was calculated to be losing 1.17 L/s (becoming a surface water contribution to groundwater), representing a reduction in streamflow of 2.7 L/s. When pumping at the maximum permitted rate, the reduction in streamflow in the 1,090 m reach was estimated to be 2.74 L/s.

In comparison, the lowest streamflow measured at SW2 (located at the downstream property boundary) for the period 2001 to 2010 was 25.8 L/s (compared to the historical mean summer streamflow of 99 L/s). CRA (2011) noted that the measured summer streamflows were already being influenced by pumping at TW3-80, and that the lowest flow recorded during that period (25.8 L/s) occurred on a date when 1,800 L/minute was being pumped. CRA (2011) estimated that, had pumping occurred at the maximum permitted rate (2,500 L/minute), the streamflow would have been reduced to 25.0 L/s, rather than being lowered by an entire 2.74 L/s down to 23.1 L/s.

During the pumping test, streamflow at SW1 and SW2 was measured manually about two to three times per week. There was no measurable change in surface water flow that could be clearly attributed to pumping (CRA, 2011). Throughout the course of the pumping test, flows at SW2 were consistently higher than flows at SW1 by 8 to 40 L/s. Based on surface water flow measurements that have been collected since December 2001, flows at SW2 generally exceed those at SW1 by about 25 to 30 L/s. The higher flows at SW2 compared to SW1 support the conclusion that the loss of surface water flow to groundwater is not significantly impacting the creek.

Influence of Pumping at TW3-80 on Surface Water Temperature

Monitoring of daily average air temperature and daily average surface water temperature was conducted at SW1 and SW2 during the long-term pumping test. It was observed that stream temperature at both locations followed the same general trend as air temperature, and that SW2 (downstream location) was consistently cooler than SW1 (upstream location). Over the course of the test, a decrease in stream temperature was observed that was attributed to decreasing air temperature; there was not a measurable change in surface water temperature that could be attributed to pumping.

A mass balance approach was used to determine the theoretical change in surface water temperature that would result from a reduction in groundwater contribution to surface water. Changes in surface water temperature were estimated under the worst case summer and worst case winter conditions, using estimates of summer and winter groundwater temperatures, and observations of maximum summer and minimum winter stream temperatures observed at SW2 in 2010. As noted previously, the 1,090 m reach of Aberfoyle Creek was calculated to be gaining 1.53 L/s from groundwater upwelling when TW3-80 is not pumping. If this groundwater contribution were halted, it was estimated that stream temperature would increase by approximately 1.2°C in the summer, and decrease by approximately 0.1°C in the winter.

In assessing the potential impacts of a 1.2°C increase in surface water temperature on aquatic biota, CRA (2011) noted that the portion of Aberfoyle Creek that crosses through the Nestlé (Aberfoyle) Site is characterized by warm water conditions. This was shown by surface water temperatures recorded in July 2010, prior to the start of the pumping test: surface water temperatures just upstream (outside) of the Nestlé (Aberfoyle) Site's northern corner exceeded 26°C on 17 days, and exceeded 28°C during nine days of that month. Surface water temperatures at the downstream end (southwestern corner) of the Site exceeded 26°C on 7 days, and exceeded 28°C during two days, during this same period. The relatively large and shallow Aberfoyle Mill Pond, located approximately 250 m northeast of the Site's northeastern boundary, was determined to be an important contributor to warm water conditions in the Aberfoyle Creek as it crosses through the Site. Aquatic surveys conducted in 2008 confirmed the dominance of warmwater fish species and low numbers of trout (coldwater fish species), indicating that there is no significant thermal refuge through the reach. It was determined that, as the aquatic fauna are already exposed to warm summer water temperatures, an increase in stream temperature of 1.2°C under the worst case scenario was not expected to measurably alter the stream fauna.

4C.4 DATA REVIEW AND STATE OF GROUNDWATER RESOURCES

4C.4.1 Water Taking Reporting System

The WTRS is the ministry's repository for collection of water taking data for active PTTWs. As a requirement of each PTTW, the water taking data must be reported on an annual basis and daily water taking data must be entered into the system. The WTRS is not publicly available, but is available for use by ministry staff when assessing the status of a PTTW or addressing potential issues associated with a PTTW. The WTRS data was provided by the ministry for use in the Water Bottling Study Area (WBSA) assessment to be inclusive of all information available to MECP for making water management decisions.

Data on the volume of water taken per year and the number of water taking days per year for the Nestlé (Aberfoyle) Site well was obtained from the WTRS for review. Table 4-C-4 below includes annual water taking data for the period from 2005 to 2017.

Table 4-C-4: Reported Water Takings – Nestlé (Aberfoyle)

Permit Number	Year	Source Name	Annual amount permitted by the PTTW (Million L)	Permitted No. of Taking Days per Year	Reported No. of Days Taken per Year	Reported annual taking (Million L)	Reported annual taking (% of permitted amount)	Average volume taken per day (L/day)
6673-6CAJWK	2005	TW3-80	1,314	365	184	426.2	32%	2,316,057
6673-6CAJWK	2006	TW3-80	1,314	365	362	759.2	58%	2,097,224
6673-6CAJWK	2007	TW3-80	1,314	365	180	426.6	32%	2,370,212
7043-74BL3K	2008	TW3-80	1,314	365	258	500.5	38%	1,939,804
7043-74BL3K	2009	TW3-80	1,314	365	361	583.3	44%	1,615,831
7043-74BL3K	2010	TW3-80	1,314	365	362	603.2	46%	1,666,297
1763-8FXR29	2011	TW3-80	1,314	365	244	403.6	31%	1,654,286
1763-8FXR29	2012	TW3-80	1,314	365	366	583.8	44%	1,595,146
1763-8FXR29	2013	TW3-80	1,314	365	351	587.8	45%	1,674,569
1381-95ATPY [1]	2013	TW3-80	1,314	365	12	12.8	1%	1,063,654
1381-95ATPY	2014	TW3-80	1,314	365	365	678.5	52%	1,858,773
		TW2-11	250	365	Data not available in the WTRS			
1381-95ATPY	2015	TW3-80	1,314	365	363	762.4	58%	2,100,175
		TW2-11	250	365	0	0.0	0%	0
1381-95ATPY	2016	TW3-80	1,314	365	213	473.8	36%	2,224,300
		TW2-11	250	365	0	0.0	0%	0
1381-95ATPY	2017	TW3-80	1,314	365	365	767.9	58%	2,103,790
		TW2-11	250	365	0	0.0	0%	0

[1] PTTW No. 1381-95ATPY was issued on December 19, 2013, so less than 2 weeks of water taking is reported for this PTTW in 2013.

As indicated in Table 4-C-4, annual water takings during the 2005 to 2017 period varied from 31% to 58% of the PTTW limit. The number of days of taking per year varied from 180 to 366 (in 2012, a leap year). The average volume of water taken per day consistently remained below the maximum permitted withdrawal amount (3.6 million L/day). No water takings were reported for well TW2-11 in 2015 to 2017 inclusively (no data on water takings in 2013 and 2014 were included in the WTRS).

As indicated on Figure 4-C-2, 18 other active PTTWs are located within a 5 km radius of the Nestlé (Aberfoyle) Site. The WTRS data for each is indicated in Table 4-C-5.

Table 4-C-5: Reported Water Takings – Neighbouring PTTWs

Permit no. (Permit Holder)	Issue Date	Expiry Date	Source	Purpose	Distance from Nestlé source well (km) [1]	PTTW limits			2016 WTRS data [2]		2017 WTRS data [2]	
						Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
7510-A34KZH (CRH Canada Group Inc.)	Oct. 9, 2015	Aug. 31, 2019	Pond 5	Aggregate Washing	0.35	8.183	235	1,923	3.04	0%	780.47	41%
			Make-Up Pond 6	Aggregate Washing		8.183	235	1,923	46.08	2%	212.26	11%
5153-A48MT9 (CRH Canada Group Inc.)	Nov. 16, 2015	Aug. 31, 2020	Supply well	Industrial	0.48	0.073	365	26.57	0	0%	0	0%
5626-7WLQ3W (replaced by 2003- AQWHTC) (Wellington Vacant Land Condominium Corporation Number 147)	Oct. 8, 2009	Oct. 31, 2017	PW7	Communal Water Supply	0.69	0.785	365	286.53	9.26	3%	11.37	4%
			PW6	Communal Water Supply		0.785	365	286.53	8.59	3%	4.98	2%
			PW5	Recreational		0.067	85	5.70	0	0%	0	0%
			PW2	Recreational		0.137	85	11.65	0	0%	0	0%
2003-AQWHTC (Wellington Vacant Land Condominium Corporation No. 147)	Sep. 29, 2017	Oct. 31, 2027	PW7	Communal Water Supply		0.500	365	182.5	-	-	1.72	1%
			PW6	Communal Water Supply		0.500	365	182.5	-	-	1.67	1%
7431-96LRQ6 (Morguard Brock McLean Limited)	Apr. 9, 2013	May 31, 2023	TW1 and TW2	Industrial	0.75	0.654	365	238.62	7.51	3%	4.98	2%
7028-7LTNV9 (St. Marys Cement Inc. (Canada))	Dec. 1, 2008	Dec. 31, 2018	Aberfoyle Main (North) Pit Pond	Industrial	0.87	23.568	365	8,602	2,641.53	31%	3,010.84	35%

