REPORT

February 2014

LOCAL AREA RISK ASSESSMENT

Midland and Penetanguishene Tier Three Water Budget and Local Area Risk Assessment

Submitted to:
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Table of Contents

TABLES

FIGURES

APPENDICES

This project has received funding support from the Government of Ontario. Such support does not indicate endorsement by the Government of Ontario of the contents of this material.

1.0 INTRODUCTION

1.1 Background

The Clean Water Act (2006) provides a framework for protection of municipal drinking water supplies in the Province of Ontario. For the purposes of Source Water Protection, the Lake Simcoe Region Conservation Authority (LSRCA), Nottawasaga Valley Conservation Authority (NVCA) and the Severn Sound Environmental Association (SSEA) formed the South Georgian Bay Lake Simcoe Source Protection Region. Under the requirements of the Act, source protection plans are developed to protect the municipal supplies within the source protection region. This includes an assessment of both water quality and water quantity threats. The focus of this project is on the water quantity requirements of the source water framework.

The Source Protection Committee has prepared Assessment Reports in accordance with Ontario Regulation 287/07 (General Regulation) and the Technical Rules for Assessment Report (MOE, 2009). A part of the assessment report is the development of water budgets to assess the risk to water quantity. The water budget assessments are conducted within a tiered framework with each tier refining the spatial scale and technical complexity as required.

Tier One Water Budget and Subwatershed Stress Assessments are conducted to estimate the cumulative hydrologic stresses placed on a subwatershed. Using simplified methodologies, the water budget assesses the percent water demand (i.e., water supply that is required by water users in the area) versus the available water supply within the subwatershed. Areas identified as having moderate or significant potential for stress require a more detailed study with a Tier Two Water Budget.

Tier Two Water Budget and Subwatershed Stress Assessments are completed to confirm the stress assignment established in Tier One using more refined methods such as groundwater flow models and/or continuous surface water models providing a more detailed assessment. The subwatershed stress is assessed and those subwatersheds assigned a moderate or significant potential for stress require a Tier Three Assessment, if there are municipal water takings within them.

The objective of the Tier Three Water Budget and Local Area Risk Assessment is to estimate the likelihood that a municipality will not be able to sustainably meet its future water quantity requirements. The risk assessment uses refined flow models and involves additional detailed assessment on the available groundwater or surface water supply sources. The ratio of water demand to water supply in Tier One and Two assessments is not undertaken in Tier Three Assessments. Instead, the risk assessment evaluates the risk that a municipality may not be able to meet its current or planned water demands.

Tier One and Two Water Budget and Stress Assessments have been conducted within the Study Area (Earthfx, 2010; Golder and AquaResource, 2010). Within the Tier Two Assessment, the 'Midland Area' subwatershed was identified as having a moderate potential for hydrologic stress. The 'Midland Area' subwatershed was classified as having a percent water demand of 22% for existing annual demand conditions and 25% under existing monthly maximum demand conditions, resulting in the moderate stress designation. As a result a Tier Three Water Budget and Local Area Risk Assessment is required for the water systems within the Midland Area subwatershed. The municipal water systems with the 'Midland Area' subwatershed include those in the Town of Midland, Town of Penetanguishene and the Whip Poor-Will municipal well system in the Township of Tiny. Golder Associates Ltd. (Golder) was retained in 2011 to complete a Tier Three Water Budget and Local Area Risk Assessment for these well systems.

The Golder project team was supported by a peer review team that included Chris Neville (S.S.Papadopulos), Igor Iskra (Stantec), Rick Gerber (Conservation Authorities Moraine Coalition) as well as representatives from Town of Midland, Township of Tiny, Town of Penetanguishene, SSEA, Ministry of Natural Resources (MNR), Ministry of the Environment (MOE) and Lake Simcoe Region Conservation Authority.

1.2 Scope of Work

The overall goal of the Tier Three Assessment is to evaluate the potential risk that the municipal supply wells would be unable to sustain their current or planned water demands and/or that impacts to other users (e.g., stream baseflow) would be unacceptable. Water quantity threats will be identified if the water supplies are classified as having either moderate or significant water quantity risk based on this current assessment.

The methodology for the Tier Three Assessment follows the Technical Rules prepared by the MOE (MOE, 2009) for the preparation of Assessment Reports and the water budget technical guidance document released by the MNR and MOE (MNR and MOE, 2011). The guidance document outlines the scope of work required for Tier Three projects relevant to groundwater supplies, as in this Study Area, as follows:

1) Develop the Tier Three water budget model. The surface water and groundwater models should be based on conceptual models representing detailed conditions around the municipal wells. The models should be calibrated to represent typical operating conditions under average and variable climate conditions.

2) Characterize municipal wells. The Tier Three Assessment requires a detailed characterization of wells, specifically identifying the low water operating constraints.

3) Estimate Allocated Quantity of Water. This task compiles and describes existing, committed and planned pumping rates for municipal wells.

4) Identify and characterize drinking water quantity threats. Drinking water quantity threats should include municipal and non-municipal consumptive water demands as well as reductions to groundwater recharge.

5) Characterize projected land use. An evaluation of the potential impact of projected land use changes on water supplies should be included; this involves a comparison of official plans with current land use and incorporates assumptions relating to imperviousness of future developments.

6) Characterize other water uses. Identification of other water uses (e.g., provincially significant wetland) that might be influenced by municipal pumping and their water quantity constraints.

7) Delineate vulnerable areas. The groundwater quantity vulnerable areas, WHPA Q1 and WHPA Q2, should be delineated using the Tier Three water budget model. WHPA Q1 is delineated by computing the drawdown cone for the municipal wells with existing plus committed plus planned rates. WHPA Q2 identifies additional areas, over those in WHPA Q1, where recharge reductions in official plan land use change areas result in a measurable impact to water levels at municipal wells.

8) Evaluate risk scenarios. These scenarios consider the allocated quantity of water for each well and intake, average and drought conditions, and projected land use. The scenarios should be evaluated both in terms of the ability to pump water at each well or intake and where required, the impact to other water uses.

9) Assign risk level. A risk ranking (low, moderate, significant) should be assigned to each of the vulnerable areas based on the results of the risk scenarios. An uncertainty level (high, low) must accompany each risk ranking.

10) Identify drinking water quantity threats and areas where they are significant and moderate. Drinking water quantity threats, such as consumptive uses or reductions in recharge, within the vulnerable areas must be identified.

11) Update the Significant Groundwater Recharge Area mapping for the Study Area using the developed Tier Three modelling tools.

To satisfy the requirements of the Tier Three process, this project has been divided into four work phases:

- Phase 1 – Historical Review and Data Gap Analysis;
- Phase 2 – Refine Conceptual Models;
- Phase 3 – Refine Numerical Models; and
- Phase 4 – Risk Assessment

This Report documents the findings of Phase 4 of the project and summarizes and appends the detailed work reported on previously for Phases 1 to 3.

1.3 Report Organization

The organization of this report is summarized as follows:

Section 2.0 Conceptual and Numerical Models - This section provides a summary of the development of conceptual and numerical modelling tools that were used for the risk assessment. This is a summary of the detailed work that was reported on previously (included as Appendix A, B and C as referenced below).

Section 3.0 Water Demand - This section provides an overview of the municipal well systems and the existing, planned and committed demands for the systems. Also included is a discussion of non-municipal water demands.

Section 4.0 Safe Additional Drawdown - A key aspect of the Tier Three Assessment is the characterization of the municipal wells and their sensitivity to water level declines. A series of calculations and plots have been prepared to better characterize the safe additional drawdown available in the municipal wells.

Section 5.0 Water Budget Summary - A model wide and subwatershed scale water budget is presented including the recharge estimated from the surface water modelling and a breakdown of the water budget components determined through both surface water and groundwater modelling.

Section 6.0 Local Area Risk Assessment - This section presents the methodology and results of the model scenarios and the delineation of WHPA-Q1, Q2 and the Local Area. The tolerance of the system and the potential impacts to other water users are assessed and a risk level is assigned to the Local Area. An uncertainty analysis and gap assessment is presented.

Section 7.0 Water Quantity Threats – A summary of the water quantity threats in the Local Areas is provided including consumptive water demands and reductions in recharge.

Section 8.0 Significant Groundwater Recharge Area (SGRA) Delineation – The methodology and results of the refined SGRA delineation completed using the Tier Three modelling tools is provided in this section.

Section 9.0 Conclusions and Recommendations - An overall summary of the study results, risk assessment outcomes and key recommendations is provided in this section.

Appended to the report are the supporting reports documenting the Conceptual Understanding (**Appendix A**), the Surface Water Model Construction and Calibration (**Appendix B**) and the Groundwater Model Construction and Calibration (**Appendix C**). A technical memorandum describing additional model scenarios that were completed to investigate increased pumping from the Town of Penetanguishene wells outside of the Tier Three Risk Assessment is also appended (**Appendix D**).

2.0 CONCEPTUAL AND NUMERICAL MODELS

2.1 Study Area Overview

Figure 1 shows the Study Area and model domain boundary for the Midland Penetanguishene Tier Three project. The Study Area is generally confined to a peninsula in the Georgian Bay region of Ontario. The extent of this area was defined to encompass the entire source area for the municipal wells and corresponds to natural boundaries (groundwater flow divides, surface water bodies, surface subwatershed boundaries).

The Study Area includes the municipal systems that are part of the Tier Three Assessment including the Midland systems, Penetanguishene systems and the Tiny Township Whip-Poor-Will system. The wells included in the assessment are outlined in Tables 1, 2 and 3. The well systems in Penetanguishene include Lepage, Robert Street and Payette Drive. The well systems in Midland include Vindin Street, Heritage Drive, Sunnyside, Russell Street, Well 1A (Fourth Line) and Dominion Avenue. The Sunnyside wells have recently been decommissioned and are no longer part of the Midland system. Note that there are several other municipal well systems within the Study Area in Tiny Township (shown on Figure 1) that are not part of this Tier Three Assessment (they are outside the Tier Two 'Midland Area' subwatershed) but are included in the model.

2.2 Topography and Drainage

The Study Area is characterized by a series of low rolling hills sloping both steeply and gently (depending on the location) towards Georgian Bay. Ground surface elevation in the Study Area ranges from 177 metres above sea level (masl) at the shores of Georgian Bay to 326 masl at a hill crest west of Penetanguishene in the Township of Tiny (Figure 2). Local streams generally drain towards Georgian Bay, with rolling terrain resulting in some small lakes and wetland areas in depressions. The Study Area encompasses an area of 148 km^2 and is divided into 13 subwatersheds/catchments as shown on Figure 2.

2.3 Climate

Climatic data for the Study Area are available from Environment Canada at six climate stations within or close to the Study Area. Due to data limitations at two of the stations, four stations (Midland Huronia A, Midland Water Pollution Control Plant, Honey HBR Beausoleil and Beausoleil) were selected as the most representative of climate conditions in the Study Area. Locations of the selected climatic stations are shown on Figure 3. Note that the Honey HBR Beausoleil station is located approximately 100 m further north on Beausoleil Island from the Beausoleil station.

Long-term climate normals (obtained from Environment Canada) for the Midland WPCP and Honey HBR Beausoleil were used to describe average conditions of the Study Area. A summary of these climate normals can be found in the Conceptual Understanding Report. Results indicate that the Study Area is within a temperate climate zone (with average annual temperatures generally in the 5-10°C (degree Celsius) range), whereas total precipitation is relatively steady throughout the year (primarily snow from December to February and rain from March to November). The stations are generally in agreement, and comparisons to annual averages will be made against the Midland WPCP station (chosen since it is within the Study Area) later in the report.

A comparison of mean monthly data at all four nearby stations (Midland Huronia A, Midland WPCP, Honey HRB Beausoleil and Beausoleil) from 1980 onwards is shown in Table 5 of the Conceptual Understanding Report. There is good agreement in annual precipitations between each of the stations; the range of average annual precipitation is between 993.1 mm/yr (Midland Huronia A) and 1,124.8 mm (Beausoleil) representing a range of 131.7 mm or 13% of the average for all four stations (1,041.4 mm/yr). The average annual temperatures at all four stations also fall within the same range, ranging from a maximum of 7.3°C (Beausoleil) and a minimum of 6.6°C (at Midland Huronia A), representing a range of 0.7°C. Supplementary graphical climatic information is provided in Appendix A of the Conceptual Understanding Report.

2.4 Land Use and Land Cover Change

The existing land use and land cover conditions of the Study Area are shown on Figure 4. The land use data shown on Figure 4 were provided by SSEA in July, 2012 and is based on Southern Ontario Land Resources Information System (SOLRIS)/Natural Resources and Values Information System (NRVIS) data and agricultural surveys completed by SSEA. This land use data was an input for the MIKE SHE modelling used to develop the existing condition recharge as further described in Appendix B.

The northern portion of the Study Area (along the northern tip of the Peninsula) is primarily forested, whereas areas of rural pasture and cropland are present in the western and southern portions of the Study Area. The two large urban centres within the Study Area (Penetanguishene and Midland) are located along the Georgian Bay shoreline on the eastern side of the Peninsula. An estimated 55% of the Study Area is woodland (including the following classifications of land use: bog, coniferous forest, deciduous forest, forest, mixed forest, plantations – trees cultivated, and swamp), 23% agricultural (hedge rows and undifferentiated), 18% built-up (built-up areas impervious, built-up areas pervious, extraction and transportation) and 5% water (marsh and open water).

Future development lands were identified based on information provided by the municipalities. The following information sources were used to identify future development areas:

- Town of Midland – Town of Midland Water Works Master Plan Update – DRAFT Report (AECOM, 2013);
- Town of Penetanguishene – Official Plan of the Town of Penetanguishene (McNair and Marshall, 1999); and
- Township of Tiny – Development Properties Map (Township of Tiny, 2013).

Figure 5 shows the projected land use for the Study Area and highlights the areas of land use change identified from the above information sources. These development areas included draft approved, approved and potential developments consistent with the official plans. As part of the risk assessment model scenarios, recharge reductions are applied and evaluated at these identified areas of projected land use change, as described in Section 6.0.

2.5 Hydrology

Surface water features in the Study Area include lakes, wetlands, marshes, creeks and streams. The Study Area encompasses 148 km^2 divided into 13 subwatersheds/catchments as shown on Figure 3. These 13 subwatersheds/catchments range in size from 1.2 km^2 (Tiffin Bay, east of Midland) to 24.1 km^2 (Copeland Creek). Each subwatershed/catchment is described in more detail in Appendix A. The subwatersheds in the Study Area and their corresponding drainage areas are summarised in the table shown on Figure 3.

Understanding the hydrologic flow system of the Study Area is important to determine the dominant flow paths. Land cover, surficial soils, wetlands, lakes and other storage reservoirs play a key role in the hydrology of the area. The majority of the land cover in the Study Area consists of woodland and pasture (77%) which has a potential for high evapotranspiration rates. The dominant soil group in the Study Area consists of sandy loam and loamy sand (86%) with “well drained” characteristics (Hydrologic soil group A), which is expected to result in increased infiltration and reduced runoff compared to less pervious soils. Moreover, the presence of lakes, marshes, wetlands and reservoirs provides storage for the runoff generated and facilitates attenuation of peak flows and floods. The combinations of high infiltration, high potential evapotranspiration and attenuation of flows results in reduced runoff, more persistent baseflow and relatively small peak flow rates during storm events.

Currently, no continuous streamflow gauging station exists in the Study Area. There was one WSC streamflow gauge station in Copeland Creek near Penetaguishene (02ED019), which was initiated in 1988 and discontinued in 1999. There are two other WSC stations adjacent to the Study Area on the Wye River: 02ED011 (Wye River at Wyebridge, 1973-1986), and 02ED013 (Wye River near Wyevale, 1986-2012). The locations of the Copeland Creek gauge and the Wye River at Wyebridge gauge are shown on Figure 3. The Wye River near Wyevale gauge is outside of the Study Area, approximately 5 km upstream (to the southwest) of the Wyebridge gauge. The years of data that are available, the WSC-estimated drainage areas and a summary of observed streamflows for each station are included in Appendix A.

The available stream data indicate high flows in the spring (March through May), low flows in the summer and early fall (June through October), then recovering flows in late fall and winter (November through February). In terms of annual yield, the Copeland Creek station reports significantly less flow than the Wye River stations (222 mm/yr versus 365 mm/yr and 373 mm/yr estimated over the subwatershed). This observation could be attributed to several variables including differing soils, land use and meteorology over the respective subwatersheds contributing to these gauges; however, it is likely that cross boundary groundwater flow (to adjacent subwatersheds and directly to Georgian Bay) and potentially gauge underflow affect the Copeland Creek Station.

Baseflow separation provides a method to infer the approximate contributions of runoff, interflow and baseflow in a measured streamflow hydrograph. Baseflow is typically assumed to represent groundwater discharge in unregulated watersheds. The results from these estimates can be used to gauge the level of groundwater/ surface water interaction within a subwatershed/catchment. Baseflow analysis was completed on the hydrographs from the three available streamflow stations in and around the Study Area. The methodology and detailed results of the baseflow separation are presented in Appendix A. The results suggest that the baseflow contribution to the three streamflow gauges is between 148 mm/yr and 237 mm/yr. As with the total streamflow gauge results described above, the estimated baseflow contribution to the Copeland Creek gauge is significantly less than the contribution at the Wye River gauges (148 mm/yr versus 237 mm/yr and 226 mm/yr). This is assumed to be the result of the small subwatershed size and groundwater flows bypassing the gauge to discharge directly into Georgian Bay. Further discussion regarding the baseflow separation is provided in Appendix A.

2.6 Ecological Features

The Provincially Significant Wetlands and identified coldwater streams within the Study Area are shown on Figure 6 and are listed below.

Provincially Significant Wetlands are identified using the Ontario Wetland Evaluation System by the MNR. This science based ranking system provides a standardized system for recognizing wetlands with a valuable ecological function.

The Provincially Significant Wetlands in the Study Area include the Wye Marsh, Midland Swamp, Penetang Marsh, Midland Little Lake Wetland, St. Andrew's Lake Wetland, Sucker Creek Wetlands and the Lalligan Lake Swamp. Many of these wetlands have been evaluated by the SSEA who have completed detailed mapping of the associated vegetative communities.

The main coldwater streams in the Study Area (NVCA and DFO, 2009) are shown on Figure 6 and include:

- Copeland Creek;
- Picotes Creek;
- Vindin Creek; and
- Lower Wye River Tributary.

All of these streams are represented in the Tier Three groundwater model tool, which simulates groundwater discharge at these locations and allows assessment of potential impacts to these streams under the model scenario risk assessment, as described in Section 6.0.

2.7 Hydrogeology

The surficial geology of the Study Area is illustrated on Figure 7A. The mapping shown (OGS, 2010) is a compilation of the mapping completed by Bajc and Paterson (1992) and Burwasser and Boyd (1974).

The surficial materials in the Study Area are largely shallow and deep water glaciolacustrine deposits, which partially mantle till deposits in the upland and other deposits in the lowlands. The upland area in the north part of Midland and largely within Penetanguishene, and the area to the west of Midland near Lalligan Lake, are mantled by till. Glaciofluvial and ice contact stratified deposits are identified to the south of Midland, where active aggregate extraction is taking place (near Well 7A/7B). With the exception of fine grained glaciolacustrine deposits or organic and recent deposits in the lowlands adjacent to the water courses, the remaining Study Area is largely covered by coarse textured glaciolacustrine sand and gravel. The locations of interpreted tunnel channels formed by glacial meltwaters in the lowland areas are shown on Figure 7B.

Following the regression of the Late Wisconsinan glacier, Lake Algonquin and the lower lake phases occupied much of the Study Area. During this time, Lake Algonquin eroded terraces in the till mantled uplands described above, and removed fine-grained sediments through wave action, leaving gravel bars and spits which now line the former shoreline. The fine-grained silts and clays were deposited in deep water in the valleys and in the present lake basins.

The highlands are silt and sand till residual landforms corresponding to the Simcoe Upland regions as well as to the higher portions of the areas around St. Andrews Lake and Lalligan Lake. Glaciolacustrine silts and clays are found primarily in the vicinity of Sucker Creek in the northeast portion of Penetanguishene, and in the southwest Copeland Creek area. Organic deposits are associated with Wye Lake and the terminus of Copeland Creek as well as St. Andrews Lake and Sucker Creek.

The hydrostratigraphic framework for the Study Area (Golder, 2005), from surface downwards, is shown on Figure 8 and can be summarized as follows:

1) Surficial Confining Unit (Aquitard UC) – This forms a discontinuous unit across the model area, mostly comprised of silty material.

2) Surficial Aquifer (Aquifer A1) – This forms a discontinuous unit across the area.

3) Upper Confining Unit (Aquitard C1) – This unit forms a fairly extensive confining layer across the area, although there are some areas where this unit is not present.

4) Upper Aquifer Unit (Aquifer A2) – This unit is found over most of the area. In many places it connects directly with the Lower Aquifer.

5) Lower Confining Unit (Aquitard C2) – This unit is less extensive than the Upper Confining Unit although it is found beneath much of Midland.

6) Lower Aquifer Unit (Aquifer A3) – As with the Upper Aquifer, this unit is found over most of the area.

7) Lower Unit – (Aquitard C3) - This unit (Basal Till) lies above the bedrock.

8) Weathered Limestone Bedrock – A continuous, relatively thin (assumed 3 m) layer of weathered limestone bedrock.

The major aquifer unit in the Study Area, referred to as the Lower Aquifer, is generally found in the elevation range of 120 masl (bedrock surface elevation) to 200 masl (approximate maximum water table elevation). This aquifer is regionally equivalent to the A3 aquifer. It is quite variable in composition, ranging from fine sand to coarse gravel. The thickness of the unit is variable depending on location, but generally ranges from 15 to 50 m. This unit is the source of groundwater for the major municipal well fields. It is continuous across most of the model Study Area, and appears to be thickest (up to 50 m) to the west of Midland and south of the Payette Drive well field.

In most areas, the Lower Aquifer is underlain by up to approximately 20 m of basal till, including the area under the Tay Peninsula. This unit appears to be non-existent in some areas, notably in the vicinity of the Robert Street, Payette Drive and parts of the Vindin Well field and Well 9 of the Midland system. In these areas, the Lower Aquifer is directly underlain by bedrock.

The Lower Aquifer is overlain by a confining layer in the vicinity of Penetanguishene Harbour, Midland Bay and Georgian Bay. It is combined with the Upper Aquifer in some areas (i.e., Payette Drive, Vindin Street). The Lower Aquifer is considered to be essentially unconfined in the uplands further removed from these water bodies, except under the upland till “islands”. Perched and smaller localized aquifers are occasionally present in areas, for example to the immediate west of the Payette Well field, where a perched aquifer is observed to discharge along the slopes towards Fox Street.

The Upper Aquifer is present across almost the entire Study Area, although it is combined with the Lower Aquifer in places, as noted above. It is a discrete unit in the immediate vicinity of the Robert Street well field and the central Midland area, as well as in the highlands to the west and is regionally equivalent to Unit A2. The thickness of this aquifer ranges up to 40 m or more to the west and 20 m under Midland. The Upper Aquifer is confined over much of the Study Area. It is unconfined in the vicinity of Penetanguishene Harbour and Little Lake (which are lower than the elevation of the unit), as well as in the central part of the Town of Penetanguishene, to the west of the Vindin Street well field and to the northeast under Midland. Exceptions to this are the areas in the vicinity of Robert Street and the Sunnyside wells, where the aquifer is confined, and is under flowing artesian conditions.

The Aquifer A3 potentiometric surface is shown on Figure 9. A prominent groundwater high trending approximately northwest and then northeast occurs centrally along the Peninsula. In Aquifer A3, the high reaches an inferred elevation of 225 masl. Moving easterly from the groundwater divide, groundwater elevations decrease, eventually reaching the Georgian Bay elevation at 176 masl. There is a component of groundwater flow that is directed to the Wye River drainage in the southeast. Finally, there is a secondary groundwater mound, occurring north of the Vindin Street well field, which reaches an elevation of about 195 masl.

A detailed characterization of the well field hydrogeology was completed and is described in the Conceptual Understanding Report (Appendix A).

2.8 Numerical Models

2.8.1 Surface Water Model (MIKE-SHE)

MIKE SHE (Danish Hydraulic Institute (DHI), 2011) was selected as the hydrologic model for the study following an analysis of options with the LSRCA and the Peer Review Committee. MIKE SHE is a physically-based, distributed, integrated watershed model maintained and distributed by the DHI and which simulates all of the major processes in the hydrological cycle.

MIKE SHE provides a selection of both empirical and physically-based methods with which to model the major hydrologic processes. This provides the flexibility to model each process using varying degrees of complexity as required by the specific project goals and data availability. As the major objective of the hydrological modelling in this study is to provide estimates of recharge rates to the saturated zone groundwater model, a combination of physically-based and lumped, empirical methods were chosen based on the processes of interest. As such, modelling methods that preserved the physically-based, distributed character of recharge to the saturated zone were preferred whereas methods for open channel flow and the saturated zone were modelled using simplified methods and a more empirical approach.

2.8.2 Groundwater Model (FEFLOW)

The numerical finite element code FEFLOW (Version 6.1, October 2012) is used to simulate the 3D groundwater flow system of the Midland-Penetanguishene area. FEFLOW is a multi-purpose three-dimensional groundwater flow code developed by WASY GmbH, Berlin, Germany (Diersch, 2002).

The Tier Three model began as a “cut-out” of the large-scale SGBWLS Tier Two FEFLOW model (Golder and AquaResource, 2010). As described in detail in Appendix C, this initial model then underwent a number of refinements to increase the numerical resolution around the wellfields and surface water features and provide a more detailed representation of the hydrogeology in the Midland-Penetanguishene area. The model was calibrated to both steady-state and transient conditions with a focus on matching higher quality water level and stream baseflow targets in the local well field areas.

3.0 WATER DEMAND

3.1 Municipal Water Systems

3.1.1 Town of Midland

The Midland well system consists of 11 production wells located at five well fields. The locations of the wells are shown on Figure 1. Of these 11 wells, ten are operating and one is not currently equipped to pump.

The Vindin Street well field (also commonly referred to as the Flume or Reservoir well field) is composed of six operating wells (Well 6, 11, 12, 14, 16 and 17) located on Vindin Street in the northern portion of Midland. The Heritage Drive well field consists of two operating wells (7A and 7B) and is located on the southern end of Midland along Highway 12.

Wells 9 and 15 also referred to as the Dominion Avenue and Russell Street wells, are single wells located in the west and central portions of the Town, respectively. Well 1A is located on Fourth Street and is included on the system permit but is not currently equipped.

The Sunnyside former municipal wells (Well 20, 24, 25 and 26), which were incorporated into the Midland system after amalgamation of a portion of Tay Township in the mid 1990’s, are located on Sunnyside Drive in the north part of Town. These wells have been recently decommissioned.

It is noted that the Portage Park well field, located in the north east part of the Town (east of the Sunnyside system), was operated by the Town through 2001 but was subsequently decommissioned.

The Midland system has a total maximum day permitted capacity of 22,180 m^3/day, not including the Sunnyside wells.

The pumping rates recorded by the Town in 2010/2011 are considered representative of the current existing conditions. In 2010/2011, 48% of the Town's water supply came from the Heritage Drive wells and 23% came from the Vindin Wells with the remaining water supply coming from the Dominion and Russell Wells. The total taking in 2010/2011 represents 27% of the Town's permitted maximum day capacity. The wells draw water from the Lower Aquifer A3.

In 2010, a well referred to as the Sundowner Well was completed west of Penetanguishene Road in Midland, Ontario to investigate potential for additional municipal water supply at this location. Water quality samples taken at the end of the 72 hour pumping test from the Sundowner Well indicated concentrations of trichloroethylene (TCE). The Sundowner Well was evaluated as a potential alternative for additional supply capacity (with treatment of the TCE) in the Midland System as part of the Midland Water Supply Master Plan Update (AECOM, 2013). As part of the Water Supply Master Plan Study, the well was ruled out as a suitable alternative and is not a planned source of supply.

3.1.2 Town of Penetanguishene

The Town of Penetanguishene obtains its water supply from three well fields (two active) composed of a total of seven wells, referred to as Payette Drive (Wells 1, 2 and 3), Robert Street (Wells 2 and 3) and Lepage (Wells 1 and 2). Two former small communal well systems, referred to as the Pinegrove and Gilwood Bay systems, were formerly located in the Tay Point area. These systems were decommissioned in 2003 and the residences in these areas are now serviced by the Payette Drive wells.

The Robert Street wells are not operational but are authorized under PTTW No.97-P-1081. This system was shut down in 1991 following identification of TCE and related solvent compounds in the wells above the Ontario Drinking Water Standards (ODWS). Operation of the well field following its shut down in 1991 included a 72-hour test conducted in 1997 as part of the PTTW application, a 30 day test completed in 2006 and a 94 day test completed in 2012. These tests indicated that the concentration of TCE and cis-1-2-dichloroethylene (cis-1,2-DCE) at the wellhead have declined since 1991, although they remain above the standards. Future operation of this well field is currently being considered in order to provide an alternative water supply to the pumping wells at Payette Drive.

The Penetanguishene system has a total maximum day permitted capacity of 14,850 m^3/day.

The pumping rates recorded by the Town in 2010/2011 are considered representative of the current existing conditions. In 2010/2011, almost all of the Town's water supply came from the Payette Drive Wells. As previously discussed, the Robert Street Wells are not currently active. The pumping rates in 2010/2011 represent 24% of the maximum day permitted water capacity. The wells draw water from the Lower Aquifer A3 with the exception of the Lepage Wells, where the wells draw water from the combined A2/A3 Aquifer that is present in the area.

3.1.3 Township of Tiny: Whip-Poor-Will

The Township of Tiny services a small residential community located south of Penetanguishene and west of Midland referred to as the Whip-Poor-Will system. The system is supplied by two wells in one well field.

The Whip-Poor-Will wells draw water from the Lower Aquifer A3. The Whip-Poor-Will system has a total maximum day permitted capacity of 532 m^3/day. The wells are constructed into the top portion of the aquifer and have little available drawdown as described in Section 4.0. The pumping rates recorded by the Town in 2010/2011 are considered representative of the current existing conditions. The total water taking in 2010/2011 represents 14% of the permitted maximum day capacity of the well field.

3.2 Municipal Water Demand and Allocated Quantity of Water

3.2.1 Allocated Quantity of Water – Background/Overview

The Tier Three Assessment risk scenarios require definition of existing and future municipal well pumping rates for model input. The model scenario pumping rates must reflect current conditions (Existing Demand) and future conditions including any additional taking that will be required to meet the needs of the approved settlement area within an Official Plan (Committed Demand) and the projected growth identified within a Master Plan or Class EA that is not already linked to growth within an Official Plan (Planned Demand). These Demands as well as the Allocated Quantity of Water and Planned Quantity of Water are defined in a recent memorandum by the MOE (MOE, 2013) and are summarized below.

- **Existing Demand:** Existing Demand is defined as the average annual pumping during the study period. For this project, the Existing Demand is based on the average pumping rates for the years 2010 and 2011, which were calculated from the MOE water taking reporting system (WTRS) database. The Existing Demand rates were also used for the groundwater model calibration period. The MOE WTRS database contains reported daily pumping rates. The maximum monthly and maximum daily demands can also be calculated from this database.
- **Committed Demand:** The Committed Demand is an amount, greater than the Existing Demand, that is necessary to meet the needs of the approved Settlement Area within an Official Plan. The portion of this amount that is within the Current Lawful PTTW Taking is part of the Allocated Quantity of Water. Any amount greater than the Current Lawful PTTW Taking is considered part of the Planned Quantity of Water. In the case of this study, the Committed Demand is within the Current Lawful PTTW Taking and there is no Planned Quantity of Water.
- **Planned Demand:** Planned Demand from an Existing Well/Intake is a specific, additional amount of water required to meet the projected growth identified within a Master Plan or Class EA, but is not already linked to growth within an Official Plan.
- **Allocated Quantity of Water:** The Allocated Quantity of Water is the combined amount of the Existing plus Committed Demand up to the Current Lawful PTTW Taking.
- **Planned Quantity of Water:** The Planned Quantity of Water for an Existing Well/Intake includes any amount of water that meets the definition of a planned system in O.Reg 287/07 and any amount of water that is needed to meet a Committed Demand above the Current Lawful PTTW Taking. As mentioned

above, in the case of this study, there is no identified Planned Quantity of Water since the Demands are within the Current PTTW.

As described in the following sections, the Allocated Quantity of Water for use in the model scenarios has been assigned using information from planning documents provided by the municipality including official plans, water supply master planning and Class EAs.

3.2.2 Allocated Quantity of Water – Town of Midland

The Existing Demand and the Allocated Quantity of Water for the Town of Midland are shown in Table 1 and are described in the following sections.

3.2.2.1 Existing Demand

The Existing Demand for the Town of Midland is calculated as the 2010/2011 average pumping rate for each well. These 2010/2011 average rates are to be used in the risk scenarios as the modelled Existing Demand pumping rates for each well. These rates were also used for the model calibration.

3.2.2.2 Committed Demand and Allocated Quantity of Water

The Allocated Quantity of Water for the Town of Midland is shown in Table 1. The Allocated Quantity of Water is based on the Town's projected water demands for 2031. The Town's 2031 water demands were estimated as part of the Town's Waterworks Master Plan Update (AECOM, 2013). The 2031 water demands were estimated using population and employment projections in conjunction with per capita water demands. Although the demands were estimated, the 2031 pumping rates at individual wells were not specified as part of the Town's Waterworks Master Plan.

The 2031 Allocated Quantity of Water model scenario pumping rates shown in Table 1 are all from existing municipal wells and are below the current PTTW rate limits for these wells. The total estimated 2031 average day demand for the Town is 9,590 m^3/day.

The 2031 model scenario rates shown in Table 1 represent a total increase from these well fields of 58%, with a total 2031 model scenario pumping rate of 9,590 m^3/day compared to the existing total pumping rate of 6,075 m^3/day.

To allocate projected demand rates for 2031, an optimization iteration was undertaken to allocate the additional 3,515 m^3/day in demand for 2031. The first iteration consisted of modelling incremental increases evenly across the system; this resulted in the Vindin St. Wells 6, 11 and 12 and Russell St. Well 15 approaching the safe additional drawdown and therefore the rates for these wells were held constant, or in the case of Well 15 were slightly reduced, in the 2031 Allocated Quantity of Water shown in Table 1.

Table 1: Allocated Quantity of Water - Tier Three Risk Assessment Scenarios - Town of Midland

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)
Vindin	Well 6	5707106	1,642	164	164
	Well 11	5715187	1,961	393	393
	Well 12	5716076	656	185	185
	Well 14	5716078	985	251	518
	Well 16	5722487	1,313	184	414
	Well 17	5722489	1,227	249	646
Heritage	Well 7A	5709697	4,925	2,176	2,592
	Well 7B	-----	4,234	769	2,228
Dominion	Well 9	5714014	1,964	780	1,034
Russell	Well 15	-----	1,309	924	566
Fourth	Well 1A	-----	1,964	0	850
Total Taking			22,180	6,075	9,590

Notes:

1) For use in Tier Three Assessment Model Scenarios requiring Existing Demand rates.
2) For use in Tier Three Assessment Model Scenarios requiring Existing plus Committed Demand rates.

3.2.3 Allocated Quantity of Water – Town of Penetanguishene

The Existing Demand and the Allocated Quantity of Water for the Town of Penetanguishene are shown in Table 2 and are described in the following sections.

3.2.3.1 Existing Demand

The Existing Demand for the Town of Penetanguishene is calculated as the 2010/2011 average pumping rate for each well. These 2010/2011 average rates are to be used in the risk scenarios as the modelled Existing Demand pumping rates for each well. These rates were also used for the model calibration.

3.2.3.2 Committed Demand and Allocated Quantity of Water

The Allocated Quantity of Water for the Town of Penetanguishene is shown in Table 2. The Allocated Quantity of Water is based on the Town's planned water demands for 2031. The Town's 2031 water demands were estimated as part of the Payette Water System Water Storage Upgrade Class EA (AECOM, 2012). The 2031 water demands were estimated using population projections as well as the historical (2008 – 2011) water demands and per capita water demand information. The 2031 Allocated Quantity of Water model scenario pumping rates shown in Table 2 are all from existing municipal wells and are below the current Permit to Take Water (PTTW) rate limits for these wells. The total estimated 2031 average day demand for the Town is 5,078 m^3/day, compared to the existing 2010/2011 taking of 3,567 m^3/day.

Although currently inactive, the Town has long-term plans to bring the Robert Street municipal wells back online to provide alternate/additional capacity and reduce its reliance on the Payette Drive system. The Robert Street wells have a completed Class EA and a current PTTW to pump a maximum of 3,273 m^3/day. As described in Section 3.1.2, the Robert Street system was shut down in 1991 following identification of TCE and related solvent compounds in the wells above the Ontario Drinking Water Standards (ODWS). Water quality sampling during pumping tests has indicated that the concentration of TCE and related solvent compounds at the wellhead have declined significantly since 1991, although they remain above the standards. It is unclear when the solvent concentrations will have declined to suitable levels below the standards. Until the contaminant levels have declined sufficiently, the use of the Robert Street Wells for water supply would require treatment for these contaminants. The 2031 model scenario pumping rates shown in Table 2 include a primary pumping configuration with the Payette Drive wells pumping at the existing rates and with the additional 2031 projected demands supplied by the Robert Street wells at rates that are below the current PTTW amount. Also shown in Table 2 is an alternate pumping configuration with no pumping from the Robert Street Wells and the additional 2031 projected demands supplied by the Payette Drive wells. Both the primary and alternate pumping configurations are included in the scenario modelling, as described in Section 6.0. The Tier Three model scenarios do not include pumping of the wells at rates above the 2031 projected demands and are within the current approved PTTW amounts for these systems. Additional model scenarios were run at higher pumping rates (see Appendix D), however these additional results are not part of the Tier Three Risk Assessment.

The 2031 model scenario rates shown in Table 2 also include a modelled long-term average yield for the Lepage wells of 24 m^3/day, which is based on the total build out rate for the associated subdivision.

The 2031 model scenario rates shown in Table 2 represent a total increase from these well fields of 42%, with a 2031 total pumping rate of 5,078 m^3/day compared to the existing total pumping rate of 3,567 m^3/day.

Table 2: Allocated Quantity of Water - Tier Three Risk Assessment Scenarios - Town of Penetanguishene

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)	Allocated Quantity of Water[2] 2031 Alternate Rates (m^3/day)
Payette	Well 1	5717696	2,851	703	703	1,000
	Well 2	5732671	4,579	2,374	2,374	3,400
	Well 3	5728347	3,715	472	472	654
Robert	Well 2	5703542	3,273	0	1,505	0
	Well 3	5703546				

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)	Allocated Quantity of Water[2] 2031 Alternate Rates (m^3/day)
Lepage	Well 1	5708732	144	18	24	24
	Well 2	5712811	288			
Total Taking			14,850	3,567	5,078	5,078

Notes:

1) For use in Tier Three Assessment Model Scenarios requiring Existing Demand rates.
2) For use in Tier Three Assessment Model Scenarios requiring Existing plus Committed Demand rates.

3.2.4 Allocated Quantity of Water – Township of Tiny (Whip-Poor-Will System)

The Existing Demand and the Allocated Quantity of Water for the Whip-Poor-Will Well System in the Township of Tiny are shown in Table 3 and are described in the following sections.

3.2.4.1 Existing Demand

The Existing Demand for the Whip-Poor-Will system is calculated as the 2010/2011 average pumping rate. The 2010/2011 average rate is to be used in the risk scenarios as the modelled Existing Demand pumping rate for the wells. This Existing Demand rate was also used for the model calibration.

3.2.4.2 Committed Demand and Allocated Quantity of Water

The Allocated Quantity of Water for the Whip-Poor-Will system is shown in Table 3. The Allocated Quantity of Water for this system is within the current PTTW and is based on the average day demand information provided by the Town, assuming total build out of the associated subdivision.

Table 3: Allocated Quantity of Water - Tier Three Risk Assessment Scenarios - Township of Tiny (Whip-Poor-Will System)

Well Field	Well	MOE#	PTTW Max Taken per Day (m^3)	Existing[1] 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water[2] 2031 Rates (m^3/day)
Whip-Poor-Will	21-1	-----	532	72	78
	21-2	5728953			

Notes:

1) For use in Tier Three Assessment Model Scenarios requiring Existing Demand rates.
2) For use in Tier Three Assessment Model Scenarios requiring Existing plus Committed Demand rates.

The 2031 model scenario rates shown in Table 3 represent a total increase from these well fields of 8%, with a 2031 total pumping rate of 78 m^3/day compared to the existing total pumping rate of 72 m^3/day.

