HURON GEOSCIENCES

Ausable Bayfield Maitland Source Protection Region

Tier 2 Water Budget

October 2010

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1.0 INTRODUCTION

1.1 LEGISLATIVE CONTEXT

The Clean Water Act (2006) received Royal Assent on October 19, 2006. The Act and five regulations came into effect on July 3, 2007. The legislation has been developed to assist and ensure that communities protect sources of their municipal drinking water supplies. These goals will be developed through the development of locally driven, science-based Source Protection Plans, designed to protect drinking water quality and quantity.

The Water Budget process has been designed to identify water quantity threats to municipal drinking water supplies. The water budget process is comprised of a tiered or phased process.

This tiered process begins with development of a conceptual water budget which characterises the important reservoirs and processes within a Source Protection Region. A more detailed, numerical water budget is then developed based on the conceptual water budget results and forms a regional-scale Tier 1 water budget.

The Tier 1 water budget is designed to evaluate subwatershed water quantity stress levels for both surface and groundwater, as per Technical Rules prepared by the Ontario Ministry of Environment (MOE, 2009). Any subwatersheds which have been assigned either a moderate or significant water quantity stress as part of the Tier 1 water budget and contain a municipal drinking water system are then analysed in greater detail within a Tier 2 water budget. There is no requirement for further water budget evaluation (either Tier 2 or Tier 3) for those subwatersheds that have been assigned either a low water quantity stress level, or a moderate or significant stress level but do not contain a municipal drinking water system.

The Tier 2 water budget is a more detailed analysis of the moderate or significantly stressed Tier 1 subwatersheds and typically includes advanced modeling and more detailed estimates of consumptive water use. Those subwatersheds that are assigned a significant or moderate water quantity stress as a result of the Tier 2 evaluation will require a Tier 3 or local-area water budget and water quantity risk assessment.

The Tier 3 water budget assessment evaluates the impact of all water takings on the municipal systems located within the designated subwatersheds. The Tier 3 water budget will identify those consumptive water takings and reductions to recharge, that are considered significant water quantity threats. The Source Protection Committee is required to develop policies to address all significant water quantity threats.

1.2 AUSABLE BAYFIELD MAITLAND SOURCE PROTECTION REGION TIER 2 WATER BUDGET

For the purposes of developing Source Protection Plans, the Ausable Bayfield and Maitland Valley Source Protection Authorities have partnered, and formed the Ausable

Bayfield Maitland Source Protection Region (the “Region”). Map 1 shows the Region, and the spatial scale at which the water budget assessment has been conducted.

This report represents the results of the Tier 2 water budget assessment, and has been conducted consistent with the requirements of the Technical Rules prepared by the Ontario Ministry of Environment (MOE, 2009) for the preparation of Assessment Reports under the Clean Water Act.

Prior to the development of those Technical Rules, the Province developed the Provincial Guidance Module #7 Water Budget and Water Quantity Risk Assessment (MOE, 2007) which provides further support to the Technical Rules and instruction on how to complete a Subwatershed Stress Assessment.

Technical Rules and MOE guidance specifically exclude Great Lakes-based surface water intakes from the water budget process.

1.3 PREVIOUS STUDIES

Preparatory water budget work was completed within municipal groundwater studies within the Region, Including those for Grey and Bruce Counties (WHI, 2004); Huron County (IWS, 2003); Lambton and Middlesex Counties (Dillon, 2003), Perth County (WHI, 2003) and for the Town of Minto (RJ Burnside, 2001), and the Township of Wellington North (RJ Burnside, 2001). Results for the Town of Minto and the Township of Wellington North were subsequently updated as part of the Wellington County Groundwater Study (Golder, 2006). These county groundwater studies provided preliminary estimates on groundwater usage, as well as developed a set of improved water well data which were further used in this water budget process.

Groundwater modeling was completed for the entire Region as part of the Six-Conservation Authority Groundwater modeling project, completed by WHI (2006). As part of this study a fully calibrated, three-dimensional finite-element (FeFlow) model was developed for a large area, including the entire Source Protection Region. This model was calibrated to the improved well data set, as well as to known baseflows in the Region (where available). This model was the foundation for groundwater modeling conducted as part of the water budget process in the Region.

A conceptual water budget was developed as part of this water budget process (ABMV, 2007). This conceptual water budget compiled and summarized the available data for use in the numerical water budget process, in addition to identifying any salient water usage, beyond drinking water, for potential incorporation into the Tier 1 water budget. Streamflow and climatic data from Conservation Authority (CA), Environment Canada and Atmospheric Environment Services operated gauges were also compiled and analysed in the conceptual water budget. The conceptual water budget indicated that there was generally low consumptive water usage throughout the Region, and identified a lack of baseflow measurements, particularly along the lakeshore, as a key data gap.

In 2007, a baseflow monitoring program was established in the Region in order to collect data for incorporation into the Tier 1 water budget process. Results of the baseflow monitoring program (for the entire Region) are published separately by the Ausable Bayfield Conservation Authority (2007; 2008; 2009). Baseflow measurement locations were identified based on known data gaps, and the measured data were screened in order to ensure that they represent baseflow conditions according to protocols established by Hinton (1995). Additional information on flows were derived from a study of streams and gullies which drain directly into Lake Huron as part of the joint MVCA and Ministry of Environment Lakeshore Gullies Study (Paliouras and Mao, 2006).

A study was completed in 2006 in order to attempt to determine actual takings for PTTW holders in the area (Luinstra, 2006). This work led to higher accuracy in developing the Tier 1 water budget.

A Tier 1 water budget was completed for the Region (ABMV, 2008). The Region was divided into thirteen (13) subwatersheds for analysis (Map 2). This work included detailed groundwater modeling, based on the previously developed six CA model, from which groundwater models for each of the thirteen (13) Tier 1 subwatersheds were extracted. Surface water models were established for 482 surface catchments using the Surface Water Assessment Tool (SWAT) under a report prepared by Mao and McKague (2007). Results from the surface water modeling work were amalgamated for each of the thirteen (13) Tier 1 subwatersheds for the Tier 1 water quantity stress assessment.

The Tier 1 water budget identified only one (1) subwatershed, the Goderich-Bayfield gullies subwatershed as having moderate groundwater stress. This watershed was therefore recommended for further Tier 2 analysis. As Great Lakes municipal supplies were specifically exempt from the water budget process, and no municipal systems exploit other surface water sources, no subwatersheds were recommended for further Tier 2 analysis from a surface water supply standpoint.

Groundwater and surface water models created as part of the Tier 1 water budget were considered to be sufficient quality and scale for the development of the Tier 2 water budget and were employed to develop water quantity stress assessments for the Goderich-Bayfield Gullies subwatershed.

A Tier 2 water budget was required for the Goderich-Bayfield Gullies subwatershed after it was shown to be moderately stressed for groundwater in the Tier 1 water budget process. Accordingly, the Tier 2 water budget focuses solely on this subwatershed, and considers only the groundwater system.