Permit no. (Permit Holder)	Issue Date	Expiry Date	Source	Purpose	Distance from Nestlé source well (km) [1]	PTTW limits			2016 WTRS data [2]		2017 WTRS data [2]	
						Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
4373-8TXQK3 (Capital Paving Inc.)	May 4, 2012	May 31, 2022	Pond B	Aggregate Washing	1.6	16.939	200	3,388	0	0%	8.65	0.26%
			Well A - Office	Industrial		0.115	300	34.38	0.78	2%	0.71	2%
			Well B - Asphalt Plant	Industrial		0.516	300	154.68	8.62	6%	7.41	5%
			Well C - Concrete Plan	Industrial		0.802	300	240.60	5.09	2%	4.34	2%
8724-9GFPQE (Con-Cast Pipe Inc.)	Feb. 27, 2014	Aug. 31, 2024	Well WSW 1	Manufacturing	1.6	0.250	365	91.25	13.09	14%	13.58	15%
			Well WSW 2	Manufacturing		0.200	365	73.0	9.45	13%	7.87	11%
3331-73RKYV (replaced by 7137-AG7SV2) (Wellington Common Elements Condominium Corporation No.214)	Jun. 29, 2007	Oct. 31, 2016	Well PW1	Communal Water Supply	1.8	0.132	365	48.18	8.53	18%	-	-
			Well PW2	Communal Water Supply		0.185	365	67.53	12.72	19%	-	-
			Well PW3	Communal Water Supply		0.323	365	117.90	21.69	18%	-	-
			Well PW4	Communal Water Supply		0.333	365	121.55	0	0%	-	-
7137-AG7SV2 (Wellington Common Elements Condominium Corporation No.214)	Dec. 7, 2016	Oct. 31, 2026	Well PW1	Communal Water Supply		0.1469	365	53.61	0.67	1%	9.84	18%
			Well PW2	Communal Water Supply		0.1966	365	71.74	0.98	1%	19.52	27%
			Well PW3	Communal Water Supply		0.3197	365	116.68	1.66	1%	32.22	28%
			Well PW4	Communal Water Supply		0.295	365	107.62	0	0%	0	0%

Permit no. (Permit Holder)	Issue Date	Expiry Date	Source	Purpose	Distance from Nestlé source well (km) [1]	PTTW limits			2016 WTRS data [2]		2017 WTRS data [2]	
						Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
8288-97HQQG (replaced by 3782-AB6MMX) (Royal Canin Canada Company)	May 17, 2013	Dec. 13, 2016	Well PW-1	Food Processing	2.2	0.240	365	87.6	15.61	18%	-	-
3782-AB6MMX (Royal Canin Canada Company)	June 27, 2016	Dec. 31, 2026	Well PW-1	Industrial		0.240	365	87.6	18.01	21%	36.76	42%
5550-9V7HXS (CBM Aggregates, a division of St. Marys Cement Inc. (Canada))	Apr. 7, 2015	Aug. 31, 2019	McNally Supply Pond	Industrial	2.5	23.568	365	8,602.32	2,493.31	29%	2,692.96	31%
8520-A48LDY (CRH Canada Group Inc.)	Nov. 16, 2015	Mar. 31, 2019	Phase 1 Pond	Aggregate Washing	3.1	8.183	275	2,250.33	1,176.06	52%	1,358.39	60%
			Pond 4	Industrial		17	364	6,188	1,656.26	27%	1,700.72	27%
0871-9FDHKG (Springfield Golf and Country Club Inc.)	Feb. 26, 2014	Feb. 28, 2024	Clubhouse Well	Water Supply	4.3	0.130	365	47.45	3.34	7%	2.70	6%
			Maintenance Well	Golf Course Irrigation		0.010	365	3.65	0.07	2%	0.13	4%
			Irrigation Well	Golf Course Irrigation		0.655	214	140.17	24.70	18%	10.97	8%
			Irrigation Pond	Golf Course Irrigation		0.910	214	194.74	41.98	22%	22.79	12%

Permit no. (Permit Holder)	Issue Date	Expiry Date	Source	Purpose	Distance from Nestlé source well (km) [1]	PTTW limits			2016 WTRS data [2]		2017 WTRS data [2]	
						Max. taken per day (Million L)	Taking Days per Year	Annual Taking (Million L)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)	Annual Reported Taking (Million L)	Annual Reported Taking (% of PTTW Limit)
5743-9UQQXX (DeCorso Enterprises Limited)	Mar. 31, 2015	Feb. 28, 2025	TW1-05	Golf Course Irrigation	4.4	0.657	214	140.60	50.39	36%	38.29	27%
			Irrigation Pond #1	Golf Course Irrigation		1.635	214	349.92	47.28	14%	31.19	9%
			Storage Pond #2	Golf Course Irrigation		1.635	214	349.92	1.23	0.004%	0	0%
			Storage Pond #3	Golf Course Irrigation		1.635	214	349.92	0	0%	0	0%
8183-825LLD (Ontario Realty Corporation)	Feb. 5, 2010	Dec. 31, 2019	Cooling Well (A063031)	Industrial	4.5	1.037	365	378.43	0	0%	-	-

[1] For PTTWs with multiple sources, the distance to the Nestlé well is measured from the approximate centroid of the sources.

[2] A hyphen (-) indicates that no taking was reported in the WTRS.

Data accurate as of September 2018

All PTTWs within 5 km of the Nestlé (Aberfoyle) Site are for groundwater takings (note that having been classified as groundwater sources, the ponds in Table 4-C-5 are likely fed by groundwater and surface water runoff, rather than being on-line water bodies). Water takings consist predominantly of industrial (including aggregate washing) and commercial activities, as well as communal water supply. One cluster of communal groundwater wells is located among the residential dwellings on the opposite side of Brock Street, approximately 690 m northeast of the Site; a second cluster of communal supply wells is located among residential dwellings south of Wellington Road, approximately 1.8 km north-northeast of the Site.

Among the permitted water users in the area, permitted water takings for aggregate operations are generally the largest, with maximum permitted withdrawal amounts for a given operation ranging from about 3,818 million L to 8,600 million L per year. Reported annual water takings for aggregate operations in 2016 and 2017 ranged from about 14 million L to 3,059 million L per year. The water takings do not, however, take into account that much of the water used in aggregate washing is returned to the natural environment and details of the geological units used for extraction and washing/infiltration have not been determined as part of this report. For the communal water taking located approximately 690 m northeast of the Site, the cumulative, maximum permitted withdrawal amount under its current permit is 365 million L per year; communal water takings of 17.85 million L and 19.74 million L were reported in 2016 and 2017, respectively. For the communal water taking located 1.8 km north-northeast of the Site, the cumulative, maximum permitted withdrawal amount under its current permit is 349.66 million; communal water takings of 46.25 million L and 51.74 million L were reported in 2016 and 2017, respectively.

4C.4.2 Provincial Groundwater Monitoring Network

The PGMN is a partnership program with all 36 conservation authorities (CAs) and 10 municipalities (in areas not covered by a CA) to collect and manage ambient (baseline) groundwater level and quality information from key aquifers located across Ontario. During the spring and summer of 1999, low water conditions in many parts of southern Ontario prompted the formation of an inter-ministerial task force to assess drought conditions, determine trigger levels and develop a response strategy. The PGMN was approved in 2000 and there are currently more than 450 monitoring wells in the network.

The PGMN datasets report on ambient (baseline) groundwater level and chemistry conditions. The PGMN well locations are typically sited to be away from areas where there is a large density of permitted water takings. Consequently, the PGMN wells are typically far too distant from any permitted water taking to be used as an indicator of potential well interference impacts.

Water level data collected for the PGMN wells is of potential value in assessing regional groundwater level trends as an indicator of stress within the watershed/subwatershed. Data has been collected for the PGMN well network since 2001, though some wells were installed more recently than this. Also, the data for some wells is not current to 2018. The PGMN database is made available by MECP on-line.

