Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	Dr. David Rudolph	8	Comment	P.8. The concept of two separate models being developed for the Tier 3 Assessment of the Region of Waterloo area and the Cambridge area is introduced here and is a fundamental aspect of the work. It would be valuable to the reader to explain where the models overlap in areal extent and how the consistency was maintained as the calibration process was followed. How was the consistency between the two models maintained? Are the solutions where the models overlap compared in some fashion? This just needs to be explained briefly up front as it is returned to later in the text.	Text was added to section 1.2.4 to note that the layer structure and hydraulic conductivity distribution from the calibrated Cambridge Model was applied in the Regional Model to ensure consistency between the two models. Additional checks were completed to ensure consistency between the Regional and Cambridge Models (as well as the Guelph Model) and are documented under separate cover.
Main Report	Dr. David Rudolph	40	Comment	P. 40. The calibration process involves an initial steady state calibration, which provided an initial condition for the transient model which was subsequently calibrated to transient data. The point is made that the new information from the transient calibration is incorporated into the steady state model for consistency. In fact the text states that this is to ensure the steady-state calibration is maintained, which is a bit confusing. The transient calibration parameters are fed back into the steady-state model and the simulations are redone again checking to see the validity of the fit. In practice this can result in very different results from the steady state model depending on how much the parameters change based on the transient results. This process should be explained in a bit more detail to illustrate how the combined calibration was assessed overall.	Text added to provide additional information. In general, the model parameters from the steady-state calibration were input into the transient calibration. Storage and hydraulic conductivity parameters were iteratively updated to improve the model-simulated fit to transient water level hydrographs. The updated parameter values from the transient calibration were then applied to the steady-state model and an iterative process was undertaken until we reached a suitable fit to both calibration datasets with an emphasis on matching the higher quality data.
Main Report	Dr. David Rudolph	44	Comment	P. 44. In Figure 4-1, the western boundary condition for the Cambridge model appears to pass through several pumping wells and is close to several other wells. This boundary is not explained in enough detail in the text and it would appear that the wells would significantly influence the boundary condition. This just needs to be clarified.	The western boundary of the Cambridge model coincides with the Grand River, a regional groundwater divide. The Woolner well field lies on the western side of the Grand River, so is not within the Cambridge Model domain. The municipal wells draw water from shallow overburden aquifers that are hydraulically connected to the Grand River, so at a regional scale, the impact of pumping from these wells will be localized and will not impact the Cambridge well fields, located several kilometers away. Text was updated in the report to clarify this.
Main Report	Dr. David Rudolph	47	Comment	P. 47. The text infers that a simplification in the relative K and water content relationships were used for the simulations in the unsaturated zone rather than using the van Genuchten parameters and Richard's equation. The text states that the vadose zone flow was modelled with the VG parameters and the Richard's equation, which does not seem to be the case. This section is a bit inconsistent and should be reworded.	Richard's equation was used to simulate flow in the vadose zone. However, a simplified constitutive relation was adopted to make the analysis feasible. This is referred to as the pseudo-constitutive relation approach. The Modified-VG model is selected for the unsaturated flow simulation, but the parameters that define the Modified-VG model are selected so that a simple linear relationship between the hydraulic conductivity and the saturation of the aquifer is specified. This approach allows the model to simulate the water table without the convergence challenges of a saturated flow model or the computational burden of a variably saturated model. We have some technical notes on the pseudo-constitutive relation if the review is interested in more details.
Main Report	Dr. David Rudolph	49	Comment	P. 49. It is not clear from the text if the specified head values assigned to the surface water features were constant values in time or change over the annual cycle. This should be stated. In the Cambridge model, how where the pumping wells that sit along the border incorporated as a boundary condition? (also on P. 52)	The specified heads assigned to the surface water feature are constant values. The regional-scale calibration analyses considers steady-state conditions; any specified heads implicitly represent time-averaged values. For the transient well field-scale calibration analyses, the boundary conditions are constant as the analyses consider only the transient effects of pumping from a particular well field. Text add to section 4.3.5.2 to clarify. For the western boundary of the Cambridge model, pumping from the Woolner well field was not simulated in the model as the wells were not operating during the 2003 calibration period. For applications involving the Cambridge bedrock well fields, it is not necessary to represent explicitly pumping from the wells adjacent to the Grand River in this area, as conditions in the overburden are controlled by the river. Text add to section 4.3.5.2 to clarify.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	Dr. David Rudolph	50	Comment	P. 50. It is not clear what is meant by the fact that the river stage decreases monotonically in the downstream direction or why this is so critical. Does this mean that the elevation of the surface water in the river decreases downstream so that the gradient remains to generate flow in the downstream direction? As flow increases downstream, so does river stage relative to the depth of flow normally.	Text reworked and additional detail added: The surface water boundary condition was represented in the model by assigning a specified head (Type I) boundary to each node along each river reach. The specified head for each boundary was equal to the estimated surface water elevation at that location, and this was estimated using the most detailed DEM available for the Region (AquaResource 2009d). In some cases, the elevation estimated using the DEM was inconsistent with the centre line of the modelled stream channel. This caused localized issues such as abrupt spikes in elevation to appear in the profile along the river; the river stage elevation profile should decrease in the downstream direction. To identify and correct these issues, the stream network was inspected in the GIS, and the river stage was manually corrected prior to being applied specified in the model was assigned to ensure the river stage decreased in the downstream direction. The data sources and approach used to define the location and nature of the surface water features within the Regional Model are outlined in detail in Appendix G (AquaResource 2011e).
Main Report	Dr. David Rudolph	51	Comment	P. 51. Were the boundary conditions in the Cambridge model, along the segments that run through the regional model along the western boundary, assigned based on the simulated heads from the regional model or from piezometric data as inferred in the text? It would seem that the values should be the same in both models and it is not clear that they would be with this approach.	Where the model is aligned along the Grand River, groundwater level elevations are controlled by the Grand River. The river is represented with specified-head conditions. Consistent levels were specified for the Grand River in all of the models, ensuring that groundwater level elevations along the boundary are consistent. Along the northwestern boundary sections that are not aligned with the Grand River, specified-head conditions are assigned using results extracted from the Guelph Tier 3 model as this was considered the best available information in this area when the model was being built. The groundwater level elevations along the boundary were updated periodically in the Cambridge modelling as the Guelph modelling progressed, to ensure consistency between the two analyses. Consistent hydraulic parameters were assigned in the areas where the Guelph and Cambridge models overlapped, effectively yielding a "seamless" integration of the two models. The effects of pumping in Cambridge do propagate north of the Cambridge model boundary and the effects of pumping in Guelph propagate south of the Guelph. The overlap between the two models ensures that these effects are accounted for. Text added to section 4.3.5.2 to clarify why the Guelph Model heads were used and not those in the Regional Model (which had not been calibrated at the time of construction of the Cambridge Model).
Main Report	Dr. David Rudolph	53	Comment	P. 53. There is a comment that a recharge threshold of 1m was incorporated into the model. How was this selected and justified? It seems like an artificial control on recharge distribution that may be insignificant but should be justified.	Text added to provide additional information: In several of these depression focused recharge areas the recharge was characterized to be greater than 5 m; however, and even as high as 16 m. Such high average annual recharge rates were not substantiated with field observations or measurements. As such, an upper limit of 1 m was applied to be conservative and. This helped to ensure volumes of water sourced from these areas would not result in misleading water budget results.
Main Report	Dr. David Rudolph	57	Comment	P. 57. The storage coefficients for the aquitards should also be provided along with their source.	Storage values for aquitards added as requested.
Main Report	Dr. David Rudolph	63	Typographical Error	P. 63. There may be a typo here as the perfect fit line is a solid line and the 5m lines are the dashed lines I believe.	Yes, comment acknowledged and the text was updated.
Main Report	Dr. David Rudolph	68	Comment	P. 68. The discussion of the manual reduction in recharge from some stream lengths to the aquifer raises the question of how significant this would be to the overall solution. This appears to be somewhat random to reduce recharge from specific stream lengths and this should be justified or explained a bit more.	Text added to provide additional information: Under such conditions the boundary condition will supply the amount of water (with no upper limit) to the subsurface necessary to maintain its specified value. During the calibration process, stream segments that were simulated to be recharging the aquifer were scrutinized and given a low conductance value, such that the volume of water recharging along streams is minimal and does not negatively impact the overall water budget. This was done to help ensure that unreasonable amounts of water would not artificially enhance recharge to the underlying flow system.
Main Report	Dr. David Rudolph	205	Comment	P. 205. Overall, the recharge values appear very low compared to available field measurements and previous modelling attempts. It would be valuable to the reader to cast these values in context with historical estimates and possibly field data to illustrate that they indeed make logical sense. They just seem to be very low although this may be due to the urban extent and the amount of till at the surface. I think it just needs to be addressed.	Recharge rates applied in the Regional Model (by WHI) were informed by the calibrated GRCA GAWSER model, so the rates in that respect were consistent. Modelling of the Blair, Bechtel, Baumann watersheds in Kitchener (CH2M, 1995) estimated recharge rates ranging from 228 to 315 mm/yr which is consistent with the Tier Three rates in that area. The study team is not aware of field based studies of urban recharge in the Region but welcome the opportunity to review and compare to rates estimated in the current study. Recharge in general, but urban recharge rates are poorly understood and as such were examined in greater detail as part of the Risk Assessment uncertainty assessment and in the Water Budget document in the sensitivity analysis.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	Dr. Hugh Whiteley		Comment	Clarify in the index and text of the report that Chapter 4 deals with two Regional Models, each of regional extent, one for the surficial aquifers and one for the bedrock aquifers, and that each of these models had been created from the same data pool, consistency of representation was checked between the two models and with the Guelph model and boundary conditions were confirmed as consistent between the two models and the adjoining regional models (Guelph Model)	Additional text added to section 1.2.4 to clarify the two models and note the presence of the Guelph Model. Text was added to reference the memo that outlines the integration completed between the Cambridge, Regional and Guelph groundwater flow models.
Main Report	Dr. Hugh Whiteley		Comment	State clearly that the variation in recharge from earlier reports was within the variability inherent in the GAWSER estimates of recharge and that the difference between periods used resulted in differences in mean annual precipitation and this contributed to a change in recharge. It would be helpful to state the mean annual precipitation for the two periods in the table comparing recharge for the two periods.	Comment acknowledged and additional text was added to Section 4.3.5.4 in this regard, and to Section 5.1.1.1 (mean annual precipitation for the two calibration periods) as suggested.
Main Report	Ontario Ministry of Natural Resources		Comment	During the peer review meeting held in December 2012, much of the information provided in Section 6.1 Risk Assessment Thresholds appeared to be preliminary and would require further evaluation based on a review of more recent pumping rates and water use assessment. As such, we suggest: a) Remove Section 6.1 from the calibration report. b) Prepare a technical bulletin on the Safe Additional Drawdown with updated information. The information should be provided in tabular and graphic formats. The well graphs should be of sufficient length in time and should illustrate the physical characteristics of the well, pumping rates, water levels and the safe additional drawdown and water level. c) Prepare a technical bulletin on the allocated pumping rates of the wells. d) Prepare a technical bulletin on an updated water use assessment identifying both surface water and groundwater takings. Information should be provided on PTTW rates, WTRS reported rates, estimated rates and consumptive rates. e) Once the bulletins have been peer reviewed, the information can be re-introduced into the Local Area Risk Assessment Report.	Section 6 (Risk Assessment Thresholds) was removed from the report and added to the Risk Assessment Report. The Safe Additional Drawdown information was moved to the Risk Assessment Report and Appendix B and G of that report. Hydrographs to support the safe additional drawdown values were added to Appendix F of the Risk Assessment Report. The Allocated Pumping rates were discussed in the Risk Assessment Report and information requested regarding the non-municipal PTTWs were added to Appendix E of the Risk Assessment Report.
Main Report	Ontario Ministry of Natural Resources		Comment	Section 5.1 Water Budget Components discusses the use and updating of the GAWSER model to establish the groundwater recharge input into the groundwater model. Section 5.1.1 discusses many improvements made to the Tier Two model for the Tier Three Local Area Risk Assessment. However, there is no discussion on how water use is addressed in the model. Please identify, from the total permitted surface water takings, the permitted takings that are represented in the model and discuss the significance of these takings and the influence that they may or may not have had on the calibration of the model.	As part of the Tier Three Assessment, the large consumptive surface water users that were interpreted to impact the hydrograph were included in the GAWSER model. These included the Region's surface water taking at Hidden Valley and the City of Guelph's Eramosa River taking. The total estimated surface water takings in the Central Grand Watershed were approximately 537 L/s, and 513 L/s of this was from the Region's Hidden Valley Intake. The second largest surface water taker is a dewatering permit (taking 17 L/s, which is interpreted as non-consumptive). As such, approximately 99% of total surface water takings were simulated in GAWSER for the Central Grand Watershed. In the Nith River Watershed, the surface water takings totaled 30 L/s, with 15 L/s being attributed to aggregate washing (largely non-consumptive). From a water budget perspective, total baseflow in the Grand and Nith watersheds are on the order of 1,000-2,000 L/s, so 15 L/s is not expected to impact the observed hydrograph. No permits to take water for surface water takings exist on the Mill Creek Watershed, and in the Speed River watershed, a total of 25 L/s are permitted for surface water with 22 L/s derived from temporary permits associated with dredging of Puslinch Lake. Based on all of the above, the most critical surface water takings were simulated in the GAWSER model and those that were not included are taking very little as compared to the river and creek baseflows. For additional information on water takings in the Grand, refer to this report: www.grandriver.ca/Water/2011_GRCA_WaterUse.pdf. Section 5.1 was updated to reflect this information.
Main Report	A.R. (Tony) Lotimer		Comment	The comments are mostly technical in nature; editorial comments are not included, although the report would benefit from an editorial review.	Editorial review was completed and the technical comments have been addressed in the document and this comment/ response matrix.
Main Report	A.R. (Tony) Lotimer		Comment	Table of Contents. Section 4.0 should be edited to include reference to the Cambridge Model. Currently, the reference is only to the 'Regional Flow Model'.	Section title updated from 'Regional Groundwater Flow Model" to "Regional and Cambridge Groundwater Flow Models". Introductory text to section is updated to distinguish between Regional Model and Cambridge Model and to avoid confusion when discussing the calibration at the regional (T3 Study Area scale).

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	A.R. (Tony) Lotimer		Figure Edit	Section 1.1 - Study Area Location. Elmira is not a city.	Agreed. Text updated accordingly.
Main Report	A.R. (Tony) Lotimer	5	Figure Edit	Section 1.2.2.2 (page 5). In the second paragraph reference is made to the Canagagigue Creek Assessment Area. This label is not used in Figure 1-1 of this report and appears to have been replaced with the Rural Well Field Characterization Area. I assume that the Canagagigue assessment area reference applies to the Tier 2 assessment, and not the Tier 3 assessment described in this report.	The Central Grand and Canagagigue Creek Assessment areas were added to Figure 1-1 of the report.
Main Report	A.R. (Tony) Lotimer		Comment	Section 1.2.4 – Region of Waterloo Tier Three Assessment Tools. Again, the table of contents should reflect the development of the two FEFLOW models, rather than one (see comment 1).	Comment acknowledged, and text updated as suggested.
Main Report	A.R. (Tony) Lotimer		Comment	Section 2.2.1 – Municipal and Non-Municipal Water Demand. The report states that municipal pumping records from the Region's SCADA system for the period from 2000 –2007 were used in the assessment. It may be useful to consider the more recent pumping records (2008 – 2012) in the next phase of the assessment, particularly with respect to the evaluation of the drawdown thresholds.	Agreed. As the study progressed, the pumping data up to 2011 was reviewed and used in the assessment. As such, the first bullet in section 2.2.1 was updated from 2007 to 2011 to reflect this.
Main Report	A.R. (Tony) Lotimer	30	Comment	Table 6 (page 30). It would be helpful if Table 6 could incorporate (or somehow cross-reference) the OGS layer names used in Table 2. Much of the discussion further on in the report makes reference to the OGS layer names and often does not use the words aquifer/aquitard in those references. It would also be helpful to include or reference the OGS layer names in Table 3 (page 14). These tables are key indicators of how the geologic/hydrostratigraphic layers from the conceptual models are incorporated into the numerical models.	Agreed. The OGS layer name acronyms were added to Tables 3 and 6 (from Table 2) as suggested.
Main Report	A.R. (Tony) Lotimer	41	Comment	Section 4.3 (page 41). Perhaps refer to the two models here (and elsewhere, if appropriate) as the 'Regional Model' and the 'Cambridge Model'.	Title for Section 4 revised from 'Regional Groundwater Flow Model' to 'Regional and Cambridge Groundwater Flow Models'. Other titles with use of the word 'regional' to refer to scale rather than a specific model have been revised as well to help avoid confusion.
Main Report	A.R. (Tony) Lotimer	42	Comment	Section 4.3 (page 42) – second bullet at top of page. It is not clear what is meant by the following statement: "the model layers from the Cambridge Model were mapped onto the appropriate Regional layers as shown in Table 6."	Text updated to clarify the meaning.
Main Report	A.R. (Tony) Lotimer	44	Comment	Section 4.3.1.2 (page 44). The chapter (section 4.0) and section numbering system in this chapter suggests that the Cambridge model is part of the Regional model, or that the Regional model is somehow at a different level than the Cambridge model in parts of the project reporting. There are important subwatersheds within the Cambridge model domain that are not referenced in the first sentence of paragraph 2 of section 4.3.1.2 (Cedar Creek, Blair Creek, Irish Creek, Moffat Creek). Are these features included as discrete surface water features in the Cambridge model? There is limited information provided in this section to support the statements in paragraph 2 concerning the Cambridge model boundaries.	The Regional and Cambridge modelling efforts were conducted in parallel. The Regional model is consistent with Cambridge model, as the interpretations developed from the detailed analyses of the Cambridge well fields were incorporated into the Regional model. Blair Creek, Irish Creek and Moffatt Creek are represented explicitly in the model, as are the tributaries of these creeks. Their watersheds occupy portions of the larger watersheds that are mentioned in the text. The Cedar Creek watershed lies just outside the southwestern boundary of the Cambridge model.
Main Report	A.R. (Tony) Lotimer	55 & 56	Comment - Additional Figures	Section 4.3.6 – Model Properties (pages 55 and 56). Section 4.3.6.1 (Hydraulic Conductivity Values) includes a series of five detailed cross-sections that show the modeled hydraulic conductivity distributions within the Regional model. These cross-sections are very useful and important as they illustrate how the model attempts to capture the complex hydrogeology. The problem is that there are no such cross-sections included for the Cambridge model. For the Cambridge model, the report includes statements such as "The available data suggested that hydraulic conductivity varied between hydrostratigraphic units and within them." This is not adequate for a project report of this scope/significance, and should be improved by providing examples of the hydraulic conductivity distributions in the Cambridge model using cross-sections, similar to those provided for the Regional model.	Cross-sections in the Cambridge Area have been added as requested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	A.R. (Tony) Lotimer		Comment	Section 4.3.6.1 (Hydraulic Conductivity Values). Figure 4-19 (St. Agatha to Erb Street FEFLOW cross section) includes hydraulic conductivity zones in some of the lower layers that have the appearance on the section as vertical windows. It is difficult to find evidence of these in the cross-sections included in the characterization report. Is there any other hydrogeological evidence or interpretations available to support the occurrence of these windows (other than to improve the model calibration in this area)?	This is a zone local to the St. Agatha Well Field and represents the open hole of an aggregate pit. This feature is represented with a high hydraulic conductivity to the top of ATB1 aquitard (Upper Maryhill Till) to allow movement of water (primarily vertical - recharge) to the underlying units. Note the saturated water table is in underlying AFB2 aquifer. (no change made in the text)
Main Report	A.R. (Tony) Lotimer	57	Reference Addition	Section 4.3.6.2 Storage Parameters. References should be included for the range of specific storage values and specific yield values reported on page 57.	Reference (Freeze and Cherry, 1979) added.
Main Report	A.R. (Tony) Lotimer		Comment	Section 4.4.2.2 Evaluation of Calibration in the Cambridge Model. This section is brief and does not provide details to support the approach taken for the Cambridge model calibration.	Section 4.4.4.2 has been expanded. In particular, more detailed descriptions of the qualification of high-quality and low-quality calibration targets are included.
Main Report	A.R. (Tony) Lotimer		Comment	Section 4.5 Groundwater Model Calibration. On page 61 this section starts out by stating that the calibration effort produced a "good" match to observed groundwater level elevations for all quality rankings of calibration targets. "Good" should be defined or perhaps changed to a "reasonable" match.	This section is intended to provide an overview of the overall calibration results for both the Regional model and the Cambridge model. In section 4.4.2.2, we did not define a descriptor for the quality of the calibration; however, according to the definitions presented for the Regional model, the overall matches to the high-quality targets are "good" for both models, and "reasonable" for the low quality targets. We have revised the text to read "reasonable match"
Main Report	A.R. (Tony) Lotimer		Comment	Section 4.5.2 Qualitative Calibration Assessment. At a number of places in this section it states that predicted or simulated groundwater level elevation contours "compare well" with observed water level elevation contours. This is an important outcome of the model development, and it might be useful if this finding could be supported with some more detail (perhaps reference to a few figures comparing simulated to manually interpreted contours for the shallow and deep aquifers to illustrate the point).	The comparisons to contours of observed groundwater level elevations were limited to the Regional model, and they were omitted in the Cambridge model as "observed contours" are a contradiction in terms (as all contours are interpreted). Interpreted contours were presented in the Tier Three well field characterization reports (Figures 7 and 8 of the Stantec well field assessment report for Cambridge Northwest and Figures 8 through 10 of the Golder Associates well field assessment report for Cambridge East. No corresponding contour maps were developed for Cambridge Southwest) and the corresponding results from the Cambridge model are presented in the water budget report.
Main Report	A.R. (Tony) Lotimer		Comment	There is no reference to the simulated groundwater level elevations for the overburden units in the Cambridge model. Was this examined or considered in the model calibration assessment?	The bedrock is the primary focus for the model calibration of the Cambridge model. The main water production zones for the Cambridge municipal wells are at the overburden/bedrock interface (Contact Aquifer) and in the deeper bedrock. With the exception of the Shades Mill area, aquifers in the Cambridge area are thin and discontinuous. The text was updated to note the qualitative focus was on the overburden for the Kitchener/Waterloo Well Fields and the bedrock in the Cambridge Well Fields. As we are comparing to contours there would be too few data points to facilitate a reasonable contour of observed data in the overburden in Cambridge, and the bedrock in the Regional Model.
Main Report	A.R. (Tony) Lotimer	72, 74, etc.	Comment	Erb Street Well Field Calibration (page 72, 74 and elsewhere). Some of the difficulties discussed with the calibration in the Erb Street well field area (discussed in both the report and at the meeting of December 19, 2012) seem to warrant more assessment and/or discussion, perhaps as part of the next phase of work. It may be helpful to consider the occurrence of very localized perching layers (shallow silt-clay and/or organics - muck) beneath the wetlands/surface water features in the area, if this has not already been done. Also, see comment 12 (above).	The calibrated model currently simulates a saturated water table condition at lower AFB2 (the production aquifer), and an overlying perched condition in this area. There are some other areas where additional work could be done to improve the representation of the perched water table in this complex area.
Main Report	A.R. (Tony) Lotimer	93 & 98	Comment	Steady-state Calibration Results – Mannheim East (page 93 and 98). The discussion of how the Laurentian & Borden wetlands are represented in the model is useful and informative. Did the model results indicate whether the wetlands were perched above the water table in the underlying layers?	The terms 'perched water table' and 'saturated water table' have been added to provide additional clarification. The model results cannot shed light into whether wetlands or perched or not; rather, the modeller needs to use nearby monitoring data to infer the function of the wetland and attempt to model it accordingly (potentially using boundary conditions). (No changes made)

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	A.R. (Tony) Lotimer	174	Comment	Elmira Well Field (E10) Calibration Results (page 174). A review of the original pumping test results for Well E10 may be helpful in improving upon or understanding the reason(s) for the poor calibration match noted for the Elmira well field. The well construction and testing report for Well E10, which contained some detailed pumping test information, is not referenced in the characterization report for the rural well fields and may have been overlooked in the assessment.	The text was clarified to note that the calibration is not necessarily poor; rather, the observed groundwater level elevations in the Elmira area are inconsistent with the pumping during the calibration period (2008). In general, the majority of the observed groundwater level elevations in the Elmira area were collected prior to 1993, when the municipal well in Elmira were pumping on average 3,800 to 9,300 m3/d. The wells were shut down in 1990 for water quality reasons, and few groundwater level elevations (domestic or otherwise) were collected after that time. As such, the 2003 calibration period reflects non-municipal pumping conditions, while the available observed groundwater level elevations reflect pumping conditions. The representative water level period was included on Table 70 to provide additional context.
Main Report	A.R. (Tony) Lotimer		Comment	Section 4.6 Recharge Sensitivity Assessment. It is not clear why the Cambridge model was not considered for use in the recharge sensitivity assessment.	The Recharge Sensitivity was only undertaken in the Regional Model to identify the potential uncertainty associated with the urban areas, and the results from the Regional Model could help inform the Cambridge Model area as well. The uncertainty with respect to the recharge was further investigated as part of the Uncertainty Analysis in the Risk Assessment in both the Regional and Cambridge Models.
Main Report	A.R. (Tony) Lotimer	193	Comment	Section 4.6.2.2 (page 193) and Figure 4-19. This section and figure address a recharge enhancement scenario intended to represent possible effects from urban infrastructure. However, the recharge enhancement applied in the model appears to include large sections of rural undeveloped land (including farm fields). The rationale for increasing the recharge in the rural areas for this scenario should be further explained and/or justified.	Comment is acknowledged. Scenario 2 examined the uncertainty associated with elevated recharge in the urban areas due to leaky infrastructure and also enhanced recharge via agricultural practices in rural areas. Additional text added to Section 4.6.2.2 to clarify.
Main Report	A.R. (Tony) Lotimer	194 & 195	Text Edit	Section 4.7 Overall Groundwater Model Calibration Assessment. The use of the word 'good' should be explained in more detail in the last paragraph of page 194 or, alternatively, replace it with 'reasonable' or 'acceptable'. At the top of page 195, 'observed flow directions' should be changed to 'inferred flow directions'.	Language revised - the word 'good' was replaced by acceptable as suggested and observed flow directions with inferred flow directions as recommended.
Main Report	A.R. (Tony) Lotimer		Comment	Summary - It appears that somewhat less supporting information has been provided for the Cambridge model in the draft report, relative to that provided for the Regional model. This should be addressed before the draft report is finalized.	Additional text and information has been provided to the main body of the report and the appendices to make the reporting more consistent between the two models.
Main Report	R.Wootton	4	added word	another "potential"	Text updated as suggested.
Main Report	R.Wootton	4	added word	another "potential"	Text updated as suggested.
Main Report	R.Wootton	9	comment	On recent floodplain deposits along the banks of the grand and nith, wonders if speed river should be included as well	Speed River added to list as suggested.
Main Report	R.Wootton	12	comment	Lower Gasport units behave more like an aquitard	Comment acknowledged, and text updated.
Main Report	R.Wootton	50	comment	Awkward sentence describing aquitard ATB3 windows at William St	Comment acknowledged, and text updated.
Main Report	R.Wootton	53	inserted word	Question regarding location of interpreted sources of industrial contaminant (west or northwest of the william st wellfield)	Comment acknowledged, and text updated.
Main Report	R.Wootton	58	comment	Need to introduce ASR wells to Mannheim introduction	ASR wells introduced and the reason why the ASR wells were not simulated in the model were also noted in the introduction to this section 4.5.4.2)
Main Report	R.Wootton	60	comment	No ASR system was not in operation in 2003. There should be no net change in water balance due to operation of ASR system. The ASR system has very little influence on peaking well field water levels.	Review of the pumping rates spreadsheet suggest the ASR wells were pumping in 2003. Text was updated to remove contentious discussion.
Main Report	R.Wootton	60	comment	RE: inclusion of low quality data, "When we know these are bad data points then why include them? It just looks bad We have long term records of other nearby mws that confirm actual wls."	Comment acknowledged and agree some low quality data points should be removed. There is a good match to high quality data (consistent with the hydraulic stress conditions simulated in the model), and adding med and low quality data was included for completeness.
Main Report	R.Wootton	61	comment	regarding conceptualizating coarsening of deposited material in AFB2 at mannheim, "not really it is quite variable"	Yes, the depositional environment is variable, but a coarsening upward sequence was inferred in a few high quality boreholes as part of the well field characterization report and carried forward into the modelling. Updates to the hydraulic conductivity zones were made during calibration to refine the zones.
Main Report	R.Wootton	63	comment	Add table summarizing 2003 rates in Greenbrook.	Table not added, but text added to clarify pumping in well field in 2003.
Main Report	R.Wootton	68	comment	No previous mention of Ottawa St Landfill	Additional text added to clarify statements.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	70	comment	All heads at Parkway are underpredicted.	Comment acknowledged. The 'high quality' data is well simulated at this well field, however, the lower quality data (as expected) tends to be underpredicted. It is likely the underpredicted groundwater level elevations are due to the fact that the observed groundwater level elevations were collected in a different time period than the pumping rates applied to represent the calibration period.
Main Report	R.Wootton	71	comment	Heads at Strasburg are overpredicted.	Comment acknowledged. The 'high quality' data is well simulated at this well field, however, the lower quality data (as expected) tends to be underpredicted. It is likely the underpredicted groundwater level elevations are due to the groundwater level elevations being collected in a different time period than the calibration period.
Main Report	R.Wootton	72	comment	This contradicts previous paragraph. Maybe these windows are more distant	Paragraphs updated to clarify.
Main Report	R.Wootton	79	comment	All heads at Pompeii/ Forwell are overpredicted.	Comment acknowledged. The 'high quality' data is well simulated at this well field, however, the lower quality data (as expected) tends to be underpredicted. It is likely the underpredicted groundwater level elevations are due to the groundwater level elevations being collected in a different time period than the calibration period. Additional text added to clarify.
Main Report	R.Wootton	81	comment	"You might want to mention that they were installed with the specific intention of being infiltration wells"	Comment added as requested to section 4.5.4.6.
Main Report	R.Wootton	81	comment	Statement regarding absence of Maryhill Till here is inconsistent with previous statements	Text updated as suggested.
Main Report	R.Wootton	81	comment	Dewatering of the Forwell pit affects drawdown cone and groundwater flow system is not mention previously.	Text regarding the Forwell Gravel Pit was moved from the summary section to the calibration section.
Main Report	R.Wootton	87	comment	RE: Puslinch Lake data "This is pretty dated surely we could do better"	The estimates of Puslinch Lake data from Harden 1999 represent the most recent available data (in 2008).
Main Report	R.Wootton	88	comment	Questions why recent pumping test by Stantec won't be applied to the western portion of the Pinebush Well Field	The tests used for the calibration were recommended by the consultants performing the well field characterization reports. Either the recent Stantec data was unavailable at the time of the calibration, or the previous 1990 test was considered to be a longer duration test, was monitored by more observation wells or the design of the test was considered to stress the hydrogeologic system in a way that was more desirable.
Main Report	R.Wootton	94	comment	Notes there is more up to date transient data available at Shades Mills	Comment acknowledged. The Shades Mills wells draw from the overburden system and the transient data is largely limited to the bedrock.
Main Report	R.Wootton	106	comment	Add 5 metre interval to Fig 4-23	5 m interval added as requested.
Main Report	R.Wootton	106	comment	Add comparative map between observed and simulated water level contours	Comment is acknowledged; however additional figures were not generated or added to the report. This document focused on quantitative calibration and all data needed to support the quantitative calibration was provided. Contours of observed groundwater level elevations should not be heavily relied upon as an indication of the quality of the calibration as the contours are highly dependent on the quality and availability of data.
Main Report	R.Wootton	106	comment	Add 5 metre contour interval for Fig 4-24	5 m interval added as requested.
Main Report	R.Wootton	107	comment	Add comparative map between observed and simulated water level contours	Comment is acknowledged; however additional figures were not generated or added to the report. This document focused on quantitative calibration and all data needed to support the quantitative calibration was provided. Contours of observed groundwater level elevations should not be heavily relied upon as an indication of the quality of the calibration as the contours are highly dependent on the quality and availability of data.
Main Report	R.Wootton	107	comment	Add a comment that bedrock low at Strasburg is a reflection of a valley in the bedrock that may be connected to the Dundas Bedrock Valley further to the south	Text updated as suggested.
Main Report	E. Hodgins-round1	Figures	comment	Can these cross sections include appropriate municipal supply well schematics to help orient the reader to scale and importance to layering?	Cross-sections updated to include wells and municipal aquifers.
Main Report	E. Hodgins-round1	8	Comment	Please add a sentence explaining that hydrologic stress does not equal ecologic stress	Text in Section 1.2 updated as suggested.
Main Report	E. Hodgins-round1	32	Comment	Another table needs to be presented to link all the info in this report with the requirements for the assessment report. This additional table should be similar to that in the AR Table 9.1. This would help link the two documents.	Drinking water system name and number appended to table 7 as requested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	E. Hodgins-round1	40	Add sentence	Notwithstanding this effort, uncertainty still exists in predicting surface water levels with a groundwater model and/or changes in levels relative to pumping from deep groundwater systems, particularly with the regional scale being used in the hydrogeologic model	Comment is acknowledged. Comments in this regard were added to the model limitations discussion.
Main Report	E. Hodgins-round1	53	Comment	But is this important for perched conditions?	It's not clear with the available data whether the perched system is important on the overall groundwater flow system in this area or not. A sentence was added to the report to this effect.
Main Report	E. Hodgins-round1	114	Comment	The map in this report is at a different scale and one can't make any useful comparisons. The corresponding observation map as well as a table summarizing observed, predicted and residuals is needed for these potentiometric surface maps.	Comment is acknowledged; however additional figures were not generated or added to the report. This document focused on quantitative calibration and all data needed to support the quantitative calibration was provided. Contours of observed groundwater level elevations should not be heavily relied upon as an indication of the quality of the calibration as the contours are highly dependent on the quality and availability of data. Calibration on a local scale is highlighted and provided in the individual well field appendices. The model simulated and observed groundwater level elevations are illustrated spatially on these maps as requested.
Main Report	E. Hodgins-round1	116	Rewrite	Rename Airport Creek to Hopewell Creek	The creek referred to is Airport Creek, not Hopewell Creek. The text regarding the location was updated to clarify.
Main Report	E. Hodgins-round1	129	Comment	Is there a bias created in these predictions if the residual in the supply well is high relative to the SAAD? Should Table 74 also list the predicted water level?	No, the predictions are not biased as calculations are completed using drawdown to avoid such issues. The calculated drawdown at the well, between pumping scenarios of the Risk Assessment will be compared to the SAAD (which is a model independent value based on observed data).
Main Report	ROW-round2	1	Comment	This figure should show the Tier 2 Assessment Areas for completeness.	Tier Two Assessment areas added to Figure 1 as requested.
Main Report	ROW-round2	1	Comment	This map should only show active supply wells. Many of the wells shown on this and other maps have not been used for 10 or more years. They should not have been used in any previous calculations as we would not have any pumping data. It is my understanding that Richard has been correcting the appendices for this as well.	Municipal wells have been updated on all maps as requested.
Main Report	ROW-round2	7	Comment	Wouldn't it be easier to just refer to it as the Study Area?	Perhaps, however, the term Assessment area is already used throughout.
Main Report	ROW-round2	7	Comment	So not in the Study Area then? (Referring to the Oxford and Statford Till Plains)	No updates made; the Oxford and Stratford Till plains are not within the Tier Three Assessment Area.
Main Report	ROW-round2	18	Comment	Use appropriate reference to define which one you are referring to	References were added to Section 2.2.3.2 as requested.
Main Report	ROW-round2	18	Comment	Use proper reference (in referring to, referencing, the LTWS report)	References were added to Section 2.2.3.2 as requested.
Main Report	ROW-round2	22	Comment	I don't understand this comment. These 4 layers are numbered 14-18 and only exist west? And these 4 don't exist to the east so the numbering of the layers below only apply to the east? Maybe these layers should be listed as 14 to 18 and the ones below have a footnote	Footnoted added to the table to clarify the bedrock layering in the models.
Main Report	ROW-round2	28	Comment	now you are talking about the Region's boundary? Which is it?	Text updated to distinguish between Regional Model domain and Region of Waterloo boundary.
Main Report	ROW-round2	45	Comment	I do not recall previous discussion of these points in this report. If you do not want to provide discussion here, then please refer to where these points are discussed	This section was updated to provide broader context to the limitations in the model.
Main Report	ROW-round2	46	Comment	These observed values are not presented anywhere so how can the reader comprehend or verify these statements?	Comment acknowledged and the text was updated as suggested to clarify the statements.
Main Report	ROW-round2	47	Comment	I presume these are the results from the Regional model?? What are the results from the Cambridge model and how do they compare?	Results from the Cambridge model were added for completeness. Figure 4-27b is the simulated groundwater level elevations in the Upper Bedrock (i.e., Guelph Formation and Reformatory Quarry Member of the Eramosa Formation). Additional text added.
Main Report	ROW-round2	47	Comment	Ditto re Cambridge model	Results from the Cambridge model were added for completeness. In the Cambridge area, most of the municipal wells are pumping from the bedrock (the only overburden wells are P16 and the wells at Shades Mill, G7, G8, G38 and G39). Therefore, the vertical water level differences between the shallow (AFB2) and deep (AFD1) overburden are not particularly relevant (at Shades Mill, it is likely that the wells derive their supply from the reservoir). An additional figure was presented for the Cambridge showing the difference in groundwater level elevations between the Upper and Lower Bedrock aquifers. The Lower Bedrock aquifer comprises the Goat Island Formation and the Middle Gasport Formation. The additional figure is Figure 4-28b.
Main Report	ROW-round2	47	Comment	Ditto re Cambridge model.	A similar map for the Cambridge area was developed (Figure 4-29b). The results presented on the map have been compared with the GRCA classification. The simulated distribution of losing and gaining streams reaches compares well with the GRCA's classification of coldwater streams.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	91	Comment	What rates were wells pumped at?	P16 was pumped at 15.1 l/s and the other well at 19 l/s. Text updated accordingly as requested.
Main Report	ROW-round2	99	Comment	Ok, I see that there are 3 ways, but so what? Is this necessary? Is it too complicated to figure out which approach? Are all three needed? I am not sure what the reader is suppose to do with this information.	Text updated to highlight the data gaps present in the Puslinch Lake area that hinder the confident approach to groundwater modelling of the Puslinch Lake area.
Main Report	ROW-round2	124	Comment	The comments for the creeks associated with the Cambridge model are less than that with the Regional model. Challenges to calibration, lengths of gaining and losing and other observations are needed for these creeks. Also how do the predictions of baseflow for the creeks that overlap the two models compare? Maybe a section on the comparison of results between the two models where they overlap should be presented>	Discussion was added with respect to the stream reaches in the Cambridge area to be more consistent with the Regional Model discussion. A map of gaining and losing reaches, as simulated with the Regional Model was also added (Figure 4-29b).
Main Report	ROW-round2	137	Comment	Reference appendix where this is found	Explanation and reference to additional text is outlined in the following paragraphs of the report; an appendix was not generated or these additional scenarios.
ErbStreetCalib	ROW-round2	10	Comment	By how much?	By ~30 m; text updated.
MannheimCalib	ROW-round2	3	Comment	Delete these perched ones	groundwater level elevations that were known to be perched were removed as suggested (i.e., ASROW 1B-02). If the nature of the groundwater level elevations were unclear, they were retained for thoroughness.
MannheimCalib	ROW-round2	10	Comment	This is always the case why emphasize for these wells?	The text was added to provide context to peer reviewers or readers that may not have a strong numeric background or understanding.
Main Report	R.Wootton	5	Comment	Can Figure 4-1 be modified to also show the Central Grand & Canagagigue ck Tier 3 assessment areas?	Figure 4-1 was updated to include the two Tier Three Assessment areas as suggested.
Main Report	R.Wootton	27	Comment	Not shown on fig 1.1 or 3.1 please add	Figure 4-1 was updated to include the two Tier Three Assessment areas as suggested.
Main Report	R.Wootton	45	Comment	why?	Text updated to clarify.
Main Report	R.Wootton	49	Comment	for all these figures showing a comparison to illustrate where there are differences and their relative magnitude would be helpful	A figure comparing the simulated and the observed equipotentials of groundwater level elevations would simply highlight areas where we are lacking data. When creating the contours of "observed groundwater level elevations", we are reliant on data to create highs and lows and in the absence of data, it may make the model look incorrect when in fact, it is the lack of data that is the problem. As such, the model calibration focused more on the quantitative calibration rather than qualitative calibration to contours.
Main Report	R.Wootton	49	Comment	Figures in this report are at a different scale, range of colour shading and have indistinct water level contours. It is not possible to undertake meaningful comparisons of these figures as they are. Please include these figures in a format that is consistent with the report figures	Comment is acknowledged; however additional figures were not generated or added to the report. This document focused on quantitative calibration and all data needed to support the quantitative calibration was provided. Contours of observed groundwater level elevations should not be heavily relied upon as an indication of the quality of the calibration as the contours are highly dependent on the quality and availability of data.
Main Report	R.Wootton	96	Comment	This sort of detailed analysis of specific intervals is inconsistent with the Regional model text.	Comment acknowledged and additional efforts were made to make the discussion in the Cambridge Model consistent with the discussion of the Regional Model.
Main Report	R.Wootton	98	Comment	Not just two wells involved in test. Data indicates a strong connection between H5 and ow1-95 but not much with H4 and H3. See testing reports.	The comment is correct, more than two wells were involved in the testing. The testing report, Lotowater (1997) was examined carefully and details of the transient simulation of the Hespeler well field test are presented in Appendix Z, Cambridge well field: Focused transient calibrations. In total, five separate observation wells were monitored during the testing. The observation wells each had multiple monitoring locations; 28 intervals were monitored. Only the two wells closest to the well field, OW1-95 and OW2-95, exhibited clear responses to the shut down. In the text of the Lotowater (1997) report it is indicated that recoveries of about 0.5 m were observed at OW2-95 in the intermediate and deep interval (B and C). In contrast, the hydrographs presented in the same report suggest much larger recoveries, of the order of 2 m. Given the uncertainty of the reported recoveries at OW2-95, the match achieved with the Cambridge model is considered to be reasonable. Much larger recoveries were observed at OW1-95, about 2.5 m for the B interval and 8.5 m for the C interval. The magnitudes of the recoveries indicate that there is a strong hydraulic connection between OW1-95 and the Hespeler municipal pumping wells. It is recognized that the match to the recoveries at OW1-95 is relatively poor, no further attempts were made to improve the local calibration because there remain major uncertainties in the hydrostratigraphic model in this area. [No changes to text made]

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	98	Comment	Long term monitoring program illustrates a strong connection to H5. Were these essential data reviewed and assessed?	We have reviewed the water level response for the well field for the period from 2001 to 2007. The data suggest a strong connection between OW1-95 and H5. However, the distance between the two wells is about 1 km; the strong connection between the two wells may be due to a small-scale feature. There is indirect elsewhere in the Cambridge area of conduits, most likely due to preferential dissolution of carbonate rocks. In theory, a direct connection can be simulated by incorporating a discrete conduit in the model. However, in practice it is not feasible to incorporate these features in the Cambridge model. The scale of the analysis is much larger than the scale of individual conduits and any model incorporating these features is speculative in the absence of any data to constrain the specification of their orientation, extent, size and properties. [No changes to text made]
Main Report	R.Wootton	98	Comment	How is this handled in the model? Or is it? The model is calibrated to an earlier time period.	The open interval of Well P10 initially extended to a depth of 64 m. Flowmeter profiling indicated that there was negligible inflow to the well from the open interval between depths of 33.4 m to 64 m and this portion of the well was grouted In 2010. The steady-state calibration considered average conditions in 2003 and existing conditions was the 2008 period - both prior to the well being grouted in 2010. As such, the boundary condition in the model was not updated to reflect the current configuration for Well P10.
Main Report	R.Wootton	99	Comment	So why wasn't this done?	No further attempts to improve the match to the cluster of targets southwest of Puslinch Lake were undertaken because there remain uncertainties regarding the structure of the groundwater system in this small area. These uncertainties are local and do not affect conditions near the Cambridge well fields. The area around Puslinch Lake is complex and at this point in time a detailed characterization of the area is not available. It is not possible to constrain the model with a definitive water budget for the lake, as there are no well-defined surface water channels that flow into or out of the lake. Furthermore, the properties of the materials that line the bottom of the lake are not known and only very rough estimates of the flows between the lake and the groundwater system have been presented in informal documents.
Main Report	R.Wootton	100	Comment	it is important to note that the Brunton logging showed that conditions are very different between these two wells. Testing has also showed limited hydraulic connection between these wells. Is this reflected in the model construction as this data was supplied some time ago?	We are not aware of the "very different" conditions between G5 and P10 that Brunton has observed in his logging. Our understanding has been that these two well are pumping from the Contact Aquifer at the interface between the overburden and the bedrock. Does the second half of the comment refer to the lowering by 1.3 m of the casing in G5 and grouting below the depth of 33.5 m at P10? If our interpretation of the comment is correct, the grouting of P10 has been addressed in a previous comment. The lowering of the casing in G5 by 1.3 m is not sufficient to change the specification of the model layers across which the well is open in the model.
Main Report	R.Wootton	107	Comment	Significance?	The comment appears to question the significance of the inference that municipal supply wells P17 and P11 fall within the inferred high-transmissivity 'tongue-shaped' zone within the Gasport Formation. Additional text added to note that the high-transmissivity zone impacts the yield of wells, the hydraulic connections and potential interference between wells. The locations of production wells with respect to the high-transmissivity zone also control the patterns of groundwater flow in the vicinity of the wells, the propagation of the drawdown cones, the shapes of the capture zones and the ultimate source of water to the wells. Text updated accordingly.
Main Report	R.Wootton	107	Comment	this was NOT previously mentioned – was this also the case for the pinebush wells?	The text has been revised to include key results of the calibration earlier. There are no definitive indications that the Pinebush production wells are also located in the high-transmissivity zone. Our analysis suggests that the Pinebush wells are either located near the edge of the high-transmissivity zone or are not open across the Gasport Formation. [no updates made to the text]

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	107	Comment	How and why is this significant?	Where the Vinemount Member is present, its vertical hydraulic conductivity inferred through calibration is relatively low. This is significant because the Vinemount Member acts to limit the hydraulic connection between the upper and lower bedrock aquifers, that is, to effectively isolate the upper bedrock from the lower bedrock. The Vinemount Member is the key aquitard in the Cambridge area. Historically, no distinction has been made between the Eramosa unit and the Vinemount Member. The distinction is crucial. The Vinemount Member is a sub-unit of the Eramosa Formation. The Vinemount Member is not present everywhere in the Cambridge area, but where it is present it supports a vertical hydraulic gradient across the rock and represents a key barrier to the vertical movement of groundwater. Text added to note that municipal aquifers present north and east of Clemens Mills that are completed in shallow bedrock will be hydraulically isolated from those completed in deeper bedrock formations.
Main Report	R.Wootton	108	Comment	no mention of the connection to the pinebush wells as previously discussed?	Our analyses do not point to a connection between the Pinebush (P11/P17) and Clemens Mill well fields. Pinebush wells P11/P17 are located near the edge of the tongue-shaped zone (so some connection may be present) and the other supply wells derive their supplies from outside the Gasport Formation. [no updates made to the text]
Main Report	R.Wootton	108	Comment	To where? Significance?	Our analyses suggest that the existence of the Vinemount Member is critical with respect to the propagation of the effects of pumping from the deeper bedrock wells at the Clemens Mill well field. Text added to note that the Vinemount Member is a key regional aquitard in the region and where it is present, it separates the bedrock aquifer to upper and lower zones. This is particularly true further east, in the area of the new Cambridge East wells, where large water level differences across the Vinemount Member are observed. The effects of pumping G16 are not observed in the overlying rock. In contrast, in the areas of the well field where the Vinemount Member is absent, around Wells G6, G17, and G18, the effects of deep pumping propagate upwards to the shallow rock.
Main Report	R.Wootton	108	Comment	Not mentioned previously and should have been	Text was moved from the Insights Toward Risk Assessment section into the overlying model calibration section.
Main Report	R.Wootton	110	Comment	?There is a new sentry well nest near P6	The text was updated to note that there was only one well near P6 with groundwater level elevation data available for the 2003 calibration period. Observation well OW6-95 was available for the 2003 steady-state calibration, however, groundwater level elevations in the new sentry well C-DB-OW1-09 have only been monitored since April 2010.
Main Report	R.Wootton	110	Comment	Not mentioned previously and should have been	A local barrier to vertical flow in the Reformatory Quarry Member has been inferred through calibration. Text indicating this finding was added to the subsection: Steady-state Calibration Results for the Dunbar well field.
Main Report	R.Wootton	111	Comment	What about the aquitard?	The text has been supplemented to include a reference to the importance of locating the vertical flow barrier between monitoring intervals C-D and D-E.
Main Report	R.Wootton	111	Comment	?There is a new multilevel nest at the G4 site and detailed testing data	The text was updated to clarify it was the only well nest available for the 2003 calibration period and to note that Observation wells C-BR-OW1-09 A/B/C/D) and C-BR-OW01AB-10 have been constructed since 2003 and can be used in subsequent studies.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	113	Comment	why not?	It is noted in the text that the similarity of observed groundwater level elevations at OW3A-92 and OW3B-92 suggests a good hydraulic connection between these two monitoring intervals. This is not quite correct. The groundwater level elevations data for OW3A-92 and OW3B-92 are very similar. Prior to 2003, the groundwater level elevation data for two monitoring wells are also very similar to the groundwater level elevations in production well G18. However, when G18 stopped pumping in 2004 and the groundwater level elevations recovered from about 275 m to over 310 m, there were no similar increases in the groundwater level elevations in OW3A-92 or OW3B-92. The text has been revised that conditions in this area are complex and there are important uncertainties in the OW3-92 data. Our inspection of the available data highlights uncertainties in the reporting of the open intervals at OW3-92. It is indicated in the WRAS+ database that there is only one monitoring interval at OW3-92 and the fields indicating the elevations of the monitoring interval are blank. The Burnside 2009 monitoring report indicates two monitoring intervals at OW3-92; the data for the A interval indicate a very long open interval, from 29 m to 91 m. In the same report, the data for the B interval indicates that the open interval extends from an unknown depth to a depth of 81 m. The Burnside 2013 monitoring report does not include any mention of OW3-92. The text has been revised to indicate OW3-92 should be excluded from the targets in light of uncertainties in the elevations of the open intervals of the monitoring well. Text updated to clarify.
Main Report	R.Wootton	113	Comment	It would appear that the influence of neither well field is properly represented in this area	As indicated in the previous comment, conditions around OW3A-92 and OW3B-92 are complex and the data are uncertain. We standby by our indication that well monitoring conditions in the Clemens Mill well field do not provide insights into conditions in the Shades Mills well field. [no changes made in the text]
Main Report	R.Wootton	113	Comment	Not really a portion of the water comes from the bedrock e.g. contact aquifer	Text updated as suggested.
Main Report	R.Wootton	115	Comment	not discussed previously and should have been	The text has been revised to include key results of the calibration earlier.
Main Report	R.Wootton	115	Comment	this has been done so this reference should be changed to possible future transient calibration	Text updated as suggested.
Main Report	R.Wootton	117	Comment	this section should be used to recap/highlight key points from the previous section not introduce entirely new analysis/discussion	The text has been revised to include key results of the calibration earlier.
Main Report	R.Wootton	120	Comment	this section should be used to recap/highlight key points from the previous section not introduce entirely new analysis/discussion	The text has been revised to include key results of the calibration earlier.
Main Report	R.Wootton	121	Comment	more recent testing and monitoring has been done. TW2-70 has been extended into deeper bedrock. Data show a significant influence of the Middleton wells on water levels at this well and G15. Maybe consider this for future calibration efforts	That is important information. Conditions at the Middleton Street well field are complex and any additional characterization is welcome. We agree that any testing conducted after modifications of existing wells or installation of new wells should inform future refinements of the calibrated model.
Main Report	R.Wootton	121	Comment	this section should be used to recap/highlight key points from the previous sections not introduce entirely new analysis/discussion	The text has been revised to include key results of the calibration earlier.
Main Report	R.Wootton	121	Comment	yes there is at G15. Deeper sources at Middleton are affected by elevated hardness and sulphate	The text updated to note that previous modelling efforts have not addressed the source of supply for the Middleton Street production wells. The Middleton Street wells are not open to the deeper bedrock (G14 is the deepest well, and it extends only into the Upper Gasport Formation). The observed effects of elevated hardness and sulphate confirm that a portion of the water pumped from the Middleton Street wells is derived from the deeper bedrock but the proportions derived from shallow and deeper sources is not well understood.
Main Report	R.Wootton	137	Comment	Need a comparison of modeled baseflows from the two models	We think that the presentation on Table 77 is sufficient and that it is not necessary to report simulated values from both the Regional and Cambridge models? A companion document will highlight the similarities and differences in modelled groundwater level elevations and baseflows in the overlap areas.
Main Report	R.Wootton	141	Comment	don't necessarily agree with this; if we getting a better fit with the these recharge changes then we should use them, particularly given that the model has a bias toward under predicting water levels and stream flows. We could come to regret this later.	Comment acknowledged and text updated to note that the model is conservative but our best guess of the recharge distribution present in the study area.
Main Report	R.Wootton	2	added word	"The Tier Three Assessment is completed for all municipalities where its drinking water sources are located within a subwatershed having a potential Moderate or Significant water quantity stress…"	As peer reviewers we always insist on the insertion of "potential". Otherwise, readers may interpret the stress assessments as facts.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	3	acronym	1.2.2 GRCA Source Protection Water Budget Assessments - comment: "Need to introduce this before abbreviating"	Text updated as requested.
Main Report	R.Wootton	3	acronym	introduce what GAWSER stands for	Text updated as requested.
Main Report	R.Wootton	3	Reference Req'd	for Tier 2 Subwatershed Stress Management Study	Addressed at bottom of first paragraph
Main Report	R.Wootton	3	comment	On proceeding directly to tier 2 assessment, "Previously you referred to this as a conceptual water budget"	Text updated as requested.
Main Report	R.Wootton	4	comment	On development of conceptual water budget - "Is this a conceptual water budget or a conceptual hydrogeologic model? Could be confused with Tier 1 WB"	Text updated as requested.
Main Report	R.Wootton	5	comment	looking for where well field and summary reports can be found (e.g. appendices?)	Text updated as requested.
Main Report	R.Wootton	7	comment	looking for figure of study area physiography	Text updated as requested.
Main Report	R.Wootton	9	comment	on table one - paleozoic geology, in the revised conceptualization heading, he asks "what is key to footnotes?"	Footnote removed (unnecessary)
Main Report	R.Wootton	9	cross referencing issue	hydrostratigraphic layers - "Not shown on Table 2 maybe reference a subsequent section for discussion?"	Text updated as requested.
Main Report	R.Wootton	11	comment	On The Region contains overburden water supply aquifers that are primarily associated with coarse-grained outwash sand and gravel deposits - comment "I don't think is entirely true as there are other modes of deposition"	Text updated; the word "outwash" was removed.
Main Report	R.Wootton	11	comment	in table, wonders if they should be called evaporites, or evaporates	Text updated for consistency (evaporites)
Main Report	R.Wootton	12	comment	on grca integrated wb report reference, "Previously you used 2007 as the report date"	Reference was updated.
Main Report	R.Wootton	13	comment	hydrostratigraphic picks vs hydrogeologic picks word choice	Hydrostratigraphic picks used throughout for consistency
Main Report	R.Wootton	17	comment	on 19 layer overburden block model, "? there are 18 layers in table or does this include "contact zone"?"	Addressed, changed to 18 layer
Main Report	R.Wootton	18	comment	"wording suggests the escarpment underlies the area but doesn't"	Wording was changed
Main Report	R.Wootton	20	comment	word choice questions	Text updated as requested.
Main Report	R.Wootton	21	comment	evaporates vs evaporites consistency	Text updated as requested.
Main Report	R.Wootton	24	comment	asks for definition of "grandfathered"	Text updated as requested.
Main Report	R.Wootton	25	comment	questions ASR wells PTTW - "there is no net taking from the aquifer"	PTTW well field pumping rate note added to address this comment.
Main Report	R.Wootton	25	comment	"ND2 and 3 have been abandoned"	Text updated as requested. Abandonment noted in table
Main Report	R.Wootton	26	comment	comments on W2A (it's disconnected) and W3 (abandoned)	Text updated as requested - status conveyed with footnote
Main Report	R.Wootton	26	comment	"what about pompeii-forwell wells" - can't find them in the pttw table	Text not updated; wells are listed in the table
Main Report	R.Wootton	33	comment	questions surface water boundary condition data sources reference - "appendix?"	Text updated as requested - Referred to as Appendix G
Main Report	R.Wootton	33	comment	wants to change "discrepancy" to "difference" regarding the way puslinch lake was modelled	Text updated as requested - applied suggested word choice
Main Report	R.Wootton	34	comment	question about computational efficiency of puslinch lake modelling strategy	Text not updated as this does not provide additional value
Main Report	R.Wootton	38	comment	questions units of specific storage	Addressed - reported units confirmed
Main Report	R.Wootton	40	comment	questions why medium quality wells weren't ranked as a stand alone stat	Addressed - typo/oversight, "medium quality" added to sentence
Main Report	R.Wootton	40	comment	"what about the quality of the wells themselves?"	These details are given in Appendix C, referred to in preceding paragraph
Main Report	R.Wootton	41	comment	"Fig 29 has no legend. No high quality observations?"	All Cambridge residuals are of same (i.e., high) quality.
Main Report	R.Wootton	41	comment	"should we be using SCADA data from pumping spreadsheets?"	Addressed - removed reference to WRAS
Main Report	R.Wootton	41	comment	wants appendix n's summary of results directly in document	Addressed - added a brief summary of Appendix N into report
Main Report	R.Wootton	42	comment	regarding ogs surfaces and generation of observation noise - "Couldn't you manually assign the wells to the right unit despite where they plot? Given the inaccuracy of the OGS layer interpolation"	Manual assignment was done at well fields where possible. This is an overwhelming task to complete for all observations over the entire model and is outside the scope of this project.
Main Report	R.Wootton	42	comment	Questions if recharge was increased in urban areas	Addressed - applied text to refer reader to well field scale calibration sections of report where this is discussed