1.4 PEER REVIEW PROCESS

The water budget process was completed in consultation and with the approval of a Peer Review Committee. This committee was formed at commencement of the water budgeting exercise and met regularly throughout the process. The following were part of the Peer Review Committee:

Dr. Trevor Dickinson, *Hydrologist and Professor Emeritus*, University of Guelph

Stan DenHoed, P. Eng, *Hydrogeologist*, Harden Environmental

Sam Bellamy, P. Eng, *Hydrologist*, AquaResource Inc.

Lynne Milford, *Water Budget Analyst*, Ministry of Natural Resources

2.0 TIER 2 SUBWATERSHEDS

The Tier 1 subwatershed initially designated for further analysis (the Goderich-Bayfield Gullies subwatershed) was refined based on the presence of large water takings and municipal well supplies in the area. Upon review, it was found that a single large water taking reported in the Goderich-Bayfield Gullies subwatershed was responsible for the bulk of the water takings in the area. Further, this taking was located at the very northern edge of the subwatershed. As it was located a far distance from any of the Municipal wells in the Goderich-Bayfield Gullies subwatershed, yet was located quite close to the Century Heights Municipal Supply, located in the MVCA Gullies Tier 1 subwatershed (See Map 2), it was felt appropriate to re-delineate the Tier 2 subwatersheds in order to better reflect the potential impacts of any takings on Municipal groundwater supplies, respecting logical topographic boundaries.

Map 3 shows the newly formed Tier 2 subwatersheds. The Goderich-Bayfield Gullies subwatershed was reduced in size, and a portion of the subwatershed included in a new Tier 2 subwatershed named the Goderich Tier 2 subwatershed. Portions of the MVCA gullies and Lower Maitland Tier 1 subwatersheds were included in the newly formed Goderich subwatershed based on surface and groundwater flow regimes. Table 1 identifies the municipal systems located in each of the Tier 2 subwatersheds.

The Goderich Bayfield Gullies subwatershed is located within both the Maitland and Ausable-Bayfield Source Protection Authority. The Goderich subwatershed is located wholly within the Maitland Source Protection Authority.

Table 1. Municipal Systems within Tier 2 subwatersheds.

Tier 2 Subwatershed	Municipality	System	Aquifer
Goderich	Ashfield-Colborne-Wawanosh	Century Heights	Bedrock
Goderich-Bayfield Gullies	Central Huron	McClinchey	Bedrock
		Kelly	Bedrock
		Vandewetering	Bedrock
		S.A.M.	Bedrock

2.1 CHARACTERIZATION OF THE TIER 2 SUBWATERSHEDS.

A detailed review of the geology of the Ausable Bayfield Maitland Source Protection Region can be found in the Region's Conceptual Water Budget (ABMV, 2007) and the Tier 2 water budget (Luinstra, 2008). A brief discussion of the geology and hydrogeology of the Tier 2 subwatersheds is included in this report in order to provide context to the discussions herein.

2.1.1 PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The Tier 2 subwatersheds are located entirely within the Huron Slope physiographic region (Chapman and Putnam, 1984). This region is characterised by generally flat to moderately sloping topography, heavy (clay-rich) soils with drainage towards Lake Huron. In both Tier 2 subwatersheds, the western limits of the subwatersheds extend to the base of the Wyoming moraine complex, which is also host to narrow band of sand and gravel, lakeshore deposits associated with the former glacial Lake Warren. Map 6 shows the surficial geology of the Tier 2 subwatersheds.

Both Tier 2 subwatersheds are bounded to the west by Lake Huron, and have distinct, actively eroding bluffs associated with the Lake. Generally small, and dominantly perennial streams drain directly into Lake Huron and have eroded through the table lands associated with the Huron Slope. The Goderich Tier 2 subwatershed is dissected by the Maitland River valley, which outlets into the Lake at Goderich.

In the Goderich-Bayfield Gullies Tier 2 subwatershed, the Lake Warren shoreline deposits and associated sands and gravels extend westward toward Lake Huron.

Underlying all the surficial deposits is a 40-60m thick layer of St. Joseph's Till, which is composed of clay with occasional matrix supported gravel clasts in this area.

2.1.2 SOILS

Soils in the area are dominated by Brookston Clay Loams, which extend through both Tier 2 subwatersheds (Map 7). Sandy soils, related to the former Lake Warren Shoreline deposits are more prevalent as a narrow, North-South oriented band in the Tier 2 subwatersheds.

2.1.3 LAND COVER

The Tier 2 subwatersheds are dominated by agricultural land use, and this is reflected in the Land Cover mapping (Map 5). The Only Major Urban area in the study areas is the Town of Goderich, located in the Goderich Tier 2 subwatershed. Forest cover is generally confined to the back of agricultural lots; however, large areas of forest cover are associated with the Maitland River valley and minor wetland areas.

2.1.4 BEDROCK GEOLOGY

The entire are is underlain by Devonian carbonate rocks of the Detroit River Group (Map 9). Western portions of the Goderich subwatershed are underlain by the Lucas formation, which outcrops extensively in the Maitland River Valley. The Goderich-Bayfield Gullies subwatershed is underlain by the Dundee formation (which overlies the Lucas Formation). Both formations are considered to be high quality and quantity aquifers.

2.1.5 HYDROGEOLOGY

The dominant aquifer in the study area is the regionally significant bedrock aquifer. In the Tier 2 subwatersheds, this aquifer is completely confined by a 40-60 m thick layer of low-permeability clay (St.Joseph's Till). Water levels in wells which exploit this aquifer are typically 10-15m above the contact between the bedrock and the overlying St. Joseph's Till, further supporting its treatment as a confined aquifer. Overburden thickness is shown in Map 10. The bedrock aquifer is recharged outside of the Tier 2 subwatersheds.

The aquifer is exposed (and therefore unconfined) in the Maitland River Valley where numerous springs are associated with bedrock outcrops. The bedrock aquifer in the Tier 2 study area is considered a high quality and quantity aquifer, and is host to all municipal supplies, as well as all private wells with records.

Overlying the St. Joseph's Till are volumetrically smaller sand and gravel deposits that are host to several smaller aquifers. These aquifers are recharged *in situ* and are important sources of baseflow for streams, yet have little to no recorded use as drinking water supplies.

3.0 GROUNDWATER MODELING

3.1 MODELING

Groundwater Flux through the system was further developed from the fully calibrated, three-dimensional 6CA FeFlow groundwater model. Tier 2 subwatersheds were extracted, and mesh refined while maintaining all assigned hydrogeological values derived from the 6CA model. This ensured that the calibration of the models was not impacted during extraction. Similarly, boundary-flux conditions were derived from the 6CA model, also ensuring that the calibration of the models was not impacted. This process allowed for extraction of models and refinement of the modeling mesh without impacting the calibration of the model. In essence the extracted models represent extracted portions of the larger, fully calibrated 6CA groundwater model, allowing for faster and more efficient computation at the local scale. These Tier 2 groundwater models are based on the fully calibrated, 6CA regional groundwater model.