As a recent internal project, the MECP has applied the Mann-Kendall (MK) and Seasonal Kendall (SK) tests to analyze the PGMN water level data for monotonic trends (i.e. consistently increases or decreases through time). The statistical analyses were performed using robust and defensible methodologies to look for longer-term trends in groundwater levels. An overall objective is to determine if there is enough data to support the presence of a widespread decrease in groundwater availability. Shorter trends within the PGMN data record (e.g. lasting for a few years) were not considered and the causes of any trends that were identified were not investigated. Both the data plots and preliminary findings for PGMN well locations nearest a WBSA were shared by the ministry and are presented and relied on herein. The data plots indicate data available for the well at the time of the assessment. Further, the MECP has indicated that the methodologies used require that certain values be dropped from the data set if the month/year in question does not have a sufficient number of data points. The release of a final report that details the methodology and results from the PGMN data trends analysis is forthcoming from the ministry (MECP, 2018).

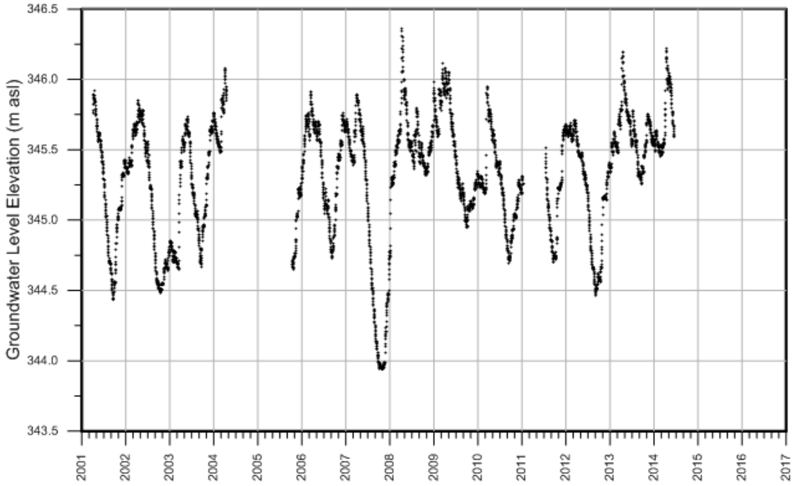
Six PGMN wells are located within 10 km of the Nestlé (Aberfoyle) Site, as shown on Figure 4-C-2. The PGMN well information is summarized in Table 4-C-6.

Table 4-C-6: Nestlé (Aberfoyle) Site – PGMN Wells Summary

PGMN Well ID	Water Well Record ID	Distance from the Nestlé (Aberfoyle) Well (km)	Well Depth (m)	Ground Elevation (masl)	Lithology of Aquifer
W0000003-1	2801739	8.6	15.54	346.77	Overburden (sand, gravel)
W0000008-1	6813466	8.8	6.1	299.98	Bedrock (limestone)
W0000024-2	6711653	5.8	25.91	331.97	Overburden (silt)
W0000024-4	6711653	5.8	39.6	332	Bedrock (limestone)
W0000031-1	6705976	5.9	27.43	294.89	Bedrock (limestone)
W0000046-1	6713287	9.4	30.48	315.94	Bedrock (limestone)

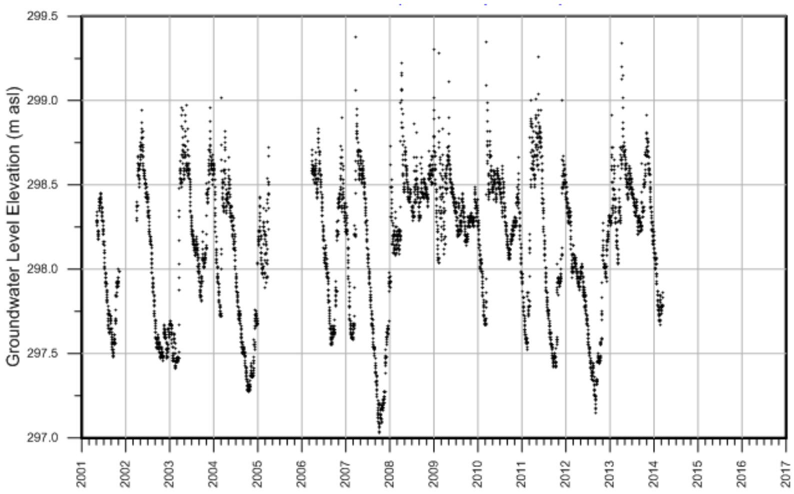
The data plot and trend analysis for the 6 PGMN well installations within 10 km of the Nestlé (Aberfoyle) Site are provided on Text Figures 4-C-7a to 4-C-7f.

Text Figure 4-C-7a: Groundwater Elevations (2001 to 2015) for PGMN Well W0000003-1



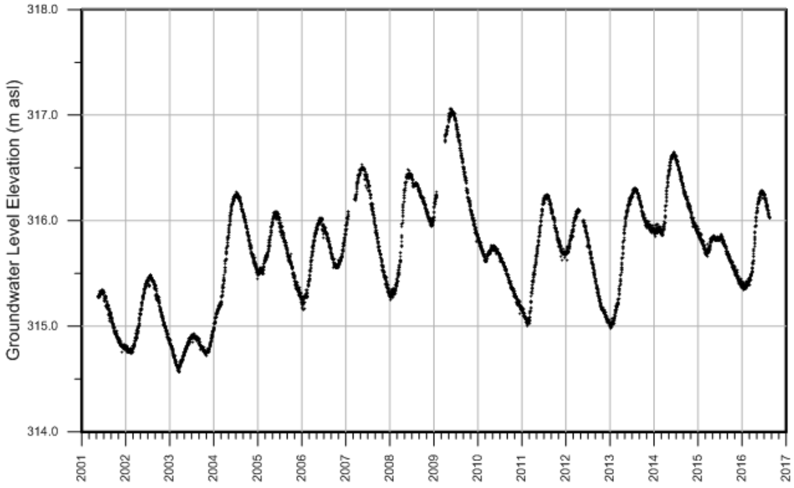
For PGMN well No. W0000003-1, the MK test (year over year) did not detect a significant trend. The SK test (season to season) detected an upward trend. Visual analysis of the water level data indicates typical seasonal fluctuations of approximately 1.5 m, with the lowest water level being observed in the late fall of 2007.

Text Figure 4-C-7b: Groundwater Elevations (2001 to 2015) for PGMN Well W0000008-1



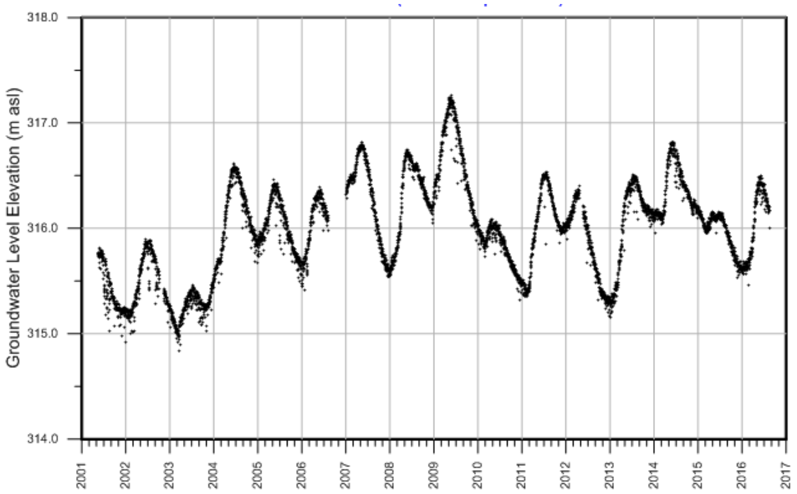
For PGMN well No. W0000008-1, the MK test (year over year) did not detect a significant trend. An SK test (season to season) was not completed for the PGMN well. Visual analysis of the water level data indicates typical seasonal fluctuations of approximately 1.5 m, with the lowest water levels being observed in the late fall of 2007 and the fall of 2012.