3.2.5 Monthly Variability in Pumping

Daily pumped volume records were reviewed for the 2010/2011 period to determine average monthly rates for use in the transient modelling scenarios. Table 4 shows the average monthly pumping rates calculated from the 2010/2011 data.

Table 4: Average Monthly Pumping Rates under 2010/2011 Existing Demand (m^3/d)

Wells		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Vindin	Well 6	142	139	143	150	204	180	251	208	155	123	139	132
Vindin	Well 11	339	333	343	358	488	430	601	500	371	296	332	316
Vindin	Well 12	160	157	161	169	230	203	283	235	175	139	157	149
Vindin	Well 14	217	213	219	229	311	275	384	319	237	189	212	202
Vindin	Well 16	159	156	161	168	228	201	281	234	174	139	156	148
Vindin	Well 17	215	211	217	227	309	273	381	317	235	188	211	200
Russell	Well 15	909	876	861	824	946	959	1007	937	911	979	1000	875
Heritage	Wells 7A&B	2764	2648	2827	2931	3305	3159	3236	3218	3325	3037	2433	2428
Dominion	Well 9	727	750	714	754	819	838	891	899	847	750	715	654
Payette	Well 1	700	722	659	640	719	757	894	736	651	674	655	627
Payette	Well 2	2349	2375	2342	2333	2497	2599	2709	2477	2367	2177	2127	2135
Payette	Well 3	404	431	410	404	542	656	754	471	365	432	388	400
Lepage	Wells 1&2	18	18	17	16	17	19	23	18	17	16	18	16
Whip-Poor-Will	Wells 21-1 & 21-2	37	39	41	69	109	102	148	124	75	43	35	37

The total pumping from these wells ranges from a low ratio of 0.86 in December to a high ratio of 1.22 in July relative to the annual average rate. The ratios of pumping for each month, calculated from the existing condition data shown in Table 4, were applied to the 2031 Allocated Quantity of Water average annual rates to develop projected average monthly pumping rates for 2031 (Table 5).

Table 5: Average Monthly Pumping Rates for 2031 Allocated Quantity of Water (m^3/d)

Wells		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Vindin	Well 6	142	139	143	150	204	180	251	209	155	124	139	132
Vindin	Well 11	339	333	343	358	488	430	601	500	372	296	333	316
Vindin	Well 12	160	157	161	169	230	203	283	235	175	139	157	149
Vindin	Well 14	447	439	452	472	643	567	792	659	490	390	438	416
Vindin	Well 16	358	351	361	378	514	453	633	526	391	312	350	332
Vindin	Well 17	558	548	564	589	802	707	988	821	611	487	547	519
Russell	Well 15	557	537	528	505	579	587	617	574	558	600	613	536
Heritage	Wells 7A&B	4524	4334	4627	4797	5410	5170	5297	5267	5443	4971	3982	3973
Dominion	Well 9	964	995	947	1000	1085	1111	1181	1191	1123	994	947	867
Fourth	Well 1A	734	721	742	775	1055	930	1300	1081	803	640	719	683
Payette	Well 1	700	722	659	640	719	757	894	736	651	674	655	627
Payette	Well 2	2349	2375	2342	2333	2497	2599	2709	2477	2367	2177	2127	2135
Payette	Well 3	404	431	410	404	542	656	754	471	365	432	388	400
Robert	Well 2	712	738	701	690	809	893	1006	775	676	700	664	662
Robert	Well 3	712	738	701	690	809	893	1006	775	676	700	664	662
Lepage	Wells 1&2	24	24	23	22	23	25	32	24	23	22	24	22
Whip-Poor-Will	21-1_2	40	42	45	74	118	110	161	135	82	46	38	41

The pumping rates shown in Tables 4 and 5 for the Heritage Drive wells (7A and 7B), the Lepage Wells (1 and 2) and the Whip-Poor-Will wells (21-1 and 21-2) are combined since they are located next to each other and are represented as a single well in the numerical model, as described in Appendix C.

3.3 Other Water Use

3.3.1 Other Takings

Permitted water use in the Study Area was reviewed based on the Province of Ontario's PTTW database. The PTTW database used for this analysis was provided by LSRCA and is up to date through to March 31, 2012. Figure 10 shows the PTTW records in the Study Area. Table 6 lists these PTTWs, along with the water uses, source of the water and permitted rates for takings within the Study Area. In total, there are five active non-municipal PTTWs in the vicinity of the municipal production wells, extracting water from groundwater. The total maximum permitted water taking from groundwater from these sources is 5,804 m^3/day. These water takings are used for industrial and commercial purposes.

The Province's PTTW program requires that PTTW holders report actual pumping rates, which are collected in the WTRS. The WTRS average annual data for 2010/2011 are presented in Table 6. The total pumping from all of these non-municipal groundwater sources in 2010/2011, as reported in the WTRS, was 914 m^3/day. Consumptive use factors are presented in Table 6, The consumptive use factors are consistent with those used in the Tier Two Study (Golder and AquaResource, 2010), which are based on the default consumptive use values listed in Appendix D of the MOE Guidance Module 7 (MOE, 2006). Consumptive use refers to the amount of water that is pumped but not returned back to the original source.

Table 6: Non-Municipal Permits to Take Water (PTTW)

Permit Number	Category	SOURCE ID	Source	Consumptive Factor	Maximum Permitted Volume (m^3/day)	Average Annual 2010/2011 Well Pumping Rate (m^3/day)	Rate Data Source
5326-74JGUF	Industrial - Aggregate Washing	Main Pond	Ground Water	0.10	1,022	56	WTRS
2311-7EKLNZ	Commercial - Golf Course Irrigation	PW1/MGCC1 (MOE ID 4502)	Ground Water	0.70	1,090	177	WTRS
		PW2/MGCC2 (MOE ID 4503)			818	111	WTRS
		PW3/MGCC3 (MOE ID 4501)			5	0	WTRS
7224-6EBQS8	Industrial	Well # 1	Ground Water	1.0	1,964	0	WTRS
		Well # 2				533	WTRS
2110-6NQLJ4	Commercial - Golf Course Irrigation	Well #1	Ground Water	0.70	451	12	WTRS
		Unnamed Stream	Surface Water	N/A	1,404	N/A	N/A
4426-7C6MPB	Commercial - Golf Course Irrigation	Well BBGC1	Ground Water	0.70	2	0	WTRS
		Well BBGC2			8	0	WTRS
		Well BBGC3			29	0	WTRS
		Well BBGC4 (MOE ID 5715544)			55	1	WTRS
		Well BBGC5 (MOE ID 5738332)			360	24	WTRS
		Pond 1 (P1) - Copeland Creek	Surface Water	N/A	1,057	N/A	N/A

Permit Number	Category	SOURCE ID	Source	Consumptive Factor	Maximum Permitted Volume (m^3/day)	Average Annual 2010/2011 Well Pumping Rate (m^3/day)	Rate Data Source
		Pond 2 (P2) - Copeland Creek				N/A	N/A
		Pond 5 (P5)				N/A	N/A
0205-7GFP76	Industrial - Aggregate Washing	Source Pond	Surface Water	N/A	6,547	N/A	N/A
1566-7C3HRU	Industrial - Manufacturing	Source 1	Surface Water	N/A	3,312	N/A	N/A
		Source 2				N/A	N/A
				Total (Groundwater)	5,804	914	

Non-permitted water use in the Study Area includes primarily unserviced domestic water use, and other demands that extract less than 50,000 L/d. Non-permitted water use was estimated at an aggregate level at the subwatershed scale in the Tier Two Water Budget Study (Golder and AquaResource, 2010); however, the individual locations of the takings were not specified. There is no indication of any large non-permitted water users in the Study Area. In terms of consumptive demand, domestic water use is less of a concern since most of the water taken is likely returned to the groundwater system through onsite septic sewage disposal systems.

3.3.2 Aquatic Habitat

The main coldwater streams in the Study Area are shown on Figure 6 and include:

- Copeland Creek;
- Picotes Creek;
- Vindin Creek; and
- Lower Wye River Tributary.

As part of the Tier Three process, modelled baseflow reductions resulting from municipal pumping increases are compared to thresholds to assign risk levels associated with potential impacts to coldwater fish communities following the MOE/MNR guidance (MOE and MNR, 2011; MOE, 2013). The Risk level assignment is described in Section 6.6.2.

3.3.3 Provincially Significant Wetlands

The Provincially Significant Wetlands within the Study Area are shown on Figure 6.

The Provincially Significant Wetlands in the Study Area include the Wye Marsh, Midland Swamp, Penetang Marsh, Midland Little Lake Wetland, St. Andrew's Lake Wetland, Sucker Creek Wetlands and the Lalligan Lake Swamp. Many of these wetlands have been recently evaluated by the SSEA who have completed detailed mapping of the associated vegetative communities.

The modelled water level changes in the vicinity of the wetlands are evaluated as part of the assessment and risk levels are assigned following the MOE/MNR guidance (MOE and MNR, 2011; MOE, 2013). The Risk level assignment is described in Section 6.6.2.

4.0 SAFE ADDITIONAL DRAWDOWN

4.1 Safe Additional Drawdown - Background and Methodology

This section describes the estimated safe additional drawdown of each of the municipal wells for the Midland and Penetanguishene Tier Three Assessment. The safe additional drawdown is defined as the additional depth that the water level within an aquifer could fall and still maintain that well's allocated pumping rate. The safe additional drawdown is the difference between the existing (2010/2011) average water level and the safe water level in the pumping well.

These municipal wells are typically only pumped for a portion of the day and therefore there are two types of water levels that may be measured in the wells on a given day including the static (non-pumping) water level and the pumping water level. Setting the baseline average water level at the level of the pumping water level is not consistent with the approach adopted for the model simulation of the scenarios and is an overly conservative approach since the wells are typically only pumped for a portion of the day. The groundwater modelling considers implicitly time-averaged conditions with continuous pumping at a constant rate. Therefore, a time-averaged water level has been calculated for consistent comparison with the pumping rates used in the model scenarios.

The time-averaged water level for the wells has been calculated as:

$$\mathrm{W}L = \frac{X}{24} WL_{pumping} + \frac{(24 - X)}{24} WL_{non-pumping}$$

Where *X* represents the average number of hours a well is pumped each day.

The safe water level is the lowest water level that the well can be pumped at and is constrained by the location of the top of the well screen and the current pump intake setting. In this case, the safe water level has been set as 1 m above the pump intake elevation or 1 m above the top of the well screen (whichever is higher). The pump intake elevations for the wells are generally set near the top of the screen ranging from about 1 m below to 5 m above the top of screen.

4.2 Safe Additional Drawdown Results

4.2.1 Safe Additional Drawdown - Town of Midland

The safe additional drawdown for the Town of Midland wells is shown in Table 7 and on Figures 11 to 20.

Table 7: Safe Additional Drawdown - Tier Three Risk Assessment - Town of Midland

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Additional Drawdown (m)
Vindin	Well 6	182.6	159.9	152.3	160.4	166.1	181.8	14	179.6	161.4	18.2
	Well 11	185.6	159.1	150.3	158.6	167.6	185.6	17	182.5	160.1	22.4
	Well 12	184.6	161.7	155.6	---	164.6	183.1	20	179.4	162.7	16.7
	Well 14	186.2	158.8	153.0	---	173.2	185.4	21	182.8	159.8	23.0
	Well 16	180.1	152.0	146.0	153.0	167.6	179.4	20	177.1	154.0	23.1
	Well 17	179.8	159.6	153.9	162.4	171.8	181.1	24	178.9	163.4	15.5
Heritage	Well 7A	215.8	169.8	152.1	169.9	174.7	188.3	50	181.5	170.9	10.6
	Well 7B	215.2	158.0	150.4	159.9	177.2	187	20	185	160.9	24.1
Dominion	Well 9	245.4	158.3	153.6	157.6	174.4	194.2	56	183.2	159.3	23.9
Russell	Well 15	220.1	179.7	173.2	178.1	181.9	185.1	91	182.2	180.7	1.5
Fourth	Well 1A	184.4	161.8	154.2	N/A	182.1	182.1	0	182.1	162.8	19.3

Note that for Wells 6, 11 and 17, pumped water levels were not monitored during 2010/2011. The water levels used for these wells are based on measurements taken during step testing completed since 2008 at representative operational pumping rates. These include measurements taken at Well 6 at a rate of 18.5 L/s in 2008, at Well 11 at a rate of 15 L/s in 2012 and at Well 17 at a rate of 13.2 L/s in 2010.

The pumps intakes are generally set close (within less than 5 m) of the well screens for the wells. The pump intakes are set slightly below the top of the well screen at Wells 9, 11 and 15.

The pump intake elevation is not listed for the Fourth St. Well 1A since this well is not currently equipped with a pump and is not active. The listed existing water level for Well 1A represents the average static water level measured in 2010/2011.

The majority of the Midland municipal wells have over 15 m of safe additional drawdown under the existing average operating conditions, with the exception of Well 7A (10.6 m) and Well 15 (1.5 m). Wells 6, 12, 7A and 15 have instantaneous pumped water levels within 5 m of the safe water level

Well 15 is particularly susceptible to small declines in water levels. As described in Seciton 3.2.2.2, the 2031 rate for Well 15 was reduced from its current rate taking into consideration the very minor amount of safe additional drawdown at this well.

In addition, although Well 12 has additional available capacity and is only pumped an average of 20% of the day, it has an instantaneous pumped water level less than 3 m above the top of the well screen and is therefore also susceptible to small water level declines as currently equiped. As described in Section 3.2.2.2, the 2031 rate for Well 12 was left constant in the 2031 scenario at the low current rate of 185 m^3/day. The Town has rehabilitated the majority of their wells in the last five years improving their efficiency but has not invested in any rehabilitation work at Well 12. If the condition of Well 12 deteriorates further, the Town may decommission this well due to poor yield/performance.

4.2.2 Safe Additional Drawdown - Town of Penetanguishene

The safe additional drawdown for the Town of Penetanguishene wells is shown in Table 8 and on Figures 21 to 25.

Table 8: Safe Additional Drawdown - Tier Three Risk Assessment - Town of Penetanguishene

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Avrg. Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Additional Drawdown (m)
Payette	Well 1	238.27	168.7	151.9	173.8	178.5	188.4	29	185.5	174.8	10.7
	Well 2	237.29	161.9	150.8	166.1	172.1	187.2	54	179.1	167.1	12.0
	Well 3	237.74	161.7	149.6	163.1	169.0	187.5	14	185.0	164.1	20.9
Robert	Well 2	181.4	138.1	125.9	N/A	189.0	189.0	0	189.0	139.1	49.9
	Well 3	180.9	141.9	123.6	N/A	189.7	189.7	0	189.7	142.9	46.8
Lepage	Well 1	201.81	168.9	168.0	173.4	187.8	190	7	189.8	174.4	15.4
	Well 2	202.26	168.3	166.8	173.4	184.3	190.1	5	189.8	174.4	15.4

The pump intake elevations are not listed for the Robert St. wells since these wells are not currently equipped with pumps and are not active. The existing 2010/2011 water levels listed for the Robert St. wells are based on the static water levels measured in August, 2012. Static water levels are used for the Robert St. wells since these wells are not pumping in the Existing 2010/2011 base condition. Note that the Robert St. wells have been inactive for decades due to the contamination issues and therefore are in a poor condition. The Robert St. wells would need extensive rehabilitation, in addition to treatment for the organic contaminants, prior to use for muncipal supply.

The majority of the Penetanguishene municipal wells have over 15 m of safe additional drawdown under the existing average operating conditions, with the exception of the Payette Drive Well 1, which has 10.7 m and Payette Drive Well 2, which has 12.0 m. Payette Drive Well 1 has an instantaneous pumped water level within about 4 m of the safe water level.

4.2.3 Safe Additional Drawdown - Tiny Township- Whip-Poor-Will System

The safe additional drawdown for the Tiny Township Whip-Poor-Will system wells is shown in Table 9 and on Figures 26 to 27.

Table 9: Safe Additional Drawdown - Tier Three Risk Assessment - Tiny Township - Whip-Poor-Will System

Well Field	Well	Ground Surface Elevation (masl)	Screen Top Elevation (masl)	Screen Bottom Elevation (masl)	Pump Intake Elevation (masl)	Existing (2010/2011) Pumped Water Level (masl)	Avrg. Static Water Level (masl)	Pump Run Time (%)	Average Water Level (masl)	Safe Water Level (masl)	Safe Additional Drawdown (m)
Whip-Poor-Will	21-1	311.8	251.2	246.6	252.7	253.6	254.8	6	254.7	253.7	1.0
	21-2	314.6	246.9	242.6	252.7	256.6	258.6	6	258.6	253.7	4.6

Well 21-1 has 1.0 m of safe additional drawdown and Well 21-2 has 4.6 m of safe additional drawdown under the existing average operating conditions. These wells only pump for several hours per day on average and the second well serves as a back-up source. Well 21-1 is susceptible to small water level declines since it is constructed only slightly into the top portion of the aquifer. In the event that water level decline in Well 21-1 prevented or reduced its operational capacity, Well 21-2 could provide the supply although there would then be no back-up source available. A new deeper well at the site that replaces Well 21-1 could provide a more robust source with a greater safe additional drawdown.

5.0 WATER BUDGET SUMMARY

The MIKE SHE and FEFLOW models were used to estimate the primary components of the Study Area water budget. The spatially distributed recharge distribution developed using MIKE SHE is presented on Figure 28. This distribution represents the average annual model recharge for the period of record of complete years of data at the Copeland Creek gauge (1989-1998).

The global (entire model) groundwater model flow budget is summarized in Table 10.

Table 10: Groundwater Model Flow Budget

Source / Sink	Input (m^3/d)	Output (m^3/d)
Recharge	368,128	0
Wells (municipal and non-municipal)	0	11,250
Georgian Bay	0	250,741
Wye River	944	26,880
Wye Marsh	0	7,126
Wye Tributaries	0	23,515
Cooks Lake	1,385	3,275
Little Lake	5,552	0
Copeland Creek	0	10,486
Vindin Creek	0	5,792

Source / Sink	Input (m^3/d)	Output (m^3/d)
Picotes Creek	0	7,944
Other Tributaries	0	29,000
TOTAL	376,009	376,009

Groundwater flow budgets are undertaken for subcatchments within the Midland-Penetanguishene area (Figure 29). Major inputs include recharge and cross-boundary inflow, whereas major outputs include discharge to lakes and streams, cross-boundary outflow, and, if the subcatchment is adjacent to the lake, discharge to Georgian Bay. Pumping wells, where present, typically represent around 10% or less of the subcatchment water balance.

With respect to total cross-boundary flow, the combined catchment area shown on Figure 29 has a net loss of 36,153 m^3/d. About 18,000 m^3/d exits to the southwest towards the Wye River. Another 12,000 m^3/d exits out of the northern catchments (principally Sawlog Bay and Picotes Creek) north and east towards Georgian Bay. The remaining 6,153 m^3/d exits west towards Tiny Township. The reason for this loss is that the western flank of the subcatchment divides are irregularly shaped following surface water catchments and do not align perfectly with the simulated A2 and A3 groundwater divides. When the flux analysis is conducted roughly coincident with the groundwater divide in the vicinity of the eastern portion of the Lafontaine subcatchment (see annotated A2/A3 groundwater divide line on Figure 29), the calculated flow west towards Tiny is small (<100 m^3/d).

6.0 LOCAL AREA RISK ASSESSMENT

6.1 Risk Assessment Scenario Methodology

6.1.1 Overview of Model Scenarios

The below table provides a summary of the risk assessment scenarios that were completed.

Table 11: Risk Assessment Scenario Overview

Scenario	Time Period	Conditions
C	Average Climate: The period for which climate and stream flow data are available for the Local Area.	Scenario reflects current conditions with existing land cover, pumping rates and stead-state, average annual recharge.
D	Ten Year Drought	Reflects existing land cover and pumping rates but reduced recharge due to ten year drought conditions
G	Average Climate: The period for which climate and stream flow data are available for the Local Area.	Multiple versions of the scenario are required to evaluate pumping rates under existing and projected demands with variable land cover conditions (existing and projected based on the Official Plans).
H	Ten Year Drought	Transient drought simulation with multiple scenarios possible with variable pumping rates and land cover conditions.

Scenarios C and D represent existing pumping rates and existing land use under average climate and drought conditions, respectively. Scenarios G and H examine projected pumping rates and projected land cover in a combined and isolated subset of scenarios to see both the cumulative effect and individual effects of these changes.

Note that impacts to other water users are not evaluated under the drought scenarios under the Technical Rules.

In addition to the above listed prescribed risk scenarios, additional scenarios were run including a scenario with an alternative pumping configuration for the Penetanguishene wells, where the projected demand increase is met by the Payette Drive wells with no pumping from the Robert St. wells, as described in Section 3.2. For this alternate pumping configuration, only Scenarios G2 and H1 were run. The alternate Scenario G2 allows the effects of the alternate pumping configuration to be evaluated in relation to the WHPA-Q1 delineation, as described in Section 6.5. Alternate Scenario H1, which includes combined effects of drought, land use change and the alternate pumping increase, allows the worst case drawdowns to be evaluated at the municipal wells in relation to the ability for the wells to meet the increased demands.

The pumping rates used in the scenarios are described in Section 3.2. The following sections provide an overview of the recharge inputs for the model scenarios including the applied recharge reductions due to the projected land use change (increased urbanization) and the drought conditions.

6.1.2 Recharge Reductions Due to Projected Land Use

Changes in land use were addressed by altering the MIKE SHE land use grid cells to the "Urban – High Intensity Residential " land use class in areas where land was zoned for future and proposed development (areas shown on Figure 5). After adjustment, a representative recharge value was required for the newly converted cells. As recharge is sensitive to the hydraulic conductivity (soil type) of the surficial soil for each cell, the recharge for each new Urban – High Intensity Residential land use cell was assigned using an average of the previously calculated (see Appendix B) single cell recharges from Urban – High Intensity Residential cells with a similar surficial soils. For the transient simulations, an average of the single cell recharges from Urban – High Intensity Residential cells with a similar surficial soil were used for each monthly period. The new recharge distributions were then applied in FEFLOW for the simulations. On average this resulted in a recharge reduction of about 60% in these areas of projected land use change. The applied recharge reductions do not take into account stormwater recharge best management practices.

6.1.3 Transient Recharge Inputs for Drought Scenarios

A ten year meteorological drought scenario was developed by identifying the driest ten year period in the available meteorological record, which includes the period from 1950 to 2005A moving average approach was used to identify the period of 1955 to 1964 as the worst meteorological drought. This is illustrated on the top graph on Figure 30. The 1955 to 1964 period included periods of higher than average precipitation during the winter of 1957/58 and 1960; however, the average precipitation for the whole ten year period was lower than average.

The drought period was included in the period modelled using MIKE SHE. The resulting spatially averaged monthly recharge, over the Study Area, during the drought period is shown on the bottom graph on Figure 30. For comparison monthly average recharge during the drought period is also shown as a percentage of the average recharge for the period of record at the Copeland Creek gauge (1988 – 1998).

6.1.4 Allocated Quantity of Water Pumping Rate Optimization

The Allocated Quantity of Water pumping rates identified in Section 3.2 were developed using preliminary scenario modelling with subsequent adjustment of the rates to optimize the pumping configuration. In these preliminary model simulations, initially higher rates were applied at Vindin Street Wells 6, 11 and 12 and at Russell St. Well 15. The preliminary model results showed significant drawdowns at these wells relative to their available drawdown and therefore the distribution of pumping in Midland was optimized and the rates for these wells were held constant, or in the case of Well 15 were slightly reduced. The additional demand requirements were met by increasing pumping at other wells with more available drawdown and underutilized capacity. The pumping was distributed to Fourth Street Well 1A, the Heritage Drive Wells 7A/B and Dominion Avenue Well 9.

6.2 Risk Assessment Scenario Results - Drawdowns

The modelled drawdown results from the risk scenarios are summarized in the below table and are described in the sections that follow.

Table 12: Risk Assessment Scenario Results (maximum drawdown in metres)

Well Field	Well	Safe Additional Available Drawdown	Average Climate (Steady-State)			Drought (Transient)			
			G1	G2	G3	D	H1	H2	H3
			Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction	Existing Demand/ Recharge	Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction
MIDLAND									
Vindin	Well 6	18.2	2.0	1.6	0.3	2.0	4.5	4.3	2.2
	Well 11	22.4	1.4	1.0	0.3	2.4	4.0	3.7	2.6
	Well 12	16.7	1.6	1.2	0.3	2.2	4.0	3.8	2.4
	Well 14	23.0	2.6	2.3	0.3	2.3	5.7	5.5	2.5
	Well 16	23.1	3.0	2.7	0.3	2.0	6.1	5.9	2.2
	Well 17	15.5	3.5	3.2	0.3	1.9	6.9	6.7	2.1
Heritage	Wells 7A and 7B	10.6 / 24.1	3.7	2.6	1.0	1.6	5.5	4.6	2.5
Dominion	Well 9	23.9	1.7	1.1	0.5	2.0	3.6	3.2	2.3
Russell	Well 15	1.5	0.4	-0.5	0.9	1.2	1.2	0.5	1.9
Fourth	Well 1A	19.3	3.7	3.4	N/A	N/A	6.6	6.5	N/A

Well Field	Well	Safe Additional Available Drawdown	Average Climate (Steady-State)			Drought (Transient)			
			G1	G2	G3	D	H1	H2	H3
			Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction	Existing Demand/ Recharge	Recharge Reduction, Increased Demand	Increased Demand	Recharge Reduction
PENETANGUISHENE									
Payette	Well 1	10.7	1.1	0.1	1.0	1.5	2.5	1.5	2.4
	Well 2	12.0	1.1	0.1	1.0	2.3	3.3	2.3	3.2
	Well 3	20.9	1.1	0.1	1.0	2.0	3.0	2.0	2.9
Robert	Well 2	49.9	0.9	0.7	N/A	N/A	2.2	2.1	N/A
	Well 3	46.8	0.9	0.7	N/A	N/A	2.3	2.2	N/A
Lepage	Wells 1 and 2	15.4	0.2	0.1	0.1	1.4	1.6	1.5	1.4
TINY									
Whip-Poor-Will	Wells 21-1 and 21-2	1.0 / 4.6	0.5	0.3	0.2	2.3	2.8	2.6	2.5

Notes:
1) N/A is listed in cases where the well is not pumping in the scenario.
2) Wells where the safe additional available drawdown is exceeded are highlighted in grey.

6.2.1 Scenario C - Average Climate, Existing Demand, Existing Land Cover

Scenario C is equivalent to the Existing Conditions steady-state model run that was used in the model calibration. This scenario uses the Existing (2010/2011) demands and the average climate recharge distribution developed using the period of record of data at the Copeland Creek gauge. The recharge distribution is based on the existing land cover. This scenario is used as the baseline for evaluation of drawdowns and impacts to baseflow from the other scenarios and therefore drawdowns and baseflow reductions are zero for this scenario.

6.2.2 Scenario D - Drought, Existing Demand, Existing Land Cover

Scenario D is a transient scenario run over the drought period (1955-1964) with the Existing demands and the recharge rates developed using the existing land cover.

This scenario shows the isolated effects of the lower recharge conditions during the ten year drought period. The results show that the modelled water levels at the municipal wells under the drought condition are up to 1.2 to 2.4 m lower than the average climate modelled levels (Scenario C). Under this condition the only municipal well where the safe available drawdown is exceeded is Whip-Poor-Will Well 21-1. The drawdown at Well 15 (1.2 m) is close to the safe available drawdown for this well (1.5 m), although it is not exceeded. The Town has the operational flexibility to pump Well 15 at lower rates moving forward to reduce its sensitivity to drought impacts, as further described in Section 6.6.2 and as reflected in the lower pumping rate assigned in the 2031 projected demand scenarios.

6.2.3 Scenario G - Average Climate

Scenario G involves three steady-state model scenarios that use the same average climate recharge input but impose both the separate and the combined effects of projected demand increase and projected land cover and associated recharge reduction.

Scenario G1 - Average Climate, Existing plus Committed plus Planned Demand, Projected Land Cover

This scenario evaluates the combined effects of the Existing plus Committed plus Planned Demand increase and the projected land cover and associated recharge reduction. The steady-state scenario uses the average climate recharge conditions.

The results show that the modelled water levels at the municipal wells are 0.2 to 3.7 m lower than those in the baseline (Scenario C). The amount of drawdown is heavily dependent on the degree of pumping increase at a given well, for example the 0.2 m drawdown occurs at wells with a small 6 m^3/day pumping rate increase (Lepage wells) and the 3.7 m drawdown occurs at wells with 850 to 1875 m^3/day increase (Fourth St. and Heritage Drive wells). These results, however, also incorporate the effects of land use change, which are separately evaluated below.

Under this condition the safe available drawdown is not exceeded at any of the municipal wells.

Scenario G2 - Average Climate, Existing plus Committed plus Planned Demand, Existing Land Cover

Scenario G2 evaluates the effects of the Existing plus Committed plus Planned Demand increase in isolation. This steady-state scenario uses the baseline average climate and baseline existing land use.

The results show that the modelled water levels at the municipal wells are 0.1 to 3.4 m lower than those in the baseline (Scenario C). As mentioned above, the amount of drawdown is heavily dependent on the degree of pumping increase at a given well, although there is also a minor amount of drawdown due to interference from pumping increases at other nearby wells. For Well 15, the projected demand pumping rate is actually less than the baseline, as explained in Section 3.2.2.2, so it shows a water level rise of 0.5 m. The remainder of the Midland wells showed drawdowns ranging from 1.0 to 3.4 m. The Payette Drive wells showed little drawdown (0.1 m) since pumping was not increased at these wells.

Under this condition the safe available drawdown is not exceeded at any of the municipal wells.

The modelled drawdowns under Scenario G2 relative to the baseline condition (Scenario C) are plotted on Figures 31, 32 and 33 for Aquifers A1, A2 and A3, respectively. The maximum drawdowns are observed in the main pumped Aquifer A3. In Aquifer A3, drawdowns over 0.5 m are simulated in the immediate vicinity of the Robert St. wells and surrounding the Midland wells, with the exception of Well 15, where there was no applied pumping increase. Drawdowns of over 1 m to a maximum of about 3 m are observed in the immediate vicinity of the Heritage Drive wells and around the Vindin St. and Fourth St. wells. Modelled drawdowns in the shallow Aquifer A1/water table are generally less than 1 m except in the immediate vicinity of the Heritage Drive wells and the Vindin St. and Fourth St. well areas. The shallow aquifer/water table drawdowns are further discussed in Section 6.3.

Scenario G3 - Average Climate, Existing Demand, Projected Land Cover

Scenario G3 evaluates the effects of projected land use change and associated recharge reduction in isolation. This steady-state scenario uses the baseline average climate and baseline existing pumping rates. As described in Section 6.1.2, the reduced recharge conditions were applied conservatively and did not account for best management practices associated with future developments

The results show that in most areas, the effects at the municipal wells from the projected land cover change are very minor (0.1 to 0.3 m drawdown), with the exception of the Payette Drive wells in Penetaguishene and the Heritage Drive, Dominion and Russell St. wells in Midland. Drawdowns of 0.5 to 1.0 m are observed at these wells due to the recharge reduction. Figure 34 shows the Scenario G3 modelled extent of drawdown in Aquifer A3 relative to the baseline condition (Scenario C). This shows the extent of the 0.5 to 1.0 m modelled drawdown predicted in the vicinity of the Payette Drive and central/southern Midland wells, which generally corresponds to concentrated areas of future land development. The drawdown modelled in this scenario is further discussed in relation to the WHPA-Q2 delineation in Section 6.5.2.

Under this condition the safe available drawdown is not exceeded at any of the municipal wells.

6.2.4 Scenario H - Drought

Scenario H evaluates drought conditions in combination with increased demands and projected land cover change, both in isolation and combined. The same drought period transient recharge input used in Scenario D is applied.

Scenario H1 - Drought, Existing plus Committed plus Planned Demand, Projected Land Cover

This scenario evaluates the combined effects of the existing plus committed plus planned demand and the projected land cover change under drought conditions. From the prescribed scenarios in the Technical Rules, Scenario H1 represents the worst case assessment of potential water level declines.

The results from Scenario H1 show water level declines at the municipal wells ranging from 1.2 to 6.9 m. Under this condition the only municipal well where the safe available drawdown is exceeded is Whip-Poor-Will Well 21-1. The drawdown at Well 15 (1.2 m) is close to the safe available drawdown for this well (1.5 m), although it is not exceeded. The Town has the operational flexibility to pump Well 15 at lower rates moving forward to reduce its sensitivity to drought impacts and potential recharge reductions as further described in Section 6.6.2.

Scenario H2 - Drought, Existing plus Committed plus Planned Demand, Existing Land Cover

Scenario H2 evaluates the effects of the Existing plus Committed plus Planned Demand increase under drought conditions. This transient drought scenario uses the baseline land cover conditions from Scenario C.

The results of this scenario show 0.5 m to 6.7 m of water level decline at the municipal wells. Scenarios D and G2 show the drawdown effects from drought and from demand increase in isolation, which are combined together in Scenario H2.

Midland Well 15 experienced minimal impact (0.5 m of drawdown) in this scenario due to the fact that the pumping rate was reduced from the baseline. Under Scenario H2 the only municipal well where the safe available drawdown is exceeded is Whip-Poor-Will Well 21-1.

Scenario H3 - Drought, Existing Demand, Projected Land Cover

This scenario evaluates the effects of the projected land cover change under drought conditions. The pumping rates are kept at the baseline existing conditions for this scenario.

The results of this scenario show 1.4 m to 3.2 m of drawdown at the municipal wells. The majority of this drawdown effect is attributed to the drought condition as a comparison to Scenario D, which shows similar results (1.2 m to 2.4 m of drawdown). Scenarios D and G3 show the drawdown effects from drought and from projected land use in isolation, which are combined together in Scenario H3. The drawdowns from Scenarios D and G3 when added together are approximately equal to Scenario H3 drawdowns.

Under Scenario H3, the municipal wells where the safe available drawdown is exceeded are Whip-Poor-Will Well 21-1 and Russell St. Well 15. The drawdown exceedance at Well 15 under this scenario does not take into account the reduced pumping rate condition and therefore Scenario H1 is a better reflection of the potential future drought conditions for this well.

6.3 Risk Assessment Scenario Results - Potential Impacts to Surface Features

The modelled impacts to stream baseflows were calculated for the Study Area coldwater streams and are presented below in Table 13. These show a comparison from steady-state projected demand Scenario G2 to Existing condition Scenario C.

Table 13: Baseflow Reductions (Model Scenario G2)

Station	Observed Baseflow (m^3/d)	Model Scenario C Baseflow (m^3/d)	Model Scenario G2 (m^3/d)	% Reduction
Copeland (gauge)	7,000 to 9,000 (BFLOW) 2,765 to 5,875 (spot flows)	7,470	7,256	3%
Copeland (at harbour)	6,396 to 7,690	10,490	9,951	5%
Lower Wye River Trib.	1,068	1,003	964	4%
Vindin (at Sunnyside)	3,633	4,300	3,887	10%

The simulated percentage reduction varies from about 3% reduction at the Copeland Creek gauge station to about 10% reduction at Vindin Creek. The locations of these observation stations are shown in Appendix C. Note that there was no modelled reduction at Picotes Creek, which is outside of the zone of influence of the municipal wells. The scale of assessment of the modelled reductions ranges from stream lengths of 3 to 5 km and corresponds to locations where observed measurements are available.

The total modelled baseflow for these streams is 15,793 m^3/day under existing pumping Scenario C and 14,802 m^3/day under the increased pumping Scenario G2. Therefore, a modelled 991 m^3/day of the 5,032 m^3/day pumping increase is sourced from a baseflow reduction at these streams. The majority of the remaining additional water is modelled as reduced groundwater outflow to Georgian Bay.

Model predicted declines in the shallow water table in response to the Allocated pumping rates are limited in extent and are generally less than 1 m (see Figure 31). The predicted shallow water level declines are primarily in the built-up areas of Midland outside of any Provincially Significant Wetland areas.

6.4 Alternate Scenario - Penetanguishene

Table 14 below presents the results of an alternate scenario that was run to assess an alternate pumping configuration to meet the Allocated Quantity of Water for the Town of Penetanguishene. This alternate scenario involves the increase in demand for Penetanguishene being met by the Payette Drive wells alone with no pumping from the Robert St. wells. The 1,505 m^3 increase applied to the Robert St. Wells as part of the Allocated Quantity of Water pumping rates (see Table 2) was assigned instead to the Payette Drive wells as part of this alternate scenario. This scenario included pumping rates of 1,000 m^3/d, 3,400 m^3/d and 654 m^3/d for Payette Drive Wells 1, 2 and 3, respectively.

For this alternate pumping configuration, only model scenarios G2 and H1 were run. The alternate Scenario G2 allows the effects of the alternate pumping configuration to be evaluated in relation to the WHPA-Q1 delineation, as described in Section 6.5. Alternate Scenario H1, which includes combined effects of drought, land use change and the alternate pumping increase, allows the worst case drawdowns to be evaluated at the municipal wells in order to assess the ability for the wells to meet the increased demands.

Table 14: Risk Scenario Results for Alternate Model Scenario (maximum drawdown in metres)

Well Field	Well	Safe Additional Available Drawdown	G2	Alternate G2	H1	Alternate H1
			Increased Demand	Recharge Reduction, Increased Demand	Recharge Reduction, Increased Demand	Recharge Reduction, Increased Demand
MIDLAND						
Vindin	Well 6	18.2	1.6	1.6	4.5	4.5
	Well 11	22.4	1.0	1.0	4.0	3.9
	Well 12	16.7	1.2	1.2	4.0	4.0
	Well 14	23.0	2.3	2.2	5.7	5.7
	Well 16	23.1	2.7	2.7	6.1	6.1
	Well 17	15.5	3.2	3.2	6.9	6.9
Heritage	Wells 7A and 7B	10.6 / 24.1	2.6	2.6	5.5	5.5

Well Field	Well	Safe Additional Available Drawdown	G2	Alternate G2	H1	Alternate H1
			Increased Demand	Recharge Reduction, Increased Demand	Recharge Reduction, Increased Demand	Recharge Reduction, Increased Demand
Dominion	Well 9	23.9	1.1	1.1	3.6	3.5
Russell	Well 15	1.5	-0.5	-0.5	1.2	1.2
Fourth	Well 1A	19.3	3.4	3.4	6.6	6.6
PENETANGUISHENE						
Payette	Well 1	10.7	0.1	1.8	2.5	4.9
	Well 2	12.0	0.1	2.8	3.3	5.9
	Well 3	20.9	0.1	2.1	3.0	5.3
Robert	Well 2	49.9	0.7	0.1	2.2	1.4
	Well 3	46.8	0.7	0.1	2.3	1.5
Lepage	Wells 1 and 2	15.4	0.1	0.0	1.6	1.5
TINY						
Whip-Poor-Will	Wells 21-1 and 21-2	1.0 / 4.6	0.3	0.2	2.8	2.7

Notes:
1) Wells where the safe additional available drawdown is exceeded are highlighted in grey.

The results of this alternate scenario show an approximate additional 2 to 3 m of drawdown in the Payette Drive wells compared to the previous H1 Scenario. The predicted drawdowns at the Payette Drive wells under these scenarios remain within the safe available drawdown for the wells. The Robert St. Wells show less drawdown than in previous Scenario H1 since they are no longer pumping in this scenario. For the other well fields, the drawdowns are essentially the same as in the previous scenarios with a minor reduction observed at some wells (0.1 m reduction at Whip-Poor-Will wells, Lepage wells, Well 9 and Well 15). As with the previous scenarios, the safe available drawdown is exceeded at the Whip-Poor-Will wells under drought conditions.

6.5 Delineation of WHPA-Q1, WHPA-Q2 and Local Area

6.5.1 WHPA-Q1

The WHPA-Q1 delineation is based on the cone of influence of the Existing plus Committed Plus Planned Demand and Existing Land Cover Scenario G2.

The steady-state simulated drawdown under Scenario G2 is plotted relative to the non-pumping steady-state condition on Figures 35 and Figure 36 for Aquifers A2 and A3, respectively. Figure 37 shows the 1 m drawdown contour encompassing both aquifers (i.e., maximum extent of 1 m drawdown for both aquifers).

The 1 m contour was selected for the appropriate drawdown threshold. This selection was based on a review of seasonal fluctuations observed in the monitoring record (see Appendix A water level monitoring hydrographs). Seasonal fluctuations with a total magnitude about 0.5 m to 1.0 m are observed at the wells. Long-term water level declines of less than 1 m become difficult to distinguish from seasonal fluctuations. Therefore the 0.5 m modelled drawdown contour, which extends considerable distances (up to 4 km) from the municipal wells into areas of poor data coverage was not used for the threshold.