3.1.1 GODERICH-BAYFIELD GULLIES MODEL

A fully calibrated, three-dimensional groundwater model was created for the Goderich Bayfield Gullies assessment area via extraction from the regional scale 6CA model. Model elements (mesh) were refined to 25m (average distance between nodes) around the assessment area boundaries preserving all original boundary conditions derived from the regional scale 6CA model. The model is composed of 78,628 elements and 15 layers. Model boundaries, mesh and hydraulic properties are included in Appendix A.

3.1.2 GODERICH MODEL

A fully calibrated, three-dimensional groundwater model was created for the Goderich assessment area via extraction from the regional scale 6CA model. Model elements (mesh) were refined to 25m around the assessment area boundaries preserving all original boundary conditions derived from the regional scale 6CA model. The model is composed of 26,166 elements and 15 layers

3.2 GROUNDWATER FLUX

Groundwater flux values were developed using continuous boundary flux within the FeFlow water budgeting module. It is most notable that the groundwater flux data did not change through refinement of the models as it is a boundary condition developed from an overall regional model. The water budgeting module also allows for a comparison of the water balance values for each subwatershed within the model. No imbalances were noted for either of the Goderich or Goderich-Bayfield Gullies models.

The quantity of groundwater fluxing into each of the two (2) Tier 2 assessment areas was developed from the models and included in Table 7.

3.3 LIMITATIONS OF GROUNDWATER MODELING

Numerical representation and simulation of groundwater flow systems using models contains limitations. Models approximate groundwater flow using mathematical equations, which make a number of assumptions which impact the results, specifically:

1. Spatial Scale. The model calculates groundwater levels at each individual node within the model. The density of the nodes is dependant primarily on the scale of the model and the data available to construct and calibrate the model. Practically, it is impossible to exceed the scale of available data without making assumptions, which can lead to minor errors at finer scales within the model.

2. Data limitations. Models can only represent the geological and hydrogeological data that is available. The model is derived from these existing data. Where limited data is available, assumptions must be made within the model. This is likely the largest source of error within any numeric model

3. Model calculations. Models employ mathematical equations to simulate groundwater levels and flow. These equations are based on physical laws and observations of hydrogeological systems, however, they can have led to error. In particular, Finite element models iteratively solve these equations for groundwater levels, which leads to some numerical error. These errors are generally considered to be minor.

4.0 SURFACE WATER MODELING

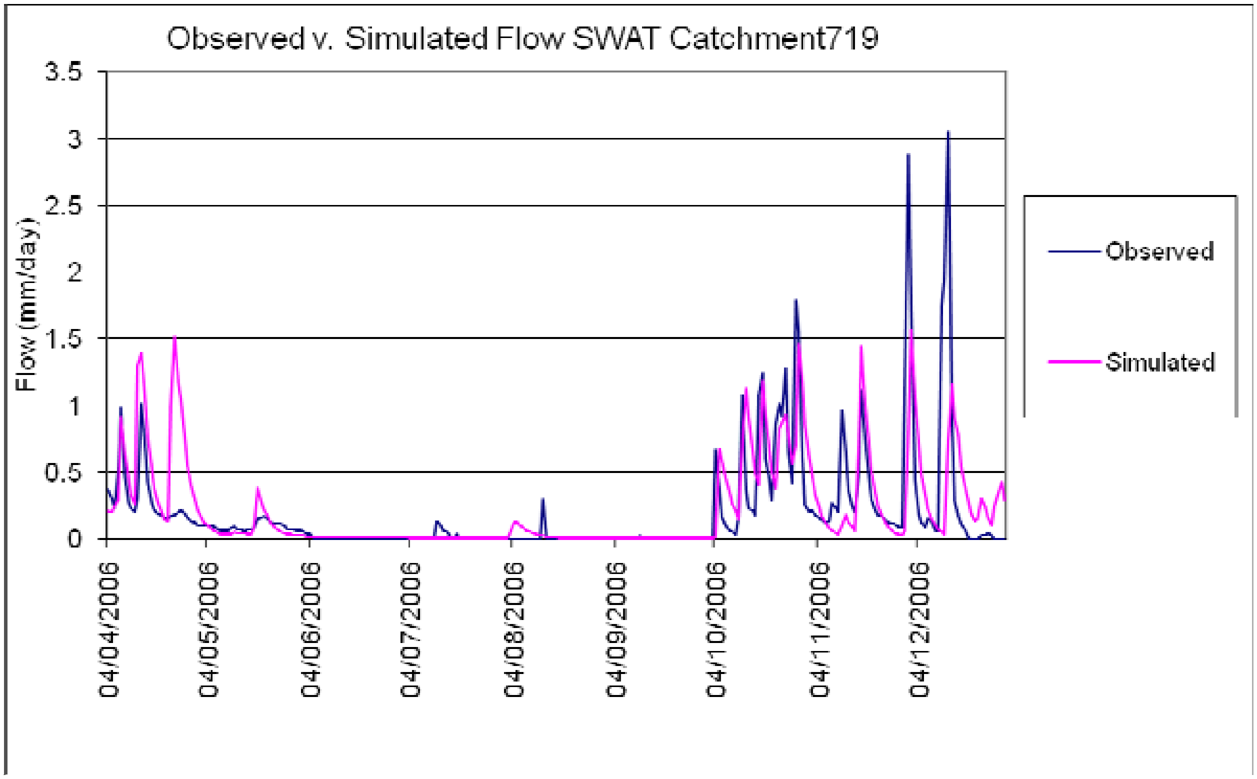
Existing SWAT models, developed as part of the Tier 1 water budget (see Mao and McKague, 2007) were used for developing new models using the Guelph All Weather Sequential Event Runoff model (GAWSER). This process included updating in order to include climatic data for 2007, and measured baseflow values for the Goderich-Bayfield Gullies and Goderich subwatersheds.

Hydrologic Response Units (HRUs) were developed in the GAWSER modeling package based on land cover, soils, and geology. HRUs are shown on Map 8. Previously defined Tier 1 catchments (SWAT catchments) were modeled and hydrologic parameters were assigned based on parameters developed from SWAT Catchment 719, for which continuous data was available for the period 2005-2006, inclusive (Paliouras and Mao, 2006). Figure 1 shows the results of the modeled versus observed simulated daily flows for SWAT catchment 719 for the period. Hydrologic parameters developed from this calibration were then used to extrapolate conditions in the remaining SWAT catchments.

Spot flow measurements collected in 2007, 2008 and 2009 were incorporated to further refine models. Most spotflow data were selected to identify baseflow (or low flow) conditions, and as a result they provide lower limits of flow within a catchment, rather than provide data for calibration of the model. Additionally, the temporal and spatial scarcity of data doesn’t allow them to be used to calibrate the models.

GAWSER models were then used to develop groundwater supply and reserve estimates as outlined below for each of the previously delineated SWAT catchments located in Map 3. Appendix B show the results of the fully calibrated GAWSER model for the Goderich-Bayfield Gullies and Goderich subwatersheds for the period 1950-2007, respectively.

Figure 1. Simulated versus observed flows for the SWAT catchment 719



4.1 RECHARGE ESTIMATE

GAWSER modeling results were considered by the Peer Review Committee to provide the most reliable estimate of recharge for use in the Tier 2 water quantity stress assessment. Recharge numbers for individual SWAT catchments are shown in Appendix B. GAWSER derived recharge values at the Subwatershed scale are shown in Table 6.