Text Figure 4-C-7c: Groundwater Elevations (2001 to 2017) for PGMN Well W0000024-2



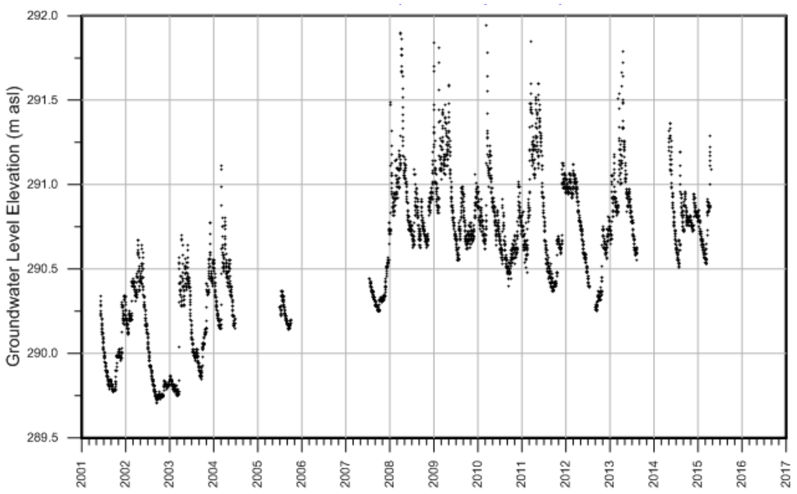
For PGMN well No. W0000024-2, the MK test (year over year) did not detect a significant trend. The SK test (season to season) detected an upward trend. Visual analysis of the water level data indicates typical seasonal fluctuations of approximately 0.5 to 1 m, with a gradual increase in water levels over the period of record.

Text Figure 4-C-7d: Groundwater Elevations (2001 to 2017) for PGMN Well W0000024-4



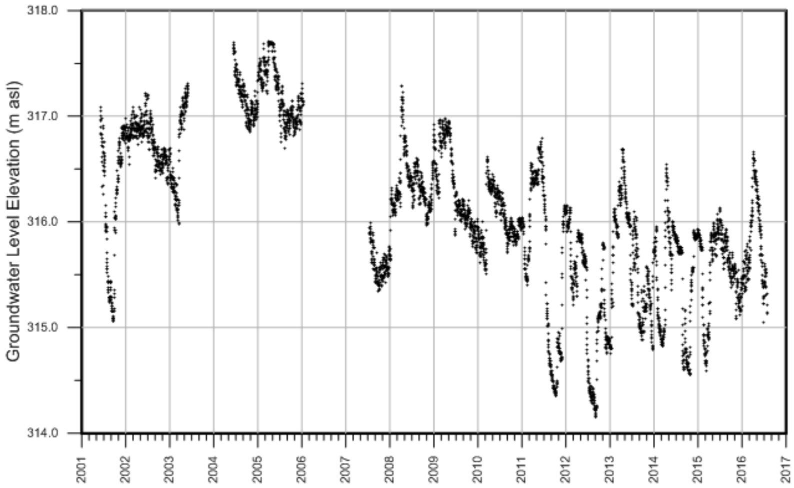
For PGMN well No. W0000024-4, the MK test (year over year) did not detect a significant trend. The SK test (season to season) detected an upward trend. Visual analysis of the water level data indicates typical seasonal fluctuations of approximately 0.5 to 1 m, with a gradual increase in water levels over the period of record (similar to W0000024-2).

Text Figure 4-C-7e: Groundwater Elevations (2001 to 2016) for PGMN Well W0000031-1



For PGMN well No. W0000031-1, the MK test (year over year) did not detect a significant trend. The SK test (season to season) detected an upward trend. Visual analysis of the water level data indicates an increase in water levels and seasonal variability after 2008.

Text Figure 4-C-7f: Groundwater Elevations (2001 to 2017) for PGMN Well W0000046-1



For PGMN well No. W0000046-1, the MK test (year over year) detected a downward trend. The SK test (season to season) also detected a downward trend. Visual analysis of the water level data indicates a gradual decrease in water levels, seasonal peaks and seasonal lows, with the lowest water levels observed in the fall of 2011 and the fall of 2012.

4C.4.3 Ontario Low Water Response (OLWR) Program

The OLWR program was initiated in 2000 and is managed by the MNRF. The program relies on the use of real time surface water monitoring data collected through the Surface Water Monitoring Centre and utilizing the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. Presently, static groundwater elevation data from the PGMN program is not a component of the OLWR program. Reportedly, this may be added to the program in future.

OLWR notifications are typically (i.e. not always) released in the last week of each month after a review of data for the previous weeks in the month. When trigger levels are identified for a monitoring station, the OLWR submits a notification to the respective CA or municipality. Based on its review of the OLWR data that accompanies the notification, combined with a review of local factors that include recent precipitation and reports of water shortfalls for surface water and well water supplies, a Low Water Conditions Alert 'may' be posted by the CA/municipality. A CA or municipality may also choose to post an Alert without any OLWR notification. Decreases in water takings that are triggered by the declaration of Level 1, 2 and 3 Low Water Condition are as follows:

- Level 1 - A voluntary reduction of 10%;
- Level 2 – A voluntary reduction of 10%, to achieve a 20% reduction;
- Level 3 – Reduce and manage water use demands to the maximum extent through regulatory measures, if required.

Note: Specific Permits to Take Water may have conditions requiring mandatory reductions of water takings during low water events. Upon renewal of their water bottling permit, the above decreases will be mandatory based on 3-month average actual flow as outlined in the guidance for bottled water renewals (MOECC, 2017).

The frequency of OLWR notifications over time can be a potential indicator of climate stress trends for surface water and possibly shallow groundwater, and an indicator of watershed/subwatersheds that are sensitive to seasonal drought conditions. However, the existing OLWR program database has not been prepared for this purpose, has inconsistencies that are attributed to different persons updating the database over the years, and the database does not provide notification Levels during the time period where a Low Water Alert has been declared by a CA/municipality. This is only indicated in the database as an 'Update'. Consequently, only a general review of the information in the OLWR database is provided herein for the geographic CA/municipality relevant to the Site.

A general review of the OLWR database indicates that a total of 22 Level 1 notifications, three Level 2 notifications, and one Level 3 notification were sent to the GRCA between 2000 and August 2018. Notifications were sent to the GRCA every year except in 2002, 2003, 2006 – 2008, 2011, 2013 and 2014. Instances when more than two notifications were issued in the same calendar year occurred in 2000 (three Level 1 notifications), 2004 (two Level 1 notifications and one Level 2 notification), 2010 (four Level 1 notifications), 2015 (three Level 1 notifications), and 2016 (one Level 1 notification, one Level 2 notification and one Level 3 notification). The only Level 3 notification to be issued between 2000 and August 2018 occurred in early December 2016. For the Mill Creek subwatershed, in which the Nestlé (Aberfoyle) Site is located, the GRCA received one Level 1 notification (and no Level 2 or 3 notifications) between 2000 and August 2018; this occurred in late April 2012.

The GRCA posted Low Water Condition Alerts on six occasions for the Mill Creek subwatershed:

- Mid-July 2002 to mid-August 2003: a Level 2 Low Water Condition Alert was posted in mid-July 2002, which was lowered to a Level 1 in early October 2002, and raised back to a Level 2 in early July 2003. The Low Water Condition Alert ended entirely in mid-August 2003 (although records suggest there was a one-week 'hiatus' in early August 2003 when there was no Low Water Condition Alert at all);
- Late October to early December 2005: a Level 1 Low Water Condition Alert was posted;
- Late August 2007 to late March 2008: a Level 1 Low Water Condition Alert was posted in late August 2007, which was raised to a Level 2 in late September 2007, and lowered back to a Level 1 at the beginning of March 2008. The Low Water Condition Alert ended entirely in late March 2008;
- Late June to late August 2012: a Level 1 Low Water Condition Alert was posted in late June 2012, which was raised to a Level 2 in early July. The Low Water Condition Alert ended entirely in late August 2012;
- July to late October 2016: a Level 1 Low Water Condition Alert was posted in July 2016, which was raised to a Level 2 in mid-July. The Low Water Condition Alert ended entirely in late October 2016; and,
- Mid-July to end of August 2018: a Level 1 Low Water Condition Alert was posted.

Although the Low Water Condition Alert in 2016 ended in late October for the Mill Creek subwatershed, the Level 2 Low Water Condition Alert remained in effect for the Grand River Watershed as a whole until mid-January 2017, before being lowered to a Level 1 until its removal in late April 2017. During the period July 2016 to April 2017, Nestlé complied with the request by the GRCA for all water users in the watershed to reduce water consumption, voluntarily limiting their water takings to 90% or 80% of their monthly maximum permitted volume during both the Level 1 and Level 2 Low Water Condition Alert (Golder Associates, 2018). With the exception of nine days during the Level 1 Condition, Nestlé's water takings were below 80% of the permitted daily amount during this period.