The 1 m drawdown contour shown on Figure 37 is connected as a single area between the pumping centres of Midland and Penetanguishene and includes the major well pumping centres. The Robert St. wells are not encompassed since the Allocated Quantity of Water pumping rates for these wells were relatively low compared to the transmissivity/capacity of the aquifer in this area, resulting in little drawdown (<1 m threshold). The Robert St. wells are acting as a partial back-up to the Payette Drive wells under this scenario. The small systems of Lepage and Whip-Poor-Will are also not encompassed in this zone.

For the alternate scenario described in Section 6.4, the resulting drawdown in A2 and A3 for these pumping rates (relative to non-pumping condition) is shown on Figures 38 and 39, respectively. The 1 m drawdown contour for this scenario combined for both A2 and A3 Aquifers is shown on Figure 40. This zone is similar to the 1 m contour shown on Figure 37 but is slightly more extensive in the vicinity of the Payette Drive wells since this alternate scenario includes higher pumping rates from these wells.

The delineated WHPA-Q1 zone is presented on Figure 41 and encompasses the 1 m drawdown areas from Aquifers A2 and A3 under both the primary and the alternate pumping configuration scenarios.

6.5.2 WHPA-Q2

The WHPA-Q2 includes the WHPA-Q1 and any area where a reduction in recharge due to the projected land use change would significantly impact the municipal aquifer water levels.

The results of Scenario G3, which evaluates the drawdowns due to the recharge reductions, indicate that at most of the municipal wells, the effects from the projected land cover change are very minor (0.1 to 0.3 m drawdown) and likely would not be measurable. Exceptions are at the Payette Drive wells in Penetaguishene and the Heritage Drive, Dominion and Russell St. wells in Midland. Drawdowns of 0.5 to 1.0 m are observed at these wells due to the recharge reduction. Figure 34 shows the Scenario G3 modelled extent of drawdown in Aquifer A3 relative to the baseline condition (Scenario C). This shows the extent of the 0.5 to 1.0 m modelled drawdown in the vicinity of the Payette Drive and central/southern Midland wells.

An additional scenario was run to evaluate the effects of the recharge reductions applied only in areas of projected land use change outside of the WHPA-Q1. This scenario was run in order to assess whether the projected development lands outside of the WHPA-Q1 could have a measurable potential impact to water levels in the municipal aquifer that would warrant including these areas in the WHPA-Q2 zone. This was considered to be a conservative estimate since the modelled scenario does not account for stormwater recharge best management practices.

The drawdown in Aquifer A3 resulting from this scenario is shown on Figure 42. Drawdown ranging from about 0.5 m to 1 m is predicted in this scenario in the vicinity of the Heritage Drive wells and the Russell St. wells in Midland. The projected land use change in this area could potentially have a measurable effect on the municipal aquifer water levels and therefore these development areas have been included in the delineation of WHPA-Q2 as shown on Figure 43.

6.5.3 Local Area

The Local Area is delineated to include the cone of influence of the municipal wells (WHPA-Q1) and the areas where a reduction in recharge would have a measurable impact on the cone of influence (included in WHPA-Q2). In this case the Local Area delineation is identical to the WHPA-Q2.

The Local Area includes the following sub-areas as labelled on Figure 43:

- Local Area A- Penetanguishene Payette Drive System and Midland Systems;
- Local Area B- Penetanguishene Lepage System;
- Local Area C- Penetaguishene Robert Street System; and
- Local Area D- Tiny Township Whip-Poor-Will System

6.6 Tolerance and Risk Level

6.6.1 Tolerance

The MOE Technical Rules (MOE, 2009) specify that if the municipality's system is able to meet existing peak demands, then the tolerance is high. The municipal systems in this Tier Three Assessment have been able to meet peak demands and therefore the tolerance of these systems is designated as high. These municipal systems have a redundancy of supply (multiple wells) with a capacity that exceeds demand, and have existing storage systems in place to meet peak demand.

6.6.2 Risk Level

The risk level for the scenarios is evaluated based on the circumstances listed in Table 15 below from the MOE Technical Bulletin: Part IX Local Area Risk Level (MOE, 2011) and the recent MOE Risk Assignment memorandum (MOE, 2013). Note that the circumstances below only relate to the Allocated Quantity of Water since there is no identified Planned Quantity of Water for this study.

Table 15: Risk Scenarios and Circumstances - Groundwater (MOE, 2011; MOE, 2013)

Significant Risk - Groundwater

Scenarios	Circumstance
C - Existing – average annual D - Existing – ten year drought	1) the quantity of water that could have been taken from groundwater in the local area would not have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells. 2) the quantity of water that could have been taken from groundwater in the local area would have been sufficient to meet the allocated quantity of water taken by those municipal groundwater wells and the tolerance is Low.
G – Planned system or existing system with committed demand – average annual	1) the quantity of water that can be taken from groundwater in the local area would not be sufficient to meet the allocated quantity of water for those municipal groundwater wells.
H – Planned system or existing system with committed demand – ten year drought	1) the quantity of water that can be taken from groundwater in the local area would not be sufficient to meet the allocated quantity of water for those municipal groundwater wells.

Moderate Risk- Groundwater

Scenarios	Circumstance
G – Planned system or existing system with committed demand – average annual	1) The difference between the Existing Demand and the Allocated Quantity of Water would result in a reduction to flows or levels of water thereby creating a measureable and potentially unacceptable impact 2) The difference between the Existing Demand and the Allocated Quantity of Water would result in a reduction to groundwater discharge to aquatic habitat that is classified as a cold water stream by an amount that is, a. At least 10 percent of the existing estimated stream flow that is exceeded 80 percent of the time (Qp80), or b. At least 10 percent of the existing estimated average monthly baseflow of the stream.

In this case the risk level is categorized as follows:

Significant Risk

- Local Area D - Tiny Township Whip-Poor-Will System- Under Drought Conditions and Allocated Quantity of Water, the safe additional drawdown was exceeded for Well 21-1.

Moderate Risk

- Local Area A - Penetanguishene Payette Drive System and Midland Systems- The modelled baseflow reduction to coldwater stream Vindin Creek was 10%.

Low Risk

- Local Area B - Penetanguishene Lepage System- no risk circumstances identified.
- Local Area C - Penetaguishene Robert Street System- no risk circumstances identified.

The risk level assignment is further discussed below.

Tolerance

- As discussed in Section 6.6.1, the tolerance of the systems is high since the systems have been able to meet peak demands. The systems havestorage capacity (storage reservoirs) and underutilized capacity of the well sources. The underutilized capacity is evident in the remaining safe available drawdowns for the majority of the wells under the model scenarios and the fact that the wells on average have only been pumping less than 25% of the time.

Meeting Allocated Quantity of Water

- The quantity of water that can be taken from groundwater in the local area is sufficient to meet the Allocated Quantity of Water for the municipal groundwater wells with the exception of Whip-Poor-Will Well 21-1.

- The safe additional drawdown for Whip-Poor-Will Well 21-1 is exceeded under drought conditions only (Scenarios D, H1, H2 and H3). The Whip-Poor-Will Wells 21-1 and 21-2 only pump for several hours per day on average and the second well serves as a back-up source. Well 21-1 is susceptible to small water level declines since it is constructed only slightly into the top portion of the aquifer. In the event that water level decline in Well 21-1 prevented or reduced its operational capacity, Well 21-2 could provide the supply although there would then be no back-up source. A new deeper well at the site that replaces Well 21-1 would provide a more robust source with a greater safe additional drawdown and would reduce the risk of impacts under drought conditions as there is additional thickness of aquifer materials below the bottom of the screen.

- For Russell St. Well 15 in Midland, although the safe additional drawdown is exceeded under drought conditions combined with reduced recharge (Scenario H3), the model scenarios show that the safe available drawdown at this well is not exceeded when the pumping rate of Well 15 is reduced from 924 m^3/d (existing 2010/2011 rate used in Scenario H3) to 566 m^3/day (Allocated Quantity of Water rate used in Scenario H1). This well is susceptible to small water level declines, however, there are operational measures the Town can employ to meet the Allocated Quantity of Water. The primary measure under potential future drought conditions would be to further shift pumping to other wells with underutilized capacity and available drawdown and reduce reliance on Well 15.

Impacts to Coldwater Streams

- The modelled reductions to baseflow at the Study Area coldwater streams are less than 10%, with the exception of Vindin Creek where the modelled impact is on the threshold at 10%. Therefore, a moderate risk is assigned to this Local Area due to potential impacts to Vindin Creek.

Impacts to Provincially Significant Wetlands

- Model predicted declines in the shallow water table in response to the Allocated pumping rates are limited in extent and are generally less than 1 m (see Figure 31). The predicted shallow water level declines are primarily in the built-up areas of Midland outside of any provincially significant wetland areas and therefore no measureable and unacceptable impacts are predicted.

6.7 Uncertainty and Gap Assessment

Uncertainty and Data Gaps - Surface Water Model

The following data gaps and uncertainties were identified during the surface water model construction and calibration:

- Stream flow data in the Study Area are limited to one streamflow gauge on Copeland Creek as described in previous sections. The Copeland Creek gauge period of record was limited to a ten year period between 1989 and 1998. During this period there were many instances of missing or suspect data. Five of the ten years in the period of record were missing more than approximately 45 days of data. The lack of continuous streamflow data in the Study Area represents a significant data gap in this study. It is recommended that operation of the Copeland Creek gauge be reinstated and that additional stream gauging stations be established on significant watercourses in proximity to or within watersheds containing municipal wells, most notably on Vindin Creek. This additional stream gauging should be established as soon as feasible in order to develop a multi-year flow record for use in future updates of this study and other similar studies. Although less relevant than Vindin Creek and Copeland Creek, additional stream gauging on the Wye River would also provide useful regional flow information for comparison to future Vindin Creek and Copeland Creek data. Storage excess runoff is not directly represented in MIKE SHE when using the linear reservoir groundwater flow option. This resulted in an underestimate of total runoff in the model results for the Copeland Creek subwatershed. A significant amount of work has been done to develop the MIKE SHE model of the Study Area. It is recommended that future updates of this study consider building upon this work by incorporating the coupled finite difference groundwater model option available in MIKE SHE, which would improve this aspect.

- Periods where data were missing from the Copeland Creek gauge record were also removed from the model results to allow comparison of total flows predicted by the model and observed at the gauge. This approach likely removed most of the potential for error to be introduced to the calibration comparisons; however, in the process of calibrating the model, it was noted that, at times, time lag in the model results caused water sourced from precipitation or snowmelt to report in the following days or weeks in the model results. For periods following missing data, residual error associated with lagged flow from within the missing data period likely contributed to calibration error and cannot be quantified. In addition, data from the periods with little gauge movement during winter are considered to be suspect. In addition to continuous gauging, it is recommended that spot flow measurements be collected on a regular basis on Copeland Creek at Penetanguishene Harbour. This information would help to improve our understanding of the ultimate destination of cross boundary flow and gauge underflow in the Copeland Creek watershed.

- Precipitation data in the Study Area are limited to two meteorological stations that span the east central part of the model domain and are nominally on the leeward side of the peninsula. There are instances of rainfall events present in the meteorological station records and corresponding modelled Copeland Creek flow results that are not observed, or are very limited, in the observed flow data. This observation is likely indicative of highly local convective storm events occurring over the meteorological stations but not affecting a significant fraction of the Copeland Creek watershed upstream of the stream flow gauge. It is recommended that an additional meteorological station, monitoring at least temperature and precipitation, be established near the west side of the peninsula and at a higher elevation than the two existing Midland meteorological stations.

- Potential evapotranspiration represents a significant part of the water budget and is not directly measurable. Small under or overestimates of evapotranspiration may result in errors in other parts of the water budget such as runoff or recharge.
- Surficial soils in the Study Area are typically sandy and conceptualised to have high infiltration rates while underlying soils in some areas have lower hydraulic conductivity properties. In these areas, mounding of water in the shallow overburden layers was addressed through reduction of the soil hydraulic conductivities in MIKE SHE and through implementation of drain boundaries in the groundwater model but there remains uncertainty as to the degree to which this could represent either runoff (rejected recharge) or interflow.
- Representation of the drainage network is not thought to be uniform across the Study Area as many small drainage features are represented in areas of interest, while the coverage of drainage features in other areas with similar topography, land use and soils includes fewer small drainage features.

Significant gauge underflow and/or cross boundary flow directly to Georgian Bay from the Copeland Creek watershed was conceptualised early in this project and reported in the Conceptual Understanding Report. This concept was further supported by the surface and groundwater modelling. As the gauge underflow and/or cross boundary flow to Georgian Bay represents a significant part of the Copeland Creek water budget and is not directly measurable, uncertainties in this aspect of the water budget of Copeland creek may result in uncertainties in other parts of the water budget.

Uncertainty and Data Gaps- Groundwater Model Results

The Midland-Penetanguishene area is underlain by a regional scale, heterogeneous, multi-unit groundwater flow system that is governed by an array of sources and sinks. The extent to which a groundwater model may approximate this system is constrained in part by 1) the flow processes that are modelled numerically; 2) the quantity and quality of available data; and 3) the degree to which the pursuit of additional complexity is judged necessary in order to produce a reasonable calibration and predictive outcome.

To this end, the FEFLOW model developed in this study uses the laws of science and mathematics to draw together data of suitable quality into a mathematical, computer-based representation of the essential features of the existing hydrogeological system. While the model itself lacks the detailed reality of the existing hydrogeological system, a rigorous calibration process demonstrates that the behavior of the groundwater model reasonably approximates fundamental aspects of the real system, particularly at the municipal wellfield where the bulk of the high-quality data exists. Thus, while the FEFLOW model is a necessary simplification of reality, there is confidence that it is a suitable tool to predict water level and water supply risks at the wellfield scale, and, to a lesser extent, regionally.

The groundwater modelling completed as part of this study reflects a significant enhancement in the hydrogeological characterization of the Midland-Penetanguishene area. Notable aspects of increased model confidence include:

- Groundwater/surface water interaction, particularly at Copeland Creek, where matching baseflows formed a significant portion of the calibration effort;
- Recharge inputs, derived from detailed MIKE-SHE output;
- Flow budgets at the subwatershed scale;

- Aquifer storage terms, derived as part of pumping test analysis and transient calibration at the Robert St. wellfield;
- Delineating the presence (or lack thereof) of “windows” in aquitard units, inferred from in-depth analysis of borehole logs at a local scale and refined through the calibration process (for example Sunnyside and Vindin St. wellfields); and
- The role of clay lenses (effectively bulk anisotropy) in defining the shallow water table in the highland areas.

Nonetheless, a groundwater system of this size and nature is complex and uncertainties remain. The most significant areas of model uncertainty include:

- The hydraulic connection (or lack thereof) between deeper aquifer units and Georgian Bay, where measured water levels suggest highly localized areas of connection;
- Hydraulic conductivity inputs for the aquitard units which remain untested;
- The bedrock aquifer properties, where hydraulic testing data in the Midland-Penetanguishene area is unavailable;
- The role of unsaturated flow processes in directing shallow groundwater flow, which was dealt with in the model in an implicit way by assigning drainage nodes over areas of mounding;
- Related to the above, the presence of highland seeps, while inferred from the model calibration vis a vis identifying areas of mounding and subsequent drain implementation, have yet to be verified in the field; and
- Hydraulic parameters distal to the wellfields, mainly west in the highland areas, where no pumping test data exists.

Further investigation into these items, most of which would involve additional field studies, would allow for additional model refinements and ultimately increased confidence in simulation results. However, most of these uncertainties pertain to areas external to the wellfields upon which the Tier Three study focuses. It follows that a reasonable degree of confidence is placed on model parameterization in the wellfield area, with uncertainty increasing further from these local areas of interest.

Uncertainty Analysis Related To Nonlinear In-Well Losses

The nonlinear in-well losses are evaluated in a general sense to determine whether they could have an effect on the risk level outcome. Table 16 below shows the calculated nonlinear well losses related to pumping increases from the Existing rates to the Allocated Quantity of Water rates. The nonlinear well losses are proportional to the pumping rate increase.

Table 16: Nonlinear Well Losses

Well Field	Well	Safe Available Additional Drawdown (m)	Existing 2010/2011 Average Pumping Rate (m^3/day)	Allocated Quantity of Water 2031 Rates (m^3/day)	Pumping Rate Increase (m^3/day)	Nonlinear Well Losses (Properly designed and developed)[1]	Non-linear Well Losses (Mild Deterioration)[2]	Scenario H1 Drawdown including Well Losses- Assuming Mild Deterioration (m)
Vindin	Well 6	18.2	164	164	0	0.00	0.00	4.5
	Well 11	22.4	393	393	0	0.00	0.00	4.0
	Well 12	16.7	185	185	0	0.00	0.00	4.0
	Well 14	23.0	251	518	267	0.05	0.10	5.8
	Well 16	23.1	184	414	230	0.04	0.07	6.2
	Well 17	15.5	249	646	397	0.09	0.18	7.1
Heritage	Well 7A	10.6	2,176	2,592	416	0.51	1.01	6.5
	Well 7B	24.1	769	2,228	1,459	1.12	2.23	7.7
Dominion	Well 9	23.9	780	1,034	254	0.12	0.23	3.8
Russell	Well 15	1.5	924	566	-358	-0.14	-0.27	0.9
Fourth	Well 1A	19.3	0	850	850	0.18	0.37	7.0
Payette	Well 1	10.7	703	1,000	297	0.13	0.26	5.2
	Well 2	12.0	2,374	3,400	1,026	1.51	3.02	8.9
	Well 3	20.9	472	654	182	0.05	0.10	5.4
Robert St.	Well 2	49.9	0	753	753	0.14	0.29	2.5
	Well 3	46.8	0	753	753	0.14	0.29	2.6
Lepage	Wells 1 & 2	15.4	18	24	6	0.00	0.00	1.6
Whip-Poor-Will	Wells 21-1 and 21-2	1.0 / 4.6	72	78	6	0.00	0.00	2.8

Notes:

1) Assuming well loss coefficient of C = 1900 sec^2/m^5 (Walton, 1962)

2) Assuming well loss coefficient of C = 3800 sec^2/m^5 (Walton, 1962)

These calculated values indicate that additional drawdowns in the well related to non-linear well losses would not affect the results of the risk assessment assuming the wells are in properly designed and developed or mild deterioration condition, which is a reasonable assumption for the active municipal wells. In most cases, the calculated well losses were minor (10s of centimeters), with the exception of Heritage Drive Well 7A and 7B and the Payette Dr. Well 2, where significant pumping increases were assigned in the 2031 demand scenarios and well losses of 1 to 3 m were calculated under the mild deterioration case.

Uncertainty Related to Transient Scenario Initial Heads

During the completion of the transient model scenarios, it was determined that the drawdown results were highly sensitive to the initial heads. To summarize the issue, it was determined for example that a starting head distribution that was 1 m too low, would result in an additional 1 m of drawdown during the course of the simulation as the model would never recover from the low starting heads.

The initial heads were first developed by scaling the average climate (1989-1998) recharge distribution by a reduction factor corresponding to the average annual precipitation at the beginning of the drought period. A set of initial heads was produced from the steady-state model with this lower recharge. The transient simulation was started at the beginning of the drought period (January, 1955) using these initial heads. These initial heads were determined to be too low since the simulated water levels steadily increased during the first few months of the simulation before starting a seasonal cycle responsive to climate variability. A series of sensitivity runs were completed to evaluate the sensitivity of the modelled drawdowns to the initial heads and optimize the most appropriate starting condition to reduce the uncertainty related to this issue.

The following describes the approach and findings for optimizing and reducing uncertainty in the starting heads:

- The most appropriate starting time for the transient model scenario was determined to be a month with pumping close to the average annual pumping rate (i.e., not during a peak pumping period in July nor in the low pumping period in December). The month of October was selected as most appropriate as the monthly pumping was close to the average annual rate.
- An appropriate length of lead up model run time was determined such that the model had adjusted to the starting heads prior to beginning the drought period in January, 1955. 15 months of lead up simulation time was determined to be sufficient and the model simulation was started in October, 1953.
- An appropriate recharge was determined for the steady-state initial heads model run. The recharge used to develop the starting heads was 91% of the average climate period recharge, generally corresponding to the average annual conditions for the year leading up the October, 1953 start.

The uncertainty in the risk level categorization is considered as low. The overall low uncertainty rating is based on the factors described above that increase the level of confidence in the modelling tools. This includes the degree of local scale refinement in the modelling tools, which incorporate well field scale high quality data in the analysis and involve both steady-state and transient model calibration.

7.0 WATER QUANTITY THREATS

As outlined in the MOE Technical Rules (MOE, 2009), for local vulnerable areas classified as having a significant or moderate risk level, drinking water quantity threats that may limit the sustainability of the municipal water supply wells are identified. The definition of a drinking water quantity threat is 1) an activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body or 2) an activity that reduces the recharge of an aquifer.

7.1 Consumptive Water Demands

For each vulnerable area identified under clause 15 (2) (d) or (e) of the Clean Water Act (2006), drinking water threats that are or would be classified as moderate or significant, need to be identified within each vulnerable area.

Table 17 illustrates the permitted consumptive water uses within the Local Areas.

Table 17: Consumptive Water Uses in Local Areas

Local Area Risk Level	Permitted Consumptive Demand (Threat)
Moderate- Local Area A	Well 6 (Midland Municipal)
Moderate- Local Area A	Well 11 (Midland Municipal)
Moderate- Local Area A	Well 12 (Midland Municipal)
Moderate- Local Area A	Well 14 (Midland Municipal)
Moderate- Local Area A	Well 16 (Midland Municipal)
Moderate- Local Area A	Well 17 (Midland Municipal)
Moderate- Local Area A	Well 7A (Midland Municipal)
Moderate- Local Area A	Well 7 B (Midland Municipal)
Moderate- Local Area A	Well 9 (Midland Municipal)
Moderate- Local Area A	Well 15 (Midland Municipal)
Moderate- Local Area A	Well 1A (Midland Municipal)
Moderate- Local Area A	Well 1- Payette Drive (Penetanguishene Muncipal)
Moderate- Local Area A	Well 2- Payette Drive (Penetanguishene Muncipal)
Moderate- Local Area A	Well 3- Payette Drive (Penetanguishene Muncipal)
Low- Local Area B	Well 1- Lepage (Penetanguishene Muncipal)
Low- Local Area B	Well 2- Lepage (Penetanguishene Muncipal)
Low- Local Area C	Well 1- Robert St. (Penetanguishene Muncipal)
Low- Local Area C	Well 2- Robert St. (Penetanguishene Muncipal)
Significant- Local Area D	Well 21-1 Whip-Poor-Will (Tiny Township Muncipal)
Significant- Local Area D	Well 21-2 Whip-Poor-Will (Tiny Township Muncipal)
Moderate- Local Area A	PTTW# 7224-6EBQS8 (2 wells - industrial)

As specified in Table 5 of the MOE Technical Rules, increased or new permitted takings are to be considered as follows:

- Where a risk level of moderate is assigned to a Local Area, any increase to an existing permitted taking or a new permitted taking within an IPZ-Q or a WHPA-Q1 will be listed as a significant drinking water threat if, by factoring the increase to the existing permitted taking or the new permitted taking into the risk level assessment, the risk level of the Local Area would increase to significant.

With the exception of the Whip-Poor-Will Local Area, the Local Areas were assigned a risk level of moderate or low and therefore the existing permitted consumptive demands are not classified as significant water quantity threats.

7.2 Reductions in Recharge

The Technical Rules (MOE 2009) specify that reductions in groundwater recharge are a potential water quantity threat within the Local Areas. As specified in Table 5 of the MOE Technical Rules:

- Where a risk level of moderate is assigned to a Local Area, any modified activity or new activity within an IPZ-Q or a WHPA-Q2 that reduces recharge to an aquifer will be listed as a significant drinking water threat if, by factoring the modified activity or a new activity into the risk level assessment, the risk level of the Local Area would increase to significant.

The Tier Three Risk Assessment model scenarios considered the impact of existing and projected land development on groundwater recharge and the resulting impact on water levels in the municipal aquifer at the wells. The model scenarios indicated that the projected land use change in the Payette Drive and Midland Well System Local Area could potentially have a measurable effect on the municipal aquifer water levels although it did not result in a significant risk level assignment.

8.0 SIGNIFICANT GROUNDWATER RECHARGE AREA DELINEATION

Following the MOE Technical Rules (MOE, 2009), Significant Groundwater Recharge Areas (SGRAs) are delineated as part of each tier of the water budget process (tier one, two and three). The SGRAs developed as part of a higher tier supercede those developed under the lower tier as they are based on more refined assessments. The groundwater recharge distribution that was estimated using the calibrated MIKE SHE model from the Tier Three Assessment (Appendix B) forms the basis for the SGRA delineation for this study.

The requirements for delineation of SGRAs are defined in the MOE Technical Rules (Part V.2) as follows:

44. Subject to Rule 45, an area is a significant groundwater recharge area if,

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

45. Despite rule 44, an area shall not be delineated as a significant groundwater recharge area unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system.

46. The areas described in rule 44 shall be delineated using the models developed for the purposes of Part III of these rules and with consideration of the topography, surficial geology and how land cover affects groundwater and surface water.

The first step in the SGRA delineation was to create a plot showing the distribution of recharge over the MIKE SHE model domain (Figure 44). Figure 44 shows the recharge rate in million m^3/year for the model cell value ranges. Also shown on Figure 44 are the percent volume exceeding and the percent area exceeding for each recharge value range.

The calculated mean recharge as shown on Figure 44 is 422 mm/year, which results in a threshold of 485 mm/year using a factor of 1.15 times the mean as specified by Rule 44 (1).

As recommended in the technical guide for SGRA delineation (MNR, 2012), a secondary analysis of the threshold was completed. As illustrated on Figure 44, the threshold of 485 mm/year lies within a large cluster of values ranging from 450 to 500 mm/year that represent a significant amount of the Study Area recharge (approximately one third of the recharge volume) and correspond to extensive areas of permeable sandy surficial sediments. A recharge threshold of 485 mm/year would exclude portions of this important grouping of permeable sediments. Also as illustrated on Figure 44, a threshold of 485 mm/year is within the steep slope portion of the % volume exceeding or % area exceeding lines and would result in a threshold that is very sensitive to small changes in values, which should be avoided given the uncertainty in the estimates. For these reasons, a threshold of 450mm/year (immediately before the cluster of permeable sediments) provides a more appropriate limit to distinguish the significant recharge areas.

As recommended in the MNR technical guide on the delineation of SGRAs (MNR, 2012), the thresholds from the broader Tier Two work are taken into account to avoid large discrepancies at the boundaries since some Tier Three studies (including this study) only consider a small portion of the broader Source Protection Area. The Tier Two Assessment used an SGRA threshold of 232 mm/year. The MNR supplemental guide (MNR, 2012) strongly recommends using the broader Tier Two threshold (232 mm/year in this case), however, the Tier Three MIKE SHE recharge estimates are higher than the Tier Two HSPF model estimates over the Tiny peninsula and therefore a higher SGRA threshold than the Tier Two Assessment is appropriate in this case. Instead of using the Tier Two threshold of 232 mm/year, a threshold of 450 mm/year as described above is an appropriate threshold that includes important groupings of permeable sediments and does not lead to significant discrepancies with the broader Tier Two SGRA mapping.

The threshold of 450 mm/year was used to delineate the SGRAs, with some subsequent adjustments as follows:

- Checks were performed to ensure that small isolated grid cells and associated significant recharge area designations were not mapped over the low permeability surficial materials and over the urban land use areas.
- Known areas of groundwater discharge in the Robert St. area and Vindin Creek areas were removed from the SGRA mapping based on areas with modelled groundwater levels within 2 m of ground surface. These areas were removed as there was a high level of confidence that they were discharge areas due to the monitoring data available, confirmed coldwater stream designations and the degree of local well field scale model calibration completed in these areas.
- Smoothing and in-filling was performed to eliminate or in-fill areas of generally 3 hectares or less in size.

The resulting SGRA mapping completed based on the above rationale is presented on Figure 45.

Figure 44 shows that this threshold results in about 50% of the land area being designated as a significant recharge area, which is appropriate given the extensive coarse soils and higher than average precipitation in the Study Area relative to the rest of the broader watershed areas. This percentage is similar, although slightly lower, than in the Tier Two SGRA delineation (Golder and AquaResource, 2010), which also showed a large portion of the Tiny peninsula designated as an SGRA with the primary exceptions of the till upland areas and the urban areas. Although the threshold is greater than the mean, the coverage is not higher than 50% since areas where removed through the modifications described above (smoothing and removing groundwater discharge areas).

To clarify the linkage between the identified significant recharge areas and sources of drinking water supply (both municipal and domestic supplies) as per Rule 45, a figure was plotted showing the distribution of water wells in relation to the delineated SGRAs (Figure 46). Given the heavy reliance on groundwater for water supply in the Tiny peninsula as illustrated by the high density of domestic wells and numerous municipal wells shown on Figure 46, no SGRAs were eliminated as they all were assumed to contribute to municipal or domestic drinking water supply aquifers.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Water budget modelling tools have been developed and groundwater simulations have been performed following the Technical Rules under steady-state and transient conditions. The simulations were performed in order to evaluate the system under existing and projected demand, projected land use changes and drought conditions. The modelled drawdown results and modelled stream baseflow reductions were assessed to complete the overall risk assessment for the Midland and Penetanguishene Tier Three Water Budget and Local Area Risk Assessment.

The WHPA-Q1, WHPA-Q2 and Local Areas have been delineated and risk levels assigned. Four separate Local Areas were delineated and assigned a risk level following the MOE guidance as follows:

- A low risk level was assigned to the Penetanguishene Robert Street and Lepage Well System Local Areas.
- A moderate risk was assigned to the Penetanguishene Payette Drive and Midland Well System Local Area based on potential for impacts to Vindin Creek.
- A significant risk was assigned to the Whip-Poor-Will System Local Area based on the potential that Well 21-1 would not meet demand requirements under drought conditions.

Areas of projected land cover change were identified where recharge reductions may impact municipal aquifer water levels, as reflected in the WHPA-Q2 delineation. The Significant Groundwater Recharge Areas for the Study Area were updated using the Tier Three modelling tools.

The modelling assisted in optimizing pumping strategies and identified wells that are most susceptible to impacts from water level declines under drought conditions such that the municipalities can plan to operate the system under these potential constraints.

The follow provides a summary of the key recommendations provided as part of this study:

Monitoring

- The lack of continuous streamflow data in the Study Area represents a significant data gap in this study. It is recommended that operation of the Copeland Creek gauge be reinstated and that additional stream gauging stations be established on significant watercourses in proximity to or within watersheds containing municipal wells, most notably on Vindin Creek. This additional stream gauging should be established as soon as feasible in order to develop a multi-year flow record for use in future updates of this study and other similar studies and to monitor potential baseflow reductions from increased pumping.

- Although less relevant than Vindin Creek and Copeland Creek, additional stream gauging on the Wye River would also provide useful regional flow information for comparison to future Vindin Creek and Copeland Creek data.
- In addition to continuous gauging, it is recommended that spot flow measurements be collected on a regular basis on Copeland Creek at Georgian Bay. This information would help to improve our understanding of the ultimate destination of cross boundary flow and gauge underflow in the Copeland Creek watershed.
- It is recommended that an additional meteorological station, monitoring at least temperature and precipitation, be established near the west side of the peninsula and at a higher elevation than the two existing Midland meteorological stations.
- The monitoring data collected by the municipalities at the pumping wells and observation wells was critical for this study and it is recommended that this monitoring be continued. In conjunction with the monitoring and reporting requirements under the PTTW for the systems, the monitoring results should be reviewed regularly to assess well performance, trends in safe available drawdown in the wells and potential for impacts to other water use. Where possible, continuous monitoring of water levels with dataloggers at the municipal pumping wells is recommended as it provides an improved understanding of water level responses to climate events and the safe available drawdown in the well during regular daily pump on/off cycling.
- Midland municipal Wells 6, 7A, 12 and 15, Penetanguishene Payette Drive Well 1 and the Whip-Poor-Will Wells all have instantaneous pumped water levels within 5 m of the safe water level. As demands increase and drought conditions are encountered, the collection and review of water level monitoring data will become more critical to help refine and optimize the operation and pumping rates/strategies for these well systems.

Well System Rehabilitation and Maintenance

- As described above, wells in these municipal systems are operated with pumped levels close to the well screens and therefore routine rehabilitation and maintenance of the wells is needed to maintain well system capacity. This will become more critical as demands increase and drought conditions are encountered.
- The safe additional drawdown for Whip-Poor-Will Well 21-1 was exceeded in the risk scenarios under drought conditions and therefore a risk level of significant was assigned to this system. Well 21-1 is susceptible to small water level declines since it is constructed only slightly into the top portion of the aquifer. A new deeper well at the site that replaces Well 21-1 should be considered to provide a more robust source with a greater safe additional drawdown, reducing the risk of impacts under drought conditions. A deeper well is feasible at the site as there is additional thickness of aquifer materials below the bottom of the screen.

Modelling Tools

- The modelling tools developed as part of this study can be used to help manage and protect the water resources in the area and should be maintained and updated periodically as new information becomes available. It is recommended that future updates of this study consider building upon this work by incorporating the coupled finite difference groundwater model option available in MIKE SHE, which would improve this water budget tool.

10.0 CLOSURE

We trust that this meets your needs and look forward to your comments. Please do not hesitate to contact us if you have any questions.

Report Signature Page

GOLDER ASSOCIATES LTD.

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Hydrogeologist and Associate

Kevin Mackenzie, P.Eng.
Water Resources Engineer and Associate

JP/KM/wlm/rh/cg

\\golder.gds\gal\barrie\active\2011\11-1170-0070 lscra tier 3 midland_penetang\report\risk assessment report\final february 2014\11-1170-0070 rpt final 2014feb21 mpt3 risk assessment.docx

11.0 REFERENCES

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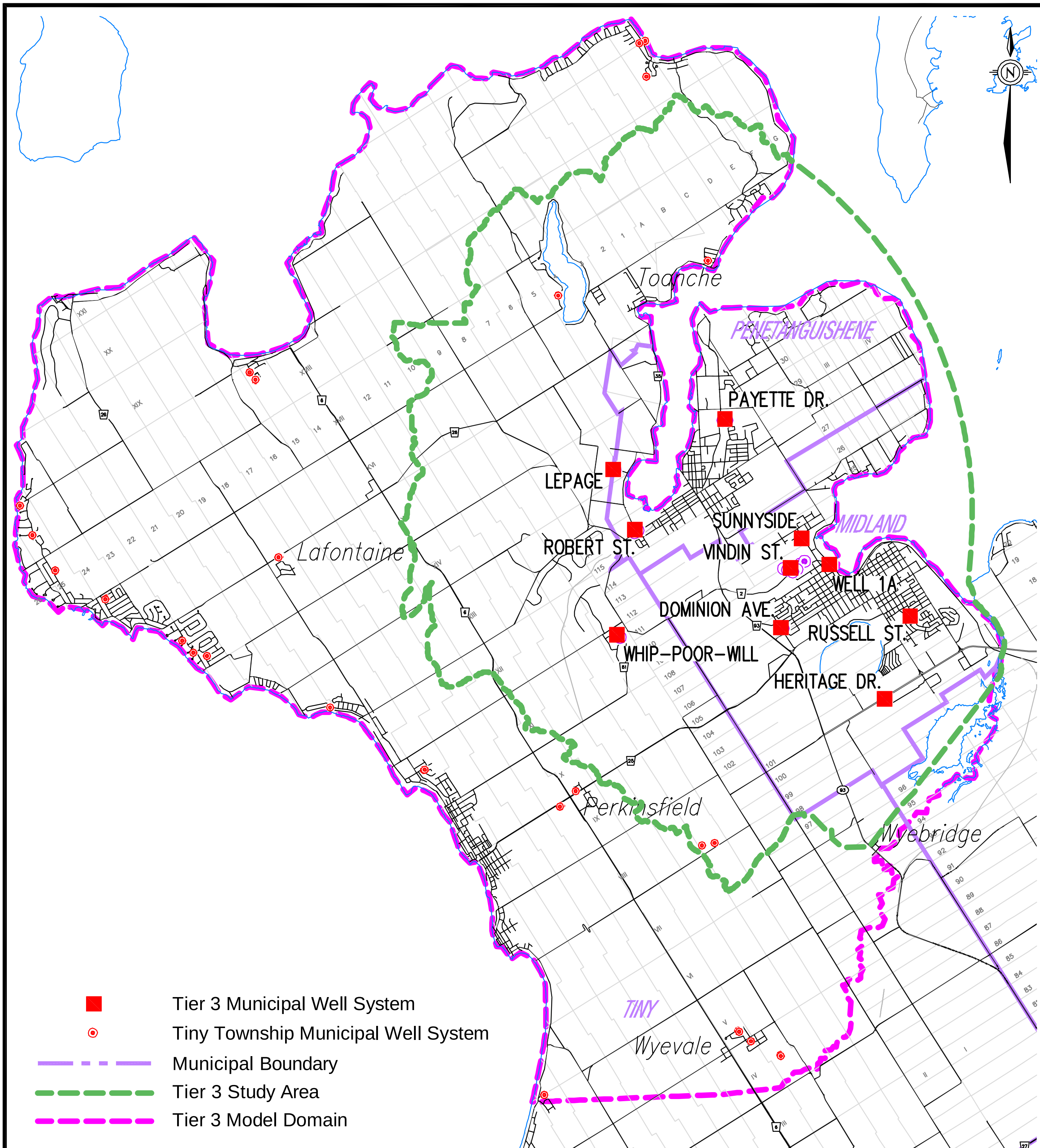
FIGURES



NOTES:

1. DATUM IS NAD UTM 83 ZONE 17

REFERENCES:

1. MAPPING BASED ON COUNTY OF SIMCOE MUNICIPAL BASE

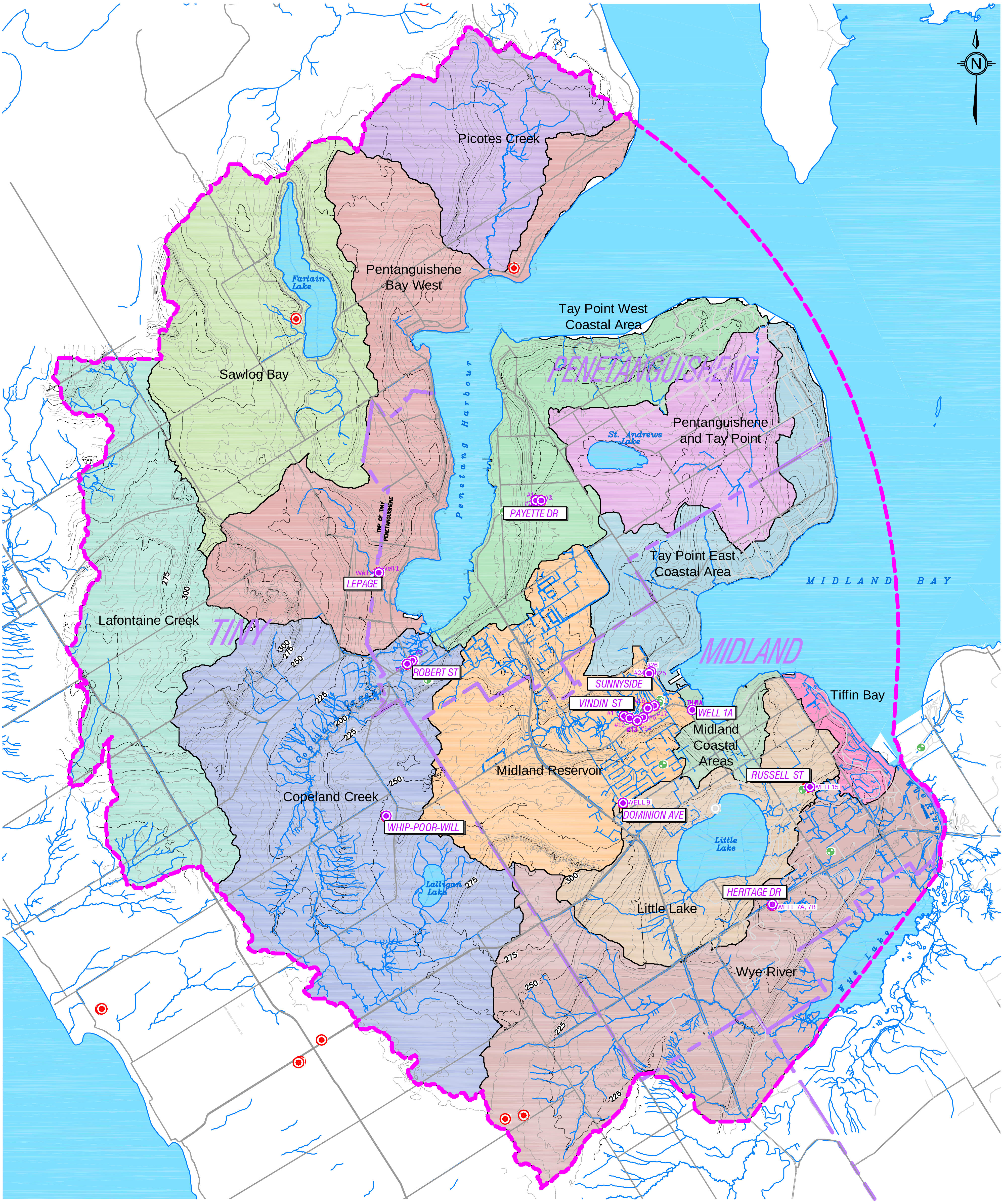
0 1000 2500 5000 10000

SCALE 1:125000 metres

Golder Associates, Mississauga, Ontario, Canada	SCALE: AS SHOWN	TITLE: **STUDY AREA LOCATION**	
	DATE: 13 MAR 2013		
	DESIGN		
	CAD: J REGIER		
FILE No. 1111700070BCREG.dwg : Figure 1	CHECK	MIDLAND PENETANGUISHENE TIER 3	FIGURE **1**
PROJECT No. 11-1170-0070 REV.	REVIEW		

PLOT DATE: March 13, 2013
FILENAME: T:\Projects\2011\11-1170-0070 (Midland Penetanguishene Model)\-BC-\1111700070BCREG.dwg

PLOT DATE: January 28, 2013
FILENAME: T:\Projects\2011\11-1170-0070 (Midland Penetanguishene Model)\-BB-\1111700070BBMAP.dwg



LEGEND:

- Municipal Boundary
- Tier 3 Study Area Boundary
- Tier 3 Study Municipal Well System
- Tiny Township Municipal Well System
- Major / Minor Contours 5 masl Interval Range 180 - 325 masl
- Detailed Drainage

0 500 1000 1500 2500

SCALE 1:60000 metres

Plotted Tabloid 11x17

NOTES:

1. Datum is UTM NAD 83 Zone 17
2. Contours OBM 1:10000, 5 masl interval

REFERENCES:

1. Mapping Based On County Of Simcoe GIS & Esri OBM Features
2. Catchment Basins, Severn Sound Environmental Association

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN	TITLE	
DATE	Jan. 28, 2013		
DESIGN			
CAD	S BOWERMAN		
CHECK			
REVIEW			

FILE No. 1111700070BBMAP.dwg

PROJECT No. 11-1170-0070 REV.