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	43	comment	Regarding simulated water levels being within 5 metres of observed at erb st landfill "If they are well within then why not just state actual range?" Also questions the accuracy of the model's representation of the perched system in this area.	Addressed - range of typical residuals reported
Main Report	R.Wootton	44	comment	This one is way off	Yes it is, shallow/perched conditions are problematic to represent in some areas of the model
Main Report	R.Wootton	46	comment	By how much?	Addressed - text re-worded
Main Report	R.Wootton	46	comment	questions if recharge upgradient of the well field is in northwest direction	Addressed - removed specific direction associated with 'up-gradient'
Main Report	R.Wootton	46	comment	Another "grandfather" definition	Addressed - definition applied previously
Main Report	R.Wootton	48	comment	"Till too tight?" -regarding the muted response of observations in units not within the pumped aquifer	Calibration is a balance between steady-state and transient analysis
Main Report	R.Wootton	49	comment	questions word choice, "competency"	Addressed - modified word choice
Main Report	R.Wootton	49	comment	questions "poor aquifer" designation of afd1 at w5a production well, given increased hydraulic connection to bedrock here	Colour scheme on figures reflect a broad classification
Main Report	R.Wootton	50	comment	comment w56 - referencing issue	Addressed - more consistent wording applied
Main Report	R.Wootton	50	comment	comment w57 - "Above is only AFB3"	Addressed - paragraphs reworked to add clarity
Main Report	R.Wootton	51	word choice/edit	replacing "patch" with "window"/"zone"	Addressed - word choice replaced
Main Report	R.Wootton	51	comment	regarding sentence about high quality observation well residual, "Is this one well or several?"	Addressed - it is a single, potentially perched, well
Main Report	R.Wootton	52	comment	"Till too tight?" -regarding OW10-87 being under simulated	Not all observations can be simulated equally well
Main Report	R.Wootton	55	word change	changes "conceptual hydrostratigraphic unit" to "aquifer" or "aquitard"	Addressed - word choice replaced
Main Report	R.Wootton	56	comment	"something is wrong with the strange st residuals table wrt to elevations	Overall, simulated groundwater level elevations are a good match to observed conditions, however some observed groundwater level elevations cannot be matched (due to either measurement error or very local heterogeneity not well represented in the model)
Main Report	R.Wootton	56	comment	added "and recovery" to transient calib section for strange st	Addressed - text updated
Main Report	R.Wootton	57	comment	asks why is there limited potential for hydraulic connection between afb2 and surface water features at strange st	Addressed - bullet paragraph removed from text
Main Report	R.Wootton	58	comment	wonders if there were changes in k values between strange and greenbrook as opposed to structural refinements as written	Addressed - text rewritten
Main Report	R.Wootton	59	comment	asks about why recharge was increased at mannheim, and wants a change in the sentence describing the presence of atb3 (it's discontinuous in this area and we don't mention this here)	Addressed - additional text provided
Main Report	R.Wootton	60	comment	"what about well quality?"	These details are given in Appendix C, referred to in earlier in text when discussing calibration dataset (prior to discussion of calibration results)
Main Report	R.Wootton	60	comment	comments that all wells at mannheim are underpredicted	Yes, simulated groundwater level elevations are a close match to observed groundwater level elevations.
Main Report	R.Wootton	61	comment	"Mannheim peaking wells and asr wells are not the same thing?'	Addressed - text updated
Main Report	R.Wootton	61	comment	"There certainly is pumping test data for the peaking wells and other wells at time of construction. Probably not in wras tho"	Addressed - sentence removed
Main Report	R.Wootton	62	comment	Wants mention of upped recharge in gravel pits placed earlier in report	Addressed - text added in preceding calibration discussion
Main Report	R.Wootton	62	comment	"Only in certain areas" regarding windows in atb2	Addressed - text modified
Main Report	R.Wootton	64	comment	Questions where of refinement of till units occurred, we say south, he thinks north	Addressed - additional text provided to be more clear and specific
Main Report	R.Wootton	65	comment	regarding bmw wells fitting so poorly, "landfill mounding influence?"	Addressed - text amended to reflect comment
Main Report	R.Wootton	66	comment	on greenbrook residuals, points out that they are all heavily underpredicted	Addressed - context provided in text
Main Report	R.Wootton	66	comment	added "and recovery" to transient calib section for greenbrook	Addressed - text added
Main Report	R.Wootton	66	comment	Regarding discussion of warm up period prior to transient shutdown, "Restate this, maybe background or pre-test period?"	Addressed - text reworded
Main Report	R.Wootton	66	comment	"Although not well levels are skewed too low?" regarding minimal model changes due to transient calibration effort	Text is consistent with results of the transient calibration, which is not skewed as being too low. This is only true of steady-state calibration.
Main Report	R.Wootton	67	comment	regarding lower maryhill till at greenbrook, suggests further k increase to raise water levels	This is a fair comment, and it was raised to the upper bounds of what is physical for the unit based on data and conceptualization in this area.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	68	comment	second bullet, not sure what deposit is being referred to	Addressed - text added to provide proper context
Main Report	R.Wootton	68	comment	wants a table of pumping rates	New table not added, this would not provide any new information to reader. This will take time (i.e., formatting and repaginating remaining text) and time away from addressing non-aesthetic issues/comments
Main Report	R.Wootton	68	deleted sentence	finds note on parkway-stras pumping rates being derived from operator estimates and being almost double wras unneccessary	Text updated as requested.
Main Report	R.Wootton	71	comment	Recovery vs drawdown question regarding nature of transient test	Text updated as requested.
Main Report	R.Wootton	72	Rewrite	Wants 'It is noted that the production rate used in the calibration for the Parkway Well Field was 10,448 m3/day; considerably greater than the maximum sustainable summer capacity and short-term peak capacity rate of 6,566 m3/day estimated by the Region as part of the Long-Term Water Strategy.' removed	Text updated as requested.
Main Report	R.Wootton	73	comment	States that "Both Parkway and Strasburg should be considered together in any analysis of sustainable aquifer yield" and that "real data indicate that the 2003 pumping rate was sustainable"	Text updated as requested.
Main Report	R.Wootton	73	comment	Asks how bedrock transition is defined, and mentions that "Too me high so4 and fe indicate a bedrock source, as you had previously mentioned. Could also be related to a formation transition "	Text updated as requested.
Main Report	R.Wootton	74	comment	Asks what a type 1 boundary condition means, in this case the grand river specifically	Text updated as requested.
Main Report	R.Wootton	80	comment	added and recovery to transient	Text updated as requested.
Main Report	R.Wootton	81	comment	"Do you mean river outwash? AFDI and AFF1 are much older sediments" regarding statement about modern sediments extending close to bedrock contact	Addressed - text added to provide additional clarity and context
Main Report	R.Wootton	84	comment	why is cambridge calibration not done?	Text updated as requested.
Main Report	R.Wootton	84	comment	wants well details of hespeler well field	Text updated as requested.
Main Report	R.Wootton	84	comment	Regarding Steady State Calibration of Hespeler: "According to the log there is about 16 m of clay and silt separating F from E. F is quite shallow and is installed above this zone. Does the model not reflect this?"	Additional text provided
Main Report	R.Wootton	85	comment	Regarding Steady State Calibration of Hespeler, OW2-95: "D and E are installed in the overburden quite close together. D appears to be installed at bedrock surface within a thin zone of clay and gravel. C is quite a bit deeper (50 m) in the bedrock. Logging shows that there is a natural downward gradient from the shallow bedrock to the deeper (80 m) bedrock. This indicates a low conductivity zone in the bedrock which isolates the overburden and shallow bedrock from the deeper bedrock. This would have to be defined in the model to represent this. Levels in B and C are similar, with C about 0.5 to 1 m higher."	Text updated as requested.
Main Report	R.Wootton	85	comment	Says Appendix Y and Z are out of order	Appendices updated
Main Report	R.Wootton	86	comment	Wants well details for pinebush	Text updated as requested.
Main Report	R.Wootton	87	deleted paragraph	Deleted repeated paragraph	Paragraph removed as requested.
Main Report	R.Wootton	87	comment	points out that pinebush is heavily underpredicted	Text updated as requested.
Main Report	R.Wootton	88	comment	Wants details on clemens mills wells	Text updated as requested.
Main Report	R.Wootton	88	comment	points out that clemens mill heads are heavily underpredicted	Text updated as requested.
Main Report	R.Wootton	90	comment	wants well details for dunbar well field	Text updated as requested.
Main Report	R.Wootton	90	comment	states that screen D for OW6-95 is not similar to P6's water level (they are claimed to be similar)	D interval removed in text as suggested.
Main Report	R.Wootton	91	comment	Wants well details on Blair Rd	Text updated as requested.
Main Report	R.Wootton	91	comment	States that for ow5-95, there is about 8 m of clay in between screend e and f, and he wonders if this is incorporated into the model	Addressed - context provided by RW added
Main Report	R.Wootton	92	comment	wants well details on Shade's mill wellfield	Text updated as requested.
Main Report	R.Wootton	94	comment	wants well details at elgin st well field	Text updated as requested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	95	comment	wants well details at middleton and willard well fields	Text updated as requested.
Main Report	R.Wootton	95	comment	This is due to well efficiency and is commonly observed when we pump bedrock wells hard	Text updated as suggested.
Main Report	R.Wootton	98	comment	regarding west montrose well field, "this is really an infiltration trench accessed by wells"	Text updated as suggested.
Main Report	R.Wootton	98	comment	West Montrose wells are screened in river outwash not AFB2	Text updated as suggested.
Main Report	R.Wootton	99	comment	Elmira consists of only one well, E10, and is only available in emergencies	Text updated as suggested.
Main Report	R.Wootton	99	comment	wants reference to this sentence: "Key structural changes made at the Elmira Well Field consisted of increasing the thickness of Aquifer conceptual hydrostratigraphic unit AFD1, to approximately 7 m and decreasing the thickness of its underlying ATE1 (Canning Drift), which is conceptualized to have been eroded by the later advance of Catfish Creek ice during the Nissouri Stade and other associated glaciofluvial activity . "	Text updated as suggested.
Main Report	R.Wootton	99	comment	Thinks that this would be due to excessive recharge through till units, "Though refinements were made in the immediately vicinity of the well field, the hydrogeologic model for the surrounding area is much coarser and may over represent the thickness of till units, causing the deep system to be overly confined resulting in higher simulated water levels "	Text updated as suggested.
Main Report	R.Wootton	99	comment	Wants well E10 in calibration residuals…	Pumping wells were not included in the calibration residuals as the range in water level elevations between pumped and non-pumped was considered too large.
Main Report	R.Wootton	100	comment	Should make mention in overall comments for elmira that wells are typically not used	Text updated as suggested.
Main Report	R.Wootton	102	comment	Why is cp1sd-02A so low?	Text updated as suggested. Footnote added to table.
Main Report	R.Wootton	104	comment	in New dundee, there are only two wells, ND4 and ND5	Text updated as suggested.
Main Report	R.Wootton	108	comment	wants table that summarizes comparisons to baseflows…	Text updated as suggested.
Main Report	R.Wootton	111	comment	Wants paragraph moved up that references bflow summary table	Text updated as suggested.
Main Report	R.Wootton	111	comment	"Figs 4--28 and 4-29 seem out of place.	Text updated as suggested.
Main Report	R.Wootton	115	comment	the classic modeling vs modelling spelling debate	Text updated as suggested.
Main Report	R.Wootton	120	Rewrite	Rewrote the Safe Water Elevation Paragraph entirely	Text updated as suggested.
Main Report	R.Wootton	122	Comment	Doesn't like calling existing 2003 pumping rate Q2008, in reference to Jacob equation	Text updated as suggested.
Main Report	R.Wootton	122	comment	first paragraph, his definition of safe additional drawdown is slightly different	Text updated as suggested.
Main Report	R.Wootton	124	comment	wants asr wells taken out of safe add. Ddown table as they produce no net water taking	Text updated as suggested. Footnote added to table.
Main Report	R.Wootton	125	comment	delete a few cambridge wells from table as they are being abandoned	Text updated as suggested. Footnote added to table.
Main Report	R.Wootton	126	comment	delete a few cambridge wells from table as they are being abandoned	Text updated as suggested. Footnote added to table.
Main Report	R.Wootton	130	comment	regarding sentence talking about low k aquitard units in the model throughout the subsurface, "Implies this is everywhere but this is not really the case"	Text updated; entire section re-worked
Main Report	E. Hodgins-round1	8	comment	Please correct this value to that in the assessment report.	Text updated as suggested.
Main Report	E. Hodgins-round1	8	comment	Please correct this value.	Text updated as suggested.
Main Report	E. Hodgins-round1	8	Rewrite	The population of the Region currently is approximately 550,000 most of whom are supplied municipal water. Within the cities of Cambridge, Elmira, Kitchener, New Hamburg and Waterloo, municipal water supply is provided through and integrated urban system consisting of exceeds 500,000, and over 75% of these residents are reliant on groundwater for the municipal water supplies, with the remaining and 25% supplied from a surface water intake on the Grand River at Hidden Valley (Kitchener). The Region also provides municipal water through wells to portions of 16 other smaller communities and settlement areas.	Text updated as suggested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	E. Hodgins-round1	9	Comment	This paragraph is a duplicate of a portion of the above paragraph.	Text updated as suggested.
Main Report	E. Hodgins-round1	9	Rewrite	Instead, the Tier Three Assessment evaluates the sustainability of individual and/or combined systems to be able to meet the community's evaluates the potential that a community may not be able to meet its current or planned water demands from a water source (e.g., stream, lake, or aquifer).	Text updated as suggested.
Main Report	E. Hodgins-round1	10	Rewrite	The GAWSER surface water model was developed iteratively over several decades to meet the GRCA's watershed management needs and was subsequently documented as part of the Tier Two Water Budget and Subwatershed Stress Assessment Study .	Text updated as suggested.
Main Report	E. Hodgins-round1	11	Comment	Refer to figure to identify these areas.	Addressed in the text. Figure 1-1 updated to clarify wells included.
Main Report	E. Hodgins-round1	12	Comment	Some reference to "coupling" challenges/limitations is necessary here or in the limitations section to address that these do not provide the same output/input necessary for each model.	Text added to limitations section.
Main Report	E. Hodgins-round1	14	Comment	All reference to the study area should be replaced with Tier 3 Assessment Area.	Text updated accordingly.
Main Report	E. Hodgins-round1	14	Comment	All reference to statistics, location etc, should be to the assessment area and not the Region.	Text updated. Model statistics are with respect to the Tier Three Assessment area, not the entire Region.
Main Report	E. Hodgins-round1	18	Comment	For the bedrock units, isn't the descriptions in the interpreted units and predominant materials reversed?	Tables updated.
Main Report	E. Hodgins-round1	20	Comment	While we appreciate the effort that went into this process, this paragraph is not necessary for the report. Please remove.	Text removed as suggested.
Main Report	E. Hodgins-round1	21	Rewrite	Municipal water supply systems for Galt, Kitchener and Waterloo were all first established in the 1890s. The first municipal wells in Kitchener the Region were constructed in 1899 at the Greenbrook Well Field. by the City of Kitchener. The Middleton Pumping Station was constructed in 1890 and included the establishment of several shallow wells collectiong water from springs atd the base of the Grand River channel. In the early 1900s, additional water supplies were developed at the William Street Well Field in the City of Waterloo. In the decades following the establishment of these systems, various water supply development programs occurred within the Region by the different municipalities and utilities but few details are available. Apart from these first few wells, ; however, the installation of the first "modern" production wells did not occur until the early 1950s. Formal water supply exploration commenced in the Cambridge area in the 1930s, within the original municipalities of Galt, Preston and Hespeler.	Text updated as suggested.
Main Report	E. Hodgins-round1	24	Comment	An updated stategy was approved by the Region in 2007. This should be mentioned.	New text added to describe the Water Protection Strategy and reference the 2007 document.
Main Report	E. Hodgins-round1	24	Rewrite	The Region initiated the Integrated Urban System (IUS) Supply Optimization and Expansion Project in 2005 to restore existing permitted capacity at several underutilized well fields and develop an additional five million gallons of water per day from underutilized groundwater supply wells within the existing municipal well fields and a further five million gallons per day from new areas to implement the recommendations from the Long Term Water Supply project.	Text updated as suggested.
Main Report	E. Hodgins-round1	25	Add sentence	Additional test well drilling and testing was undertaken following this initial program.	Text updated as suggested.
Main Report	E. Hodgins-round1	25	Rewrite	The investigation in the Well W5 area examined W5this well as well asand additional wells Additional investigations were conducted at Well W5,to the west near Erbsville and north of the cCity of Waterloo LTWS Area 1, located in the Waterloo North Area.	Text updated as suggested.
Main Report	E. Hodgins-round1	28	Comment	Still reversed?	Tables updated as requested.
Main Report	E. Hodgins-round1	32	Comment	The Region has formally approved the decommissioning of the 4 St Agatha wells so they need to be removed from this table.	Text updated as suggested. Footnote added to table.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	E. Hodgins-round1	32	Comment	Where is C5/C6 or are these outside the study area	C5 and C6 are on the other side of the River and therefore, outside the Canagagigue Watershed area. Included in well field introduction despite it's location on the east side of the Grand River.
Main Report	E. Hodgins-round1	32	Comment	None of G5A, H5A, H3A or G4B are in the Assessment Report and should not be used in the calibration or Risk assessment.	Removed from table
Main Report	E. Hodgins-round1	32	Comment	W14 is not a municipal supply well and should not be in this table.	Removed from table
Main Report	E. Hodgins-round1	33	Comment	It is not clear whether you mean the Region or the study area. Shouldn't all statistical quotes be confined to the study area.	Text updated as suggested.
Main Report	E. Hodgins-round1	33	Comment	As above … what is the rates for the Region	Text updated as suggested.
Main Report	E. Hodgins-round1	33	Comment	89 wells in Tier 3	Text updated as suggested.
Main Report	E. Hodgins-round1	34	Comment	Minor is subjective. Please provide permitted and consumptive rates calculated for non municipal takers.	Numbers from the Tier Two Assessment were included in this report.
Main Report	E. Hodgins-round1	43	Comment	Please add a statement related to recharge from closed depressions over and above that stipulated in GAWSER.	Text updated as suggested.
Main Report	E. Hodgins-round1	46	Comment	Can any examples or common challenges be brought forward to support this statement?	Text updated as suggested.
Main Report	E. Hodgins-round1	48	Comment	As the degree of calibration is subjective, can more definitive categories be used to standardize the language. Also, this is an opportunity to restate that underpredictions may constrain the extent to which impacts to surface water can be predicted with this model.	Text updated; reviewed text at each well field
Main Report	E. Hodgins-round1	48	Comment	Please provide a figure showing resicuals for a shallow and deeper aquifer units to substantiate this claim.	Additional examples in text and referred to already existing figures in well field memo appendices
Main Report	E. Hodgins-round1	49	Comment	Is there an example? This is a pretty significant statement but is not supported in any way.	Addressed - example added
Main Report	E. Hodgins-round1	49	Comment	Can this presented in a table?	Addressed - table and summary of appendix discussed in text
Main Report	E. Hodgins-round1	50	Comment	See comments about inconsistency of these subjective terms and the need to be less subjective.	Addressed for steady state in a consistent fashion. Not done for transient as they cannot be summarized with a single statistic (e.g., AMR). The comparison of response on hydrographs is, by its nature, qualitative and subjective and I feel this was applied in the documentation fairly and consistently.
Main Report	E. Hodgins-round1	51	Comment	What aquifer unit is this?	Text updated to clarify.
Main Report	E. Hodgins-round1	51	Comment	Can a column be added to these tables to identify the high verses medium quality data? Also as we have no geographic reference to these wells, it might be better to list them by layer i.e. how representative of the calibration is the supply aquifer AFB2?	The text indicates what level of quality these observations are (i.e., high and also medium if space permits); this detail was reserved for the well field calibration appendices.
Main Report	E. Hodgins-round1	52	Comment	In terms of absolute water levels and pumping response?	Text updated to clarify.
Main Report	E. Hodgins-round1	53	Rewrite	As this regional recharge area also provides source water to Water captured at the Erb Street Well Field could capture some of the regional recharge to the Strange Street Well Field and the Greenbrook Well Fields and as such, total pumping from these well fields should be considered together.	Text updated as suggested.
Main Report	E. Hodgins-round1	71	Comment	These are not current supply wells and do not need to be discussed, unless it is part of a detailed history of the development of this well field.	Text updated to clarify.
Main Report	E. Hodgins-round1	80	Comment	Comments on future predictions are beyond the scope of the calibration report and should be avoided.	Comment acknowledged and paragraph removed
Main Report	E. Hodgins-round1	89	Comment	A reference can be supplied for this if necessary.	Text edited, suggestion by Region accepted
Main Report	E. Hodgins-round1	106	Comment	There is no current permit for this well.	Text removed; also removed in overall comments

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	E. Hodgins-round1	106	Comment	Reference to extensive non-municipal taking for groundwater remediation is needed to support why this well is being considered in a moderately stressed watershed.	Text updated as suggested.
Main Report	E. Hodgins-round1	110	Comment	Two of the other wells SA5 and SA6 must also have been operating to supply water in this area. Pumping data should be available for these wells. Also need to mention up front that these wells can be excluded from further assessment as per the director's rules and the amended AR.	Text updated as suggested.
Main Report	E. Hodgins-round1	113	Remove sentence	The impact of pumping at the permitted rate has not been fully assessed. Given the location of the wells and proximity to surface water features, there is the potential for impacts to the surface water under full pumping conditions and further assessment may be necessary under these conditions.	Text updated as suggested.
Main Report	E. Hodgins-round1	113	Comment	This has nothing to do with calibration.	Text updated as suggested.
Main Report	E. Hodgins-round1	115	Comment	Reference to Table 72 is needed here to help support the interpretation for each creek/river.	Reference applied as suggested.
Main Report	E. Hodgins-round1	119	Comment	Footnote?	Footnote applied as suggested.
Main Report	E. Hodgins-round1	119	Comment	This statement needs support. Can this be said if there has not been any systematic analysis to identify sensitivity to changing any specific feature at a well field?	Sentence removed as suggested.
Main Report	E. Hodgins-round1	121	Add sentence	the depth to the water table can vary from several metres to over 50 m.	Sentence added as suggested.
Main Report	ROW-round2	1	Comment	Update all references to final versions of reports/memos	Text updated as suggested.
Main Report	ROW-round2	1	Add word	as well as **five** rural well fields	Text updated as suggested.
Main Report	ROW-round2	1	Remove word	as well as urban areas, aggregate extraction areas and rural agricultural**. land use areas**.	Text updated as suggested.
Main Report	ROW-round2	2	Sentence edit	the Province's drinking water sources, and identify**ing** drinking water threats located within local vulnerable areas	Text updated as suggested.
Main Report	ROW-round2	2	Sentence edit	Instead, the Tier Three Assessment evaluates the sustainability of individual and/or combined pumping systems to supplybe **supply** the community's current or planned water demands from a water source (e.g., stream, lake, or aquifer).	Text updated as suggested.
Main Report	ROW-round2	2	Add word	hydrogeologic conditions at a water supply well (or **surface water** intake) and, whenever possible,	Text updated as suggested.
Main Report	ROW-round2	4	Sentence edit	and the Township of Woolwich **(Forewell** Well Field)	Text updated as suggested.
Main Report	ROW-round2	5	Comment	Update to final versions	Text updated as suggested.
Main Report	ROW-round2	5	Comment	Make note of where the tables and figures can be found	Text updated as suggested.
Main Report	ROW-round2	5	Sentence edit	Two types of modelling tools have been applied for use in the Tier Three Risk Assessment. Specifically The first type was using the Guelph All Weather Simulation … (GAWSER) was used to simulate surface water partitioning and streamflow generation, while the second type was using FEFLOW was used to simulate sub-surface (groundwater) flow.	Text updated as suggested.
Main Report	ROW-round2	6	Comment	Make note of where the tables and figures can be found	Text updated as suggested.
Main Report	ROW-round2	7	Sentence edit	The Waterloo Moraine is **a** distinct topographic feature within the Region and it dominates the western portions of the Region**. The** Grand River valley in the central and eastern portions of the Region is also a prominent topographic feature.	Text updated as suggested.
Main Report	ROW-round2	7	Sentence edit	The physiography of the Tier Three Assessment Area **was** shaped by glacial events that came to an end approximately 10,000 years ago.	Text updated as suggested.
Main Report	ROW-round2	7	Comment	Don't need to repeat above reference	Reference removed (for all bullets)
Main Report	ROW-round2	8	Comment	The major rivers affect more than **shallow** systems as they are major regional gw discharge areas	Text updated. Removed the word 'shallow' in sentence
Main Report	ROW-round2	9	Comment	update to final versions	Text updated as suggested.
Main Report	ROW-round2	9	Remove word	are listed in Table 2 **below** (from youngest to oldest)	Text updated as suggested.
Main Report	ROW-round2	10	Comment	ALL references need to be updated to final versions of these reports	Text updated as suggested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	10	Word edit	Upper Waterloo Moraine **S**tratified **S**ediments	Text updated - not tracked (minor table edit)
Main Report	ROW-round2	10	Word edit	Lower Waterloo Moraine Stratified **S**ediments or Catfish Creek Till Outwash	Text updated - not tracked (minor table edit)
Main Report	ROW-round2	11	Word edit	Upper Waterloo Moraine **S**tratified **S**ediments	Text updated - not tracked (minor table edit)
Main Report	ROW-round2	12	Comment	I think the lower gasport may be more like an aquitard? Also what about the deeper units down to the cabot head which defines the “base” of the model?	Table updated. Proceeding table, additional text is provided
Main Report	ROW-round2	12	Sentence edit	The Region’s Water Resource Analysis System (WRAS+) database, which includes historical pumping and water level data for all municipal wells **and monitoring wells within the Region’s Groundwater Monitoring Program (GMP).**	Text updated as suggested.
Main Report	ROW-round2	12	Remove word	Table 4 **below** summarizes the databases that were developed and are maintained by the Region	Text updated as suggested.
Main Report	ROW-round2	13	Word edit	GIS spatial dataset outlining the results of short and long-term pumping tests conducted across the Region	Text updated as suggested.
Main Report	ROW-round2	14	Sentence edit	The first municipal wells **in the Region** were constructed in 1899 at the Greenbrook Well Field **in** the City of Kitchener	Text updated as suggested.
Main Report	ROW-round2	14	Sentence edit	**However,** apart from these first few wells **however,** the installation of the first “modern” production wells did not occur until the early 1950s.	Text updated as suggested.
Main Report	ROW-round2	14	Sentence edit	During this study, **three** primary aquifer systems were identified **within** the Region, with aquitard units separating the aquifers	Text updated as suggested.
Main Report	ROW-round2	15	Sentence edit	The potential for **development of** additional areas of groundwater supply was evaluated	Text updated as suggested.
Main Report	ROW-round2	15	Sentence edit	, infiltration rates and baseflow **were** assessed and a simplified two-dimensional groundwater flow model was	Text updated as suggested.
Main Report	ROW-round2	16	Remove word	Region of Waterloo Comprehensive Water Supply Strategy **(updated** 2007)	Text updated as suggested.
Main Report	ROW-round2	16	Sentence edit	An update to the LTWS was completed in 2007 to form a comprehensive Water Supply Strategy, which was most recently updated in 2007	Text updated as suggested.
Main Report	ROW-round2	17	Sentence edit	The report concluded that additional groundwater supplies would be needed by 2018 and that a displacement pipeline would be needed to meet demand if the water efficiency and watering restrictions are maintained. Otherwise the pipeline would be needed by 2029.	Text updated as suggested.
Main Report	ROW-round2	17	Remove word	...that documented the interpreted borehole and geophysical logs, the creation of a **the** three-dimensional 18 layer overburden hydrostratigraphic block model of the Region, ...	Text updated as suggested.
Main Report	ROW-round2	17	Sentence edit	...additional five million gallons of water per day **from underutilized groundwater supply wells within the existing municipal well fields and a further five million gallons per day** from new areas to implement the recommendations from the Long Term Water Supply project. The IUS project was comprised of three components, **as follows**:	Text updated as suggested.
Main Report	ROW-round2	18	Sentence edit	The investigation in the Well W5A area examined W5A **this well as well as** and additional wells **Additional investigations were conducted at Well W5,** to the west near Erbsville and north of the City of Waterloo in LTWS Area 1, located in the Waterloo North Area. Test wells were drilled in Erbsville and in the Waterloo North area and three wells were pumped for 30-days as part of an ongoing Class Environmental Assessment**, which is ongoing**	Text updated as suggested.
Main Report	ROW-round2	18	Sentence edit	The Ontario Geological Survey (OGS) revised the bedrock stratigraphic naming convention and conceptual deposition understanding for **the** Silurian bedrock, which underlies the refined portion of the Region of Waterloo and the City of Guelph (Brunton, 2008).	Text updated as suggested.
Main Report	ROW-round2	18	Remove word	This work evolved the previous understanding of the bedrock stratigraphy and **has** provided a better conceptual model for understanding groundwater resources within these bedrock systems	Text updated as suggested.
Main Report	ROW-round2	19	Comment	Inconsistent spelling in report pick one (reffering the spelling of modelling)	Text updated as suggested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	20	Word edit	Three-dimensional groundwater flow model **was** developed for the Parkway/Strasburg Well Fields to delineate capture zones for the well fields under steady-state pumping conditions.	Text updated as suggested.
Main Report	ROW-round2	20	Word edit	The GAWSER continuous s**tream flow generation** model's outputs were used as inputs into a MODFLOW three-dimensional groundwater flow model for the subwatersheds. Involved examination of land use planning options and the assignment of hydrologic response units in the GAWSER model.	Text updated as suggested.
Main Report	ROW-round2	20	Word edit	Three-dimensional MODFLOW model developed for the Alder Creek watershed to delineate capture zones, conduct **a** GUDI analys**i**es and assess groundwater / surface water interactions along Alder Creek.	Text updated as suggested.
Main Report	ROW-round2	21	Word edit	...re-logging of selected archived core, examining available sediment exposures, drilling and logging additional cores and geophysics **geophysical** techniques	Text updated as suggested.
Main Report	ROW-round2	21	Word edit	...In a similar manner, the bedrock **stratigraphic** understanding developed by the OGS (Brunton, 2008) was used as the basis for delineating and characterizing the hydrogeologic conditions throughout the Cambridge Area model	Text updated as suggested.
Main Report	ROW-round2	23	Comment	Update references	Text updated as suggested.
Main Report	ROW-round2	24	Word edit	Hydraulic conductivity values and/or model boundary conditions were adjusted based on available information to improve the fit between the observed and model predicted **water levels** and **stream flow** values	Text updated as suggested.
Main Report	ROW-round2	24	Word edit	...for example, may have interbeds of gravel, sand or silt and **may** be less dense or competent than expected	Text updated as suggested.
Main Report	ROW-round2	25	Comment	Edit Table A1, Appendix F accordingly	Text updated as suggested.
Main Report	ROW-round2	25	Comment	Assessment report planning year is 2009 so newer wells have been removed. We will need to discuss how to address new wells in analysis	Text updated as suggested.
Main Report	ROW-round2	26	Table Edits	Table 7 edits	Text updated as suggested.
Main Report	ROW-round2	27	Sentence edit	In addition to the municipal **supply wells**...	Text updated as suggested.
Main Report	ROW-round2	28	Comment	What about Cambridge model?	Text updated as suggested.
Main Report	ROW-round2	28	Comment	ditto	Text updated as suggested.
Main Report	ROW-round2	28	Comment	ditto	Text updated as suggested.
Main Report	ROW-round2	28	Comment	ditto	Text updated as suggested.
Main Report	ROW-round2	28	Sentence edit	...the MOE Water Taking and Reporting System **(WTRS**, 2008).	Text updated as suggested.
Main Report	ROW-round2	28	Sentence edit	This **equated** to 62% of the non-municipal permitted groundwater wells having reported data available either in the WTRS or in a survey by the GRCA. Consumptive **demands** for the remaining 38% of the groundwater wells **were** calculated using the…	Text updated as suggested.
Main Report	ROW-round2	28	Comment	Estimated? (referring to use of the word calculated)	Text updated as suggested.
Main Report	ROW-round2	28	Sentence edit	Based on the Tier Two Water Budget Assessment, the consumptive water taking from non-permitted groundwater takers within local subwatersheds **was** expected to be **less than** 2% of the total municipal demand (AquaResource, 2009i).	Text updated as suggested.
Main Report	ROW-round2	28	Sentence edit	...the Region developed and maintains a comprehensive monitoring **program** to collect the following hydrogeologic data	Text updated as suggested.
Main Report	ROW-round2	29	Comment	Repeat of above	Text updated as suggested.
Main Report	ROW-round2	29	Sentence edit	To supplement these data and fill data gaps where gauge and spot baseflow data were lacking, two rounds of spot baseflow monitoring were conducted as part of the Tier Three Assessment.	Text updated as suggested.
Main Report	ROW-round2	29	Sentence edit	...at the Mannheim East Well Field and the deep bedrock aquifer **at** the Middleton Well Field	Text updated as suggested.
Main Report	ROW-round2	31	Sentence edit	An efficiency of localized mesh discretization that require**s** far fewer calculation points to achieve the same level of precision as with finite difference grids ...	Text updated as suggested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	32	Sentence edit	..., they were used will be to assess the potential changes in the hydraulic heads and groundwater discharge to surface water features in response to changes in land use (recharge), ...	Text updated as suggested.
Main Report	ROW-round2	32	Comment	Or will be? (referring to sensitivity analysis)	Text updated as suggested.
Main Report	ROW-round2	32	Comment	There is very little reference in this section to how consistency in the Cambridge and Guelph model set ups were ensured. This needs to be addressed for all subsections	Text updated as suggested.
Main Report	ROW-round2	32	Comment	Also I do not recall seeing any discussion on how the regional and Cambridge models were kept consistent and were"stitched" together	Text updated as suggested.
Main Report	ROW-round2	32	Sentence edit	The northern and southern boundaries corresponded **with** various surface water features and subwatershed divides	Text updated as suggested.
Main Report	ROW-round2	32	Sentence edit	The numerical model domain **of the Cambridge model**...	Text updated as suggested.
Main Report	ROW-round2	33	Comment	Have these been confirmed with the current regional model? (referring to setting up of regional flow conditions along model perimeter	Text updated as suggested.
Main Report	ROW-round2	34	Sentence edit	...concurrent Cambridge East Environmental Assessment, which are both **are assessing** the potential **for** impact**s** of municipal pumping on other water users and surface water features.	Text updated as suggested.
Main Report	ROW-round2	34	Sentence edit	Although the FEFLOW model **was** simulated in variably saturated mode, only the numerical results pertaining to the saturated zone **were** evaluated.	Text updated as suggested.
Main Report	ROW-round2	34	Sentence edit	This simplification **avoided** some of the non-linearities within the unsaturated zone and **allowed** ...	Text updated as suggested.
Main Report	ROW-round2	35	Sentence edit	To accommodate **pinching out of layers**, the thicknesses of these model layers are were set to a minimum thickness of 0.1 m, and the hydraulic properties of the underlying unit **were** applied. In cases where multiple layers **were** 'pinched out', the hydraulic properties of the closest underlying unit **were** applied to the overlying minimum thickness layers so the numerical model closely **resembled** the conceptual model.	Text updated as suggested.
Main Report	ROW-round2	35	Sentence edit	Boundary conditions represent the interaction between **the** groundwater within the model domain and the surrounding areas outside the model domain.	Text updated as suggested.
Main Report	ROW-round2	35	Sentence edit	• Specified Flux boundary conditions **were**…	Text updated as suggested.
Main Report	ROW-round2	35	Sentence edit	• Specified Head boundary conditions **were** assigned in the model where the head value at a particular location **was** known	Text updated as suggested.
Main Report	ROW-round2	35	Sentence edit	The interaction between groundwater and surface water **was** simulated in the two FEFLOW groundwater flow models using boundary conditions. Based on the model simulated groundwater levels, and the water level**s** in **respective** surface water features, groundwater ...	Text updated as suggested.
Main Report	ROW-round2	36	Comment	It should be pointed out that we have little information on wetlands. In fact there is no discussion on wetlands at all although App K does discuss	Text updated. Copied a paragraph from Appendix K. A sentence has been added to indicate that wetlands have not been simulated as separate features.
Main Report	ROW-round2	36	Sentence edit	...streams, lakes and reservoirs **were** well represented ...	Text updated as suggested.
Main Report	ROW-round2	36	Sentence edit	Both approaches **were** considered ...	Text updated as suggested.
Main Report	ROW-round2	36	Sentence edit	...and rivers that **were** reported by the GRCA or MNR to host coldwater fish communities.	Text updated as suggested.
Main Report	ROW-round2	37	Comment	A summary of how wetlands were simulated as boundary layers is needed and appropriate reference to appendix K.	Text updated. Copied a paragraph from Appendix K. As indicated previously, wetlands were not simulated explicitly.
Main Report	ROW-round2	37	Sentence edit	...however, in areas where natural flow boundaries **did** not exist, additional boundary conditions were applied to simulate the flux of water into or out of these outer boundaries.	Text updated
Main Report	ROW-round2	37	Comment	Previously you said these boundary conditions came from the WHI model which is it?	Text updated. WHI model used to help define perimeter Type BCs for Regional Model and reference to WHI model inserted. The WHI model was not used to help define perimeter Type BCs for the Cambridge Model. The WHI model was not used to assign groundwater level elevations along any boundary. The assignment of the bounding groundwater level elevations is discussed (correctly) in previous Section 4.3.1.2
Main Report	ROW-round2	37	Comment	Double check these rates as there have been inconsistencies in these rates	These rates have been verified against the dataset supplied (and vetted) by Region staff

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	37	Comment	Why not reference Table 7 above instead?	Reference to Table 7 applied.
Main Report	ROW-round2	38	Sentence edit	A total of approximately 370 municipal and non-municipal pumping wells **were** represented in the Regional Model (Figure 4-2a); however, approximately 80 of these wells **were** either standby wells, or wells that are were not currently being used as supply wells but may be used in the future (i.e.e.g., Lancaster wells, Pompeii/Forwell municipal wells). Within the Cambridge model, a total of 120 municipal and non-municipal pumping wells **were** represented in the model (Figure 4-2b). The reported or estimated consumptive pumping rates for 2003 were applied in both models as they are were more accurate for model calibration than using the maximum permitted rates, and provided a more realistic water budget for the area.	Text updated as suggested.
Main Report	ROW-round2	38	Sentence edit	Recharge **rates** for the Regional Model and the Cambridge Model were primarily estimated based on output from the Grand River Watershed GAWSER continuous stream flow- generation model. The GAWSER model was revised as part of the Tier Three Assessment (see AquaResource, 2009b), and **represented** approximately ...	Text updated as suggested.
Main Report	ROW-round2	38	Sentence edit	Within the Grand River Watershed, the highest groundwater recharge rates **were** simulated in the hummocky sand and gravel deposits associated with the Waterloo Moraine (where not capped by till; Figure 4-3a), and the outwash sediments that flank the Paris and Galt Moraines in the Cambridge area (Figure 4-3b). High groundwater recharge rates **were** also simulated along the Grand and Speed Rivers where coarse-grained sediments **were** mapped at surface.	Text updated as suggested.
Main Report	ROW-round2	38	Sentence edit	**Comparisons** of the resultant recharge applied for this Tier Three study and earlier recharge predictions (for both the Tier Two Stress Assessment and the previous Regional Model) **are** presented in Appendix L.	Text updated as suggested.
Main Report	ROW-round2	39	Sentence edit	These values and zones were subsequently updated through the model calibration process, using interpreted results of pumping tests or slug tests that **helped** to constrain the conductivity estimates within particular geologic formations.	Text updated as suggested.
Main Report	ROW-round2	39	Sentence edit	During the calibration process, it was determined that these zones of hydraulic conductivity required further subdivision and greater detail in their estimated parameter values that **reflected** the borehole lithology within these zones.	Text updated as suggested.
Main Report	ROW-round2	40	Comment	In a bedrock model, depostional environment could not be considered to subdivide into different K zones. Some more discussion of this needs to written in the appendix and in the discussion of calibration results for the individual well fields. For individual well fields, what key features were changed to achieve calibration?	Text updated. For the Cambridge model, several sources were reviewed in the assignment of initial hydraulic conductivity values and the adjustment of those values during calibration. The available data suggested that hydraulic conductivity varied between hydrostratigraphic units and within them. The information that we reviewed included the results of pumping tests, packer tests, specific capacities inferred from the water well records, hydraulic gradients within units, and water level differences across units. These data were used to delineate the initial hydraulic conductivity zones within each hydrostratigraphic unit. The shapes of the initial hydraulic conductivity zones and the properties of the zones were adjusted systematically during model calibration to improve the matches to the observations.
Main Report	ROW-round2	40	Comment	Usually referred to as 1e-5 elsewhere in report	Text updated. All powers of 10 are updated to be "x10" from "e". The main report and appendix are now consistent with respect to this nomenclature.
Main Report	ROW-round2	41	Sentence edit	The purpose of calibration is to establish that the groundwater flow model can reproduce field-measured **water levels** and **stream** flows.	Text updated as suggested.
Main Report	ROW-round2	41	Comment	What do you mean by this? Was this previously defined?	Text updated. Additional context provided.
Main Report	ROW-round2	41	Comment	Actually the Region's SCADA data was provided for use on the project	Text updated as suggested.
Main Report	ROW-round2	41	Remove sentence	The rates for municipal wells were reviewed and vetted by Region staff to ensure consistency with operator knowledge.	Text updated. Average 2003 pumping rates for the steady state model calibration were determined in conjunction with the Region staff.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	41	Sentence edit	Following the calibration in all well fields to steady-state conditions, the model was calibrated to several transient pumping **or shutdown** tests to increase the confidence in the model calibration. The transient calibration involved fitting the simulated drawdown water level responses at pumping wells and monitoring wells (particularly those in the production aquifers) to water level responses observed during the pumping **or shutdown** test. The match of simulated water levels to observed water levels in areas where there was little response to pumping improved with the hydraulic conductivity value refinements through the calibration process; however, the priority was to match the water levels in wells with strong responses to pumping **or shutdown**. For the Regional Model, Table 9 below lists the pumping and shutdown tests used in the transient calibration. For the Cambridge Model, additional details of the pumping **and shutdown** tests used in the transient calibration are provided can be found in Appendix Y.	All screen captures re-done to not include a 1km buffer around former municipal well W9
Main Report	ROW-round2	42	Comment	A shut down test for Middleton as listed in Appendix Y is missing from this table.	Records added to tables. For the Cambridge model, the various information regarding the transmissivity of the aquifer (hydrostratigraphic units) were examined, these information includes the previous pumping tests, pack test, well development test from the water well records, water level gradients, thickness of the hydrostratigraphic units, etc.. The initial hydraulic conductivity zones were delineated as the results. These initial hydraulic conductivity zones for each model layers were refined/revised when the model calibration in order to match the observations.
Main Report	ROW-round2	42	Sentence edit	Calibration targets are measurements or estimates of **water levels or stream** flow that are compared to the model-predicted values during the model calibration process. The steady-state groundwater flow models were calibrated to **water level** measurements reported ...	Text updated as suggested.
Main Report	ROW-round2	43	Sentence edit	High and medium quality observations are were reflective of 2003 and near 2003 (i.e., 2000-2003 and post-2006) average water level conditions, respectively, which **were** expected to be most representative of the 2003 average annual municipal production rates. The medium-low quality observations **were** reflective of pre-2000 average water level conditions, while low quality observations **were** typically water levels measured at the time of drilling and as such may contain considerable 'noise' and **were** deemed to be less reliable from a calibration perspective.	Text updated as suggested.
Main Report	ROW-round2	43	Sentence edit	In general, the monitoring wells that were located close to the pumping wells or exhibited a strong response to pumping **or shutdown** (especially those screened within the same production aquifer) were the focus of the calibration. **Monitoring** wells that were located further from the pumping well or screened in upper or lower layers were also consulted to ensure the model predicted response in those wells was reasonable.	Text updated as suggested.
Main Report	ROW-round2	43	Sentence edit	...and **the** normalized root mean squared residual (NRMS). Residuals **were** calculated ...	Text updated as suggested.
Main Report	ROW-round2	44	Insert sentence	The absolute mean residual is an indicator of the overall magnitude of the level of fit. This differs from the mean residual as it does not allow for over- and under-predicted water levels to negate each other. A low magnitude of mean residual values indicates a reasonable balance between over- and under-predicted water levels (with the ideal value being zero). The root mean squared residual is a measure of the central tendency of the absolute mean residual. The normalized root mean squared residual normalizes the root mean squared residual to the range in observed water levels to provide context to the variation of the absolute mean.	Text updated as suggested.
Main Report	ROW-round2	44	Remove sentence	A low magnitude of mean residual values indicates a reasonable balance between over- and under-predicted water levels (with the ideal value being zero).	Text updated as suggested.
Main Report	ROW-round2	44	Remove sentence	The absolute mean residual is an indicator of the overall magnitude of the level of fit. This differs from the mean residual as it does not allow for over- and under-predicted water levels to negate each other.	Text updated as suggested.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	44	Sentence edit	Spatially, the lowest residuals **were** within the extents of the Tier Three Assessment Area, reflecting the level of refinement and calibration rigour applied in this focus area. **Further** evidence of this is presented throughout the individual well field discussions in the following sections. It also reflects **reflected** the area where more high quality data are **were** available.	Text updated as suggested.
Main Report	ROW-round2	44	Comment	Why no other quality groupings? (referring to cambridge residuals only be reported for high quality)	Text in section updated. Records added to table for "High", "Low" and "All" quality groupings. The quality groupings are subjective, and at the discretion of the modeller. Different definitions of quality were adopted for the Cambridge model. For the Cambridge model, the calibration targets were grouped into two classes: relatively higher quality and relatively lower quality. The higher quality data corresponded to targets derived from long-term records from dedicated monitoring wells and the snapshot measurement at the recently drilled observation wells during the IUS studies. We generally would not consider targets derived from snapshots to be of higher quality. However, in this case the data provided significant additional spatial coverage. The targets from the 'old' WHI calibration were considered to be of lower quality, as they are derived primarily from water well records.
Main Report	ROW-round2	45	Sentence edit	The fit of the calibration is also presented visually for the Regional **Model,** grouped by observation quality, and the Cambridge **Model,** models in Figure 4-23 and Figure 4-24, respectively. A perfect fit (dashed diagonal) line and 5 m offset (solid diagonal) lines are shown **on the figures** to help illustrate the fit.	Text updated as suggested.
Main Report	ROW-round2	45	Sentence edit	The results of the verification simulation showed an excellent match **to the** snapshot of groundwater levels collected for this purpose,	Text updated as suggested.
Main Report	ROW-round2	45	Comment	These are not data gaps but more observations and limitations to the modeling conceptualization and approach. Maybe this title could be modified	Text updated as suggested.
Main Report	ROW-round2	46	Sentence edit	The generalized stratigraphy from the OGS surfaces also led to the generation of observation "noise". **In some cases,** observed water levels evidently screened within the same hydrostratigraphic unit (similar elevations and similar water levels), **fell** on opposite sides of different OGS aquitard units. Where detailed well field scale cross-sectional characterization was completed **(in the** Tier Three Assessment Area) observation screen completion intervals were checked for consistency between the conceptual and numeric models. Where appropriate, the representations of screened intervals in the model were adjusted to ensure that the simulated water levels are were reported consistent with the conceptual unit of the observation screen interval. Not all issues of this nature **could** be resolved due to observations being located off-section or outside of the re-interpreted area. In such cases, the OGS stratigraphy would infer a large hydraulic gradient, despite water level observations to the contrary	Text updated as suggested.
Main Report	ROW-round2	46	Comment	Not a sentence but just a statement.	Text updated. Is now a sentence.
Main Report	ROW-round2	46	Comment	Not a sentence but just a statement.	Text updated. Is now a sentence.
Main Report	ROW-round2	46	Sentence edit	Figure 4-25 illustrates the predicted water level **elevation** contours ...	Text updated as suggested.
Main Report	ROW-round2	47	Sentence edit	Figure 4-28 illustrates the simulated vertical **water level** difference calculated as the difference in **water level** between the shallow (AFB2) and deep (AFD1) potentiometric surfaces described above for the Regional Model	Text updated as suggested.
Main Report	ROW-round2	47	Sentence edit	The map is shaded to show where there is downward (blue-**grey**) and upward (yellow-red) differences in water levels between AFB2 and AFD1. Within the Regional Model, upward **hydraulic** gradients are illustrated to exist along the Grand River and its tributaries; a reflection of groundwater discharge to those areas. The greatest positive **head** differences	Text updated as suggested.
Main Report	ROW-round2	48	Comment	No this is 5.2 so it is not less than 4!	Reporting (of < 4m) refers to combining of the high and medium quality groupings - thus is consistent. The high quality on its own is 5.2m.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	48	Sentence edit	This good match was achieved between the simulated and observed water levels in the production aquifer (AFB2) as well as in observed perched **aquifer** conditions north of the well field and in the Erb Street Landfill, situated down gradient of the well field in a southeasterly direction.	Text updated as suggested.
Main Report	ROW-round2	48	Sentence edit	...appropriate **hydraulic** conductivity of the Maryhill Till units ….	Text updated as suggested.
Main Report	ROW-round2	48	Comment	This was not discussed in the memo (refering to fining upward sequence in Erb Street Calibration Memo)	Text updated. Additional text added to memo.
Main Report	ROW-round2	49	Sentence edit	Simulated water levels at the **Waterloo** Landfill showed an excellent match	Text updated as suggested.
Main Report	ROW-round2	49	Comment	If separate statistics are being developed for the medium and high wells, why are these two well categories listed in the following table. This would assist in reviewing the report. This comment applies to all the wells. Perhaps the high quality wells could be marked with an asterick?	No action. Due to the large number of observations only a short list of the highest quality observations at each well field are presented in the main body of the report. A full listing is provided in the memo/appendix for each well field.
Main Report	ROW-round2	49	Comment	Please make similar changes in Appendix O.	Memo Text updated.
Main Report	ROW-round2	49	Comment	above you said it was an excellent match	Text updated. Additional text provided in previous section of report.
Main Report	ROW-round2	49	Comment	If separate statistics are being developed for the medium and high wells, why are these two well categories listed in the following table. This would assist in reviewing the report. This comment applies to all the wells. Perhaps the high quality wells could be marked with an asterick?	In this case there were 2 high quality and 20 medium quality observations
Main Report	ROW-round2	50	Sentence edit	...increased emphasis was placed on matching water level responses in observation wells located within the **production** aquifer (AFB2).	Text updated as suggested.
Main Report	ROW-round2	50	Comment	Appendix O lists many more medium quality monitoring wells than those listed here. Please explain.	This is just a representative selection. The entire list is too voluminous for the main body of the report and are included in the appendix. The appendix also includes observations from the Waterloo Landfill. The text in the main report indicates only a short list of the highest quality observations are presented in the main report (for brevity).
Main Report	ROW-round2	50	Comment	How defined (referring to fit of transient calibration)	No action. Degree of calibration to transient conditions (comparing hydrographs) does not lend itself well to a statistical summary. The fit is assessed visually and given a descriptor/adjective.
Main Report	ROW-round2	50	Comment	Not really looks identical	Text updated. Additional text provided to help provide clarity.
Main Report	ROW-round2	50	Comment	Inconsistent format	Document checked and consistent format for exponential numbers applied.
Main Report	ROW-round2	50	Sentence edit	Aquifer AFB2 is hydraulically isolated from surface water in the vicinity of the well field. Perched **ground**water conditions exist near the well field and water levels in the production aquifer (AFB2) are below the upper aquitard	Text updated as suggested.
Main Report	ROW-round2	51	Sentence edit	Calibration of conditions throughout **aquifer** AFB1 (above ATB2) was challenging and suggests suggested that additional shallow stratification occurs exists in this area and …	Text updated as suggested.
Main Report	ROW-round2	52	Comment	Figure 3 in Appendix C shows 4 areas where water supply systems exist. The area around former well W9 should be removed as this well has not been operational for approximately 20 years.	All screen captures re-done to not include a 1km buffer around former municipal well W9
Main Report	ROW-round2	52	Comment	Please change in appendix P as well.	Text updated as suggested.
Main Report	ROW-round2	52	Comment	says “good” in appendix	Text updated. Appendix updated to 'excellent' to be consistent with main report
Main Report	ROW-round2	52	Comment	In appendix it says shallow calibration “weaker”	Text updated. Appendix is consistent with main report
Main Report	ROW-round2	53	Comment	inconsistent with previous paragraph	Text updated. Sentence removed.
Main Report	ROW-round2	54	Comment	also Jan 2007?	Text updated as suggested.
Main Report	ROW-round2	55	Comment	Reference (wrt short-term peak capacity of W10)	Text removed. Text also removed from memo.
Main Report	ROW-round2	55	Comment	Appendix says four wells. Well W2A exists but it is disconnected and never used	Text updated. Count is reduced from 5 municipal wells to 4.
Main Report	ROW-round2	56	Sentence edit	The well field as a whole is permitted to pump at a maximum rate of 22,051 m3/day**, but is restricted to an annual daily average pumping rate of 9,227 m3/day.**	Text updated as suggested.
Main Report	ROW-round2	56	Comment	Appendix says it is “good” which is it?	No action. Memo updated to 'excellent' to be consistent with main report
Main Report	ROW-round2	56	Sentence edit	The first window extends from production well W1B west **to the former business supply well** (now labeled W14).	Text updated as suggested.
Main Report	ROW-round2	57	Comment	Or layer?	Text updated to provide context to layer.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	57	Comment	Or aquifer system?	No action. Act as a single package conveys the correct context
Main Report	ROW-round2	57	Comment	Again appendix says it is a “good” match	No action. Memo updated to 'excellent' to be consistent with main report
Main Report	ROW-round2	57	Sentence edit	All simulated water levels are were well within 5 m of observed values, with the exception of a shallow screen interval for a high quality observation well, which is potentially **within a** perched **aquifer system**	Text updated as suggested.
Main Report	ROW-round2	58	Comment	Appendix says also AFD1	Update memo to be consistent with this report
Main Report	ROW-round2	57	Comment	Again appendix says it is a “good” match	No action. Memo updated to 'excellent' to be consistent with main report
Main Report	ROW-round2	59	Sentence edit	The Strange Street Well Field currently **consists of five** production wells: **Wells K10A, K11A, K13, K19, and K19**	Text updated as suggested.
Main Report	ROW-round2	59	Sentence edit	The entire well field is permitted to pump at a maximum combined rate of 16,512 m3/day **but is restricted to an annual daily average pumping rate of 10,575 m3/day** .	Text updated as suggested.
Main Report	ROW-round2	60	Comment	Inconsistent with appendix	No action. Rates for individual production wells are not reported in appendix. I do not see inconsistency.
Main Report	ROW-round2	60	Comment	I have 829 for K13 based on estimates. Table 7 above uses 829	Text updated. Value corrected.
Main Report	ROW-round2	59	Comment	?K15 not used in 2003?	Is applied in model. Carried over from WHI model. Is also noted in characterization report. Rate reflects a small taking and its inclusion would not offset the calibration of the flow system.
Main Report	ROW-round2	61	Comment	Appendix makes reference to other more regional areas where recharge was increased in the model but that section is confusing	Text updated. Text in appendix simplified.
Main Report	ROW-round2	61	Comment	Above and in appendix calibration was referred to as “good” which is it?	Text updated. Defined as good to be consistent within this section and with memo.
Main Report	ROW-round2	61	Comment	ditto	Text updated. Defined as good to be consistent within this section and with memo.
Main Report	ROW-round2	61	Comment	strong vs good (appendix) vs excellent (above) what do these terms mean and why are statements inconsistent?	Text updated. Defined as good to be consistent within this section and with memo. The descriptions are
Main Report	ROW-round2	62	Comment	8 in table	Text updated. Consistent with appendix and text.
Main Report	ROW-round2	63	Comment	? in appendix reference is made to how the aquifer changes form confined to unconfined conditions with pumping which seems inconsistent with what is said here	Text updated. Additional text provided.
Main Report	ROW-round2	63	Comment	Inconsistent format	Text updated. Consistent formatting applied.
Main Report	ROW-round2	63	Comment	ditto (referring to inconsistent formating)	Text updated. Consistent formatting applied.
Main Report	ROW-round2	63	Comment	ditto (referring to inconsistent formating)	Text updated. Consistent formatting applied.
Main Report	ROW-round2	63	Comment	ditto (referring to inconsistent formating)	Text updated. Consistent formatting applied.
Main Report	ROW-round2	65	Comment	Was ASR1 in use as a production well?	Text updated as suggested.
Main Report	ROW-round2	65	Comment	Inconsistent with appendix where referred to as “good” and “strong”	Not updated. Report is specifically referring to High Quality wells where as this paragraphs is addressing all quality rankings of observations
Main Report	ROW-round2	65	Comment	Do you mean ASR operations? If so exclude these wells and select data from 2002-2003 before system commissioning	This selection of water level data (with respect to time frames) was done during the compilation of the water level dataset.
Main Report	ROW-round2	66	Comment	The asr system has limited affect on the peaking well field water levels, or are you actually referring to wells on the MWTP site?	No action. Not referring to MWTP.
Main Report	ROW-round2	66	Comment	This doesn’t make sense as there is no net taking. As noted in the comments on the memo, the well/aquifer designations are not correct which needs to be examined further	Text updated to remove reference to ASR
Main Report	ROW-round2	66	Comment	Water levels in this aquifer as a whole have recovered on the order of 3 m due to changing climate – see mikes memo as these calibration data in particular may have to be corrected to 2003 conditions.	Text updated as suggested.
Main Report	ROW-round2	66	Comment	Water levels declined in this aquifer following development of the well fields. E.g. at K22A groundwater used to discharge to Alder Creek but now water levels are several m below the creek. Thus old static levels should probably not be used for this aquifer calibration	Comment acknowledged. Will keep this in mind for future calibration efforts.
Main Report	ROW-round2	67	Comment	There should be more high quality data than this as a number of other monitoring wells were available in 2003	Comment noted. High quality data may not be commensurate with the calibration period (2003) and therefore, not used. Details regarding the quality of the data are found in the appendices.
Main Report	ROW-round2	68	Comment	Inconsistent reference with App S.	Text updated. Appendix and Main Report are consistent