4C.4.4 Water Budget Analyses

For the Grand River Watershed, a water budget study was initiated as a more detailed Tier 2 study in 2005, so a Conceptual Water Budget and Tier 1 Assessments were not required to be completed separately (LERSPC, 2017). In the Mill Creek subwatershed, in which the Nestlé

(Aberfoyle) Site is located, the surface water quantity potential stress level was determined to be low.

The commercial and industrial sectors were identified as having the highest percent consumptive water demands for groundwater in the subwatershed, at 37% and 42%, respectively. The remaining 21% was attributed to private water supply (19%), livestock and rural domestic (1%), and miscellaneous uses (1%). The average annual percent water demand for groundwater was determined to be 12%; based on average demand, the subwatershed has a potential groundwater stress classification of Moderate. As there are no municipal groundwater supplies within the subwatershed, a Tier 3 water budget was not recommended for the subwatershed.

Based on the findings of the Tier 2 water budget, the Nestlé (Aberfoyle) Site is located in an area where groundwater may be stressed.

City of Guelph and the Township of Guelph/Eramosa Tier Three Water Budget and Local Area Risk Assessment

A Tier 3 assessment (Matrix Solutions Inc., 2017) was completed for the municipal water supply systems of the City of Guelph and the Township of Guelph/Eramosa in Rockwood and Hamilton Drive (GGET). The Nestlé (Aberfoyle) Site was located within the Tier 3 model boundary, but outside of the Upper Speed Assessment Area in which the municipal wells for the City of Guelph and the Township of Guelph/Eramosa are located. Therefore, the subwatershed stress was not recalculated in the Tier 3 assessment for the Mill Creek subwatershed.

The Nestlé (Aberfoyle) Site is located within the GGET groundwater Vulnerable Areas, namely WHPA-Q1, which is approximately 20 km across and is derived from the 2.0 m drawdown contour surrounding the City of Guelph wells and the Hamilton Drive (Township of Guelph/Eramosa) wells. As the Tier 3 model scenarios predicted that the City of Guelph's Queensdale municipal well (located 11.9 km northwest of the Nestlé (Aberfoyle) Site) may not be able to meet future needs under normal climate conditions and during prolonged drought, and due to the high level of uncertainty surrounding the results of the City's Arkell Well 1 (located 9.5 km north of the Nestlé (Aberfoyle) Site), WHPA-Q1-A was assigned a Significant Risk Level. As a result, all of the Eramosa River surface water intakes, all of the water supply wells for the City of Guelph and the Township of Guelph/Eramosa in Hamilton Drive, and other non-municipal permitted consumptive water uses (including Nestlé's water bottling operation) were classified as Significant Water Quantity Threats.

As part of a Risk Management Measures Evaluation Process, the water quantity threats were ranked from greatest to lowest impact, and the maximum percent impact on the municipal wells were determined (Matrix Solutions Inc., 2018). Of the 24 water quantity threats that were considered, Nestlé ranked low, with a rank of 20, and was predicted to have a maximum percent impact of 1% on municipal wells.

4C.5 WBSA IMPACT AND SUSTAINABILITY ASSESSMENT

The following section provides a general assessment of the potential for water taking at the Nestlé (Aberfoyle) Site to result in water quantity interference with other groundwater uses and the environment. The reader is referred to the Guelph WQSA (Section 4 of the main report) for a discussion of regional water sustainability.

4C.5.1 Municipal Groundwater Use

No municipal groundwater supply wells are located in the Township of Puslinch or within 5 km of the Nestlé (Aberfoyle) Site; the closest municipal groundwater wells are the City of Guelph's Burke well and Downey well, located 6.9 km north-northwest and 8.4 km northwest of the Site, respectively. The Township recently commissioned a feasibility study to assess the viability of implementing municipal water and wastewater services within key areas of the township, but no formal decision has been made about pursuing the study's recommendations.

A population increase from 7,336 (2016 census population) to 9,808 by 2034 is projected for the Township of Puslinch; 6% and 4% of the housing growth is assigned to the urban settlement areas of Aberfoyle and Morriston, respectively. Morriston is located approximately 2.7 km southeast of the Site, beyond the estimated zone of influence of TW3-80 (discussed further in Section C.5.2). The Hamlet of Aberfoyle is located immediately north of the Site, but is expected to accommodate only a modest proportion of the projected growth in the township, and there is currently no indication of any 'planned' new municipal groundwater system for Aberfoyle. In addition, per the County of Wellington Official Plan (2018), when considering new lot creation, the County will consider (among other factors) whether new lots can be adequately serviced with water without undue financial burden on the municipality.

In summary, the general assessment of potential water quantity interference with existing or planned municipal water supply systems did not identify any potential for unacceptable impact/ interference.

4C.5.2 Well Interference Potential

Using water levels measured during a 46-day pumping test in 2010 (CRA, 2011), when TW3-80 was pumped at a rate of 2,460 L/minute (equivalent to 98.4% of the permitted capacity), the zone of influence for a pumping rate of 2,500 L/minute was estimated; in the Amabel Aquifer, the zone of influence was estimated to extend about 1,400 m to the north-northwest, 1,100 m to the northeast and 800 m to the southwest of TW3-80. In the Guelph Aquifer, the zone of influence was estimated to extend about 1,200 m to the north-northwest, a maximum distance of 550 m to the west, and 220 m to the east of TW3-80. No drawdown exceeding 1 m was observed in the overburden.

Nestlé reported that no complaints arose from the water taking in 2010, 2015, 2016 and 2017 (the annual monitoring reports for other years were not reviewed). Similarly, Nestlé reported no complaints during the pumping tests in 2004, 2007 and 2010. Monitoring of water levels in the Amabel, Guelph and overburden aquifers identified no overall decreasing trend over the past five years.

Based on the information reviewed, a potential for unacceptable well interference impacts to neighbouring groundwater supplies has not been identified at the current permitted water taking rates and volumes. No new, high water use activities were identified and/or are apparent near the Nestlé (Aberfoyle) Site based on the information reviewed, and growth in Aberfoyle is projected to be modest. Any new neighbouring land development on private wells and/or any new PTTW of significant scale are expected to require a site-specific hydrogeological study and a well interference assessment in support of the proposed development/water taking.

4C.5.3 Impact to Surface Water and Natural Functions of the Ecosystem

During the 46-day pumping test conducted in 2010, when TW3-80 was pumped at a rate of 2,460 L/minute, it was determined that an approximately 1,090 m long reach of Aberfoyle Creek, largely confined to the property boundaries of the Nestlé (Aberfoyle) Site, is measurably affected by pumping. A streamflow reduction of 2.7 L/s was calculated, which also resulted in that portion of the creek switching from a gaining stream (groundwater-fed) to a losing stream. If TW3-80 is pumped at the maximum permitted rate of 2,500 L/minute, the streamflow reduction as a result of pumping was estimated to be 2.74 L/s.

A streamflow reduction of 2.74 L/s was considered to be relatively small compared to flows in the Aberfoyle Creek, which has an historical mean summer streamflow of 99 L/s. In addition, stream flow at the downstream end of the reach was consistently higher than the stream flow at the upstream reach prior to, during, and after the pumping test, indicating that the overall function of the stream is not being significantly impacted by pumping.

The loss of groundwater input to the stream was estimated to result in an approximate 1.2°C increase in stream temperature in the summer, and an approximate 0.1°C decrease in the winter. As water temperatures in the creek are already heavily influenced by the warm water discharged from the Aberfoyle Mill Pond (located approximately 250 m northeast of the Site's northeastern boundary), and there is no significant thermal refuge throughout the reach, it was determined that a stream temperature increase of 1.2°C under the worst case scenario would not measurably alter the stream fauna.

Per the conditions of PTTW 1381-95ATPY, water levels in Aberfoyle Creek are monitored continuously at the upstream and downstream boundaries of the Nestlé (Aberfoyle) Site, and streamflow is measured monthly. Water levels in three off-site locations on Aberfoyle Creek and Mill Creek, and in two off-site ponds, are monitored on a monthly basis. Stream temperature is measured continuously at six locations on Aberfoyle Creek. Surface water levels, streamflow and water temperatures in the creek were observed to be relatively stable over time, with no observable increasing or decreasing trend.

Based on the findings from the information review, continued water takings at the permitted water taking levels are not expected to impact surface water and natural functions of the ecosystem.

The monitoring program currently in place serves to identify any possible changes to these features.