TOPOGRAPHY AND DRAINAGE

MIDLAND PENETANGUISHENE TIER 3

FIGURE 2

PLOT DATE: January 6, 2014
FILENAME: T:\Projects\2011\11-1170-0070 (Midland Penetanguishene Model)\-DA-\1111700070DAMAP.dwg

Catchment	Area (km²)
Copeland Creek	24.1
Lafontaine Creek (Study Area Portion)	14.2
Little Lake	9.1
Midland Coastal Areas	1.6
Midland Reservoir	13.3
Penetanguishene Bay West	16.5
Penetanguishenen and Tay Point	7.7
Picotes Creek	7.7
Sawlog Bay	15.2
Tay Point East Coastal Areas	7.1
Tay Point West Coastal Areas	9
Tiffin Bay	1.2
Wye River (Study Area Portion)	21.1

LEGEND:

- Municipal Boundary
- Tier 3 Study Area Boundary
- Tier 3 Study Municipal Well System
- Tiny Township Municipal Well System
- Streamflow Gauge
- Spot Flow Measurement Location
- Weather Station
- Detailed Drainage

0 500 1000 1500 2500
SCALE 1:60000 metres
Plotted Tabloid 11x17

NOTES:

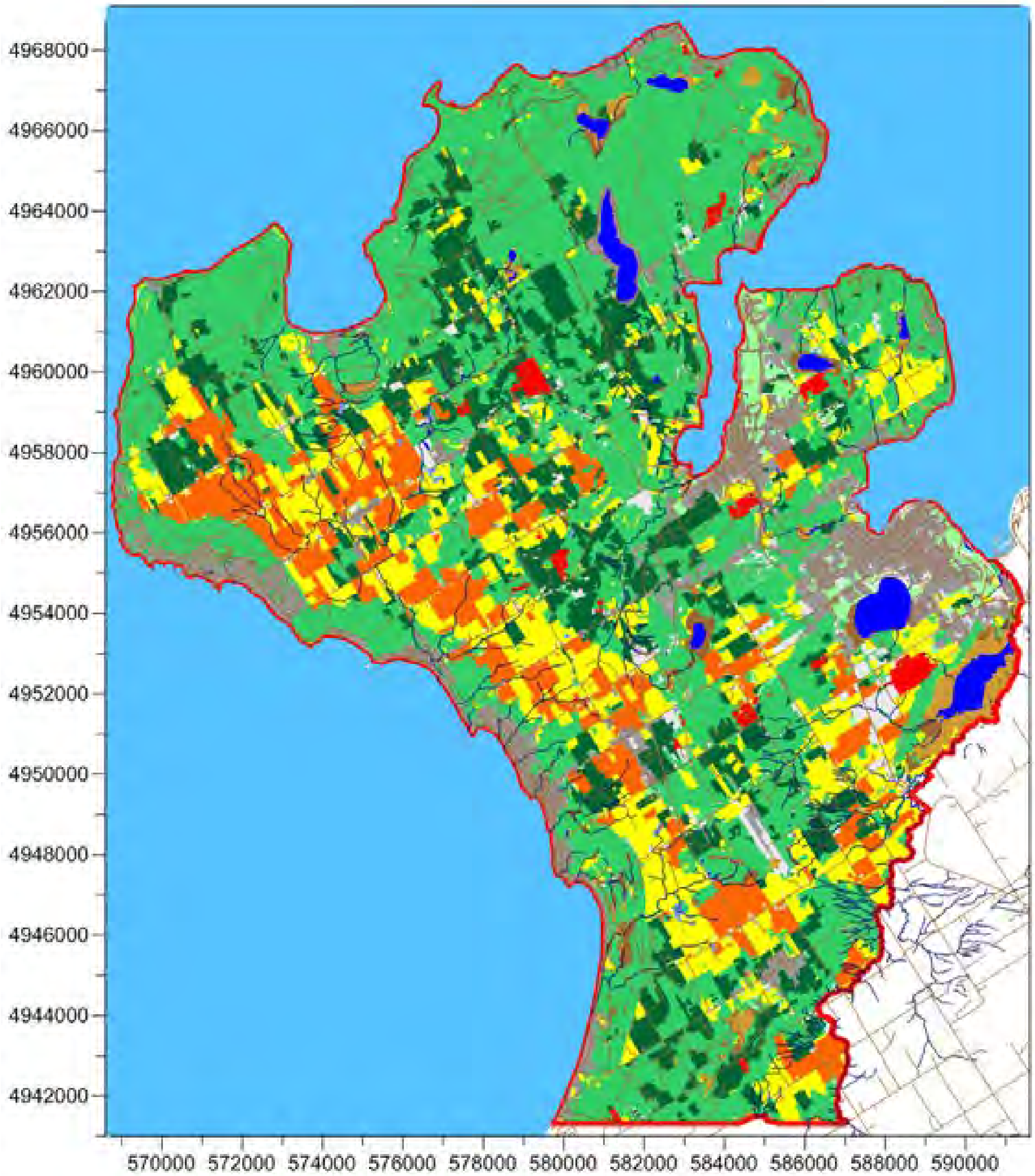
1. Datum is UTM NAD 83 Zone 17

REFERENCES:

1. Mapping Based On County Of Simcoe GIS & Esri OBM Features

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN	TITLE	SURFACE WATER CATCHMENTS AND MONITORING STATIONS
DATE	Jan. 6, 2014		
DESIGN			
CAD			
FILE No. 1111700070DAMAP.dwg	CHECK		MIDLAND PENETANGUISHENE TIER 3
PROJECT No. / REV.	REVIEW	FIGURE	3



LEGEND:

- Surface Water
- Road
- Model Domain

Land Use Classes

- Urban Water
- Water – Shallow / Sedimented
- Urban Green Space
- Wetland – Treed/Shrub/Thicket
- Aggregate
- Woodland - Coniferous
- Wetland - Open
- Water – Clear / Deep
- Rural – Hay / Pasture / Idle
- Rural - Cropland
- Urban / High Intensity Residential
- Woodland – Mixed
- Urban / Infrastructure

REFERENCES:

Roads and Surface Water- MNR LIO, obtained 2009
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2012

Land Use Classes received from SSEA – obtained 2011
2000/02 Interim Land Use and Cover based on SOLRIS/NRVIS data and SSEA Agricultural Survey

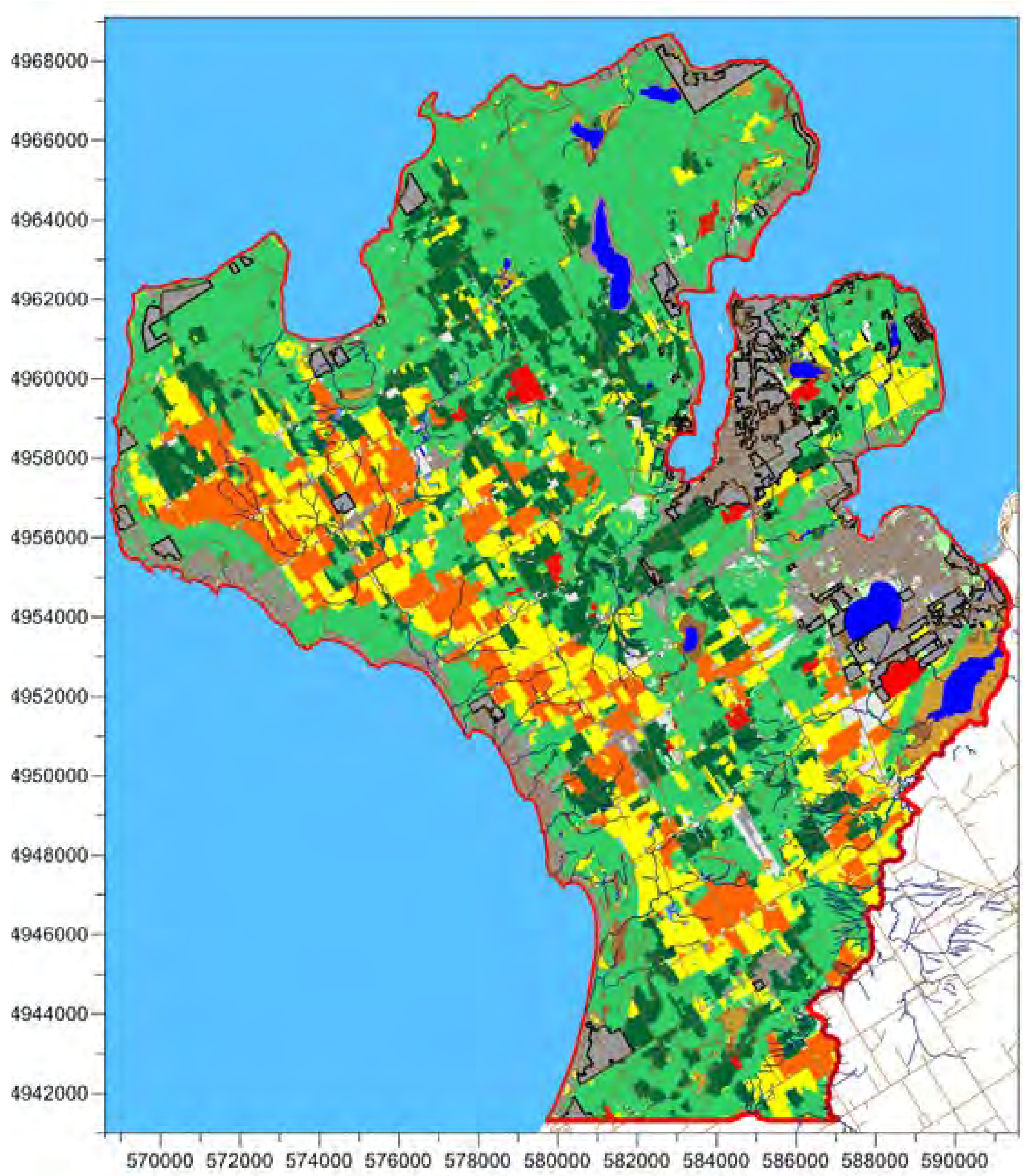
Golder Associates

Golder Associates Ltd.
BARRIE, ONTARIO, CANADA

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

EXISTING LAND COVER

MAY 2013	PROJECT: 11-1170-0070	FIGURE 4



LEGEND:

- Surface Water
- Road
- Model Domain
- Areas of Land Use Change

Land Use Classes

- Urban Water
- Water – Shallow / Sedimented
- Urban Green Space
- Wetland – Treed/Shrub/Thicket
- Aggregate
- Woodland - Coniferous
- Wetland - Open
- Water – Clear / Deep
- Rural – Hay / Pasture / Idle
- Rural - Cropland
- Urban / High Intensity Residential
- Woodland – Mixed
- Urban / Infrastructure

REFERENCES:

Roads and Surface Water- MNR LIO, obtained 2009
Produced by Golder Associates Ltd under licence from Ontario Ministry of Natural Resources, © Queens Printer 2012

Land Use Classes received from SSEA – obtained 2011
2000/02 Interim Land Use and Cover based on SOLRIS/NRVIS data and SSEA Agricultural Survey

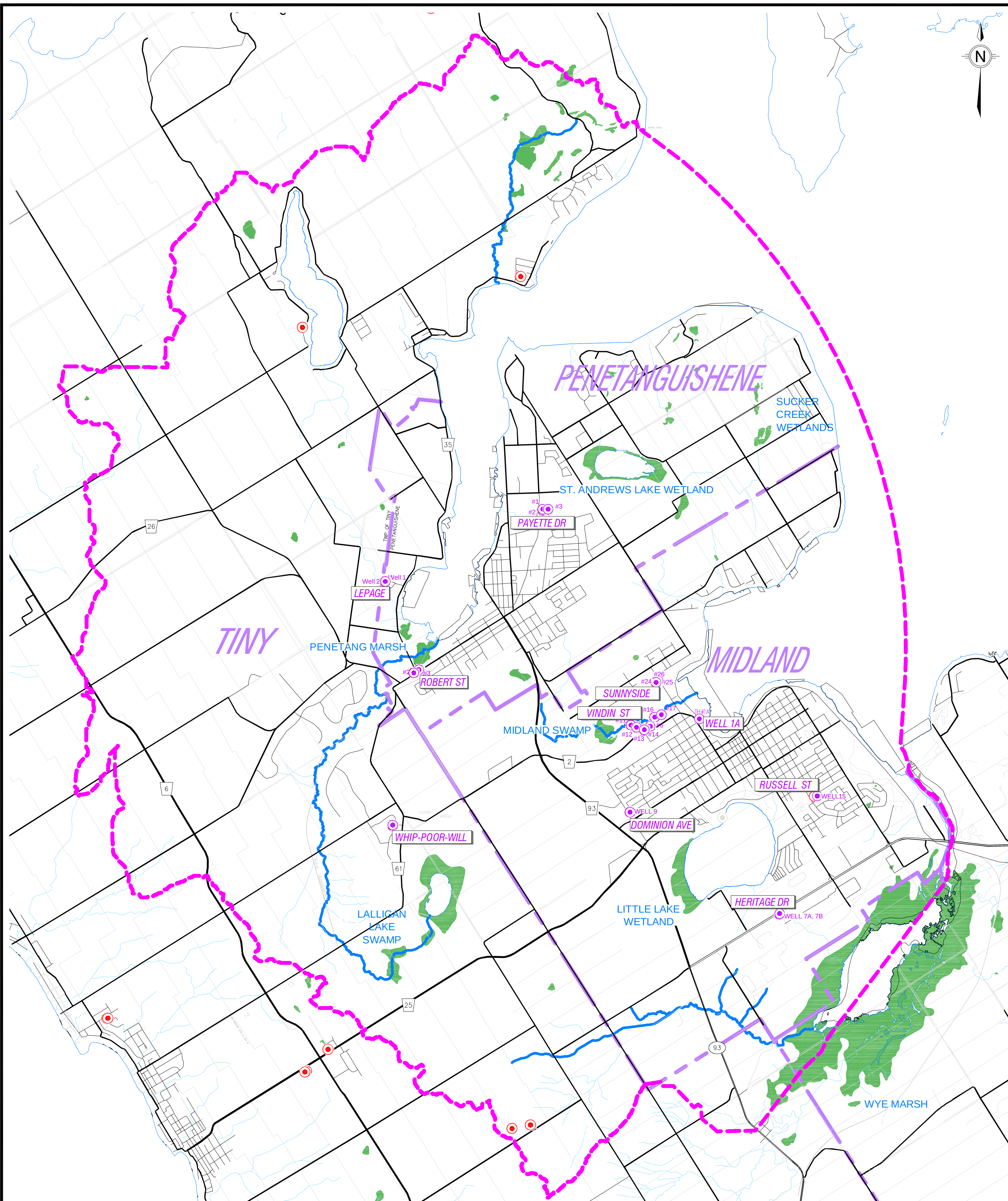
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

PROJECTED LAND COVER

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 5

Golder Associates Ltd.
BARRIE, ONTARIO, CANADA

PLOT DATE: June 18, 2012
FILENAME: T:\Projects\2011\11-1170-0070 (Midland Penetanguishene Model)\-BB-\1111700070BBECO.dwg



0 500 1000 1500 2500

SCALE 1:60000 metres

Plotted Tabloid 11x17

LEGEND:

- Municipal Boundary
- Tier 3 Study Area Boundary
- Coldwater Streams
- Tier 3 Study Municipal Well System
- Tiny Township Municipal Well System
- Provincially Significant Wetlands

NOTES:

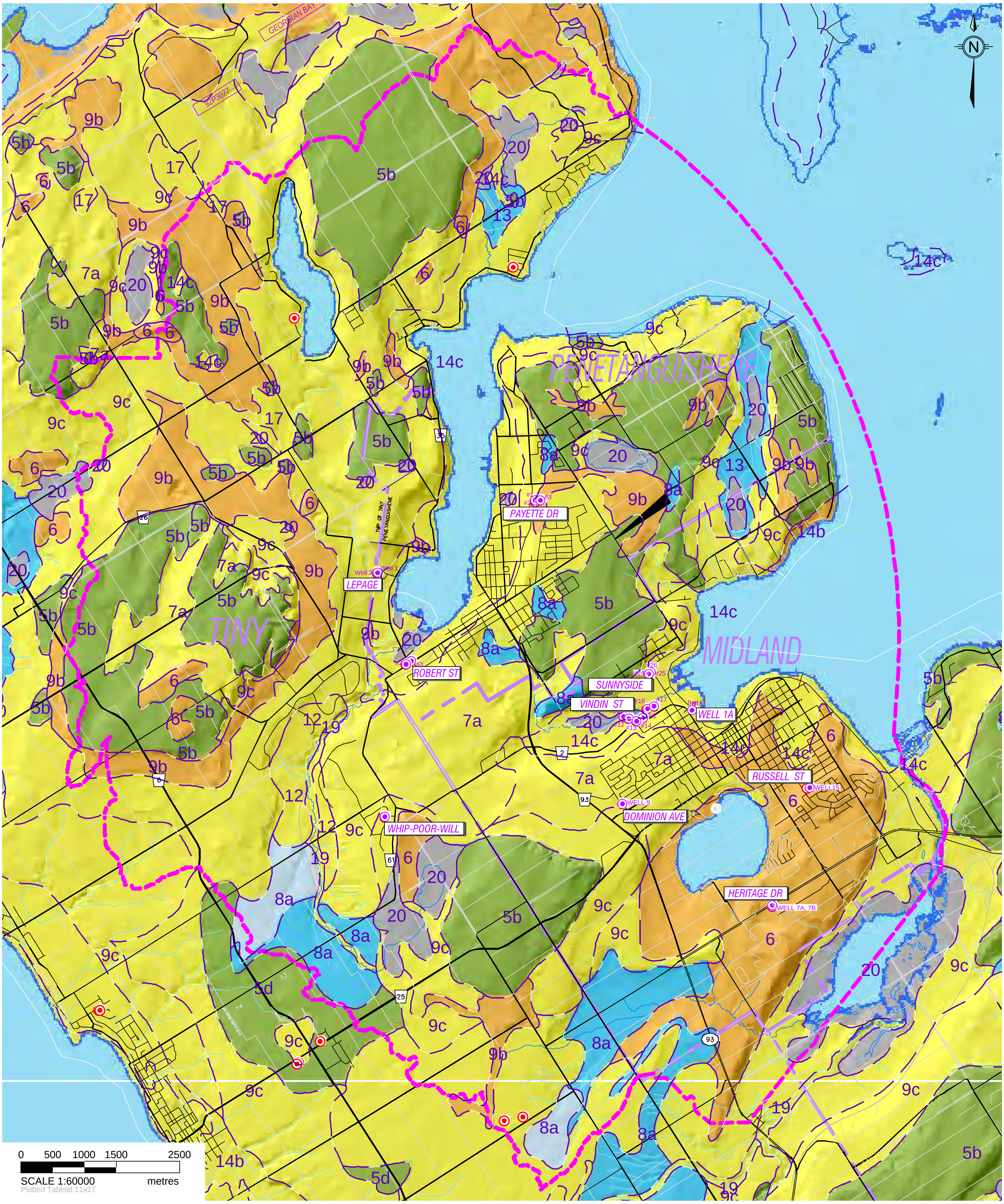
1. Datum is UTM NAD 83 Zone 17

REFERENCES:

1. Mapping Based On County Of Simcoe GIS & Esri OBM Features

Golder Associates, Mississauga, Ontario, Canada	SCALE: AS SHOWN	TITLE	
	DATE: 15 MAY 2012	**PROVINCIALLY SIGNIFICANT WETLANDS AND COLDWATER STREAMS**	
	DESIGN		
	CAD: S BOWERMAN		
FILE No. 1111700070BBECO.dwg	CHECK	MIDLAND PENETANGUISHENE TIER 3	FIGURE 6
PROJECT No. 11-1170-0070 REV.	REVIEW		

PLOT DATE: January 6, 2014
FILENAME: T:\Projects\2011\11-1170-0070 (Midland Penetanguishene Model)\-BC-\1111700070BCQUAT.dwg



9b	Glaciolacustrine Sand Deposits
9c	Glaciolacustrine Silt & Sand Deposits
8a	Glaciolacustrine Deep Water Deposits
7	Glaciofluvial Outwash Sand & Gravel
7a	Distal Sand & Gravel
6	Ice Contact Sediments, Eskers
5d	Black Shale Till
5b	Ablation Till
20	Organic Deposits
19	Fluvial Clay, Silt, Sand
19	Fluvial Sand, Gravel
17	Eolian Sands
14c	Silt, Sand
14b	Modern Shoreline Deposits
13	Lacustrine Clays And Silts
12	Fluvial Sand

LEGEND:

- Municipal Boundary
- Tier 3 Study Area Boundary
- Tier 3 Study Municipal Well System
- Tiny Township Municipal Well System

NOTES:

1. Datum is UTM NAD 83 Zone 17

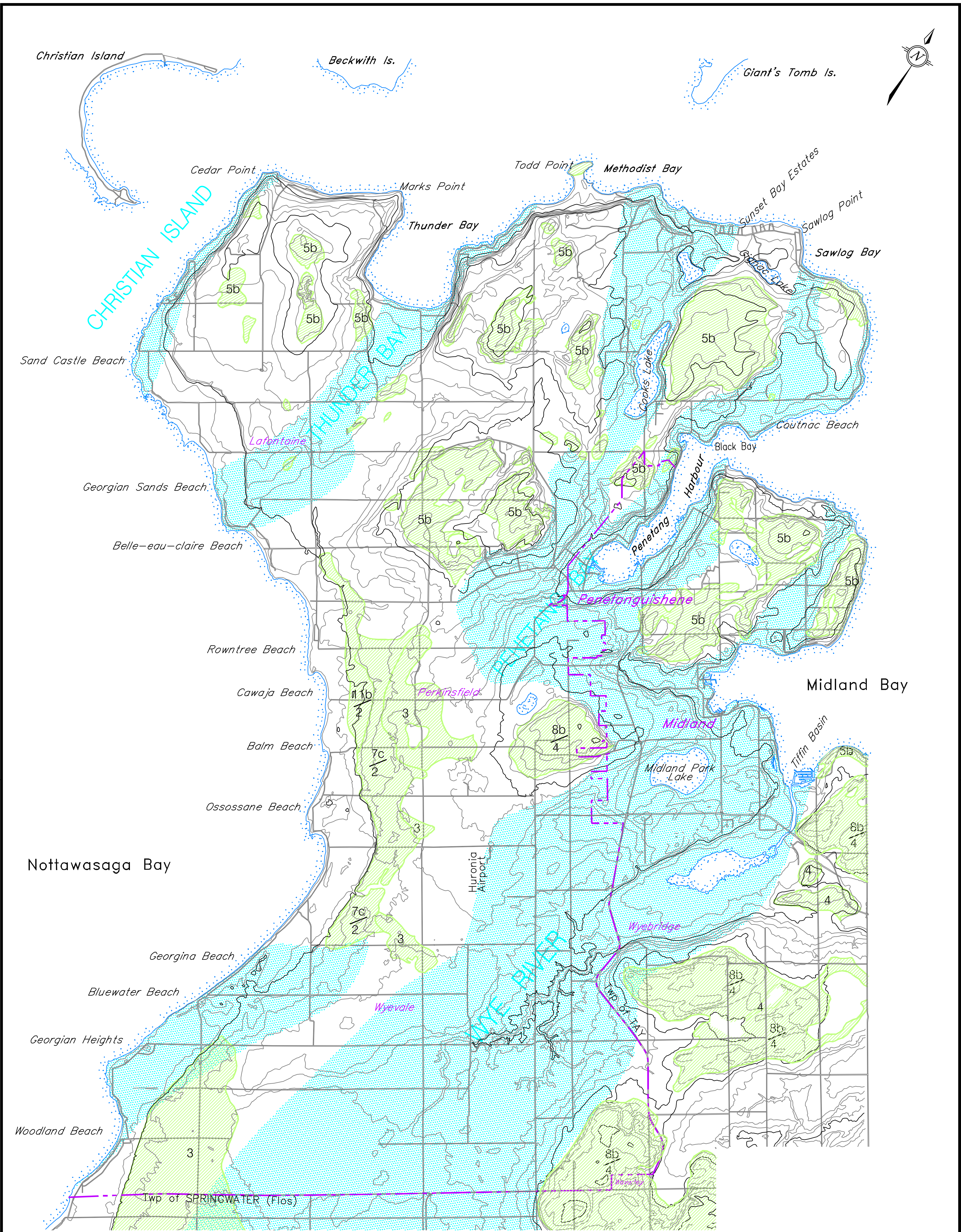
REFERENCES:

1. Mapping Based On County Of Simcoe GIS & Esri OBM Features
2. Ontario Geological Survey, 2010; Release - Data 128 - Revised

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN	TITLE	QUATERNARY GEOLOGY MAP
DATE	15 MAY 2012		
DESIGN			
CAD	S BOWERMAN		
FILE No. 1111700070BCQUAT.dwg	CHECK		MIDLAND PENETANGUISHENE TIER 3
PROJECT No. 11-1170-0070	REV.	REVIEW	FIGURE 7a

PLOT DATE: January 6, 2014
FILENAME: T:\Projects\2011\11-1170-0070 (Midland Penetanguishene Model)\-DA-\1111700070DATUNL.dwg: [Figure 7b]



Contours OBM 5 masl Interval

Municipal Boundary

Residual Landforms : Till Upland Areas

Approximated Tunnel Valley Extent

0 500 1000 2500 5000

SCALE 1:100000 metres

Plotted Tabloid 11x17

Golder Associates
Barrie, Ontario, Canada

SCALE	AS SHOWN
DATE	2014-01-06
DESIGN	
CAD	JPR
CHECK	JAP
REVIEW	

FILE No. 1111700070DATUNL.dwg

PROJECT No. 11-1170-0070 REV.

TITLE

UPLAND TILL LANDFORMS AND TUNNEL CHANNEL AQUIFERS

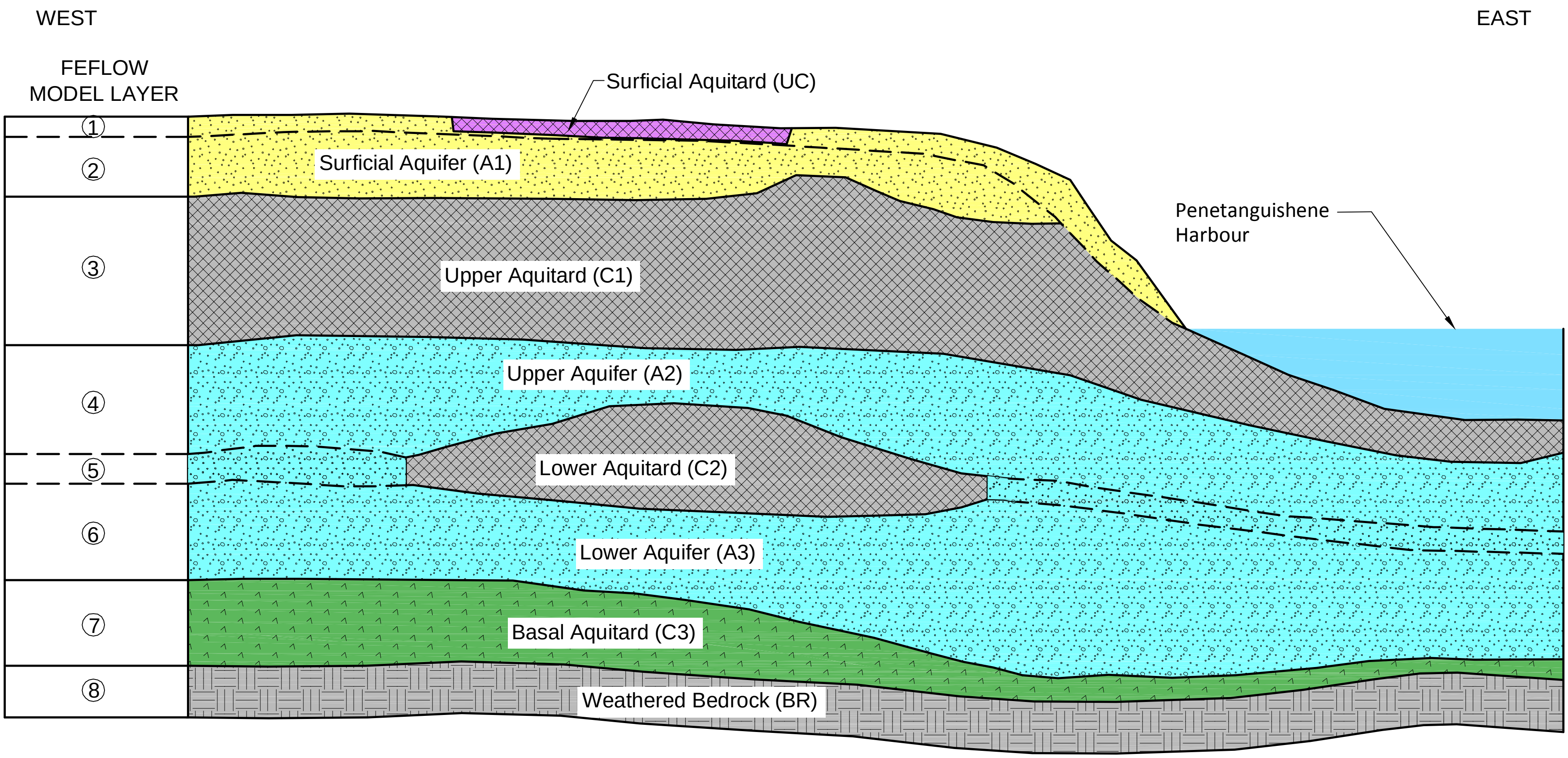
MIDLAND PENETANGUISHENE TIER 3

FIGURE 7b

PLOT DATE: October 03, 2013
FILENAME: T:\Projects\2011\11-1170-0070 (Midland, Tier 3)\-BA- 4000\1111700070BA08.dwg

GENERAL MODEL HYDROSTRATIGRAPHY

FIGURE 8



NOT TO SCALE

DATE: October 3, 2013

PROJECT: 11-1170-0070

Golder Associates

CAD: JDR /KD

CHK: DH

PLOT DATE: January 6, 2014
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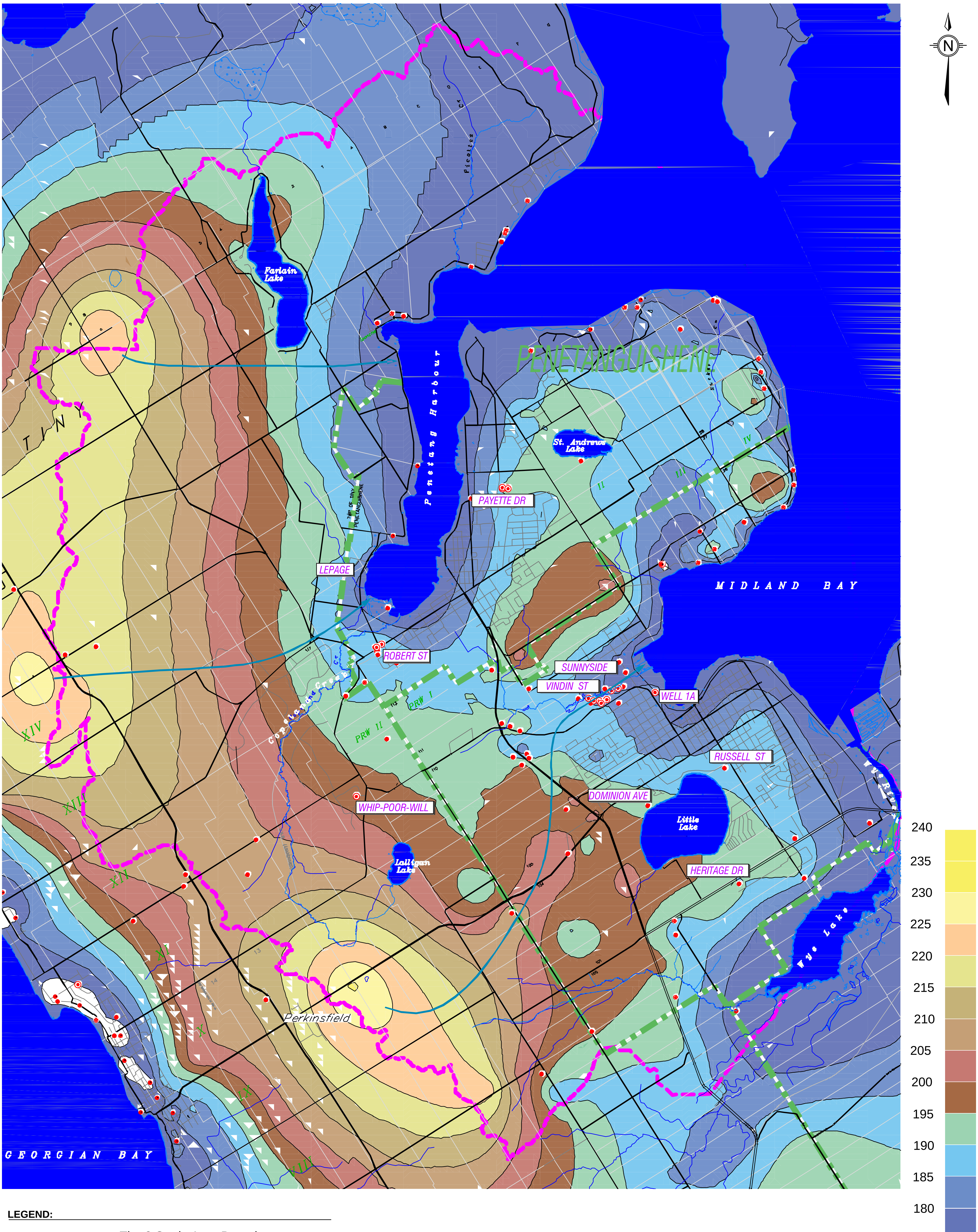
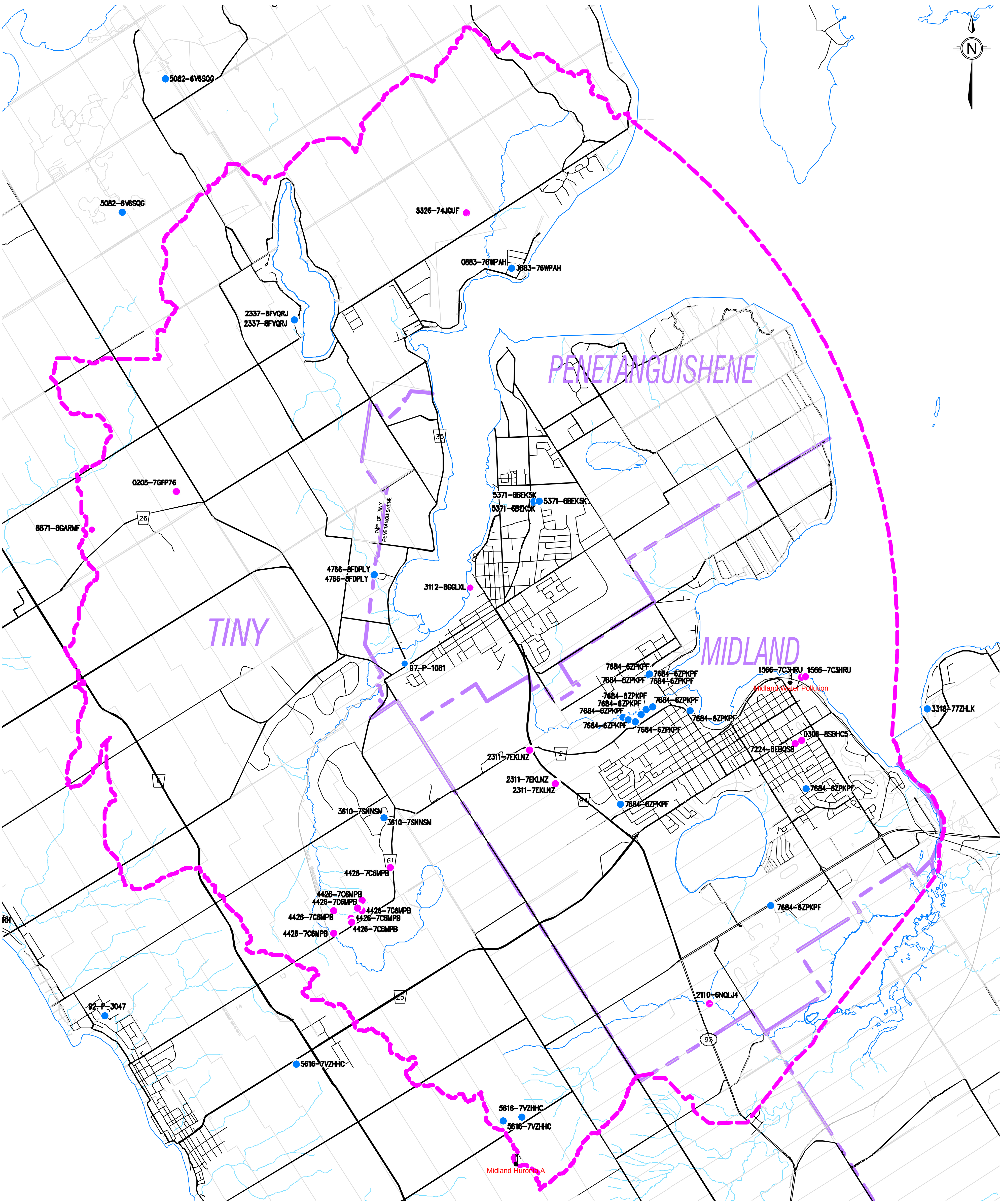


LEGEND:

- Tier 3 Study Area Boundary
- Municipal Boundarys
- Well Constructed in Lower Aquifer A3
- Inferred Direction of Groudwater Flow

0 500 1000 1500 2500
SCALE 1:60000 metres
Plotted Tabloid 11x17

Golder Associates, Mississauga, Ontario, Canada	SCALE: AS SHOWN	TITLE	
	DATE: 13 JUN 2012	POTENTIOMETRIC SURFACE AQUIFER A3	
	DESIGN		
	CAD: J REGIER		
FILE No. 1111700070DAEQA3.dwg	CHECK	MIDLAND PENETANGUISHENE TIER 3	FIGURE 9
PROJECT No. 11-1170-0070 REV.	REVIEW		



0 500 1000 1500 2500

SCALE 1:60000 metres

Plotted Tabloid 11x17

LEGEND:

- Municipal Boundary
- PTTW Municipal Water Supply
- PTTW Commercial / Industrial
- Weather Stations
- Tier 3 Study Area Boundary

NOTES:

1. Datum is UTM NAD 83 Zone 17

REFERENCES:

1. Mapping Based On County Of Simcoe GIS & Esri OBM Features
2. MOE Permit to Take Water Database, March 2012

Golder Associates
Mississauga, Ontario, Canada

SCALE	AS SHOWN
DATE	15 MAY 2012
DESIGN	
CAD	S BOWERMAN
CHECK	
REVIEW	

FILE No. 1111700070DAPTTW.dwg

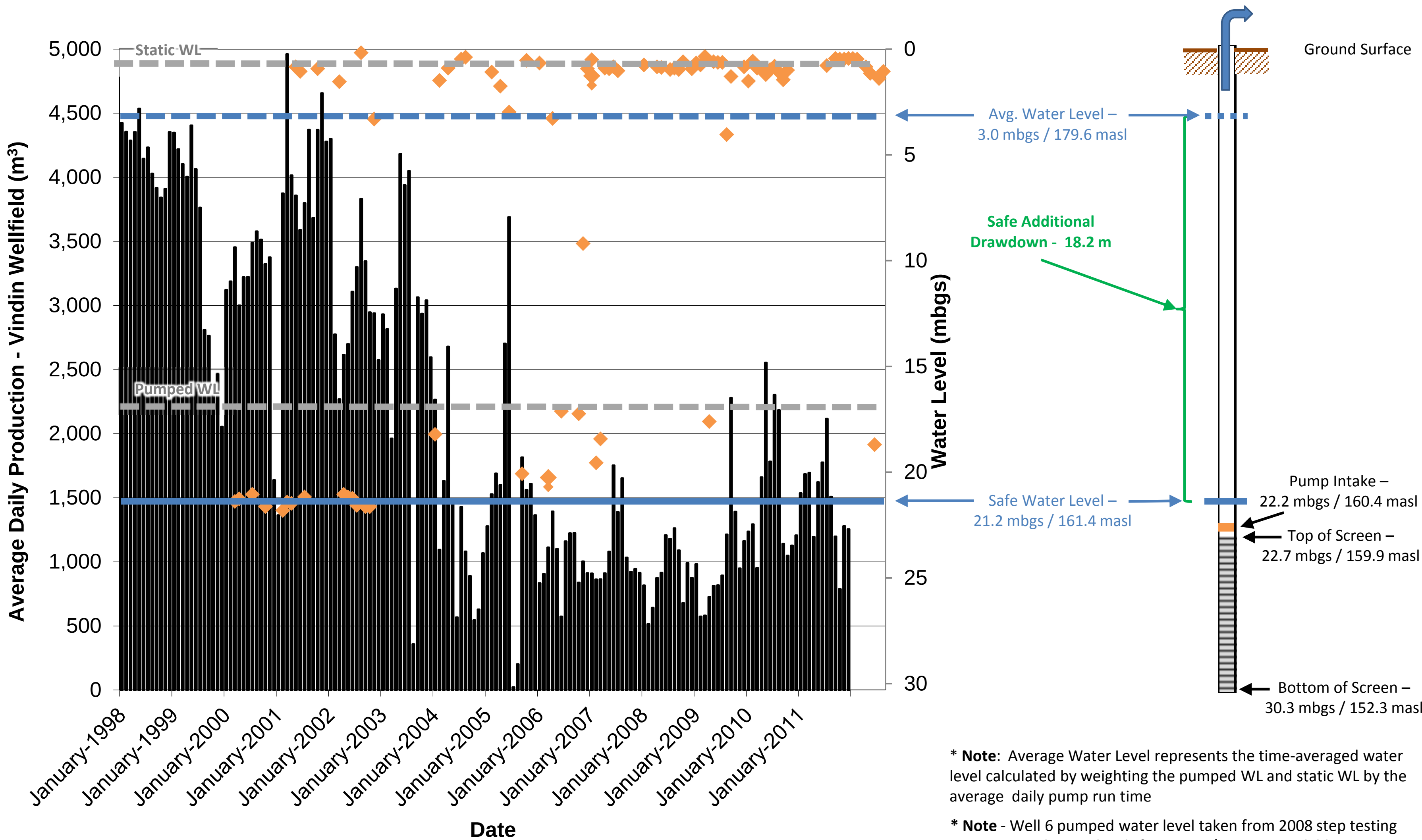
PROJECT No. 11-1170-0070 REV.