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	68	Comment	This is always the case, why emphasize it for these wells?	The aim is to provide context to readers that may not have the numeric background to appreciate this.
Main Report	ROW-round2	68	Comment	Format inconsistent and value is different from text.	Text updated. Formats and values applied consistently.
Main Report	ROW-round2	68	Comment	As noted in App S not really windows. Layer is discontinuous. What concurrent investigations?	Text updated as suggested.
Main Report	ROW-round2	68	Comment	Inconsistent format, also values inconsistent with text	Text updated. Formats and values applied consistently.
Main Report	ROW-round2	68	Comment	Inconsistent format, also text uses a range	Text updated. Formats and values applied consistently.
Main Report	ROW-round2	70	Comment	? I total up 5776 for 2006?	The well field production rate of 6,246 m3/d is based on the data in the WRAS+ database and is consistent with estimates of well field production from Figure 2 of the Stantec Well Field Characterization Report. This value was also used when calibrating the well field to 2006 conditions.
Main Report	ROW-round2	70	Comment	Im not sure the rates have returned to 2003 levels yet check pumping data	Characterization report indicates rates after 2009 are similar to 2003 and earlier. Sentence simplified.
Main Report	ROW-round2	70	Sentence edit	The ability to calibrate water levels at the Greenbrook Well Field is was hindered by the water level rebound that occurred **in the production aquifer** during and following the shutdown of the well field in 2004.	Not updated. groundwater level elevations in the other units are affected as well (but to a lesser degree).
Main Report	ROW-round2	70	Comment	(Also used to be a snow dump to the east along homer Watson) just fyi	Comment noted.
Main Report	ROW-round2	73	Comment	Maybe it wasn't increased far enough?	Comment acknowledged. Hydraulic conductivity values in this area were adjusted to their conceptual upper bounds.
Main Report	ROW-round2	74	Comment	As discussed there may be separate glaciofluvial channel aquifers that supply the Greenbrook and Parkway/Strasburg well fields, that are separated by low conductivity tills	This comment was acknowledged in the text as a data gap.
Main Report	ROW-round2	75	Comment	Not mentioned previously	Text updated. A brief discussion of recharge was introduced earlier in this section.
Main Report	ROW-round2	75	Add sentence	Included in the Parkway-Strasburg Well fields are the three private wells used by Kuntz Electroplating (Permit to Take Water 87-P_2009) in their daily operations. One of these wells was active during the 2003 calibration period, pumping at an average rate of 914 m3/day.	Text updated. Sentence added.
Main Report	ROW-round2	78	Comment	Inconsistent with appendix	Text updated. References and timeframes are now consistent between main report and appendix.
Main Report	ROW-round2	79	Comment	I did not see this in the memo	Not updated. Previous section, discussing refinements during the steady-state calibration process, described the updates/refinements made.
Main Report	ROW-round2	79	Comment	As discussed there may be separate glaciofluvial channel aquifers that supply the Greenbrook and Parkway/Strasburg well fields, that are separated by low conductivity tills	This comment was acknowledged in the text as a data gap.
Main Report	ROW-round2	79	Comment	No discussion provided	Text updated. Sentence deleted.
Main Report	ROW-round2	80	Comment	And length?	Text updated as suggested.
Main Report	ROW-round2	80	Comment	And length?	Text updated as suggested.
Main Report	ROW-round2	80	Comment	Could this also be related to the presence/absence of the Salina Formation?	Text updated as suggested.
Main Report	ROW-round2	81	Comment	Appendix says good which is it?	Text updated. Memo and main report are consistent.
Main Report	ROW-round2	82	Comment	And monitoring wells?	Text updated as suggested.
Main Report	ROW-round2	82	Comment	Appendix says good which is it?	Text updated. Memo and main report are consistent for both steady-state and transient calibration descriptors.
Main Report	ROW-round2	83	Comment	Inconsistent format	Text updated throughout report to establish consistency in format.
Main Report	ROW-round2	83	Comment	Inconsistent format	Text updated throughout report to establish consistency in format.
Main Report	ROW-round2	89	Comment	This well is actually located in Cambridge, so technically it should be moved to section 4.5.5.	Text moved to Cambridge well fields section.
Main Report	ROW-round2	90	Comment	Says good in appendix which is it?	Text updated. Additional clarification provided.
Main Report	ROW-round2	90	Comment	Contradicts above sentence	Text updated. Text is now consistent.
Main Report	ROW-round2	90	Comment	Same comment	Text updated. Text is now consistent.
Main Report	ROW-round2	91	Comment	Why is this reference different than above?	Text updated. Text is now consistent.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	92	Comment	Reporting for Cambridge model is missing some components that are included with Regional model, please make consistent	From this point on in the document we were careful to indicate that the results are obtained with the Cambridge model.
Main Report	ROW-round2	92	Comment	Up to this point there was clear separation of the Regional and Cambridge models. Now the results for Cambridge are being discussed but it is not clearly stated which model is being referred to here	From this point on in the document we were careful to indicate that the results are obtained with the Cambridge model.
Main Report	ROW-round2	92	Comment	Reference?	When referring to “the hydrostratigraphic model”, we will cite the relevant SSPA (2012) appendix to the Tier 3 report. The logs for the municipal wells in the Hespeler well field do not indicate what geologic formations were penetrated. We have inferred what formations are penetrated by combining the data on the elevations of the top and bottom of the open interval of the well with our mapping of the contacts between the units.
Main Report	ROW-round2	95	Comment	Not entirely true as they are limited by the CofA, now DWL	Comment acknowledged.
Main Report	ROW-round2	95	Comment	The discussion of results is limited to residuals at two locations. There is no discussion of whether K values were adjusted or whether additional manipulation was needed to achieve calibration. There is also not data gaps or insights in this section of the other Cambridge wells. This needs to be addressed. This discussion is critical to articulating how the model is working and its limitations on a well field basis.	With respect to the comment on whether K-values were adjusted, we have inserted a description at the beginning of this section on the general approach that has been adopted during the steady-state and transient calibration. The starting point for the calibration effort associated with the Tier 3 study was the model that was calibrated intensely in the Cambridge East area. Adjustments were made to match both steady-state and transient targets, and the modifications were cumulative as we moved from well field to well field. For each well field, discussed has been added with respect to the assessment of the overall calibration, insights for risk assessment and data gaps."
Main Report	ROW-round2	96	Comment	Appendix C Table 2 lists 12 monitoring wells. There are 13 including the supply wells in these tables.	Only high quality targets and groundwater level elevations from the pumping wells were used in the calculation of the goodness of fit statistics at each well field. The count of 13 includes 2 observation wells, each with 5 monitoring intervals plus 3 pumping wells. The 12 wells listed in Appendix C include 2 observation wells that each have 6 monitoring intervals. Only 5 of the intervals are considered in the calibration, as the “A” monitoring intervals at both OW1-95 and OW2 95 fall within the Cabot Head Formation, below the bottom of the model.
Main Report	ROW-round2	97	Add text		Subsections added for Overall Comments on Well Field Calibration, Insights toward Risk Assessment, and Identified Data Gaps
Main Report	ROW-round2	98	Comment	Reference?	The units that are intersected by the open intervals of the production wells are inferred from a comparison of the reported elevations of the top and bottom of the open intervals and the tops of the surfaces interpolated in the hydrostratigraphic model that has been developed as part of the modeling effort.
Main Report	ROW-round2	99	Comment	A steel liner has been installed in this well to 48.2 mbgs	We will note this change for any future analyses. Our understanding is that the liner was installed recently. We are not sure about the date – we think June or July 2011 – but is definitely after 2003 (the transient pumping test that has been examined for Pinebush are even earlier, 1991). Since the liner was installed later than the collection of the water level targets, the installation of the liner does not affect either the steady-state or the transient calibration. If we make any mention of the installation of the liner, someone may ask why the liner was installed and if it was to prevent P17 from pumping from the same interval as P11, and how the installation of the liner affected the yield of both P11 and P17.
Main Report	ROW-round2	99	Comment	Limited by CofA/DWL	Text updated to include reference to operational considerations. We do not know what “DWL” stands for."
Main Report	ROW-round2	99	Comment	There was extensive work needed to calibrate the model at this well field that took months of assessment. The key findings of this modeling should be discussed here.	Additional detail was provided.
Main Report	ROW-round2	99	Comment	Do you mean the vertical K here?	Yes; text updated to clarify.
Main Report	ROW-round2	99	Sentence edit (replace)	However, during the Tier Three peer review meeting on December 20, 2011, Stephanie Shifflett from GRCA indicated that they are in the process of updating the GAWSER model. In the follow up email communications afterwards with both Sam Bellamy from AquaResource Inc. and Stephanie Shifflett, both of them indicated that the recharge can be adjusted by looking in detail at the percentage of impervious coverage of the specific area. Ms. Shifflett also indicated that the GAWSER model is designed to look at the large-scale flow systems. Therefore, the GAWSER model may not be sufficiently resolved for direct application at the local scale of an individual Well Field	The GAWSER model is designed to look at large-scale flow systems and so it may not be sufficiently resolved for direct application at the local scale of an individual well field. Improved local scale resolution could be potentially achieved through a more detailed review of land use, for example percentage of impervious land cover in a given area.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	103	Add text		Subsections added for Overall Comments on Well Field Calibration, Insights toward Risk Assessment, and Identified Data Gaps
Main Report	ROW-round2	104	Comment	Reference?	The units that are intersected by the open intervals of the production wells are inferred from a comparison of the reported elevations of the top and bottom of the open intervals and the tops of the surfaces interpolated in the hydrostratigraphic model that has been developed as part of the modeling effort.
Main Report	ROW-round2	104	Comment	Well has recently been deepened to 126.2 m bgs	Our understanding is that G16 was deepened in June-July 2011. The modification of the well does not affect the calibration, as the targets are representative of earlier conditions. Going forward, the new depth of the well will be incorporated in any predictive modelling. We also noticed from the well deepening report that almost 80% of water is from the extended section of the well. G16 is located at the transition zone that has been inferred south of the tongue shaped high transmissivity zone (the inference is from John Piersol, and from the modeling). The increase in production from G16 is consistent with the existence of a zone of elevated transmissivity in the middle Gasport Formation at this location.
Main Report	ROW-round2	110	Add text		Subsections added on Overall Comments on Well Field Calibration, Insights toward Risk Assessment, and Identified Data Gaps
Main Report	ROW-round2	111	Comment	Reference?	The units that are intersected by the open intervals of the production wells are inferred from a comparison of the reported elevations of the top and bottom of the open intervals and the tops of the surfaces interpolated in the hydrostratigraphic model that has been developed as part of the modeling effort.
Main Report	ROW-round2	112	Add text		Subsections added on Overall Comments on Well Field Calibration, Insights toward Risk Assessment, and Identified Data Gaps
Main Report	ROW-round2	113	Comment	Reference?	The units that are intersected by the open intervals of the production wells are inferred from a comparison of the reported elevations of the top and bottom of the open intervals and the tops of the surfaces interpolated in the hydrostratigraphic model that has been developed as part of the modeling effort.
Main Report	ROW-round2	115	Add text		Subsections added on Overall Comments on Well Field Calibration, Insights toward Risk Assessment, and Identified Data Gaps
Main Report	ROW-round2	116	Comment	Not sure what you are saying here	Section was re-written to clarify.
Main Report	ROW-round2	118	Comment	Reference?	The units that are intersected by the open intervals of the production wells are inferred from a comparison of the reported elevations of the top and bottom of the open intervals and the tops of the surfaces interpolated in the hydrostratigraphic model that has been developed as part of the modeling effort.
Main Report	ROW-round2	120	Add text		Subsections added on Overall Comments on Well Field Calibration, Insights toward Risk Assessment, and Identified Data Gaps
Main Report	ROW-round2	121	Comment	There has been a lot of interpretation of the stratigraphy at Middleton also of the challenge of representing recharge into the bedrock layers from the Grand. Some more details of this and any challenges it might have created in calibrating the model would be helpful.	The section on data gaps has been expanded to highlight the advantages and challenges of working within a framework of a rigorous geologic characterization of the area (we will not qualify them as disadvantages, but they have caused us several sleepless nights).
Main Report	ROW-round2	121	Comment	Reference?	The units that are intersected by the open intervals of the production wells are inferred from a comparison of the reported elevations of the top and bottom of the open intervals and the tops of the surfaces interpolated in the hydrostratigraphic model that has been developed as part of the modeling effort.
Main Report	ROW-round2	122	Comment	Why good when same as Middleton?	The classification has been corrected.
Main Report	ROW-round2	111	Comment	AB??	Not updated. AC is the correct appendix
Main Report	ROW-round2	115	Comment	C2 was abandoned early in 2003 and replaced with C6	Text updated as suggested.
Main Report	ROW-round2	117	Add sentence	In 2003, the well field consisted of wells SA3 and SA4; the Region commenced operating SA5 and SA6 in January 2004 following the MOE's order to take over this private system.	A modification of this sentence was added to the text.
Main Report	ROW-round2	117	Add sentence	The Region does not have 2003 pumping data for wells SA5 and SA6.	Text updated as suggested.
Main Report	ROW-round2	117	Add sentence	In accordance with O.Reg. 287, the Region has approved a council resolution to discontinue use of these supply wells and revoke all associated permits.	Sentence added to clarify text.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	ROW-round2	117	Delete sentence	Under 2003 production conditions, which are essentially steady-state non-pumping conditions, a strong calibration was achieved.	Sentence removed to clarify text.
Main Report	ROW-round2	117	Comment	Above you said reasonable	Sentence removed to clarify text.
Main Report	ROW-round2	117	Comment	?specifiy	Text updated. Additional context provided.
Main Report	ROW-round2	117	Comment	?specifiy	Text updated. Additional context provided.
Main Report	ROW-round2	119	Comment	Inconsistent with above	Sentence removed - is redundant.
Main Report	ROW-round2	121	Comment	??As I recall creek returned to discharge conditions around the middle of the well field	Text updated as suggested.
Main Report	ROW-round2	122	Comment	How defined?	Not updated. Context provided at end of sentence.
Main Report	ROW-round2	127	Comment	Can the results of this approach be equally transferred to the Cambridge model? Are there any other implications in Cambridge?	Text updated as suggested.
Main Report	ROW-round2	130	Comment	So what are we going to do with this? If we are achieving a better calibration then should we not be using these recharge rates? Particularly since the model shows a bias toward under-predicting water levels and stream flows in many areas, indicating insufficient recharge is being applied to the model.	Text updated to reflect that this is an alternative calibration. All model realizations maintain a calibrated state. Thus, from a water quantity risk perspective it is more conservative to move forward with the calibrated model than these scenarios of increased recharge. The text has been updated with the point.
Main Report	ROW-round2	130	Comment	As part of calibration should there not be an evaluation of the water budget/conservation of mass for each well field (i.e. water in minus water out etc.)?	Text regarding the global mass balance is applied to Section 4.5.1. A mass balance on a well field basis is not appropriate as its source waters often reach far beyond the immediate vicinity of the well field.
Main Report	ROW-round2	131	Comment	So we should use this then!	Text updated to reflect that this is an alternative calibration. All model realizations maintain a calibrated state.
Main Report	ROW-round2	131	Comment	Do these limitations also apply to the bedrock layers? What about fracture flow in Cambridge?	Yes they do. Text has been added to include this point.
Main Report	ROW-round2	131	Comment	Or " in addition"?	Text updated as suggested.
Main Report	ROW-round2	131	Add sentence	The geology of the Waterloo Moraine area in particular, is highly variable and although aquifers and aquitards may be continuous across several kilometers, the texture and characteristics of the respective units are highly variable.	Sentence added.
Main Report	ROW-round2	132	Comment	Why not? This needs to be clearly stated	Additional context provided.
Main Report	ROW-round2	132	Comment	Bedrock …?	Text updated as suggested.
Main Report	ROW-round2	132	Comment	Why? (referring to OGS discarding municipal well borehole logs)	Additional context provided.
Main Report	ROW-round2	133	Comment	I presume you are referring to GMP here?	Text updated. Additional text provided.
Main Report	ROW-round2	136	Comment	What exactly are the implications of this e.g. increased imperviousness?	Text updated. Additional text provided.
Main Report	ROW-round2	142	Comment	P17 doesn't have a negative value in table. Also it appeared there was something wrong with the elevation calculation for G9	Text updated. Table edited.
Main Report	ROW-round2	148	Comment	Or allocated?	Text updated as suggested.
Main Report	ROW-round2	150	Comment	I do not recall this discussion being part of the main body of the report and it should be as the interconnected nature of the model setups was not clearly discussed. This section should summarize what is in the body of the text.	Additional text added in preceding section.
Main Report	ROW-round2	151	Comment	I thought it was done??	Yes. This is complete and text has been updated appropriately.
Main Report	ROW-round2	156	Comment	?? (referring to incorrrect reference of ASR report)	Reference updated as requested.
ErbStreetCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
ErbStreetCalib	ROW-round2	1	Comment	Not in Table 2 do you mean C1?	Text updated. Yes, the intention was to reference table C1, which has now been done.
ErbStreetCalib	ROW-round2	2	Sentence edit	...pre-2000, and static conditions at **the** time **of** drilling.	Text updated.
ErbStreetCalib	ROW-round2	2	Sentence edit	At the **Erb** Street Well Field there are **only two** observations with water level data for the 2003 year…	Text updated.
ErbStreetCalib	ROW-round2	2	Sentence edit	Residuals weare calculated as **observed** water level less **simulated** water level (after Anderson and Woessner, 1992).	Text updated.
ErbStreetCalib	ROW-round2	3	Comment	Table 4 should be here?	Table moved and text updated.
ErbStreetCalib	ROW-round2	3	Sentence edit	During calibration, emphasis was placed on matching water level responses in observation wells located within the **production** aquifer.	Text updated.
ErbStreetCalib	ROW-round2	3	Sentence edit	Title incorrect not Mannheim	Text updated. Title fixed.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
ErbStreetCalib	ROW-round2	3	Sentence edit	What is below fig no reference to it?	Text updated. Typo, cross-reference applied to figure caused it to show up with label in text. Fixed.
ErbStreetCalib	ROW-round2	4	Sentence edit	Shutdown? (With respect to describing transient calibration at well field instead of pumping)	Text updated.
ErbStreetCalib	ROW-round2	4	Comment	Not all present	Annotation and footnote applied to table.
ErbStreetCalib	ROW-round2	5	Comment	Highlight units that are actually present and relevant to calibration	Annotation and footnote applied to table.
ErbStreetCalib	ROW-round2	6	Sentence edit	At this well field there **were** a limited number of water level observations for the **deeper aquifer** system. Those that are available tend to be over-predicted. At the **Waterloo** Landfill, water levels are were both over- and under-predicted with the majority being over-predicted in the range of 6 m.	Text updated.
ErbStreetCalib	ROW-round2	6	Comment	These figs look like before not after calibration	Text updated. Yes, the intention of these figures is to show the level of fit prior to calibration. There is a typo in the sentence that refers to this figure. Fixed
ErbStreetCalib	ROW-round2	6	Comment	ditto (referring to same comment as above)	Text updated. Yes, the intention of these figures is to show the level of fit prior to calibration. There is a typo in the sentence that refers to this figure. Fixed
ErbStreetCalib	ROW-round2	6	Comment	Why (referring to anisotropy of 50)	Text updated. Addressed in text with additional explanation with respect to stratification.
ErbStreetCalib	ROW-round2	7	Comment	Define area	Text updated. Additional context provided.
ErbStreetCalib	ROW-round2	7	Sentence edit	...a hydraulic conductivity zone with a value of 1x10-7 m/sec **was defined** to compensate for the interpolation ...	Text updated.
ErbStreetCalib	ROW-round2	8	Sentence edit	During the calibration process, a hydraulic conductivity value of 5x10-9 m/sec was applied at the well field, which was necessary to create **water level** support conditions for the overlying AFB2 aquifer.	Text updated.
ErbStreetCalib	ROW-round2	8	Comment	Or area? (referring to the use of the word footprint	No action. Terms 'footprint' and 'area' are synonymous
ErbStreetCalib	ROW-round2	9	Comment	repeat (referring to transient K)	Table 4 moved up and duplication removed
ErbStreetCalib	ROW-round2	9	Comment	what is below fig no reference to it?	Text updated. Typo, cross-reference applied to figure caused it to show up with label in text. Fixed.
ErbStreetCalib	ROW-round2	9	Comment	why not mentioned in transient calibration section?	No action. Memo template and formatting is established and should remain consistent through-out all well field calibration memos.
ErbStreetCalib	ROW-round2	9	Comment	no comment on calibration quality/improvements?	No action. The improvement to the simulated response is noted in the following bullet.
ErbStreetCalib	ROW-round2	10	Comment	Inconsistent format	Text updated. Consistent formatting applied.
ErbStreetCalib	ROW-round2	10	Comment	ditto (referring to formating)	Text updated. Consistent formatting applied.
ErbStreetCalib	ROW-round2	10	Comment	unitless, inconsistent format	Text updated. Consistent formatting applied.
ErbStreetCalib	ROW-round2	10	Comment	And northwest	No action.
ErbStreetCalib	ROW-round2	11	Sentence edit	Perched **ground**water conditions exist near the …	Text updated.
WatNorthCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
WatNorthCalib	ROW-round2	1	Sentence edit	W5A is a replacement well for W5, which was grandfathered **under the permit to take water process**.	Text updated.
WatNorthCalib	ROW-round2	1	Sentence edit	A Class Environmental Assessment (CEA) is currently being conducted **to assess the potential** for additional water taking throughout the Waterloo North area.	Text updated.
WatNorthCalib	ROW-round2	2	Comment	repeat - The low quality observation data are based on static water level measurements typically taken at the time of drilling and therefore may contain considerable 'noise' and are deemed to be less reliable from a calibration perspective. These water level observations are included as a matter of completeness.	Text updated. Removed duplicate text between paragraphs.
WatNorthCalib	ROW-round2	2	Sentence edit	At the **Waterloo North** Well Field there was **one** observation with water level data for the 2003 year	Text updated. Typo corrected
WatNorthCalib	ROW-round2	2	Comment	not in Table 1 do you mean C1?	Text updated. Typo corrected
WatNorthCalib	ROW-round2	3	Comment	Table 3 should be here?	Text updated. Table moved up into this section
WatNorthCalib	ROW-round2	3	Comment	Also Jan 2007?	Text updated.
WatNorthCalib	ROW-round2	3	Comment	Not all present?	Text added and annotation provided in table indicating which units are more relevant to the calibration
WatNorthCalib	ROW-round2	4	Comment	Highlight units that are present and actually relevant to the calibration	Text added and annotation provided in table indicating which units are more relevant to the calibration

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
WatNorthCalib	ROW-round2	5	Comment	And observation wells?	Text updated to reflect deeper (production) aquifer, not just production wells.
WatNorthCalib	ROW-round2	5	Comment	These figs look like before not after calibration	Text updated. Yes, the intention of these figures is to show the level of fit prior to calibration. There is a typo in the sentence that refers to this figure. Fixed
WatNorthCalib	ROW-round2	5	Comment	ditto (referring to same comment as above)	Text updated. Yes, the intention of these figures is to show the level of fit prior to calibration. There is a typo in the sentence that refers to this figure. Fixed
WatNorthCalib	ROW-round2	5	Comment	Not our well!	Text updated. Reference to W4 being a municipal well is removed.
WatNorthCalib	ROW-round2	5	Comment	What about area D?	Text updated, description of area D location provided.
WatNorthCalib	ROW-round2	5	Comment	Why (referring to anisotropy of 50)	Text updated. Addressed in text with additional explanation with respect to stratification.
WatNorthCalib	ROW-round2	5	Comment	Or Tavistock?	Text updated to just indicate Till.
WatNorthCalib	ROW-round2	7	Comment	Do you mean northward?	Text updated.
WatNorthCalib	ROW-round2	7	Comment	Or creating?	Text updated.
WatNorthCalib	ROW-round2	8	Comment	What are these figures there is no reference to them?	Text updated. Cross-reference error in word.
WatNorthCalib	ROW-round2	8	Comment	Why was this not mentioned in the transient calibration section?	These property updates are part of the transient calibration and are presented in this section, accordingly.
WatNorthCalib	ROW-round2	9	Comment	No comment on the calibration quality/improvements?	The calibration is discussed in terms of the fit to water level response, which is appropriate to the transient calibration. Fit of water level values are discussed in the steady-state calibration section.
WatNorthCalib	ROW-round2	9	Comment	Inconsistent format	Text updated.
WatNorthCalib	ROW-round2	10	Comment	By who? I don't think this was previously mentioned or discussed	Text is removed "but is rated at a supply capability of 10 L/s for both sustainable summer capacity and short - term peak capacity".
WilliamStCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
WilliamStCalib	ROW-round2	1	Comment	W15 not active	Text updated to reflect that this well is not active.
WilliamStCalib	ROW-round2	2	Add sentence	The William Street wells were pumped at an average daily rate of 4,721 m3/day in 2003. Well W14 was pumped at an average daily rate of 301 m3/day in 2003	Text updated. Sentence added.
WilliamStCalib	ROW-round2	2	Remove words	The simulated groundwater flow provided a good match to observed geochemical trends at the well field and water level responses to pumping at the William Street Well Field and W14 **a former Seagram Well**.	Text updated.
WilliamStCalib	ROW-round2	3	Comment	I have 4636 +301? Report has 4875	Text updated. Rates removed, already stated in introduction.
WilliamStCalib	ROW-round2	3	Remove sentence	These findings would imply that it is unlikely that additional long-term water supply could be obtained from the William Street Well Field, based on the sensitivity of water level drawdown at the well field, relative to changes in pumping rates	Text updated. Sentence Removed.
WilliamStCalib	ROW-round2	3	Remove sentence	Based on this understanding, it is recommended that pumping at this well field not be further increased for planned pumping as part of the Tier Three Risk Assessment.	Text updated. Sentence Removed.
WilliamStCalib	ROW-round2	3	Sentence edit	At the **William** Street Well Field **???** there were **three** observations with water level data for the 2003 year	Text updated.
WilliamStCalib	ROW-round2	4	Comment	This section is repetitive	Text updated. Some of the duplication is removed
WilliamStCalib	ROW-round2	4	Remove sentence	The low quality observation data are based on static water level measurements typically taken at the time of drilling and therefore may contain considerable 'noise' and are deemed to be less reliable from a calibration perspective. These water level observations are included as a matter of completeness.	Text updated. Remove duplication.
WilliamStCalib	ROW-round2	4	Comment	repeat (referring to duplication of above sentence)	Text updated. Remove duplication.
WilliamStCalib	ROW-round2	4	Comment	Table 3 should be here?	Text updated. Table moved up into this section
WilliamStCalib	ROW-round2	4	Comment	Units?	Text updated. Units fixed.
WilliamStCalib	ROW-round2	5	Comment	Which is? (referring to identifying/naming well discussed in text)	Text updated to provide clarity regarding chloride and sodium sources and the suggestion of a pathway from the shallow to deeper system.
WilliamStCalib	ROW-round2	6	Comment	Which are?	Text updated to provide clarity regarding nitrate sources and the suggestion of a pathway from the shallow to deeper system.
WilliamStCalib	ROW-round2	6	Comment	specify	Text updated to be well specific.
WilliamStCalib	ROW-round2	6	Comment	Not all present	Text added and annotation provided in table indicating which units are more relevant to the calibration

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WilliamStCalib	ROW-round2	6	Comment	It would be helpful to highlight the units that are actually present and relevant to the calibration	Text added and annotation provided in table indicating which units are more relevant to the calibration
WilliamStCalib	ROW-round2	8	Comment	Why (referring to anisotropy of 50)	Text updated. Addressed in text with additional explanation with respect to stratification.
WilliamStCalib	ROW-round2	8	Comment	Of what?	Text updated. Additional surface water context provided.
WilliamStCalib	ROW-round2	12	Comment	Why?	As discussed in the following sentences in the paragraph, the anisotropy was reduced to create a stronger connection to the deeper system.
StrangeStCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
StrangeStCalib	ROW-round2	1	Remove Sentence	Additional production wells at well field that were not active for municipal supply in 2003 include K11 , K12, K14A, K15, K16 and K17	Text updated. Sentence removed
StrangeStCalib	ROW-round2	1	Edit Sentence	The combined water taking from these wells is not to exceed an annual daily average a maximum taking of 16,512 m3/day **and an annual daily average taking of 10,575 m3/day**	Text updated.
StrangeStCalib	ROW-round2	1	Comment	Inconsistent with report	Text updated. Sentence removed
StrangeStCalib	ROW-round2	1	Comment	These have all been abandoned and should not be referenced or plotted	Text updated. Sentence removed
StrangeStCalib	ROW-round2	1	Comment	The format of this section in this memo is more readable compared to other memos	No action. All calibration memos follow the same follow the same template
StrangeStCalib	ROW-round2	2	Comment	I calculate 3308	Text updated to 3,308 m3/d as suggested.
StrangeStCalib	ROW-round2	2	Comment	Generally the format used has referred to “water levels” rather than “groundwater levels” Maybe we should discuss this further to establish a consistent convention and then make it clear in the reports/memos. Maybe we need a “glossary of terms” for the reader?	Text updated. Efforts are being made in the revision process to adopt the term 'water level' consistently.
StrangeStCalib	ROW-round2	2	Comment	Which table?	Text updated. Sentence is a duplicate of previous, removed sentence.
StrangeStCalib	ROW-round2	2	Comment	Golder not in references	Text updated. Reference corrected (to Stantec) and appended.
StrangeStCalib	ROW-round2	2	Comment	Should Table 3 be here instead?	Text updated. Table moved up into this section.
StrangeStCalib	ROW-round2	3	Comment	How defined? (referring to excellent match)	Given that we are speaking about a match to a hydrograph, it is still subjective as we do not have a number or statistic it can be reduced to.
StrangeStCalib	ROW-round2	3	Comment	Not all present?	Text added and annotation provided in table indicating which units are more relevant to the calibration
StrangeStCalib	ROW-round2	3	Comment	Highlight units that are present and relevant to calibration	Text added and annotation provided in table indicating which units are more relevant to the calibration
StrangeStCalib	ROW-round2	4	Comment	Why what was the purpose/result? (referring to anisotropy)	Text updated. Additional context provided consistent with other well field calibration memos.
StrangeStCalib	ROW-round2	5	Sentence Edit	Henry Strum Creek, shown on Figure B1, runs along the **south** side of the Strange Street Well Field. This tributary was is characterized (Stantec, 2009) as not receiving groundwater discharge and any interaction it does have with the shallow groundwater system **is limited** as it is situated either on ATB1 or is concrete lined (west of Fischer-Halman).	Text updated.
StrangeStCalib	ROW-round2	6	Sentence Edit	This zone strengthensed the numeric representation of the conceptual model ias it preventsed upgradient **groundwater** levels (sourced from the Erb Street Well Field area) from dissipating too quickly and thereby establishing an appropriate shallow **hydraulic** gradient into the well field.	Text updated.
StrangeStCalib	ROW-round2	7	Comment	This paragraph is confusing rewrite	Text updated. Simplified and clarified.
StrangeStCalib	ROW-round2	7	Comment	Huh? Not consistent – wrong value?	Text updated. Added text to complete thought and is now consistent.
StrangeStCalib	ROW-round2	9	Comment	Mentioned but not explained as to why?	Additional text provided in earlier section of memo.
StrangeStCalib	ROW-round2	9	Comment	K15 not used?	Text updated. Additional text provided in introduction based on Stantec Characterization Report. This production rate was carried over from the WHI model and it is noted in the characterization report that this well is used to in relation to city parks.
StrangeStCalib	ROW-round2	9	Comment	Huh same as above?	Text updated. Sentence clarified.
StrangeStCalib	ROW-round2	9	Comment	Repeat of previous	Not updated. Not repeated.
StrangeStCalib	ROW-round2	10	Comment	How defined?	Given that we are speaking about a match to a hydrograph it is still subjective as we do not have a number or statistic it can be reduced to.
StrangeStCalib	ROW-round2	10	Comment	Do you mean drawdown?	Text updated. Yes - drawdown

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StrangeStCalib	ROW-round2	10	Comment	And/or Drawdown?	Text updated. Yes - and drawdown
StrangeStCalib	ROW-round2	10	Comment	Some of these comments were not well explained in the body of the memo, or not mentioned at all	Not updated. I think all these points are discussed.
StrangeStCalib	ROW-round2	10	Comment	Format inconsistent	Formatting of notation for hydraulic conductivity is now consistent throughout
StrangeStCalib	ROW-round2	10	Comment	Format inconsistent	Formatting of notation for hydraulic conductivity is now consistent throughout
StrangeStCalib	ROW-round2	10	Comment	ditto (referring to inconsistent formating)	Formatting of notation for hydraulic conductivity is now consistent throughout
StrangeStCalib	ROW-round2	10	Comment	ditto (referring to inconsistent formating)	Formatting of notation for hydraulic conductivity is now consistent throughout
StrangeStCalib	ROW-round2	10	Comment	No “d” in references	Reference corrected to be Stantec 2009
MannheimCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
MannheimCalib	ROW-round2	2	Comment	Inconsistent with report - says excellent	Not updated. Report is specifically referring to High Quality wells whereas this paragraph is addressing all quality rankings of observations
MannheimCalib	ROW-round2	3	Comment	These data should not be used for the steady state calibration at all as they will be affected by the ASR system. There is a lot of available data from the 2003 era that could be used for the steady state calibration	Not updated. groundwater level elevations were preferentially taken from 2003 where possible. When this was not possible another time frame was adopted.
MannheimCalib	ROW-round2	3	Comment	2B and 3B are also perched and should be excluded	Not updated. ASROW1 is not excluded, it is used in the absence of 2003 not being available. The calibration focused on 2003 data with other time frames providing additional coverage.
MannheimCalib	ROW-round2	3	Comment	Excellent in main report?	Not updated. Report is specifically referring to High Quality wells whereas this paragraphs is addressing all quality rankings of observations
MannheimCalib	ROW-round2	3	Comment	Which one?	Text updated. Peaking Well Field
MannheimCalib	ROW-round2	3	Comment	Reference?	Test updated. Reference appended.
MannheimCalib	ROW-round2	4	Comment	What is this figure there is no title or reference to it?	Text updated. Cross-reference error in Word.
MannheimCalib	ROW-round2	4	Comment	Not all present?	Annotation and footnote applied to table.
MannheimCalib	ROW-round2	5	Comment	Highlight units that are actually present and relevant to the calibration	Annotation and footnote applied to table.
MannheimCalib	ROW-round2	5	Comment	Define this do you mean below the production aquifer and Maryhill till?	Text updated. Additional context provided.
MannheimCalib	ROW-round2	6	Comment	The division between what is shallow and deep is not correct. The majority of the wells are in the municipal aquifer. There are a few wells that truly monitor a shallow perched system but that is not widespread. These need to be reviewed and corrected	Text updated. Context between figures 3 and 4 was reversed and is now corrected.
MannheimCalib	ROW-round2	6	Comment	Why? (referring to default anisotropy of 50)	Text updated. Additional context provided.
MannheimCalib	ROW-round2	7	Comment	Not really windows. This unit is laterally discontinuous in the area. In much of the area, particularly to the west the aquifer is essentially one unit from ground surface.	Text updated. Text reworked and additional text provided.
MannheimCalib	ROW-round2	8	Comment	The asr system has limited affect on the peaking well field water levels, or are you actually referring to wells on the MWTP site?	Text updated. Sentence removed.
MannheimCalib	ROW-round2	8	Comment	This doesn’t make sense as there is no net taking. As noted in the comments on the memo, the well/aquifer designations are not correct which needs to be examined further	Text updated. Sentence removed.
MannheimCalib	ROW-round2	8	Comment	Water levels in this aquifer as a whole have recovered on the order of 3 m due to changing climate – see mikes memo as these calibration data in particular may have to be corrected to 2003 conditions.	Text updated. Sentence removed.
MannheimCalib	ROW-round2	10	Comment	What figure is this no reference to it or title?	Text updated. Cross-reference error in Word.
MannheimCalib	ROW-round2	11	Comment	Inconsistent format. Also this value is inconsistent with text.	Text updated. Formats applied consistently and values updated.
MannheimCalib	ROW-round2	11	Comment	As noted above not really windows. Layer is discontinuous. What concurrent investigations?	Text updated. Additional text provided. Sentence regarding concurrent investigations removed.
MannheimCalib	ROW-round2	11	Comment	Inconsistent format, also values inconsistent with text	Text updated. Formats and values applied consistently.
MannheimCalib	ROW-round2	11	Comment	Inconsistent format, also text uses a range	Text updated. Formats and values applied consistently.
GreenbrookCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
GreenbrookCalib	ROW-round2	1	Comment	K3, 5 and 6 are abandoned and should not be referenced or plotted	Screen captures updated.

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GreenbrookCalib	ROW-round2	1	Remove Sentence	Additional production wells at well field that were not active in 2003 include K3, K5, and K6 .	Text updated. Sentence removed
GreenbrookCalib	ROW-round2	2	Comment	I total up 5776 for 2006?	The well field production rate of 6,246 m3/d is based on reviewing the data in the WRAS database. This value is consistent with estimating well field production from Figure 2 of the Stantec Characterization Report. This value is consistent with that applied during the parallel calibration of this well field. Text updated to note these rates are approximate.
GreenbrookCalib	ROW-round2	3	Comment	K2 also?	Text updated. Yes K2 was also not producing, text now reflects this.
GreenbrookCalib	ROW-round2	3	Comment	This title is not used	Text updated. Full title of section provided.
GreenbrookCalib	ROW-round2	3	Comment	Not all present?	Annotation and footnote applied to table.
GreenbrookCalib	ROW-round2	4	Comment	Highlight units that are actually present and relevant to the calibration	Annotation and footnote applied to table.
GreenbrookCalib	ROW-round2	5	Comment	Now it seems there isn't enough recharge or lateral flow as heads are all under-predicted	Not updated. Yes groundwater level elevations are under-predicted at Greenbrook. Allowing recharge boundary conditions at upgradient tributaries was not appropriate. During the calibration process all efforts were made to allow more recharge to reach the well field.
GreenbrookCalib	ROW-round2	5	Comment	I don't really understand what is being said here	Text updated. Sentence removed.
GreenbrookCalib	ROW-round2	5	Comment	Why? (referring to default anisotropy of 50)	Text updated. Additional context provided.
GreenbrookCalib	ROW-round2	6	Comment	Also Infrastructure?	Not updated. This would be true of more than just the Greenbrook Well Field and re-visiting the recharge for the entire urban footprint is beyond the scope of this memo.
GreenbrookCalib	ROW-round2	7	Comment	For what??	Text updated. Additional context provided.
GreenbrookCalib	ROW-round2	10	Comment	48? 4 or 8?	Text updated.
GreenbrookCalib	ROW-round2	11	Comment	As discussed there may be separate glaciofluvial channel aquifers that supply the Greenbrook and Parkway/Strasburg well fields, that are separated by low conductivity tills	Text updated. A brief discussion of recharge was introduced earlier in this section. Additional text provided in this paragraph/bullet as well.
GreenbrookCalib	ROW-round2	11	Comment	I did not see discussion of this in the body of the text	Sentence added to AFD1 section of memo and WBR. Reworded, additional context provided in this paragraph/bullet.
GreenbrookCalib	ROW-round2	11	Comment	As noted in the parkway memo, these two aquifer system may be separate "channel" aquifers created by flowing water, with a zone of un-eroded till in between	Not updated.
ParkStrasCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
ParkStrasCalib	ROW-round2	2	Comment	Or this till was not eroded by the flowing water that created the "channel aquifers" at Greenbrook and Parkway	Text updated. Additional context provided.
ParkStrasCalib	ROW-round2	3	Comment	In report you reference Terraqua, 1998 also date references are different	Text updated. References and timeframes are now consistent between main report and appendix.
ParkStrasCalib	ROW-round2	3	Comment	Table 4 should be here?	Text updated. Table 4 moved to this section.
ParkStrasCalib	ROW-round2	4	Comment	Not all present?	Annotation and footnote applied to table.
ParkStrasCalib	ROW-round2	5	Comment	Highlight units that are present and actually relevant to the calibration	Annotation and footnote applied to table.
ParkStrasCalib	ROW-round2	6	Comment	Why? (referring to default anisotropy of 50)	Text updated. Additional context provided.
ParkStrasCalib	ROW-round2	6	Comment	No reference to fig b1	Text updated.
ParkStrasCalib	ROW-round2	6	Comment	Of what?	Text updated. Context provided.
ParkStrasCalib	ROW-round2	7	Comment	As discussed there may be separate glaciofluvial channel aquifers that supply the Greenbrook and Parkway/Strasburg well fields, that are separated by low conductivity tills	This comment was acknowledged in the text as a data gap.
ParkStrasCalib	ROW-round2	9	Comment	Inconsistent with report	Text updated. References and timeframes are now consistent between main report and appendix.
ParkStrasCalib	ROW-round2	10	Comment	Why?	Text updated.
ParkStrasCalib	ROW-round2	11	Comment	I don't thinks this was mentioned previously?	Not updated. Previous section, discussing refinements during the steady-state calibration process, described the updates/refinements made.
ParkStrasCalib	ROW-round2	11	Comment	this is appendix U and there is no discussion that I could see. Ref my comments about channel aquifers?	Text updated. Typo carried over from main report.
ParkStrasCalib	ROW-round2	11	Comment	And length?	Text updated.
ParkStrasCalib	ROW-round2	12	Comment	And length?	Text updated.
ParkStrasCalib	ROW-round2	12	Comment	Could this also be related to the presence/absence of the Salina Formation?	Text updated.
LancasterCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA

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LancasterCalib	ROW-round2	2	Comment	Not in references	Text updated. Reference appended
LancasterCalib	ROW-round2	3	Comment	What is this fig no title or reference to it?	Text updated. Incorrect cross-referencing in Word - fixed.
LancasterCalib	ROW-round2	3	Comment	Not all present?	Annotation and footnote applied to table.
LancasterCalib	ROW-round2	4	Comment	Highlight units that are present and actually relevant to the calibration	Annotation and footnote applied to table.
LancasterCalib	ROW-round2	5	Comment	And monitoring wells?	Text updated.
LancasterCalib	ROW-round2	5	Comment	Aren't these showing the initial calibration?	Text updated.
LancasterCalib	ROW-round2	5	Comment	Why? (referring to default anisotropy of 50)	Text updated. Additional context provided.
LancasterCalib	ROW-round2	7	Comment	Not in references	Text updated. Reference appended.
LancasterCalib	ROW-round2	8	Comment	What is this fig no title or reference to it?	Text updated. Cross-reference error in Word.
LancasterCalib	ROW-round2	8	Comment	Is the same as, or different from above? Two different transient calibrations? Wells not operational?	Text updated. Same pumping test. Additional text provided to give clarity.
LancasterCalib	ROW-round2	8	Comment	Not in references	Text updated. Reference appended.
LancasterCalib	ROW-round2	9	Comment	Inconsistent format	Text updated.
LancasterCalib	ROW-round2	9	Comment	ditto (referring to specific storage)	Text updated.
RiverWellsCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
RiverWellsCalib	ROW-round2	1	Comment	In report it also says AFF1	Text updated. Main report and memo are now consistent.
RiverWellsCalib	ROW-round2	3	Comment	Not in references	Text updated. Reference provided.
RiverWellsCalib	ROW-round2	4	Comment	What is this fig no title or reference to it	Text updated. Cross-reference error in Word.
RiverWellsCalib	ROW-round2	4	Comment	Not all present?	Annotation and footnote applied to table.
RiverWellsCalib	ROW-round2	5	Comment	Highlight units that are present and actually relevant to the calibration	Annotation and footnote applied to table.
RiverWellsCalib	ROW-round2	6	Comment	Aren't these figs showing initial simulations?	Text updated.
RiverWellsCalib	ROW-round2	6	Comment	Why? (referring to default anisotropy of 50)	Text updated. Additional context provided.
RiverWellsCalib	ROW-round2	7	Comment	? do you mean toward the grand or airport creek?	Text updated. Additional context provided.
RiverWellsCalib	ROW-round2	7	Comment	East or west?	Text updated. East.
RiverWellsCalib	ROW-round2	8	Comment	?Or within or along?	Text updated. Along
RiverWellsCalib	ROW-round2	8	Comment	Under or along?	Text updated. Along
RiverWellsCalib	ROW-round2	8	Comment	Is this discussed somewhere? Otherwise it is kind of random	Additional context provided to clarify.
RiverWellsCalib	ROW-round2	8	Comment	production aquifer?	Text updated. This is now noted within the discussion of AFD1 calibration.
RiverWellsCalib	ROW-round2	8	Comment	Or conceptualized unlikely it was "mapped"	Text updated. "Conceptualized" used in place of "mapped".
RiverWellsCalib	ROW-round2	9	Comment	What do you mean by this?	Text updated. Recovery phase was not monitored, this is now noted in text.
RiverWellsCalib	ROW-round2	9	Comment	What about pumping rates?	Text updated with note that rates are variable. Complex (highly variable) power functions are applied and not really appropriate to put in text.
RiverWellsCalib	ROW-round2	10	Comment	What is this fig no title or reference to it?	Text updated. Cross-reference error in Word.
RiverWellsCalib	ROW-round2	10	Comment	Is this the same as or different from above. Two transient calibrations?	Text updated. Same pumping test. Additional text provided to give clarity.
RiverWellsCalib	ROW-round2	10	Comment	Or within?	Text updated.
RiverWellsCalib	ROW-round2	10	Comment	Increase?	Text updated. Sentence modified to provide more specific context.
RiverWellsCalib	ROW-round2	10	Comment	Reference?	Text updated. Reference provided.
RiverWellsCalib	ROW-round2	10	Comment	Or maybe it is not AFD1 at all?	Not updated. The characterization report notes that in some areas the separation of AFD1 and AFF1 are indistinguishable due to the erosion of ATE1. They are screened (partially) in AFD1 and in some cases may extend into AFF1.
RiverWellsCalib	ROW-round2	10	Comment	Or within?	Text updated.
RiverWellsCalib	ROW-round2	10	Comment	Increase?	Text updated. Sentence modified to provide more specific context.
RiverWellsCalib	ROW-round2	11	Comment	Inconsistent references to this work	Text updated. Consistent referencing with previously mentioning of the Earth FX work.
RiverWellsCalib	ROW-round2	11	Comment	First mention of AFF1 not discussed in text?	Text updated. Additional text provided earlier in memo to introduce that in some areas AFF1 is indistinguishable from AFD1.
RiverWellsCalib	ROW-round2	11	Comment	First mention of this?	Reference to discussion in the surficial geology section added. AFA2 unit noted to provide additional clarity.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
RiverWellsCalib	ROW-round2	12	Comment	First mention of this not discussed in text? Interpretations in this memo are inconsistent	Removed from the comments on model calibration, but kept as an insight toward the risk assessment. Although this is the first point of mention within this memo, we feel it is a worth-while flag to raise so that if we need to discuss it in the Risk Assessment report, it has already been raised.
RiverWellsCalib	ROW-round2	12	Comment	Inconsistent format	Text updated. Formats consistent.
RiverWellsCalib	ROW-round2	13	Comment	?First mention of this not discussed in the text	Text updated. Text introduced earlier in memo.
RiverWellsCalib	ROW-round2	13	Comment	?First mention of this not discussed in the text	Text edited.
RiverWellsCalib	ROW-round2	13	Comment	AFF1 also?	Text updated.
RiverWellsCalib	ROW-round2	13	Comment	And the wells?	Text updated.
FountainCalib	ROW-round2	1	Comment	Update all references to final versions	Done
FountainCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
FountainCalib	ROW-round2	1	Comment	Update to current	Text updated.
FountainCalib	ROW-round2	2	Comment	Reported in? or are you referring to the IUS study report which is not in references	Reference updated.
FountainCalib	ROW-round2	3	Comment	What is this fig no title or reference to it	Text updated. Cross-reference error in Word.
FountainCalib	ROW-round2	3	Comment	Not all present?	Annotation and footnote applied to table.
FountainCalib	ROW-round2	4	Comment	Highlight units that are present and actually relevant to the calibration	Annotation and footnote applied to table.
FountainCalib	ROW-round2	6	Comment	Where?	Text updated. Context provided.
FountainCalib	ROW-round2	7	Comment	Reported in? or are you referring to the IUS study report which is not in references	Reference updated.
FountainCalib	ROW-round2	7	Comment	What rates were the wells pumped at?	Text updated.
FountainCalib	ROW-round2	8	Comment	What is this fig no title or reference to it?	Text updated. Cross-reference error in Word.
FountainCalib	ROW-round2	8	Comment	Is this is in addition to tests described above i.e. were there two sets of calibrations done?	Text updated. Additional clarification provided.
FountainCalib	ROW-round2	8	Comment	No discussion of this in the text	Text updated. Additional text provided in discussion of AFD1 and in this paragraph.
FountainCalib	ROW-round2	8	Comment	No discussion of this in the text at all (referring to gw chemistry at P16)	Text updated.
FountainCalib	ROW-round2	9	Comment	No discussion of this in the text (referring to aquitard thikcness)	Text updated. Additional text provided in discussion of ATC1/AFC1/ATC2. Description of combined thickness of ATB1, ATB3, and ATC1 is presented in text. Interpretation/characterization of it's abilities to transmit water is not noted.
FountainCalib	ROW-round2	9	Comment	No discussion of this in the text (referring to connection west of Grand)	Paragraph is removed from calibration memo as this was not part of the calibration but is retained in the WBR.
FountainCalib	ROW-round2	9	Comment	No discussion of this in the text (referring to lateral extent of production aquifer)	Text updated. Additional context provided in preceding discussion of AFD1.
RuralCalib	ROW-round2	1	Comment	Inconsistent reference	Text updated to refer to the technical rules and the Tier Two reporting work completed for the GRCA
RuralCalib	ROW-round2	2	Comment	No all present at every well field	Text updated.
RuralCalib	ROW-round2	5	Comment	To what?	Text updated. Sentence rewritten for greater clarity.
RuralCalib	ROW-round2	5	Comment	These wells are abandoned and should not be referenced or plotted (Linwood)	Figure updated.
RuralCalib	ROW-round2	7	Comment	These wells are abandoned and should not be referenced or plotted (New Hamburg)	Figure updated.
RuralCalib	ROW-round2	8	Comment	R5 and R6 constructed in a deeper aquifer	Text updated. Typo AFB1 fixed to AFB3. Figure Updated
RuralCalib	ROW-round2	8	Comment	Were you calibrating against 0 taking?	Not updated. Calibration was to R5 and R6 @ 35.2 and 55.9, respectively.
RuralCalib	ROW-round2	8	Comment	SC1 has been abandoned and should not be referenced or plotted	Figure updated.
RuralCalib	ROW-round2	9	Comment	2,3 and 4 were abandoned and should not be referenced or plotted (reffering to Wellesley)	Figure updated.
RuralCalib	ROW-round2	9	Comment	Repeat - unnecessary (refering to observation quality)	Text updated. Redundant text removed
RuralCalib	ROW-round2	9	Comment	Which?	Text updated.
CAM_hydrostratigraphic_model	ROW-round2	1	Comment	Doesn’t make sense, clarify	What we want to express here is that the extents of the hydrostratigraphic model were set to exceed the largest likely size of a groundwater model of the Cambridge area. This ensured that the hydrostratigraphic model would be sufficiently large if a decision had been made to enlarge the groundwater model. The text has been revised to clarify this.
CAM_hydrostratigraphic_model	ROW-round2	15	Comment	What is this?	A reference was added to Section 14 of the document.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
CAM_hydrostratigraphic_model	ROW-round2	18	Comment	Switch from present tense to past tense in this section. Pick one and stick with it. I prefer past tense	We have gone through the document to change the verb tenses.
CAM_hydrostratigraphic_model	ROW-round2	18	Comment	This doesn't make sense	The original surface was developed excluding the data of Bajc and Shirota (2007). Bajc and Shirota's data were used to check the quality of the surface. Large discrepancies were noted at the locations of some of Bajc and Shirota's data. The bedrock surface was re-mapped incorporating Bajc and Shirota's data where we judged that data to be reliable.
CAM_hydrostratigraphic_model	ROW-round2	18	Comment	Why Stantec over Golder?	We are not really assigning Stantec's data greater weight with respect to Golder's data. Rather, Stantec's data were received later than Golder's data. There is some overlap between the two datasets. Golder's compilation included their own picks and some data provided by Stantec. John Piersol, Golder Associates, suggested that we use Stantec's data because Stantec may have revised the data between the time it was transmitted to Golder Associates, and the time when Stantec issued the final data package. The text were updated to clarify this.
CAM_hydrostratigraphic_model	ROW-round2	20	Comment	We have surveyed elevations why didn't you ask for them?!!	We were not aware that these wells were surveyed at that time we developed the hydrostratigraphic model. We would appreciate receiving the survey data to assess the quality of the surfaces of the hydrostratigraphic model at these locations.
CAM_hydrostratigraphic_model	ROW-round2	21	Comment	Mix of present tense and past tense pick one	These were revised.
CAM_hydrostratigraphic_model	ROW-round2	26	Comment	IWS?	The title of the figure has been revised to indicate IWS.
CAM_hydrostratigraphic_model	ROW-round2	39	Comment	Again tenses mixed up I give up	The verb tenses have been revised.
CAM_hydrostratigraphic_model	ROW-round2	45	Comment	Inference? Interpolation?	The text has been revised to indicate "inference".
CAM_hydrostratigraphic_model	ROW-round2	46	Comment	Tenses mixed	The verb tenses have been revised.
CAM_hydrostratigraphic_model	ROW-round2	47	Comment	Vinemount?	The reference to the Reformatory Quarry Member is correct.
CAM_hydrostratigraphic_model	ROW-round2	55	Comment	Tenses mixed up in section 9	The verb tenses have been revised.
CAM_hydrostratigraphic_model	ROW-round2	65	Comment	Tenses mixed up	The verb tenses have been revised.
CAM_hydrostratigraphic_model	ROW-round2	85	Comment	In other reports format is 1e-7	We have changed the format to be consistently "10^{-x}". In our opinion, this is preferred approach for referring to powers of 10.
CAM_MSWF_Curretn_S	ROW-round2	1	Comment	Is this out of date? Did you do the analysis outlined herein?	The document was intended to serve as a proposed work plan for refinement of the Cambridge groundwater model in the area of the Middleton Street well field (MSWF). The Cambridge groundwater model extended to this area, and the steady-state calibration (2003 average conditions) included targets from the Middleton Street area. However, the focus of the initial refined efforts was in the Cambridge East area. Following completion of that work, attention turned to the other well fields in Cambridge. The MSWF is the most important well field in Cambridge, so it is appropriate to give it special attention. The assessment of the current Cambridge model in the vicinity of the MSWF described in Section 1, combined with the transient calibration with the results of the IWS 1993 discussed in Section 3 pumping test, has motivated refinement of the model. During that refinement, it was confirmed that the transmissivity of the bedrock in the vicinity of the MSWF that is specified in the model is consistent with the results from independent analyses. The additional "potential" analyses discussed in the second part of Section 3, Response to cyclic pumping from the Middleton Street Well Field, have not been conducted as part of the Tier Three study.
CAM_Adjust_Rech_G5P	ROW-round2	1	Comment	What rate were you using because G5 cannot pump at the original specified rate?	For the steady-state calibration, the average pumping rate for 2003 that we were provided for G5 was 14.2 L/s. A rate of 32 L/s was specified for the Cambridge East scenario modelling. This rate is close to the IWS recommended maximum pumping rate of 30.5 L/s, which corresponds to the average pumping rate in 1973 (IWS, 1974; p. 19 and Table 4).