4C.6 SUSTAINABILITY OF WATER RESOURCES

Water resources are considered sustainable if the total amount of water entering, leaving, and being stored in the system meet existing needs without compromising the ability to meet the needs in the future. Typical indicators used to assess the sustainability of water quantity include Water Budgets completed at the watershed/subwatershed scale and/or for the specific water taking(s) and the evaluation of water level data for trends over time to ensure resources are remaining in a steady state. The following provides a general assessment of the sustainability of regional water resources and of the potential impact from the Nestlé (Aberfoyle) Site water taking on sustainability, now and in the future.

Regional Water Resources

The characterization of the regional study area indicates that the Nestlé (Aberfoyle) Site is located in the Mill Creek subwatershed, where more detailed Tier 2 assessment Water Budget analyses were initiated (LERSPC, 2017). In the Mill Creek subwatershed, surface water has not been an identified concern; moderate potential for groundwater stress was identified. Monitoring of groundwater levels in the Amabel and Guelph bedrock aquifers and overburden aquifers, as well as surface water flows, levels and temperature, and aquatic and terrestrial communities/habitats, have not provided any indications of unacceptable or increasing stress to groundwater or surface water due to the water taking.

The OLWR Program uses real time surface water monitoring data collected from the WSC stream gauge (HYDAT) station network to identify potential drought conditions based on set trigger levels. BluMetric's review of the OLWR Program notification data (2000 to August 2018) for the GRCA did not identify any trends indicating the depletion in the availability of surface water (and possibly shallow groundwater where directly connected to surface water) resources. While Level 1 and Level 2 Low Water Condition Alerts have been necessary within the boundaries of the GRCA, the information indicates these have been in response to extended dry seasonal conditions, and no annual trends suggesting increasing stress to water resources were identified.

BluMetric's review of PGMN groundwater level data for 6 wells located within 10 km of the Nestlé (Aberfoyle) Site water taking (Section C.4.2) did not identify any trends indicating a potential depletion in the availability of regional groundwater resources.

The Tier Three Assessment Water Budget models were used to delineate the WHPA-Q (Groundwater Vulnerable Area) and IPZ-Q (Surface Water Vulnerable Area). The WHPA-Q and IPZ-Q are the areas where the municipal drinking water systems could be affected by other existing, new, or expanded water takings (Matrix, 2017). Since delineation of the original WHPA-Q and IPZ-Q for the City of Guelph's water supply was initiated in 2008, it was recently determined that they should be re-delineated. This was completed to ensure that the Tier Three model reflected revised plans for future land development in 2017 as well as current, non-municipal permitted water use including water taking at the Nestlé (Aberfoyle) Site. These consumptive takings were later used as the starting point in the Risk Management Measures

Evaluation Process (RMMEP) described in the Guelph – Guelph/ Eramosa Water Quantity Policy Development Study Threats Management Strategy (Matrix, June 2018). The threats identified as significant were assessed at progressively finer levels of detail in order to rank which threats have the greatest impact on municipal drinking water systems within the WHPA-Q or IPZ-Q. Based on the threat ranking process within the WHPA-Q, it was determined that among the group of 32 non-municipal, permitted takings assessed, Nestlé Water Canada in Aberfoyle had a maximum percent impact of 1% on the Burke municipal well. In summary, the Tier Three Assessment scenarios predicted that the GGET municipal wells can meet current water demands; though the Tier Three model scenarios also predicted that the City's Queensdale municipal well may not be able to meet future needs under normal climate conditions and during prolonged drought (Matrix, 2017). The City's other wells and Guelph/Eramosa Township's (GET) wells were expected to meet future needs under all scenarios. However, the Tier Three Assessment indicated that there is a high level of uncertainty for the results of the City's Arkell Well 1. Of note, because water pumped from the Eramosa River intake is not pumped directly into the City of Guelph's drinking water system, and that the Glen Collector was included in the Risk Assessment for groundwater, a Risk Assessment for the surface water supply was not completed. However, to ensure the sustainability of the Glen Collector and the Eramosa intake, the IPZ-Q was assigned the same Risk Level (Significant) as the WHPA-Q, containing the Glen Collector. Furthermore, the Tier Three Assessment predicted that groundwater discharge into some coldwater streams may be reduced by 10% or more as municipal pumping is increased to future rates. This magnitude of impact resulted in a Moderate Risk Level being applied to the WHPA-Q; however, the Moderate Risk Level associated with the surface water impacts was superseded by the Significant Risk Level designation (Matrix, June 2018).

In addition, as a follow up to the GGET Tier Three Study, a Climate Change Assessment was conducted for the GGET WHPA-Q area by modelling predicted Climate Change scenarios to determine potential impacts on the sustainability of the groundwater and surface water resources (Matrix, 2018). Due to expected warmer temperatures and increased precipitation in the winter, the modelling exercise suggests a slight increase in recharge; thus, no impact to the sustainability of the groundwater resource is anticipated. Similarly, no stress concerns were identified for the sustainability of regional surface water quantity resources, which appear to be sustainable under current pumping conditions (Matrix, 2018). However, the risk ranking exercise for IPZ-Q threats has not been completed at this time. The net consumptive water use within the IPZ-Q is small as compared to the natural variability of flow of the Eramosa River at the intake; therefore, on an average basis, consumptive water taking threats are not expected to impact the municipal surface water intake's ability to pump. Further evaluation of the threats in the IPZ-Q will be completed as part of the Climate Change Assessment being carried out. In addition, assessments of environmental flow needs in the Guelph WQSA have focused on the Speed River and the Eramosa River. Target thresholds were quantified for the two rivers, and it was determined that flow requirements are generally achieved in most years. Matrix Solutions Inc. (2018) recommended that the City of Guelph maintain its current groundwater and surface water monitoring program to ensure that the hydrologic regime in the Eramosa River is maintained.

A moderate potential for groundwater stress exists for the sustainability of regional groundwater resources in the future under projected municipal groundwater demand. As discussed in Section 4.3.3 of the main report, available reports and communication with local Water Managers determined that, within the Guelph WQSA, the use of water resources is sustainable under existing population, land use and climate conditions. However, findings from the Local Area Risk Assessments indicate that population growth is the most significant stressor on the groundwater resources in general. In contrast, simulated recharge reduction due to land use changes had a near negligible effect on water levels in the Guelph municipal supply wells, indicating a minimal effect on the groundwater resources in general.

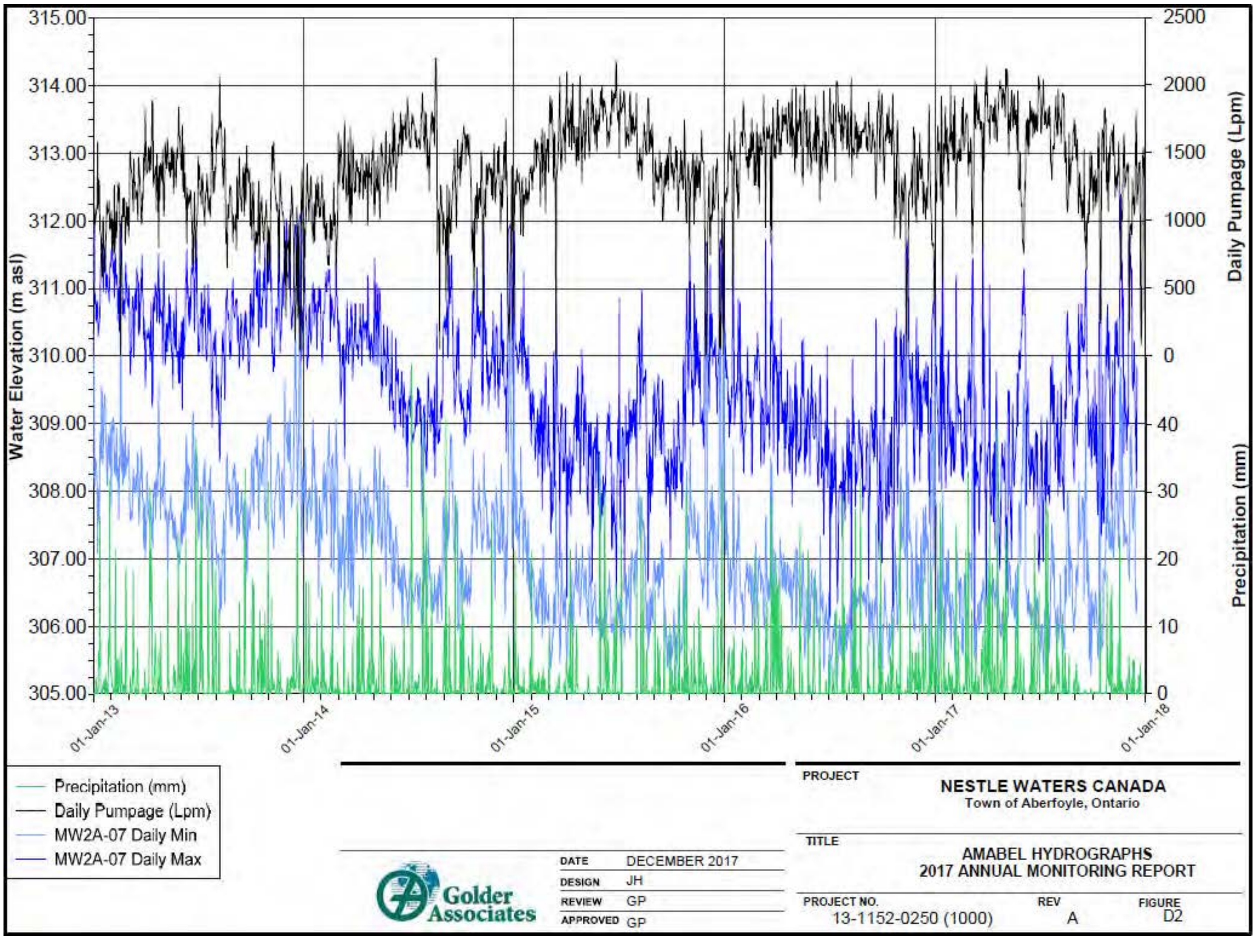
Based on the findings of studies/reports/data conducted and collected in the Guelph WQSA, and information collected from Water Managers, groundwater and surface water resources appear to be sustainable under existing conditions. However, groundwater resources may become unsustainable in the future due to population growth and the associated increase in water demand, and increases in water demand in the future may render the surface water resources unsustainable with respect to ecological flow needs. The reader is referred the Guelph WQSA (Section 4 of the main report) for a more detailed discussion of regional groundwater and surface water resources.