TITLE

PTTW LOCATIONS

MIDLAND PENETANGUISHENE TIER 3

FIGURE **10**



*** Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

*** Note** - Well 6 pumped water level taken from 2008 step testing as no pumped water levels from 2010/11 were available.

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

PROJECT

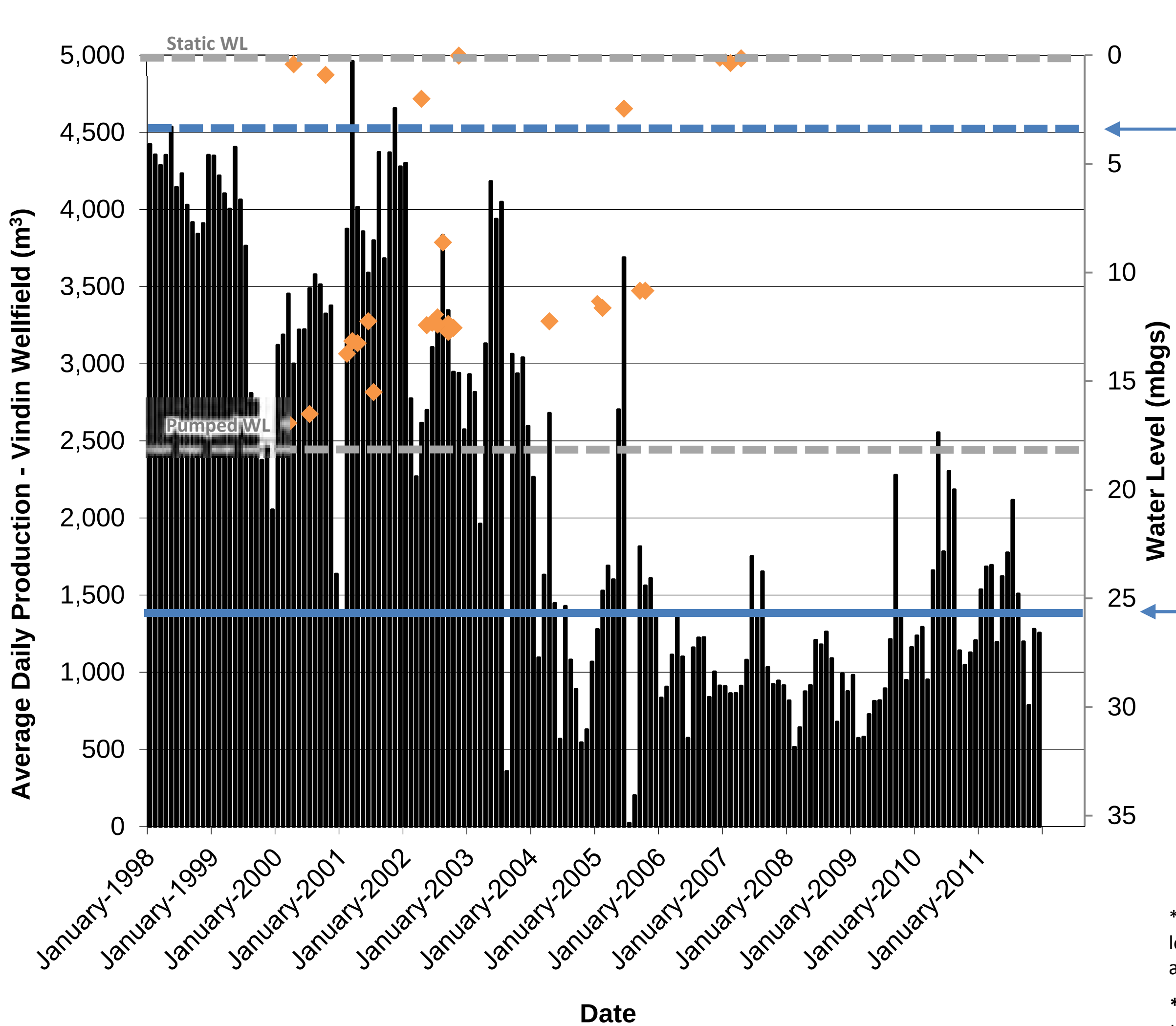
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

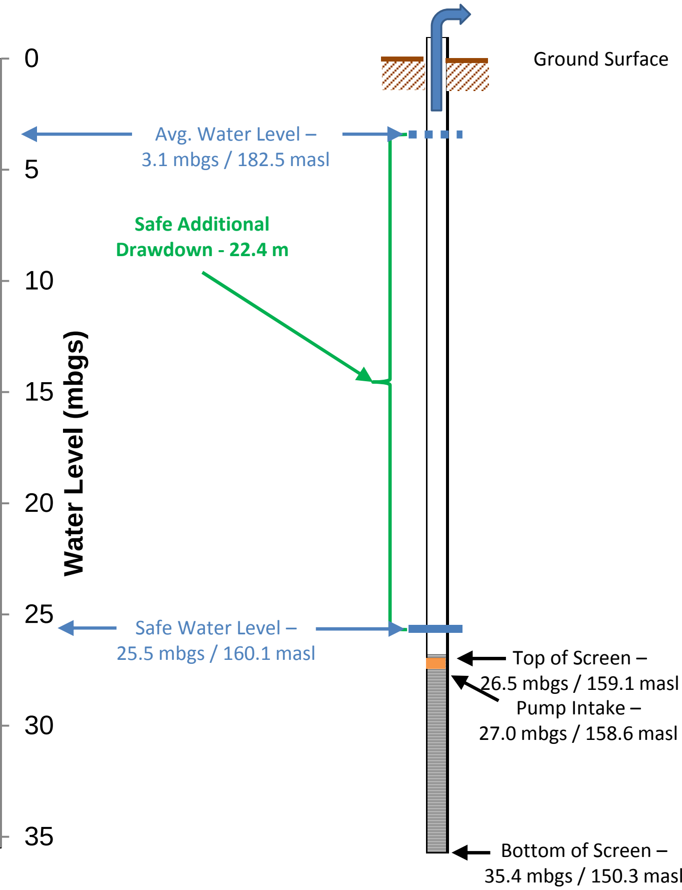
TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 6

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 18, 2013	**FIGURE 11**	
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		





* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

* **Note** - Well 11 pumped water level taken from 2012 step testing as no pumped water levels from 2010/11 were available.

LEGEND

Well Casing

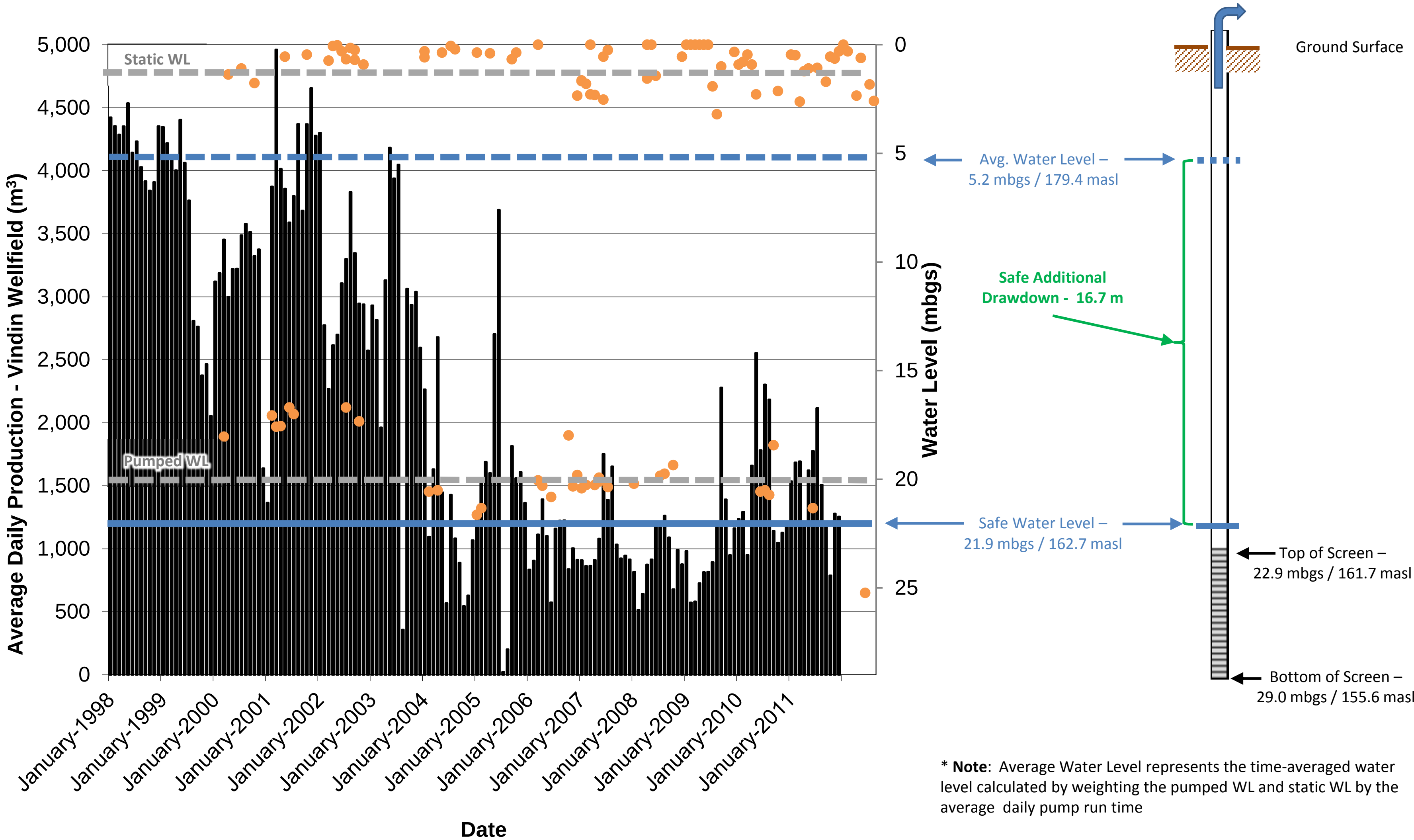
Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

PROJECT	MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT			
TITLE	**SAFE ADDITIONAL DRAWDOWN – WELL 11**			
Golder Associates	PROJECT #: 11-1170-0070		SCALE AS SHOWN	REV. 1
	DESIGN	NGG	JUN 18, 2013	**FIGURE 12**
	GIS	NGG	SEPT 22, 2013	
	CHECK	NGG	SEPT 22, 2013	
	REVIEW	JAP	SEPT 22, 2013	



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

PROJECT

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

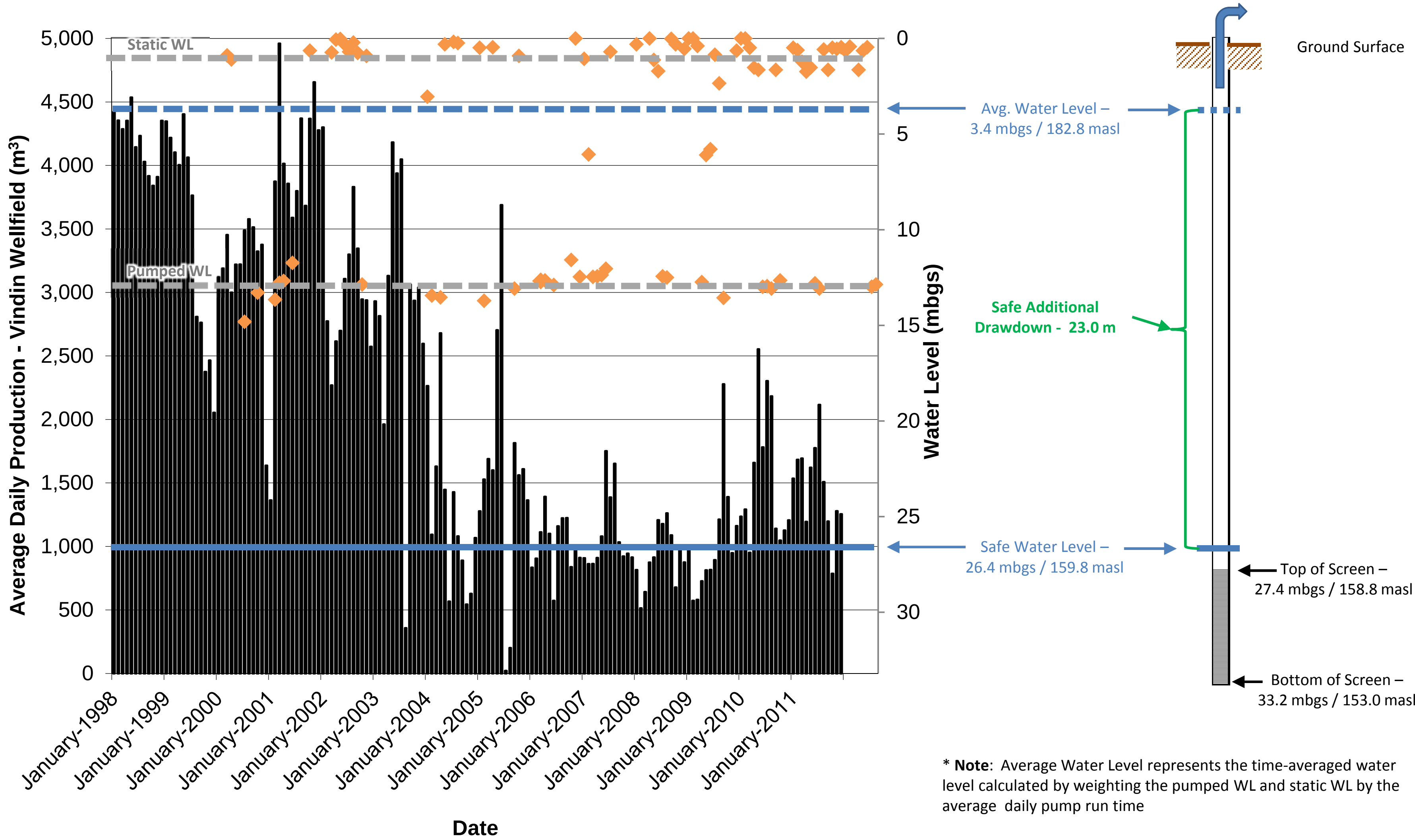
TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 12

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 18, 2013		
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		

FIGURE 13



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

PROJECT

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 14

Golder Associates

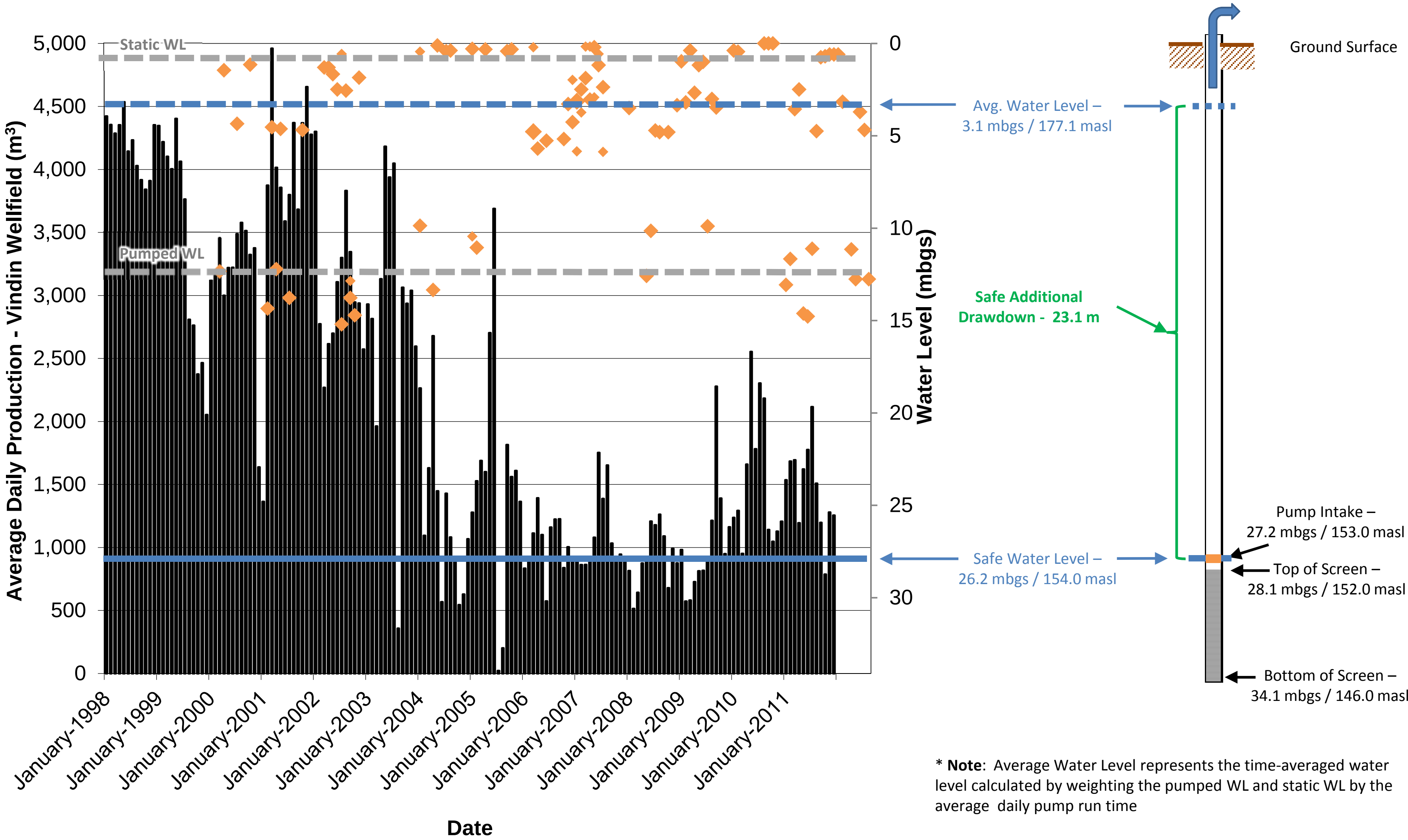
PROJECT #: 11-1170-0070

DESIGN	NGG	JUN 18, 2013
GIS	NGG	SEPT 22, 2013
CHECK	NGG	SEPT 22, 2013
REVIEW	JAP	SEPT 22, 2013

SCALE AS SHOWN

REV. 1

FIGURE 14



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

- Well Casing
- Screened Interval
- 2010/11 Average Water Level
- Safe Water Level
- Water Level Measurement

PROJECT

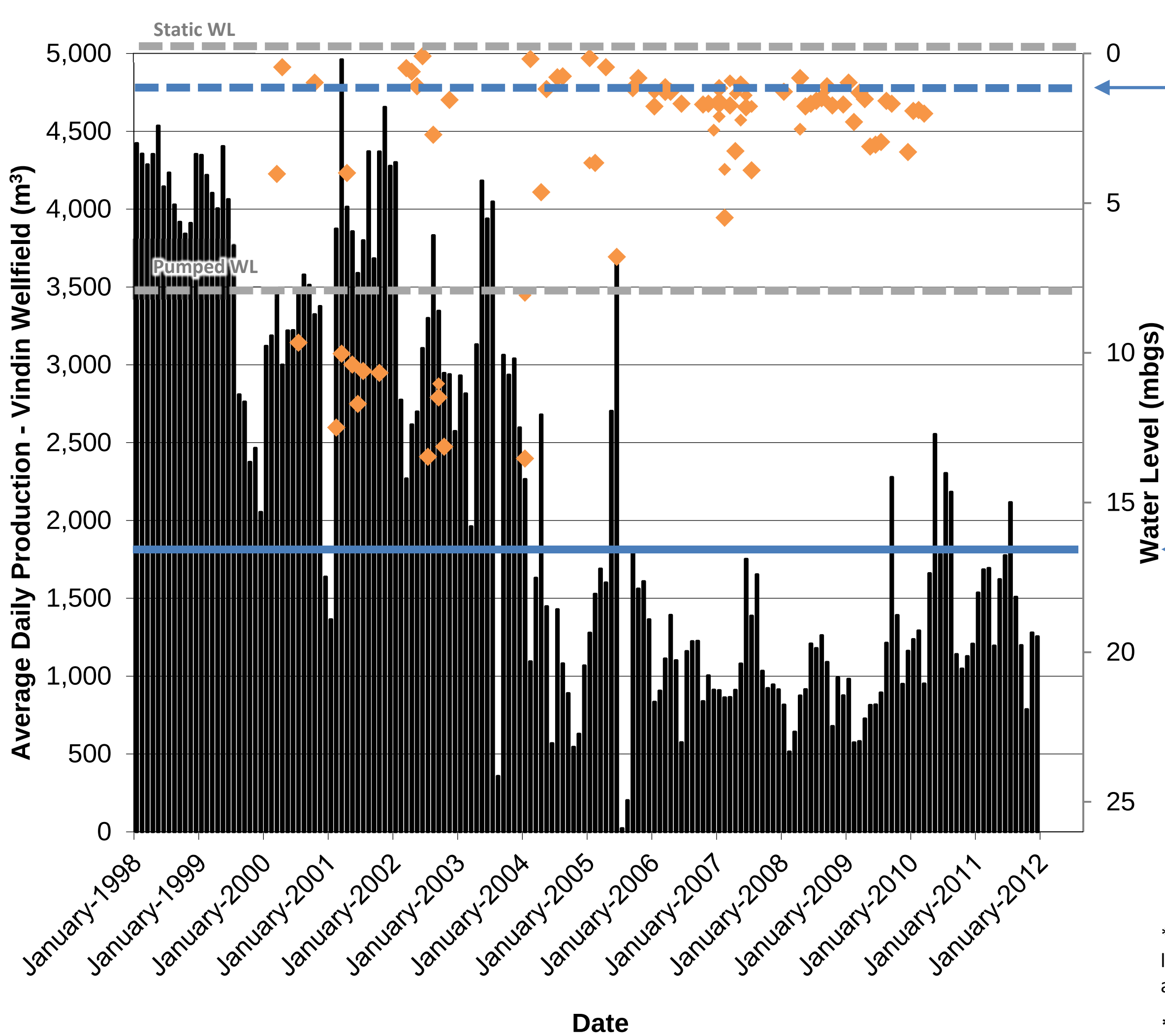
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

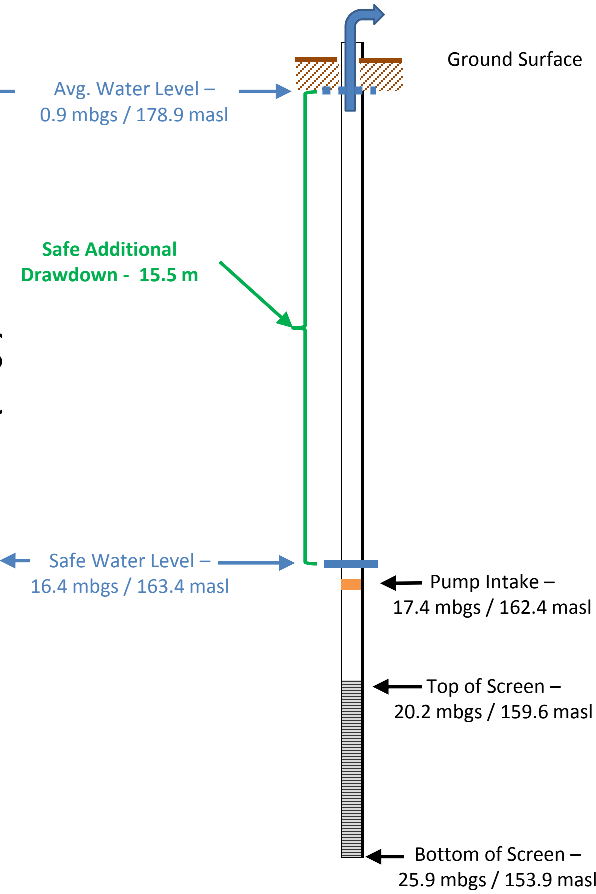
TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 16

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 18, 2013		
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		

FIGURE 15





* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

* **Note** - Well 17 pumped water level taken from 2010 step testing as no pumped water levels from 2010/11 were available.

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

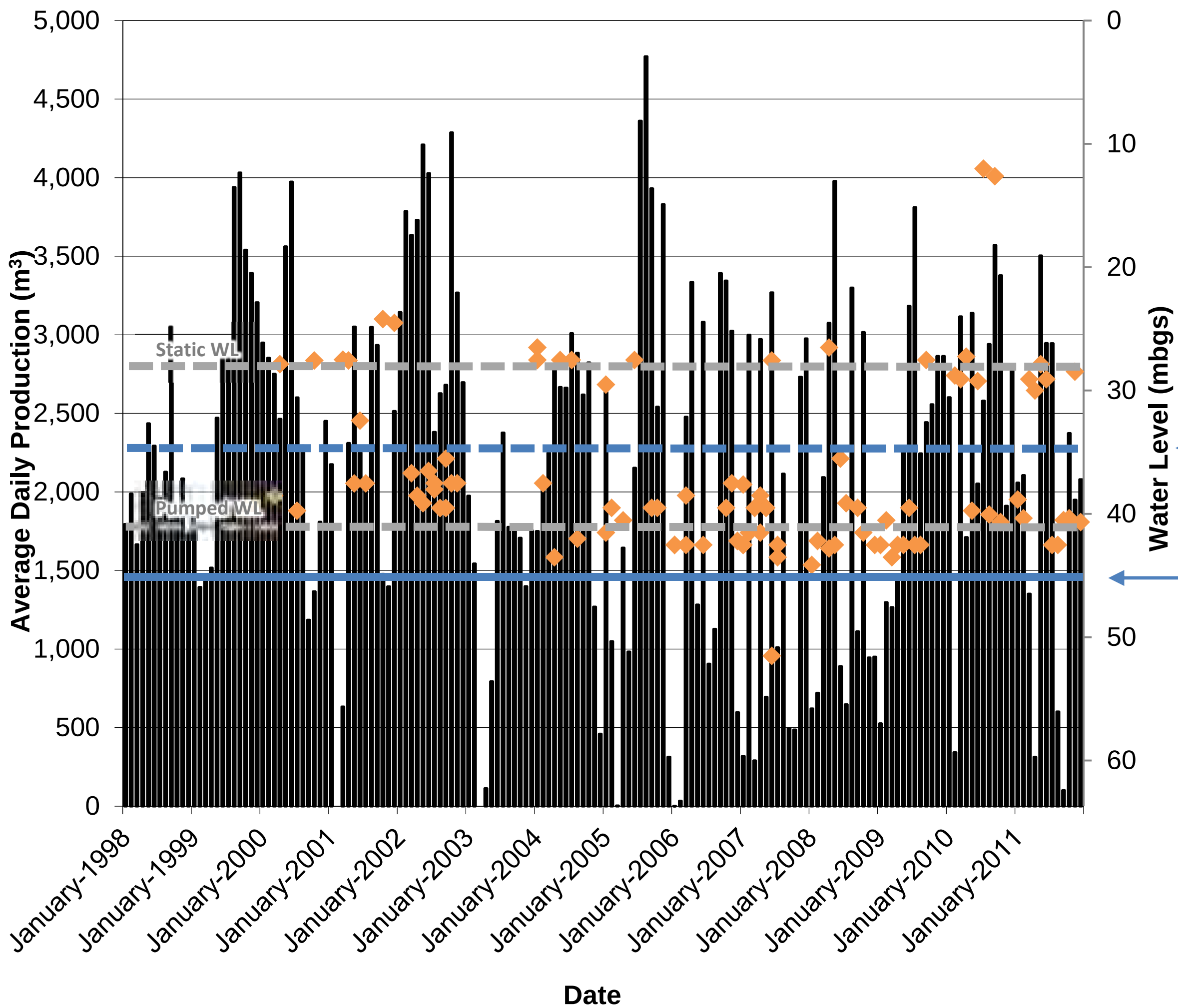
PROJECT

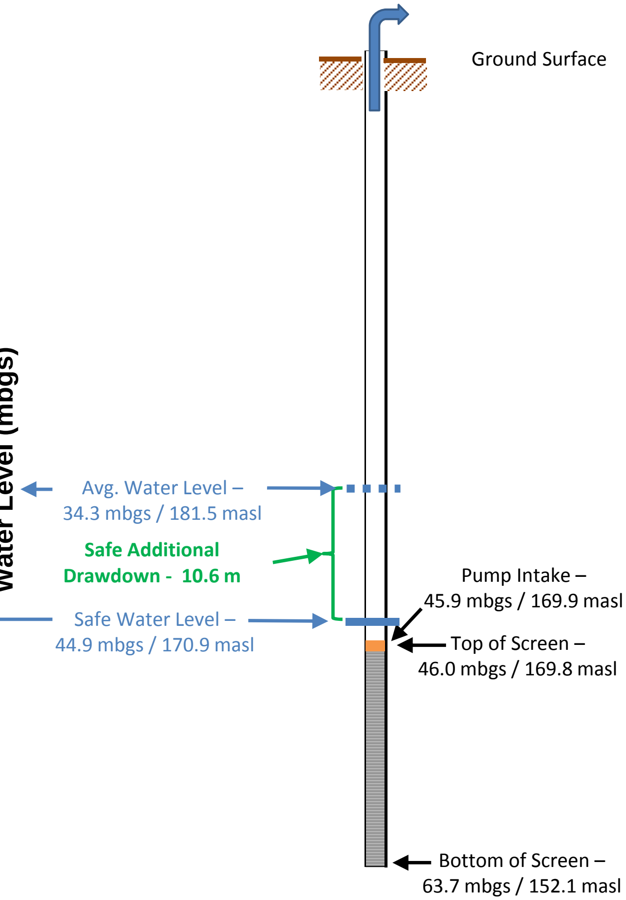
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 17

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 18, 2013	**FIGURE 16**	
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		





* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

← Well Casing

← Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

PROJECT

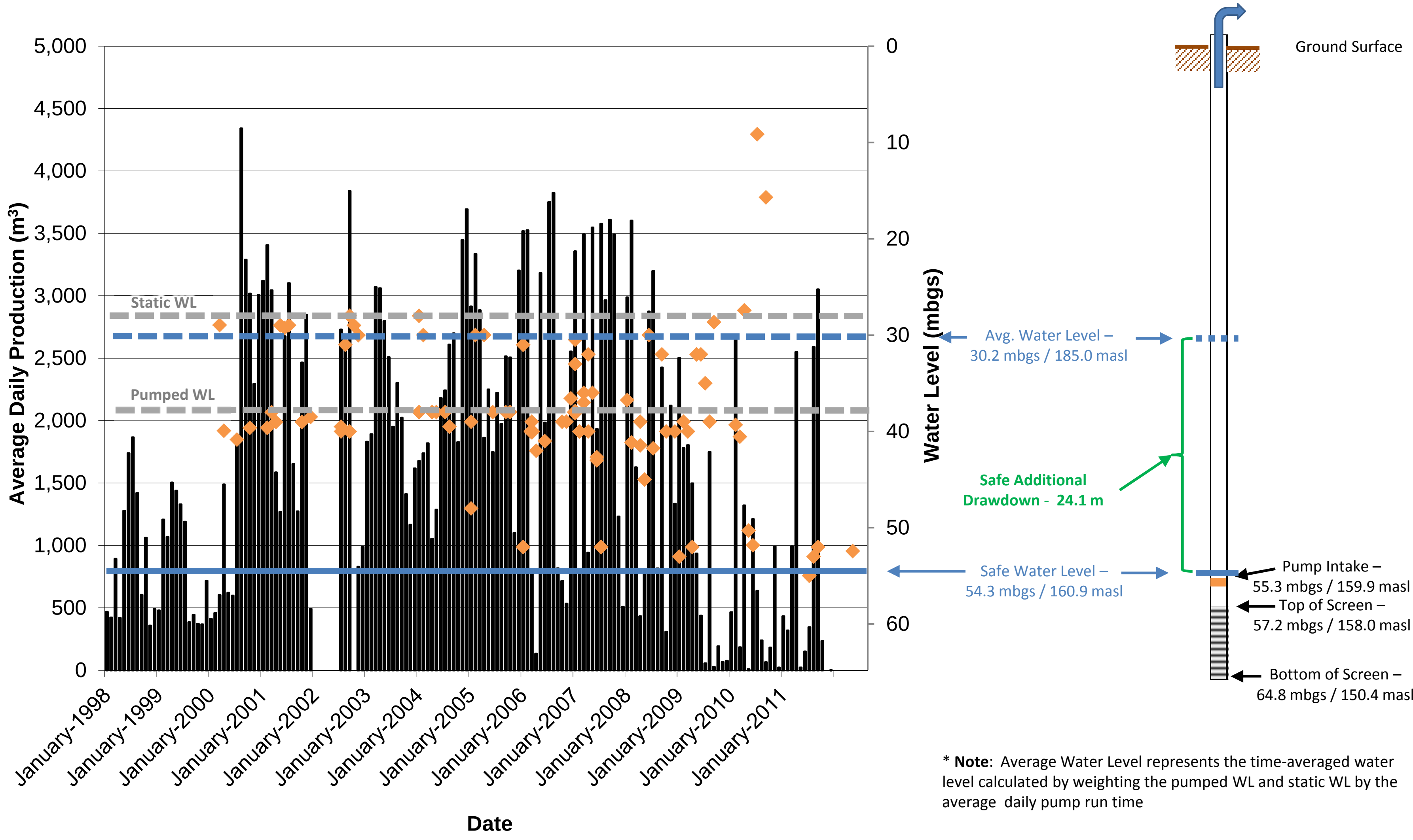
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 7A

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013		
GIS	NGG	SEPT 22, 2013	**FIGURE 17**	
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

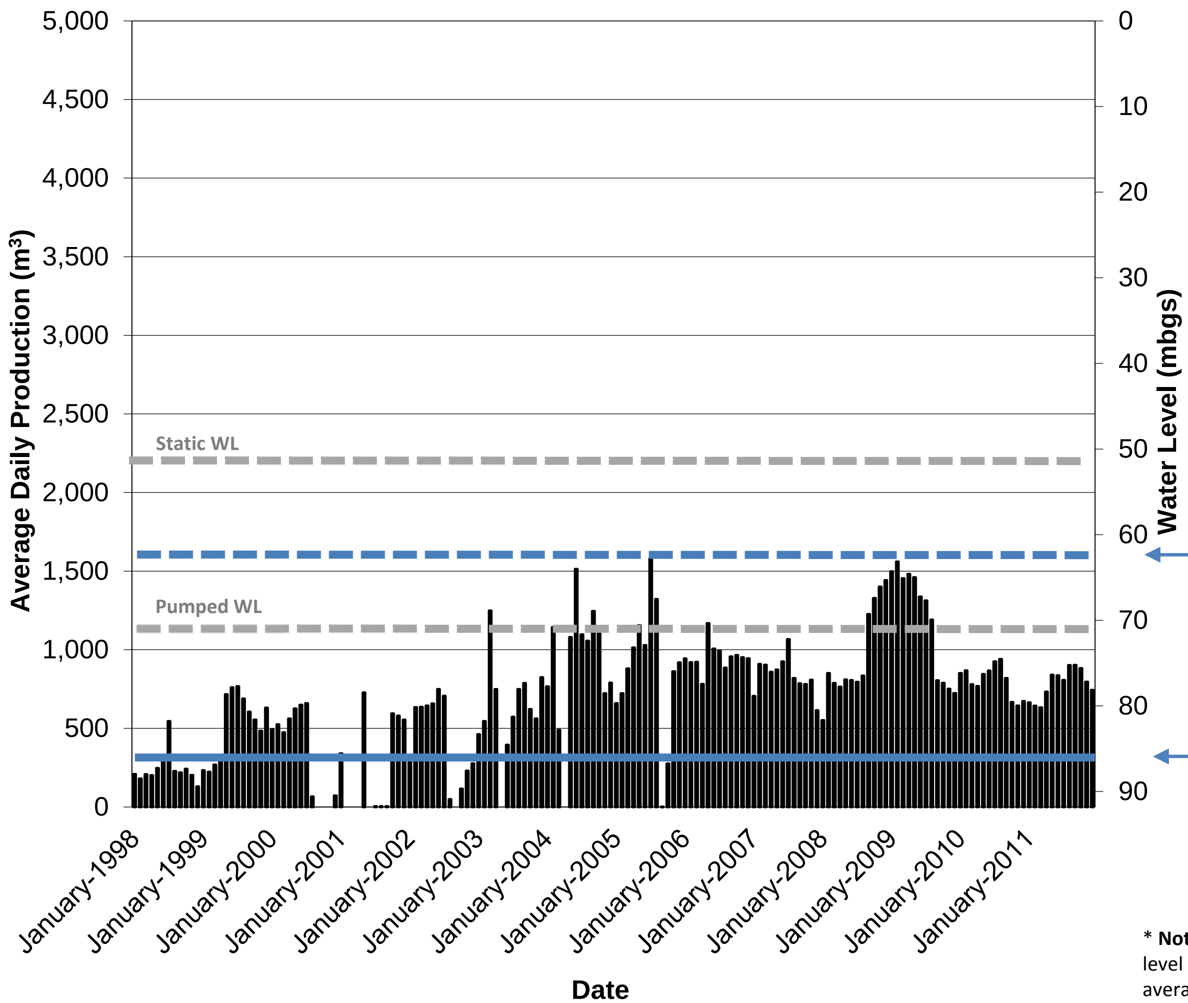
Safe Water Level

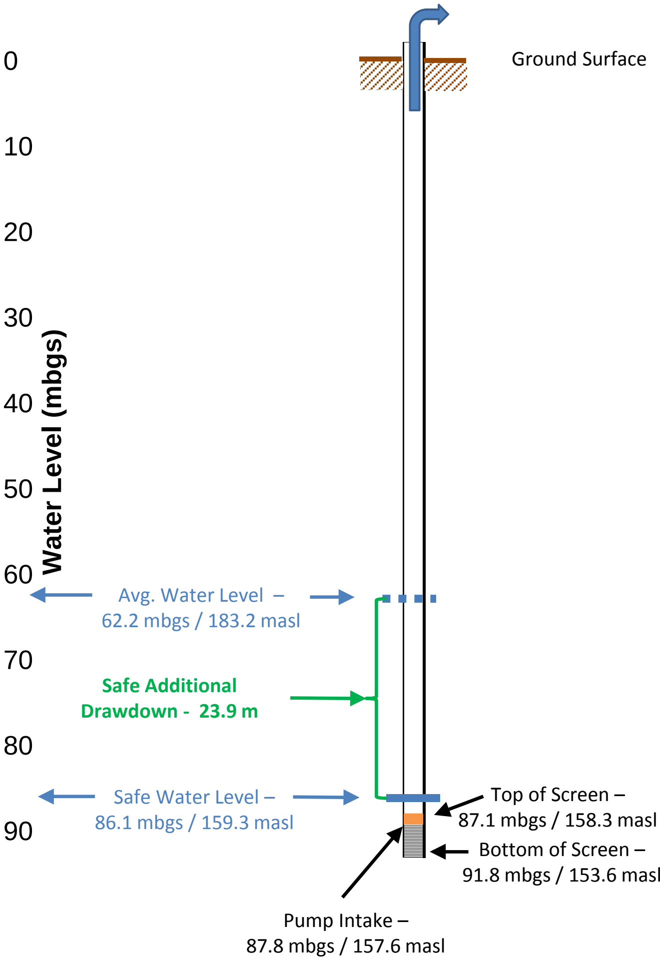
Water Level Measurement

PROJECT	MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT
TITLE	**SAFE ADDITIONAL DRAWDOWN – WELL 7B**

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013	**FIGURE 18**	
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		

Golder Associates





* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

* **Note** - Well 9 water level taken from 2012 step testing as no water levels were available.