5.0 CONSUMPTIVE GROUNDWATER DEMAND BY SUBWATERSHED

Consumptive use estimates developed for the Tier 1 water quantity stress assessment were re-evaluated as part of the Tier 2 water budget process. This activity focused on the PTTW data, which is considered the least accurate of the water usage information, due to the lack of reported takings for a majority of permit holders. Where actual takings were not available, reasonable estimates were developed, details are included below in Section 5.2.

5.1 MUNICIPAL WATER USE

Municipal water takings were based on annual average values supplied by municipal water system operators. Water takings are available for 2009 on a monthly basis, and with long term averages based on reported municipal pumping rates for the years 2001-2009 shown below in Table 2. Monthly maximum pumping rates were developed based on the 2009 year, for which monthly data were available.

Table 2. Municipal Pumping rates in the Goderich and Goderich-Bayfield Gullies Tier 2 subwatersheds in m^3/day.

System	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Avg*	Avg**
S.A.M	13.9	14.2	12.2	10.6	11.4	9.0	9.6	10.7	11.0	10.0	8.2	11.1	11.0	9
Vandewetering	7.6	8.3	7.7	9.4	13.6	14.8	15.0	16.4	13.6	8.4	8.0	7.1	10.3	9
Kelly	14.0	11.6	13.1	14.9	18.8	20.6	20.3	24.4	22.8	15.3	15.0	15.0	17.2	22
McClinchey	5.5	5.4	4.7	5.0	6.8	9.2	9.6	9.6	9.7	6.6	4.9	4.9	6.8	8
Century Heights	140	129	146	138	153	114	97	147	135	101	103	115	129	160

*2009 Average Daily Taking. **Average daily taking for 2001-2009

Municipal pumping rates were lower than the long term average for 2009 due to an unusually wet summer season. Therefore, the long-term average values for 2001-2009 were used for the purposes of estimating consumptive water use. Any reduction in these pumping rates are unlikely to impact water quantity stress calculations due to the low pumping rates relative to other takers (see Table 6)

All municipal wells are exploiting the deep bedrock aquifer, and discharging via on-site septic systems to shallow, surficial deposits. As the bedrock aquifer is confined in the study area, no water is returned to the source, therefore the consumptive factor for municipal supplies was determined to be 1 (100% of municipal water takings were determined to be consumptive).

5.2 PERMITTED USE

A study was completed in 2006 in order to attempt to determine actual takings for PTTW holders in the area (Luinstra, 2006). The results of this work have been included in the calculations of consumptive surface water use for the study area. For the Tier 1 water quantity stress assessment, the best available water taking data (actual, estimated average, maximum permitted) was used to estimate permitted amounts, which were subsequently adjusted using the consumptive factor outlined in the MOE guidance document (2006).

For the Tier 2 water quantity stress assessment, it was felt that further confirmation of takings was appropriate for those permits located within the Goderich-Bayfield Gullies and Goderich subwatersheds. Accordingly, a request was made to the Ministry of Environment, the regulator of permitted takings, to provide this information for all permits which had no information on actual takings. Data from the Water Taking Reporting System (WTRS) was used to estimate actual takings where such information was available.

Permit holders were contacted and requests made to include actual takings into the water budget calculations. Accordingly, consumptive water demand is based on actual takings, or where that information was not shared, with estimated values from WTRS or without any other data on permit requirements.

Seasonal water takings, for which no actual data were available, were adjusted to exclude pumping from periods when they are not expected to be pumping. The only seasonal usage is associated with a Golf Course and associated Campground for which actual water takings were obtained. Table 3, below shows permitted users with their associated water takings, and consumptive use factors.

Table 3. Permitted water use in the Goderich and Goderich Bayfield Gullies Subwatersheds in m^3/day.

Permit	Operator	Max	Avg	Permitted Rate	Method	Aquifer	Cons Factor
03-P-1012	Forrest Estates Homes	100	100	200	WTRS	Bedrock	1
03-P-1114	Bluewater Golf Club	52.2	28.6	1102	Actual*	Bedrock	1
71-P-0129	Pine Lake Campground	193	193	589	Estimated	Bedrock	1
94-P-0031	Lighthouse Cove	45	45	259	Estimated	Bedrock	1
5161-5RPS27	Princess Huron Resort	98	98	544	Estimated	Bedrock	1
93-P-0018	Sifto Evaporator plant	16353	16353	26512	Actual**	Bedrock	1

*reported for 2003-2006 ** reported 2008 values

All permitted users with the exception of the Sifto Evaporator plant are in the Goderich-Bayfield Gullies subwatersheds. All takings within the Goderich-Bayfield Gullies, with the exception of the Bluewater Golf Club, were considered to be year round as they are mobile home developments with significant year round populations.

The Sifto Evaporator plant is the dominant permit holder for the Goderich Tier 2 Subwatershed. This plant exploits the bedrock aquifer to provide cooling water for a brine evaporation facility. Actual data from 2008 was provided by the permit holder directly for this study.

All permitted takers are exploiting the deep bedrock aquifer, and discharging via on-site septic systems to shallow, surficial deposits, or directly into the Maitland River (in the case of the Sifto Evaporator Plant). As the bedrock aquifer is confined in the study area, no water is returned to the source, therefore the consumptive factor for permitted takings was determined to be 1 (100% of municipal water takings were determined to be consumptive).

5.3 NON-PERMITTED USE

Agricultural water usage was developed based on 2006 census data for the subwatersheds following methodology developed by de Loë (2001). Domestic usage was estimated based on the number of wells with records in each subwatershed, and assigning an estimated usage of 450 l/day for each well. Results of this analysis are included below in Table 4. Neither Domestic nor Agricultural water takings were adjusted seasonally, as it is assumed that pumping rates will be consistent throughout the year.

5.4 CONSUMPTIVE USAGE FACTOR

In the Tier 1 water budget, water use was reduced through the usage of a consumptive use factor. In both the Goderich-Bayfield Gullies and Goderich subwatersheds, no consumptive factor was applied to takings for the Tier 2 Water Quantity stress Assessment. The takings in this area are exclusively from a deep bedrock aquifer, which is confined by a minimum of 25 metres of fine-grained, low permeability sediments. It is, therefore, prudent to consider all water takings in these areas to be consumptive relative to the deep bedrock aquifer. As a result, the consumptive factor for permitted takings was determined to be 1 (100% of water takings were determined to be consumptive).

5.5 CONSUMPTIVE USE ESTIMATES

Table 4 shows annual consumptive water usage for the Goderich-Bayfield Gullies and Goderich subwatersheds. The dominant usage in the Goderich subwatershed is a large commercial water taking, while in the Goderich-Bayfield Gullies subwatershed Permitted use only comprises approximately 36% of the overall takings. Overall, the Goderich-Bayfield gullies have very low consumptive water use.