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
CAM_ClemensMill_Incr	ROW-round2	1	Comment	Did you confirm this with any independent analysis?	No. This simulation was originally conducted just for a quick test to see how well the calibrated model could match the observed long-term effects of a major change in pumping. The 2003 average rates were used for the steady-state model calibration, following the guidance of the Region of Waterloo. Average conditions in 2003 have been assumed to be representative of long-term average conditions.
CAM_ClemensMill_Incr	ROW-round2	1	Comment	Did you confirm this with any independent analysis? Later you state pinebush wells were below average in 2003.	No – see the response above.
CAM_ClemensMill_Incr	ROW-round2	2	Comment	Drawdown in Fig 4 does not match hydrograph in Fig 7 for OW4	They do not match because the results correspond to different hydrostratigraphic units. The results shown in Figure 4 are for the Middle Gasport (the so-called Production Zone). Monitoring intervals A, B and C of OW4-92 fall within the Guelph Formation and Overburden, respectively. A table has been added to indicate clearly the units across which each of the well screens are open.
CAM_ClemensMill_Incr	ROW-round2	3	Comment	Need more discussion than this. Why is it important? Are observed declines in B and F wells due to increased pumping of Pinebush wells in mid 1990s?	The text has been revised to suggest that OW5F 94 may have been affected by pumping from both the Clemens Mill and Pinebush well fields, and that the rates specified for the Pinebush well field may have been lower for the period during which the drawdown has been inferred. It is important to note that our explanation for the mismatch for OW5F is just one possibility. The assessment of the long-term effects of pumping is definitely not an exact science.
CAM_ClemensMill_Incr	ROW-round2	3	Comment	What about other OW5 wells?	The hydrographs for OW5 are taken from the Burnside annual monitoring report for 2007. Only the data for monitoring intervals B and F are presented, which we interpret to mean that only these two intervals were monitored regularly. OW5F is screened in the overburden and OW5B is screened in the Middle Gasport. The Pinebush wells, G5 and P10, pump from the Contact Aquifer. In our opinion, if the cause of the mismatch at OW5F is the specification of rates for the Pinebush well field that are not representative, it is more likely to be observed in shallow than deeper observation wells. A better match is obtained for the deeper observation well OW5B.
CambridgeE_Calib_Note	ROW-round2	1	Comment	Show on a figure also	Figure 1 has been added to indicate the locations of the wells
CambridgeE_Calib_Note	ROW-round2	1	Comment	Any independent analysis to confirm these were "average" conditions?	No. It was decided long before we started our analyses to use 2003 average conditions as the basis for any steady-state calibrations.
CambridgeE_Calib_Note	ROW-round2	1	Comment	Show test wells on a figure.	The wells are indicated in the new Figure 1.
CambridgeE_Calib_Note	ROW-round2	2	Comment	Reference where this can be found	There is no reference. The text has been revised to provide more details regarding the increase in pumping at the Clemens Mill well field that occurred in the mid-1990s.
CambridgeE_Calib_Note	ROW-round2	13	Comment	Describe where it can be found	A reference of the memo was added in the text
CambridgeE_Calib_Note	ROW-round2	13	Comment	How do you define this? What is the actual margin of error etc	As far as we are aware, there are no formal criteria for assessing the matches between observed and simulated time series. For computer-assisted pumping test interpretation packages, the adjustment of parameters continues until the sum of the squared errors cannot be reduced further, regardless of whether the match is any good. In the case of the G5A simulation, no parameters are adjusted at all. We have decided that the fit is “relatively good” based on our experience of trying to match transient responses at other complex sites. The use of the term “relatively good” is deliberate – it is meant to imply that our assessment of the match is qualitative.
CAM_MSWF_Calib	ROW-round2	1	Comment	Provide details on depths and formations	Detailed information about the wells has been added.
CAM_MSWF_Calib	ROW-round2	2	Comment	Pumping?	The text has been revised to refer to a stage pumping test.
CAM_MSWF_Calib	ROW-round2	2	Comment	Water about these wells?	Only paper copies of the hydrographs are available for these wells. We had to digitize the paper hydrographs to use the data for model calibration.
CAM_MSWF_Calib	ROW-round2	3	Comment	So how did this influence the simulation. What was the impact of G15 pumping on TW2-70 i.e. were there any changes in pumping rates?	The complexity of conditions between the MSWF and G15 has made it impossible to reproduce the general trend of the observations at TW2/70 with the groundwater flow model as currently configured. The rapid changes in groundwater level elevations observed at the location of the Willard well in response to pumping at the MSWF led IWS to infer the presence of a "pipeline". Our present inability to match the response at TW2/70 confirms that there is something “extraordinary” about this area. G15 was not pumped during the IWS test, so the water level changes observed at TW2-70 were not due to pumping from G15.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
CAM_MSWF_Calib	ROW-round2	3	Comment	What refinements, where are they discussed? How did you incorporate the reef mounds into the model with K zones?	The reef mounds are incorporated in the structure of the model layers. In particular, at the locations of the mounds the Gasport Formation is significantly thicker. This is best visualized by examining Figures 11 7 and 11 8 of SSP&A's report on the hydrostratigraphy of Cambridge, which show cross-sections through the MSWF. The presence of the reef mounds is also implicit in the elevated hydraulic conductivity values that are required to match the observations. It is important to note that the reef mounds are inferred to be present in the Gasport Formation, but that the Gasport Formation underlies the open intervals of the production wells at the MSWF. The results of packer testing reported in Beak et al. (1995) suggest that the most transmissive intervals are located in the Reformatory Quarry Member and the Gasport Formation. In our opinion, it is likely that most of the regional groundwater flow to the wells occurs through the Gasport Formation, but in the immediate vicinity of the well field, the water is 'funneled' into the Reformatory Quarry Member. It is possible that a higher cumulative transmissivity of the bedrock might be inferred if pumping wells were extended into the Gasport Formation. The text has been revised to include discussion of the refinement of hydraulic conductivity zones.
CAM_MSWF_Calib	ROW-round2	3	Comment	What does this mean? Did you do this? What were the results?	An assessment has been added regarding the consistency of the parameters inferred through model calibration and the results of independent estimates of aquifer properties.
HespelerCalib	ROW-round2	1	Comment	Provide details on depth and completion formation	Detailed information about these wells has been added to the text.
HespelerCalib	ROW-round2	1	Comment	No comment?	Additional discussion has been incorporated in the text.
HespelerCalib	ROW-round2	1	Comment	Provide details on depth and completion formation	Details regarding the observation wells has been added.
HespelerCalib	ROW-round2	3	Comment	By who?	SSPA prepared these cross-sections to assist in the interpretations of conditions at these sites.
HespelerCalib	ROW-round2	13	Comment	Is this consistent with Bruntons logging?	We are not sure whether Frank Brunton has logged all of the wells in the area. Golder Associates and Stantec provided the picks that we used to construct the hydrostratigraphic model. It is our understanding that Frank Brunton is responsible for many of these picks.
PinebushCalib	ROW-round2	1	Comment	What are their depths and completion formations?	A table of depths and the formations that are penetrated has been added.
PinebushCalib	ROW-round2	1	Comment	What is depth and completion formation?	A table of depths and the formations that are penetrated has been added.
ElginCalib	ROW-round2	1	Comment	Provide details on depth and formation, provide map of location	The text has been updated to include this information, and a figure has been added to show the location of the wells.
ElginCalib	ROW-round2	3	Comment	Need a figure showing well locations	A figure has been added to show the location of the wells.
DunbarCalib	ROW-round2	1	Comment	Provide details on depth and completion formation	A table of depths and the formations that are penetrated has been added.
DunbarCalib	ROW-round2	1	Comment	Provide details on depth and completion formation	A table of depths and the formations that are penetrated has been added.
DunbarCalib	ROW-round2	2	Comment	Formations	In the original document, it is indicated only that observation wells are completed in the Upper, Intermediate, or Lower Bedrock. The formations across which the wells are open are not indicated. Based on the results of ongoing monitoring of groundwater level elevations, our impression is that at this location OW6-96C (Reformatory Quarry Formation) corresponds to the Upper Bedrock monitoring interval, OW6-95B (Upper Gasport Formation) likely corresponds to the Middle Bedrock monitoring interval and OW6-95A (Lower Gasport Formation) corresponds to the Lower Bedrock monitoring interval.
Main Report	R.Wootton	8	Comment	Has this not been more recently edited/finalized?	The GAWSER report was updated and report reference updated.
Main Report	R.Wootton	20	Comment	Do you mean WATFLOW?	Yes, text updated as suggested.
Main Report	R.Wootton	21	Comment	What about the AQR CWA quality modeling reports?	GRCA Tier Two Water Budget report and Capture Zone Delineation Report added as suggested to table.
Main Report	R.Wootton	23	Comment	Clarify these designations as they are confusing – maybe define units with a number and a letter that designated east vs west or something. Salina formation is present east of moraine. Section 4.3.4 refers to 6 bedrock layers	Text updated to clarify how bedrock units are simulated in the model in the text and table.
Main Report	R.Wootton	26	Comment	formatted table…large area marked up	Table updated as suggested.
Main Report	R.Wootton	27	Comment	formatted table…large area marked up	Table updated as suggested.
Main Report	R.Wootton	28	Comment	Of this report or guidance module – confusing?	Table updated to clarify.
Main Report	R.Wootton	33	Comment	Or values?	Table updated to clarify.
Main Report	R.Wootton	33	Comment	What does this mean?	Table updated to clarify.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	33	Comment	Or values?	Table updated to clarify.
Main Report	R.Wootton	37	Comment	How was this handled in the model – link back to Table 3 and the accompanying explanations	Updated bedrock units in Table 6 and footnote added to clarify the bedrock layering in the model. Text also added to clarify in subsequent section.
Main Report	R.Wootton	37	Comment	What happened to the discussion on the differences in representation of Puslinch Lake?	Text added to outline how Puslinch Lake was simulated in the two models (both models simulate the lake in the same way with enhanced recharge).
Main Report	R.Wootton	42	Comment	Bolded text	Text updated.
Main Report	R.Wootton	43	Comment	Previously you had used groundwater level elevations – be consistent	Text updated for consistency.
Main Report	R.Wootton	44	Comment	Shutdown?	Text updated.
Main Report	R.Wootton	44	Comment	Previously you had used groundwater level elevations – be consistent	Text updated for consistency.
Main Report	R.Wootton	45	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	45	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	45	Comment	See below comment	Text updated to clarify.
Main Report	R.Wootton	45	Comment	I believe they were in this version of the report?	Text updated to clarify.
Main Report	R.Wootton	46	Comment	Levels vs elevations	Text updated for consistency.
Main Report	R.Wootton	46	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	46	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	46	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	46	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	46	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	47	Comment	ditto (levels)	Text updated for consistency.
Main Report	R.Wootton	48	Comment	– I think you get the idea choose one and be consistent throughout	Text updated for consistency.
Main Report	R.Wootton	49	Comment	elevation vs water level in same sentence	Text updated for consistency.
Main Report	R.Wootton	49	Comment	no reference to convergence on rivers as above?	Text updated as suggested to clarify.
Main Report	R.Wootton	67	Comment	Can we create an updated map of depth to water table as a basis for determining where this can occur i.e. recharge won't occur where the water table is shallow and will only occur where infrastructure is above water table	Regarding clarification on the additional recharge sourced from urban infrastructure in the Greenbrook area. The following text was added: "Increased recharge sourced from leaks in the urban buried infrastructure (i.e., water mains and sanitary lines) may contribute to the available water in this area; however, the location and contribution of this potential source of additional recharge is unknown." It is conservative to assume that there is no additional water leaking into the area and it is outside the scope of this study to conduct additional mapping of the depth of the water table locally to identify where this may be occurring.
Main Report	R.Wootton	67	Comment	What do you mean by this?	Text updated to clarify.
Main Report	R.Wootton	69	Comment	?This sentence is not relevant to this paragraph	Text removed as requested.
Main Report	R.Wootton	72	Format	formatted : superscript	Text updated for consistency.
Main Report	R.Wootton	72	Comment	Greenbrook conceptualization report identifies AFB3 as the Greenbrook aquifer	Text updated to clarify.
Main Report	R.Wootton	83	Comment	Or boundary?	Text updated to clarify.
Main Report	R.Wootton	97	Format	Font: Bold	Font updated
Main Report	R.Wootton	97	Comment	See comment below	Font updated
Main Report	R.Wootton	98	Format	Font: Bold	Font updated
Main Report	R.Wootton	98	Comment	Unlikely these are available from 1995	Text updated.
Main Report	R.Wootton	99	Comment	Elevations vs water levels -inconsistent with rest of report?	Text updated for consistency.
Main Report	R.Wootton	99	Comment	ditto (elevations	Text updated for consistency.
Main Report	R.Wootton	100	Comment	this is not necessary, so the elevation was wrong and it was fixed	Comment removed as suggested to improve clarity.
Main Report	R.Wootton	100	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	100	Comment	Are you referring to the reefal complex that Brunton defined, if so there is no mention of that at all	Text updated to add discussion of the Brunton interpretation and the concept of the reefal structures and the tongue of high transmissivity bedrock extending from Guelph to Cambridge. Most of the updated text was taken from the Middleton Street well field discussion (as suggested).
Main Report	R.Wootton	100	Comment	how defined? What is significance?	Text updated.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	100	Comment	this is confusing you are referring to different well field areas and two different formations – rewrite this	Text updated as suggested to clarify.
Main Report	R.Wootton	102	Comment	perhaps a comment on observed lake infilling that has reduced the conductance of the lake bed?	Text updated.
Main Report	R.Wootton	104	Comment	Again water levels vs elevations	Text updated for consistency.
Main Report	R.Wootton	105	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	105	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	106	Comment	this section makes specific reference to figures in appendixes where other sections in report do not - inconsistent	Text updated as suggested
Main Report	R.Wootton	107	Comment	Are you referring to the reefal complex that Brunton defined, if so there is no mention of that at all	Comment acknowledged, and text updated to add discussion of Brunton interpretation.
Main Report	R.Wootton	107	Comment	Also north	Text updated as suggested.
Main Report	R.Wootton	108	Comment	ditto	Text updated as suggested.
Main Report	R.Wootton	108	Comment	well field or production aquifer?	Text updated to clarify.
Main Report	R.Wootton	108	Comment	whoa that is quite a stretch! and was not previously mentioned or justified. Are you referring to the reefal complex that Brunton defined, if so there is no mention of that at all	Comment acknowledged, and text updated to add discussion of Brunton interpretation.
Main Report	R.Wootton	109	Comment	Elevations vs water levels	Text updated for consistency.
Main Report	R.Wootton	109	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	109	Comment	what is the point of this?	Text updated to clarify.
Main Report	R.Wootton	110	Comment	And surface water features	Text updated as suggested.
Main Report	R.Wootton	111	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	111	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	111	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	112	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	113	Comment	delete G10/11	Reference to G10 and G11 was removed.
Main Report	R.Wootton	113	Comment	elevations vs water levels	Text updated for consistency.
Main Report	R.Wootton	113	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	115	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	116	Comment	elevations vs water levels	Text updated for consistency.
Main Report	R.Wootton	116	Comment	how many days?	Length of test added as requested.
Main Report	R.Wootton	116	Comment	why is the well not in above tables?	Well added to table as requested.
Main Report	R.Wootton	116	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	117	Comment	what about ow101-90 as noted above?	No change made; Well OW101-90 was not included in the steady state calibration as it is not part of the municipal monitoring network and was not monitored in 2003 (only monitored in 1990 as part of the 24-hour G9 pumping test).
Main Report	R.Wootton	117	Comment	ditto	Text updated for consistency.
Main Report	R.Wootton	118	Comment	elevations vs water levels	Text updated for consistency.
Main Report	R.Wootton	120	Comment	how many days?	Text updated as requested.
Main Report	R.Wootton	120	Comment	vs water levels	Text updated for consistency.
Main Report	R.Wootton	120	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	121	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	121	Comment	why is this buried in this section? It applies to the overall approach to modeling of the bedrock in Cambridge and should be addressed in an introductory section on the modeling approach. An abbreviated reference could be included here.	As suggested, this text was moved up into an introductory section as it applies to all the Cambridge bedrock well fields.
Main Report	R.Wootton	121	Comment	What estimate?	Text updated for consistency.
Main Report	R.Wootton	122	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	122	Comment	again this applies to the entire modeling effort not just middleton	As suggested, this text was moved up into an introductory section as it applies to all the Cambridge bedrock well fields.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	122	Comment	again this applies to the entire modeling effort not just middleton	As suggested, this text was moved up into an introductory section as it applies to all the Cambridge bedrock well fields.
Main Report	R.Wootton	122	Comment	vs water level	Text updated for consistency.
Main Report	R.Wootton	123	Comment	vs water levels	Text updated for consistency.
Main Report	R.Wootton	124	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	125	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	126	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	127	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	127	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	128	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	129	Comment	ve water levels	Text updated for consistency.
Main Report	R.Wootton	129	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	130	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	130	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	131	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	132	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	133	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	134	Comment	recharge area?	Text updated to clarify.
Main Report	R.Wootton	139	Comment	vs water levels	Text updated for consistency.
Main Report	R.Wootton	139	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	139	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	139	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	139	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	139	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	140	Comment	what happened to references to figs 4-34/35?	Figures removed from the report.
Main Report	R.Wootton	140	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	140	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	141	Comment	vs water levels	Text updated for consistency.
Main Report	R.Wootton	141	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	143	Comment	Vs water levels	Text updated for consistency.
Main Report	R.Wootton	143	Comment	Or bodies?	Text updated to clarify.
Main Report	R.Wootton	144	Comment	Vs water levels	Text updated for consistency.
Main Report	R.Wootton	144	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	145	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	148	Comment	not mentioned previously in recharge sensitivity section re: scenario 1?	Text updated for consistency.
Main Report	R.Wootton	148	Comment	Vs water levels	Text updated for consistency.
Main Report	R.Wootton	149	Comment	Were these not removed? Should this be section 4.6?	Text updated as suggested.
Main Report	R.Wootton	152	Comment	Vs water levels	Text updated for consistency.
Main Report	R.Wootton	152	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	152	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	153	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	154	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	154	Comment	ditto (elevations)	Comment addressed
Main Report	R.Wootton	159	Comment	reference section where this was previously discussed or was that in an appendix?	Text was in an appendix. No change.
Main Report	R.Wootton	160	Comment	Vs water levels	Text updated for consistency.
Main Report	R.Wootton	162	Comment	Vs water levels	Text updated for consistency.

Main Report or Appendix Name	Reviewer	Page	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Main Report	R.Wootton	162	Comment	ditto (elevations)	Text updated for consistency.
Main Report	R.Wootton	163	Comment	I thinh previously you said 100?	Text updated to read over 100 for consistency.
MainReport	ROW	Figure 1-1	Figure Edit	Add Tier2 assessment areas for completeness (Eric Comment)- add canagigague and central grand river assessment areas.	Figure updated as requested.
MainReport	ROW	Figure 4-1	Figure Edit	Add the Central Grand and Canagigague asst areas.	Figure updated as requested.
MainReport	ROW	Figure 4-27	Figure Edit	Revise figure number to 4-27a	Figure updated as requested.
MainReport	ROW	Figure 4-27b	Figure Edit	Create companion figure for Cambridge	Figure added as requested.
MainReport	ROW	Figure 4-28	Figure Edit	Revise figure number to 4-28a; Title should be "Vertical Water Level Difference Mapping"	Figure updated as requested.
MainReport	ROW	Figure 4-28b	Figure Edit	Create companion figure for Cambridge	Figure added as requested.
MainReport	ROW	Figure 4-29	Figure Edit	Revise figure number to 4-29a	Figure updated as requested.
MainReport	ROW	Figure 4-29b	Figure Edit	Create companion figure for Cambridge	Figure added as requested.

Main Report or Appendix Name	Reviewer	Reviewer Comment	Matrix Response to Comment
Risk Assessment Approach Memo	Dr. David Rudolph	The first subsection in the memo is titled “Non-Municipal Permits to Take Water” yet a major portion of the text is devoted to the characteristics of the new FEFLOW model. I would recommend renaming that section of the memo and expanding the detail on what exactly is different in the new version and how these changes influence the way the existing model configuration has to be changed. Specific emphasis on the impacts these changes have on the model and how they influence the results would be useful. Much of this is already in the text but it could be expanded to help the reader understand what the challenges were.	The Water Budget Update Memo updated the peer review team on changes made to the Water Budget model since the WAter Budget report was issued. The information within the memo was subsequently updated in the Water Budget Report. The FEFLOW implementation of multi-layer wells was not discussed in the Water Budget Report as the software developer (in early 2014) released a new version of FEFLOW with the original (more stable) configuration of the pumping well boundary conditions. As such, no additional action was taken to address this comment.
Risk Assessment Approach Memo	Dr. David Rudolph	The second subsection can use the existing title noted above, although referring to wells as permits throughout the text is potentially a bit confusing as there are permits for surface water takings as well. Maybe a short disclaimer up front stating the use of the term permit refers to well extraction rate. In this second section, the issues related to how the permit to take water information was used to resolve the problems arising from adopting the new version of FEFLOW could be explained.	Comment acknowledged, and the terminology used to describe the wells/ permits was updated in the Water Budget and Risk Assessment Reports.
Risk Assessment Approach Memo	Dr. David Rudolph	In Table 1 on P.3 in the second comment box, the text reads “Pumping wells for these wells” and should likely read ”Pumping rates for these wells”	Text updated in the Water Budget Report.

Main Report or Appendix Name	Reviewer	Reviewer Comment	Matrix Response to Comment
Risk Assessment Approach Memo	Dr. David Rudolph	In reading through the changes that were made to reduce model instability and to maintain or enhance the calibrated fit it seems that a combination of changes in stratigraphy and K along with changes in pumping rates (or removal of wells) was adopted. There is a significant difference between adjusting hydraulic parameters and geologic geometry to provide the hydrogeologic conditions that will allow a good calibration and the reduction in groundwater extraction. The later can influence the water balance significantly. It is not clear how these decisions were made throughout the model domain and what the implication of these changes could be. This needs to be explained in a bit more detail. A further note on this is provided below.	Discussion was added to the Water Budget Report regarding the wells for the ten permits that were removed from the model. The wells in the Regional Model that were removed were located downgradient from the municipal wells either on the till plains, or the western flanks of the Waterloo Moraine, over 9 km from the closets municipal well. No wells were removed from the Cambridge Model.
Risk Assessment Approach Memo	Dr. David Rudolph	At the wells were the screened levels had to be changed or the stratigraphy modified to reduce instability, were there no original driller's logs available? I interpret that there was little or no geologic data available in the vicinity of these wells or that the quality was poor. Maybe this could be explained with more detail.	The permit to take water database does not contain any geologic information; linkages are often made to nearby water well logs, but often there may be 4 or 5 wells in the vicinity of the permit so there is little certainty as to where to screen the well representing the permit to take water. This is why permits located within the urban area of the Region are so complex as there are potentially 4 or 5 possible aquifers that the wells could be screened within. This discussion is provided in the Permit to Take Water memo in the Water Budget Report appendix, and was re-interated in the Water Budget Report to clarify.

Main Report or Appendix Name	Reviewer	Reviewer Comment	Matrix Response to Comment
Risk Assessment Approach Memo	Dr. David Rudolph	In reviewing the tables that contain the changes to pumping rates from the wells, there are several very large producers that have been removed from the domain. How was the influence of removing them on the levels in the main municipal wells assessed? Maybe more importantly, there appears to be a major reduction in pumping rate overall in the new version of the model. What was the change relative to the past extraction total? Can we show that it was an insignificant change? What impact will this have in the water balance? Changing the pumping rate in 99 of the wells does seem to be a significant change and it raises a red flag that by just changing the numerical formulation of the model required a major change in the conceptual model and water balance. It may be that overall these changes were minor but it is hard to judge this based on the tables unless there is some comparison to what was previously calculated with the old model version. Just by being able to recalibrate the new model under these modified conditions to an equivalent level illustrates the non-uniqueness and uncertainty associated with any regional model. It would be useful for the modeling team to provide some insight into the overall sensitivity of the model to the changes that were made here. One can likely make the argument that overall the changes were small so that one would expect the calibration and water balance not to change much.	Text was added to the Water Budget and Risk Assessment Reports to explain the changes at the ten wells that were removed from the model due to instabilities. As noted above, the wells are located downgradient of the municipal wells (and are separated by a groundwater divide) so removing their takings from the model will not impact the water budget at the municipal wells. From an overall water budget perspective, the removed wells equate to a total reduction of

Main Report or Appendix Name	Reviewer	Reviewer Comment	Matrix Response to Comment
Risk Assessment Approach Memo	Dr. David Rudolph	On P. 4 it is noted that the calibration stats are much better now for Blair Rd., Dunbar Rd. and Middleton St yet on P.3 the overall calibration on a global basis is about the same. Somehow it would seem that the global calibration should have also improved.	The number of calibration targets in the two well fields where the largest changes were made (Dunbar and Blair) represented only 6% of the total number of calibration points in the global statistics (i.e., 11 targets out of 171), so the improvement in the global stats was lower than expected. Improvements were made at Middleton but those were not as significant as the statistical improvements made at the other two well fields.
Risk Assessment Approach Memo	Dr. David Rudolph	In Table 7 there are a series of negative values in the simulated baseflow numbers. I am not complete sure what these mean. Also, maybe the team could comment on how good overall the model is at representing the surface water flow metrics that are listed in Table 7. Some explanation is provided but what can be said overall regarding this aspect of the calibration?	These were typos; the negative values were updated and additional text was added to the Water Budget report to discuss in general how good the model is at representing surface water flow (Table 7).

Reviewer	Section	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
A.R. (Tony) Lotimer	Executive Summary	Comment	The first paragraph of the executive summary indicates that the project was completed as a 'pilot' project for conducting a Tier 3 assessment. I could not find any meaningful reference or discussion about how the RMOW project served as a 'pilot' project for the Tier 3 program in Ontario (other Tier 3 projects were completed before this one). Perhaps the intent was there at the start of the RMOW project, but the importance or role of the project as a pilot for Tier 3 projects may have diminished with time.	Comment acknowledged. The proejct was one of the first initiated but due to the number of wells and the complexity of the system, the project has taken longer than several other pilot projects that were undertaken in the Province.
A.R. (Tony) Lotimer	5.1.1	Comment	The use of a 100 m buffer (circle) to define the WHPA-Q1 for the Conestogo Plains and Blair Road wells appears to somewhat arbitrary (similar to the designation of WHPA - A under the water quality component of source protection). Was consideration given to using an analytical solution, or the actual pumping test data, to evaluate the 2 m drawdown limit for these wells?	The two metre drawdown cone for the wells can be delineated for the wells, but it is so small (i.e., less than 25 m) that it would not be sufficient to apply policy measures. As such, the 100 m buffer was applied.
A.R. (Tony) Lotimer	5.1.1	Comment	Further to comment 2, it is not clear (to me) why the Blair Road wells (G4, G4A) are not part of WHPA-Q1B (i.e. the WHPA-Q1 for the greater Cambridge area). The WHPAQ1B oundary is a near vertical line near the Blair Road wells, which appears odd. Do the field data (pumping/recovery test data) clearly support the conclusion that there is less than 2 m of drawdown within 100 m of the Blair Road wells when they are operating at flow rates of 11 – 20 L/s (945 – 1,728 m^3/day) ?	We used the Theim equation to calculate the drawdown at the well assuming a representative T (635 m2/d) for the aquifer, a production rate of 1,728 m3/d and a boundary condition (Grand River) lying at approx 480 m from the well. Results predict the 2 m drawdown cone lies 90 to 140 m from the well, suggesting the modelled approach is reasonable. The closest monitoring well to the well is 600 m away and water level fluctuations in the well due to municipal puming variations are minor (<20 cm). As such, we feel the modelled results and the 100 m buffer area around the well is reasonable.
A.R. (Tony) Lotimer	5.2.2.11	Comment	A reference figure showing the location of the wetlands discussed in this section of the report would be helpful. A figure with the wetlands was provided on-screen during the presentation on May 9.	The wetlands discussed in Section 5.2.2.11 are illustrated and labelled on Figures 5-9 and 5-10 of the Risk Assessment Report. Additional references to the figures were added to the report to add clarity.

Reviewer	Section	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
A.R. (Tony) Lotimer	5.3.1	Comment	This section refers to 'peak' demand and provides a discussion of municipal water supply methods of meeting peak demand. Table 3.2 (page 31) indicates that in most cases the existing and allocated rates are below the PTTW limits currently assigned to the individual wells. If peak demand is addressed in the Tier 3 assessment, does it mean that the maximum water taking limits in the PTTWs are currently set at levels that are higher than necessary?	The maximum PTTWs are necessary at the current rates as they provide flexibility for the Region in the event that a well field needs to be shut down for rehabilitation, contamination or operational challenges. In general, the total permitted rates are higher than needed but the individual and well field permitted rates provide flexibility to the IUS to meet daily and peak demands.
A.R. (Tony) Lotimer	6.3.1	Comment	On page 99, second paragraph from bottom dealing with percent cumulative volume series. Should it state that 18% of the subwatershed recharge volume corresponds to areas where recharge rates are less than, or equal to, 150 mm/year (rather than 8%)?	The 8% estimate is correct. Reference to Figure 6-2 was added to help clarify the values cited in the text.
A.R. (Tony) Lotimer	7.1.5	Comment	The possible presence of 'windows' in the aquitards, and their importance with respect to the Region's groundwater supplies, has been recognized and investigated since at least the early 1980s. This section of the report leaves the impression that the issue is just now coming to light. Given the scope of the Tier 3 project, it could be viewed as somewhat of a disappointment that some improvement in the understanding of the role of windows and aquitards has not been achieved by the project.	Comment acknowledged. Text was updated to note that the size, shape and location of the windows in the aquitards is the data and knowledge gap. The *role* of those windows was improved in this project, but only additional drilling or geophysical studies can help fill the data and knowledge gaps with respect to the spatial extent of the windows in the aquitards.
Dr. Hugh Whiteley		Comment	The recommendation of the report for further baseflow monitoring should be supported by the comment that a 20% reduction in average annual baseflow could result in much larger percentage reductions in baseflow during annual minimum periods and monitoring is required to assess the extent of the reduction in the periods of baseflow-minimum extremes.	Comment is acknowledged. Text in Section 7.2.2 was updated as suggested.
Dr. Hugh Whiteley		Comment	The statement(s) in the report on the interaction between perched-watertable wetlands and the deeper regional watertable should be modified to state that recharge to the regional watertable would occur under the perched watertable region but the rate of recharge, and the temporal variation in the perched watertable was independent of the variations in the elevation of the regional watertable.	Comment is acknowledged. Text in Section 5.2.2.11 was updated as suggested.

Reviewer	Section	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Dr. Hugh Whiteley		Comment	The discussion on uncertainty of the effect on wetlands of temporal variation in the piezometric surface in the deeper Gasport aquifer should emphasize that the model predictions were for the drawdown in the Gasport and evaluation of the effect on watertable variation in the overlying wetland would differ depending on whether the wetland was perched or resulted from a mounding of the watertable and on very local properties of the overlying layers. Detailed study for each instance of substantial drawdown in the deeper aquifer under a wetland would be needed before a lack of appreciable effect was established.	The model predictions represented the declines in the water table aquifer and not the deeped bedrock or lower overburden units. Comment is acknowledged though - the impact on the wetlands is dependent on whether the wetland is perched above the regional water table or not.
Dr. Hugh Whiteley		Comment	The report "could" note that future studies undertaken by stormwater utilities that included continuous measurements of stormflow from subwatersheds, and the necessary meteorological data (precipitation, air temperature and a representative wind speed) would provide the data needed to establish better estimates of the recharge to groundwater from the permeable areas within the measured subwatershed.	Section 7.1.1 was updated as suggested to note that this could be applied to improve groundwater recharge estimates in some subwatersheds.
Dr. Hugh Whiteley		Comment	The report should expand somewhat on the possible existence of a no-flow boundary in the lower Gasport over at least a portion of the potential connective flowpath between the Guelph and Cambridge models. This would include comment on whether the zer0-flow plane exists most of the time or is present under steady-state analysis but may be only intermittently present in continuous modelling. The implications of such a boundary on the requirement for definition of a zone of overlap where assessment of effects needs to take account of results of both the Guelph and Cambridge models should be discussed.	Section 5.1.1 was updated as suggested to note the presence of a groundwater flow divide between the two cities.

Reviewer	Section	Comment Type	Reviewer Comment	Matrix / SSPA Response to Comment
Dr. Hugh Whiteley		Comment	As noted in other reports I suggest that the reference to GAWSER should be as a watershed-based flow generation model rather than a surface-flow model. On first reference there should be a slightly expanded description to say that GAWSER had sufficient spatial discrimination to allow delineation of the variation in recharge amount from the principal soil-profile/topographical-form response units. Although GAWSER represented interflow and baseflow components of streamflow by single units lumped at a subwatershed scale and could not be used to characterize spatial properties in groundwater flow the calibration of the model to observed streamflow did provide an overall confirmation that the spatially-distributed recharge rates were correct on a watershed-averaged basis.	All references to "surface water model" were changed to "watershed based flow generation model". Section 1.4.3 was updated as suggested.
Dr. Hugh Whiteley		Comment	In suggesting the term surface flow model not be used I am thinking ahead to possible readers of this report from outside the community of experts familiar with the specifics of the source-water study and with the content of previous reports. Some of these readers might interpret surface model as being a simplistic overland-flow stormwater peak flowrate estimation technique. This interpretation of surface flow model would lead to a puzzling over how such a model could produce reliable estimates of recharge.	Agreed. Updates were made to avoid confusion. Thank you for your suggestion.
Dr. Hugh Whiteley		Comment	A small final point is the Whiteley has two e's.	Updated and our apologies for the spelling error. :)

- MEMORANDUM -

TO: Region of Waterloo Peer Review Committee

FROM: Matrix Solutions Inc. and S.S. Papadopulos and Associates

RE: Tier Three Regional Model Post-Water Budget Report Updates

DATE: July 11, 2013

Since the December 2012 peer review meeting and the presentation of the groundwater modelling report for the Region of Waterloo, Matrix Solutions Inc. and S.S. Papadopulos and Associates have updated the FEFLOW model in response to changes in the groundwater flow modelling software. Challenges arose when transitioning to the most recent version of FEFLOW (V6.1). This transition was necessary to allow the project team to utilize features within the new version, including the ability to run multiple parallel simulations using cloud computing without requiring hundreds of individual licenses. Further, select input/output routines are only compatible with the latest software version. Changes to the treatment of wells between versions created excessive drawdown at a number of non-municipal permits to take water (PTTW) within the model domain that propagated to the municipal well field areas necessitating a resolution. Additional effort to resolve those issues included:

- Request for updated Water Taking Reporting System (WTRS) data from the GRCA and review of 2010 and 2011 data (previously data was limited to 2009 WTRS and permit to take water (PTTW) data);
- Review of the permit location and pumping rate, based on information available in the PTTW and 2010 and 2011 WTRS databases; and
- Model parameter (hydraulic conductivity value) adjustments local to the permits of interest.

This memo documents the changes to the model in the vicinity of the permits and the resultant statistical change in the calibration statistics at each individual well field. There was no discernible change to regional groundwater flow conditions.

Non-Municipal Permits to Take Water

In the most recent version of FEFLOW (version 6.1) the numeric implementation of well boundary condition differs from previous versions. Well boundary conditions that spanned multiple layers are connected via a one-dimensional line element that essentially acts as an open screen (hydraulically connecting layers over which it is screened). In previous versions, all nodes along the well screen remained connected regardless of the saturation state; in the current version, if there are unsaturated portions of the well screen, they become disconnected from the model (i.e., the elements go dry) and the entire pumping well production rate is applied to the lowest (node) boundary condition. When the lowest layer does not have the transmissivity to support the well's allotted production, the model becomes unstable and produces non-physical results that include excessive drawdown within the model. Outside the urban areas in the Regional and Cambridge models, little characterization was completed to refine the OGS model layer structure in the vicinity of the municipal and non-municipal permits. In some areas, the production aquifer is thin or does not exist, which in the latest FEFLOW

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version lead to numerical instability in the model, necessitating a more updated review of the WTRS and PTTW datasets.

Following the distribution of the Water Budget Report several local updates to the current version of the Regional Model (internally referred to as Sim 835) were made:

- Several permit to take water (PTTW) wells were updated to better represent permitted water takings based on our review of the 2008, 2010 and 2011 WTRS databases (Tables 1 and 2). The pumping rates for 99 groundwater wells were updated in the model, which improved model stability within the latest FEFLOW version (V6.1).
    - Where possible, non-municipal well production rates were updated with the annual average values from the WTRS based on actual (measured) takings rather than estimated takings.
    - One PTTW well was moved based on revised coordinates.
    - The screened interval of some PTTW wells were moved to a different hydrostratigraphic unit based on more accurate information. Outside the municipal boundary of the Region of Waterloo, beyond the OGS layer extent, model layers are generalized and pumping from those generalized layers can result in model instabilities. As these wells are far removed from the Tier Three Assessment area, the inclusion of them adds little value to this study and as such, these permits were removed (see Figure 1 for location of wells removed from the Regional Model).
- Similar efforts were made in both the Regional and Cambridge models. Efforts were made to synchronize the parameters in the two models and led to some hydraulic conductivity adjustments in both models.
- Minor hydraulic conductivity value updates were made to improve numerical stability at permit locations in the current Regional and Cambridge models, which are using the most up to date version of FEFLOW (Figures 1 to 4).

Table 1: Permit to Take Water Production Updates for Regional Model

PTTW ID	Total Rate Applied in WBR Model (m^3/d)	Total Updated Rate (m^3/d)	Comment
01-P-2068	151.4	33.2	Maximum taking reported rate in the most recent WTRS (2008, 2010 or 2011) was applied in the model for this permit.
01-P-2198	40	0.5	
0302-7CEL63	583	23	
03-P-2379	9.3	7.2	
0700-6YTS5P	54.5	16.2	
2640-6CFH9G	45	12.9	
4845-6E8HA5	59.1	29	
6268-6QJLB3	0	488	Permit holder reported annual taking of 3258.25 m^3/d in a 2009 Annual Report. A consumptive factor of 0.15 was applied to reflect aggregate washing from a pond.
00-P-2786	5917.7	0	Permits are located outside Region of Waterloo boundary and beyond the OGS layer extent. Pumping rates of 0 m^3/d were applied as the wells were causing model instabilities, and are at a sufficient distance from the municipal wells
01-P-2265	164	0	
1115-6XHLUR	532.8	0	

PTTW ID	Total Rate Applied in WBR Model (m^3/d)	Total Updated Rate (m^3/d)	Comment
1212-64CNJ5	7.8	0	examined in the Tier Three Assessment that they will not impact the sustainability of the municipal wells.
1843-6FYGT7	7.1	0	
4345-6PVHWP	63.5	0	
4484-6FKLMP	22.6	0	
5546-5ZSJ5M	336.6	0	
5557-6BUKDB	141.9	0	
74-P-2065	55	0	
8688-5Q8K76	16.7	0	
89-P-2059	44	0	
99-P-1097	31.2	0	
99-P-1239	29.1	0	
3878-6Z3JUU	186.8	0	Pumping wells for these wells were assigned a rate of 0 m^3/d to improve model stability. Reported pumping rates were not listed in the 2010 or 2011 WTRS. Wells are associated with the Toyota Plant located near Fountain Street and Maple Grove in Cambridge. Additional subsurface characterization in this area may be conducted in the future to improve the stability and simulation of these permits. (Total consumptive taking from these wells is less than 200 m^3/d; the wells are located over 1 km from the closest active municipal pumping well.)
6708-6FLNRH	1522.6	2524	Reported rate from the 2008 WTRS were applied for this permit.
1501-6FEJ2B	699.2	0	Reported rate from the 2010 WTRS were applied for this permit.
7724-73VQCX	189.7	0	
3615-79ULJX	438.4	57.4	Reported rate from the 2011 WTRS were applied for this permit.
4084-7AXSP4	1800	0	
6066-6VXQU2	739	23	
6661-65YPPD	2939	731.1	
7522-6ZAHY6	26.8	0	
81-P-2018	105	1.9	
8708-6LLS2Z	303	0	
4116-7CELMY	733	27.7	Reported rates from the most recent available WTRS (2008, 2010 or 2011) were applied in the model for these permits.
7338-6ZPRBC	12.4	3.8	
73-P-0546	10	2.2	
1351-6D5LEK	9.2	8.9	
5201-6B7HDA	15.7	12.5	
90-P-2013	1474	1633	
99-P-2012	412.4	509	
6634-6ZAHEZ	71.4	61.3	
2540-6PLKFX	189.5	58.0	Reported rates from the 2010 and 2011 WTRS were applied for this permit.
00-P-2176	16.5	9	Reported rates from the 2010 WTRS were applied for this permit.
00-P-2791	58.4	0	
03-P-2384	191.1	162.0	
00-P-2010	30.9	0	
6560-6DYPGH	200	93.8	
97-P-2001	920	460	Two sources with a permitted consumptive rate of 460 m^3/d each. One well reported a zero pumping rate in the recent WTRS, and was assumed to be a standby well. A rate of 460 m^3/d applied to the second of the two wells.

Table 2: Permit to Take Water Production Updates for Cambridge Model

PTTW ID	WBR Rate (m^3/d)	Updated Rate (m^3/d)	Comment
00-P-2176	9.8	5.0	Reported rates from the most recent available WTRS (2010 or 2011) were applied in the model for these permits.
00-P-2176	6.6	4.0	
0717-63RNYF	98.4	86.0	
6560-6DYPGH	200.0	93.8	
03-P-2384	191.1	162.0	
2540-6PLKFX	188.5	58.0	
2540-6PLKFX	1.1	0.0	
7724-73VQCX	231.9	0.0	
3615-79ULJX	438.4	57.0	
6066-6VXQU2	739.0	23.0	
00-P-2791	58.3	0.0	

Hydraulic Conductivity Values and Distributions

In response to feedback from the Region of Waterloo regarding the level of calibration at the Blair Road and Shades Mills well field areas, the well field scale calibration was examined in greater detail in these areas. The hydraulic conductivity values in the bedrock were refined to improve the fit between the model predicted and observed water levels in these areas. Appendix A and B outline the updates made in these well field areas in greater detail.

Quantitative Results

The level of calibration presented in the Water Budget Report was maintained, as demonstrated by the calibration statistics outlined on Tables 3 to 6. Analysis of all observations (Table 3 and 4) indicates that 88% and 90% of observations in the Regional Model and Cambridge model respectively, have an absolute residual within 1 m of the results presented in the previous Water Budget Report. The histograms illustrated on Figures 5 and 6 illustrate that the change in model calibration were minor in both the Regional and Cambridge Models, respectively. The original and updated calibration scatterplots for the Regional and Cambridge models are presented on Figures 7 to 10.

Table 3: Updated Global Model Calibration Statistics for Regional Model

Observation Quality*	Count	Mean Residual (m)		Absolute Mean Residual (m)		Root Mean Squared Residual (m)		Normalized Root Mean Squared Residual (%)	
		WBR[1]	Updated	WBR[1]	Updated	WBR[1]	Updated	WBR[1]	Updated
High Quality	104	0.98	1.10	3.87	3.97	5.21	5.34	4.62	4.97
Medium Quality	422	1.95	2.13	3.65	3.76	4.88	5.09	3.96	4.29
Medium-Low Quality	127	0.31	0.41	4.14	4.32	5.04	5.28	4.24	4.68
Low Quality	703	1.06	1.01	4.58	4.58	6.32	6.34	5.54	5.77
All	1356	1.26	1.30	4.19	4.25	5.71	5.81	4.40	4.42

[1] WBR refers to previously distributed Water Budget Report

*Quality is defined in **Section 4.4.2 of the WBR** and refers to availability of water level data relative to the 2003 municipal pumping conditions.

Table 4: Updated Calibration Statistics for Tier Three Assessment Well Fields in the Regional Model

Well Field	Quality*	Count	Mean Residual (m)		Absolute Mean Residual (m)		Root Mean Squared Residual (m)	
			WBR[1]	Updated	WBR[1]	Updated	WBR[1]	Updated
Waterloo North	All	23	-0.13	-0.15	1.65	1.72	2.35	2.39
Waterloo North	High	1	3.11	3.11	3.11	3.11		
Waterloo North	Medium	13	-0.02	-0.01	0.93	0.98	1.20	1.26
Waterloo North	Medium-Low	1	3.09	3.09	3.09	3.09		
Waterloo North	Low	8	-1.10	-1.20	2.45	2.59	3.33	3.38
William Street	All	33	-0.12	0.13	1.65	1.53	2.22	2.14
William Street	High	3	3.06	3.42	3.06	3.42	3.84	3.90
William Street	Medium	24	-0.30	-0.02	1.32	1.14	1.70	1.61
William Street	Low	6	-1.02	-0.92	2.26	2.17	2.85	2.68
Erb Street	All	35	-0.07	-0.11	3.71	3.63	4.43	4.35
Erb Street	High	2	5.20	4.51	5.20	4.51	5.20	4.51
Erb Street	Medium	20	1.15	1.14	3.26	3.20	3.82	3.76
Erb Street	Medium-Low	6	-5.59	-5.58	5.59	5.58	6.59	6.60
Erb Street	Low	7	-0.35	-0.34	2.96	2.94	3.36	3.35
Strange Street	All	39	4.24	2.47	5.35	4.10	6.40	5.22
Strange Street	High	3	2.24	1.76	2.24	4.11	2.57	4.53
Strange Street	Medium	7	8.33	1.13	8.33	1.65	8.95	2.73
Strange Street	Medium-Low	13	3.21	3.22	4.27	4.21	5.15	5.10
Strange Street	Low	16	3.65	2.58	5.51	5.09	6.48	6.17
Greenbrook	All	93	8.42	6.66	8.58	6.82	9.37	7.32
Greenbrook	High	6	4.17	5.10	4.17	5.10	4.72	5.56
Greenbrook	Medium	63	10.50	7.29	10.50	7.35	10.88	7.78
Greenbrook	Medium-Low	15	3.93	5.72	4.91	6.49	5.20	7.13
Greenbrook	Low	9	4.24	4.84	4.24	4.84	4.39	5.02
Mannheim East	All	18	4.90	5.00	5.27	5.32	6.27	6.35
Mannheim East	High	4	3.08	3.17	3.08	3.17	3.20	3.26
Mannheim East	Medium	4	6.75	6.76	6.75	6.76	6.75	6.76
Mannheim East	Medium-Low	2	1.15	1.17	4.01	4.00	4.17	4.17
Mannheim East	Low	8	5.83	6.00	5.93	6.01	7.50	7.62
Mannheim Peaking	All	15	9.28	9.27	9.28	9.27	12.77	12.77
Mannheim Peaking	Medium	8	7.04	7.03	7.04	7.03	7.09	7.08
Mannheim Peaking	Medium-Low	1	6.43	6.43	6.43	6.43		
Mannheim Peaking	Low	6	12.74	12.75	12.74	12.75	18.27	18.28
Mannheim West	All	30	1.64	1.59	2.77	2.75	3.64	3.61
Mannheim West	High	7	1.35	1.32	1.35	1.32	1.54	1.51
Mannheim West	Medium	8	1.16	1.10	1.85	1.90	2.10	2.11
Mannheim West	Medium-Low	5	2.86	2.80	2.86	2.80	3.38	3.34
Mannheim West	Low	10	1.61	1.57	4.46	4.41	5.37	5.33
Parkway	All	10	6.29	5.88	6.29	5.91	8.45	8.19
Parkway	High	5	2.64	2.21	2.64	2.26	3.55	3.35
Parkway	Medium-Low	1	2.82	2.29	2.82	2.29		
Parkway	Low	4	11.73	11.37	11.73	11.37	12.68	12.34
Strasburg	All	11	-0.67	-1.38	4.09	4.28	4.78	4.92
Strasburg	High	2	3.46	2.65	3.46	2.65	3.52	2.71
Strasburg	Medium	1	-0.99	-1.66	0.99	1.66		
Strasburg	Medium-Low	7	-2.25	-2.98	4.95	5.43	5.60	5.91
Strasburg	Low	1	2.45	2.04	2.45	2.04		
Woolner	All	55	0.35	0.58	2.37	2.74	3.62	3.90

Well Field	Quality*	Count	Mean Residual (m)		Absolute Mean Residual (m)		Root Mean Squared Residual (m)	
Woolner	High	1	-0.59	-0.71	0.59	0.71		
Woolner	Medium	15	-1.06	-1.24	1.12	1.26	1.35	1.50
Woolner	Medium-Low	9	-2.01	-2.22	2.01	2.22	2.25	2.45
Woolner	Low	30	2.32	2.37	3.44	3.70	4.96	4.99
West Montrose	All	2	-2.62	-1.86	2.62	1.86	2.65	1.89
West Montrose	High	1	-3.06	-2.23	3.06	2.23		
West Montrose	Medium	1	-2.17	-1.48	2.17	1.48		
Elmira	All	26	-4.23	-4.57	5.15	5.46	5.98	6.29
Elmira	High	3	-7.45	-7.76	7.45	7.76	7.69	8.00
Elmira	Medium	2	-4.53	-4.79	4.53	4.79	4.53	4.79
Elmira	Medium-Low	4	-6.50	-6.89	6.50	7.87	7.49	7.87
Elmira	Low	17	-3.09	-3.43	5.15	4.79	5.35	5.65
Conestogo	All	22	1.16	1.08	3.13	3.12	4.50	4.48
Conestogo	High	2	-0.41	-0.42	0.41	0.42	0.42	0.43
Conestogo	Medium	7	4.36	4.32	5.16	5.14	6.87	6.81
Conestogo	Low	13	-0.31	-0.44	2.45	2.45	2.97	2.99
St. Agatha	All	26	-0.47	-0.44	4.94	4.92	6.93	6.91
St. Agatha	High	3	-7.67	-7.57	7.67	7.57	8.20	8.06
St. Agatha	Medium	3	-2.65	-2.65	2.65	2.65	2.78	2.78
St. Agatha	Medium-Low	2	0.36	0.37	4.45	4.44	4.47	4.46
St. Agatha	Low	18	1.01	1.03	4.91	4.91	7.40	7.39
New Dundee	All	25	-0.21	-0.23	2.30	2.29	2.73	2.73
New Dundee	High	2	-0.61	-0.67	0.61	0.67	0.63	0.69
New Dundee	Medium	8	0.30	0.27	1.70	1.67	2.03	1.99
New Dundee	Low	15	-0.43	-0.44	2.84	2.84	3.19	3.20

[1] WBR refers to previously distributed Water Budget Report

*Quality is defined in **Section 4.4.2 of the WBR** and refers to availability of water level data relative to the 2003 municipal pumping conditions.

Table 5: Updated Global Model Calibration Statistics for Cambridge Model

Observation Quality*	Count	Mean Residual (m)		Absolute Mean Residual (m)		Root Mean Squared Residual (m)		Normalized Root Mean Squared Residual (%)	
		WBR[1]	Updated	WBR[1]	Updated	WBR[1]	Updated	WBR[1]	Updated
High Quality	205	1.34	-1.29	3.69	3.48	5.08	4.37	8.49	7.41
Low Quality	1421	0.78	1.00	4.61	4.70	6.19	6.24	6.13	6.24
All	1626	0.46	0.71	4.50	4.54	6.08	6.03	6.00	6.03

[1] WBR refers to previously distributed Water Budget Report

*Quality is as defined in **Section 4.4.2 of the WBR**, to be consistent with 2003 pumping conditions.

Due to the refinements made in the Cambridge area, the statistics for Blair Road, Dunbar Road and Middleton Street well field area improved dramatically, as illustrated in Table 6 The absolute mean residual for Dunbar Road improved from 5.77 m to 1.62 m, and the absolute mean residual at Blair Road similarly improved from 8.63 m to 2.73 m.

Table 6: Updated Calibration Statistics for Tier Three Assessment Well Fields in the Cambridge Model

Well Field	Quality*	Count	Mean Residual (m)		Absolute Mean Residual (m)		Root Mean Squared Residual (m)	
			WBR[1]	Updated	WBR[1]	Updated	WBR[1]	Updated
Hespeler	All	10	2.16	2.27	3.26	3.25	4.21	4.22
Pinebush	All	37	3.70	3.71	3.94	3.99	4.29	4.32
Clemens Mill	All	34	2.29	2.46	3.92	3.98	4.56	4.61
Dunbar Road	All	6	-5.77	-1.62	6.99	3.51	8.03	3.69
Blair Road	All	5	-8.63	2.73	10.88	8.25	15.03	8.49
Shade's Mill	All	35	-1.12	-1.26	2.58	2.37	3.58	3.43
Elgin Street	All	6	-1.39	-1.58	1.65	1.76	2.50	2.63
Middleton Street	All	37	2.16	0.58	5.08	4.32	6.35	5.49
Willard	All	1	-1.16	-1.34	1.16	1.34	1.16	1.34

[1] WBR refers to previously distributed Water Budget Report

*Quality is defined in **Section 4.4.2 of the WBR** and refers to availability of water level data relative to the 2003 municipal pumping conditions.

Updated baseflow calibration statistics are presented in Table 7 (Regional Model) and Table 8 (Cambridge Model). The level of calibration was maintained and is considered acceptable. In some instances, observed stream flow values were used as baseflow calibration targets as observed baseflow values were unavailable (see Tables 7 and 8). In a few stream reaches, such as Airport Creek and Strasburg Creek, the model simulated groundwater discharge is lower than observed spot baseflow values collected in 2008 as part of the Tier Three Assessment field program. Climate data collected at the Waterloo Wellington and Waterloo Airport Climate Stations shows the average precipitation in 2008 (973 mm/year) was above average while the average precipitation in 2003, the model calibration year, was below average (905 mm/year). As such, the spot baseflow values collected in 2008 are expected to be higher than the model simulated values. Examination of total rainfall between June and September in 2003 and 2008 showed a similar trend with 333 mm of rain falling during this period in 2003 and 481 mm in 2008.

Table 7: Updated Simulated Baseflows within the Regional Model

Reach	Measurement Type	Observed Estimated Baseflow (L/s)		Simulated Baseflow (L/s)	
		Minimum	Maximum	WBR[1]	Updated
Alder Creek headwaters	Min/ Max based on 14 spot flows measurements[2] collected between 1995 and 2002	2	64	26	25
Alder Creek at Mannheim West	WSC gauge (1986-2005); min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1. (Flows includes upstream Alder Ck headwaters)	20	101	37	32
Alder Creek at New Dundee[4]	Min/ max based on difference in **spot flow** readings[2] between 2 locations (8 measurements upstream; 1 measurement downstream)	51	145	13	14
Clair Creek at Well W10	GRCA gauge (1996-2005); min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1.	33	81	22	23

Reach	Measurement Type	Observed Estimated Baseflow (L/s)		Simulated Baseflow (L/s)	
		Minimum	Maximum	WBR[1]	Updated
Laurel/ Beaver Creek Headwaters[4]	GRCA gauge (1993 to 2005); Min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1.	72	181	172	174
Laurel Creek at William Street	Calculated as the difference in flow between a GRCA and WSC stream gauge; Min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1.	58	215	23	23
Airport Ck[4]	2 spot baseflow values collected in 2008.	49	59	30	27
Hopewell Creek[4]	2 spot baseflow values collected in 2008.	92	163	370	335
Idlewood Creek	2 spot baseflow values collected in 2008 plus 1 spot flow collected by GRCA in 2000.	12	20	-36	-41
Freeport Creek	2 spot baseflow values collected in 2008.	11	73	1	2
Schneider Creek	Difference in flow between a WSC stream gauge and two spot baseflow values collected in 2008. Min based on average summer flows (Jun to Aug) and max based on BFLOW Pass 1.	42	135	-4	-3
Shoemaker Creek	WSC gauge (1986-2005); min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1.	36	112	-3	-5
Strasburg Creek[4]	2 spot baseflow values collected in 2008.	72	81	25	16

[1] WBR refers to previously distributed Water Budget Report
[2] Spot flows collected are measures of total streamflow at a point in time and may not represent baseflow conditions. (Used in the absence of gauged or spot baseflow measurements)
[3] Summer Low Flows are the average monthly low flows during the months of June, July and August in the period of record. (na refers to locations where gauge data is not available)
[4] Reaches, or portions of reaches identified as hosting coldwater fish communities (also identified using **Bold** typeface).

Table 8: Updated Simulated Baseflows within the Cambridge Model

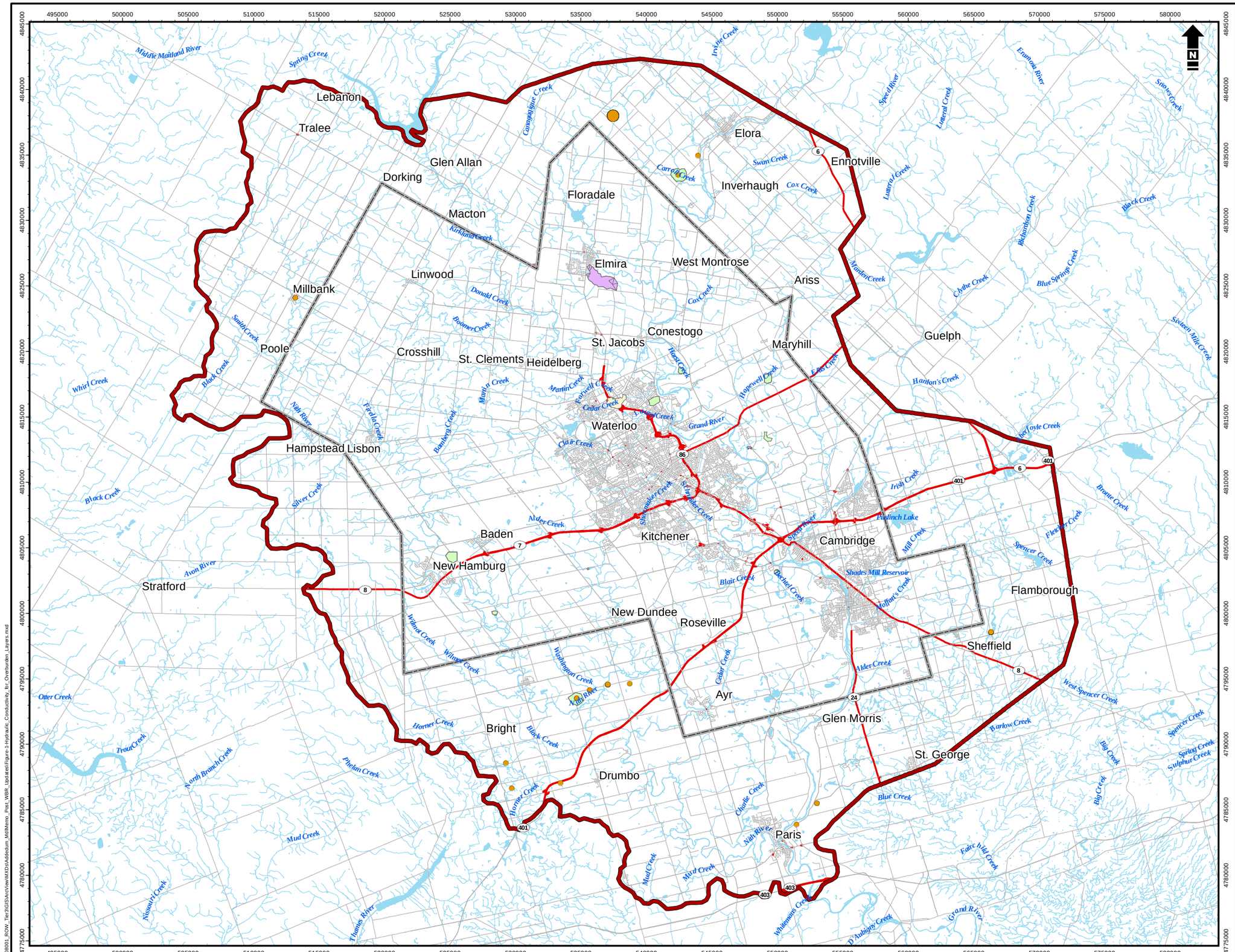
Reach	Measurement Type	Observed Estimated Baseflow (L/s)		Simulated Baseflow (L/s)	
		Minimum	Maximum	WBR[1]	Updated
Aberfoyle Creek[2]	GRCA gauge (2002-2005); min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1.	135	241	239	231
Cedar Creek Headwaters	4 spot flows measurements collected between 1998 and 2000.	5	14	25	27
Ellis Creek[2]	Spot baseflows measurements between 2 locations (2 measurements upstream; 3 measurements downstream) collected in 2008.	27	101	83	83
Irish Creek	3 spot baseflows measurements collected in 2008.	62	107	70	76
Mill Creek[2]	GRCA gauge (1990-2005); min based on average summer flows[3] (Jun to Aug) and max based on BFLOW Pass 1. Values based on the difference in flow between 2 gauged locations.	232	444	642	530

[1] WBR refers to previously distributed Water Budget Report
[2] Reaches, or portions of reaches identified as hosting coldwater fish communities (also identified using **Bold** typeface).

Summary

This memo summarizes the changes that took place in the Regional and Cambridge Models since the release of the Draft Tier Three Water Budget Report for the Region of Waterloo Tier Three Assessment. Updates were made to the permits to take water in the model and also to refine the calibration in two of the well fields within the Cambridge area. The updates in the model were minor, and the there was no discernible change to regional groundwater flow conditions. The local groundwater flow conditions improved markedly in the Cambridge well field areas where local calibration updates were made. The changes to the model calibration statistics and baseflow values presented in this memo will be incorporated into an updated and revised Water Budget Report.

FIGURES



Numerical Model Domain; Regional Model
Region of Waterloo Municipal Boundary
Water Body
Watercourse
Expressway/Highway
Road

Updated Hydraulic Conductivity Zones

Updated for Numerical Stability
Updated to Support Water Taking (updated characterization)
Updated to Support Water Taking (no detailed characterization)

Permits to Take Water Removed from Regional Model (m^3/d)

0 - 500
500 - 1000
1000 - 1500
1500 - 2000
2000 - 2500
> 2500

Reference: Data obtained from Geobase used under license.
Base Data - Region of Waterloo, 2008; GRCA, 2008, MNR NRVIS obtained 2012.
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Water Budget Report Addendum

Hydraulic Conductivity Updates for Overburden Layers; Regional Model

Date: 05 Jun 2013	Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

Disclaimer: Prepared solely for the use of Region of Waterloo as specified in the accompanying report. No representation of any kind is made to other parties with which Region of Waterloo has not entered into contract.