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

Safe Water Level

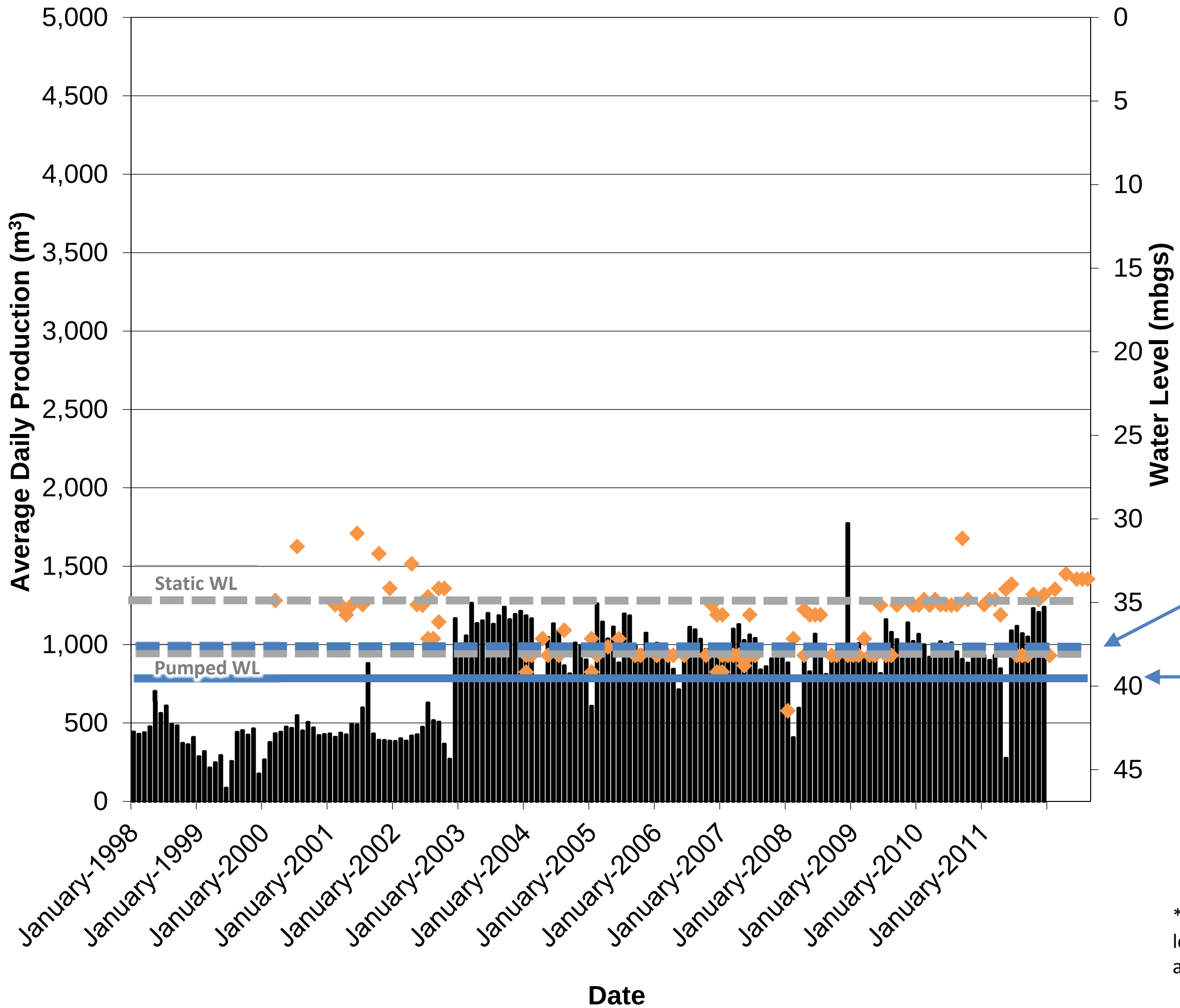
PROJECT

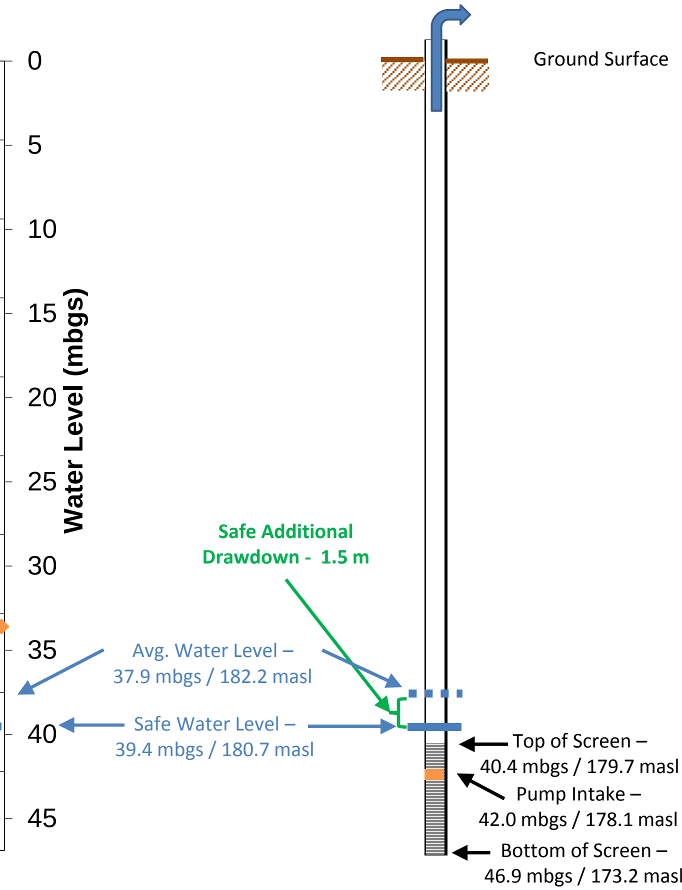
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – WELL 9

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013		
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013	**FIGURE 19**	
REVIEW	JAP	SEPT 22, 2013		





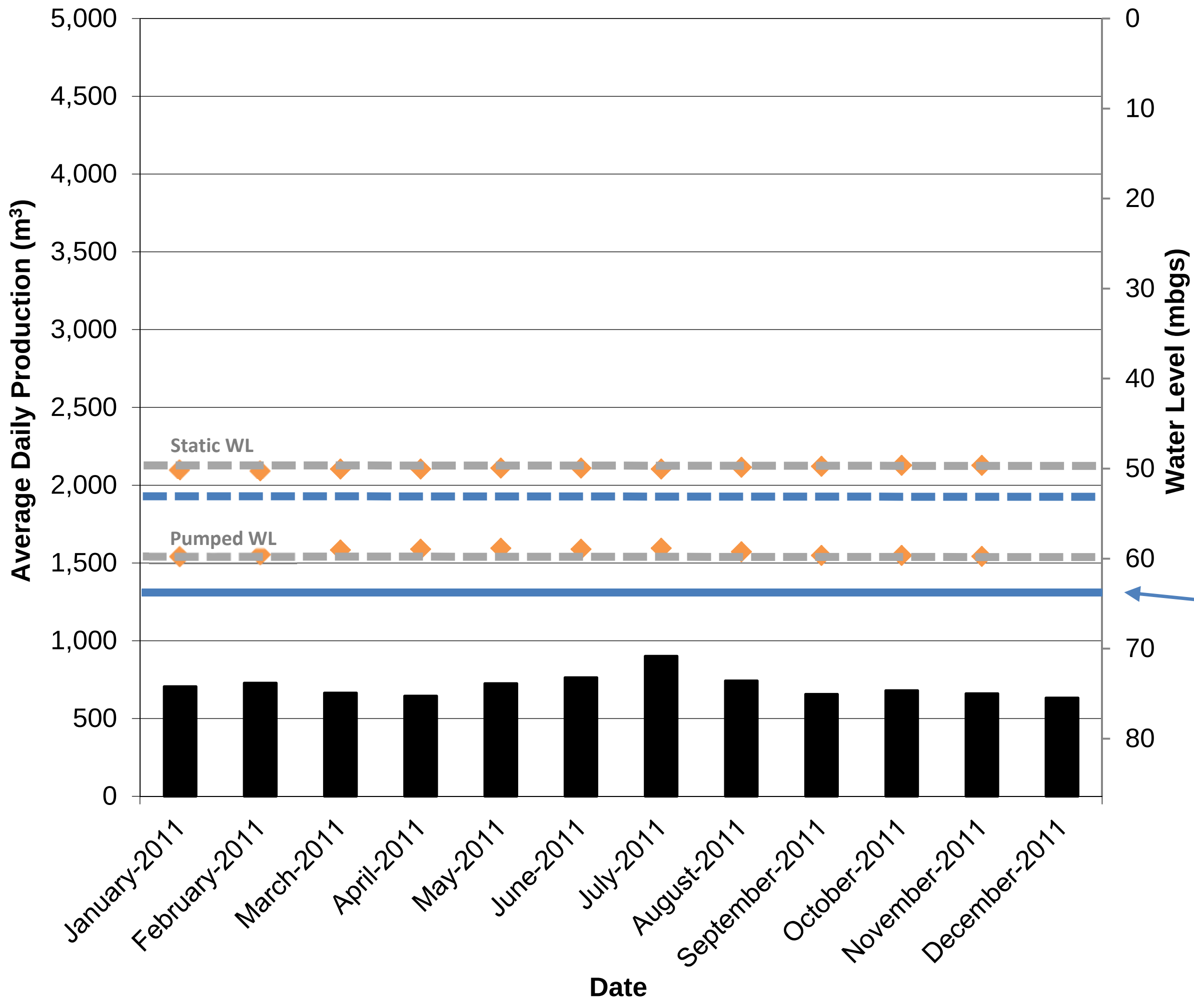
* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

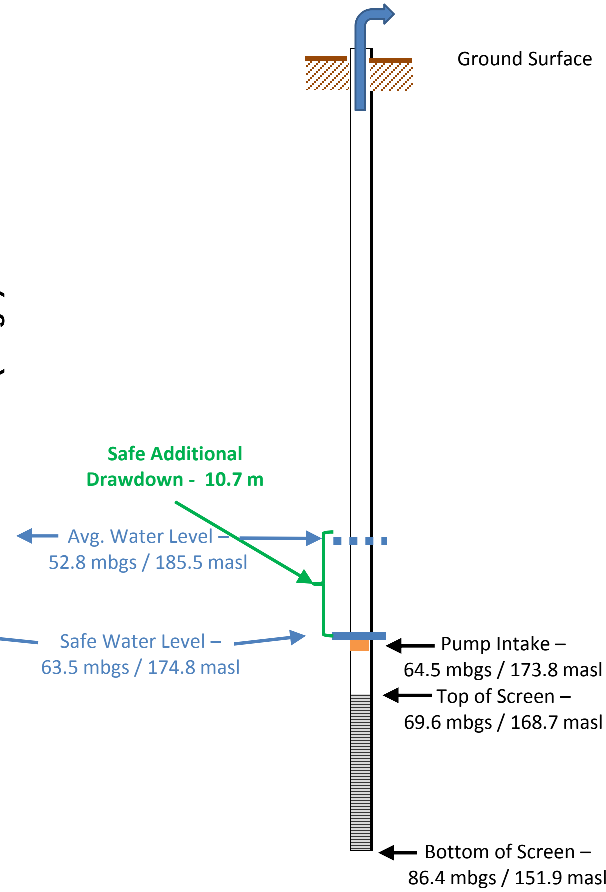
LEGEND

- Well Casing
- Screened Interval
- 2010/11 Average Water Level
- Safe Water Level
- Water Level Measurement

PROJECT	MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT	
TITLE	**SAFE ADDITIONAL DRAWDOWN – WELL 15**	

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013	**FIGURE 20**	
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		





* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

Well Casing
Screened Interval
Average Pumped Water Level
Safe Water Level
Water Level Measurement

PROJECT
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE
SAFE ADDITIONAL DRAWDOWN – PAYETTE WELL 1

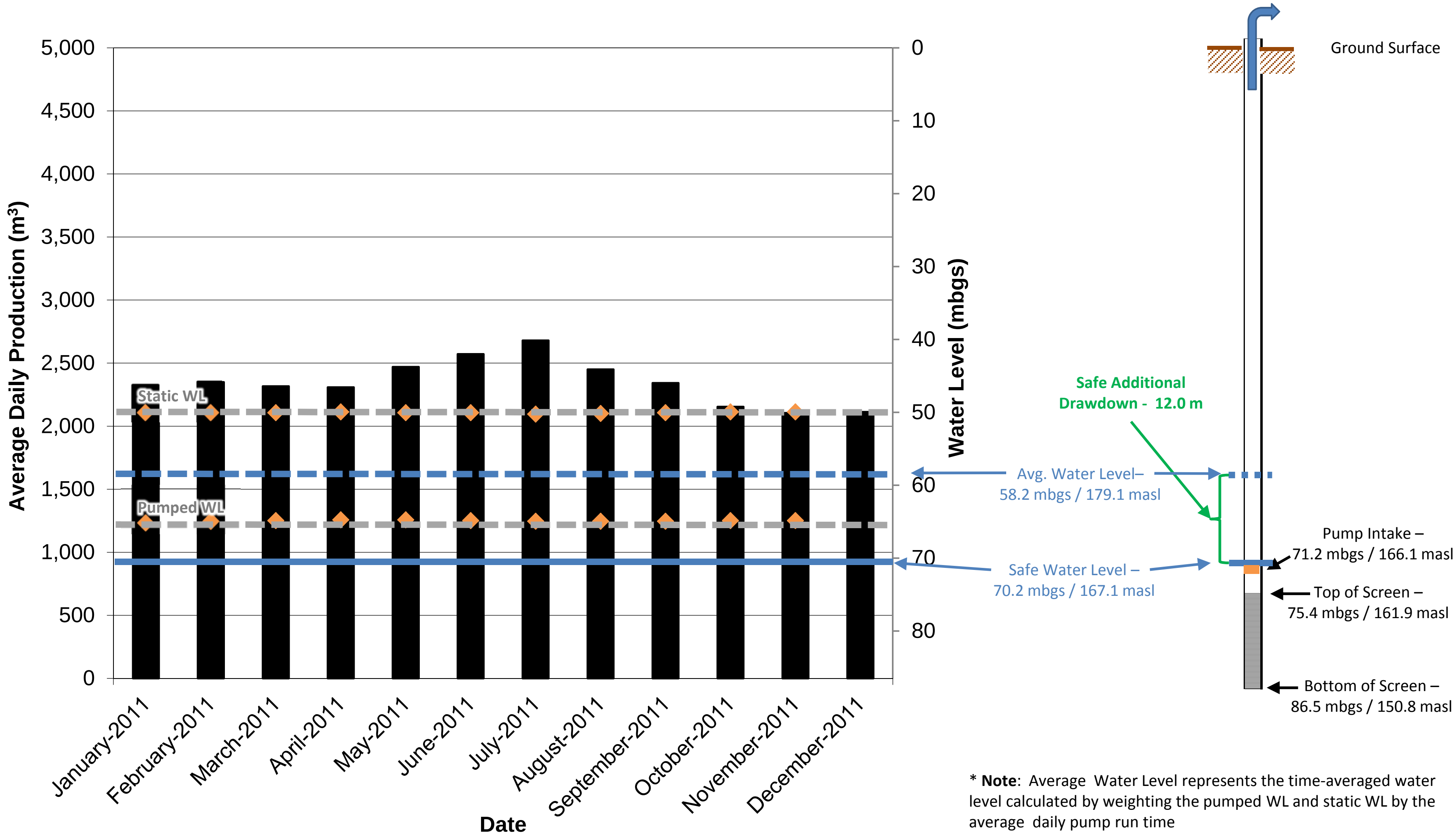
Golder Associates

PROJECT #: 11-1170-0070

DESIGN	NGG	JUN 17, 2013
GIS	NGG	SEPT 22, 2013
CHECK	NGG	SEPT 22, 2013
REVIEW	JAP	SEPT 22, 2013

SCALE AS SHOWN
REV. 1

FIGURE 21



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

- Well Casing
- Screened Interval
- Average Pumped Water Level
- Safe Water Level
- Water Level Measurement

PROJECT

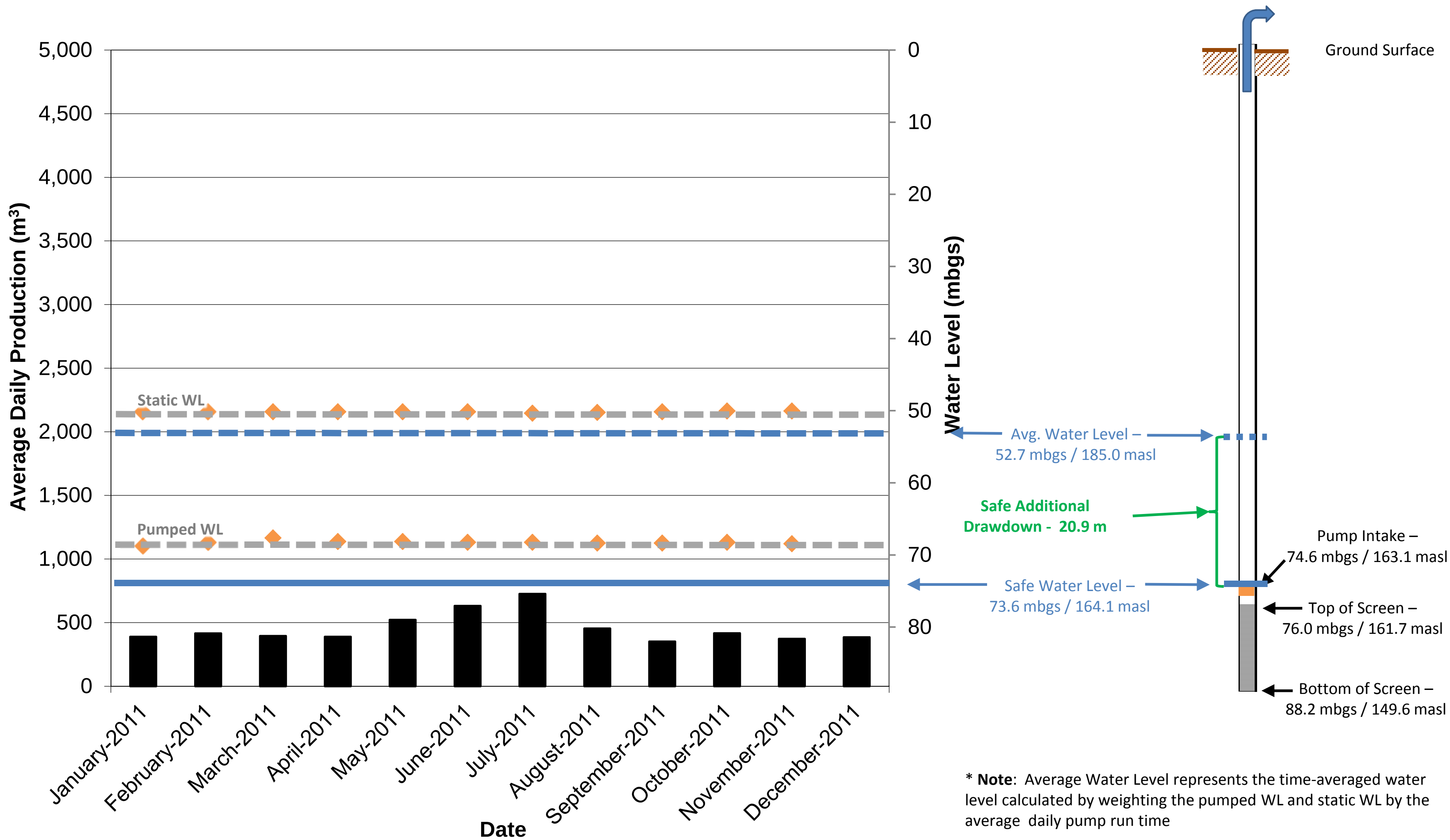
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – PAYETTE WELL 2

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013		
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013	**FIGURE 22**	
REVIEW	JAP	SEPT 22, 2013		



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

Well Casing

Screened Interval

Average Pumped Water Level

Safe Water Level

Water Level Measurement

PROJECT

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

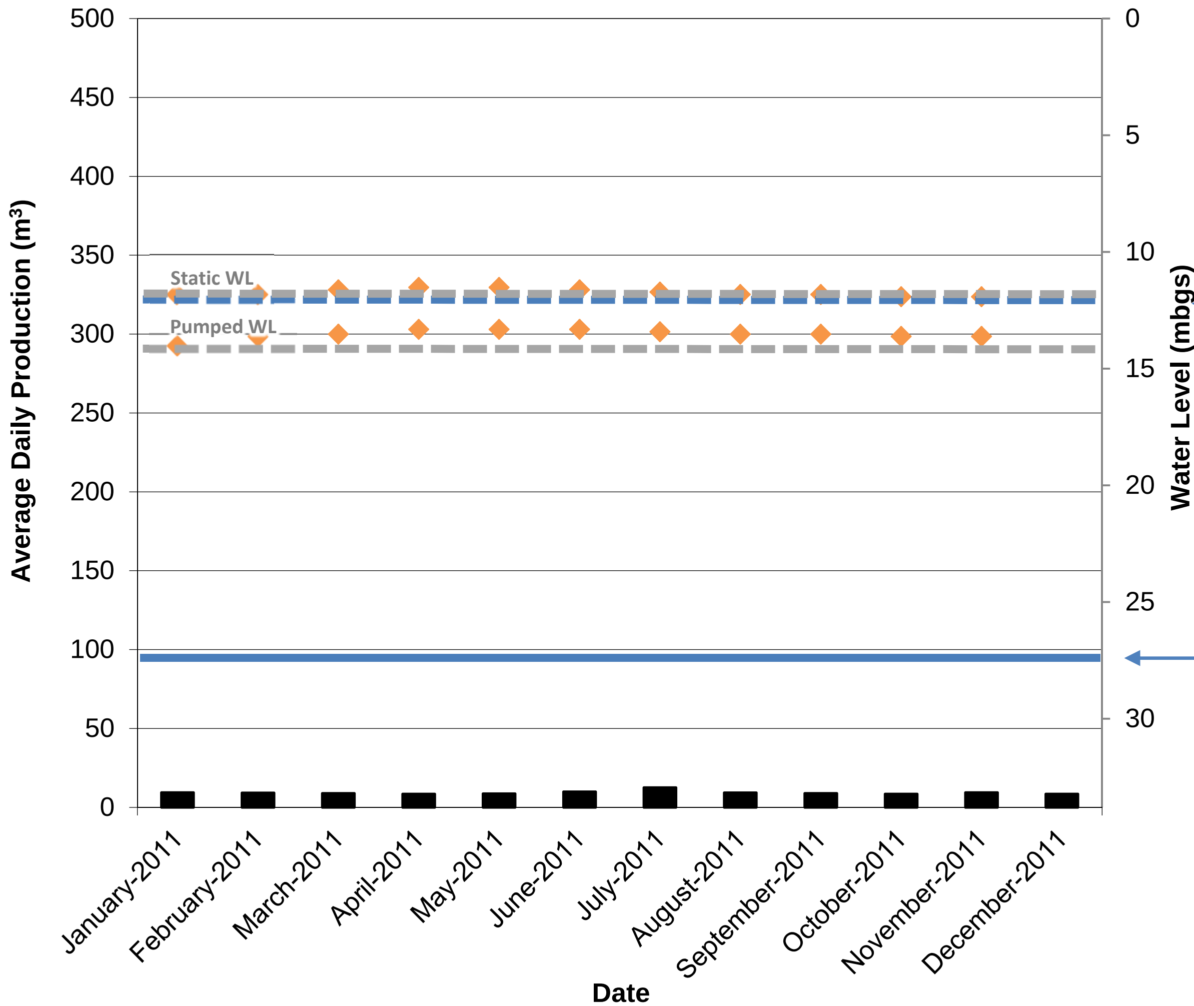
TITLE

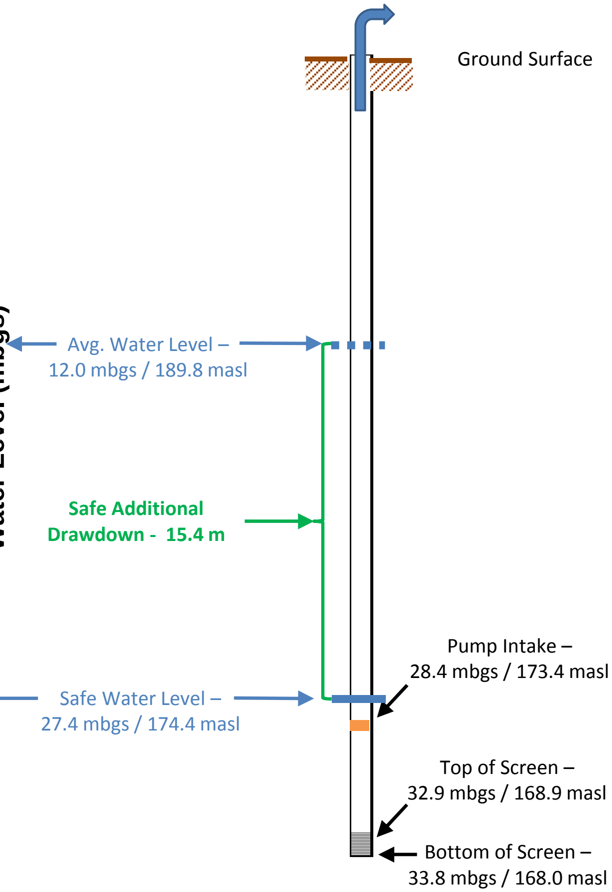
SAFE ADDITIONAL DRAWDOWN –
PAYETTE WELL 3

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013		
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		

FIGURE 23





* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

- Well Casing
- Screened Interval
- Average Pumped Water Level
- Safe Water Level
- Water Level Measurement

PROJECT

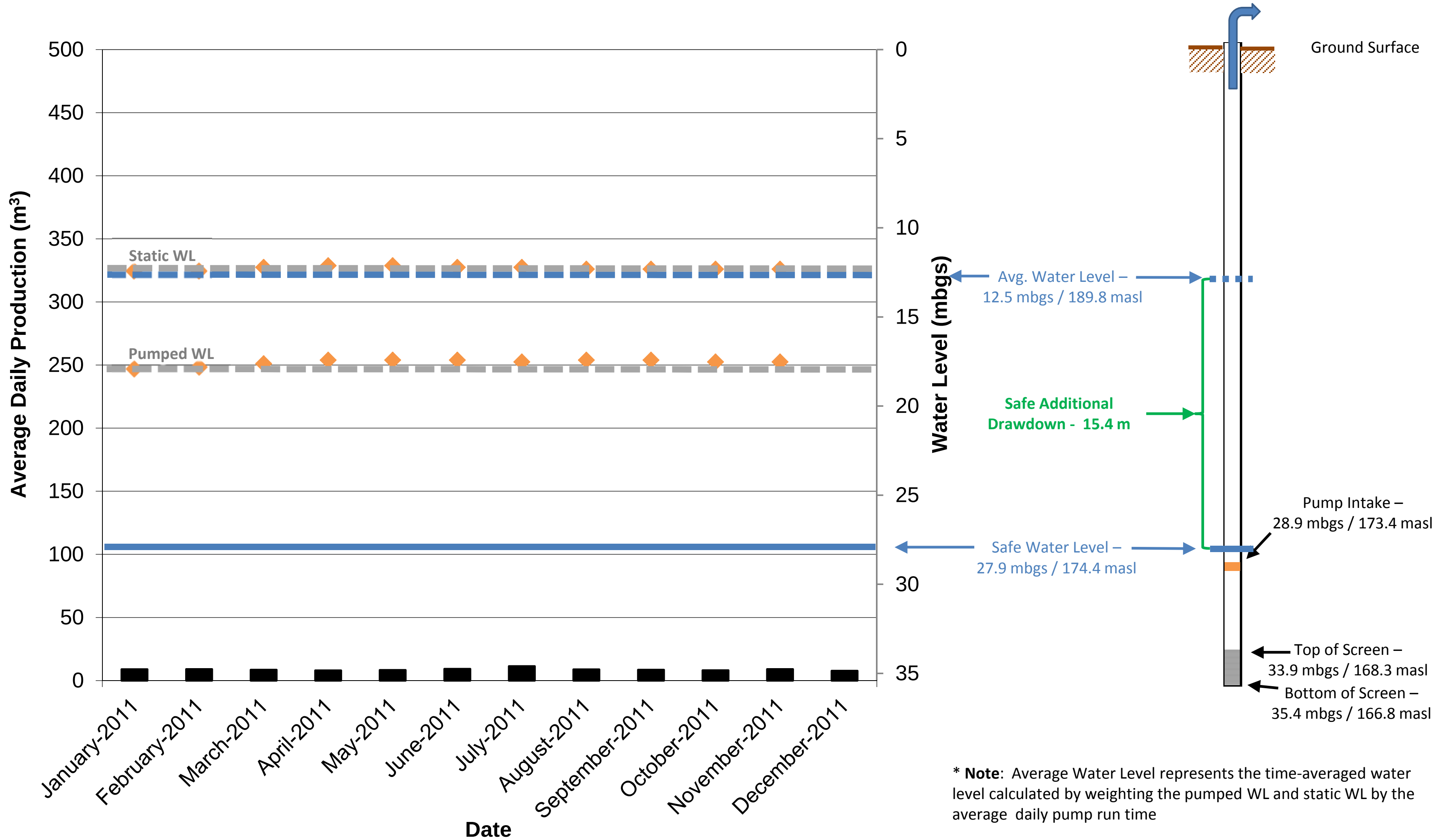
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – LEPAGE WELL 1

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013	**FIGURE 24**	
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 22, 2013		



LEGEND

Well Casing

Screened Interval

Average Pumped Water Level

Safe Water Level

Water Level Measurement

PROJECT

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – LEPAGE WELL 2

Golder Associates

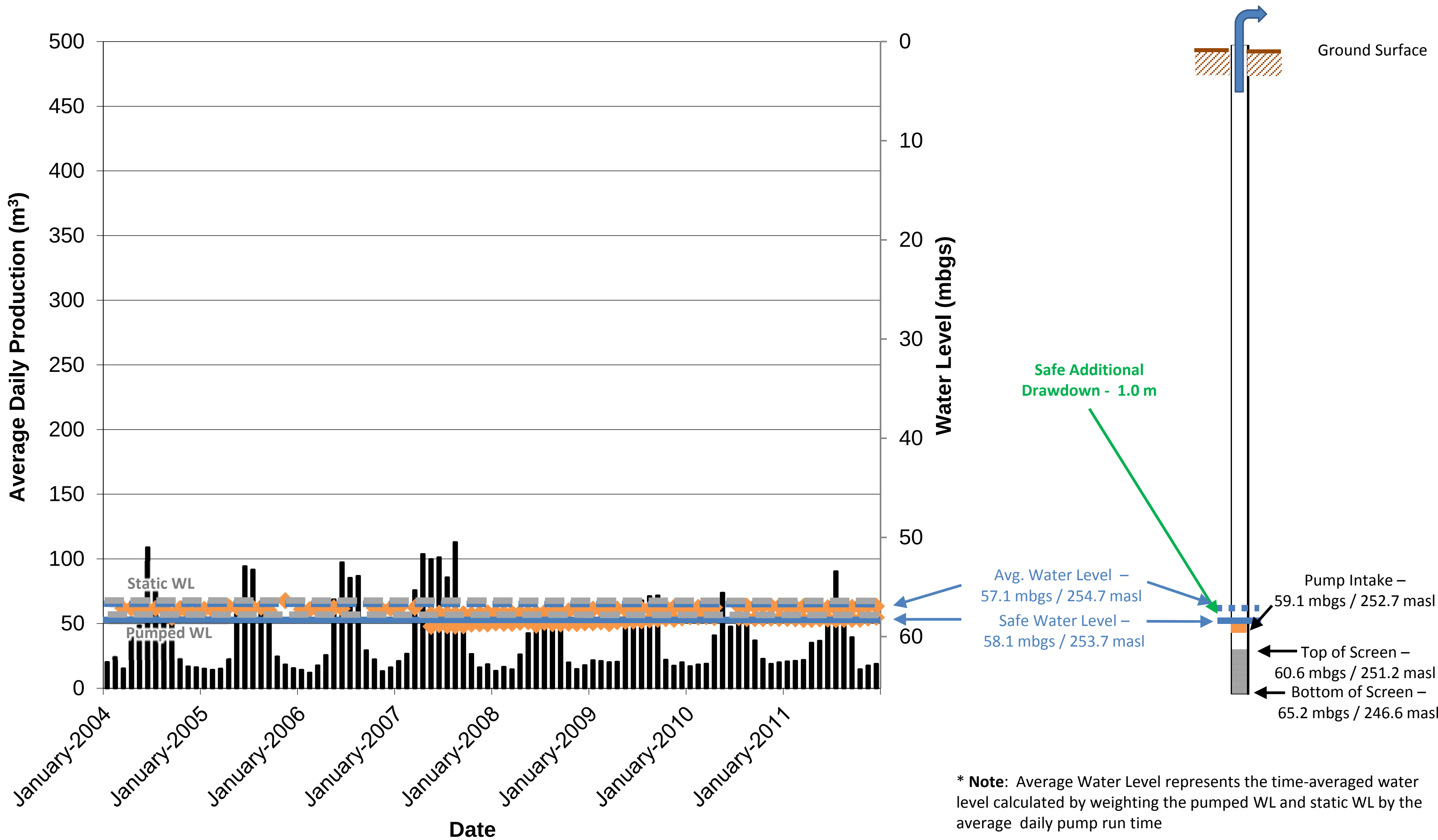
PROJECT #: 11-1170-0070

DESIGN	NGG	JUN 17, 2013
GIS	NGG	SEPT 22, 2013
CHECK	NGG	SEPT 22, 2013
REVIEW	JAP	SEPT 22, 2013

SCALE AS SHOWN

REV. 1

FIGURE 25



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

- Well Casing
- Screened Interval
- 2010/11 Average Water Level
- Safe Water Level
- Water Level Measurement

PROJECT

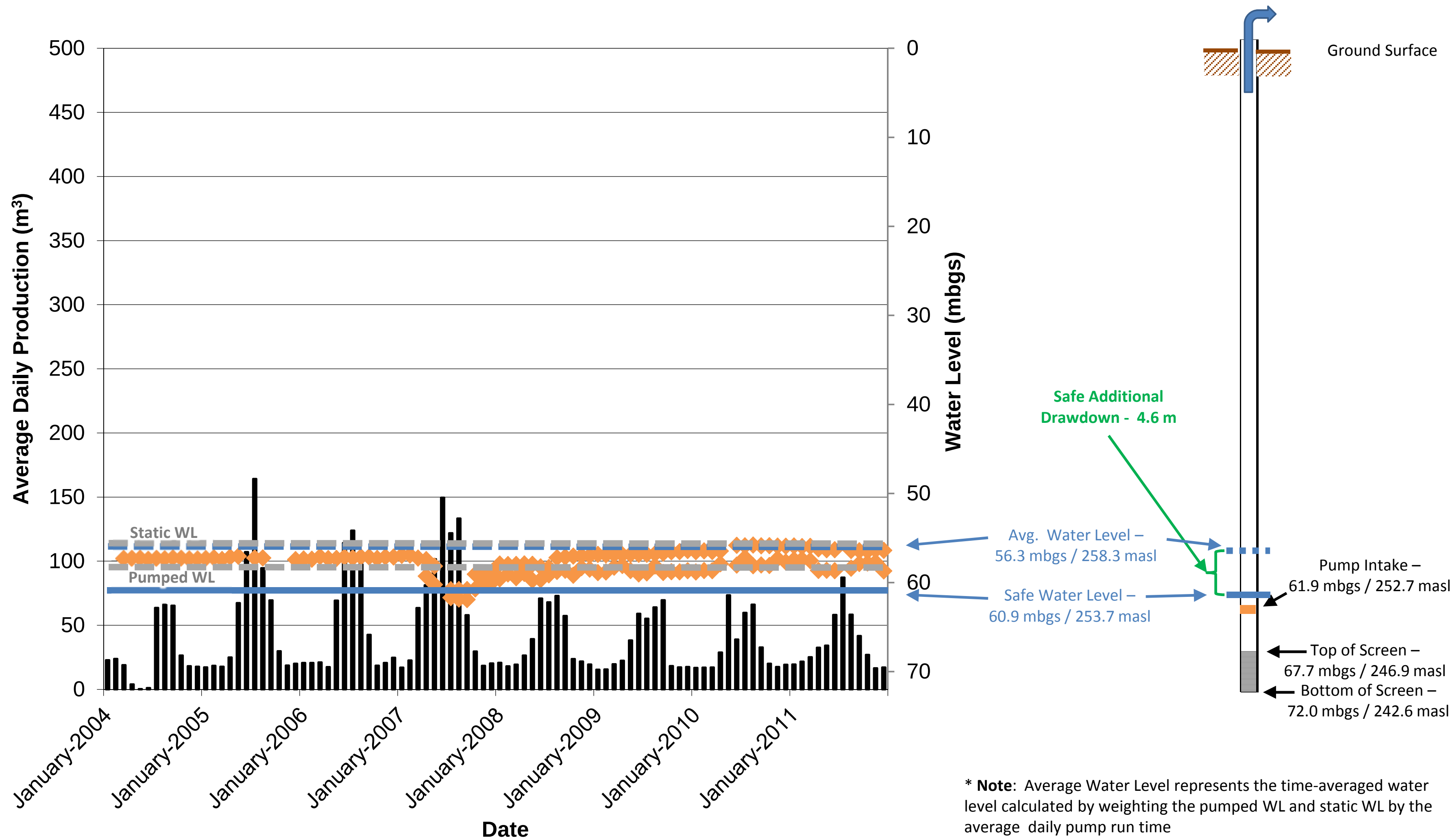
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN – WHIP-POOR-WILL WELL 21- 1