Nestlé (Aberfoyle) Water Taking

Historical information relating to the Nestlé (Aberfoyle) Site indicates the groundwater resources have been used for commercial purposes for close to 40 years, and water withdrawals for commercial water bottling have been permitted since 1994. The reported water taking amounts from 2005 to 2017 have consistently remained below 60% of the maximum permitted annual amount. Maximum withdrawal rates and maximum annual withdrawal amounts have remained unchanged since 2005. The last monitoring report, for water takings in 2017, did not identify any adverse impact from the water taking. No documented well interference complaints/impacts were identified in the ministry files/reports provided for review.

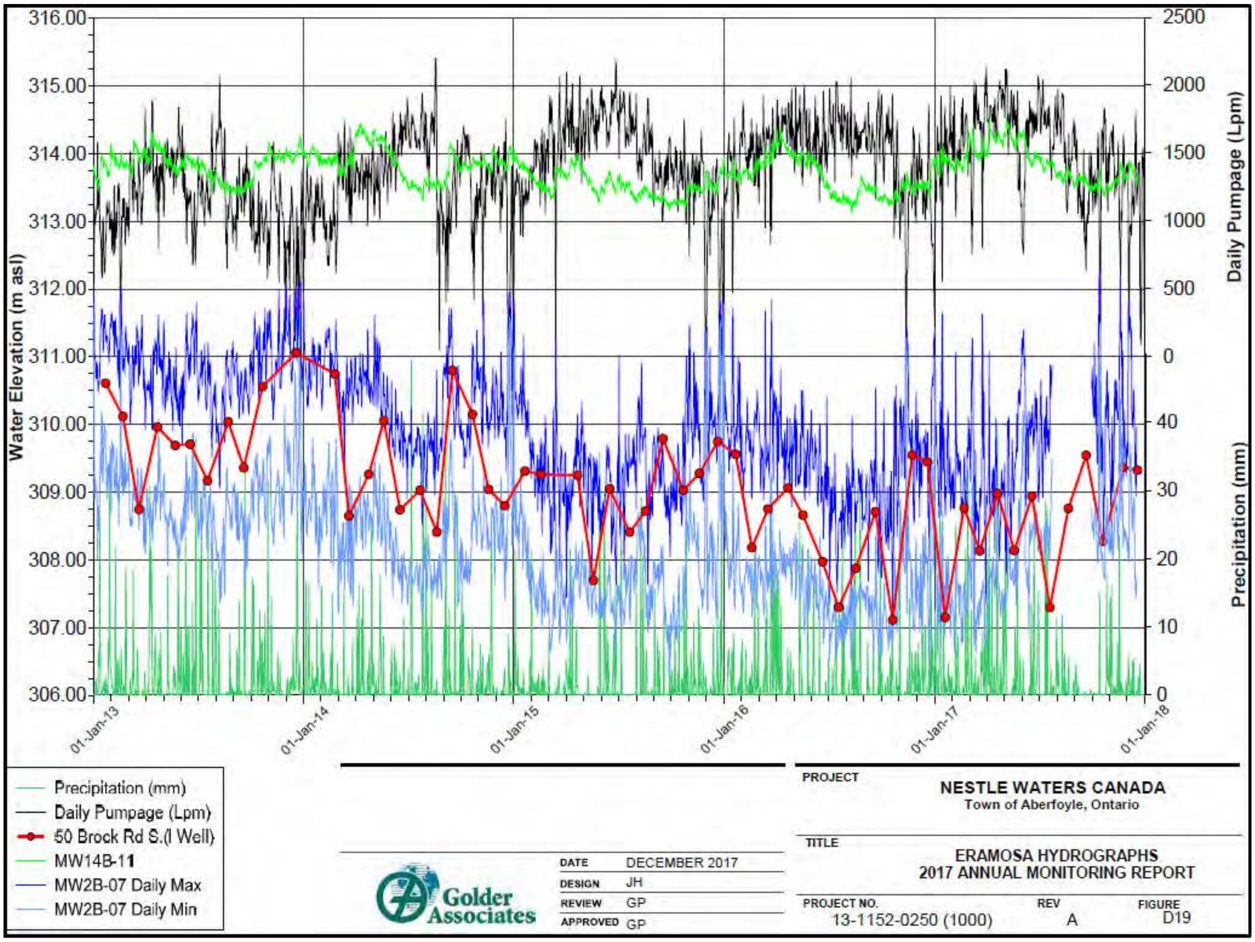
The 2017 monitoring report indicates that groundwater levels in the overburden and bedrock aquifers, as well as monitoring of stream flows and levels and terrestrial and aquatic environments, do not indicate any unacceptable or increasing stress to groundwater or surface water due to the water taking. The hydrographs for long term groundwater elevation data for monitoring wells MW02A-07, MW02B-07, MW02C-07, and TW1-99, completed in the Amabel aquifer, the Eramosa aquitard, the Guelph aquifer, and the overburden, respectively, are reproduced below in Text Figures 4-C-8a through 8d, and are generally within the range measured over the previous five years. MW02A-07, MW02B-07 and MW02C-07 are located approximately 190 m northwest of source well TW3-80, in the same general location as MW02D-07 and MW02-E07 (see Figure 4-C-1b). Monitoring well TW1-99 is located approximately 80 m west-northwest of source well TW3-80.

Text Figure 4-C-8a: Groundwater Elevations (2013 to 2018) in MW02A-07 (Amabel Aquifer)