Table 4. Annual Rates of Consumptive Water Use (in M^3/day)

Subwatershed	Permitted use	Agricultural	Domestic	Municipal	Total Use
Goderich	16353	304	107	160	16924
God-Bay Gullies	477	688	110	48	1323

Monthly consumptive water use is necessary to complete maximum monthly water demand for the Tier 2 water budget exercise. Permitted water takings were adjusted seasonally based on anticipated peak monthly flows, developed from actual takings information or, if these data were not available, permit requirements. Domestic and agricultural takings were assumed to be constant over the year, and averaged for each month. Municipal takings from 2009 were used to develop maximum monthly pumping rates. Table 5 shows maximum monthly rates of consumptive water usage for the Goderich-Bayfield Gullies and Goderich subwatersheds.

Table 5. Maximum Monthly Rates of Consumptive Water Use (in M^3/day)

Subwatershed	Permitted	Agricultural	Domestic	Municipal	Total Use
Goderich	16353	304	107	153	16917
God-Bay Gullies	500	688	110	64	1362

It should be noted that no seasonal permit holders were identified within the Goderich subwatershed, and therefore the resultant maximum monthly water takings are identical to the annual rates.

6.0 TIER 2 WATER BUDGET

A summary of the Tier 2 water budget values for the Goderich-Bayfield Gullies and Goderich subwatersheds, including precipitation (PPT), evapotranspiration (ET), Runoff, Recharge, Groundwater flux in and consumptive use are shown below in Table 6. Precipitation, evapotranspiration, Runoff and Recharge are derived from GAWSER modeling, groundwater flow in from the 6CA regional FeFlow model, and consumptive use base d on estimates developed for the Tier 2 water budget.

Table 6. Tier 2 water budget for the Goderich-Bayfield Gullies and Goderich subwatersheds. All values expressed as equivalent mm/year of rainfall.

Tier 2 Subwat	PPT	ET	RUNOFF	Recharge	Gw Flow IN	Use
Goderich	1018	552	338	129	123	116
God-Bay Gullies	1023	543	338	142	153	5

7.0 TIER 2 STRESS ASSESSMENT

Groundwater quantity stress is developed from percent water demand values under several scenarios. Percent water demand is based on the following formula:

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

Where Q_{Demand} is the consumptive water usage, Q_{Supply} the groundwater supply, and $Q_{Reserve}$ groundwater reserve. Groundwater quantity stress is then developed based on the percent water demands according to the Technical Rules and is shown below in Table 7.

Table 7. Thresholds for Groundwater Quantity Stress (MOE, 2009)

Groundwater Quantity Stress	Average Annual Percent Water Demand	Monthly Maximum Percent Water Demand
Significant	> 25%	> 50%
Moderate	> 10%	> 25%
Low	0 – 10%	0 – 25%

Groundwater quantity stress is then evaluated according to a number of different scenarios, including:

1. Existing Conditions
2. Planned Systems
3. Future Usage Conditions
4. Drought Conditions.

If a subwatershed is considered under moderate or significant stress under any of these scenarios, the subwatershed are recommended for a Tier 3, local-area water budget study to ensure the municipal supplies located within it are able to supply adequate quantities of water for the present and future.

7.1 GROUNDWATER SUPPLY

An estimation of the amount of groundwater available to supply a subwatersheds' groundwater users is determined as a summation of groundwater recharge and the influx of groundwater into the subwatershed. The outflux of groundwater from a subwatershed is not considered in the development of the groundwater supply term (MOE, 2009).

The percent water demand can then be calculated as both average annual and average monthly conditions for current and future scenarios. For this Tier 2 analysis, aquifer storage is not considered and as such the water supply terms for the subwatersheds are assumed to be consistent on an average annual basis.

Groundwater flux through the system was further developed from the 6 CA FeFlow model. Tier 2 subwatersheds were refined and extracted and flux values determined using continuous boundary flux within the FeFlow water budgeting module.

For the study area GAWSER modeling results were considered to be the most accurate reflections of actual recharge conditions, given the sensitivity of their calibration when compared with the FeFlow results. GAWSER was considered to be the more robust of the two surface water models (i.e. in comparison with SWAT) in calculating recharge. As a result, GAWSER-derived recharge values were used for the developing groundwater supply estimates for the Tier 2 subwatersheds.

7.2 GROUNDWATER RESERVE

The groundwater reserve for Tier 2 analysis is determined by estimating the reserve quantity as 10% of the calculated water supply for the subwatershed.

7.3 EXISTING CONDITIONS

Groundwater quantity stress is developed for Tier 2 subwatersheds based upon existing pumping rates and modeled groundwater and surface water values.

Tier 2 groundwater quantity stress assessment under existing conditions was developed for the Goderich-Bayfield Gullies and Goderich subwatersheds incorporating the results of the Tier 2 water budget and is shown in Table 8, below and graphically in Map 11.

Table 8. Tier 2 annual groundwater quantity stress assessment for the Goderich Bayfield Gullies and Goderich subwatersheds. All values expressed in m^3/day

Tier 2 Subwat	GW IN	Recharge	Supply	Reserve	Cons. Use	% Water Demand	Stress
Goderich	17921	19847	37768	3777	16917	50	High
God-Bay Gullies	38960	34241	73201	7320	1323	2	Low

GW IN – Groundwater flux into subwatershed; Cons. Use – Consumptive Groundwater use

Table 9. Tier 2 monthly maximum groundwater quantity stress assessment for the Goderich Bayfield Gullies and Goderich subwatersheds. All values expressed in m^3/day

Tier 2 Subwat	GW IN	Recharge	Supply	Reserve	Cons. Use	% Water Demand	Stress
Goderich	17921	19847	37768	3777	16924	50	High
God-Bay Gullies	38960	34241	73201	7320	1362	2	Low

GW IN – Groundwater flux into subwatershed; Cons. Use – Consumptive Groundwater use

Tier 2 water quantity stress was developed under maximum monthly conditions for both Tier 2 subwatersheds and is shown in Table 9. Due to the relatively low amount of water taking in the Goderich-Bayfield Gullies, maximum monthly percent water demands are not changed from annual values. No seasonal water takings were identified in the Goderich subwatershed.

Based on the Tier 2 groundwater quantity stress assessment a Tier 3, local area water budget is required for the Goderich Tier 2 subwatershed. The relatively low water demand for the Goderich-Bayfield Gullies indicate that it is not under water quantity stress. However, the Goderich-Bayfield Gullies subwatershed must be evaluated under both Future Use and Drought conditions in order to assess any potential stress.

7.4 PLANNED SYSTEMS

There are no planned systems for either the Goderich-Bayfield Gullies or Goderich Tier 2 subwatersheds.

7.5 FUTURE USE CONDITIONS

Technical rules require that a future use scenario be undertaken for all Tier 2 subwatersheds not already identified as being stressed under existing conditions. In order to complete this, population growth projections based on official plans are used to estimate future water consumption, and are evaluated based on present day water supply and reserve estimates.

For the Goderich-Bayfield gullies, future population projections range from 20-35% for the 20 year time period (Lakeshore Class EA, 2010). Given the relatively low initial population, the impacts of future growth may have dramatic implications on the water quantity assessment. In order to evaluate this and be conservative, present water use was increased by 35% and water demand estimates produced, shown in Table 10.