Figure 1

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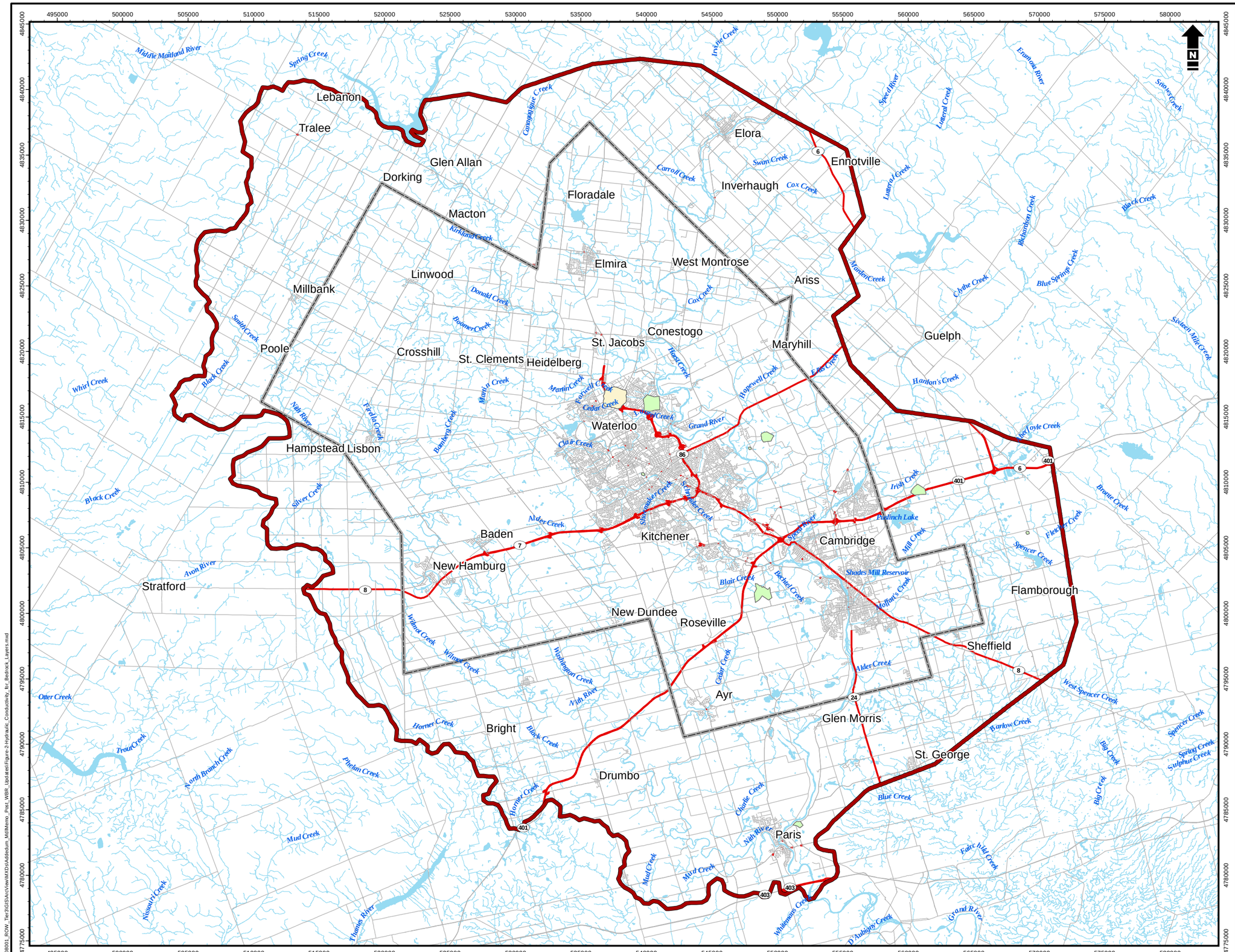

Numerical Model Domain; Regional Model

Region of Waterloo Municipal Boundary

Water Body

Watercourse

Expressway/Highway

Road

Updated Hydraulic Conductivity Zones

Numerical Stability Consideration

Updated to Support Water Taking (updated characterization)

Updated to Support Water Taking (no detailed characterization)

Reference: Data obtained from Geobase used under license.
Base Data - Region of Waterloo, 2008; GRCA, 2008, MNR NRVIS obtained 2012.
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Water Budget Report Addendum

Hydraulic Conductivity Updates for Bedrock Layers; Regional Model

Date: 05 Jun 2013		Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer		Drawn: C. Curry

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Figure 2

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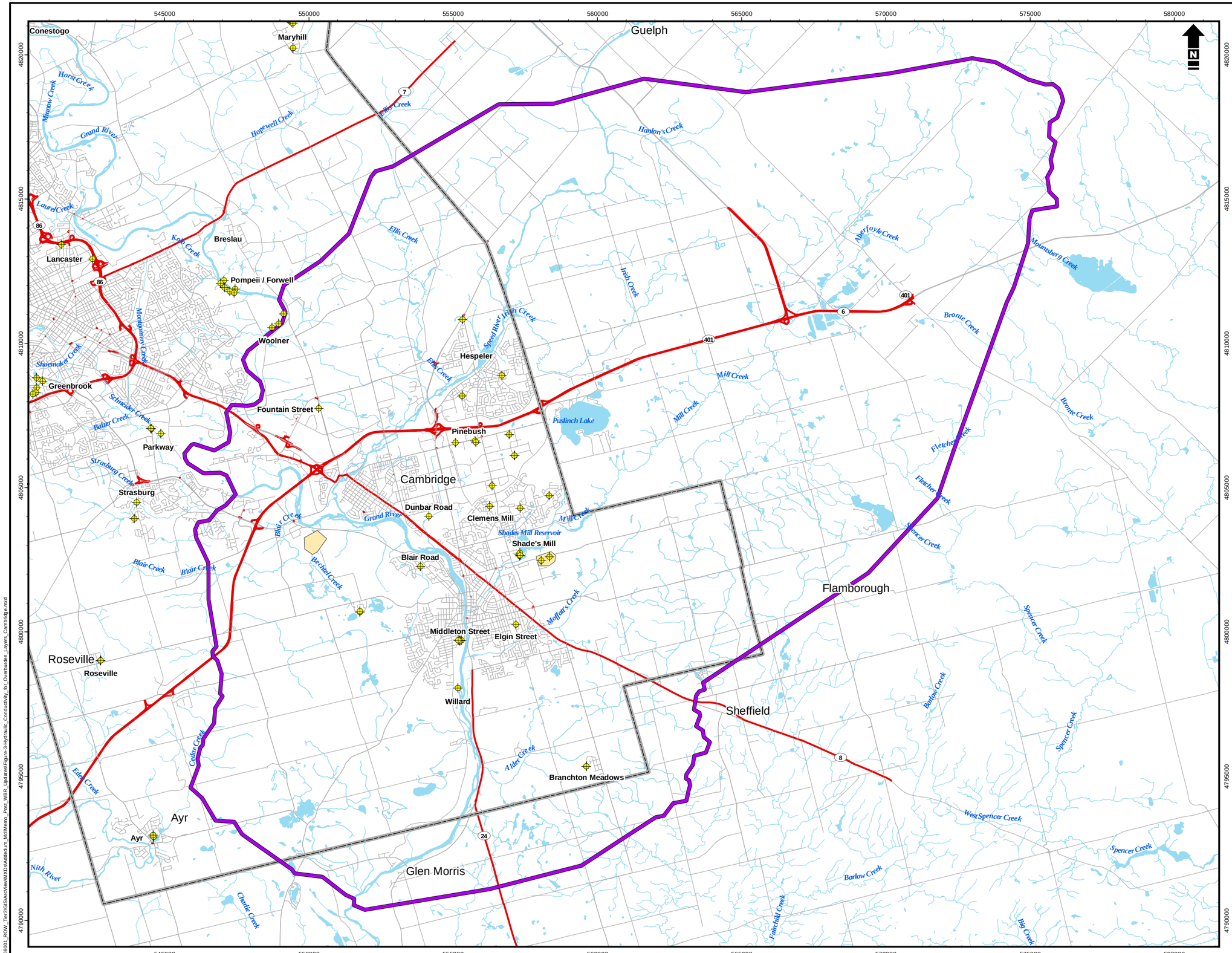

Cambridge Numerical Model Domain
Region of Waterloo Municipal Boundary
Updated Hydraulic Conductivity Zones
Water Body
Watercourse
Expressway/Highway
Road
Municipal Well

Maryhill Well Field Name

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Water Budget Report Addendum

Hydraulic Conductivity Updates for Overburden Layers; Cambridge Model

Date: 12 Jun 2013	Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

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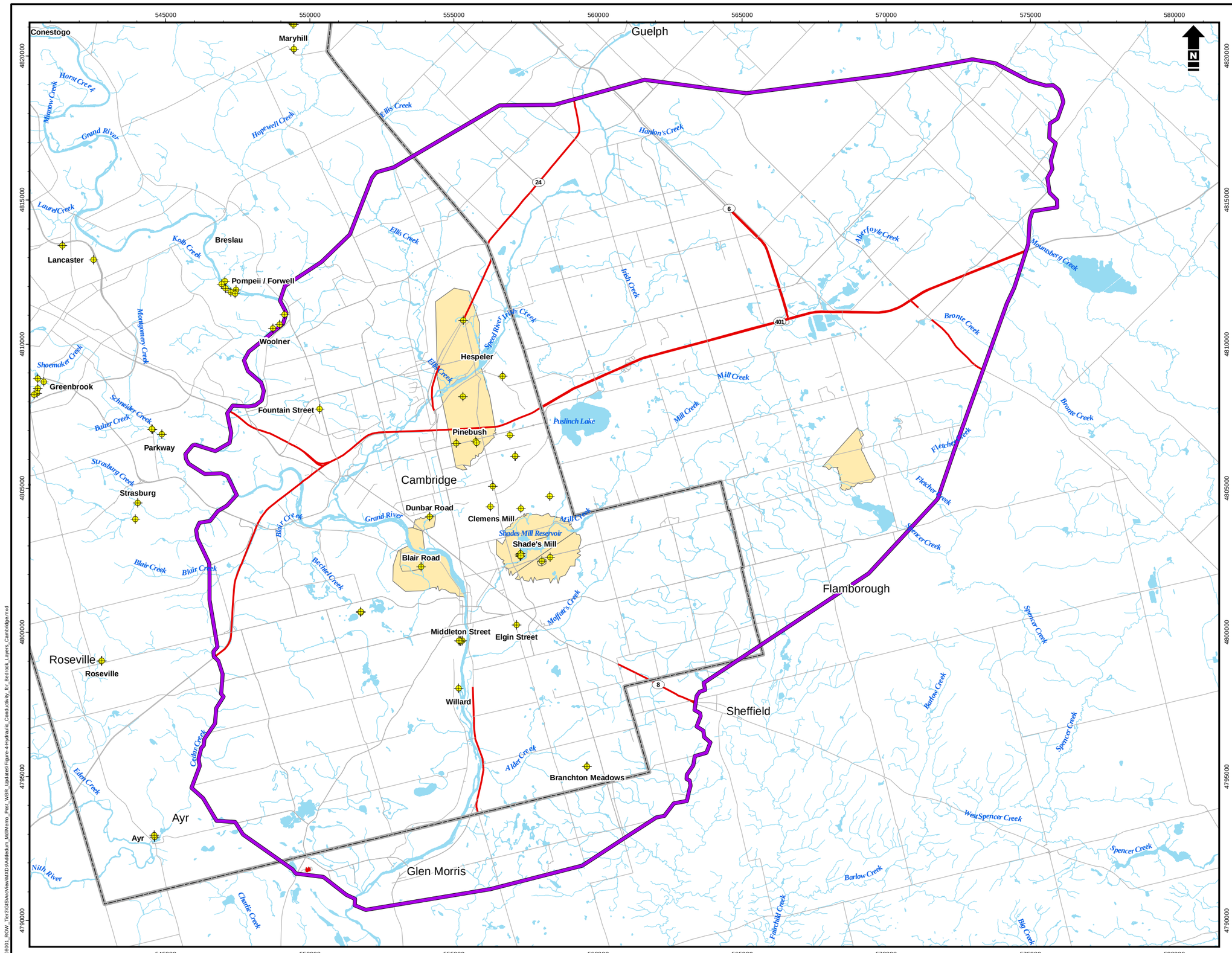
Figure 3

T:\2008001_ROW_Tier3\GIS\ArcView\MXDs\Addedum_MdlMemo_Post_WBR_Updates\Figure-3-Hydraulic_Conductivity_for_Overburden_Layers_Cambridge.mxd



Cambridge Numerical Model Domain
Region of Waterloo Municipal Boundary
Updated Hydraulic Conductivity Zones
Water Body
Watercourse
Expressway / Highway
Road
Municipal Well
Maryhill Well Field Name

Reference: Data obtained from Geobase used under license.
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Kilometres

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Water Budget Report Addendum

Hydraulic Conductivity Updates for Bedrock Layers; Cambridge Model

Date:	Project:	
12 Jun 2013	15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

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Figure 4

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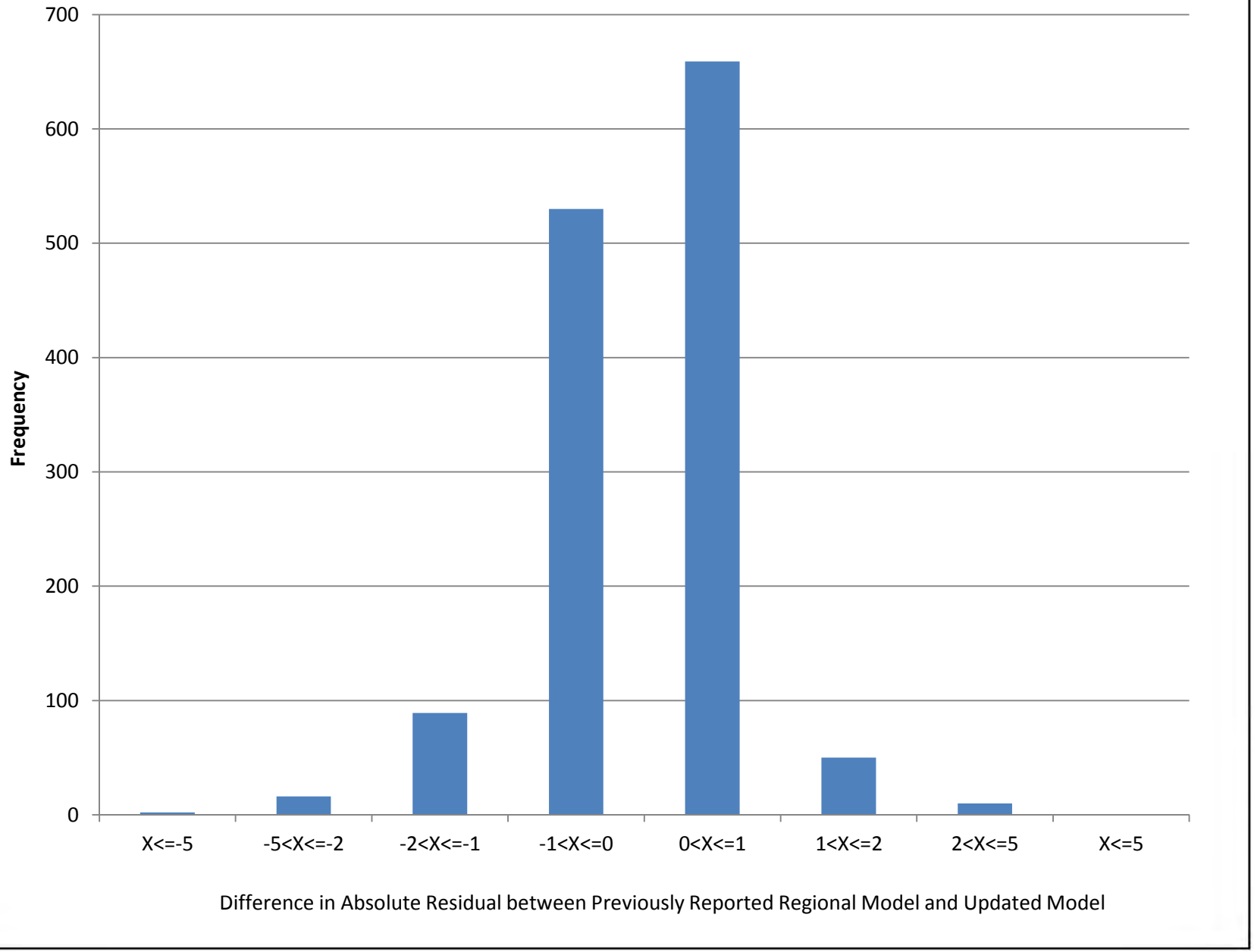

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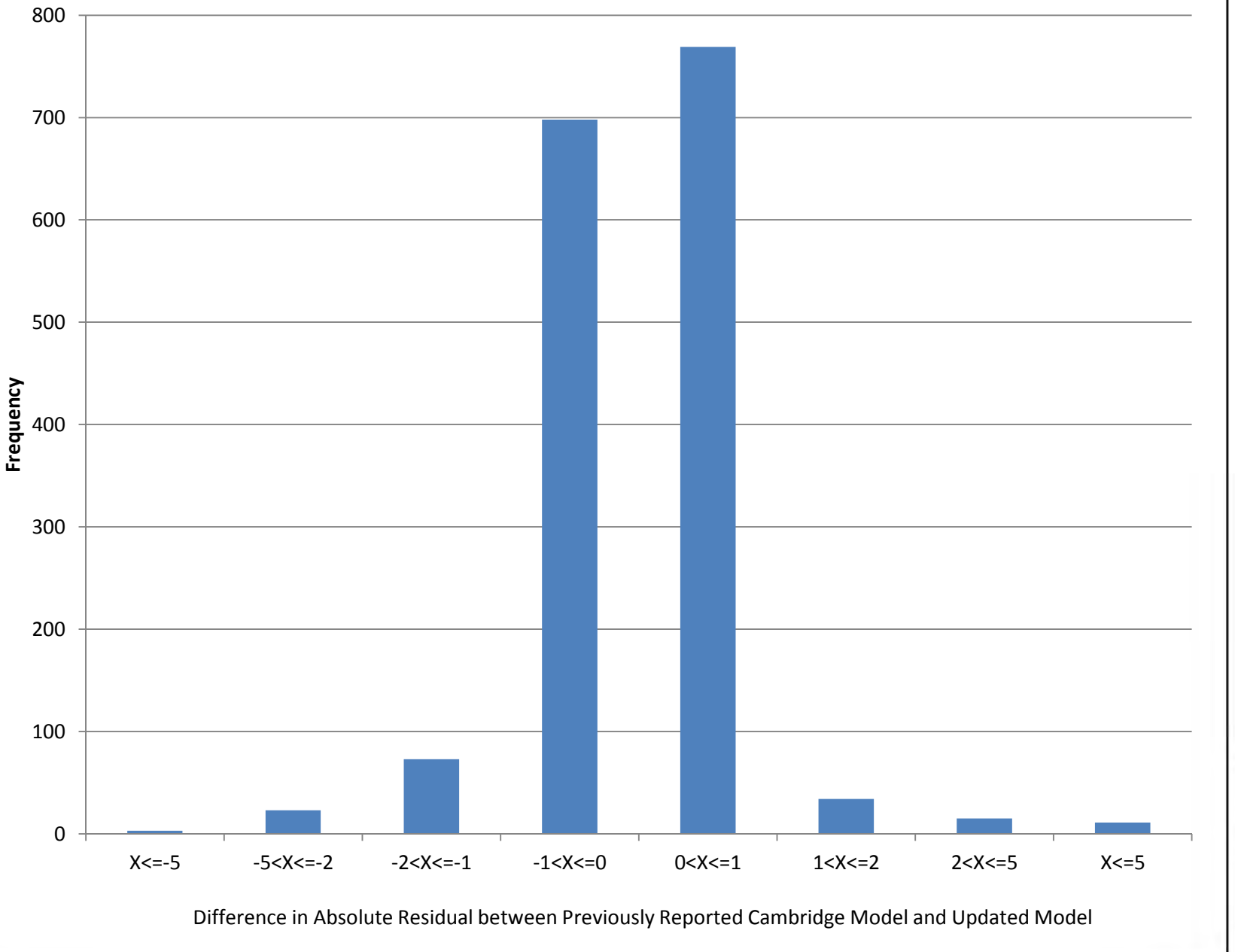
Water Budget Report Addendum

Histogram of Difference Absolute Residual between WBR and Updated Model (Regional Model)

Date: 06 Jun 2013	Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

Figure: 5



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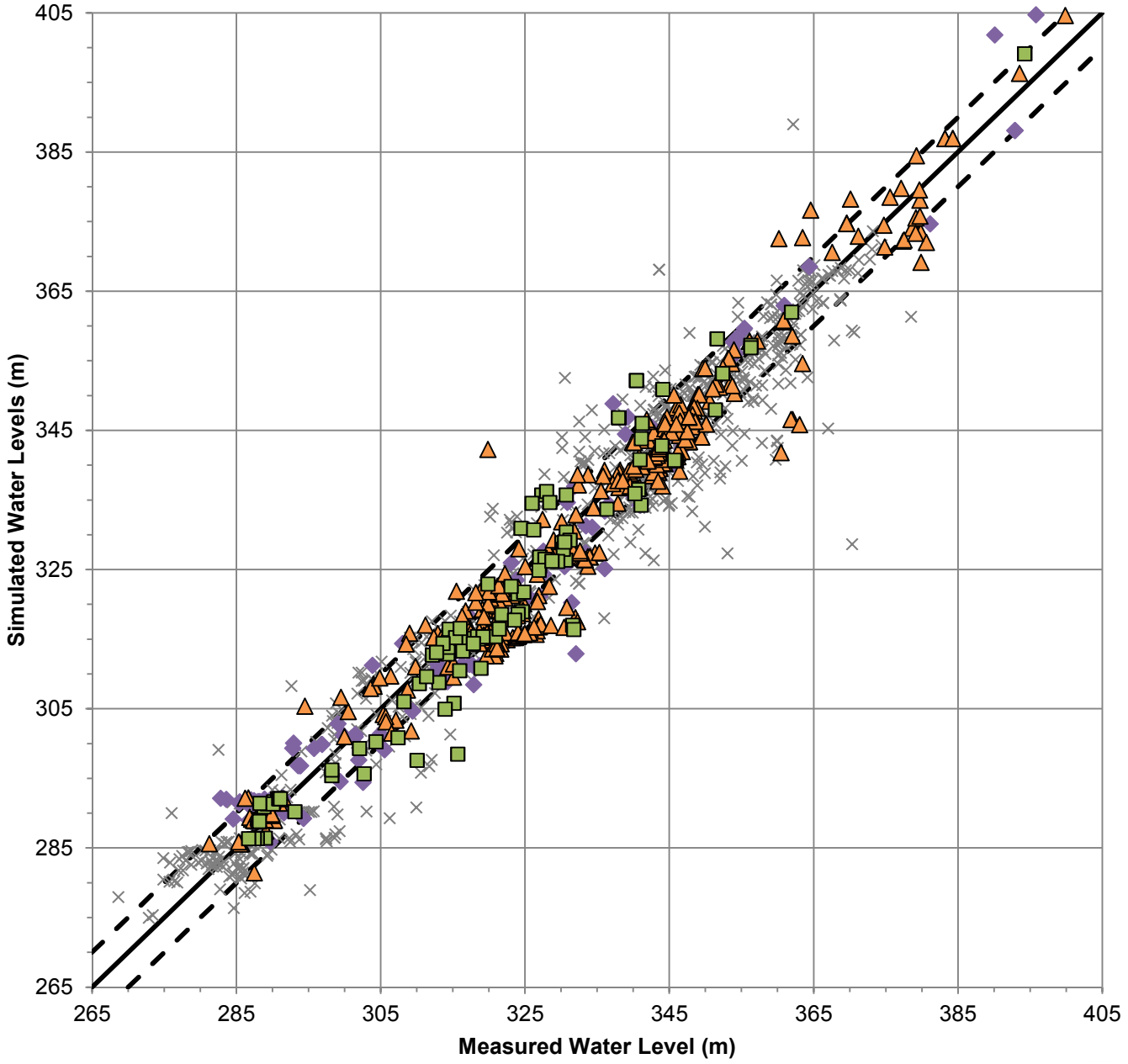
Water Budget Report Addendum

Histogram of Difference Absolute Residual between WBR and Updated Model (Cambridge Model)

Date: 06 Jun 2013	Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

Figure 6



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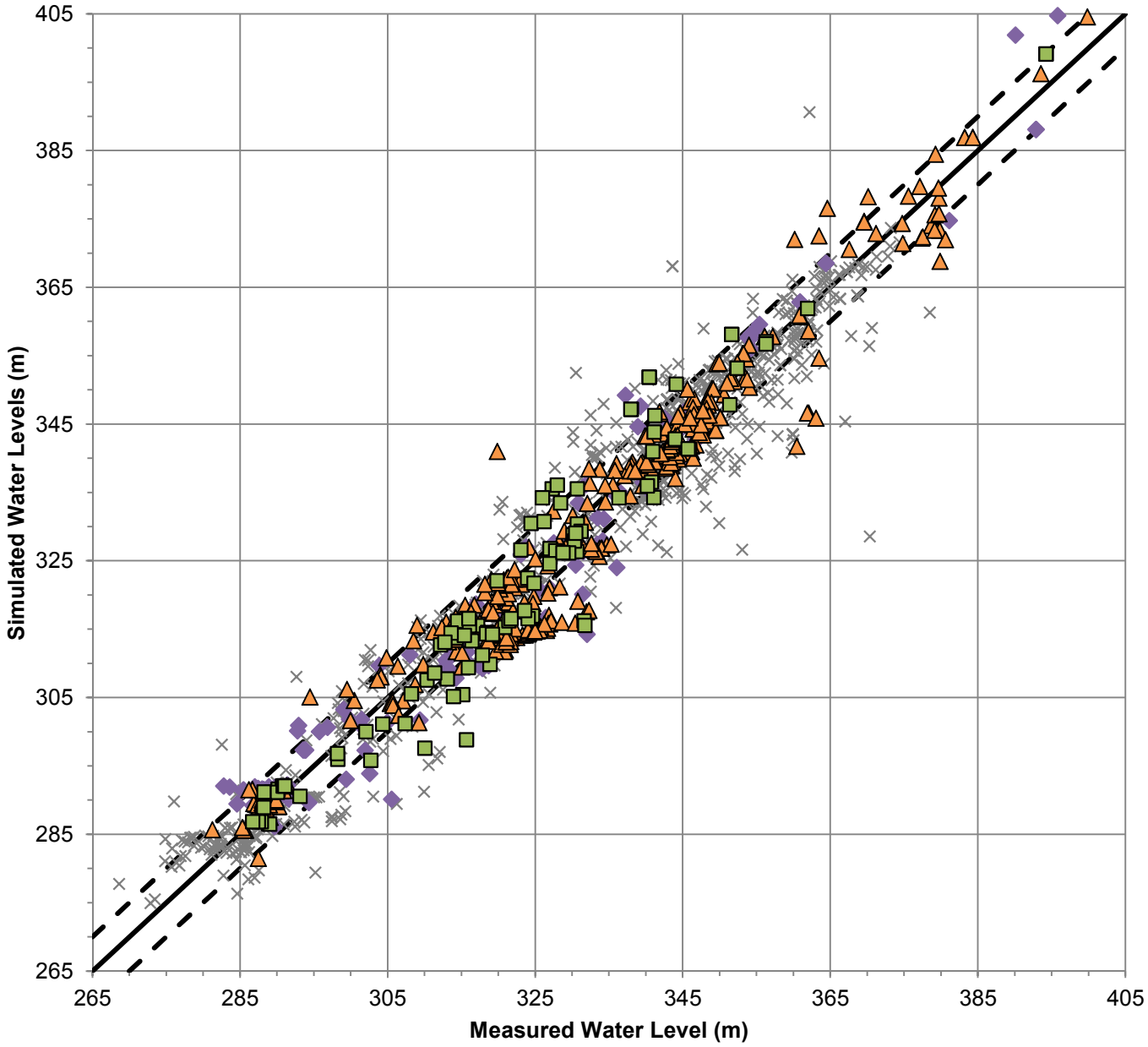
Water Budget Report Addendum

WBR Global Calibration Scatterplot (Regional Model)

Date: 06 Jun 2013		Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry	

Figure 7



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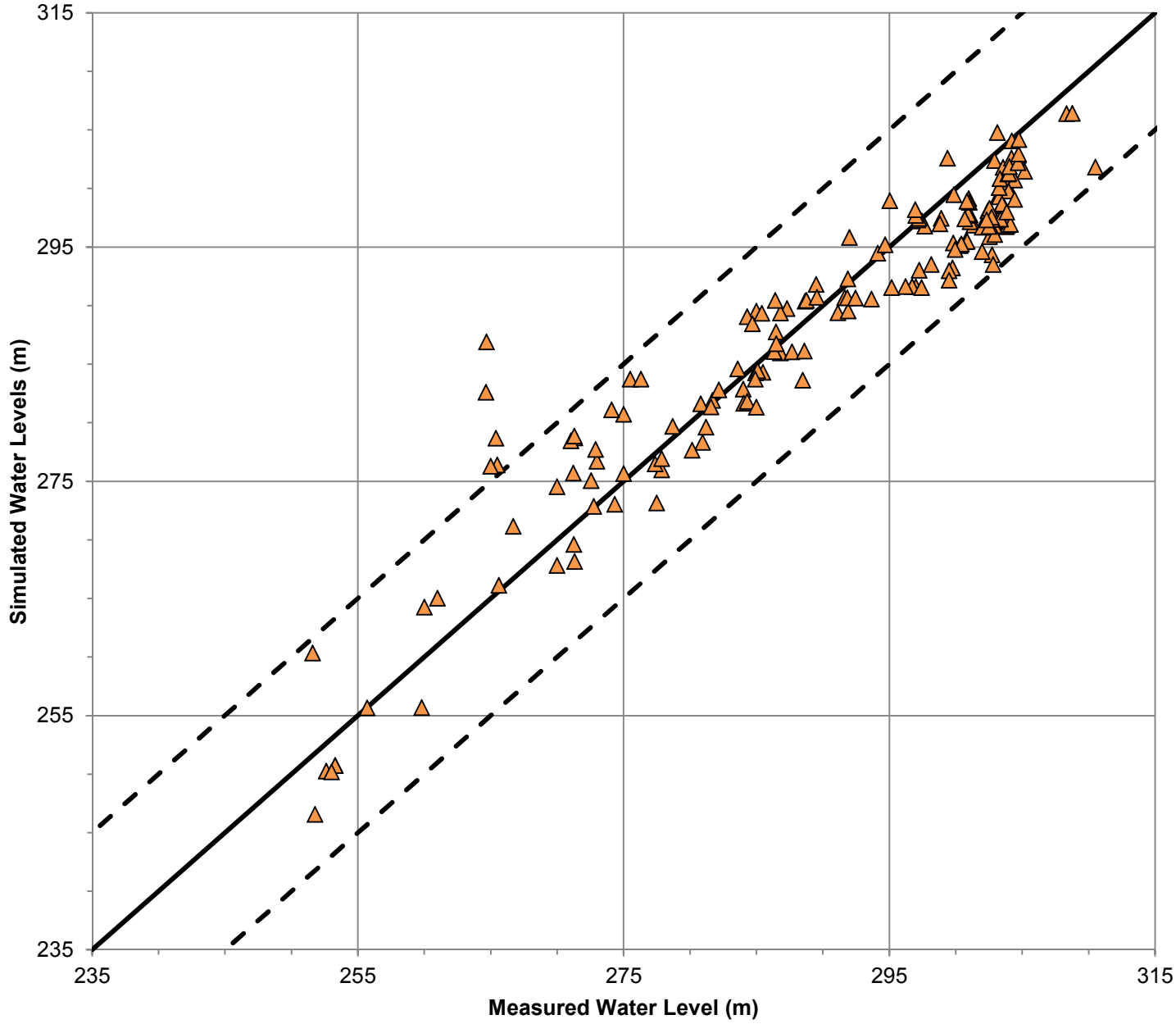
Water Budget Report Addendum

Updated Global Calibration Scatterplot (Regional Model)

Date: 06 Jun 2013	Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

Figure 8



△ High Quality

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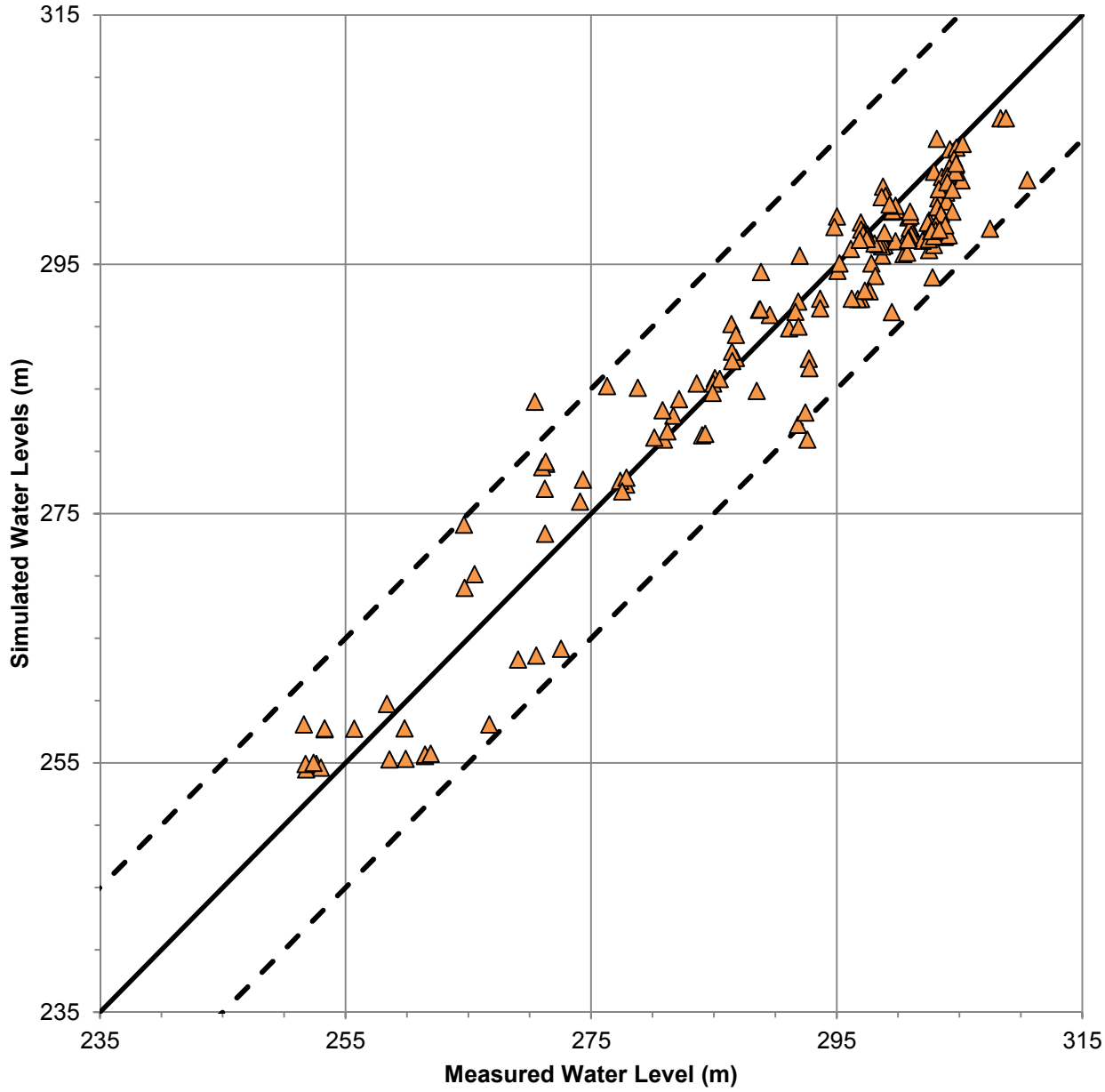
Water Budget Report Addendum

WBR Global Calibration
Scatterplot (Cambridge Model)

Date: 06 Jun 2013	Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry

Figure 9



△ High Quality

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Water Budget Report Addendum

Updated Global Calibration Scatterplot (Cambridge Model)

Date: 06 Jun 2013		Project: 15087-527	
Technical: G. Merritt	Reviewer: P. Meyer	Drawn: C. Curry	

Figure 10

APPENDICES

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

Memorandum

Date: April 17, 2013

From: Jinhui Zhang and Christopher Neville

To: File

Project: SSP-1185

Subject: **Refinement of the Cambridge groundwater model in the vicinity of Blair Road well G4**

1. Summary of conditions in the vicinity of G4

A location map for Blair Road well G4 is shown in Figure 1. Cross-sections through the well field are presented in Figures 2 and 3. The sections were developed from the hydrostratigraphic model developed for the Cambridge area (SSPA, 2012).

- As shown in Figure 4, the water level at G4 is close to the water level in the Grand River (about 265 mASL).
- Richard Wootton from Region of Waterloo has suggested that G4 is close to the Grand River, and is a regional discharge zone.
- OW5-95 is about 600 m west of G4. The water levels at G4 are almost the same as the observed water levels for the screen intervals B and C of the monitoring well OW5-95 (Figures 5 and 6).
- Responses to pumping G4 are observed in the hydrographs for interval B and C of OW5-95. Drawdowns in these intervals were also observed during the pumping of G4A.
- IWS (1974) reported a transmissivity of about 260 m^2/d.
- SSPA estimated a transmissivity of about 600 m^2/d at G4 based on the "raw" specific capacity. The analyses are documented in an appendix to this memorandum.
- The formation transmissivity estimated from the G4A pumping test was about 350 m^2/d; however, the drawdown at G4A was less than expected for this transmissivity. Additional analyses of the G4A testing suggest that G4A is surrounded by a zone of transmissivity that is higher than estimated for the bulk formation.

2. Revisions of the model in the vicinity of G4

The revisions have been made to the model in the vicinity of G4:

- The fixed head boundary nodes that represent the Grand River in the vicinity of G4 have been extended up to the Reformatory Quarry Member (model layer 10). This has the effects of maintaining the water level at G4 to be close to the water level in the Grand River, which ensuring that this is an area of a regional groundwater discharge zone; and
- A new zone has been added in the Reformatory Quarry Member that includes G4 and OW5-95, and extends to the Grand River. A higher hydraulic conductivity is assigned to this zone to achieve similar water levels in G4 and OW5-95-B, C. The revised zonation is shown in Figure 7.

After the revisions of the model, the cumulative transmissivity in the immediate vicinity of G4 is about 570 m^2/d, which is consistent with independent estimates of the transmissivity of G4 based on the "raw" specific capacity.

The target and simulated water levels at G4 and OW5-95 are tabulated below.

Well ID	Target water level (m ASL)	Simulated water level before revision (m ASL)	Simulated water level after revision (m ASL)
G4	265.00	265.52	266.40
OW5-95-B	264.64	286.37	274.25
OW5-95-C	264.69	290.16	269.19
OW5-95-D	291.85	293.24	282.42
OW5-95-E	292.45	293.24	282.43
OW5-95-F	299.49	293.85	290.97

The simulated water levels at G4 and OW5-95 are compared with the targets in Figure 8. An improved match to the targets is achieved with the revised model.

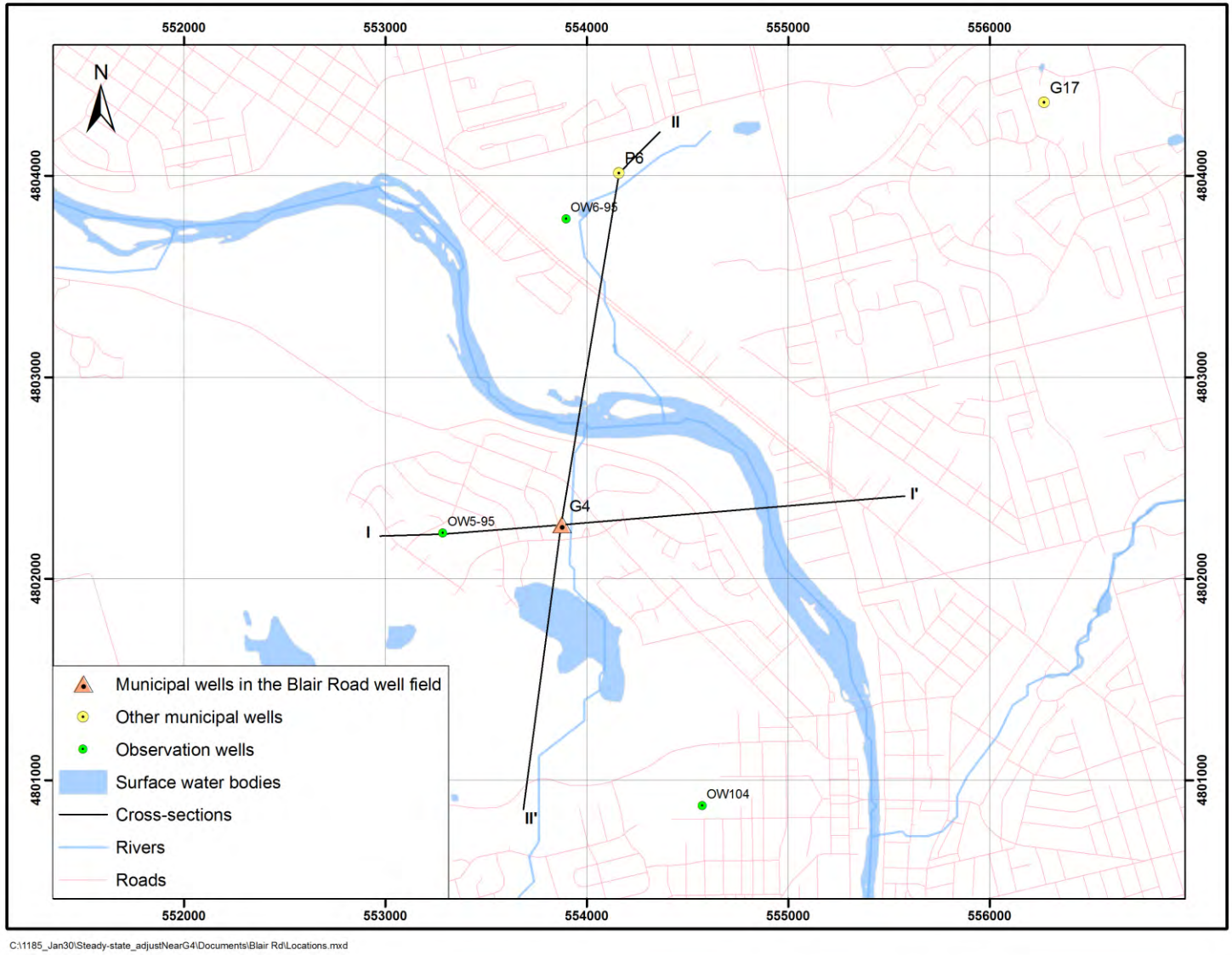


Figure 1 Blair Road well field

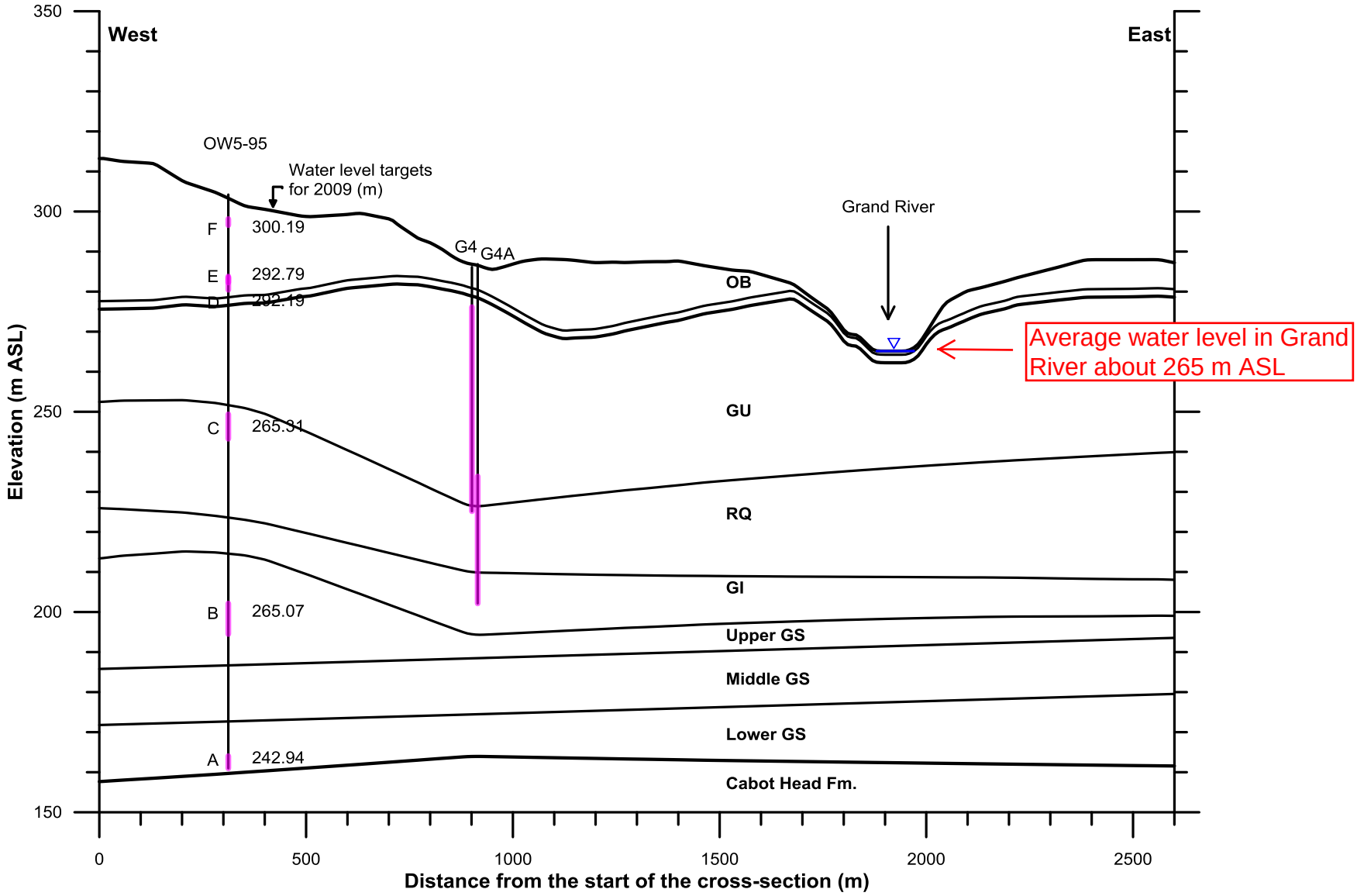


Figure 2 Cross-section through the Blair Road well field (I-I')

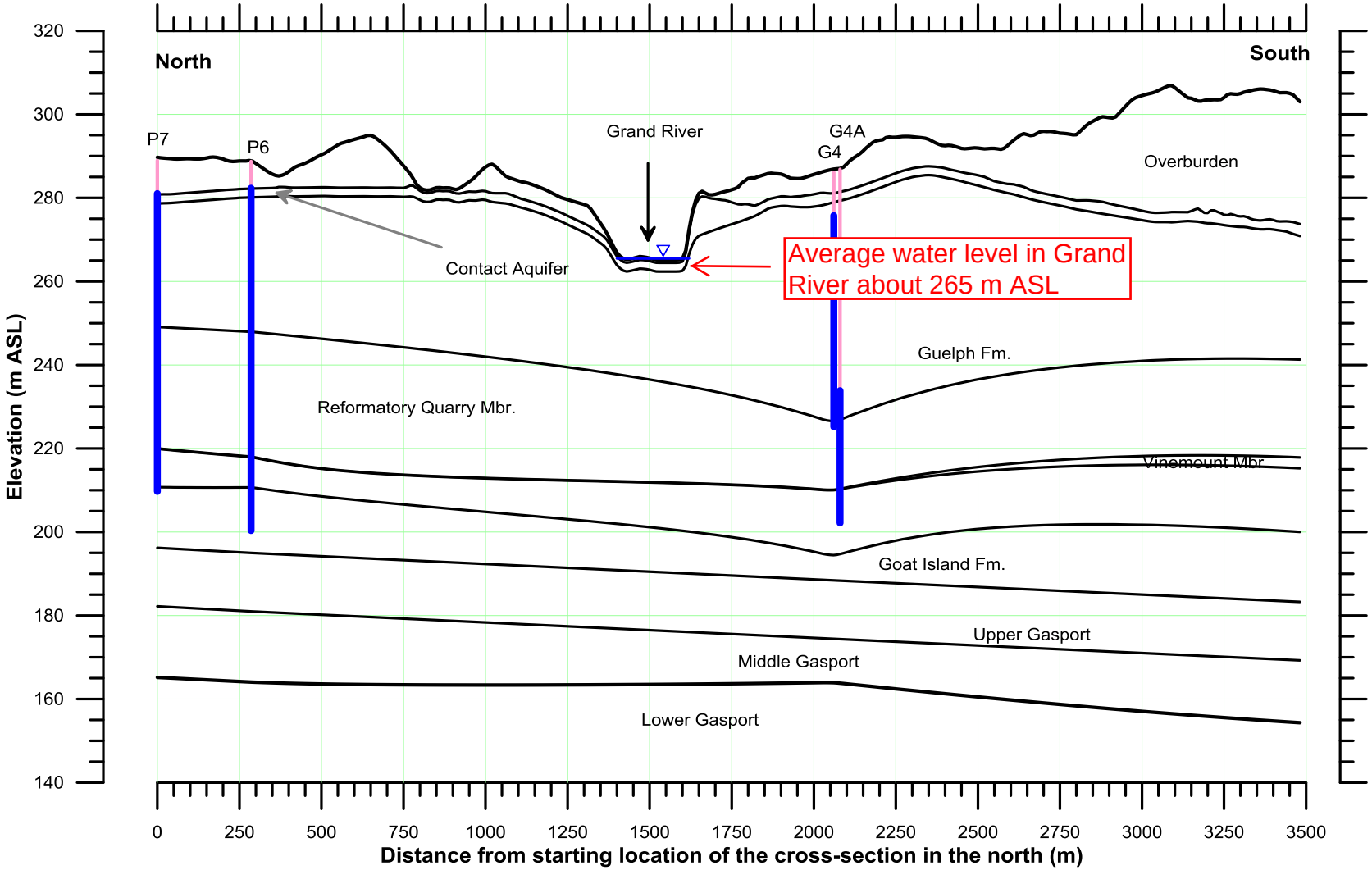


Figure 3 Cross-section through the Blair Road well field (II-II')

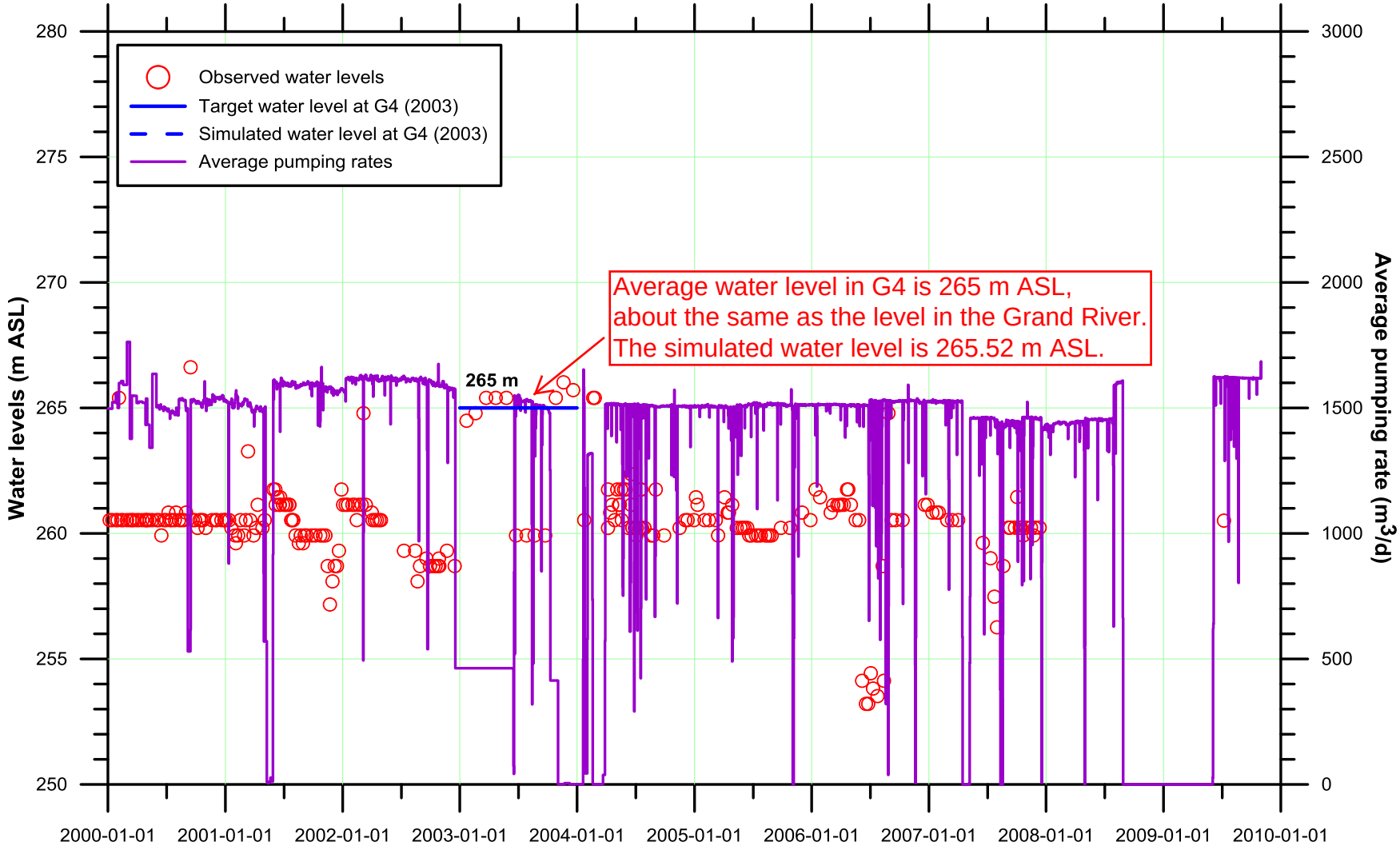


Figure 4 Observed water levels and pumping history at G4

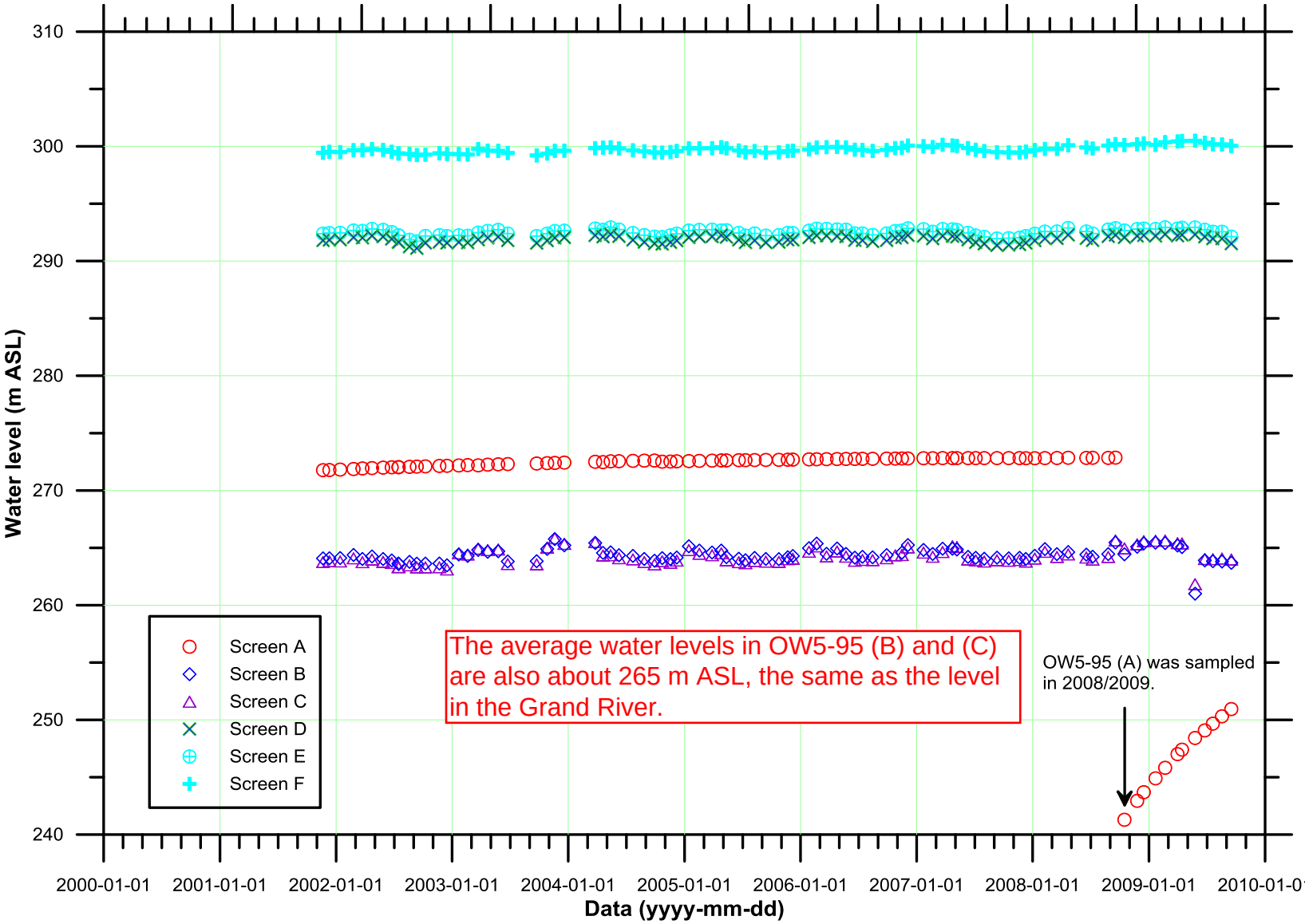


Figure 5 Observed water levels at OW5-95

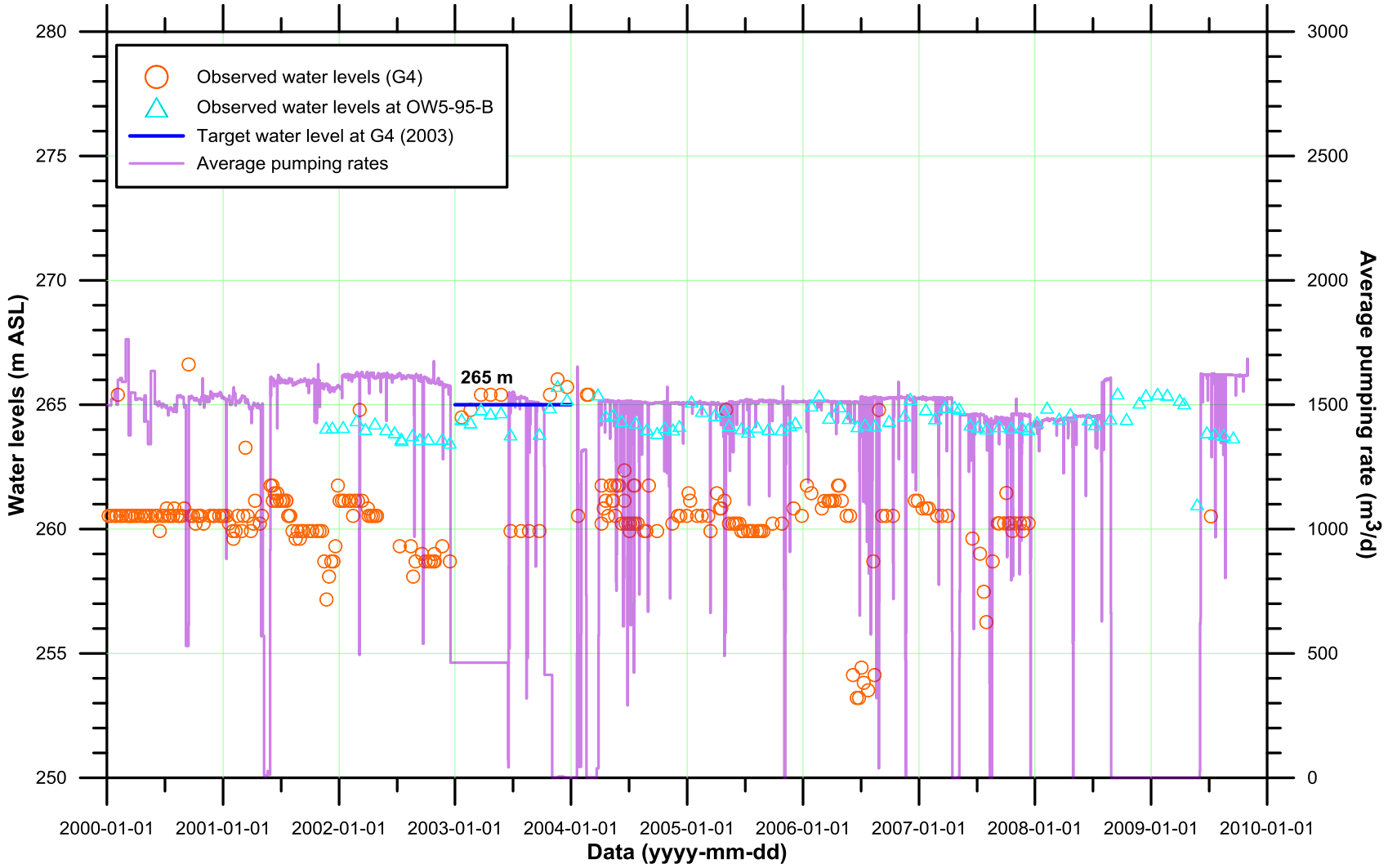


Figure 6 Comparison of water levels at G4 and OW5-95-B

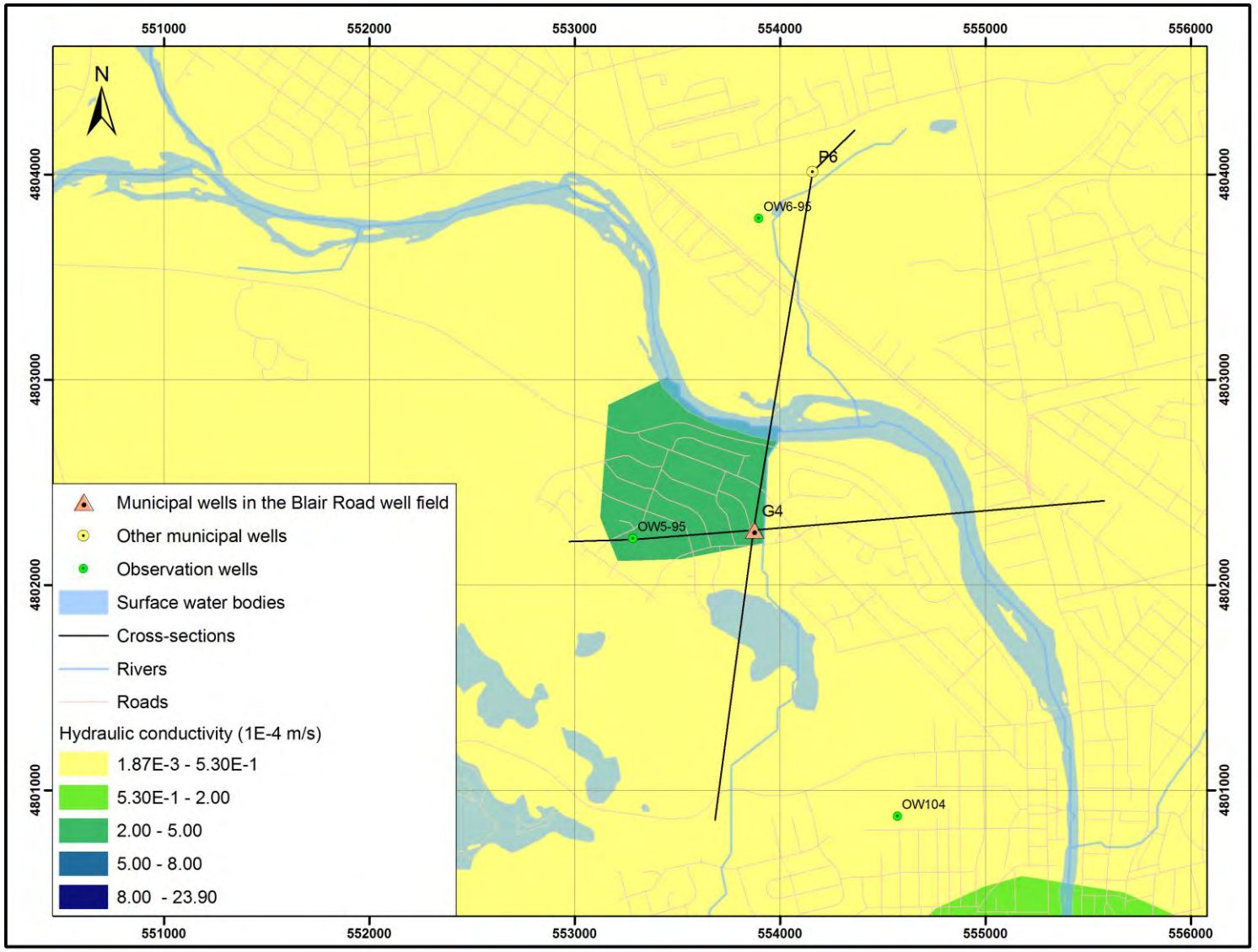


Figure 7 Tentative zonation of hydraulic conductivity in the Reformatory Quarry Member around G4