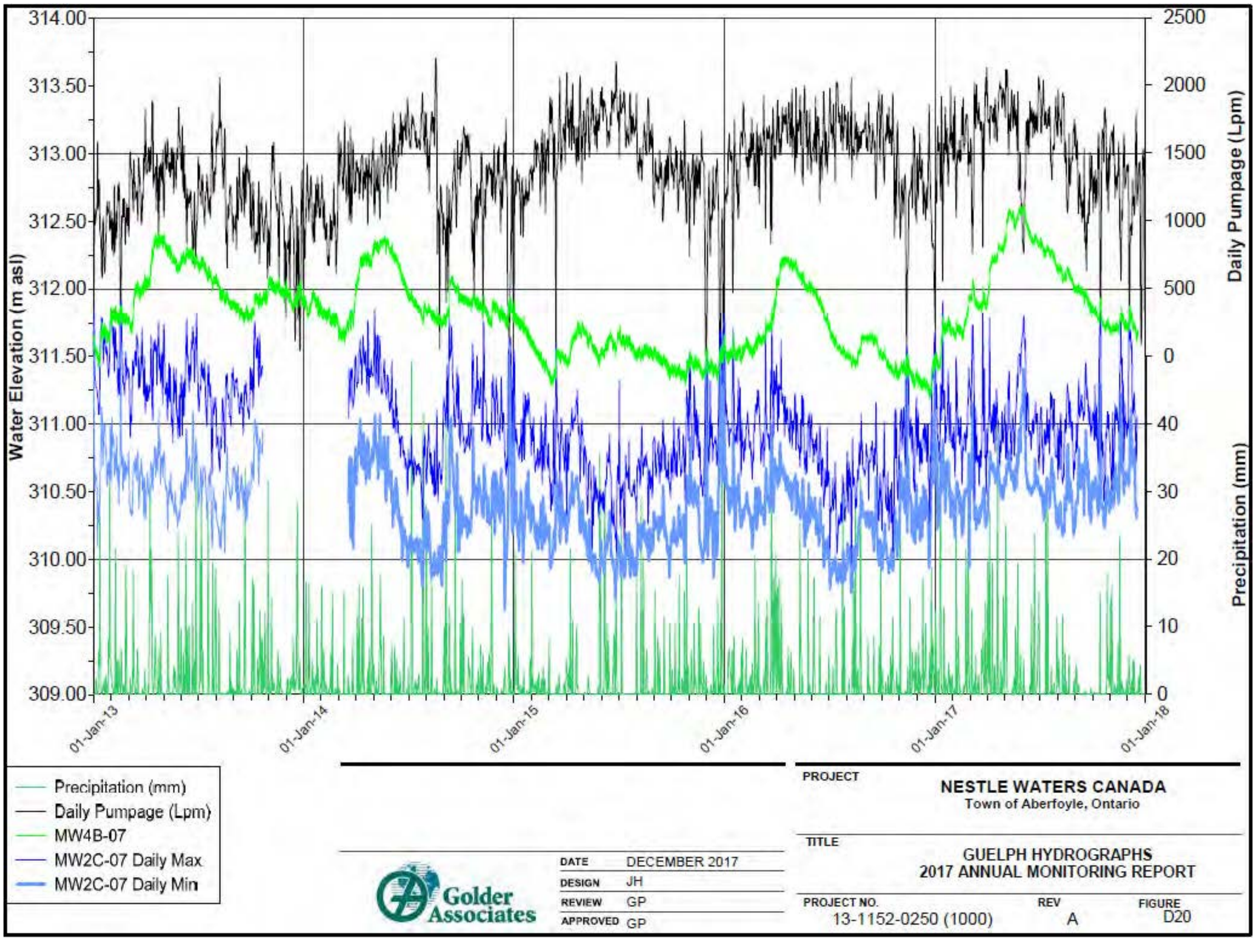
Source: Figure D2 of Golder Associates, 2018

Text Figure 4-C-8b: Groundwater Elevations (2013 to 2018) in MW02B-07 (Eramosa Aquitard)



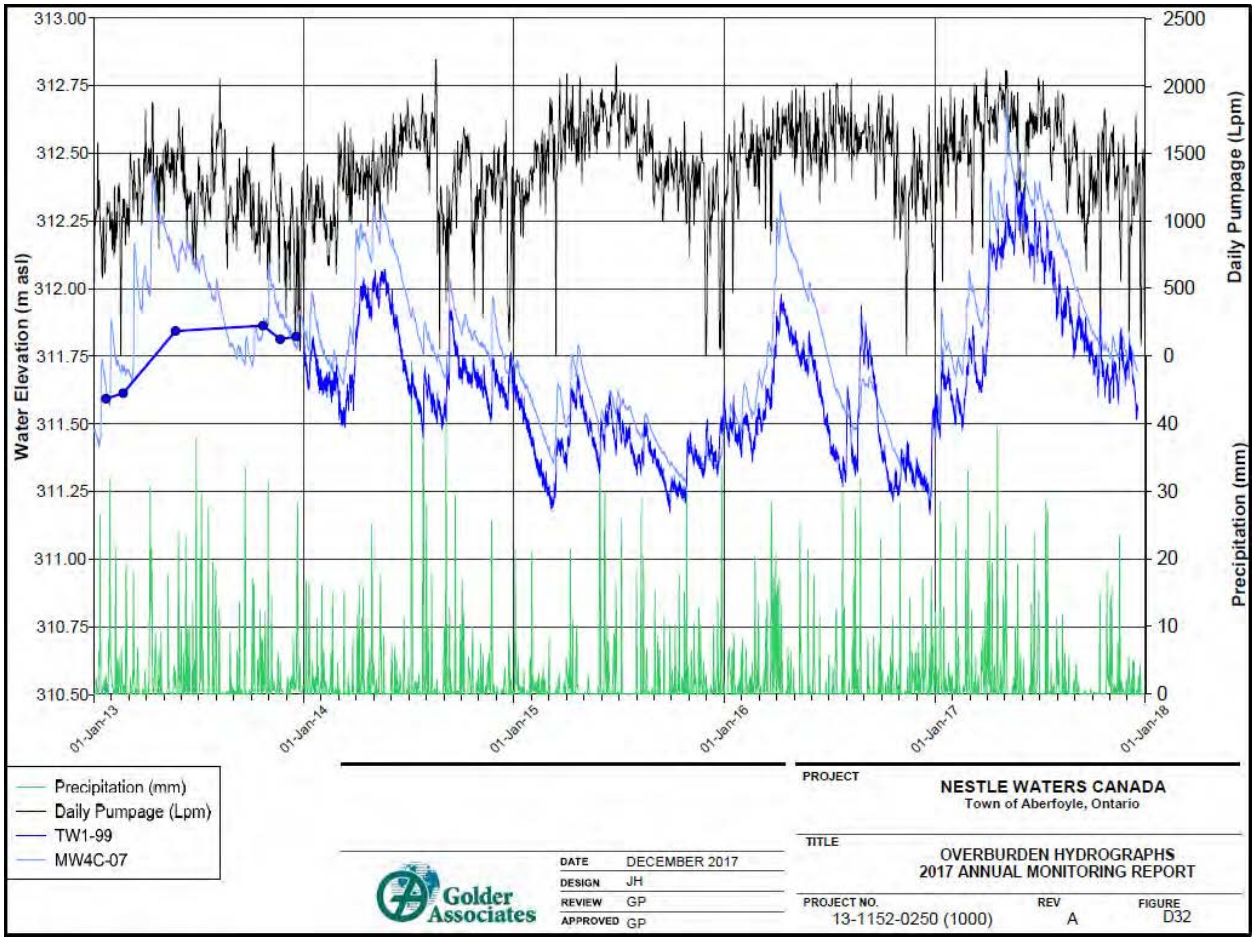
Source: Figure D19 of Golder Associates, 2018

Text Figure 4-C-8c: Groundwater Elevations (2013 to 2018) in MW02C-07 (Guelph Aquifer)



Source: Figure D20 of Golder Associates, 2018

Text Figure 4-C-8d: Groundwater Elevations (2013 to 2018) in TW1-99 (Overburden)



Source: Figure D32 of Golder Associates, 2018

Based on the information reviewed, there are no indicators of the Nestlé (Aberfoyle) water taking having an impact on the sustainability of existing and future water resources at the current levels of taking; the water taking was determined to have a predicted maximum percent impact of 1% on municipal wells in the area. Consequently, it is BluMetric's opinion that the water taking is sustainable under current conditions. Additional insight on the sustainability of the groundwater resource under future climate scenarios will be possible based on the additional Tier Three Modelling when completed. The permit requirements as summarized in Section C.1, including the ongoing adherence to the monitoring and mitigation plans required by the permit, are deemed adequate to identify any unacceptable changes to Site conditions.

4C.7 GAPS AND RECOMMENDATIONS

A summary of information gaps and potential enhancements identified from the assessment of the Nestlé (Aberfoyle) Site is provided as follows:

1. The results of the Risk Management Measures Evaluation Process for the City of Guelph and the Township of Guelph/Eramosa, as well as the additional Tier Three modelling currently underway by Nestlé, S.S. Papadopulos & Associates Inc. and Matrix Solutions Inc., should be considered as part of future assessments of water takings at the Nestlé (Aberfoyle) Site.
2. The integrity of the Eramosa as an aquitard has been questioned in some parts of the WQSA in which this WBSA is located. Further review and testing to determine the hydraulic properties of the unit should be conducted. Nestlé should use this review to determine the implications (if any) to the water taking at the Nestlé (Aberfoyle) Site.

Based on the assessment of water takings at Nestlé (Aberfoyle), Aquaterra (Hillsburgh) (Appendix A), and Nestlé (Erin) (Appendix B), as well as various other bottling facilities assessed in BluMetric (2019), gaps and recommendations relating to all water bottling facilities were identified. The reader is referred to Section 11 of the main report for a summary of the gaps and recommendations.

4C.8 FIGURES

Figures are provided in Appendix A of the main report.

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