Table 10. Water Quantity Stress for the Goderich-Bayfield Gullies based on 35% increase in water use. All values expressed in M^3/day, unless otherwise indicated.

Tier 2 Subwat	GW IN	Recharge	Supply	Reserve	Cons. Use	% Water Demand	Stress
God-Bay Gullies	38960	34241	73201	7320	2423	4	Low

These future water use conditions are highly conservative, as it is not expected that future population growth would require a 35% increase in water takings. Therefore, under extreme future use scenarios, no water quantity stress is anticipated for the Goderich-Bayfield Gullies subwatershed.

7.6 DROUGHT CONDITIONS

Technical rules require that a drought scenario be undertaken for all Tier 2 subwatersheds not already identified as being stressed under existing conditions. The intention of the analysis is to determine if a prolonged period of drought could result in a drop in water levels that could interfere with the operation of municipal wells. This is completed by simulating water levels under a drought scenario, and comparing the drop in water levels in the aquifer and with the available drawdown for each municipal well.

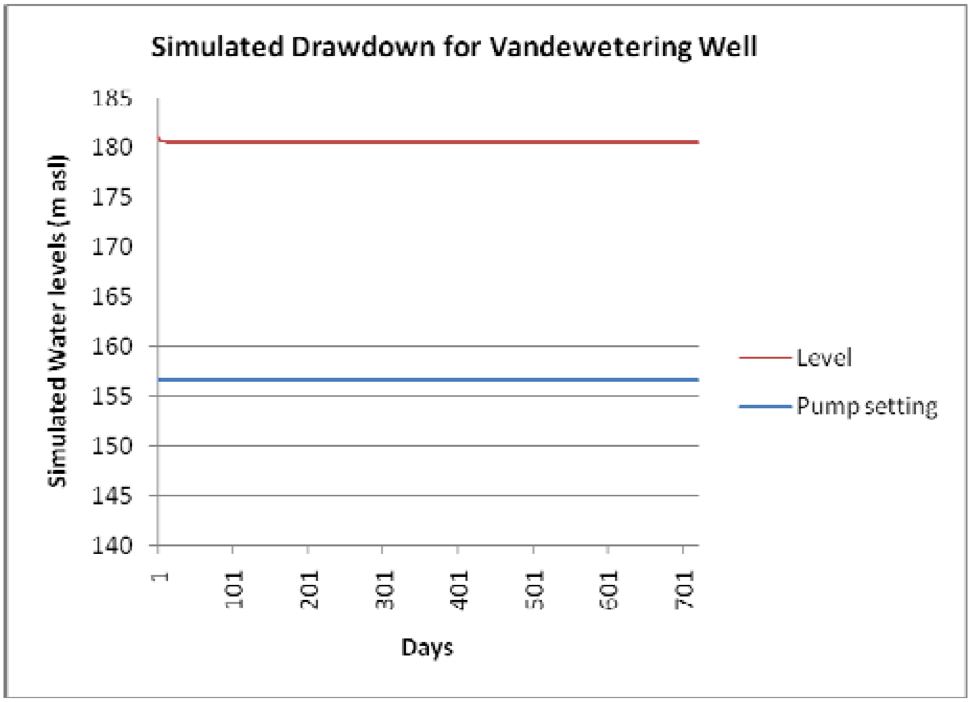
In order to complete this analysis, the Feflow model for the Goderich-Bayfield gullies was run in transient mode for a period of 2 years with no recharge. This analysis is thought to represent an extreme drought event. Initial water levels for each municipal well were based on simulated, steady-state water levels. Pumping was assumed to be constant in all municipal wells.

If the 2-year drought scenario results in a municipal water well reaching a critical operational threshold where it is unable to meet municipal water demand, then an evaluation of a 10-year drought scenario using an observed 10-year period of record must be undertaken.

7.6.1 VANDEWETERING WELL

The Vandewetering well was constructed in 1989 and services a residential area with approximately 24 connections. The well is a nominal 150mm diameter well completed to a depth of 42.1m into the bedrock aquifer and is cased to a depth of 27.1m. Steady-state modeled water level of 181.2 masl was derived from the 6CA FeFlow model under constant pumping conditions. The well was established as an observation point and run in a transient mode using the Goderich-Bayfield Gullies extracted model for a two year (730 day) period under transient conditions with no recharge. Figure 2 below, shows the water levels drop initially approximately 60cm under these conditions.

Figure 2. Results of the 2-year drought scenario simulation for the Vandewetering well derived from the Goderich-Bayfield Gullies groundwater model.

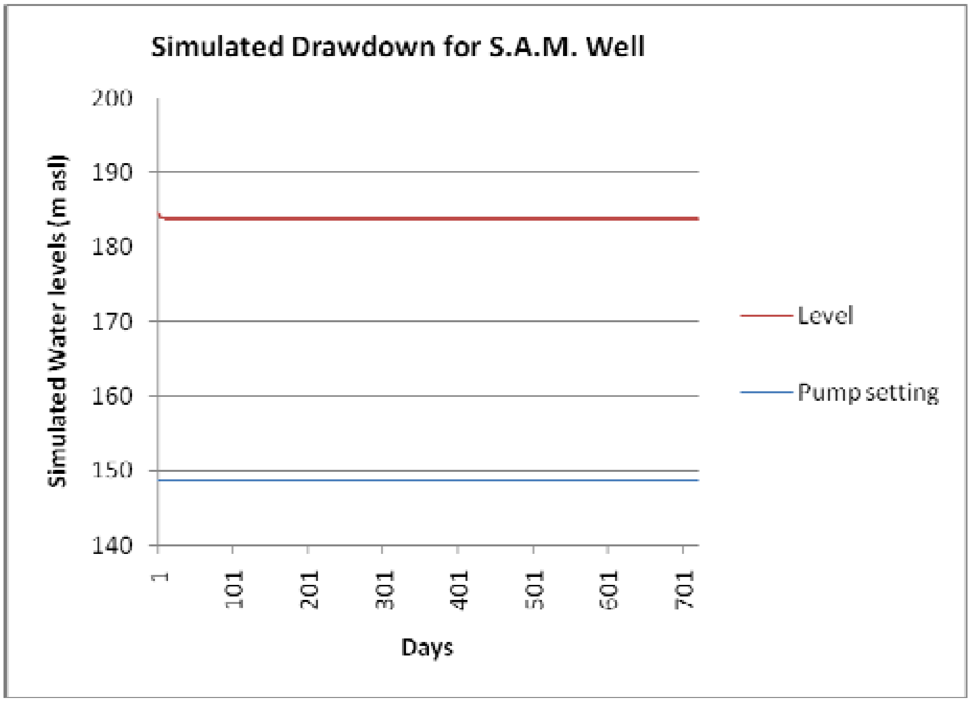


These results are consistent with the conceptual hydrogeology of the area, as the Vandewetering well is completed into the confined bedrock aquifer, which is dominantly recharged outside of the assessment area. Based on the simulated drop in water levels during the 2-year drought conditions, ample drawdown remains available for the well.