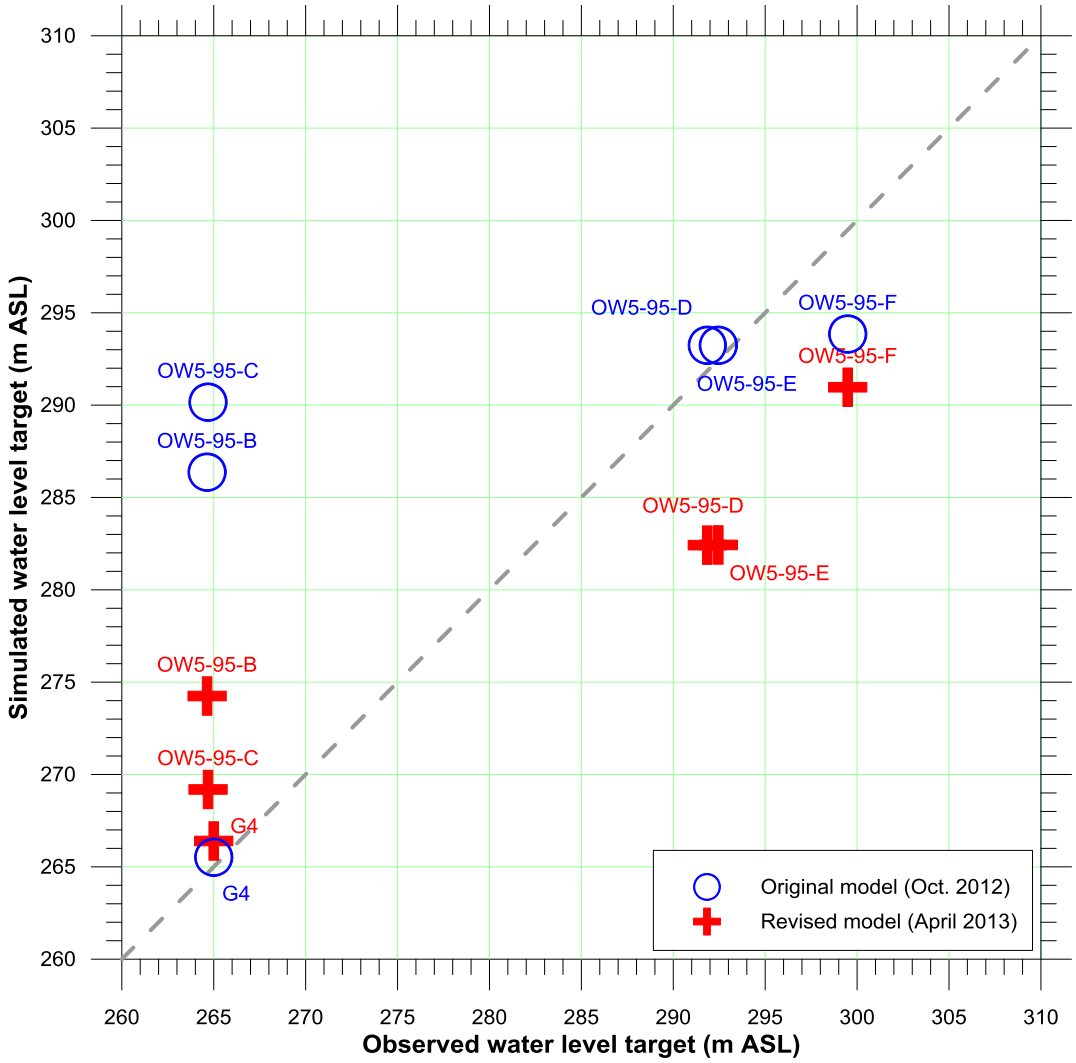


Figure 8 Comparison of simulated and observed water levels in the vicinity of the Blair Road Well Field

APPENDIX

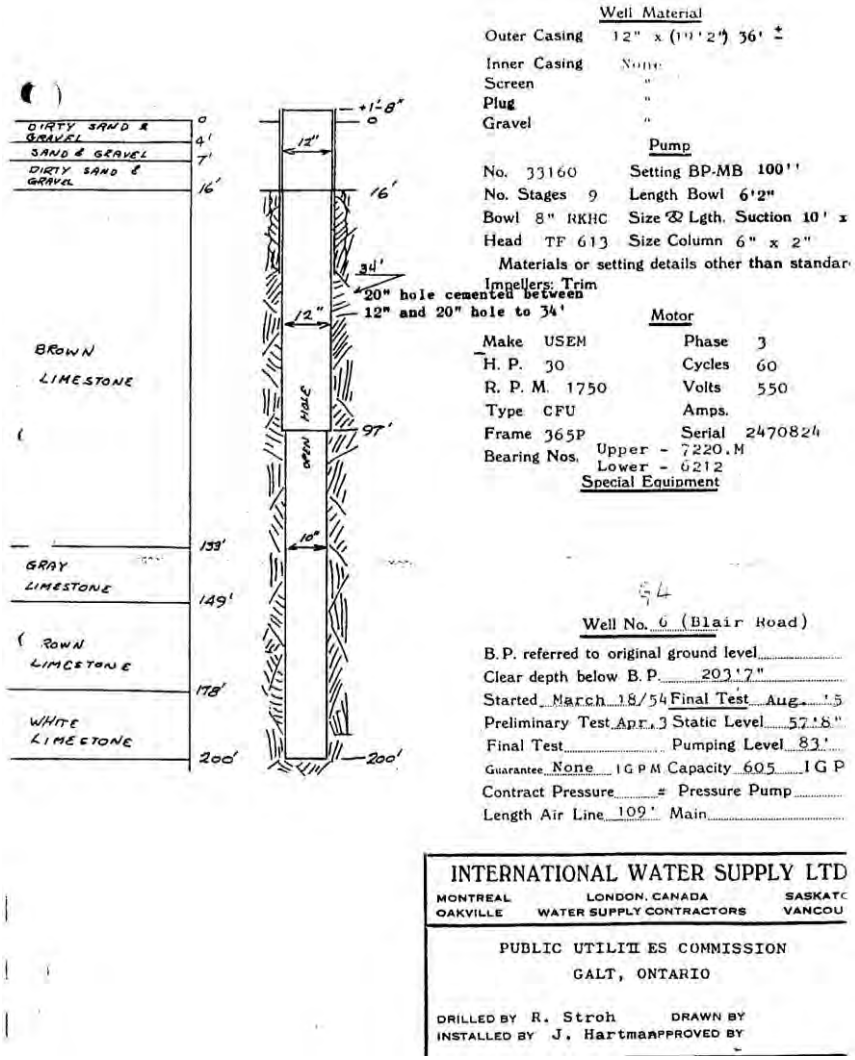
SSP1185: Region of Waterloo Tier 3

Transmissivity estimates at G4 and G4A

Christopher J. Neville
S.S. Papadopulos & Associates, Inc.
Last update: March 21, 2013

1. G4

The log for G4 is reproduced below. A transmissivity of **670 m^2/d** is estimated from the information on the log (the supporting calculations are reproduced after the log). IWS (1974) reported a transmissivity of 17,500 Igpd/ft. This is equivalent to **260 m^2/d**. The transmissivity estimated from the specific capacity is significantly higher than the value reported in IWS (1974).



Estimation of transmissivity of G4 from information in the well log

1. SPECIFIC CAPACITY (1954/03/18)

STATIC WL	57'8" (57.67 ft)	BMP
PUMPING WL	83'	BMP
CAPACITY	605	IGPM

$$SC = \frac{605\ IGPM}{83\ ft - 57.67\ ft} = 23.88\ IGPM/ft$$

$$= \frac{23.88\ IGPM}{ft} \left| \frac{3.281\ ft}{m} \right| \frac{m^3}{219.97\ IGAL} \left| \frac{1440\ min}{d} \right|$$

$$= 513\ m^3/d/m$$

2. FIRST-CUT TRANSMISSIVITY

$$T \sim 1.3\ SC$$

$$= 1.3\ (513\ m^3/d/m) = \underline{\underline{670\ m^2/d}} \longleftarrow$$

2. G4A pumping test (Burnside, 2010/05)

1. Cooper-Jacob time-drawdown analyses
   - G4A, G4-TW1-08 (B): 335 m^2/d
   - G4A, G4-TW1-08 (B): 335 m^2/d
   - OW5-95 (B): 600 m^2/d

2. Distance-drawdown analysis of stabilized drawdowns
   G4, G4-TW1-08 (B), OW5-95 (B, C, D), OW6-95 (A-H) [?]: 390 m^2/d

We have conducted additional analyses to assess conditions in the immediate vicinity of G4A.

The composite analysis with G4A and G4-TW1-08 (B) yielded a transmissivity of 330 m^2/d. This value is almost the same as the value estimated from the Cooper-Jacob analyses. The incorporation of OW5-95 (B) in the composite analysis is tenuous at best.

The results of the G4A step test have been analyzed to separate linear and nonlinear well losses. The Hantush-Bierschenk analysis is shown in Figure 1. A confirmatory plot of the pumping rate versus the pumping well drawdown is shown in Figure 2.

Transmissivity estimated from specific capacity (nonlinear well losses removed)

B = 0.177 m/L/s

$SC = 1/B$ = 5.650 L/s/m

$$T \sim 1.3\,SC = 1.3\left(5.650\frac{L}{s}/m\right)\left|\frac{m^3}{1000\,L}\right|\left|\frac{86400\,s}{d}\right| = \mathbf{635\ m^2/d}$$

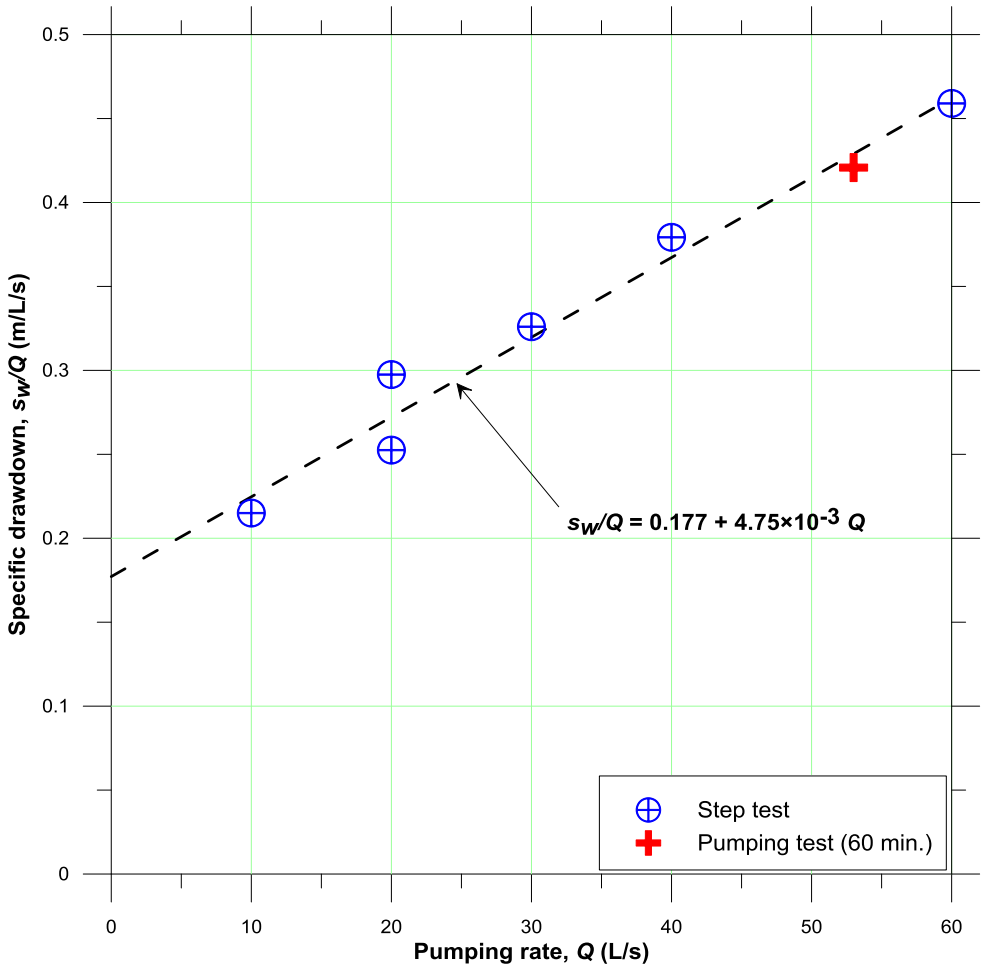


Figure 1. G4A step test - Hantush-Bierschenk analysis

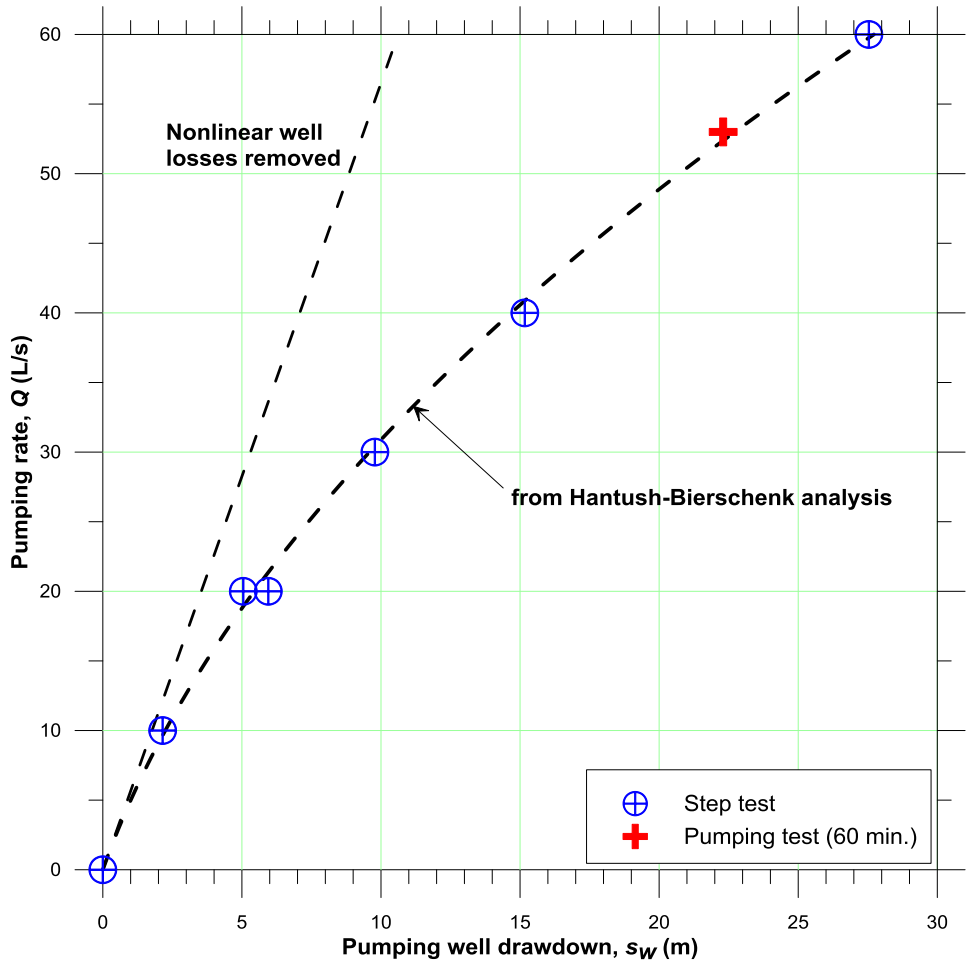


Figure 2. G4A step test – Check on the results of the Hantush-Bierschenk analysis

Additional analyses

The transmissivity estimated from the specific capacity with nonlinear well losses removed is significantly higher than the values estimated from the Cooper-Jacob analyses, and the distance-drawdown plot.

- The stabilized drawdown at G4A during the pumping test was about 24.48 m.
- The nonlinear well losses estimated for a pumping rate of 4,579 m^3/d (53 L/s) are 13.34 m:

$$\Delta s = 4.75 \times 10^{-3} \frac{\text{m}}{\left(\frac{\text{L}}{\text{s}}\right)^2} (53 \text{ L/s})^2 = 13.342 \text{ m}$$

- The linear well losses estimated by subtraction are 11.14 m.

  The specific capacity and transmissivity estimated for a pumping rate of 53 L/s and a drawdown of 11.14 m are:

$$SC = \frac{53 \text{ L/s}}{24.48 \text{ m} - 13.34 \text{ m}} = 4.76 \frac{\text{L}}{\text{s}}/\text{m}$$

$$T \sim 1.3\, SC = 1.3 \left(4.76 \frac{L}{s}/m\right) \left|\frac{m^3}{1000\, L}\right| \left|\frac{86400\, s}{d}\right| = 530 \text{ m}^2/\text{d}$$

- The distance-drawdown plot of the stabilized drawdowns suggests that the drawdown in the formation at G4A are about 18.0 m.

  The transmissivity estimated for a pumping rate of 53 L/s and a drawdown of 18.0 m is:

$$T \sim 1.3\, SC = 1.3 \left(\frac{53 \frac{L}{s}}{18.0\, m}\right) \left|\frac{m^3}{1000\, L}\right| \left|\frac{86400\, s}{d}\right| = 330 \text{ m}^2/\text{d}$$

  This value is consistent with the previous estimates.

Assessment

The stabilized drawdown in G4A with the nonlinear well losses removed, 11.14 m, is significantly smaller than the drawdown in the formation inferred from the distance-drawdown plot (18 m). This suggests that G4A is surrounded by a zone that has a transmissivity that is larger than the surrounding formation. This inference is consistent with the systematic differences between the transmissivity estimates obtained from the specific capacity of G4 and G4A and the high-reliability bulk-average values inferred from the G4A pumping test.

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

Memorandum

Date: March, 14, 2013

From: Jinhui Zhang and Christopher Neville

To: File

Project: SSP-1185

Subject: **Refinement of the Cambridge groundwater model in the vicinity of Shade's Mills wells G7 and G8**

1. Introduction

During the steady-state model calibration based on 2003-average conditions, the target water levels for the municipal pumping wells were assigned lower reliabilities compared with the targets derived from dedicated monitoring wells. In effect, reduced emphasis was directed towards achieving a close match to the water levels in the pumping wells. Richard Wootton of the Region of Waterloo has requested that an attempt be made to improve the match to the water levels at G7, as the difference of about 7 m between the simulated and average observed water level was considered to be too large. This memorandum describes additional analyses that have been conducted to achieve a better match at G7.

2. Geology and hydrogeology conditions in the vicinity of G7 and G8

Well G7 is one of four municipal wells at the Shade's Mill well field, along with G8, G38 and G39. The locations of the four municipal wells are shown in **Figure 1.** To help in visualizing the geology and hydrogeology of this area, a cross-section through the Shade's Mills well field has been developed (**Figure 2**). The location of the cross-section is indicated in **Figure 1**. The cross-section is based on the hydrostratigraphic model developed recently for the Cambridge area (SSPA, 2012). The hydrostratigraphic model forms the basis for the layers of the numerical model. Referring to the cross-section, G7 is open across both the Grand River Outwash material and the Contact Aquifer (the interface between the overburden and the weathered bedrock of Guelph Formation). Well G8 is screened in the Grand River Outwash materials.

The observed groundwater levels and the average pumping rates at G7 and G8 between 2000 and 2009 are plotted in **Figure 3** and **Figure 4**. As shown in the hydrographs, the representative average water levels for 2003 for G7 and G8 are estimated to be 278.5 m and 279.7 m, respectively. The simulated steady-state water levels at G7 and G8 calculated with the current calibrated model are 272.02 m and 280.58 m. The simulated steady-state water level at G7 is about 6.5 m lower than the target. The simulated water level for G8 is within 1 m of the target.

The simulated water levels at G38 and G39 match the 2003 targets relatively closely. The target water levels of G38 and G39 for the steady-state model calibration are 277.65 m and 264 m; the simulated steady-state water level at G38 and G39 are 277.27 m and 267.15 m, respectively.

3. Refinement of the model in the vicinity of wells G7 and G8

To constrain the adjustments of the hydraulic conductivities around G7 and G8, SSPA re-analyzed the historical step tests conducted at both G7 and G8. The re-analyses suggested that the transmissivities are about 2000 and 1000 m^2/day at G7 and G8, respectively. The analyses are documented in an appendix to this memorandum.

A review of the model suggests that the transmissivity of the aquifer at G7 and G8 is lower than the estimates derived from the re-interpretation of the step tests. The review suggested that there is some basis for adjusting the model parameters.

Revision #1

In an attempt to improve the match to the average water level at G7, the hydraulic conductivities of the model layers across which G7 is screened were adjusted. The first adjustments were made based on the existing distribution of properties in the model. For a first attempt, the hydraulic conductivities of the relevant zones in both the Grand River Outwash material (model layer 3) and Contact Aquifer (model layer 8) were increased. This yielded a better match for G7, but worse matches at the other three wells. This attempt resulted in an overall deterioration of the model because all four municipal wells at Shade's Mills are within the same hydraulic conductivity zone in the current model.

Revision #2

For the second attempt, the hydraulic conductivity zone in the Contact Aquifer that contains all four municipal wells was separated into two zones: a zone containing G38 and G39, and a zone containing G7 and G8. For the zone around G38 and G39, the existing hydraulic conductivity values were retained. For the zone containing G7 and G8, the hydraulic conductivities were increased. Increasing the hydraulic conductivity of the zone around G7 and G8 by a factor of 5 times yielded a relatively good match to the targets for all four wells. The results are tabulated below.

Well ID	2003 target WL (m ASL)	Simulated WL (m ASL)
G7	278.50	277.53
G8	279.70	279.19
G38	277.65	277.86
G39	264.00	267.53

The cumulative transmissivities that yielded improved matches at G7 and G8 are about 400 m^2/d and 130 m^2/d. These values were significant smaller than the estimates derived from the re-interpretations of the step tests, 2000 m^2/d and 1000 m^2/d.

Revision #3

The hydraulic conductivity zones around the area of G7 and G8 were refined further to achieve a closer consistency with the properties inferred from the independent analyses. The final hydraulic conductivity zones in the close vicinity of G7 and G8 for the Grand River Outwash and the Contact Aquifer are shown in **Figure 5** and **Figure 6**, respectively. The final cumulative transmissivities of the model at G7 and G8 are 1200 and 800 m^2/d, respectively. The final simulated and the target water levels at the Shade's Mills wells are tabulated below.

Well ID	2003 target WL (m ASL)	Revised simulated WL (m ASL)
G7	278.50	278.76
G8	279.70	281.45
G38	277.65	277.34
G39	264.00	267.27

The simulated water levels in the pumping wells have been adjusted to account for non-linear well losses. The interpretations of the step test data suggest that the non-linear losses are about 0.97 m and 0.47 m for 2003-average pumping rates of 25.4 L/s and 12 L/s at G7 and G8, respectively.

4. Summary

Relatively good matches were achieved for all four municipal wells. The differences between the target water levels and the simulation results at G7 and G8 are 0.3 m and 1.8 m. The values are similar to the magnitudes of the water level variations observed in 2003. Much larger variations are observed over the full duration of the records shown in **Figure 3** and **Figure 4**. The observed water level is likely sensitive to the instantaneous pumping rate at the time of the measurement. Monthly water level measurements are not sufficiently frequent to capture the effects of brief changes in pumping rates.

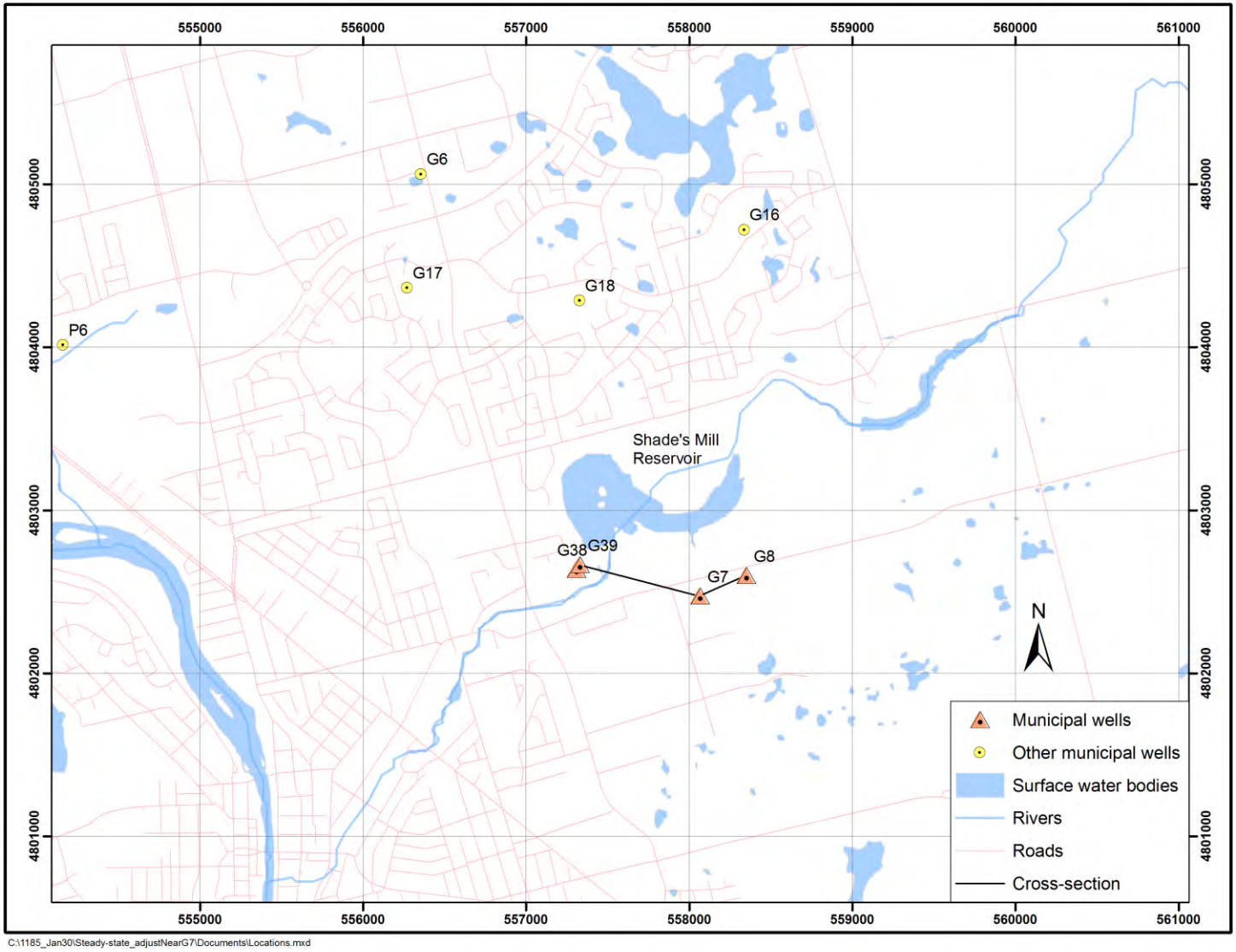


Figure 1 Shade's Mills well field

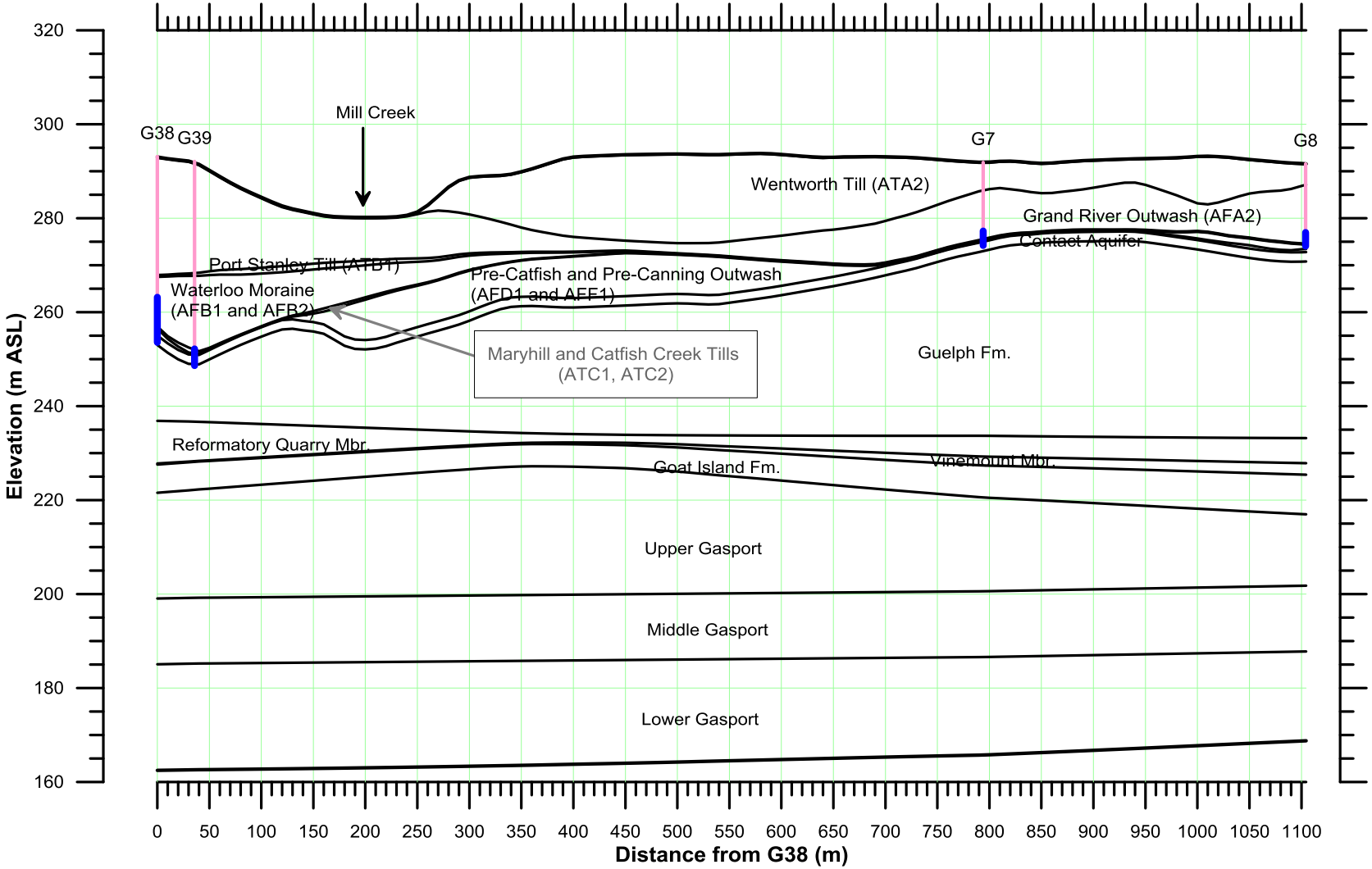


Figure 2 Cross-section through the Shade's Mill well field

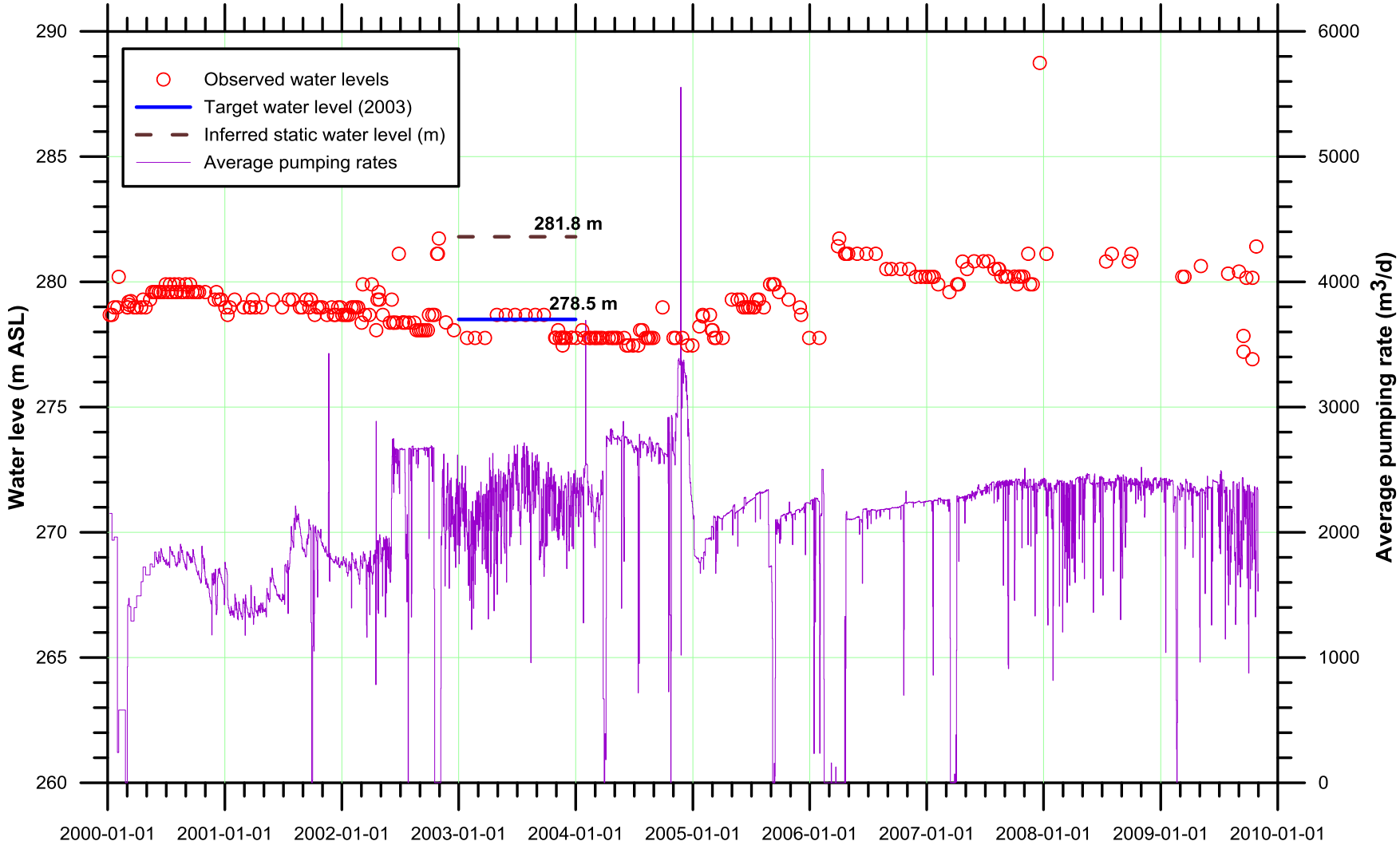


Figure 3 Observed water level and pumping history at G7

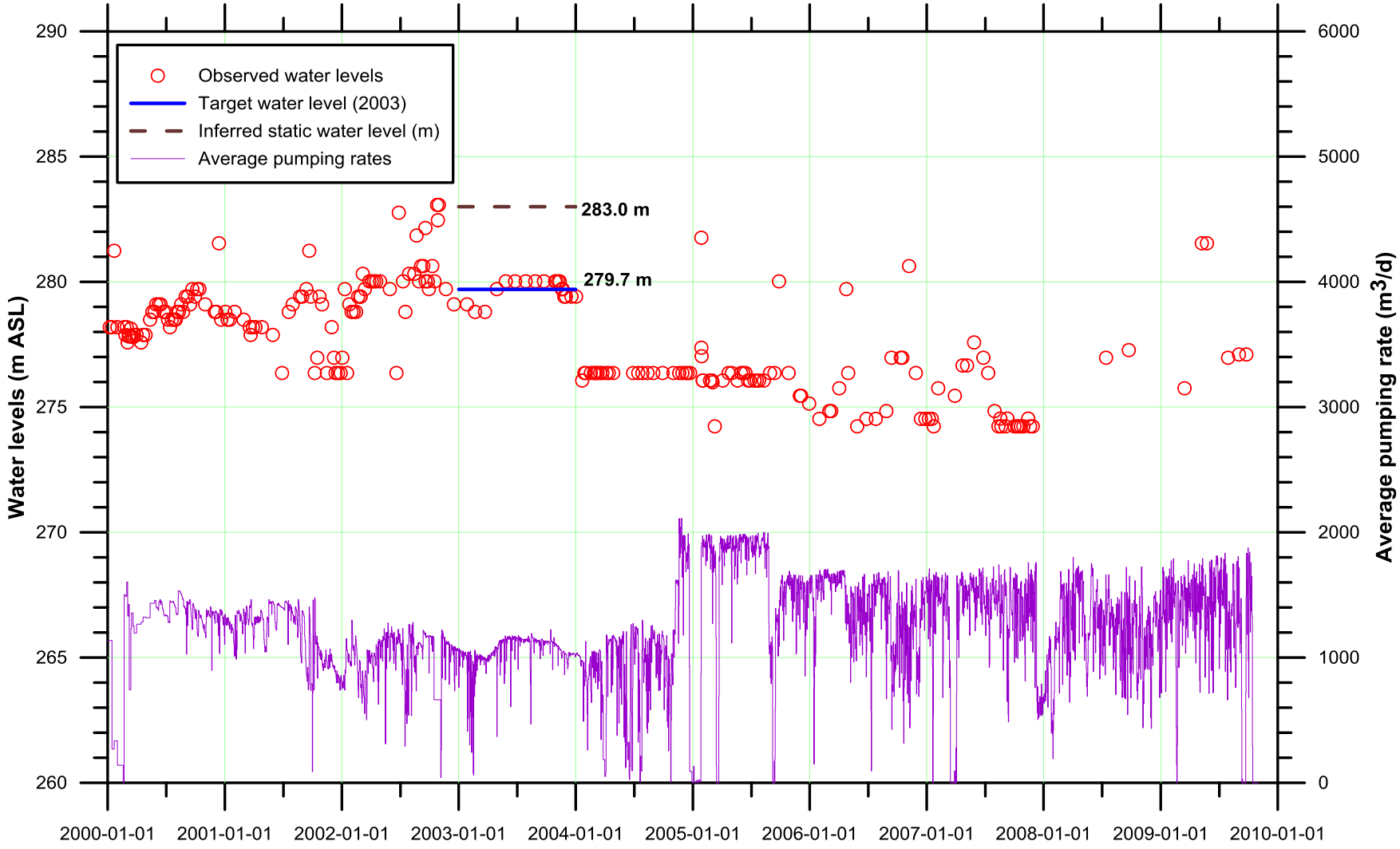


Figure 4 Observed water level and pumping history at G8

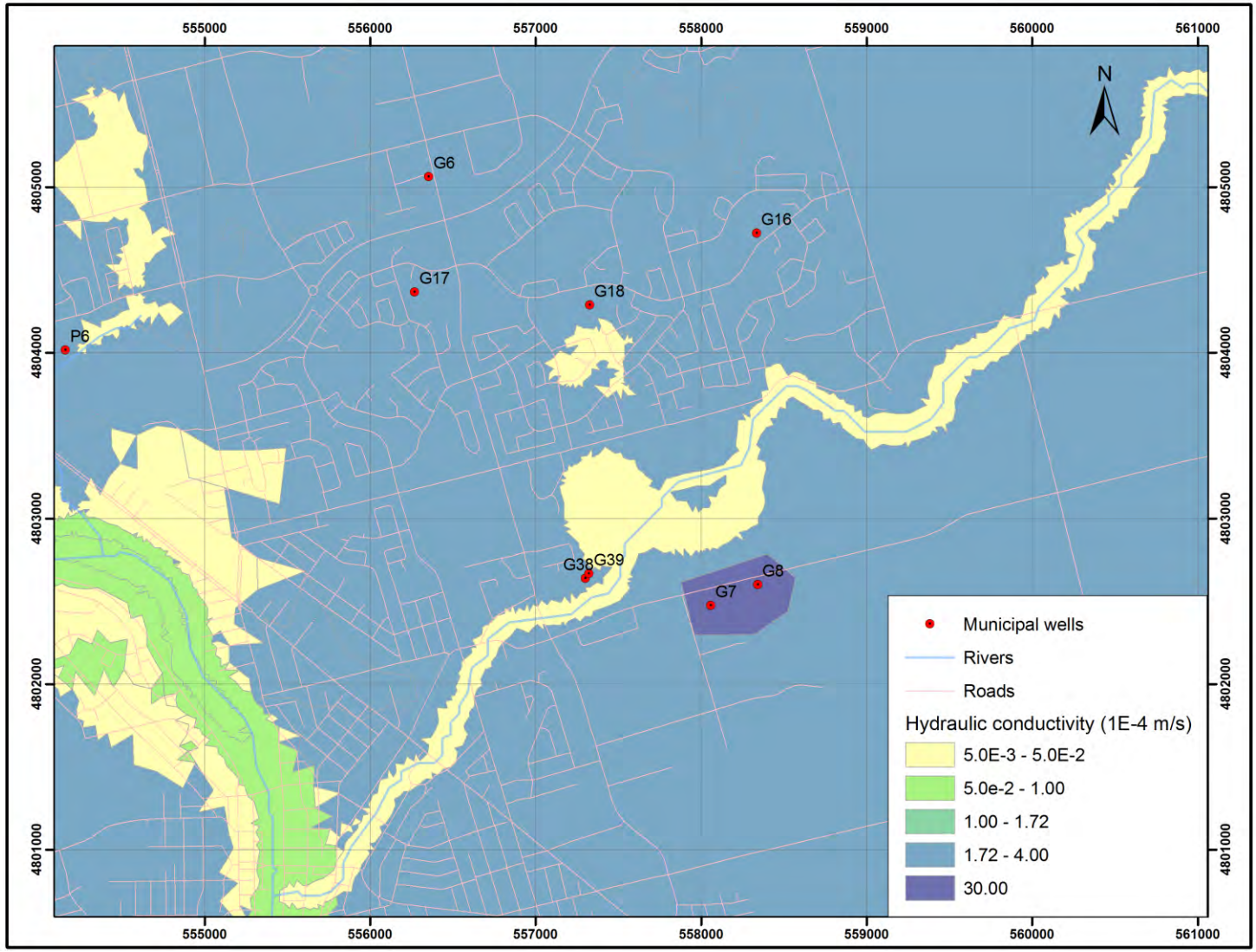


Figure 5 Final hydraulic conductivity distribution for the Grand River Outwash around the Shade's Mills well field

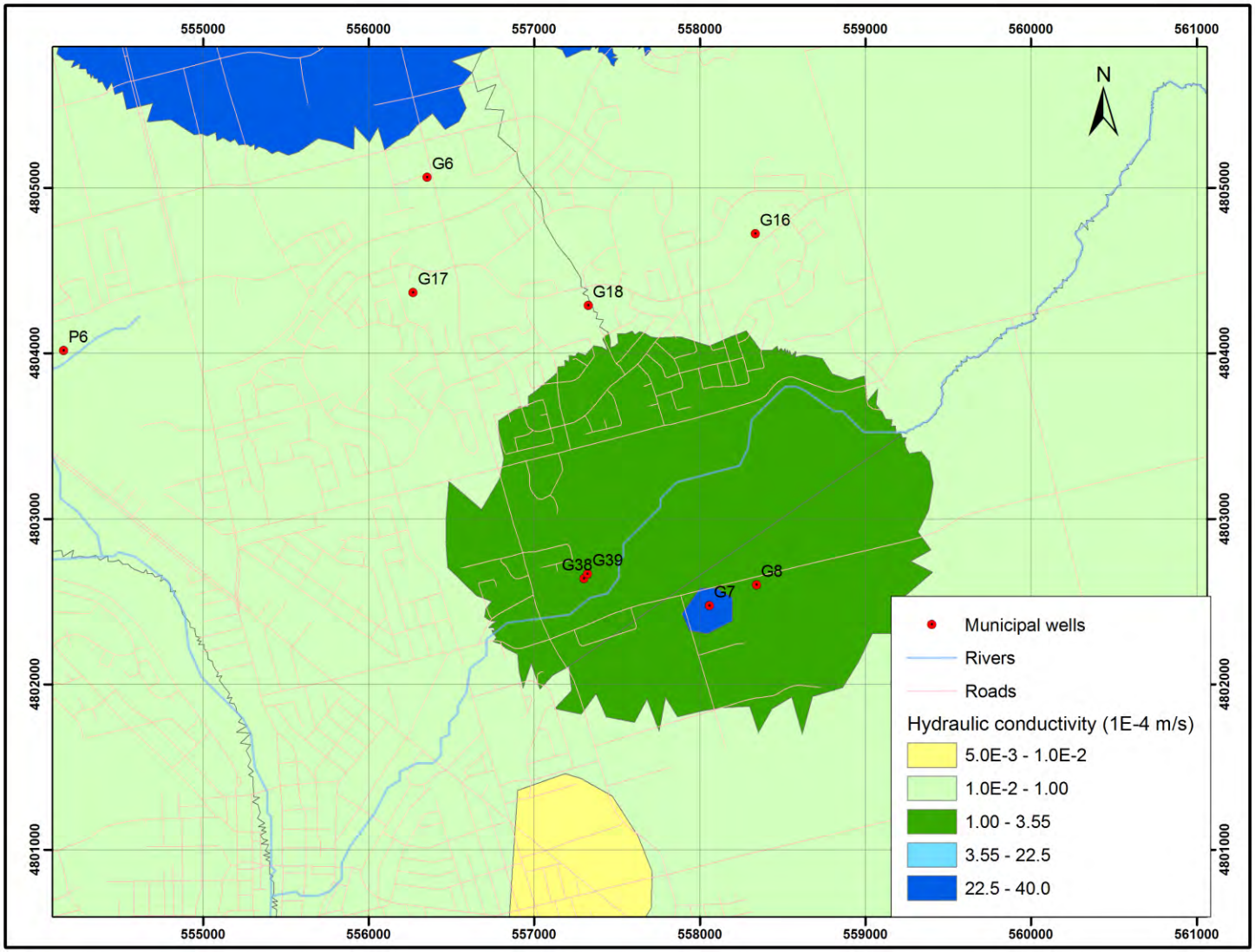


Figure 6 Final hydraulic conductivity distribution for the Contact Aquifer around the Shade's Mills well field

APPENDIX

Estimation of transmissivity at Cambridge wells G7 and G8

Christopher J. Neville and Xiaomin Wang
S.S. Papadopulos & Associates, Inc.
Last update: March 6, 2013

Overview

Two municipal wells G7 and G8 located close to the Shade's Mills Conservation Area in the City of Cambridge were constructed in 1958 and 1965, respectively. The locations of G7 and G8 along a cross-section through the Shade's Mills areas are shown in Figure 1. The wells are screened across sediments of the Grand River Outwash. Well G7 is likely open across the overburden/bedrock Contact Aquifer.

Well performance tests (step tests) have been conducted at G7 and G8 since they were constructed, prior to and after rehabilitation programs. This note has been prepared to summarize estimates of the transmissivity at wells G7 and G8 derived from the well performance tests, to guide the adjustment of aquifer properties in the vicinity of the wells.

The transmissivity estimates are developed for the step tests which we have judged to be representative of current "optimal" well performance. A simple first-cut method and a refined analysis are applied. The first-cut estimates are obtained from a calculation of the specific capacity with the nonlinear well losses removed following the Hantush-Bierschenk analysis (Hantush, 1964; Bierschenk, 1964). The refined analysis is designed to match a complete time history of drawdown using the expanded form of the Theis (1935) solution.

The results indicate that the transmissivity values estimated from the first-cut analysis and the refined analysis are internally consistent at wells G7 and G8 and the transmissivity estimate by IWS (1974) is within the range of these estimates. The ranges of the transmissivity estimates are:

- G7: 1,800 m^2/d to 2,400 m^2/d; and
- G8: 800 m^2/d to 1,500 m^2/d.

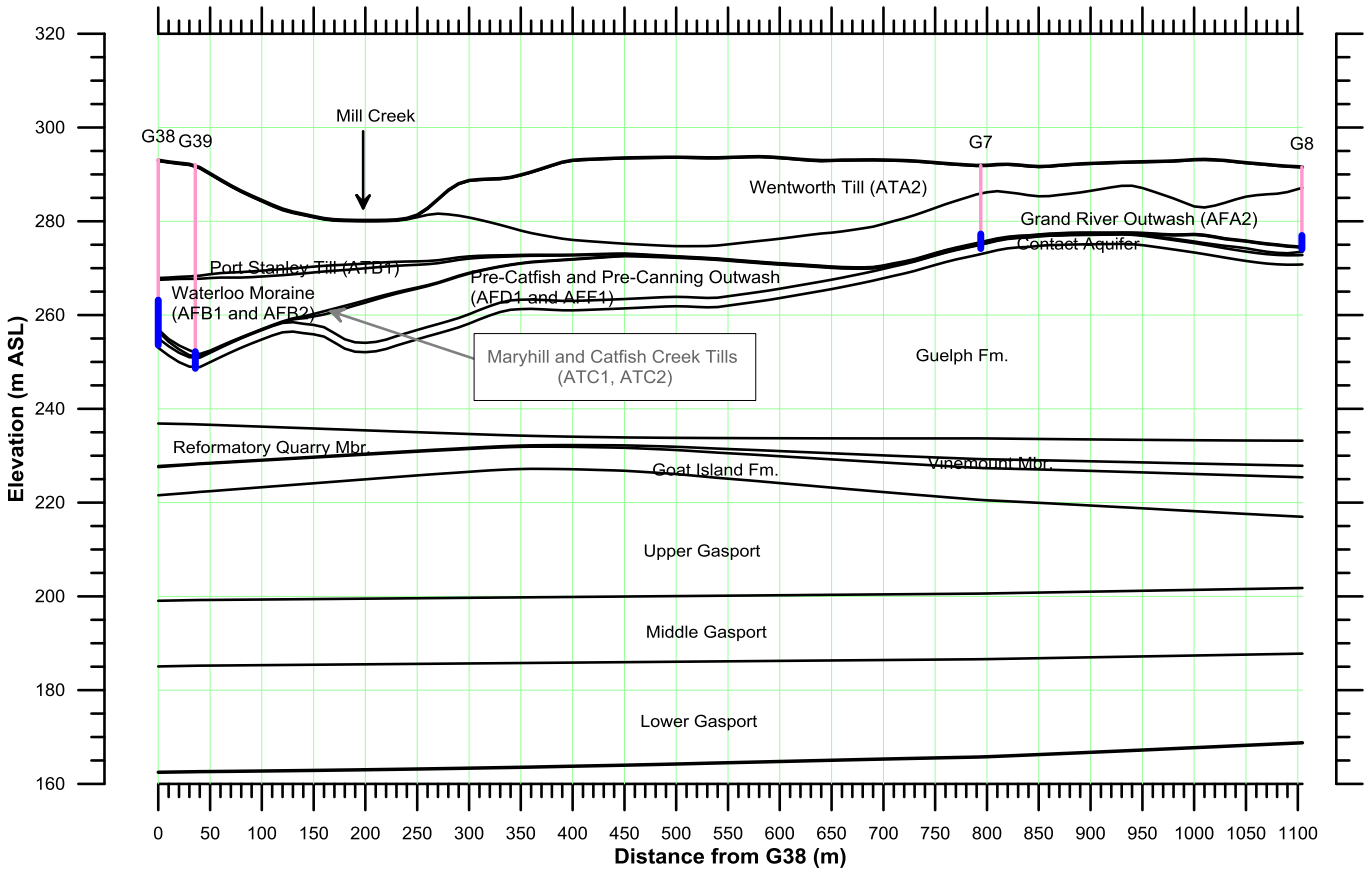


Figure 1. Cross-section through Shade's Mills well field

1. G7: First-cut estimate derived from specific capacity

A first-cut transmissivity at G7 is estimated from the results of well performance testing. The transmissivity is estimated from a calculation of the specific capacity with the nonlinear well losses removed. The first step in the analysis is therefore to separate the linear and nonlinear well losses. This is accomplished with the Hantush-Bierschenk analysis of step tests (Hantush, 1964; Bierschenk, 1964).