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013	**FIGURE 26**	
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013		
REVIEW	JAP	SEPT 23, 2013		



* **Note**: Average Water Level represents the time-averaged water level calculated by weighting the pumped WL and static WL by the average daily pump run time

LEGEND

Well Casing

Screened Interval

2010/11 Average Water Level

Safe Water Level

Water Level Measurement

PROJECT

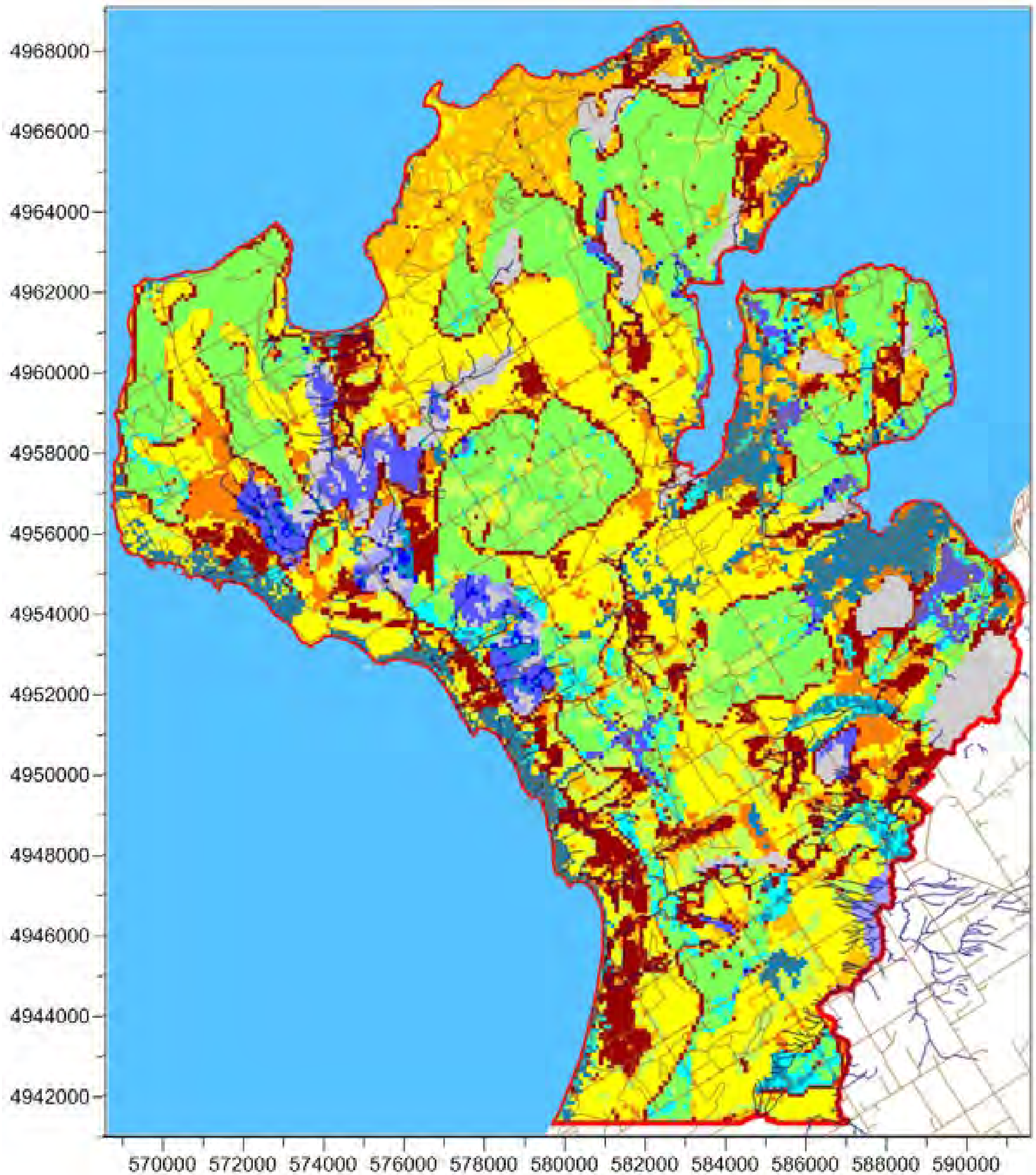
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

TITLE

SAFE ADDITIONAL DRAWDOWN –
WHIP-POOR-WILL WELL 21-2

Golder Associates

PROJECT #: 11-1170-0070			SCALE AS SHOWN	REV. 1
DESIGN	NGG	JUN 17, 2013		
GIS	NGG	SEPT 22, 2013		
CHECK	NGG	SEPT 22, 2013	**FIGURE 27**	
REVIEW	JAP	SEPT 22, 2013		



LEGEND:

Surface Water
Road
Model Domain

Recharge (mm/yr)

0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
> 600

REFERENCES:

Roads and Surface Water- MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

MIKE SHE AVERAGE ANNUAL GROUNDWATER RECHARGE

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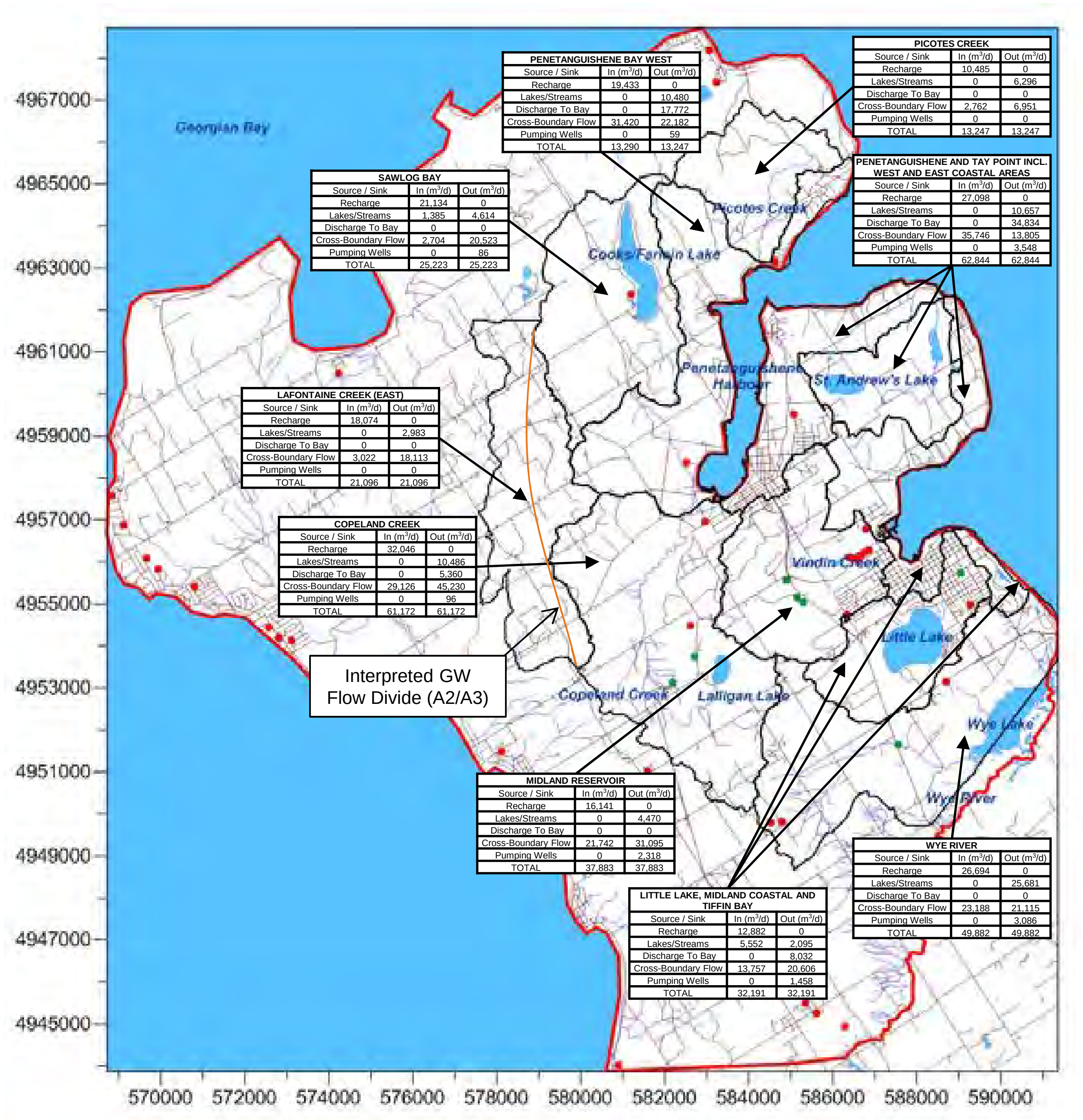
MAY 2013	PROJECT: 11-1170-0070	FIGURE 28



PENETANGUISHENE BAY WEST

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	19,433	0
Lakes/Streams	0	10,480
Discharge To Bay	0	17,772
Cross-Boundary Flow	31,420	22,182
Pumping Wells	0	59
TOTAL	13,290	13,247

PICOTES CREEK

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	10,485	0
Lakes/Streams	0	6,296
Discharge To Bay	0	0
Cross-Boundary Flow	2,762	6,951
Pumping Wells	0	0
TOTAL	13,247	13,247

PENETANGUISHENE AND TAY POINT INCL. WEST AND EAST COASTAL AREAS

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	27,098	0
Lakes/Streams	0	10,657
Discharge To Bay	0	34,834
Cross-Boundary Flow	35,746	13,805
Pumping Wells	0	3,548
TOTAL	62,844	62,844

SAWLOG BAY

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	21,134	0
Lakes/Streams	1,385	4,614
Discharge To Bay	0	0
Cross-Boundary Flow	2,704	20,523
Pumping Wells	0	86
TOTAL	25,223	25,223

LAFONTAINE CREEK (EAST)

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	18,074	0
Lakes/Streams	0	2,983
Discharge To Bay	0	0
Cross-Boundary Flow	3,022	18,113
Pumping Wells	0	0
TOTAL	21,096	21,096

COPELAND CREEK

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	32,046	0
Lakes/Streams	0	10,486
Discharge To Bay	0	5,360
Cross-Boundary Flow	29,126	45,230
Pumping Wells	0	96
TOTAL	61,172	61,172

MIDLAND RESERVOIR

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	16,141	0
Lakes/Streams	0	4,470
Discharge To Bay	0	0
Cross-Boundary Flow	21,742	31,095
Pumping Wells	0	2,318
TOTAL	37,883	37,883

WYE RIVER

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	26,694	0
Lakes/Streams	0	25,681
Discharge To Bay	0	0
Cross-Boundary Flow	23,188	21,115
Pumping Wells	0	3,086
TOTAL	49,882	49,882

LITTLE LAKE, MIDLAND COASTAL AND TIFFIN BAY

Source / Sink	In (m^3/d)	Out (m^3/d)
Recharge	12,882	0
Lakes/Streams	5,552	2,095
Discharge To Bay	0	8,032
Cross-Boundary Flow	13,757	20,606
Pumping Wells	0	1,458
TOTAL	32,191	32,191

LEGEND:

- Municipal Pumping Well
- Non-Municipal PTTW
- Surface Water
- Road
- Model Domain
- Catchment Boundaries

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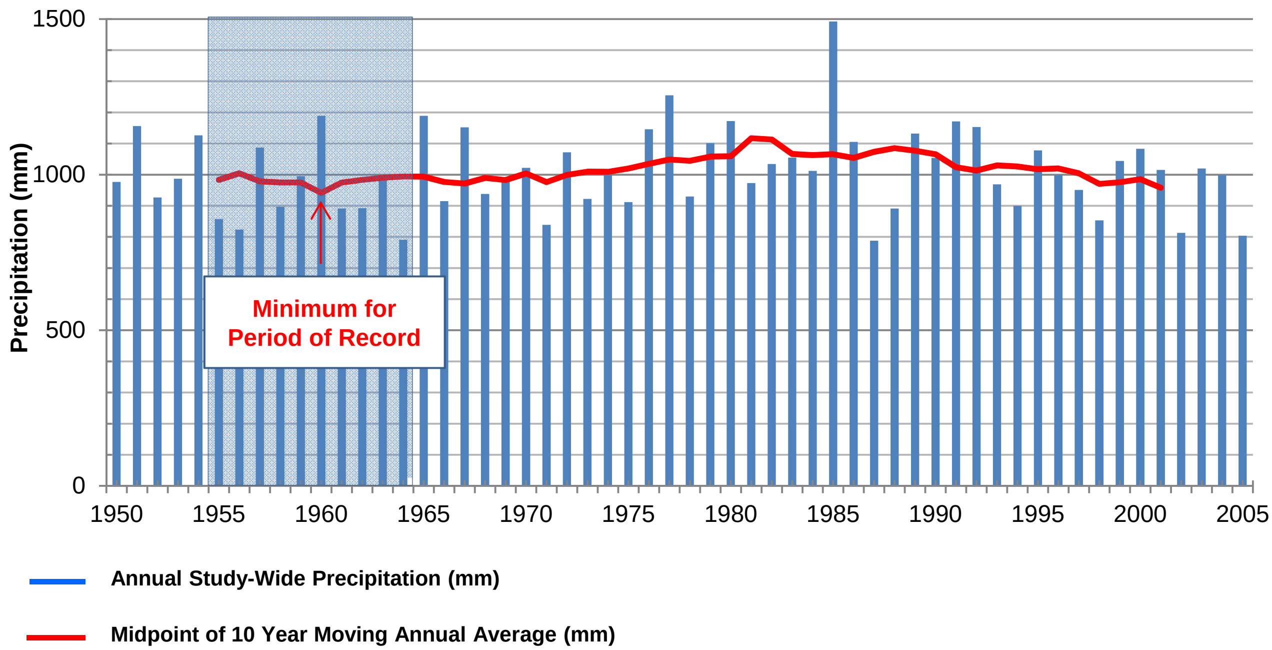
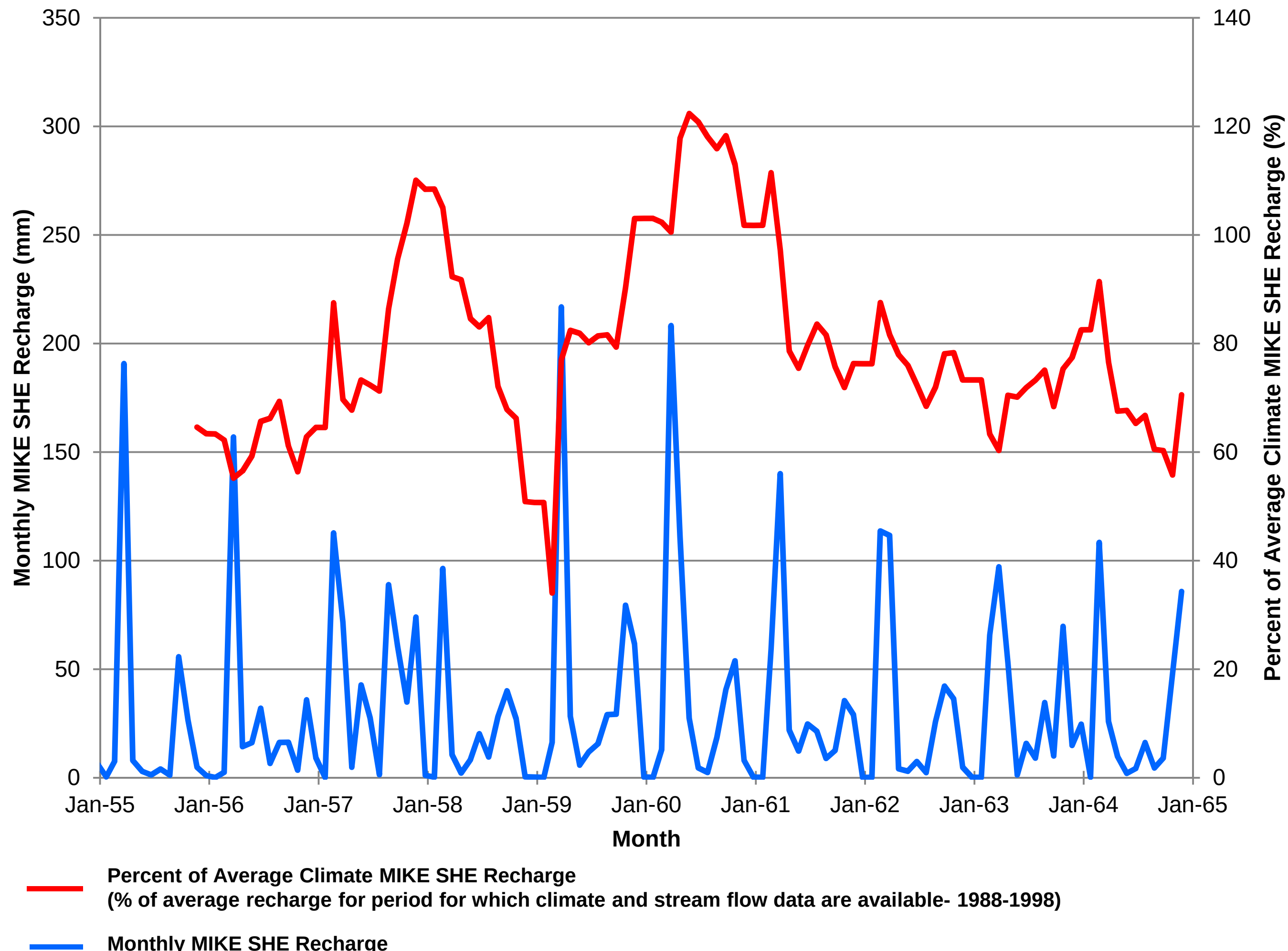
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

SIMULATED SUBCATCHMENT GROUNDWATER BUDGETS

MAY 2013	PROJECT: 11-1170-0070	FIGURE 29





MIDLAND AND PENETANGUISHENE TIER THREE ASSESSMENT

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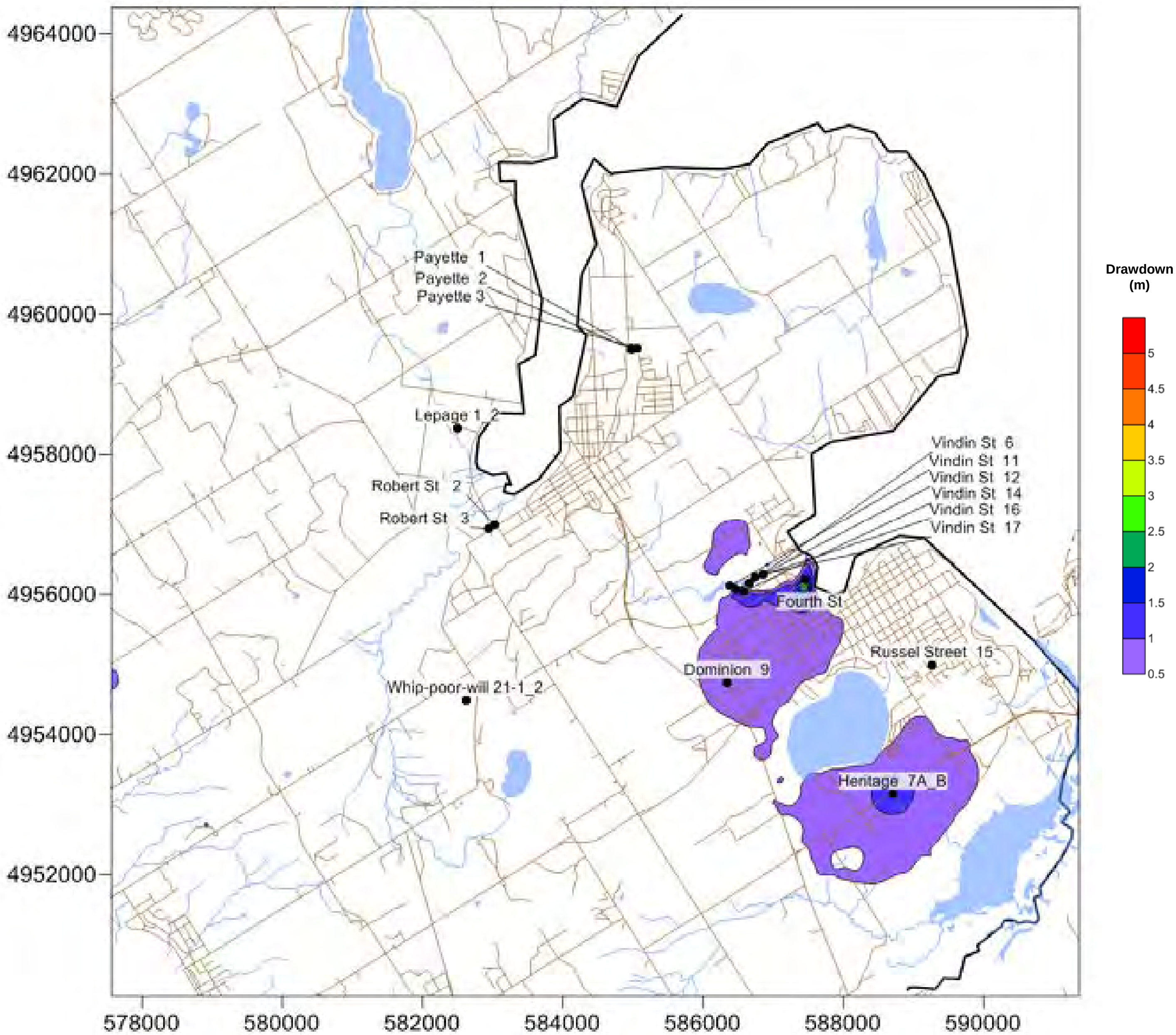
MIKE SHE DROUGHT PERIOD AND RECHARGE

JANUARY 2014	PROJECT: 11-1170-0070	FIGURE 30



REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

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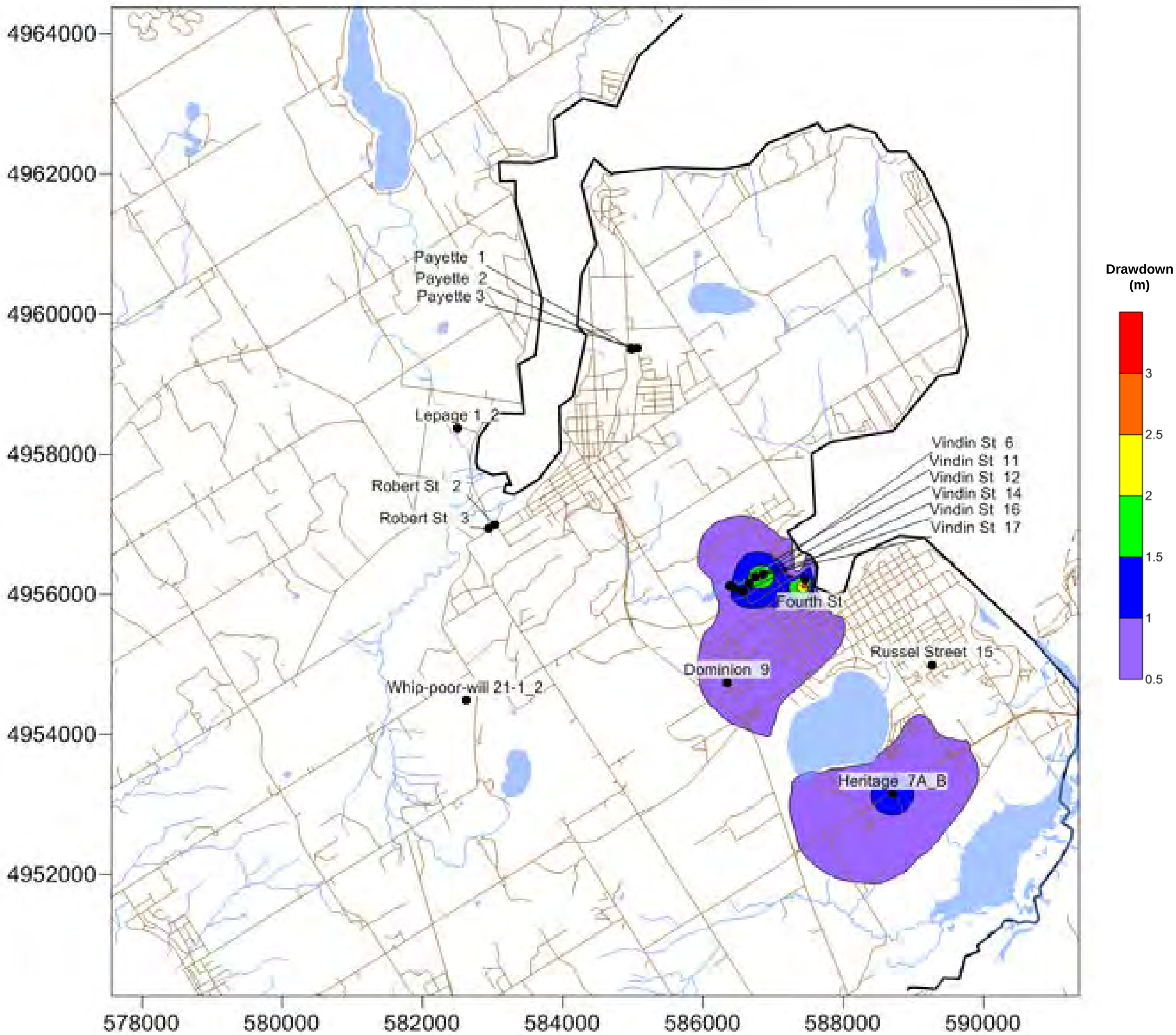
SCENARIO G2: A1 AQUIFER DRAWDOWN (RELATIVE TO SCENARIO C)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 31



REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

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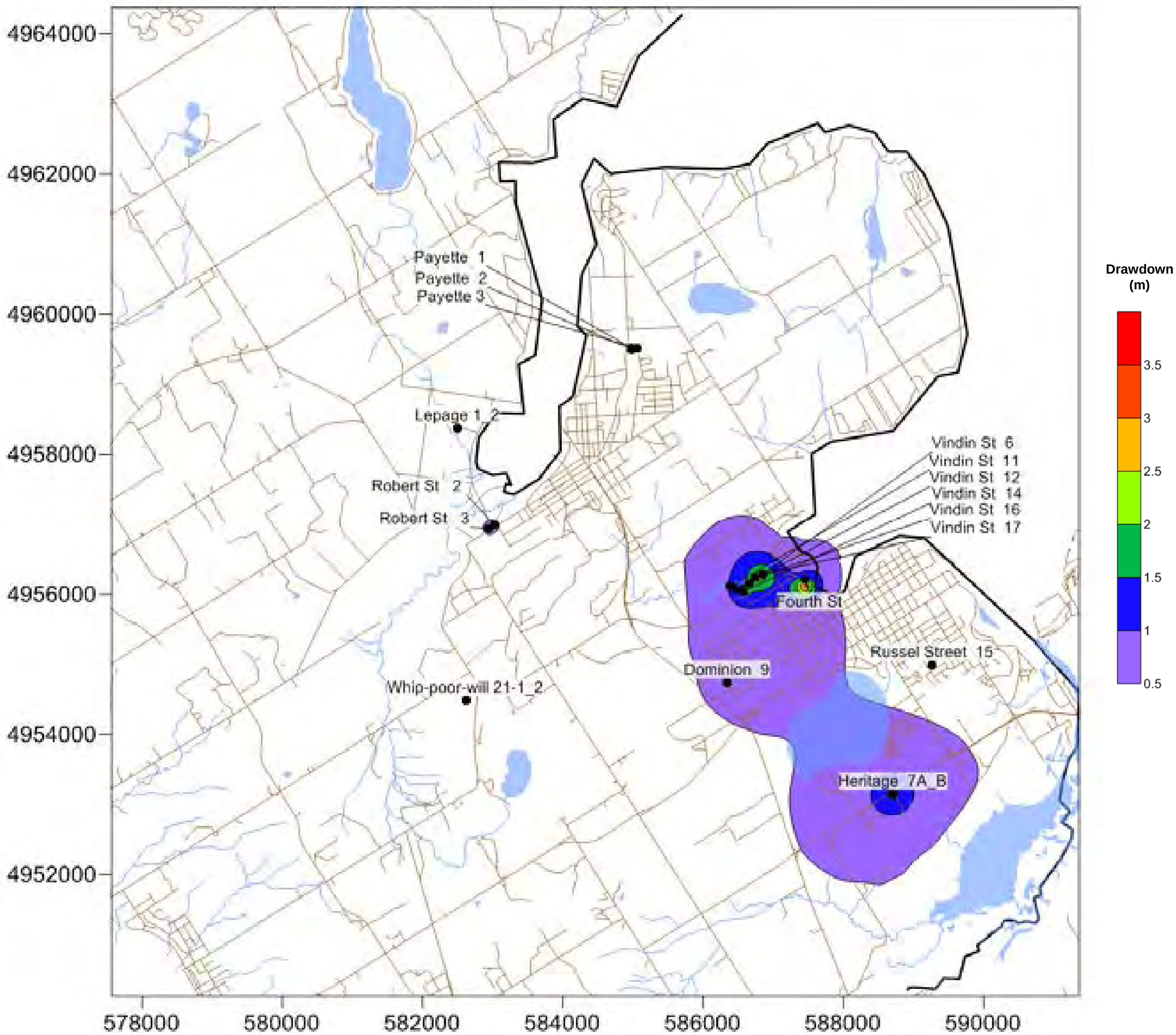
SCENARIO G2: A2 AQUIFER DRAWDOWN (RELATIVE TO SCENARIO C)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 32



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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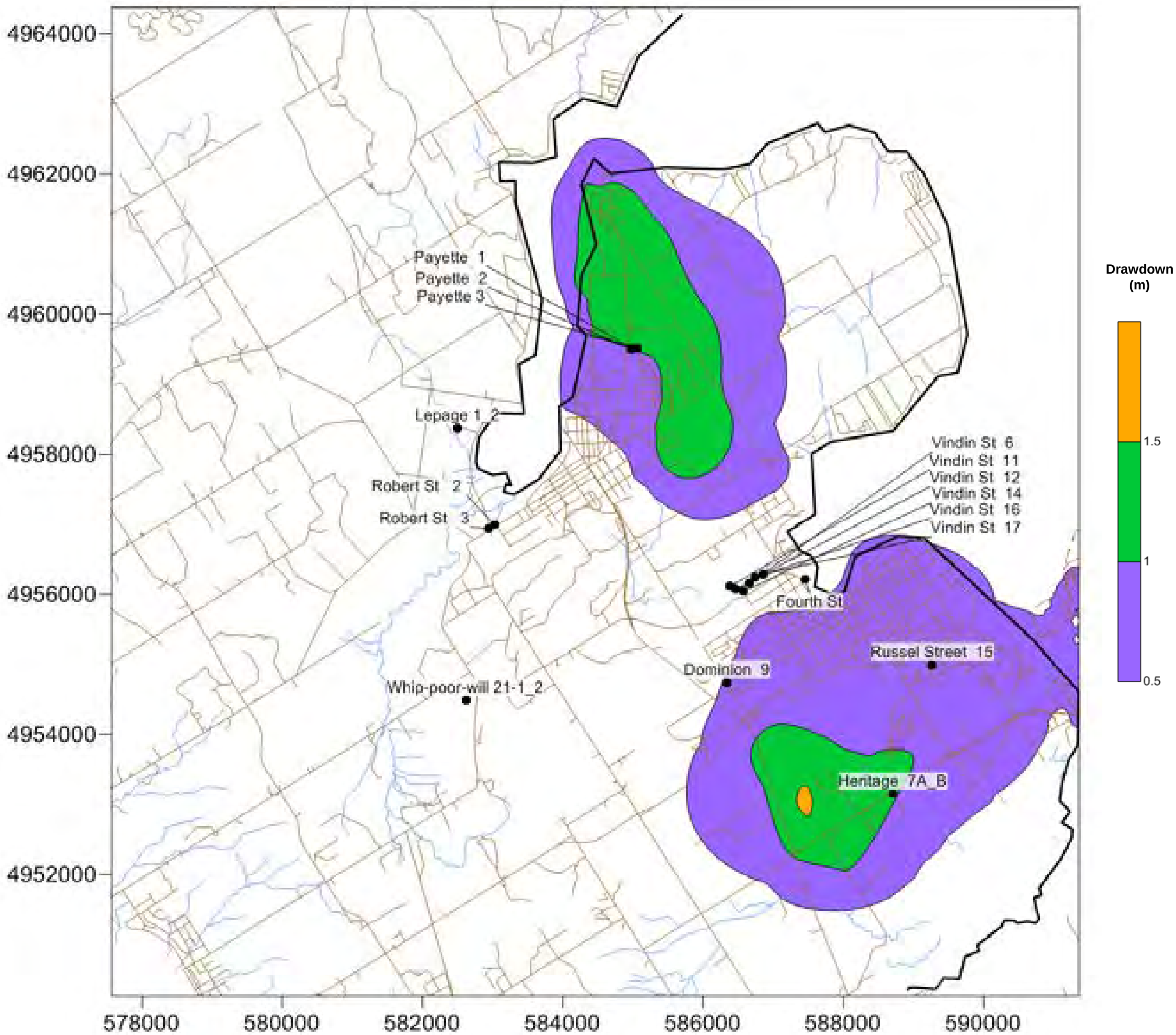
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

SCENARIO G2: A3 AQUIFER DRAWDOWN (RELATIVE TO SCENARIO C)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 33



REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

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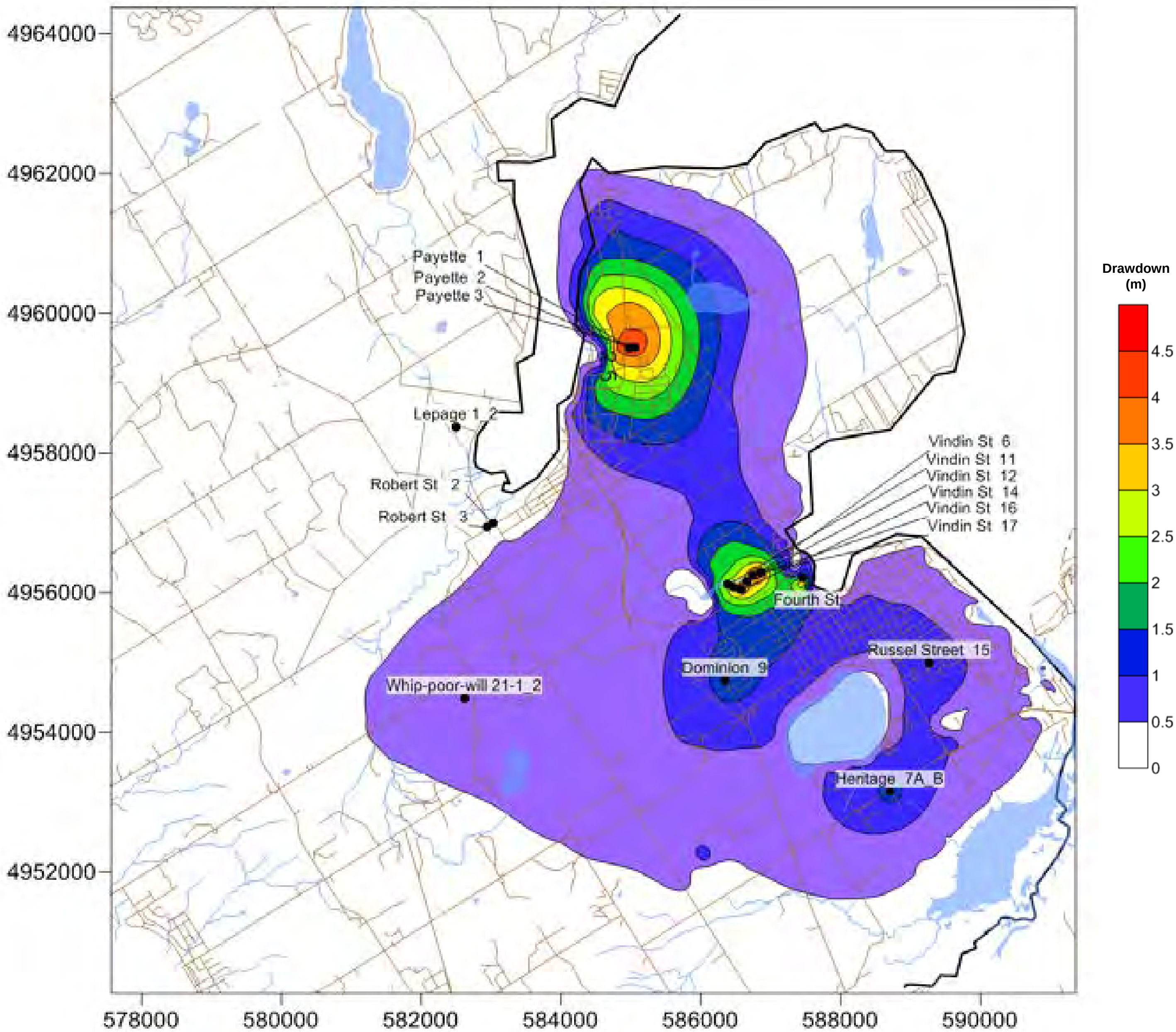
SCENARIO G3: A3 AQUIFER DRAWDOWN (RELATIVE TO SCENARIO C)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 34



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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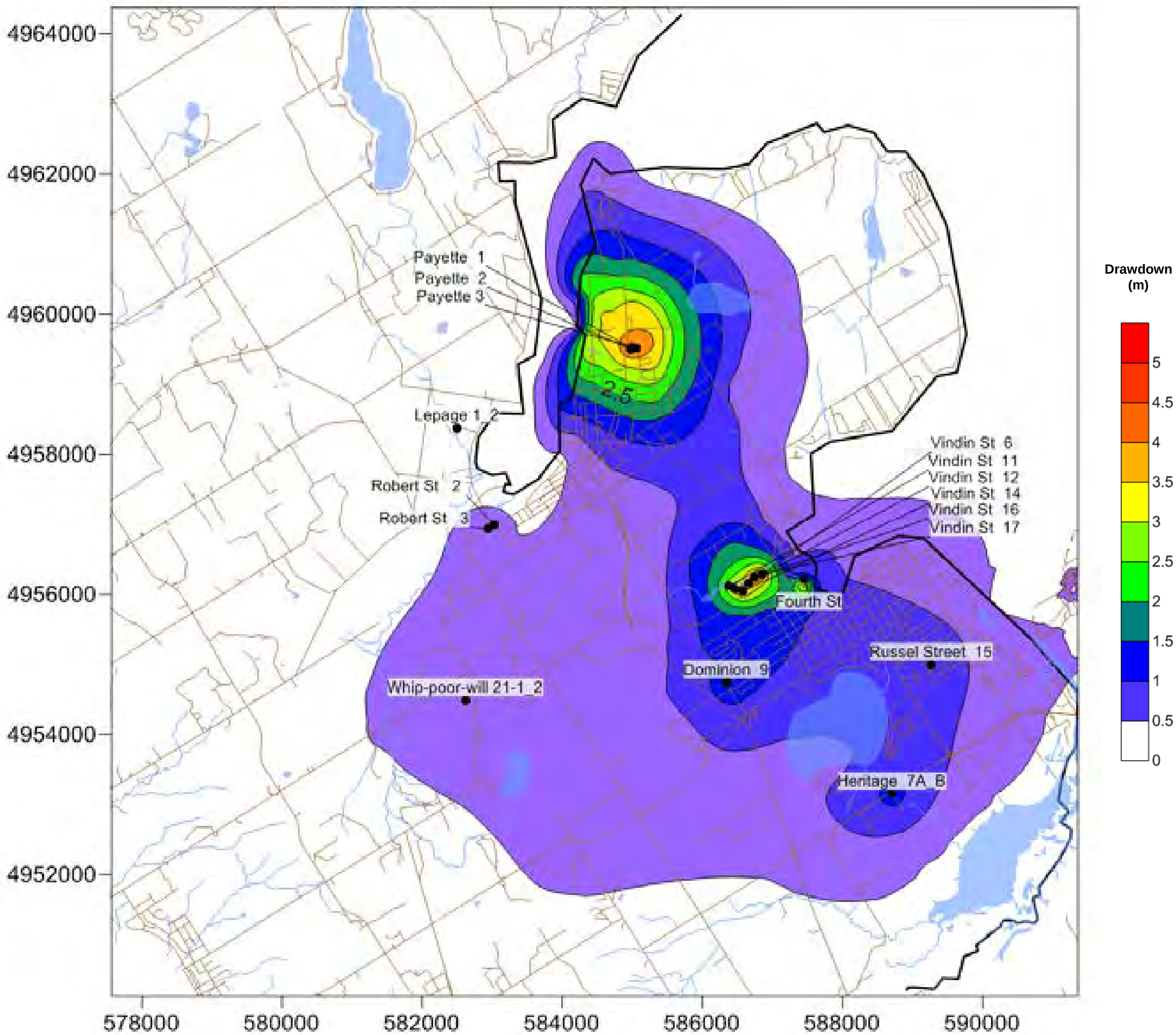
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