7.6.2 S.A.M. WELL

The S.A.M. well was constructed in 1979 and services a residential area with approximately 14 connections. The well is a nominal 150mm diameter well completed to a depth of 59.4m into the bedrock aquifer and is cased to a depth of 42.7m. A steady-state modeled water level of 184.6 masl was derived from the 6CA FeFlow model under constant pumping conditions. The well was established as an observation point and run in a transient mode using the Goderich-Bayfield Gullies extracted model for a two year (730 day) period under transient conditions with no recharge. Figure 3 below, shows the water levels drop approximately 80cm in the first two weeks of the simulation under these conditions, and no further drop in water levels are noted.

Figure 3. Results of the 2-year drought scenario simulation for the S.A.M. well derived from the Goderich-Bayfield Gullies groundwater model.

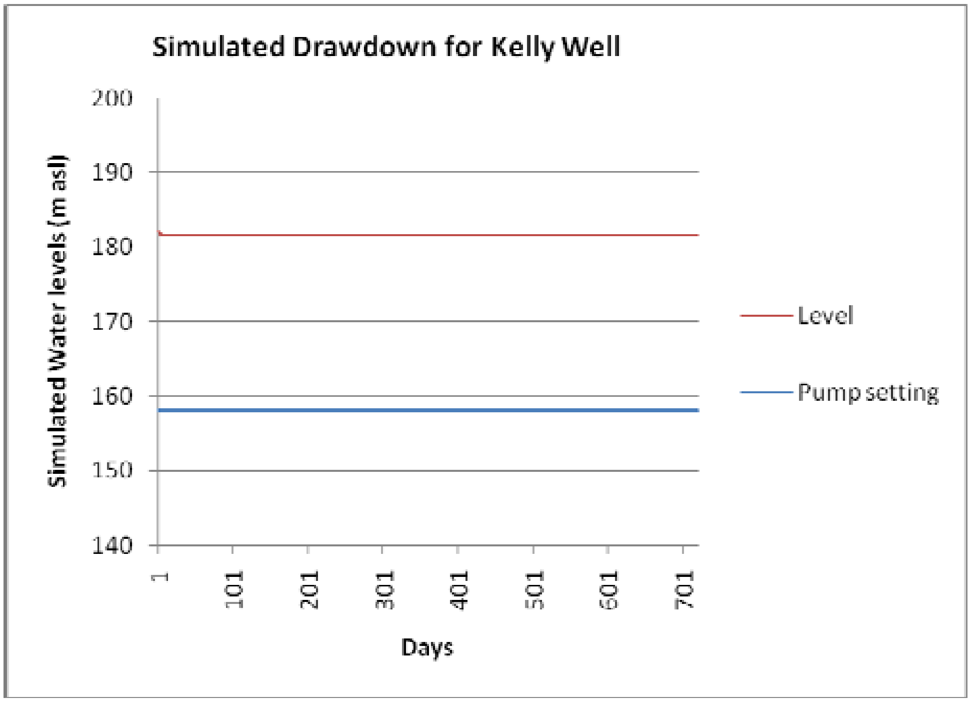


These results are consistent with the conceptual hydrogeology of the area, as the S.A.M. well is completed into the confined bedrock aquifer, which is dominantly recharged outside of the assessment area. Based on the simulated drop in water levels, ample drawdown remains available for the well.

7.6.3 KELLY WELL

The Kelly well was constructed in 1981 and services a residential area with approximately 24 connections. The well is a nominal 150mm diameter well completed to a depth of 45.7m into the bedrock aquifer and is cased to a depth of 31.7m. A steady-state modeled water level of 182.1 masl was derived from the 6CA FeFlow model. The well was established as an observation point and run in a transient mode using the Goderich-Bayfield Gullies extracted model for a two year (730 day) period under transient conditions with no recharge. Figure 4 below, shows the water levels drop approximately 60cm within the first 2 weeks of the simulation under these conditions, and no further drop in water levels are noted.

Figure 4. Results of the 2-year drought scenario simulation for the Kelly well derived from the Goderich-Bayfield Gullies groundwater model.

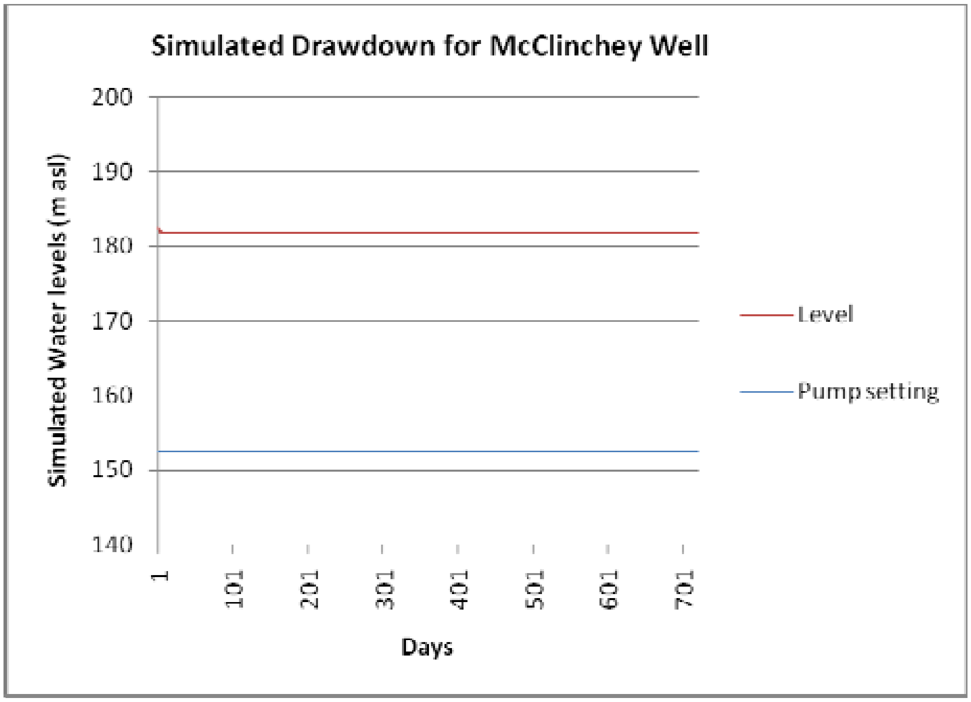


These results are consistent with the conceptual hydrogeology of the area, as the Kelly well is completed into the confined bedrock aquifer, which is dominantly recharged outside of the assessment area. Based on the simulated drop in water levels, ample drawdown remains available for the well.

7.6.4 MCCLINCHEY WELL

The McClinchey well was constructed in 1967 and services a residential area with approximately 15 connections. The well is a nominal 150mm diameter well completed to a depth of 43.3m into the bedrock aquifer and is cased to a depth of 30.2m. A steady-state modeled water level of 182.4 masl was derived from the 6CA FeFlow model. The well was established as an observation point and run in a transient mode using the Goderich-Bayfield Gullies extracted model for a two year (730 day) period under transient conditions with no recharge. Figure 5 below, shows the water levels drop approximately 60cm within the first 2 weeks of the simulation under these conditions, and no further drop in water levels are noted.