The results from eight tests are presented in International Water Supply Ltd. (2006; Dwg. No. L06034, on the right). The results from tests conducted in October 1991 and February 2006 are considered. The results for the 1991 and 2006 tests are similar and are considered because they appear to be representative of current optimal well performance. A time-drawdown record is also available for the 2006 test presented in International Water Supply Ltd. (2006; Dwg. No. L06034, on the left); these data will be used subsequently for a more refined analysis.

For the Hantush-Bierschenk analysis it is assumed that the drawdown at the end of each pumping step has stabilized and that the drawdown can be approximated by the Jacob (1947) model:

$$s_w = BQ + CQ^2 \quad (1)$$

Here s_w is the drawdown, Q is the pumping rate, B is the linear well loss coefficient and C is the nonlinear well loss coefficient. Dividing both sides yields:

$$\frac{s_w}{Q} = B + CQ \quad (2)$$

The results for the best-fit matches of Equation (2) to both the 1991 and 2006 step tests are plotted in Figure 2. As a check on the analyses, the pumping rates predicted with Equation (1) for a range of drawdowns are compared with the observations in Figure 3. The results match closely.

The estimated linear well loss coefficient from the 1991 and 2006 data is:

$B = 0.063$ m/L/s.

The specific capacities with the well losses removed are equal to the reciprocal values of B:

$$SC_{lin} = \frac{1}{B} \quad (3)$$

Following the approach of Theis and others (1963), Walton (1970) and Driscoll (1986), the transmissivity is estimated as:

$$T \sim 1.3 \times SC_{lin} \quad (4)$$

Therefore, for the 1991 and 2006 tests:

$$SC_{lin} = \frac{1}{B} = \frac{1}{0.063\ \mathrm{m}/(\frac{\mathrm{L}}{\mathrm{s}})} \left|\frac{\mathrm{m}^3}{1000\ \mathrm{L}}\right| \left|\frac{86400\ \mathrm{s}}{\mathrm{d}}\right| = 1371 \left(\frac{\mathrm{m}^3}{\mathrm{d}}\right)/\mathrm{m}$$

$$T \sim 1.3 \times SC_{lin} = \underline{\mathbf{1800\ m^2/d}}$$

The results shown in Figures 1 and 2 suggest that the well performance observed in 1991 and 2006 is different from that observed when the well was installed in 1958. In particular, the specific capacity declined from about 20 L/s/m to 15 L/s/m. It is unlikely that the transmissivity of the formation has declined in the vicinity of G7; it is more likely that there has been a long-term reduction in the capacity of the well screen.

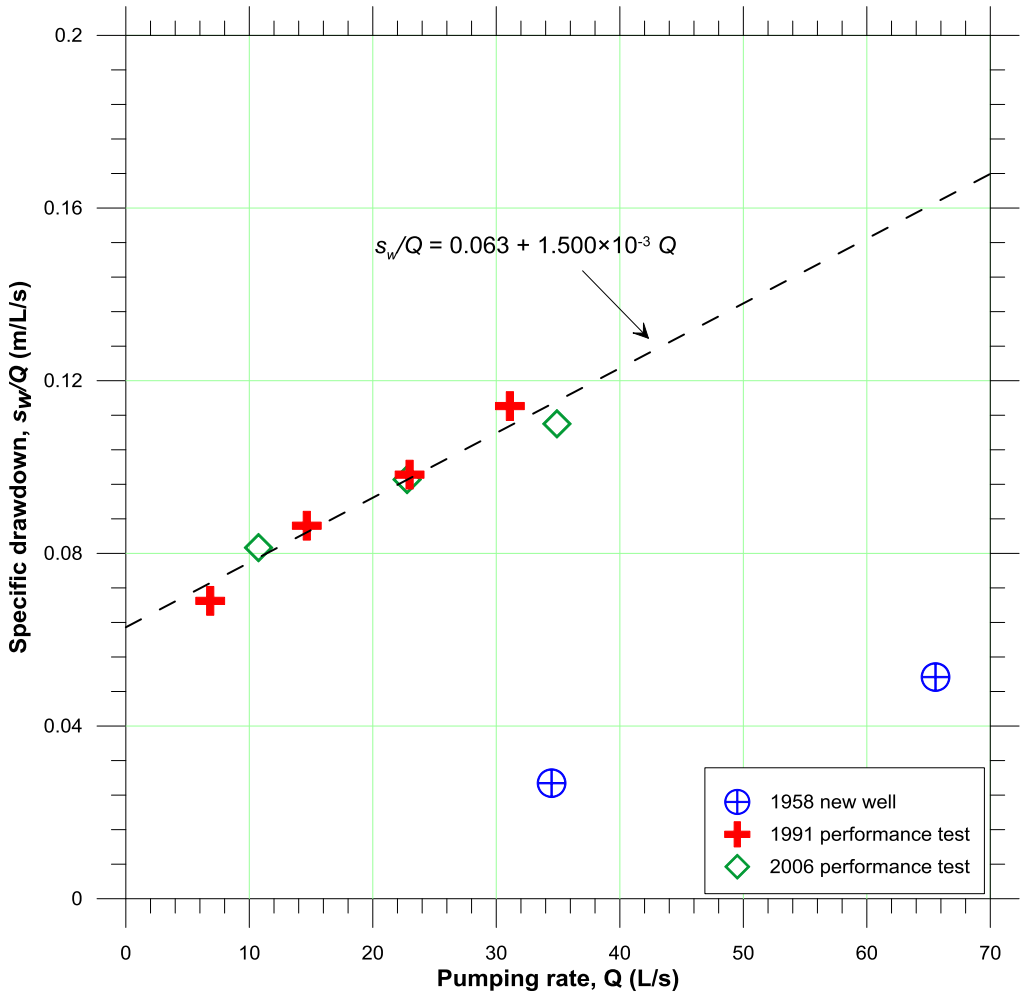


Figure 2. G7 selected step test results – Hantush-Bierschenk analyses

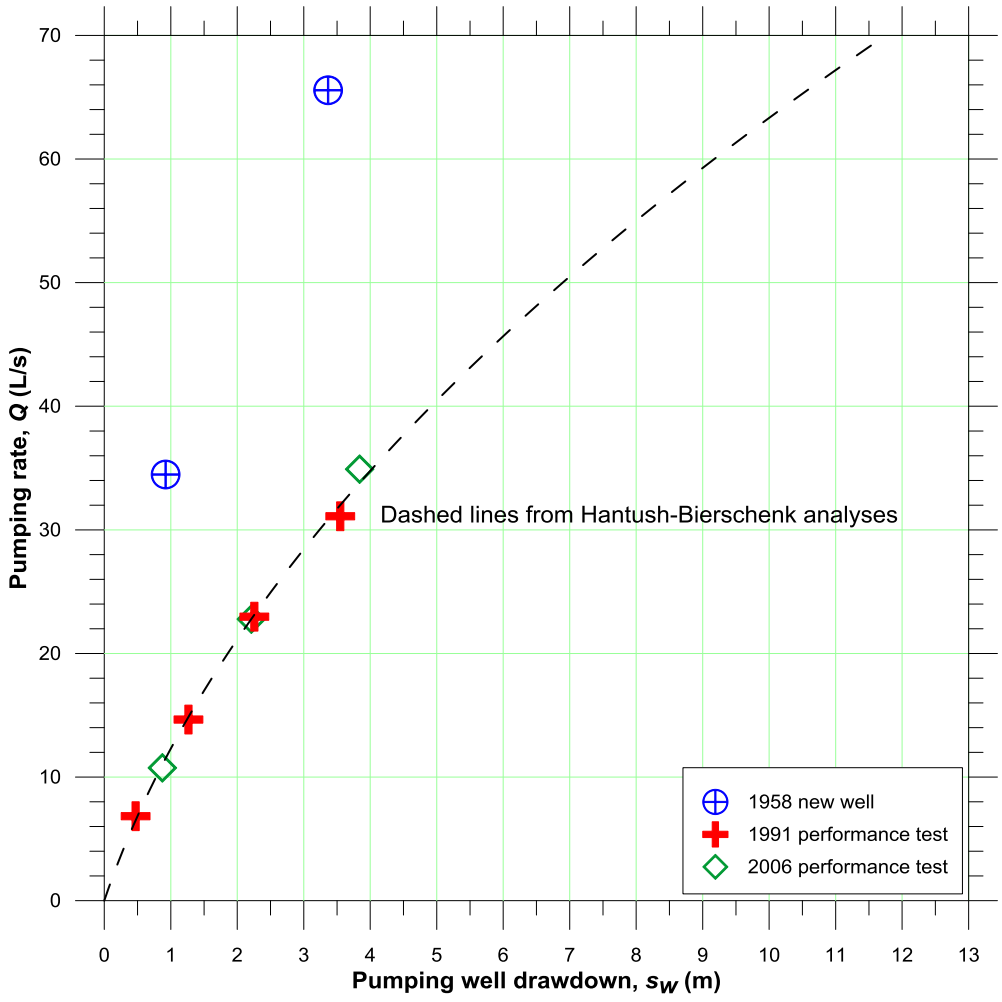


Figure 3. G7 selected step test results – Check on Hantush-Bierschenk analyses

2. G7: Refined analysis of 2006 step test

A complete time history of drawdown is available during the 2006/02 step test, which can be used to conduct a transient analysis using the expanded form of the Theis (1935) solution:

$$s_w(t) = \frac{1}{4\pi T}\sum_{i=1}^{NP(t)} \Delta Q_i \, W\left(\frac{r_w^2 S}{4T(t-t_{si})}\right) + \frac{Q}{4\pi T} 2S_w + CQ^P. \quad (5)$$

Here T is the transmissivity, S is the storage coefficient, r_w is the radius of the pumping well, Q is the pumping rate at time t, NP is the number of pumping steps that have occurred up to time t, ΔQ_i is the increment of pumping during the i^{th} pumping step, t_{si} the starting time for the i^{th} step, S_w is the skin loss coefficient, C is the nonlinear well loss coefficient and P is the well loss exponent.

The analysis is conducted using the aquifer test analysis package AQTESOLV to assist with fitting the full transient solution based on the non-linear least-squares method.

This transient analysis considers a fully penetrating pumping well in a confined aquifer. Recognizing that some of the parameters are correlated and have relatively limited influence on the estimation of the transmissivity, to limit the number of fitting parameters the storage coefficient is fixed at a typical value for the aquifer, $S = 10^{-5}$ and the well loss exponent is set at $P = 2$. The presence of a skin zone is not considered in the analysis, $S_w = 0$. The well loss coefficient is fixed based on the results of the Hantush-Bierschenk analysis. The transmissivity estimated from a best-fit match is **$T = 2400$ m^2/d**. The transmissivity is similar to the first-cut estimated developed from the specific capacity (1800 m^2/d).

The results of the match of Equation (5) to the complete set of observations from the 2006 step tests are plotted in Figure 4. The theoretical solution matches the observations during the first two steps relatively closely. The theoretical solution does not match the trend of the drawdowns for the final step. The relatively poor match during the last step may reflect the fact that the high rate of pumping 34.2 L/s causes the water level in the pumping to approach the top of the well screen.

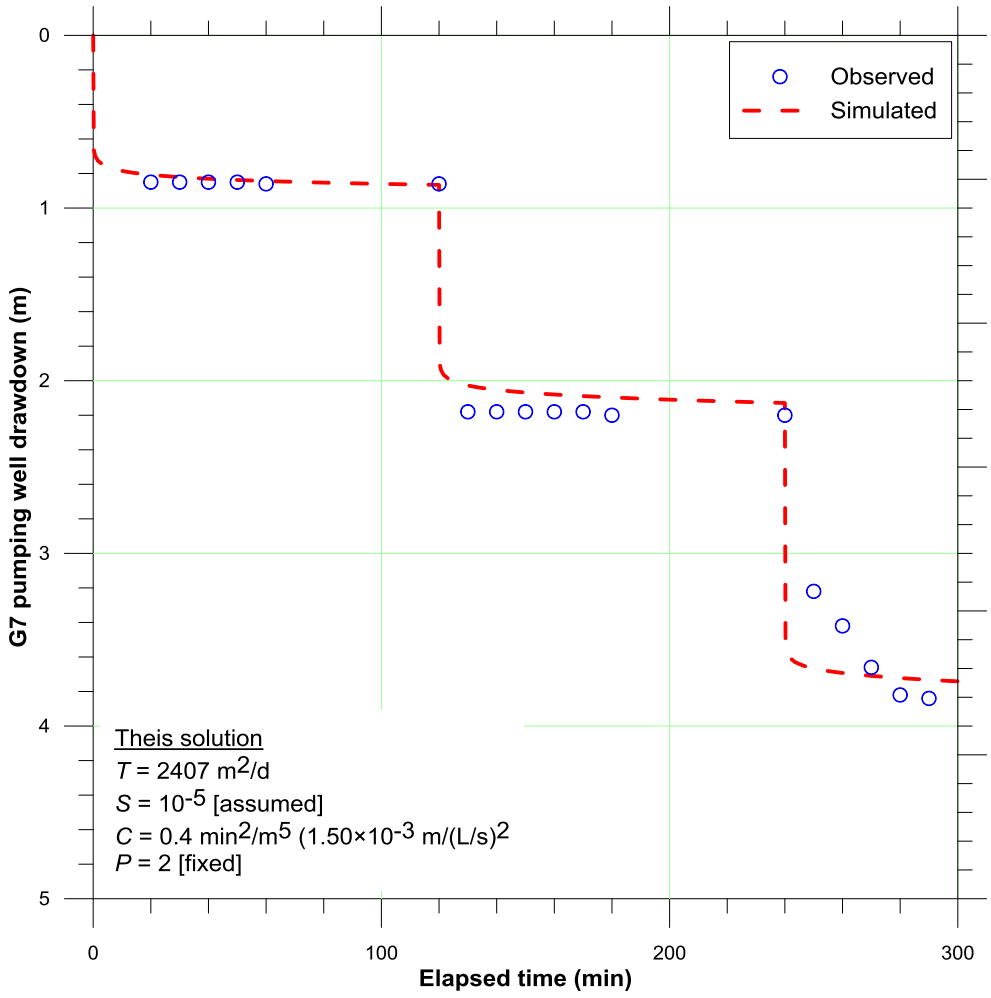


Figure 4. G7 2006/02 step test – Refined analysis with extended Theis solution

3. G8: First-cut estimate derived from specific capacity

A first-cut transmissivity at G8 is estimated from the results of well performance testing. The results from seven tests are presented in Lotowater (2009; Figure 1). The results from tests conducted in May 1983 and October 2009 are considered. The results from the 1983 step test are selected because the well performance appears to be similar to newly constructed well in June 1966. The results from the 2009 test are considered because they appear to be representative of current optimal well performance. A complete time-drawdown record is also available for the 2009 test; these data will be used subsequently for a more refined analysis.

The results for the Hantush-Bierschenk analysis are shown in Figure 5. As a check on the analyses, the pumping rates predicted with Equation (1) for a range of drawdowns are compared with the observations in Figure 6. The results match closely.

The estimated linear well loss coefficients are:

1983: B = 0.134 m/L/s; and
2009: B = 0.082 m/L/s

For the 1983 step test:

$$SC_{lin} = \frac{1}{B} = \frac{1}{0.134\ \mathrm{m}/(\frac{\mathrm{L}}{\mathrm{s}})}\left|\frac{\mathrm{m}^3}{1000\ \mathrm{L}}\right|\left|\frac{86400\ \mathrm{s}}{\mathrm{d}}\right| = 640\left(\frac{\mathrm{m}^3}{\mathrm{d}}\right)/\mathrm{m}$$

$$T \sim 1.3 \times SC_{lin} = \mathbf{800\ m^2/d}$$

For the 2009 step test:

$$SC_{lin} = \frac{1}{B} = \frac{1}{0.082\ \mathrm{m}/(\frac{\mathrm{L}}{\mathrm{s}})}\left|\frac{m^3}{1000\ L}\right|\left|\frac{86400\ s}{d}\right| = 1050\left(\frac{\mathrm{m}^3}{\mathrm{d}}\right)/\mathrm{m}$$

$$T \sim 1.3 \times SC_{lin} = \mathbf{1400\ m^2/d}$$

The range of the values of the transmissivity is relatively narrow considering these are first-cut estimates.

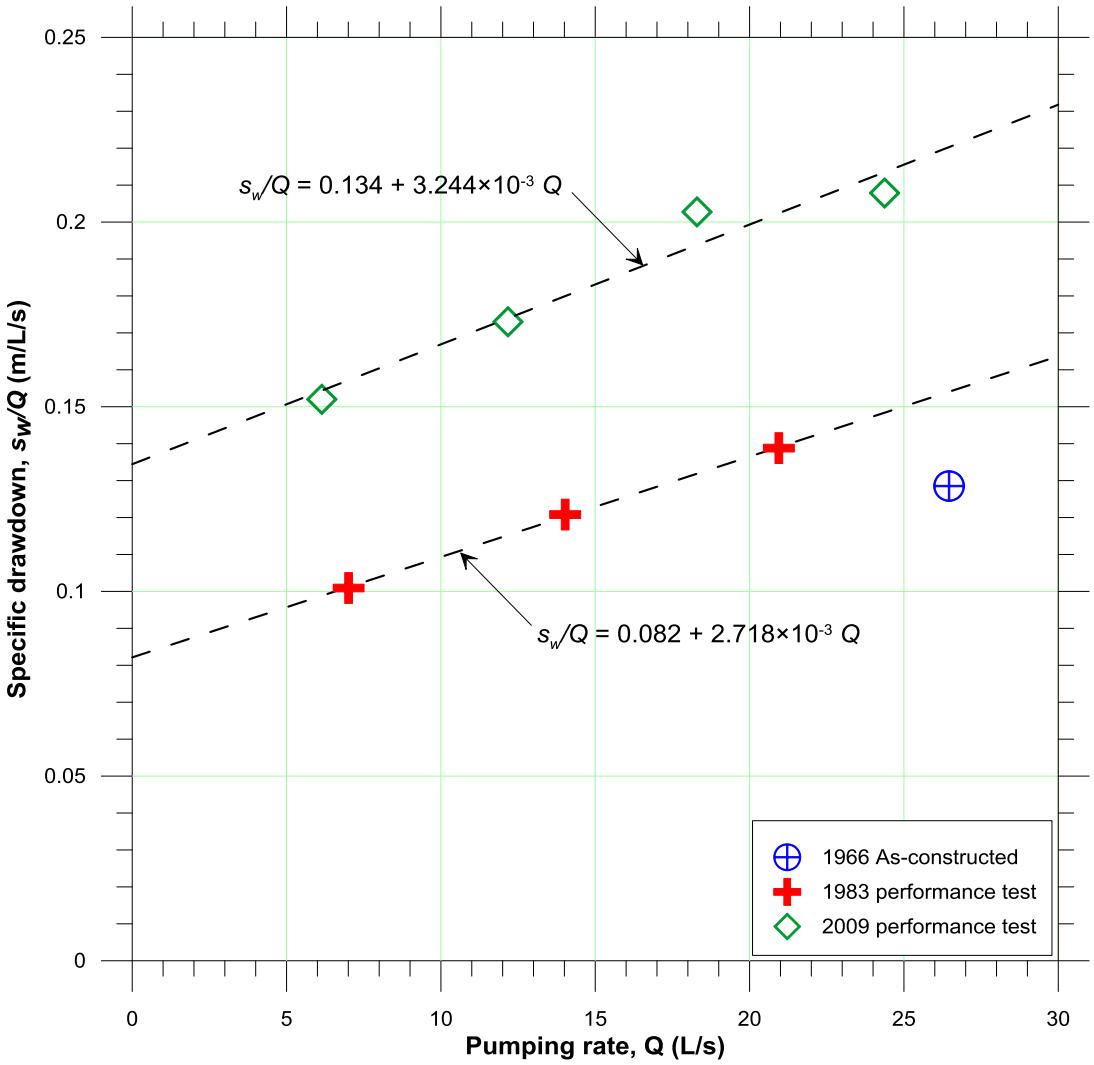


Figure 5. G8 selected step test results – Hantush-Bierschenk analyses

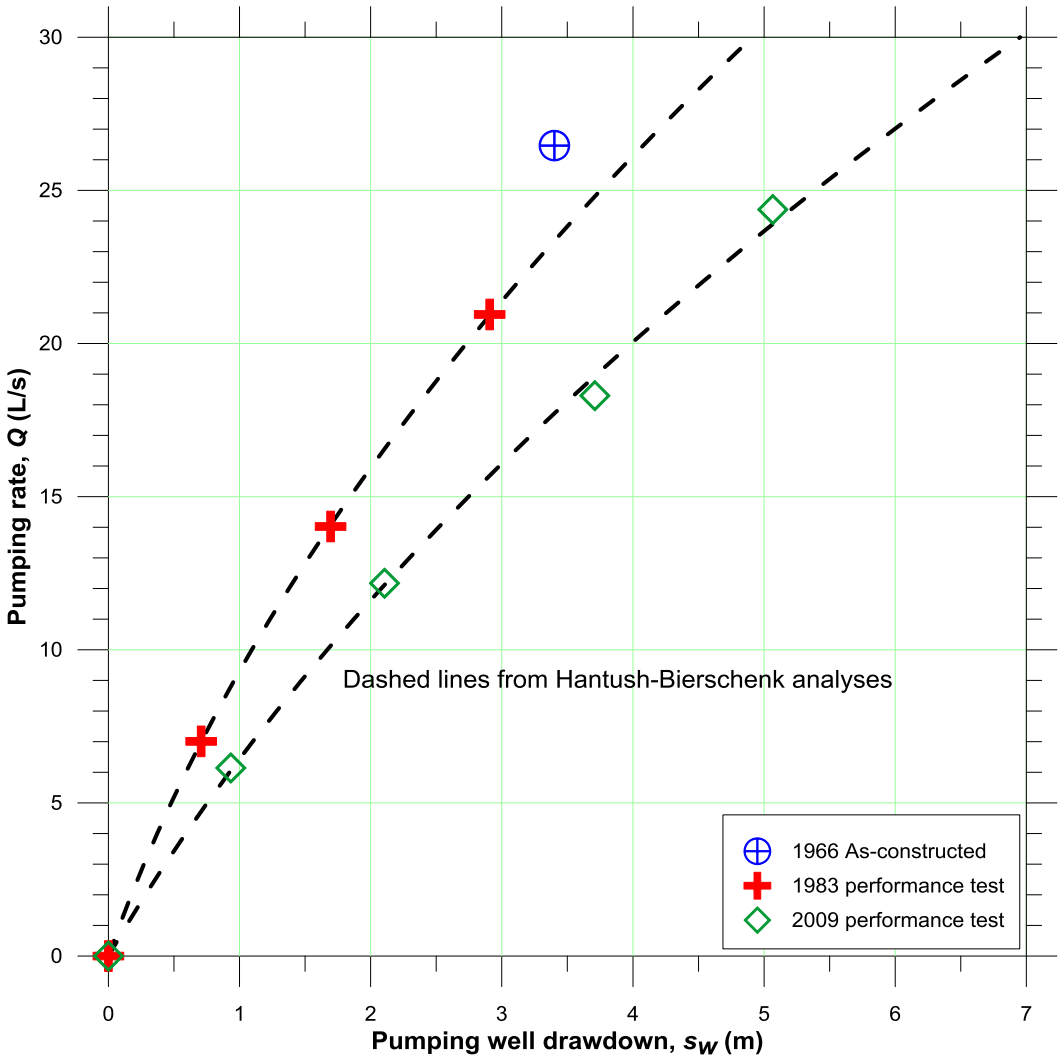


Figure 6. G8 selected step test results – Check on Hantush-Bierschenk analyses

4. G8: Refined analysis of 2009 step test

A complete time history of drawdown is available during the 2009/10 step test. Using the same approach that was used to interpret the results of the 2006 step test at G7, a transmissivity of **980 m^2/d** is estimated.

The results for the best fit of Equation (5) to the 2009 step tests are plotted in Figure 7. The theoretical solution reproduces the general trends of the observations. The observed drawdowns appear to stabilize almost immediately after the start of each pumping step. This suggests that either the formation has negligible storage or that there is additional process that causes water levels in the pumping well to stabilize.

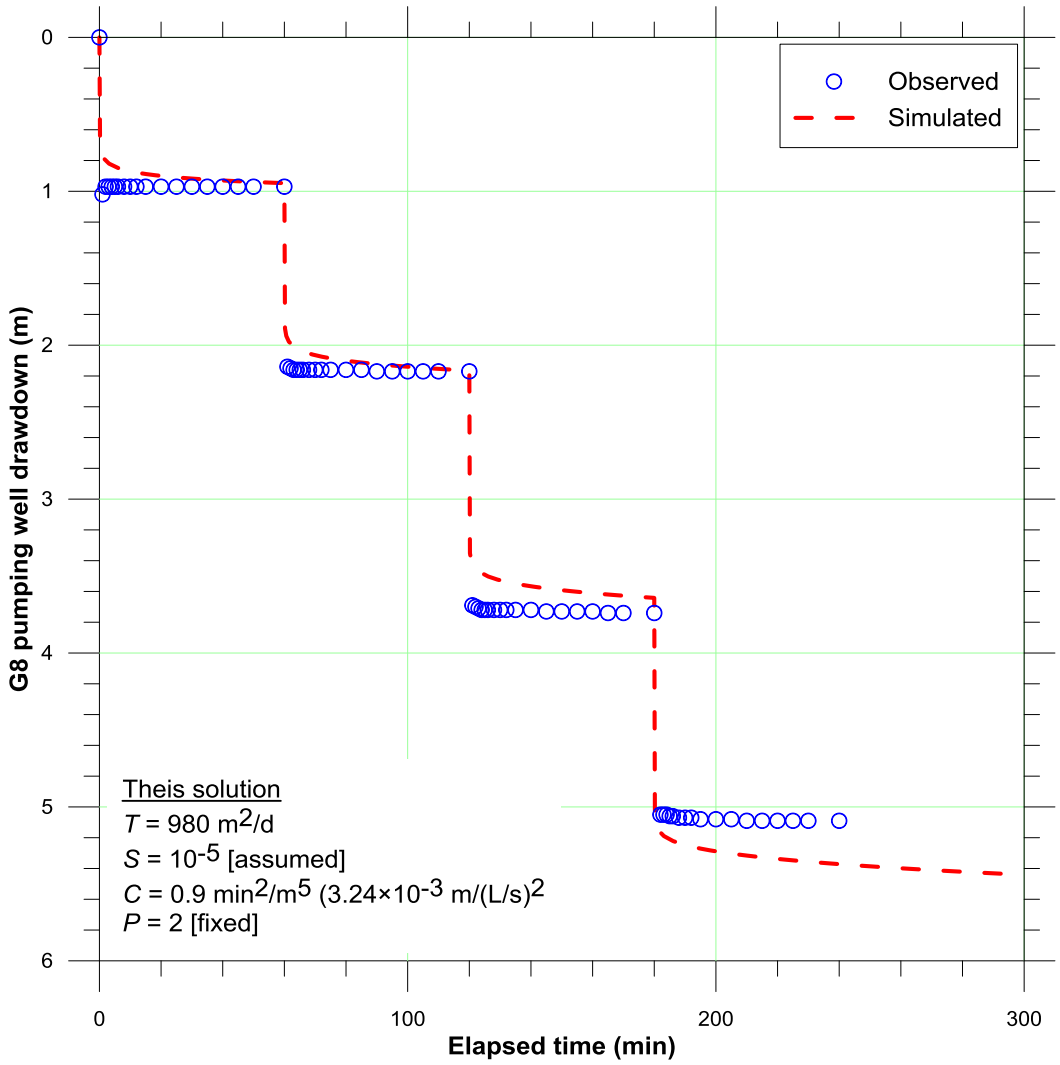


Figure 7. G8 2009/10 step test – Refined analysis with extended Theis solution

5. Evaluation of the interpretations

The first-cut transmissivity estimated at G7 is 1800 m^2/d. The refined estimate derived from an interpretation of a complete analysis of the 2006 step test is 2400 m^2/d. There values are internally consistent.

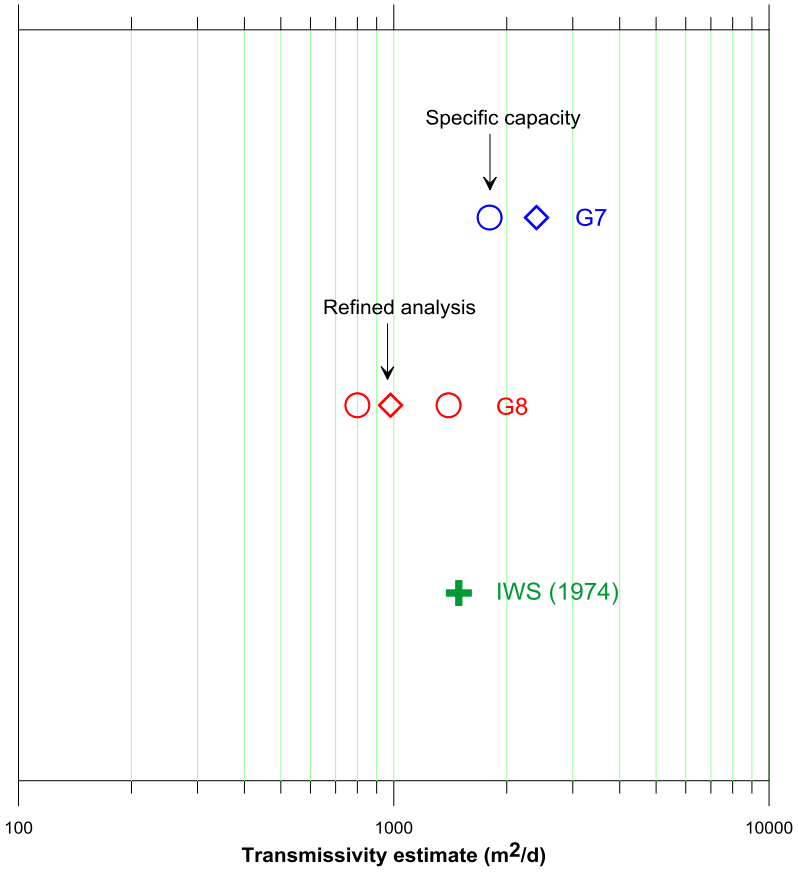
The first-cut transmissivities estimated at G8 range from 800 to 1400 m^2/d. The refined estimate derived from an interpretation of a complete analysis of the 2009 step test is 980 m^2/d. There values are also internally consistent.

IWS (1974) presented a transmissivity estimate of 100,000 Igpd/ft for the overburden at G7 and G8. This estimate is converted as:

$$T = 100{,}000 \frac{\text{Igpd}}{\text{ft}} \left| \frac{\text{m}^3}{219.97\ \text{Igal}} \right| \left| \frac{3.281\ \text{ft}}{\text{m}} \right| = \underline{\mathbf{1490\ m^2/d}}$$

This value is within the range of the estimates developed here.

Wells G7 and G8 are screened across the lowermost portion of the sediments of the Grand River Outwash (AFA2) and the Contact Aquifer. The well screens extend across only a small fraction of the Grand River Outwash and it is therefore inappropriate to assume the inferred properties are representative of the full thickness of these sediments.



6. References

Bierschenk, W.H., 1964: Determining well efficiency by multiple step-drawdown tests, International Association of Scientific Hydrology, Publication No. 54 (General Assembly of Berkeley, Commission of Subterranean Waters), pp. 493-507.

Driscoll, F.G., 1986: **Groundwater and Wells**, 2nd edition, Johnson Division, Dt. Paul, Minnesota.

Hantush, M.S., 1964: Hydraulics of wells, *Advances in Hydroscience*, vol. 1, pp. 281-433.

International Water Supply Ltd., 2006: Regional Municipality of Waterloo G7 well and pump maintenance program.

Jacob, C.E., 1947: Drawdown test to determine effective radius of artesian well, *Transactions, American Society of Civil Engineers*, vol. 112, paper 2321, pp. 1047-1064.

Lotowater, Technical Services Inc., 2009: Well G8 - well inspection, RMOW contract P2008-01, prepared for Region Municipality of Waterloo.

Theis, C.V, 1935: The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage, *Transactions of the American Geophysical Union*, 16th Annual Meeting, Part 2, pp. 519-524.

Theis, C.V., R.H. Brown, and R.R. Meyer, 1963: Estimating the transmissibility of aquifers from the specific capacity of wells, in *Methods of Determining Permeability, Transmissivity, and Drawdown*, R. Bentall (ed.), Water Supply Paper 1563-I, United States Geological Survey Washington, DC.

Walton, W.C., 1970: **Groundwater Resource Evaluation,** McGraw-Hill Book Company, New York, New York.

Matrix Solutions Inc.
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MEMORANDUM

TO: Region of Waterloo Tier Three Peer Review Committee
(Dave Rudolph, Hugh Whiteley and Tony Lotimer)

FROM: Matrix Solutions Inc.

RE: Comparison and Integration of the Region of Waterloo Cambridge Model and City of Guelph Tier Three Assessment Model

DATE: August 13, 2014

1 INTRODUCTION

Several peer review comments on the Region of Waterloo Tier Three Water Budget and Local Area Risk Assessment (Tier Three Assessment) reports and memos requested additional information regarding the integration between the groundwater flow models developed for the City of Guelph and Region of Waterloo Tier Three Assessments. This memo was prepared in response to those comments and highlights the similarities and consistency between the numeric modelling tools.

For the Region, two FEFLOW groundwater flow models were developed; the Regional Model focuses on the Waterloo Moraine overburden system and includes the entire Region of Waterloo, whereas the Cambridge Model focuses on the bedrock groundwater flow system in Cambridge and extends northeast toward the City of Guelph. These two models have consistent layer structures, boundary conditions, and parameter values. Developing separate models for these two areas allowed each model to focus on different flow systems specific to each area, and allowed the Tier Three Assessment to progress in two areas in parallel. The two models are presented in detail in Section 4 of the Model Calibration and Water Budget Report (Matrix and SSPA, 2012); a summary is provided herein.

A FEFLOW groundwater flow model was also developed for the City of Guelph Tier Three Assessment (Matrix, 2014), referred to as the Guelph Model. The model boundaries and the common area between the Regional, Cambridge and Guelph Models are shown on Figure 1 and a detailed view of the overlap area between the models is highlighted in pink hatching on Figure 2. In the common overlap areas between the Regional, Cambridge, and Guelph Models, the model structures, boundary conditions, and model input parameters are consistent between the three models.

Consistency regarding the model structures (e.g., mesh design, layer thickness and layer elevations) and boundary conditions (e.g., recharge, rivers/lakes/reservoirs and production wells) between the Regional and Cambridge Models was previously discussed (see Section 4.3 of Matrix and SSPA, 2012), and is not repeated in this memo.

2 GROUNDWATER FLOW MODEL COMPARISON

2.1 Model Structure

Model structure refers to the subdivision of the model domain in the horizontal and vertical directions. When the meshes for the Regional, Cambridge and Guelph Models were created, the same spatial mapping of surface water and well features were applied in all models to guide the mesh generation process. These features included streams, lakes, dams, lakes and reservoirs, wetlands, and municipal and non-municipal permitted production wells. This has resulted in similar meshes being applied for each model.

The vertical structure of a model refers to the sequence of layers within the model domain. The layer structures applied to represent the hydrogeologic overburden and bedrock units for each model are summarized in Table 1 for the overburden layers and Table 2 for the bedrock layers.

Table 1: Model Structure Comparison – Overburden

<table>
<tr><th rowspan="2">OGS Name</th><th rowspan="2">Interpreted Units</th><th colspan="2">Regional Model</th><th rowspan="2">Cambridge Model</th><th rowspan="2">Guelph Model</th></tr>
<tr><th>Waterloo Moraine</th><th>Cambridge Area</th></tr>
<tr><td></td><td>Surficial Geology</td><td>Layer 1</td><td>Layer 1</td><td>Layer 1</td><td rowspan="6">Layer 1, Layer 2</td></tr>
<tr><td>ATA1</td><td>Whittlesey clay</td><td rowspan="5">Units not present in the Waterloo Moraine area.</td><td rowspan="2">Layers 2 and 3</td><td rowspan="2">Layer 2</td></tr>
<tr><td>AFA1</td><td>Whittlesey sand</td></tr>
<tr><td>ATA2</td><td>Wentworth Till (may contain abundant stratified drift)</td><td rowspan="2">Layer 4</td><td rowspan="3">Layer 3</td></tr>
<tr><td>AFA2</td><td>Outwash deposits (mainly Grand River valley outwash)</td></tr>
<tr><td>ATA3</td><td>Fine-grained deposits in the Grand River valley (beneath AFA2)</td><td>Layer 5</td></tr>
<tr><td>ATB1</td><td>Upper Maryhill Till, Port Stanley, Tavistock, Mornington and/or Stratford Tills</td><td>Layer 3</td><td>Layers 6 and 7</td><td>Layer 4</td><td>Layer 3</td></tr>
<tr><td>AFB1</td><td>Upper Waterloo Moraine Stratified Sediments and equiv.</td><td>Layer 4</td><td rowspan="3">Layers 8 and 9</td><td rowspan="3">Layer 5</td><td rowspan="11">Interpreted to be absent (or not present in significant thicknesses) within the City of Guelph area</td></tr>
<tr><td>ATB2</td><td>Middle Maryhill Till and equivalents</td><td>Layer 5</td></tr>
<tr><td>AFB2</td><td>Middle Waterloo Moraine Stratified Sediments and equivalents</td><td>Layers 6 and 7</td></tr>
<tr><td>ATB3</td><td>Lower Maryhill Till and stratified equivalents</td><td>Layer 8</td><td rowspan="4">Layers 10 and 11</td><td rowspan="4">Layer 6</td></tr>
<tr><td>AFB3</td><td>Lower Waterloo Moraine Stratified Sediments or Catfish Creek Till Outwash</td><td>Layer 9</td></tr>
<tr><td>ATC1</td><td>Upper/ Main Catfish Creek Till</td><td rowspan="3">Layer 10</td></tr>
<tr><td>AFC1</td><td>Middle Catfish Creek Stratified Deposits</td></tr>
<tr><td>ATC2</td><td>Lower Catfish Creek Till</td><td rowspan="4">Layers 12 and 13</td><td rowspan="4">Layer 7</td></tr>
<tr><td>AFD1</td><td>Pre-Catfish Creek coarse-grained glaciofluvial/lacustrine deposits</td><td>Layer 11</td></tr>
<tr><td>ATE1</td><td>Canning Drift- till and fine-textured glaciolacustrine deposits</td><td>Layer 12</td></tr>
<tr><td>AFF1</td><td>Pre-Canning coarse-textured glaciofluvial/glaciolacustrine deposits</td><td rowspan="2">Layer 13</td></tr>
<tr><td>ATG1</td><td>Pre-Canning coarse-textured till</td></tr>
</table>

Table 2: Model Structure Comparison – Bedrock

Bedrock Member/ Formation	Regional Model		Cambridge Model	Guelph Model
	Waterloo Moraine	Cambridge Area		
Contact Zone	Layer 14	Layer 14	Layer 8	Layer 4
Bass Islands, Bois Blanc, Salina Formations	Layer 15 to 21	Formations not present		
Guelph Formation		Layer 15	Layer 9	Layer 5
Eramosa Fm., Reformatory Quarry Mbr.	Deeply buried beneath Waterloo Moraine (not part of active groundwater flow system; not simulated)	16	Layer 10	Layer 6
Eramosa Fm., Vinemount Mbr.		17	Layer 11	Layer 7 – 9
Goat Island Fm.		18	Layer 12	Layer 10
Upper Gasport		19	Layer 13	Layer 11
Middle Gasport		20	Layer 14	Layer 12
Lower Gasport		21	Layer 15	Layer 13
Cabot Head				Layer 14

The Regional Model consisted of 21 layers; 13 overburden and 8 bedrock (Tables 1 and 2). The overburden layers were required to represent the complex hydrostratigraphy within the Waterloo Moraine and underlying sediments. The Cambridge Model consisted of 15 layers; 7 overburden and 8 bedrock. As many of the Waterloo Moraine sediments do not extend into the Cambridge area, fewer overburden units were required in the Cambridge Model relative to the Regional Model.

In the Regional Model east of the Grand River, the overburden layer elevations were modified to reflect the layer structure established in the Cambridge Model such that two Regional Model overburden layers were used to define each overburden Cambridge Model layer (see Table 1).

The Guelph Model consisted of 14 layers; 3 overburden and 11 bedrock (Table 1 and 2). As the City of Guelph water supply is predominately concentrated on the bedrock aquifers, the model characterization focused on the bedrock groundwater flow systems.

2.2 Boundary Conditions

Recharge, specified head, and production well boundary conditions were applied to represent recharge, surface water features and regional groundwater levels on the perimeter of the models, as well as municipal and non-municipal production wells. Each of the boundary conditions applied in the Regional, Cambridge, and Guelph Models are discussed in the following sections.

2.2.1 Recharge

A Guelph All Weather Sequential Event Runoff (GAWSER) model was developed and calibrated to simulate surface water partitioning and stream flow generation within the Grand River Watershed (AquaResource 2009a). The recharge estimated with GAWSER was used as boundary condition inputs for the Regional, Cambridge and Guelph Models. As the GAWSER model was developed for the entire Grand River Watershed, the resulting recharge input was consistent between the three models. The elements have different sizes in each model, so the spatial distribution of recharge at overlapping elements may be different. Consequently, an area weighted approach was applied to aggregate the recharge outputs from GAWSER's Hydrologic Response Unit distribution onto the individual FEFLOW elements in the three models.

The spatial distributions of the simulated average annual recharge rates applied in the three FEFLOW models are shown on Figure 3. The total average annual recharge volumes applied in the models were compared in the overlap area (relative to the volume applied in the overlap area of the Regional Model) and are summarized in Table 3. The percent difference in recharge volumes relative to the total volume applied in the overlap area wa approximately 1%, indicating a good agreement in the recharge volumes applied within the three models.

Table 3: Recharge Comparison

Model	Annual Recharge Volume (m^3/a)	Percent Difference
Regional	61,720,848	-
Cambridge	61,329,909	1%
Guelph	61,016,756	1%

2.2.2 Specified Head

Specified head boundary conditions were applied to represent surface water features (e.g., streams, lakes, reservoirs, etc.) that were present at ground surface, and to represent regional-scale groundwater flow into or out of the model domains.

2.2.2.1 Surface Water Features

The surface water features applied within the three models showed good agreement with only a few local differences (Figure 4). In the overlap area, boundary conditions representing headwater reaches simulated in the Guelph Model were absent from the Regional and Cambridge Models. These features were removed during calibration of the Regional and Cambridge Models as it was unclear if these headwater streams represented perennial baseflow conditions or streams that flow only part of the year. This local discrepancy was interpreted to be minor and did not impact the water budget or model predictions made within any of the models.

2.2.2.2 Lateral Groundwater Heads

Specified head boundary conditions were applied to simulate flow of groundwater into or out of the model domains (Figure 5). Where boundary conditions were not specified, no flow boundary conditions were implicitly applied within the model.

The head values for the specified head boundary conditions applied along the northern perimeter of the Cambridge Model near the City of Guelph Well Fields were derived from the simulated head solution of the Guelph Model. This was done to ensure the heads in the Cambridge Model were consistent with the Guelph Model, and vice versa. Similarly, the head values for the specified head boundary conditions applied along the southwestern perimeter of the Guelph Model were derived by the simulated head solution of the calibrated Cambridge Model. The boundary conditions are illustrated on Figure 5.

In the Regional Model, a no flow boundary was specified along the eastern perimeter near the southern limits of the City of Guelph. The no flow boundary condition was examined by comparing model simulated hydraulic head contours and particle tracks in the Middle Gasport Formation in the Guelph and Cambridge Models. The Middle Gasport was conceptualized to have a high hydraulic conductivity feature (see orange zone on Figure 6) to represent an interpreted series of bedrock reefal mounds that extend between the cities of Cambridge and Guelph.

The predicted hydraulic head contour lines (Figure 6) for the Middle Gasport Formation were comparable. In both the Guelph and Cambridge Models there was a simulated groundwater divide between the two cities (see 300 m to 305 m contours on Figure 6). To aid in the visualization of the flow divide, fictitious water particles were released in the model in the Middle Gasport Formation layer and tracked forward in time for 2 years toward their point of discharge. The particle tracks are illustrated on Figure 6 and they highlight the presence of a divide in both models in the same area. Particles released in the Cambridge and Guelph Models south of the divide were predicted to travel south toward the City of Cambridge and those released just north of the divide consistently travelled northward toward the City of Guelph.

2.2.3 Production Wells

The municipal and non-municipal permitted groundwater production wells applied in the three models are discussed in the following subsections.

2.2.3.1 Municipal Production Wells

The municipal production wells applied in the models for the cities of Cambridge and Guelph are summarized in Table 4. As outlined in Table 4, the type of boundary conditions applied in the three models was consistent and the wells included in the simulations were also consistent.

For the Guelph Model, the municipal production wells in the Blair Road, Middleton, and Willard Well Fields were not represented as they lie outside the Guelph Model domain on the west side of the Grand River. The influence of groundwater pumping on the western side of the river was implicitly simulated (via the assignment of simulated heads from the Cambridge Model) in the boundary conditions that lie along the Grand River in the Guelph Model.

The Cambridge Model represented the City of Guelph Downey Road Well using a well boundary condition (as it lies completely within the Cambridge Model), while the Burke, Queensdale and University Well Fields for the City of Guelph were simulated using specified head boundary conditions, as they lie along the perimeter of the Cambridge Model domain.

The municipal production rates applied in the Guelph and Cambridge Models were consistent for the wells simulated in both models, and varied by less than 1% of the total volume simulated in the common overlap area.

Table 4: Water Budget for Municipal Production Wells

Well Field	Name	Rate (m^3/d)	Boundary Condition Type		
			Regional Model	Cambridge Model	Guelph Model
City of Cambridge					
Blair Road	G4	1728	Well	Well	N/A
Clemens Mill	G16	2938	Well	Well	Well
Clemens Mill	G17	2160	Well	Well	Well
Clemens Mill	G18	1296	Well	Well	Well
Clemens Mill	G6	864	Well	Well	Well
Dunbar Road	P6	0	Well	Well	Well
Elgin Street	G9	0	Well	Well	Well
Hespeler	H3	864	Well	Well	Well
Hespeler	H4	1296	Well	Well	Well

Well Field	Name	Rate (m^3/d)	Boundary Condition Type		
			Regional Model	Cambridge Model	Guelph Model
Hespeler	H5	864	Well	Well	Well
Middleton Street	G1	5184	Well	Well	N/A
Middleton Street	G14	2160	Well	Well	N/A
Middleton Street	G1A	1728	Well	Well	N/A
Middleton Street	G2	6912	Well	Well	N/A
Middleton Street	G3	4752	Well	Well	N/A
Pinebush	G5	1296	Well	Well	Well
Pinebush	P10	3110	Well	Well	Well
Pinebush	P11	1728	Well	Well	Well
Pinebush	P15	1296	Well	Well	Well
Pinebush	P17	0	Well	Well	Well
Pinebush	P9	1296	Well	Well	Well
Shade's Mill	G10	0	Well	Well	Well
Shade's Mill	G38	1296	Well	Well	Well
Shade's Mill	G39	2592	Well	Well	Well
Shade's Mill	G7	1728	Well	Well	Well
Shade's Mill	G8	864	Well	Well	Well
Willard	G15	2592	Well	Well	N/A
City of Guelph					
Glen Collector	-	6900	N/A	N/A	Well
Arkell	Arkell 1	1400	N/A	N/A	Well
Arkell	Arkell 6	4900	N/A	N/A	Well
Arkell	Arkell 7	4900	N/A	N/A	Well
Arkell	Arkell 8	4900	N/A	N/A	Well
Burke	-	6000	N/A	Specified Head	Well
Calico	-	1100	N/A	N/A	Well
Carter Wells	-	4000	N/A	N/A	Well
Clythe Creek	-	2200	N/A	N/A	Well
Dean Ave.	-	1500	N/A	N/A	Well
Downey Rd.	-	5100	N/A	Well	Well
Emma	-	2100	N/A	N/A	Well
Helmar	-	1100	N/A	N/A	Well
Membro	-	4200	N/A	N/A	Well
Paisley	-	800	N/A	N/A	Well
Park 1 and 2	-	6400	N/A	N/A	Well
Queensdale	-	2000	N/A	Specified Head	Well
Sacco	-	1150	N/A	N/A	Well
Smallfield	-	1400	N/A	N/A	Well
University	-	2500	N/A	Specified Head	Well
Water Street	-	2300	N/A	N/A	Well
N/A refers to wells where boundary conditions were not applied as the wells lie outside the model domain.					

2.2.3.2 *Non-Municipal Production Wells*

The same permit to take water datasets were used to characterize the non-municipal production wells in the three models and, as such, the simulated non-municipal production wells were consistent. The rates applied in the models were compared in the common overlap area between the three models (see pink hatched area of Figure 7) and there was <1% difference in pumping rates between the Cambridge and Guelph Models. Appendix F of the Water Budget Report (Matrix and SSPA, 2012) outlines the reported rates applied in the Cambridge and Regional Models.

2.3 Model Input Parameters (Hydraulic Conductivity)

Consistency between the simulated material properties (i.e., hydraulic conductivity values and zones) was emphasized during the calibration process of all three models. In general, the three models had the same model layer structures, as derived through cross-section generation throughout the Guelph and Cambridge areas. Through an iterative process, the hydraulic conductivity zones and values in the three groundwater flow models were also made to be consistent by drawing on the strengths of the calibration in each area. The Guelph Model was the first model calibrated and as such, the hydraulic conductivity zones and values in the south Guelph area were applied in the Cambridge and Regional Models in the overlap areas. When the calibration in the Cambridge area was nearing completion, the calibrated hydraulic conductivity values and zones were applied in the Regional and Guelph Models in the overlap area. Minor changes were made in each model to improve the overall calibration and the zones were re-applied in each of the areas, with the detailed calibration in Guelph and Cambridge taking precedence in those areas. The Regional Model was updated with values from the Guelph and Cambridge Models in the common overlap areas.

The Middle Gasport Formation was the unit with the greatest hydraulic connection between the cities of Cambridge and Guelph. The horizontal hydraulic conductivity distributions of this formation for all three models were consistent, as shown on Figure 6.

Regional scale cross-sections were generated to compare the model structures and hydraulic conductivity distributions across all simulated hydrogeological units in the three models. Figure 8 illustrates a comparison of cross-sections between the Regional and Cambridge Models, from the Elgin Street Well Field in Cambridge to an area south of the Downey Street Well Field in Guelph. Figure 9 illustrates a comparison of the same cross-sections in the Cambridge and Guelph Models. The cross-sections have a 20x vertical exaggeration and illustrate the horizontal hydraulic conductivity values applied, the simulated hydraulic head contours (2 m intervals), and the water table elevations.

As illustrated on Figure 8, the hydraulic conductivity distributions, simulated hydraulic head contours and simulated water table elevations were comparable between the three models. Some differences existed between contour intervals greater than 314 m at the northern up-gradient (right side of section) end of the cross-section due to the no flow boundary condition specified at the perimeter of the Regional Model in this area.

Figure 9 compares the simulated hydraulic conductivity values for the bedrock in the Cambridge and Guelph Models. The bedrock units were consistent along this section; however, differences exist within the overburden units due to differences in the number of overburden model layers represented. The Cabot Head Formation (shown in purple) was represented within the Guelph Model but was not represented in the Cambridge or Regional Models. The simulated water table elevations and water level elevations within the deeper aquifers were similar between the Cambridge and Guelph Models.

3 SUMMARY

The model layer structures, boundary conditions and material properties (i.e., hydraulic conductivity values and distributions) were compared between the Regional, Cambridge, and Guelph Models where the models overlap. The mesh and layer structures of the models were generated from common input features that resulted in model structures that were in good agreement, yet allowed for detailed expression of features that were important to each model to be applied. The Regional Model contained

additional layers in the overburden to represent the Waterloo Moraine sediments, whereas the Cambridge and Guelph Models contained a more detailed representation of the bedrock flow systems.

In general, the boundary conditions were in agreement in all three models with some small local-scale deviations. The recharge distributions were consistent amongst the three as they were derived using the output of the same GAWSER model. The representation of surface water features were derived from common datasets, with minor differences in the inclusion of headwater reaches between models. Lateral boundary conditions for the Cambridge Model were informed by the Guelph Model and vice-versa. Near the City of Guelph, the Regional Model applied a no flow boundary condition which was shown to be consistent with the simulated flow systems of the Cambridge and Guelph Models. Municipal production wells had a common representation in all models, and the non-municipal PTTWs were also in good agreement between the models.

The hydraulic conductivity distributions and values were comparable between the models, particularly for the bedrock systems where the layer structure (with the exception of the Cabot Head Formation) was common to all three models. Varying degrees of model refinement and simplification were made in the overburden system between the models.

Overall, there is agreement and consistency between the three groundwater flow models within the overlap area, with some local differences, as each model was developed with a particular purpose and local study area in mind.

4 REFERENCES

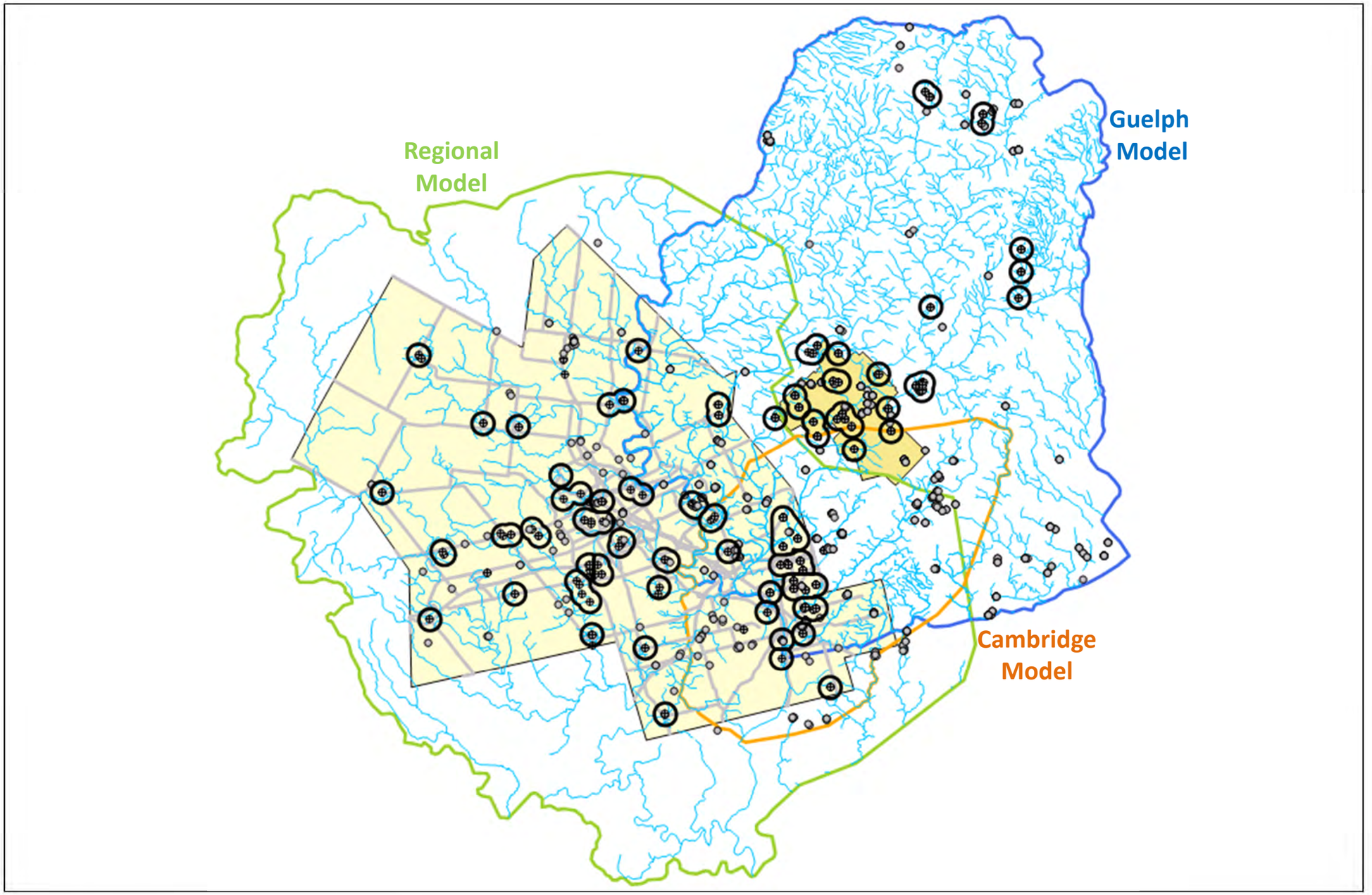
AquaResource Inc. (AquaResource). 2009a. Tier Three Water Budget and Local Area Stress Assessment: Hydrological Model Update, Regional Municipality of Waterloo and City of Guelph. Draft report prepared for the Regional Municipality of Waterloo and City of Guelph. Waterloo, Ontario. August 2009.

AquaResource Inc. (AquaResource). 2009b. Integrated Water Budget Report, Grand River Conservation Authority. Report prepared for Grand River Conservation Authority. Waterloo, Ontario. June 2009.

Matrix Solutions Inc. (Matrix). 2013. Draft Tier Three Water Budget and Local Area Risk Assessment. Report prepared for the City of Guelph. May 2013.

Matrix Solutions Inc. (Matrix) and S.S. Papadopulos and Associates (SSPA). 2012. Draft Tier Three Water Budget and Local Area Risk Assessment, Model Calibration and Water Budget Report. Report prepared for the Regional Municipality of Waterloo. November 2012.

Matrix Solutions Inc. (Matrix) and S.S. Papadopulos and Associates (SSPA). 2014. Draft Tier Three Water Budget and Local Area Risk Assessment. Report prepared for the Regional Municipality of Waterloo. May 2014.