SCENARIO G2: A2 DRAWDOWN (RELATIVE TO NON PUMPING CONDITION)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 35



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

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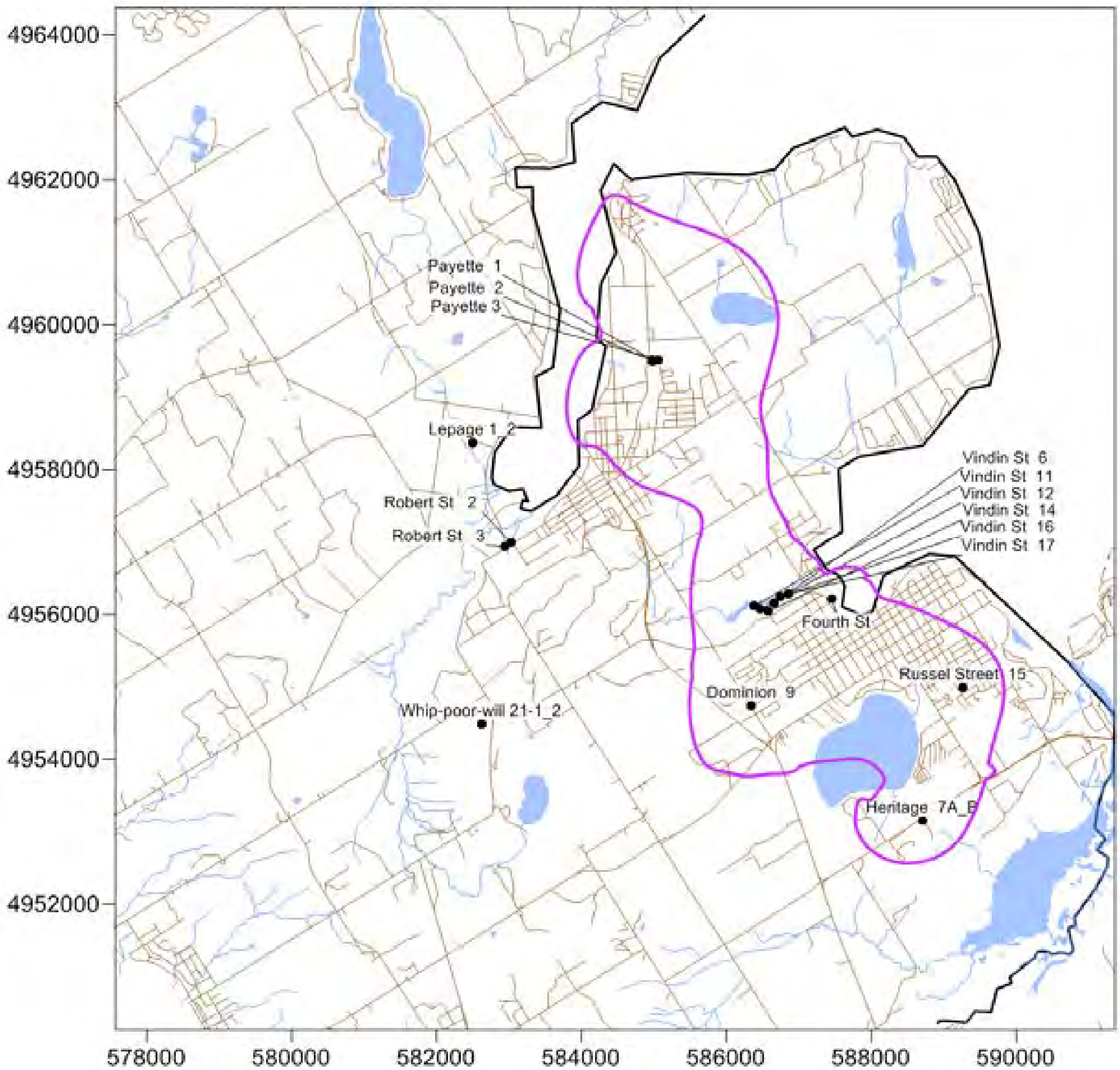
SCENARIO G2: A3 DRAWDOWN (RELATIVE TO NON PUMPING CONDITION)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 36



REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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LEGEND:

- ● Municipal Pumping Well
- Surface Water
- Road
- Model Domain

MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

SCENARIO G2: A2 AND A3 MERGED 1 m DRAWDOWN CONTOUR (RELATIVE TO NON PUMPING CONDITION)

Golder Associates

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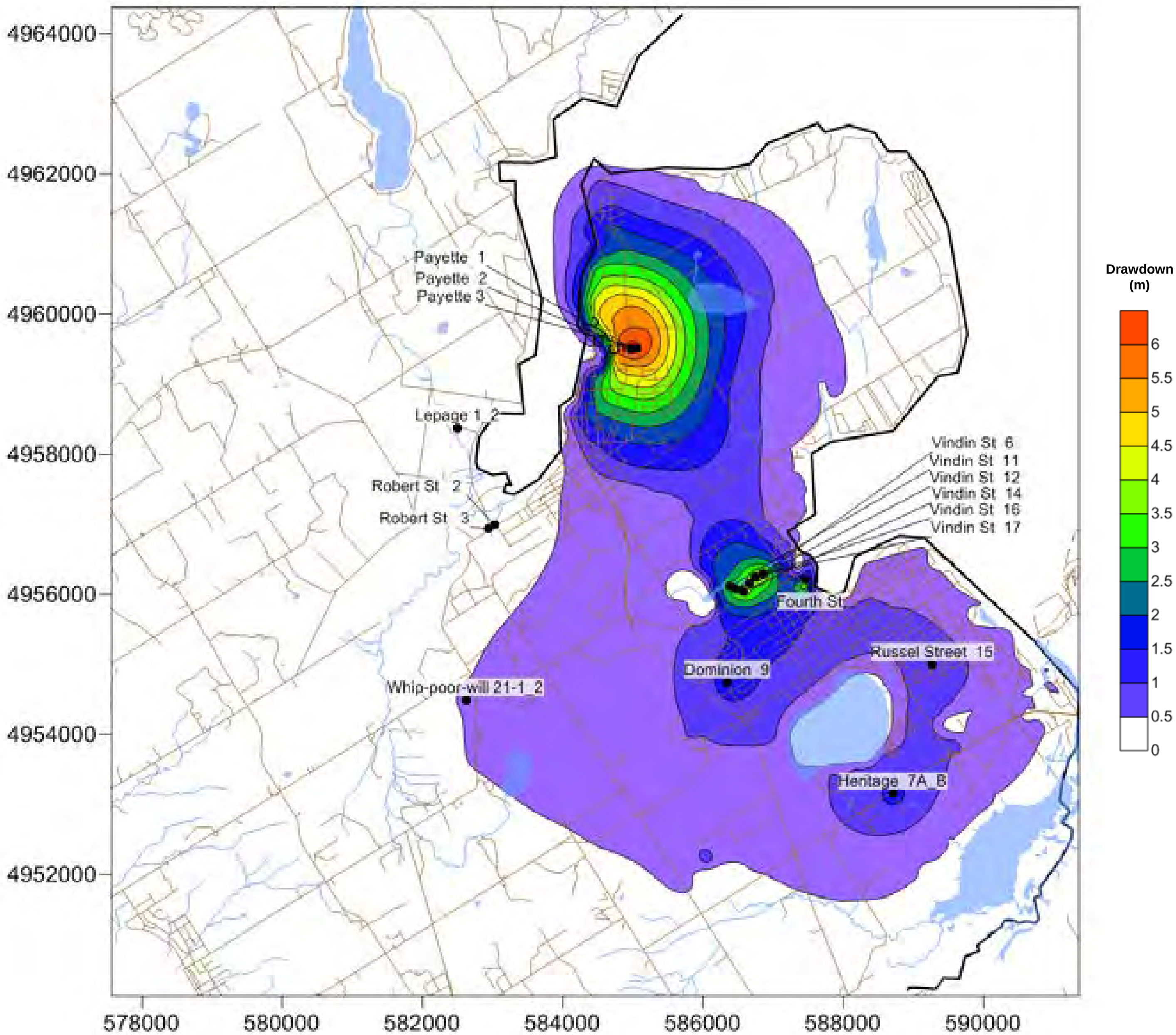
OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 37



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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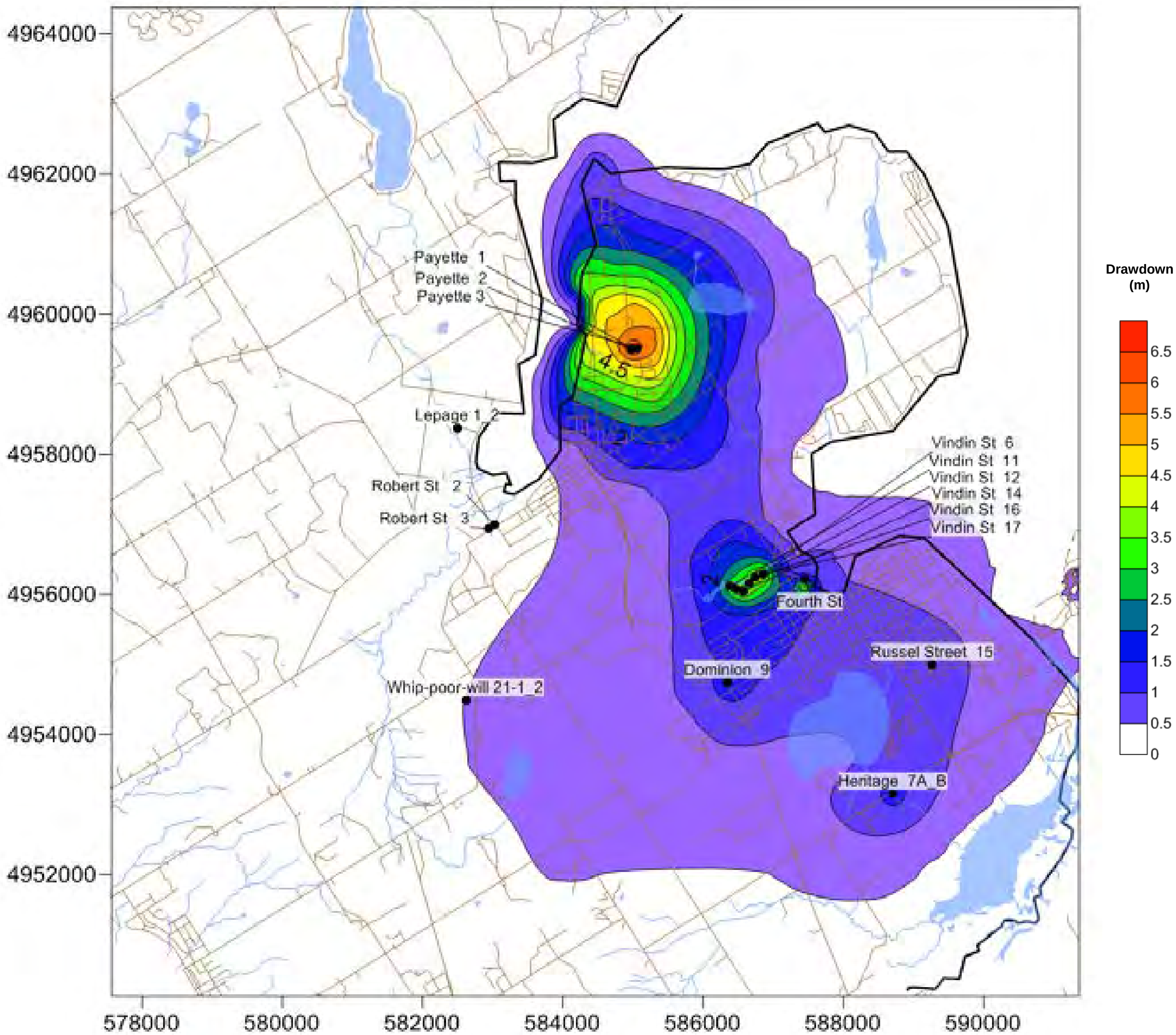
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

ALTERNATE SCENARIO G2: AQUIFER A2 DRAWDOWN (RELATIVE TO NON PUMPING CONDITION)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 38



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

ALTERNATE SCENARIO G2: AQUIFER A3 DRAWDOWN (RELATIVE TO NON PUMPING CONDITION)

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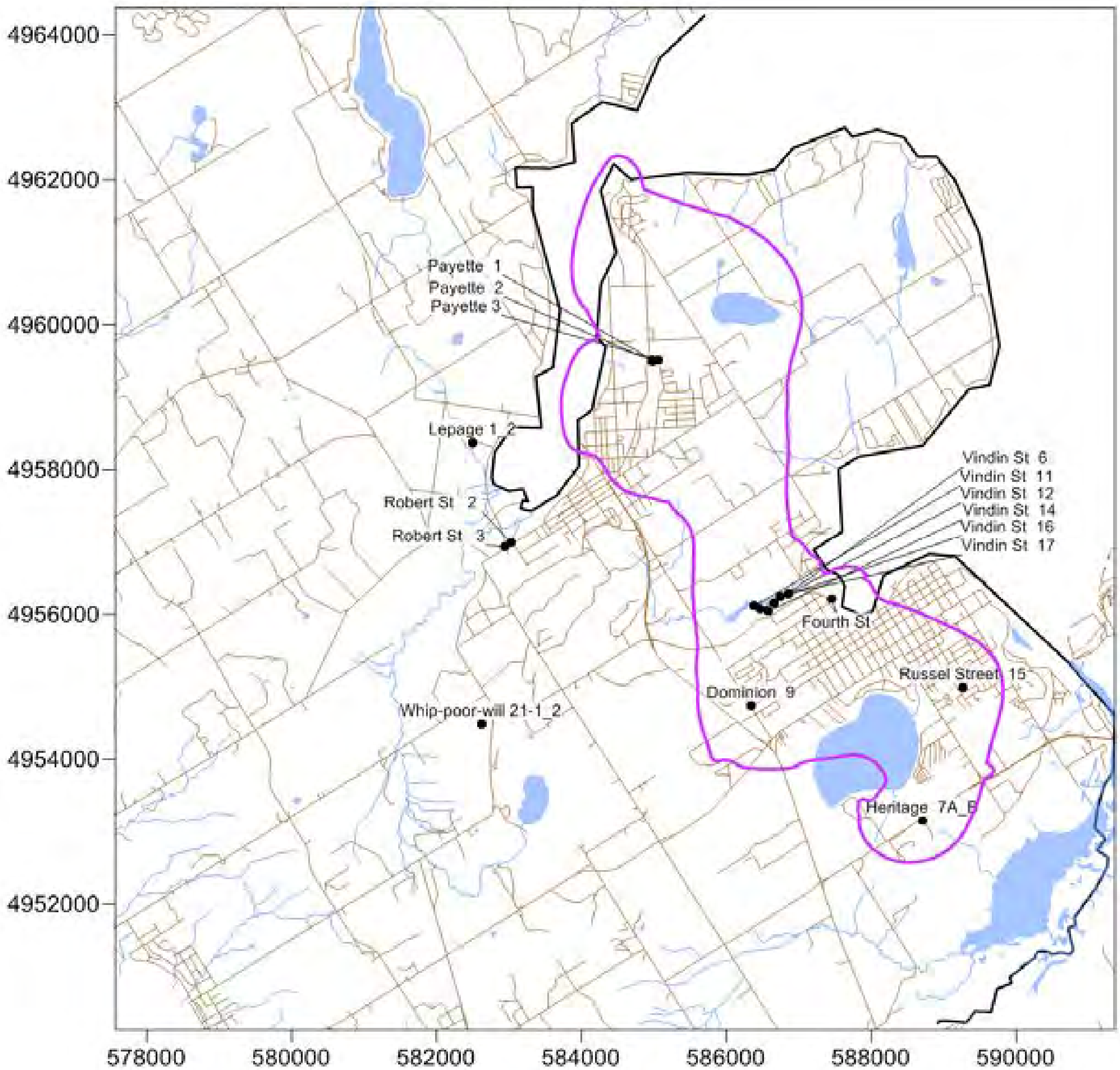
BARRIE, ONTARIO, CANADA

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 39



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

ALTERNATE SCENARIO G2: A2 AND A3 MERGED 1 m CONTOUR (RELATIVE TO NON PUMPING CONDITION)

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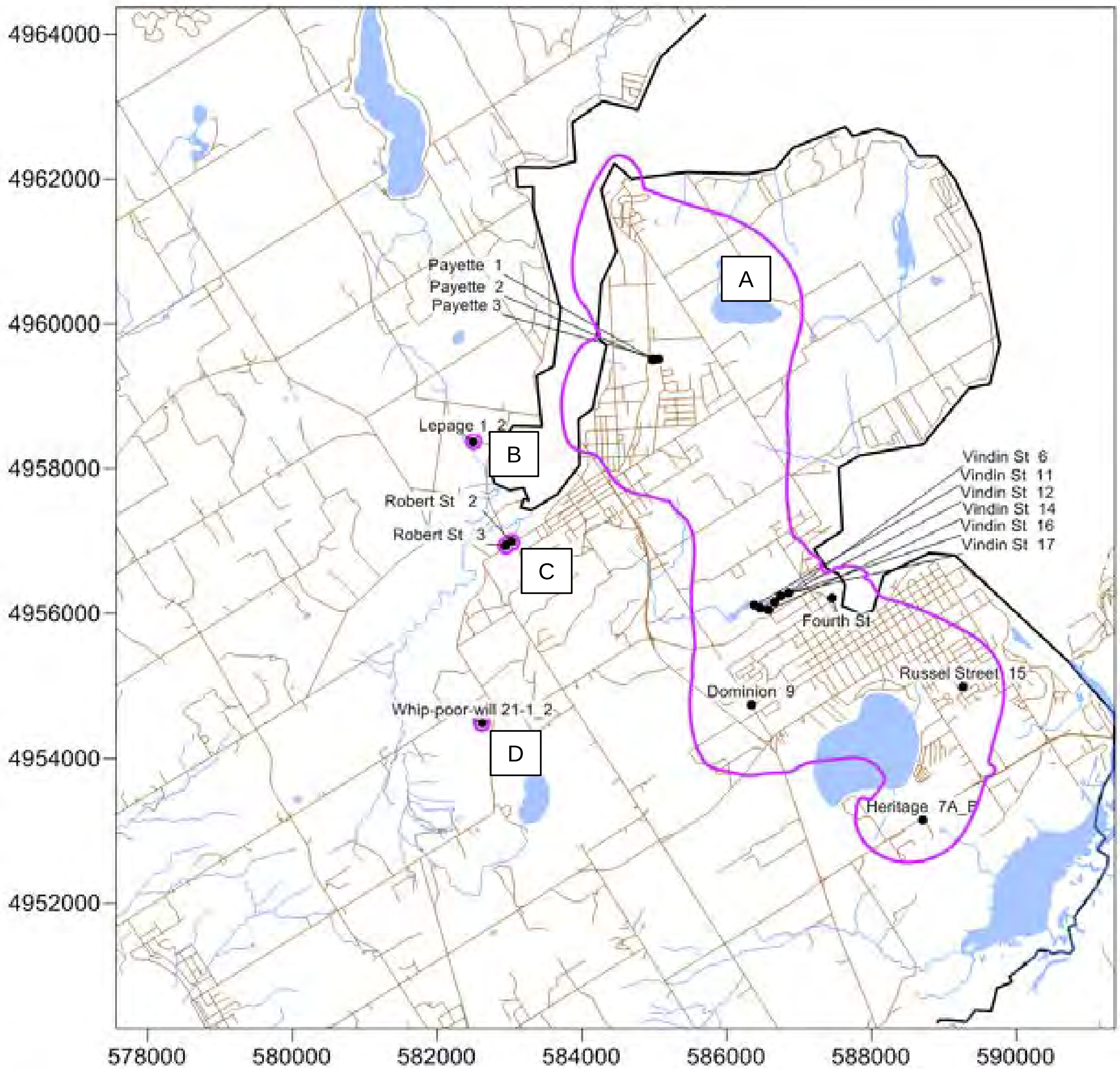
OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 40



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain
- WHPA-Q1

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

WHPA-Q1 DELINEATION

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 41

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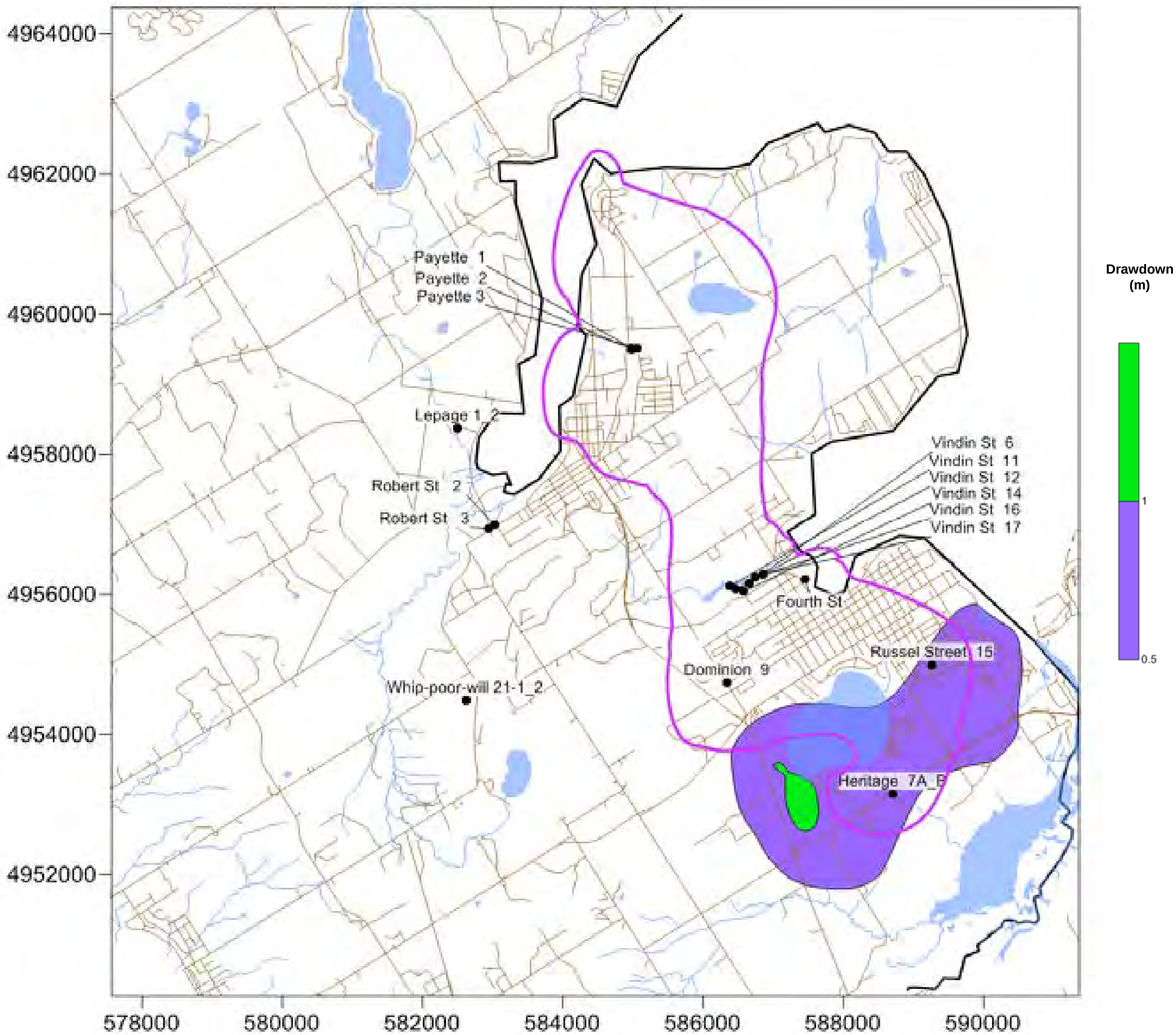

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain
- Merged A2 and A3 1m contour from Scenario G2 and Alternate Scenario G2

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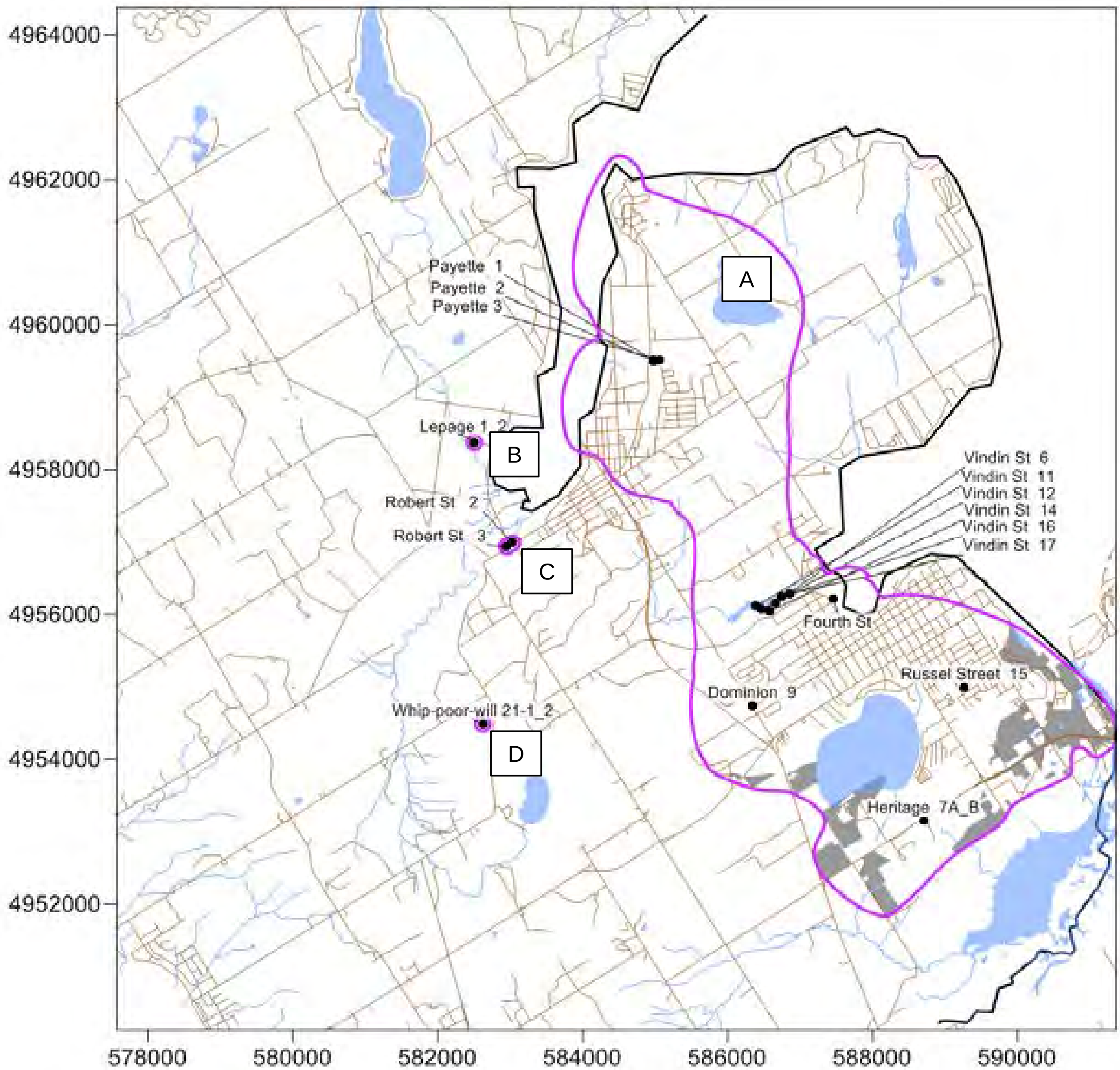
MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

WHPA-Q2 ASSESSMENT SCENARIO: AQUIFER A3 DRAWDOWN (RELATIVE TO SCENARIO C)

OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 42



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Model Domain
- WHPA-Q2
- Areas of Land Cover Change (Outside WHPA-Q1) Where Recharge Reductions May Impact Municipal Aquifer Water Levels

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

WHPA-Q2

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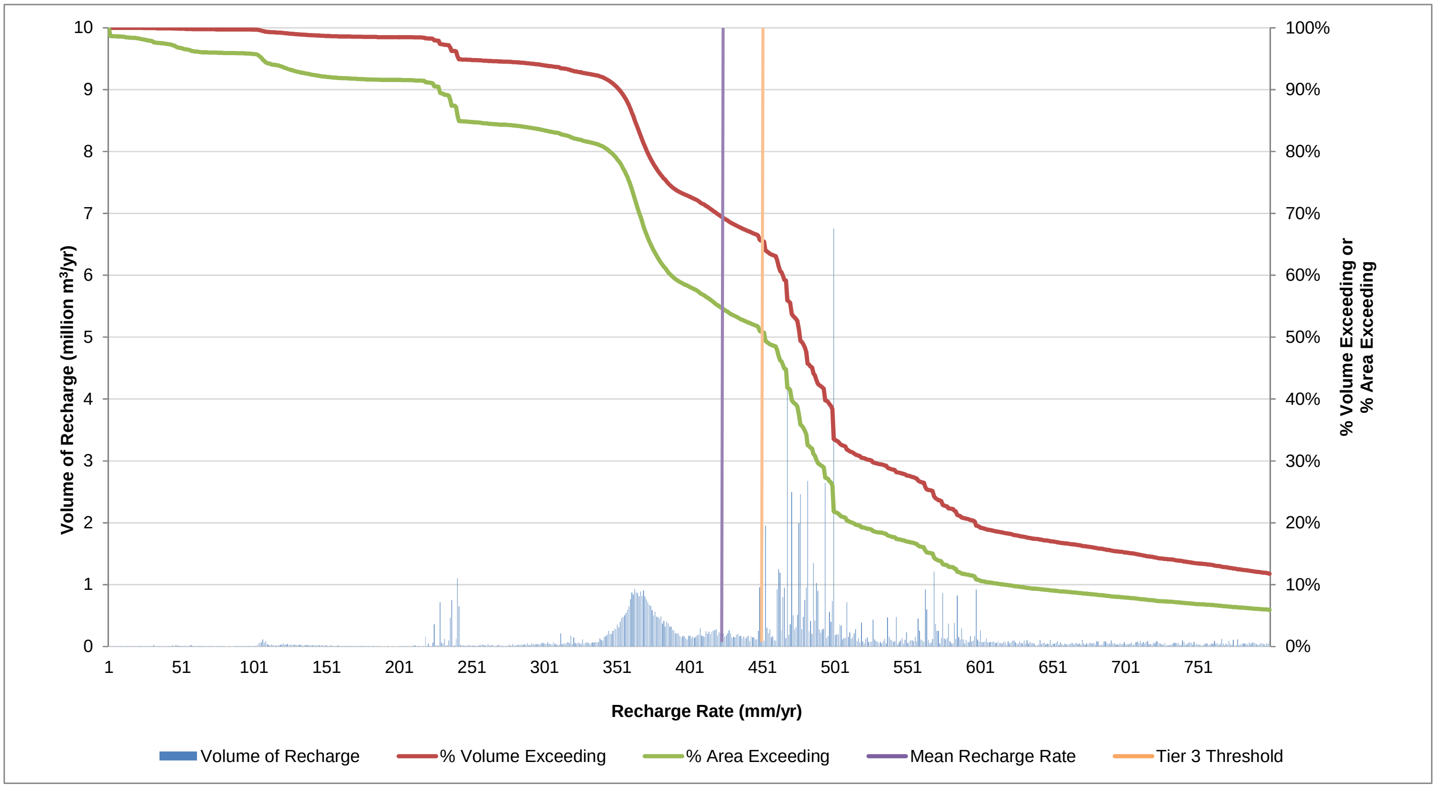
OCTOBER 2013	PROJECT: 11-1170-0070	FIGURE 43



MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

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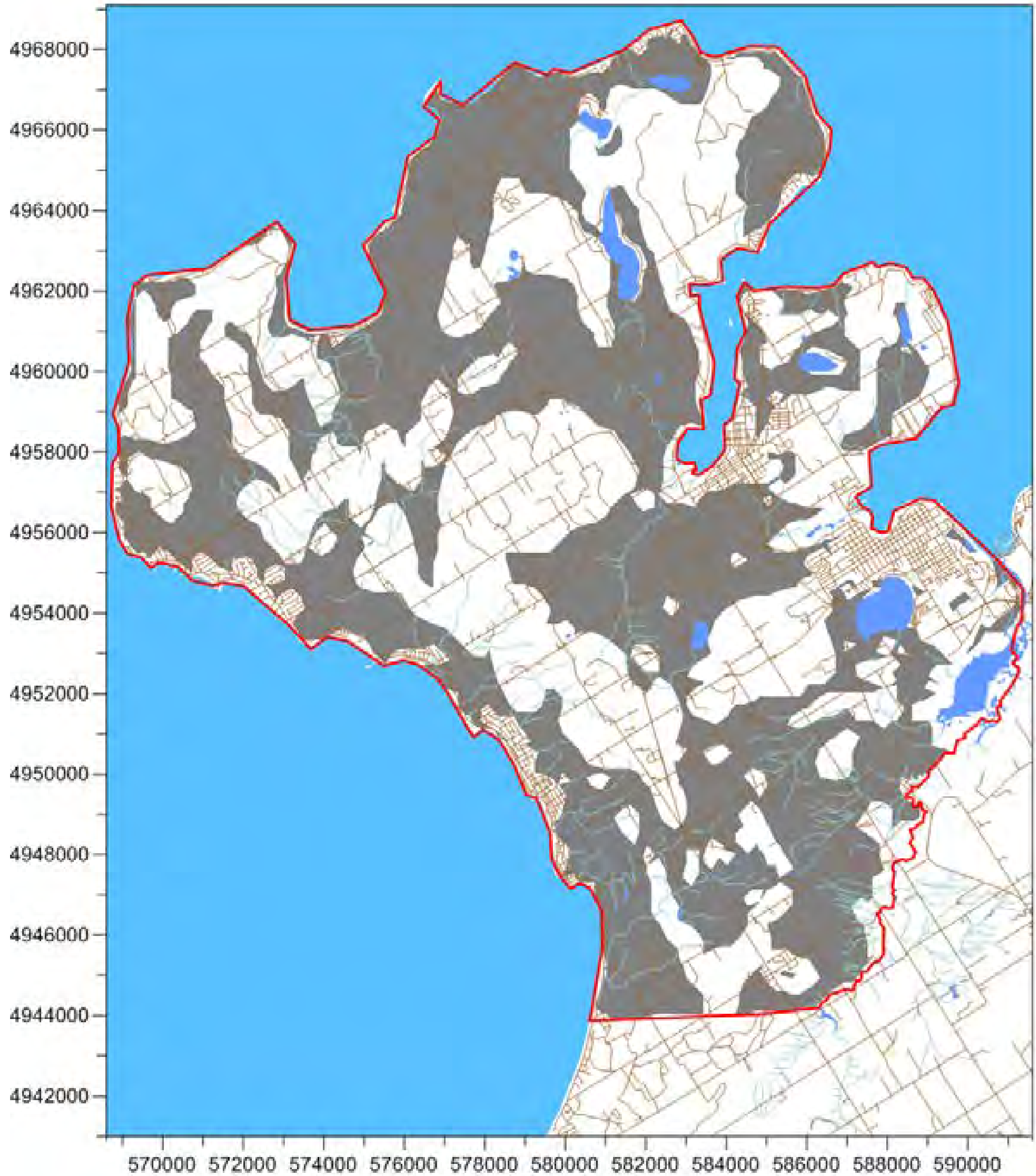
MIKE SHE Recharge Distribution

JANUARY 2014	PROJECT: 11-1170-0070	FIGURE 44



LEGEND:

Surface Water
Road
Groundwater Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

SIGNIFICANT GROUNDWATER RECHARGE AREAS

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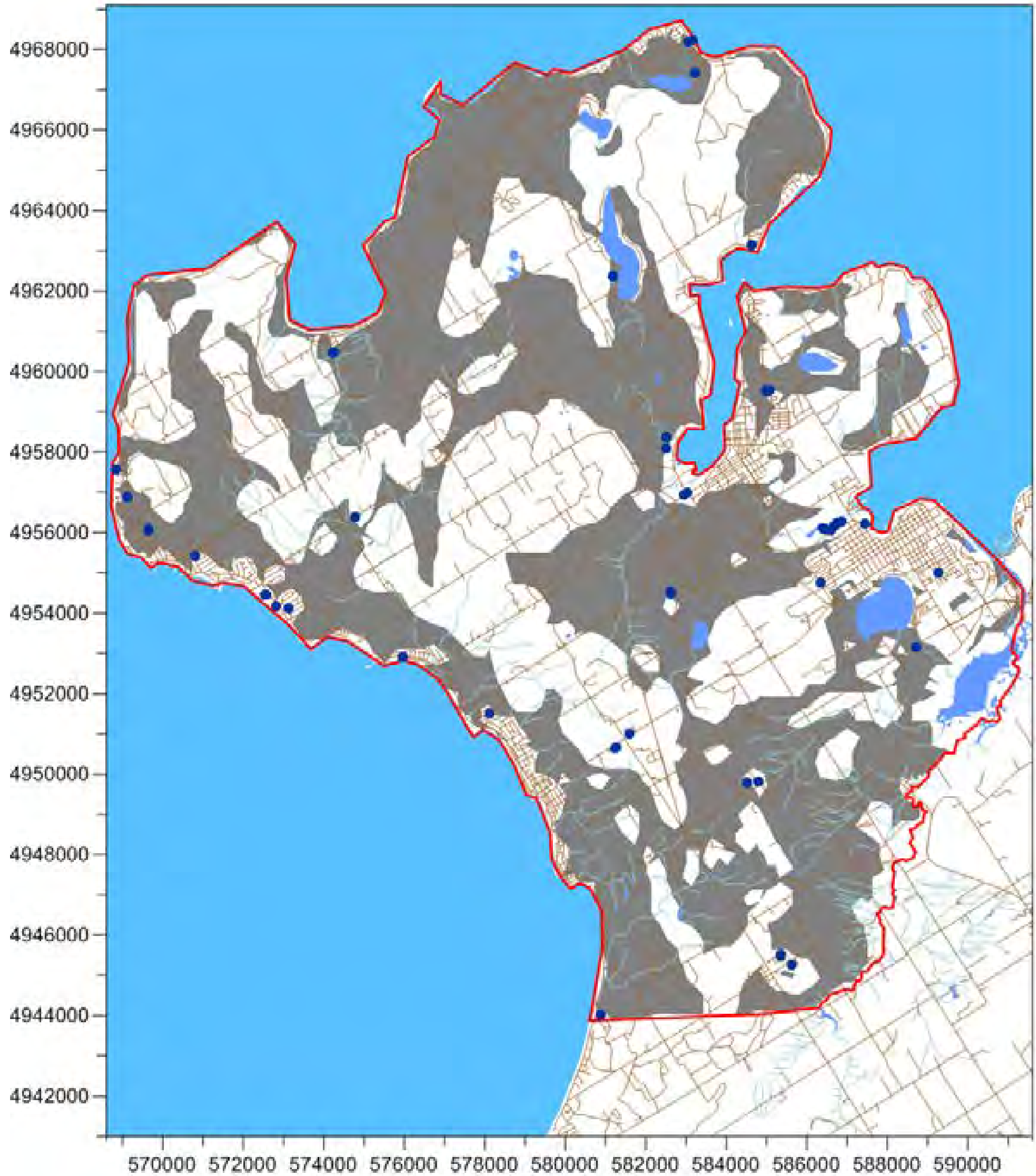
JANUARY 2014	PROJECT: 11-1170-0070	FIGURE 45



LEGEND:

- Municipal Pumping Well
- Surface Water
- Road
- Groundwater Model Domain

REFERENCES:

Roads, Lakes and Ponds, Permanent Watercourses - MNR LIO, obtained 2009
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MIDLAND PENETANGUISHENE TIER THREE ASSESSMENT

SIGNIFICANT GROUNDWATER RECHARGE AREAS AND WATER WELLS

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JANUARY 2014	PROJECT: 11-1170-0070	FIGURE 46

APPENDIX A

Conceptual Understanding

APPENDIX B

Surface Water Model Construction and Calibration

APPENDIX C

Groundwater Model Construction and Calibration

APPENDIX D

Additional Model Scenarios - Increased Pumping at the Robert St. Well Field - Town of Penetanguishene

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