Figure 5. Results of the 2-year drought scenario simulation for the McClinchey well derived from the Goderich-Bayfield Gullies groundwater model.



These results are consistent with the conceptual hydrogeology of the area, as the Kelly well is completed into the confined bedrock aquifer, which is dominantly recharged outside of the assessment area. Based on the simulated drop in water levels, ample drawdown remains available for the well.

7.6.5 SUMMARY OF DROUGHT SCENARIO RESULTS

Under extreme conditions of no recharge for a two (2) year period, simulated water levels across the subwatershed were reduced less than 1.0 metre. These conditions were compared with available drawdowns in all municipal wells in the Goderich-Bayfield Gullies subwatershed and the results are shown in Table 11. Based on the results of the 2-year drought scenario results, there is no requirement for a 10-year drought scenario.

Table 11. Available drawdown in municipal wells and observed reductions in water levels in the bedrock aquifer under 2-year, extreme drought conditions.

Well	Pump level (masl)	Steady-state water level* (masl)	Available Drawdown	Drought scenario water level (masl)	Modeled head reduction
S.A.M	148.6	184.6	36 m	183.8	0.8 m
van de Wetering	156.7	181.2	24.5 m	180.6	0.6 m
Kelly	158.1	182.1	24 m	181.5	0.6 m
McClinchey	152.4	182.4	30 m	181.8	0.6 m

*under constant pumping conditions

Given the extremely high available drawdowns in the Goderich Bayfield gullies subwatershed, interference with operational capacity of municipal wells under drought conditions is unlikely under extreme drought conditions.

8.0 UNCERTAINTY

Uncertainty in the Water Budget process is closely tied to the data sources and models that have been utilized to develop the important data. In the case of the Goderich-Bayfield Gullies subwatershed, potential uncertainty exists due to the widely differing values for recharge which have been developed through separate groundwater and surface water modeling processes. In order to develop an estimate of the potential change in water quantity stress due to changes in water flux, two scenarios were developed.

Firstly, in Table 12 a reduction of the water supply term by 20% was undertaken, in order to account for potential uncertainties in groundwater flux and recharge values.

Table 12. Water Quantity Stress Assessment with a 20% reduction in Water Supply.

Tier 2 Subwat	GW IN	Recharge	Supply	Reserve	Cons. Use	% Water Demand
Goderich	17921	19847	30214.4	3021	16924	62
God-Bay Gullies	38960	34241	58560.8	5856	1346	3

Table 13. Water Quantity Stress Assessment with a 20% increase in Water Supply.

Tier 2 Subwat	GW IN	Recharge	Supply	Reserve	Cons. Use	% Water Demand
Goderich	17921	19847	45321.6	4532	16924	41
God-Bay Gullies	38960	34241	87841.2	8784	1346	2

Secondly, a 20% increase in water supply was evaluated to account for potential uncertainties in water supply and is shown in Table 13.

Additionally, a 20% increase in consumptive water use was evaluated to account for potential uncertainties in water takings and is shown in Table 14.

Table 14. Water Quantity Stress Assessment with a 20% Increase in Consumptive Water Use.

Tier 2 Subwat	GW IN	Recharge	Supply	Reserve	Cons. Use	% Water Demand
Goderich	17921	19847	37768	3777	20309	60
God-Bay Gullies	38960	34241	73201	7320	1615	2

Under all scenarios, no changes in water quantity stress are noted. Therefore, uncertainty for the Tier 2 water quantity stress assessments is considered low.

9.0 TIER 2 SIGNIFICANT GROUNDWATER RECHARGE AREAS

Recharge values derived from GAWSER analysis for the Goderich-Bayfield and Goderich Tier 2 subwatersheds were incorporated into the delineation of significant recharge areas. GAWSER derived recharge values are dispersed to HRUs, and values for specific HRU's were included in the overall delineation of SGRAs in the area.

Recharge values for specific HRUs were averaged across each Source Protection Area, and those HRUs with recharge values greater than 115% of the average were identified as being groundwater recharge areas. All HRUs considered significant recharge areas in the Tier I water budget remain above the threshold of 115% of the average for the SPA, and all HRUs not considered significant recharge areas in the Tier I water budget remain below the threshold of 115% of the average for the SPA. For the Maitland SPA the threshold was established at 209mm/year, and the Ausable SPA, this threshold was established at 248mm/year, based on mean recharge rates of 182 mm/year and 216 mm/year, respectively.

Due to the likely presence of undocumented wells in most areas and the high uncertainty of local geological conditions, the Ausable Bayfield Maitland Source Protection Committee has resolved that a conservative approach by included in the delineation of SGRAs. Accordingly, hydraulic connection was inferred for all the identified HRUs with greater than 115% average recharge, and as such all were similarly considered to be Significant Groundwater Recharge Areas. Similarly, the ABMV SPC requested that all areas with greater than 115% average recharge be included, unless significant geological evidence suggested that they were not recharge areas. Map 12 shows the Significant Groundwater Recharge Areas, based on HRUs where annual recharge exceeds 115% of the average (mean) for the Tier 2 subwatersheds.

Although different models were used in the determination of recharge for Tier 2 subwatersheds, SGRA delineation for the Tier 2 subwatersheds were unchanged from the Tier 1 delineations.

10. SUMMARY AND CONCLUSIONS

A Tier 2 water budget was conducted for the Goderich and Goderich-Bayfield subwatersheds within the Ausable Bayfield Maitland Source Protection Region. This water budget utilized the existing 6CA three dimensional FeFlow groundwater model to develop groundwater in flux. The subwatersheds were modeled using the GAWSER software package and calibrated to existing spot flow measurements where possible.

GAWSER modeling results produced the most reliable estimates of recharge, which were combined with groundwater influx derived from the 6CA three dimensional FeFlow groundwater model to develop water supply and reserve (10% of supply) terms for the Percent water demand calculations.

Consumptive water use was estimated from existing Permits to Take Water based on takings submitted by permit holders and stored in the MOE's Water Taking Reporting System. Municipal, domestic and agricultural consumptive usage were estimated based on existing pumping information, number of domestic wells, and livestock populations, respectively.

The Tier 2 water budget stress assessment identifies the Goderich subwatershed as being under significant groundwater quantity stress, largely the result of a large commercial taking in the watershed. Groundwater quantity stress for the Goderich-Bayfield Gullies subwatershed was low, primarily due to the low consumptive takings in the area.

Future use and drought scenarios were completed for the Goderich-Bayfield Gullies subwatershed and did not indicate any potential for interruption of future supplies due to water takings.

10.1 RECOMMENDATIONS FOR FURTHER WORK

A Tier 3 (local area) water budget is required for the Goderich subwatershed, and the Century Heights Municipal Water system. This area has been identified as being under significant groundwater quantity stress, and more detailed work is required in order to assess the impacts of large commercial water takings on the long-term viability of the Century Heights system.

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