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

- Stream
- Lake
- Road
- ROW Boundary
- City of Guelph Boundary
- Municipal Well Field
- Municipal Well
- Non-Municipal Well
- Regional Model Boundary
- Cambridge Model Boundary
- Guelph Model Boundary

N

0 10 km

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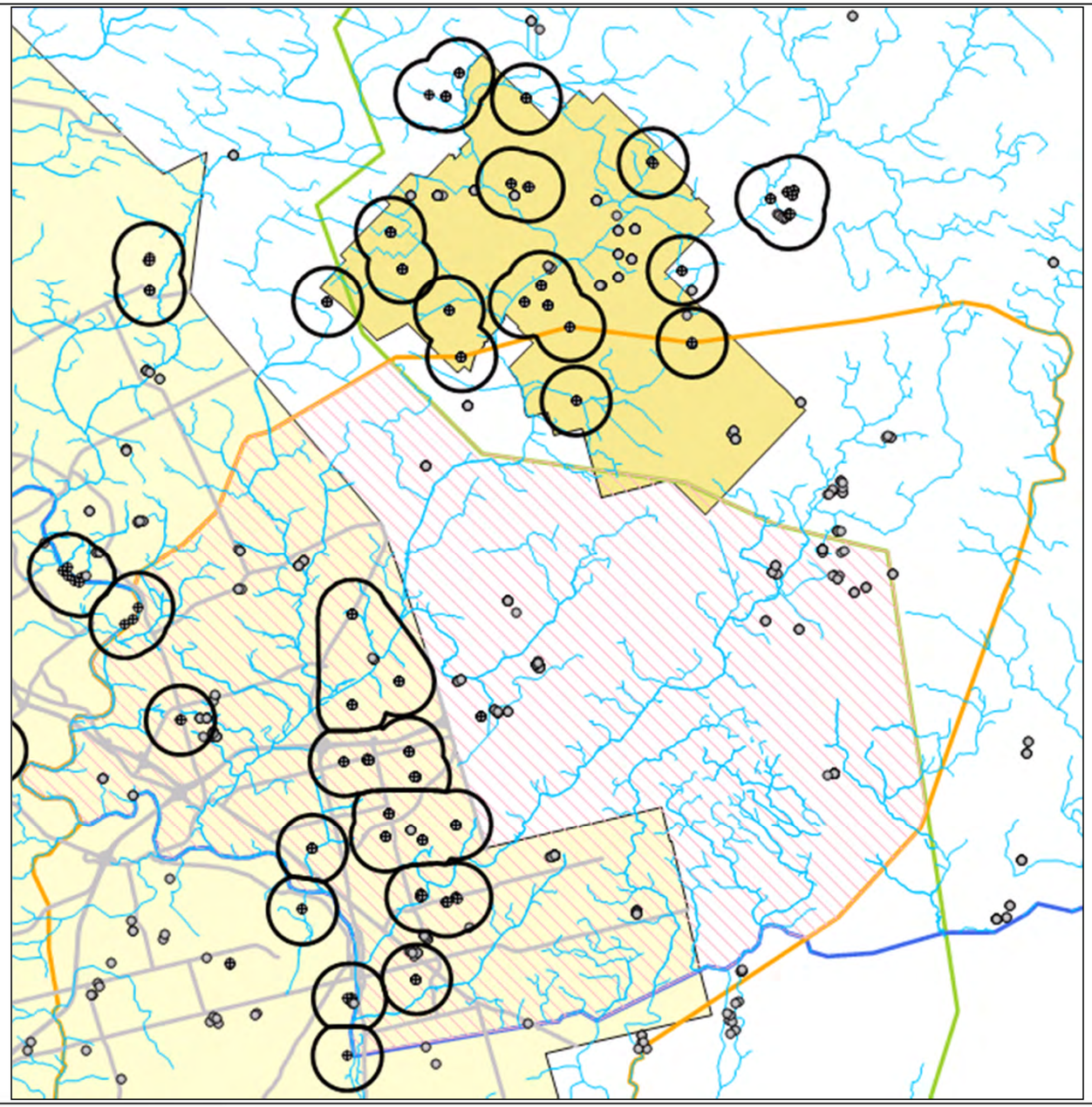
Figure 1: Extent of Regional, Cambridge, and Guelph Models



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

- Stream
- Lake
- Road
- ROW Boundary
- City of Guelph Boundary
- Municipal Well Field
- Municipal Well
- Non-Municipal Well
- Regional Model Boundary
- Cambridge Model Boundary
- Guelph Model Boundary
- Common Area between Models

N

0 10 km

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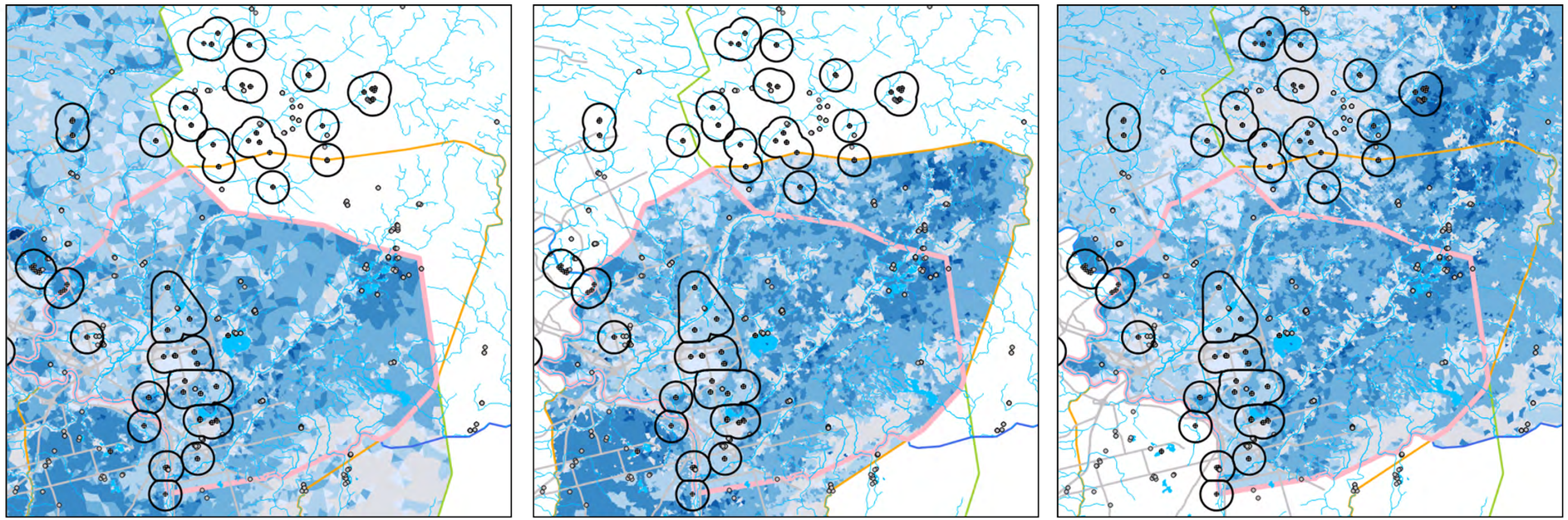
Figure 2: Common Area between Regional, Cambridge, and Guelph Models

Regional Model

Cambridge Model

Guelph Model



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

Stream
Lake
Road

Municipal Well Field

Municipal Well
Non-Municipal Well

Regional Model Boundary
Cambridge Model Boundary
Guelph Model Boundary

Common Area between Models

Recharge (mm/a)
<50
50...100
100...200
200...300
300...400
400...500
>500

N

0 10 km

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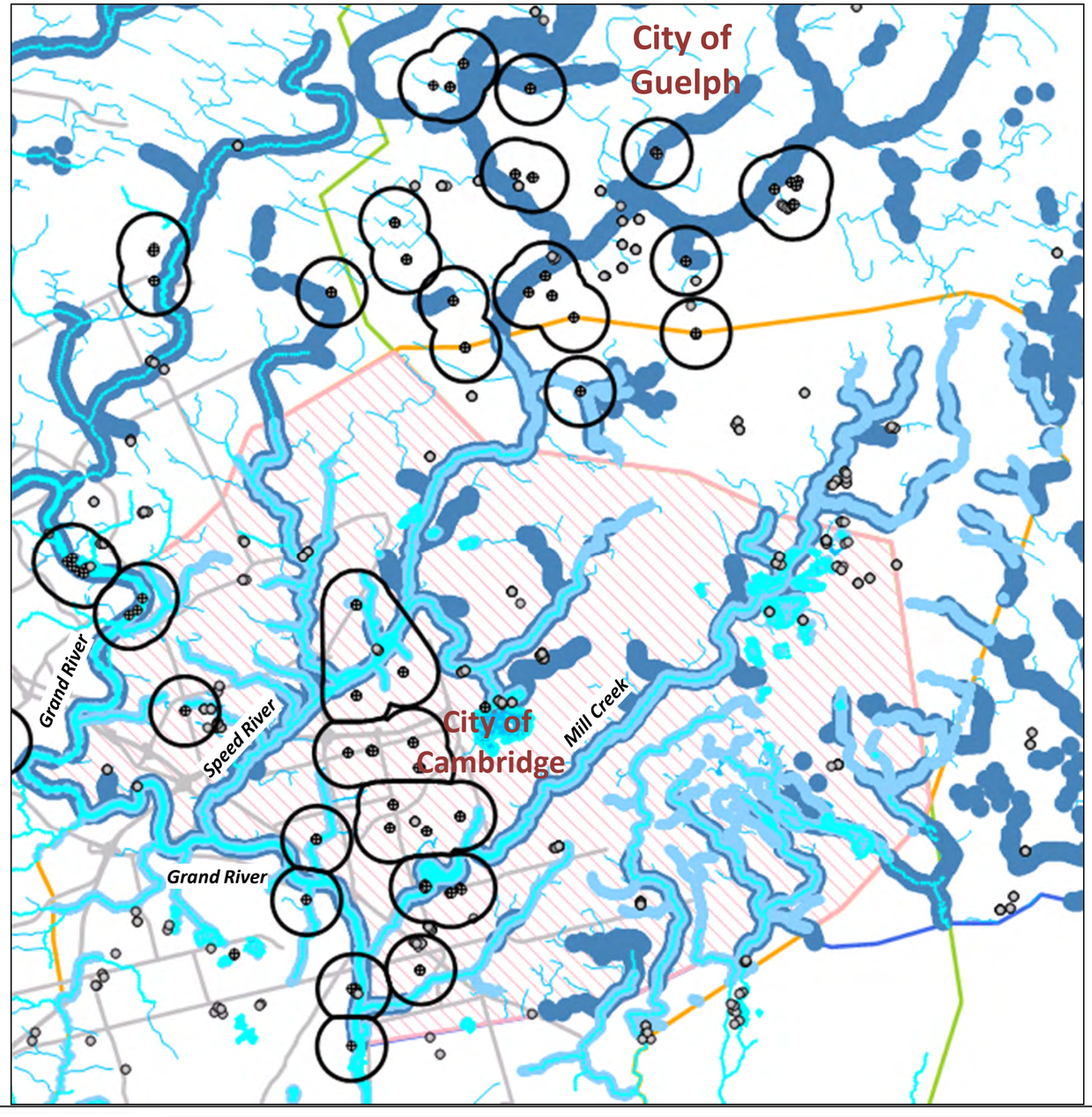
Figure 4: Comparison of Simulated Recharge



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

Stream
Lake
Road

ROW Boundary
City of Guelph Boundary
Municipal Well Field

Municipal Well
Non-Municipal Well

Regional Model Boundary
Cambridge Model Boundary
Guelph Model Boundary

Common Area between Models

Simulated Surface Water Feature
Regional Model
Cambridge Model
Guelph Model

N

0 10 km

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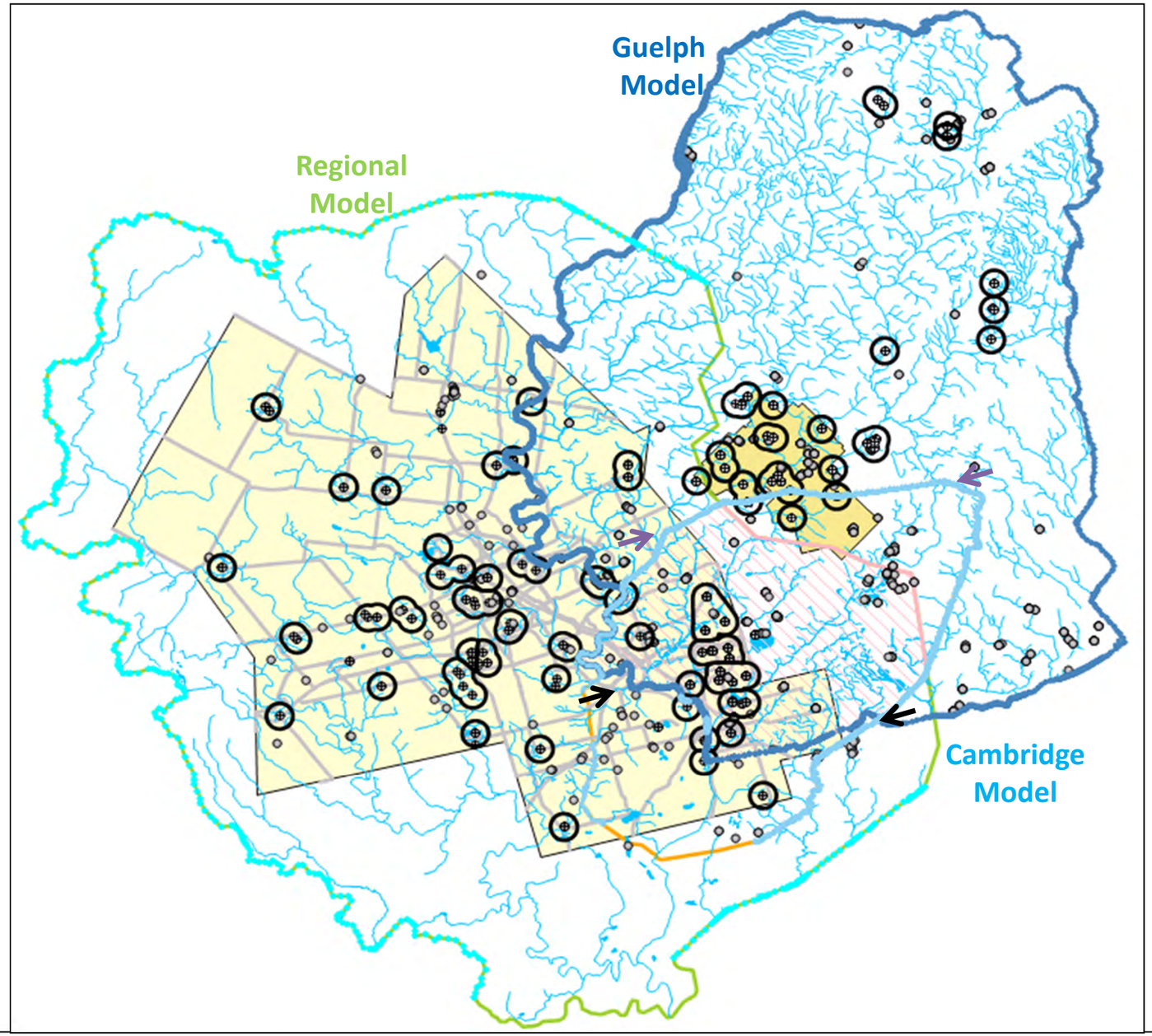
Figure 4: Comparison of Simulated Surface Water Features



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

- Stream
- Lake
- Road
- Municipal Well
- Non-Municipal Well
- ROW Boundary
- City of Guelph Boundary
- Municipal Well Field
- Regional Model Boundary
- Cambridge Model Boundary
- Guelph Model Boundary
- Common Area between Models
- Simulated Regional Hydraulic Head
  - Regional Model
  - Cambridge Model
  - Guelph Model
- Boundary condition informed by Cambridge Model
- Boundary condition informed by Guelph Model

N

0 10 km

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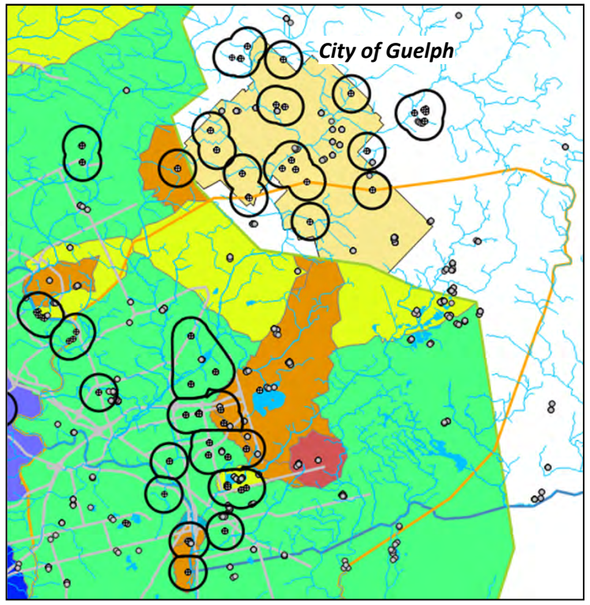
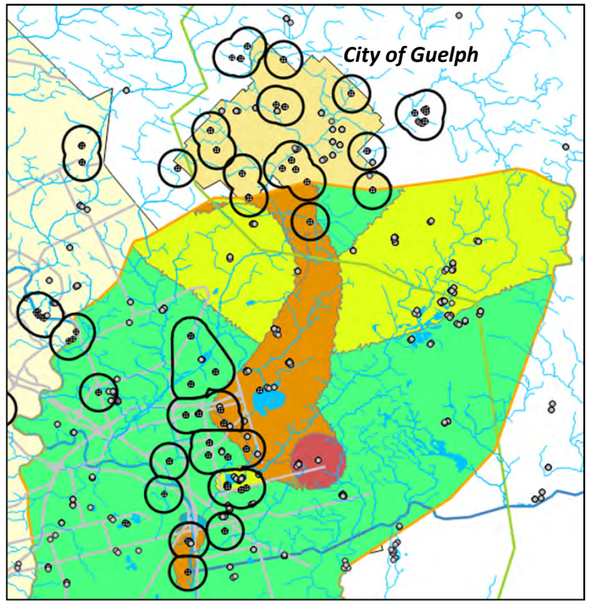
Figure 5: Comparison of Simulated Lateral Hydraulic Head

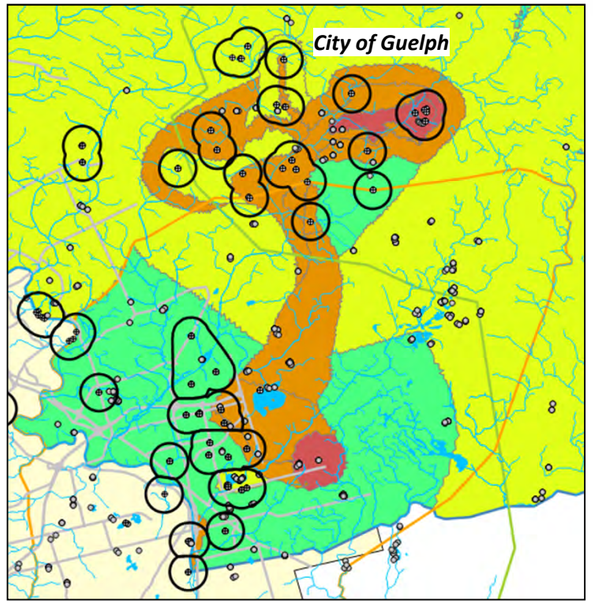
Regional Model

Cambridge Model

Guelph Model







Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

Stream
Lake
Road

Municipal Well
Non-Municipal Well

ROW Boundary
City of Guelph Boundary
Municipal Well Field

Regional Model Boundary
Cambridge Model Boundary
Guelph Model Boundary

Common Area between Models

Simulated Hydraulic Conductivity (m/s)
<1E-9
1E-9...1E-8
1E-8...1E-7
1E-7...1E-6
1E-6...1E-5
1E-5...1E-4
1E-4...1E-3
>1E-3

Simulated Hydraulic Head
Particle Track

N

0 10 km

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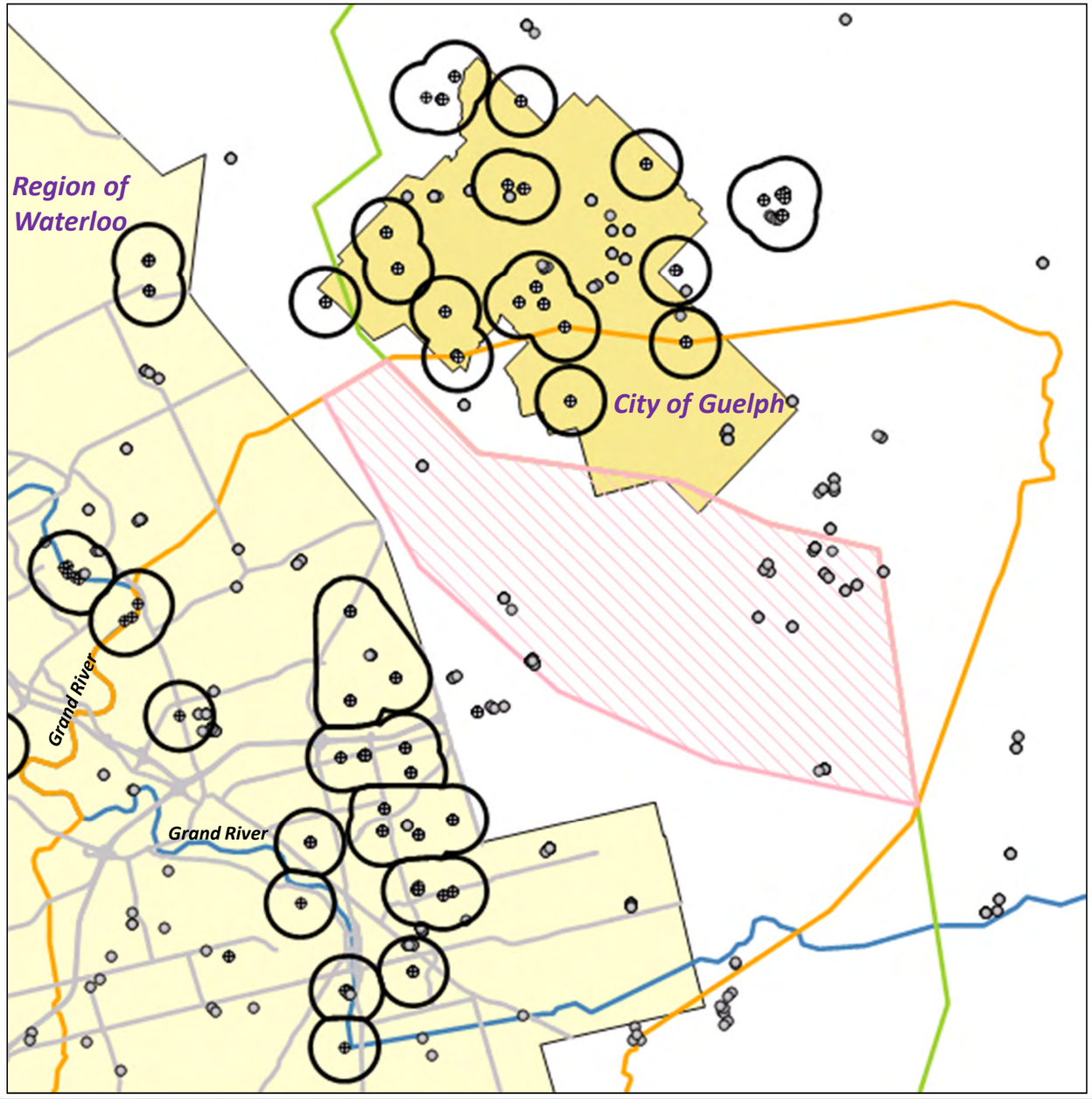
Figure 6: Comparison of the Middle Gasport Fm.



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

- Stream
- Lake
- Road
- Municipal Well
- Non-Municipal Permit to take Water
- ROW Boundary
- City of Guelph Boundary
- Municipal Well Field
- Regional Model Boundary
- Cambridge Model Boundary
- Guelph Model Boundary
- Area of Non-Municipal Production Check

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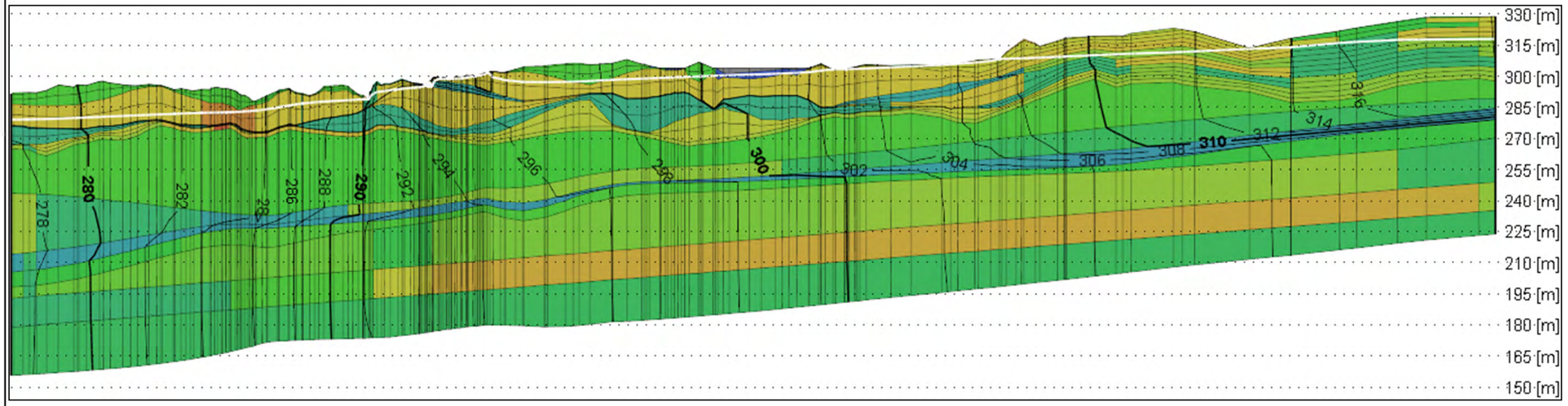
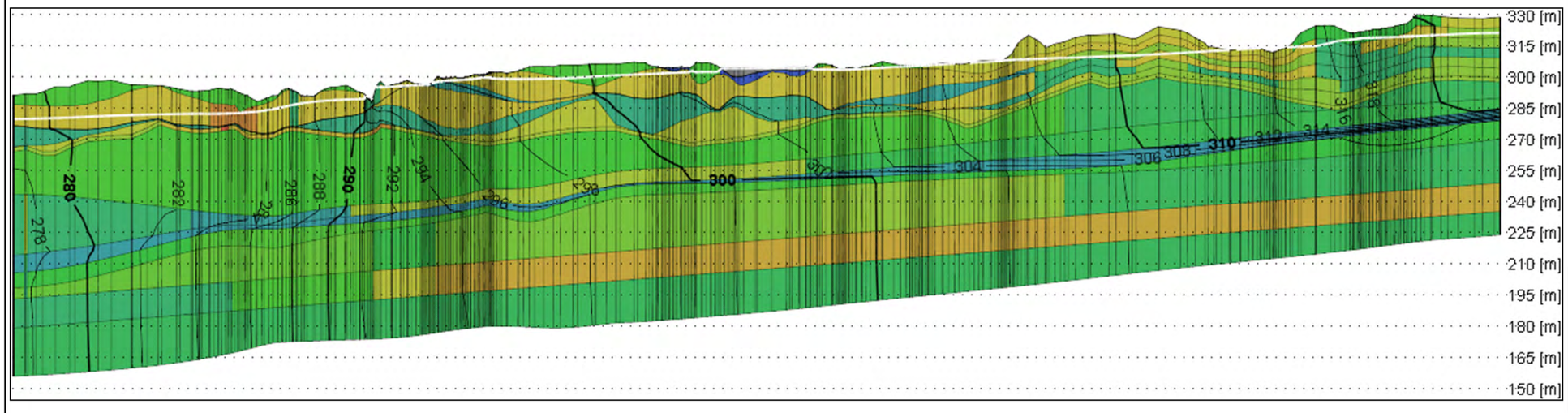
Figure 7: Non-Municipal Production Well Water Balance

Regional Model



Cambridge Model



Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo

Simulated Hydraulic Conductivity (m/s)

- 0.01
- 0.001
- 0.0001
- 1e-05
- 1e-06
- 1e-07
- 1e-08
- 1e-09
- 1e-10

Simulated Hydraulic Head Contour (m)

Simulated Water Table

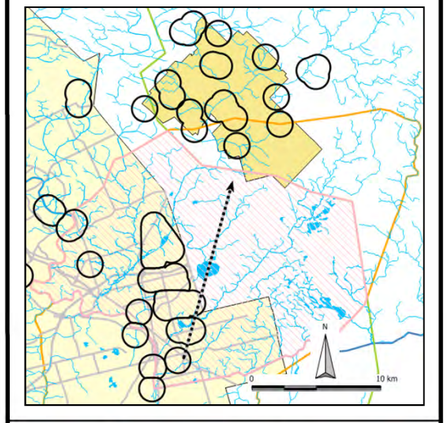


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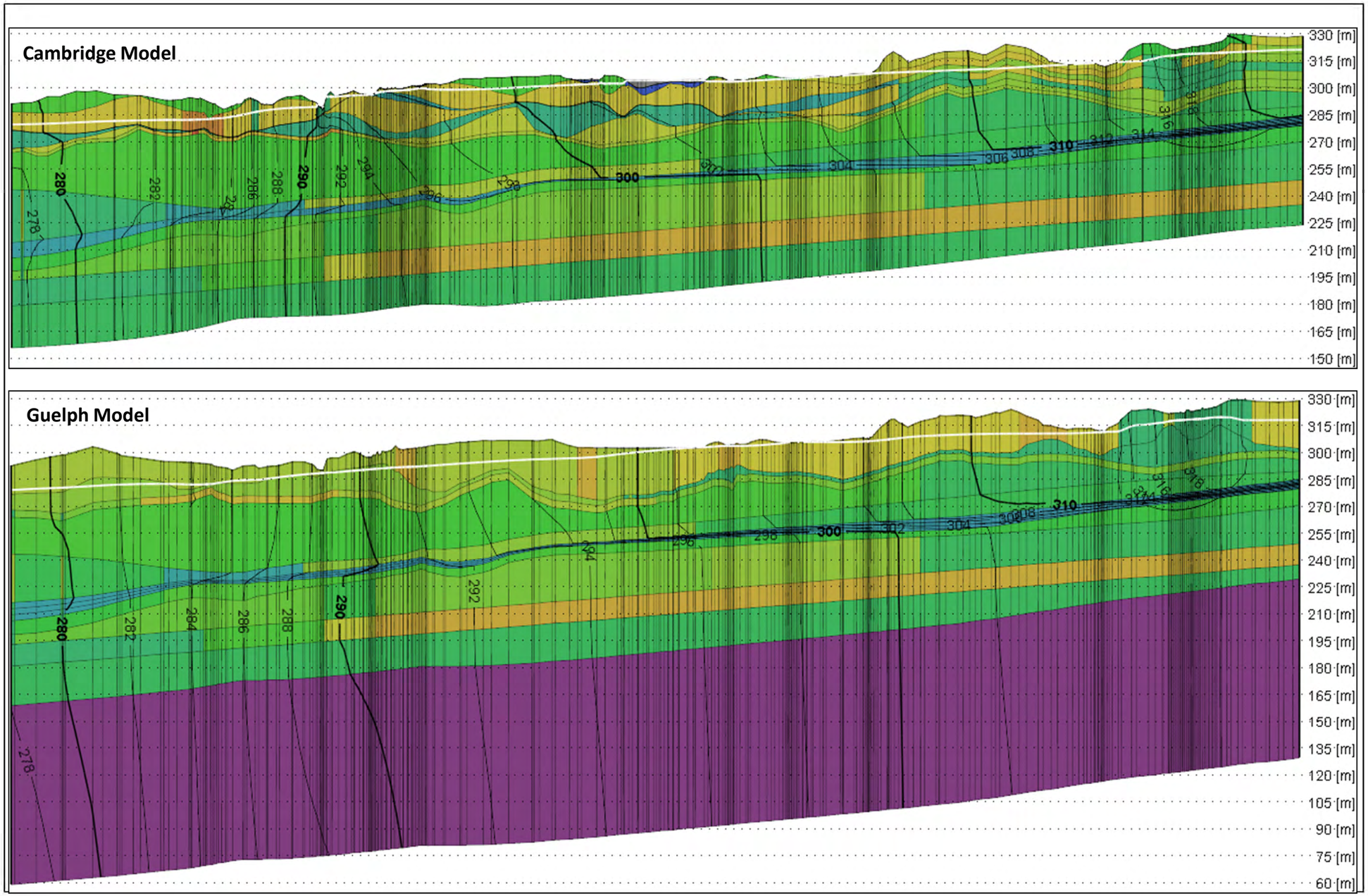
Figure 8: Cross-Sectional Comparison – Regional and Cambridge Models

Region of Waterloo, City of Guelph Tier Three Assessment Groundwater Model Integration Memo



Simulated Hydraulic Conductivity (m/s)

- 0.01
- 0.001
- 0.0001
- 1e-05
- 1e-06
- 1e-07
- 1e-08
- 1e-09
- 1e-10

Simulated Hydraulic Head Contour (m)

Simulated Water Table

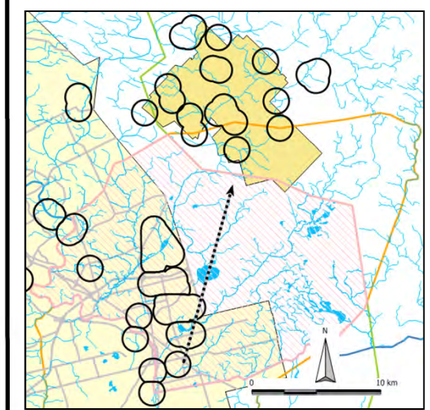


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Figure 9: Cross-Sectional Comparison – Cambridge and Guelph Models

MEMORANDUM

To: Martin Keller, Grand River Conservation Authority

CC: Region of Waterloo (Richard Wootton and Eric Hodgins), City of Guelph (Dave Belanger)

From: Paul Chin and Patricia Meyer, Matrix Solutions Inc.

Re: Division of the Combined Local Area between the Cities of Guelph and Cambridge

Date: March 29, 2017

1. INTRODUCTION

As part of the Tier Three Water Budget and Local Area Risk Assessments (Tier Three Assessment) for the City of Guelph and Township of Guelph/Eramosa (Guelph/GET; Matrix 2017) and Region of Waterloo (Region; Matrix and SSPA 2014), groundwater flow models were developed to simulate groundwater flow conditions and groundwater-surface water interactions. Figure 1 illustrates the model area for both the Cambridge model and part of the Guelph/GET model.

One of the key outcomes of the Tier Three Assessments was the delineation of water quantity vulnerable areas, termed Local Areas. Local Areas are areas on the landscape where reductions in recharge (due to land use development) or increases in groundwater demand, may impact the sustainability of the municipal wells under current or future conditions. A Risk Level (Significant, Moderate or Low) was assigned based on the results of modelling scenarios that assessed potential impacts associated with increased demands, climatic variability and reductions in recharge. A Risk Level of Significant or Moderate will require identified water quantity threats in the Local Area to be managed.

The Cambridge and Guelph/GET groundwater flow models were developed and calibrated simultaneously and effort was spent to ensure consistency and integration between the two models, as documented in Matrix, 2014. In 2014, the groundwater flow model calibration in the Cambridge Model was completed, and the Risk Assessment Report was drafted (Matrix and SSPA 2014). While the Region of Waterloo Tier Three Assessment was concluding, updates were made in the Guelph/GET model, including changes to the conceptual and numerical models in the Rockwood and Hamilton Drive area as part of a Risk Assessment for those water supply systems. Updates were also made in 2015 and 2016 to the Guelph/GET model in the south Guelph and Puslinch Township areas. The impact of these changes on the Risk Assessment results in Cambridge were tested and found to be negligible (see Appendix A for details).

The Local Areas for the Region and Guelph/GET were delineated following the Technical Rules laid out for the Tier Three Assessment water budget framework (MOECC 2016). Local Area A for the City of Guelph/GET was delineated in 2016 and encompasses the entire city and surrounding lands, and extends south into Cambridge (Figure 2). Local Area B for the City of Cambridge wells was delineated in 2014 and encompasses much of the Cambridge area and south Guelph (Figure 3). As noted previously,

the Local Areas were delineated using separate, yet complementary, groundwater flow models designed to simulate the groundwater flow conditions within the respective cities. Each of the two Local Areas was delineated by contouring the drawdown induced by the estimated future municipal and non-municipal permitted pumping rates in the area (relative to historic non-pumping conditions), with consideration for the location and impact of future land use development on water levels in the municipal wells (see Matrix and SSPA 2014 and Matrix 2017 for additional details).

Several bedrock aquifers including productive horizons in the Guelph, Gasport and Goat Island formations, underlie the cities of Guelph and Cambridge and are used as a water supply sources in both cities. The drawdown cones induced by the future estimated municipal groundwater demand (Allocated Rates) for the two cities overlap and underlie the Cities of Guelph and Cambridge. As such, the overlapping Local Area (based on the 2 m drawdown contour) underlies both cities. The Risk Level applied to Local Area A of the Guelph/GET Tier Three Assessment was Significant, whereas a Risk Level of Low was assigned to Local Area B of the Region's Tier Three Assessment. As the two areas overlap, there was a need to separate the Local Area that is common to Guelph/GET and Cambridge, so appropriate water resource policies can be drafted to address the water quantity threats in the area.

2. METHODOLOGY APPLIED TO DELINEATE SEPARATE LOCAL AREAS

This section outlines the technical methodology used to separate the overlapping Local Area between the Cities of Guelph and Cambridge, recognizing the groundwater interaction within the bedrock aquifer system that supplies the two cities. The management zones will identify areas where water use policies under the Clean Water Act could be implemented. The underlying subsections outline the technical rationale used to subdivide the common Local Area for Guelph/GET and Cambridge to create a unique groundwater management area (Local Area) for each of the two cities.

2.1 Bedrock Groundwater Level Elevations

While the drawdown and the Local Area between the two cities overlap, observed and simulated groundwater level elevations in the Gasport Formation indicate a groundwater flow divide exists between the two cities. Figure 4 illustrates the simulated groundwater level elevations and the interpreted groundwater flow divide location in the Middle Gasport Formation, as simulated in the Guelph/GET and Cambridge groundwater flow models under future Allocated Rates. North of the divide, groundwater flows toward Guelph, and south of the divide, groundwater flows toward Cambridge. This flow divide represents a logical location to subdivide the common Local Area; however, this boundary is not fixed and will move dynamically as recharge and municipal and non-municipal pumping in Cambridge and Guelph changes. As such, this groundwater divide was one piece of technical information used to divide the Local Area between the two cities.

2.2 Potential Areas of Well Contribution

Backward particle tracking was conducted within the two groundwater flow models. Hypothetical particles of water were released at the municipal wells in Cambridge and Guelph, and they were tracked backward in time to their sources (i.e., the recharge areas). The particle tracking was undertaken to provide insight on the source areas of the Cambridge and Guelph municipal supply wells and to enhance the understanding of the groundwater flow divide noted in the deep bedrock aquifer (Gasport Formation). Figure 5 illustrates a cross-sectional view from the Clemens Mill Well Field in Cambridge in the south (left) through the Downey Road Well in Guelph in the northeast (right). As illustrated, a

groundwater flow divide exists within the Gasport Formation, and a shallower groundwater flow divide within the overburden lies northeast of the flow divide in the bedrock (Figure 5). (Note: three-dimensional particles are projected onto the two-dimensional cross-section so some particles that are behind the cross-sectional plane appear to extend above ground surface).

As part of the Region's Tier Three Assessment, three alternative (calibrated) numerical models were created (see Appendix C of Matrix and SSPA 2014 for details) to test the uncertainties associated with model input parameters on the model results. As part of this memorandum, backward particle tracking was conducted in the base case and each of the three uncertainty case models to test the uncertainties associated with model input parameters on the particle traces and the groundwater flow divide. Figure 6 illustrates the resultant steady-state particle traces from all of the calibrated Cambridge models and the Guelph/GET model. As illustrated on the figure, the source areas for the Cambridge and City of Guelph wells lies south of the City of Guelph.

[Note: The particle tracking presented on Figure 6 represents only backward tracking particles that were released at the municipal wells. The wells were pumped at their future Allocated Rates; these rates may be different than the pumping rates applied to delineated capture zones for the City of Guelph and Region of Waterloo water supply wells.]

2.3 Model Simulated Drawdown Contours

In addition to the groundwater level elevations and the potential well contribution areas, the model simulated drawdown contours generated in the two models were also reviewed to provide further support for the delineation of the separate Local Areas. The drawdown was calculated as the difference between the groundwater level elevations under non-pumping conditions and groundwater level elevations when all municipal wells are pumped at their future Allocated Rates (and non-municipal water supplies were pumped at their existing consumptive rates). As noted earlier, the 2 m drawdown contour encompassed both cities; however, the 4 and 5 m drawdown contours (Figure 7) do not overlap and provide insight on the groundwater divide between the two cities.

3. LOCAL AREA DELINEATION RESULTS

Using all of the technical data assembled and described in Section 2, separate Local Areas were delineated for the Cities of Cambridge and Guelph. The Local Area for Cambridge was extended to the southern portion of Guelph to coincide with the interpreted groundwater flow divide (Figure 8). Similarly, the southern extent of Guelph's Local Area was informed by the extent of the 5 m drawdown contours (Section 2.3), and where the 2 m drawdown cone narrows east of Cambridge (Figure 9). Figure 10 illustrates both Local Areas on the same map and illustrates the overlap area within Wellington County where groundwater policies for the Region and Guelph will apply. As Guelph has a Significant Risk Level, their policies will be mandatory; however, within that overlap area, the Region may choose to comment on or review any new water demands that may have a potential impact on their groundwater supplies.

4. CONCLUSIONS/IMPLICATIONS

Two Local Areas were delineated for the Cities of Cambridge and Guelph and these will become groundwater management areas to safeguard the long-term sustainability of the respective cities' groundwater resources under the *Clean Water Act*. The delineation of the two Local Areas was based on

observed groundwater level elevations and results of numerical modelling analyses. The overlap area between the two zones acknowledges the variability in the location of the groundwater flow divide between the two cities. This overlap area represents a groundwater management area within which the City of Guelph and the Region will work cooperatively to assess any potential impacts on their municipal water supplies that may arise, for example, due to a new groundwater permit or a reduction in groundwater recharge due to land development.

5. REFERENCES

Matrix Solutions Inc. (Matrix) 2017. City of Guelph and Township of Guelph/Eramosa Tier Three Water Budget and Local Area Risk Assessment; Draft Risk Assessment Report. January, 2017.

Matrix Solutions Inc. (Matrix) 2014. Comparison and Integration of the Region of Waterloo Cambridge Model and City of Guelph Tier Three Assessment Model. Memorandum to Region of Waterloo Tier Three Peer Review Committee. August 13, 2014.

Matrix Solutions Inc. (Matrix) and S.S. Papadopulos and Associates (SSPA). 2014. Region of Waterloo Tier Three Water Budget and Local Area Risk Assessment; Final Risk Assessment Report. September, 2014.

Ontario Ministry of the Environment and Climate Change. (MOECC). 2016. *Technical Rules: Assessment Report, Clean Water Act, 2006*. November 20, 2008. Amended on December 12, 2008 (administrative amendments), November 16, 2009 (EBR Posting Number EBRO10-7573), and December 2, 2013 (Technical Bulletin). Updated on May 19, 2016. https://www.ontario.ca/page/technical-rules-assessment-report

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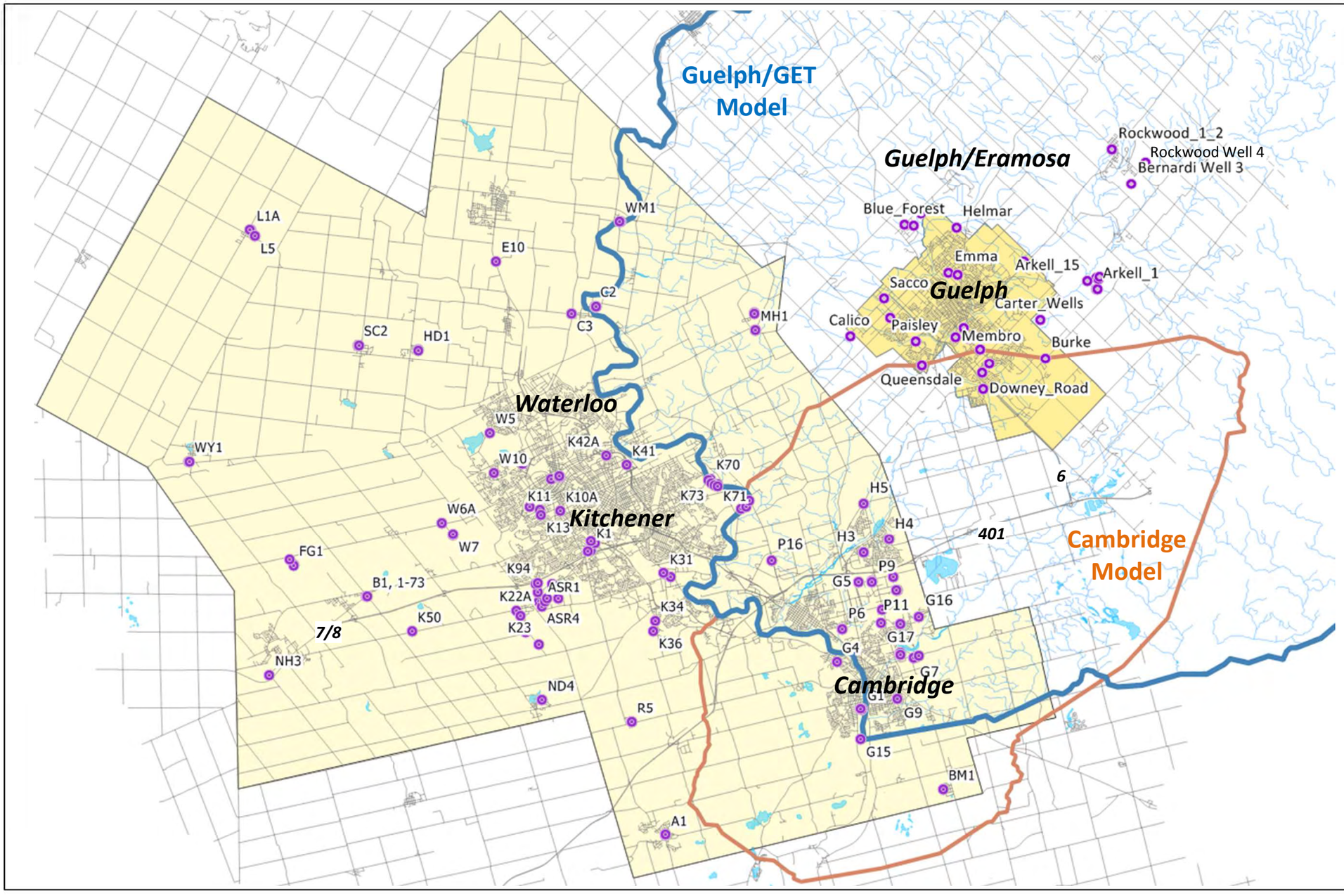
Senior Hydrogeologist
March 29, 2017



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Streams
- Lakes
- Roads
- City of Guelph Boundary
- Region of Waterloo Boundary
- Municipal Wells
- Guelph/GET Model Domain
- Cambridge Model Domain

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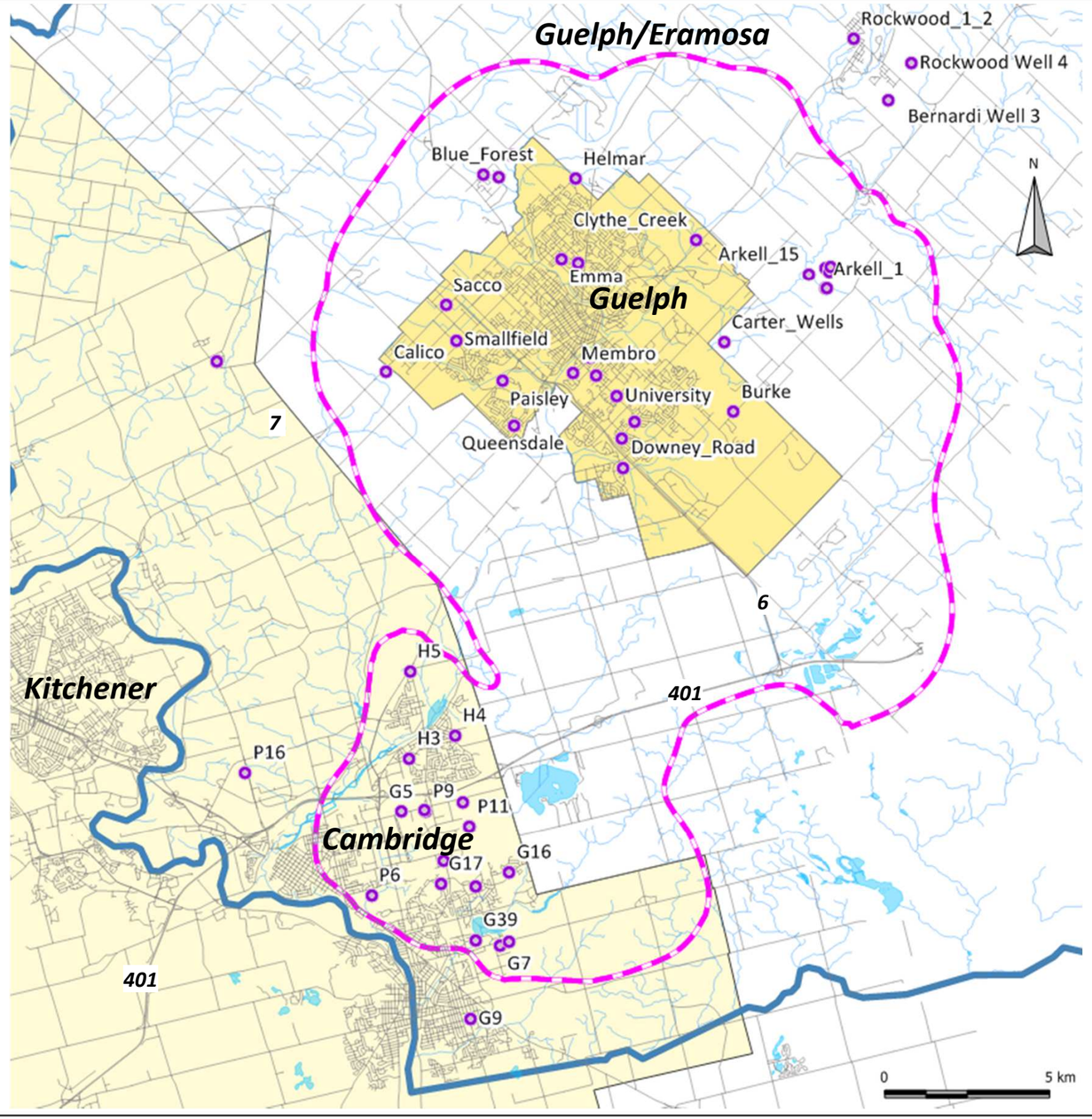
Figure 1: Cambridge and Guelph/ GET Groundwater Flow Models



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- Guelph/GET Local Area A
- Guelph/GET Model Domain

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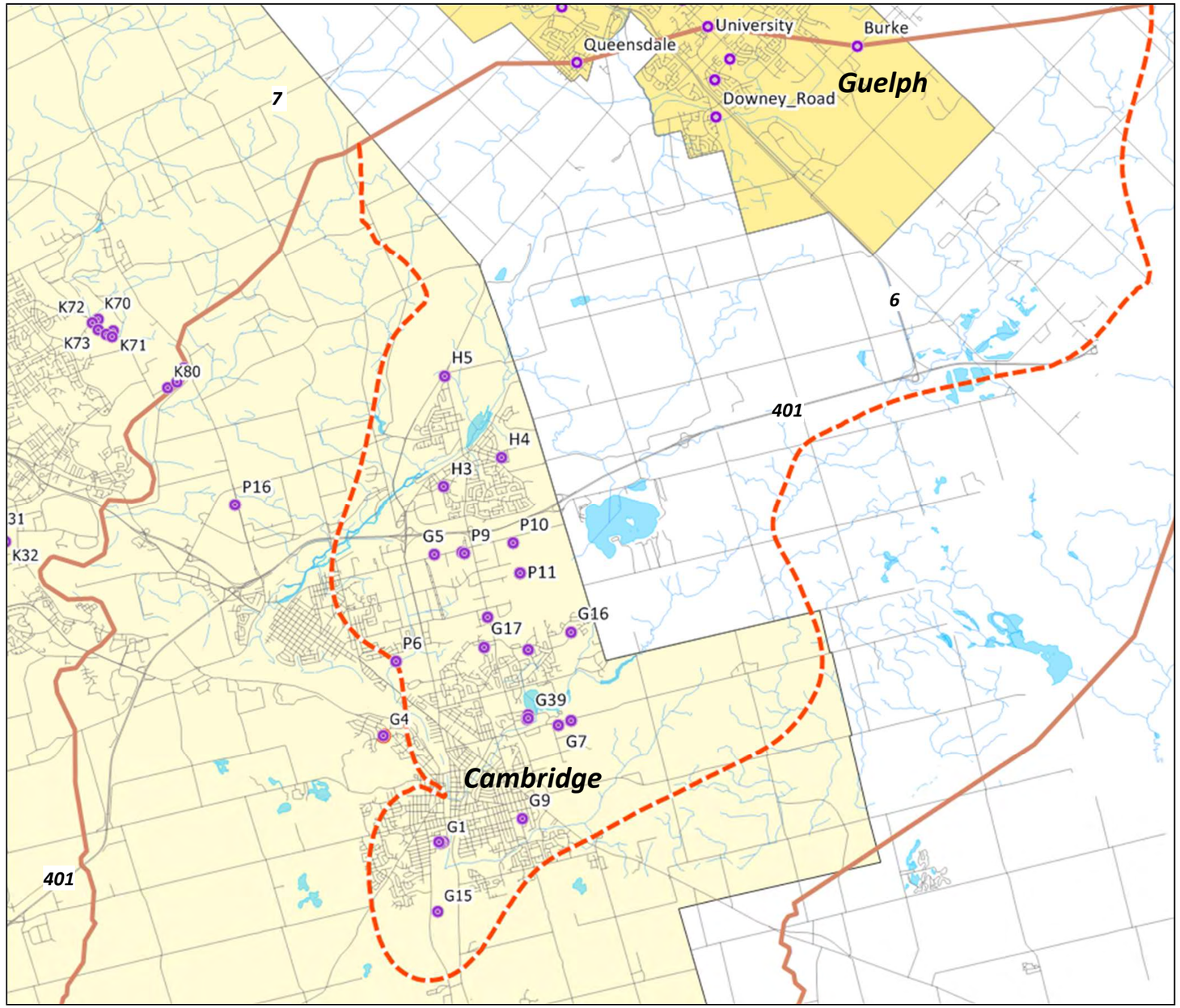
Figure 2: City of Guelph and Township of Guelph/Eramosa Local Area A



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- ROW Local Area B

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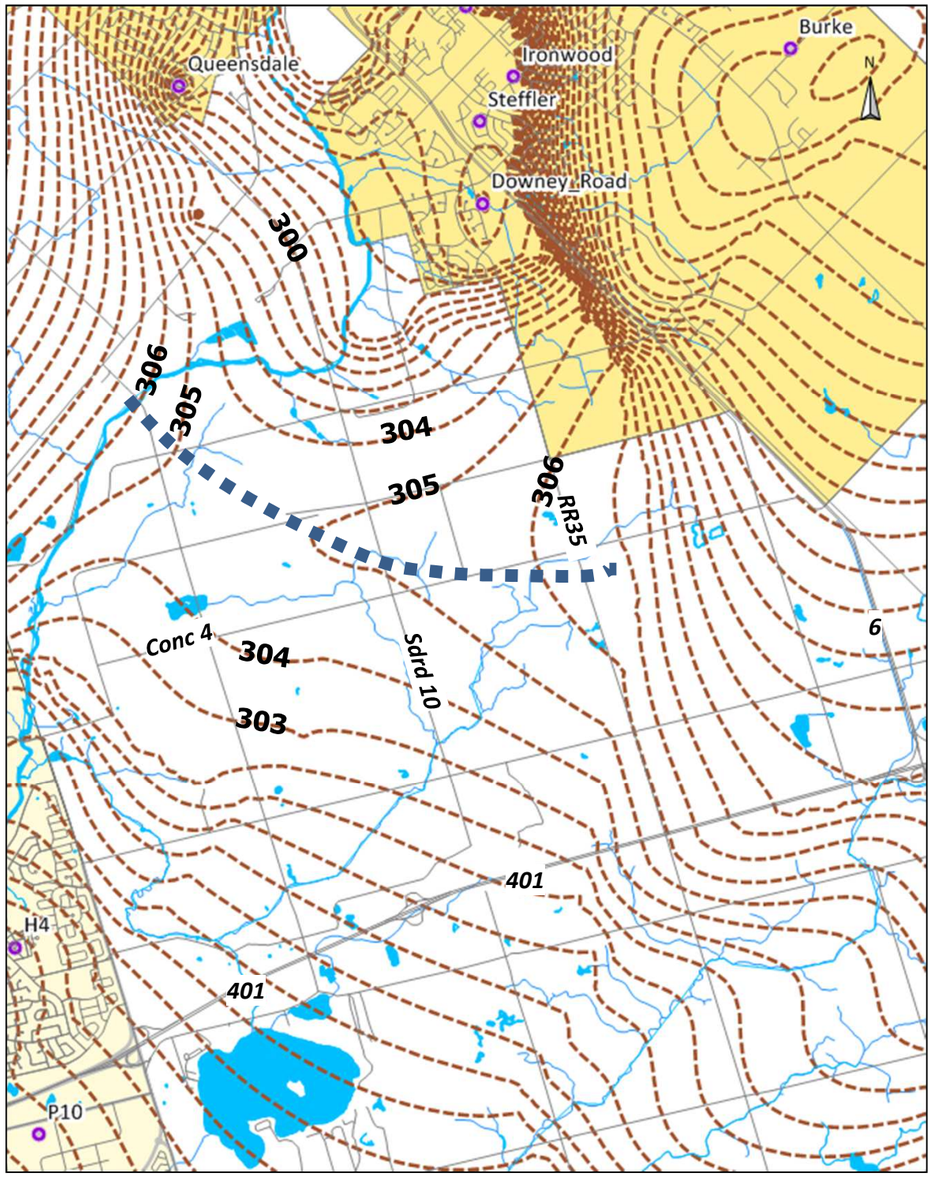
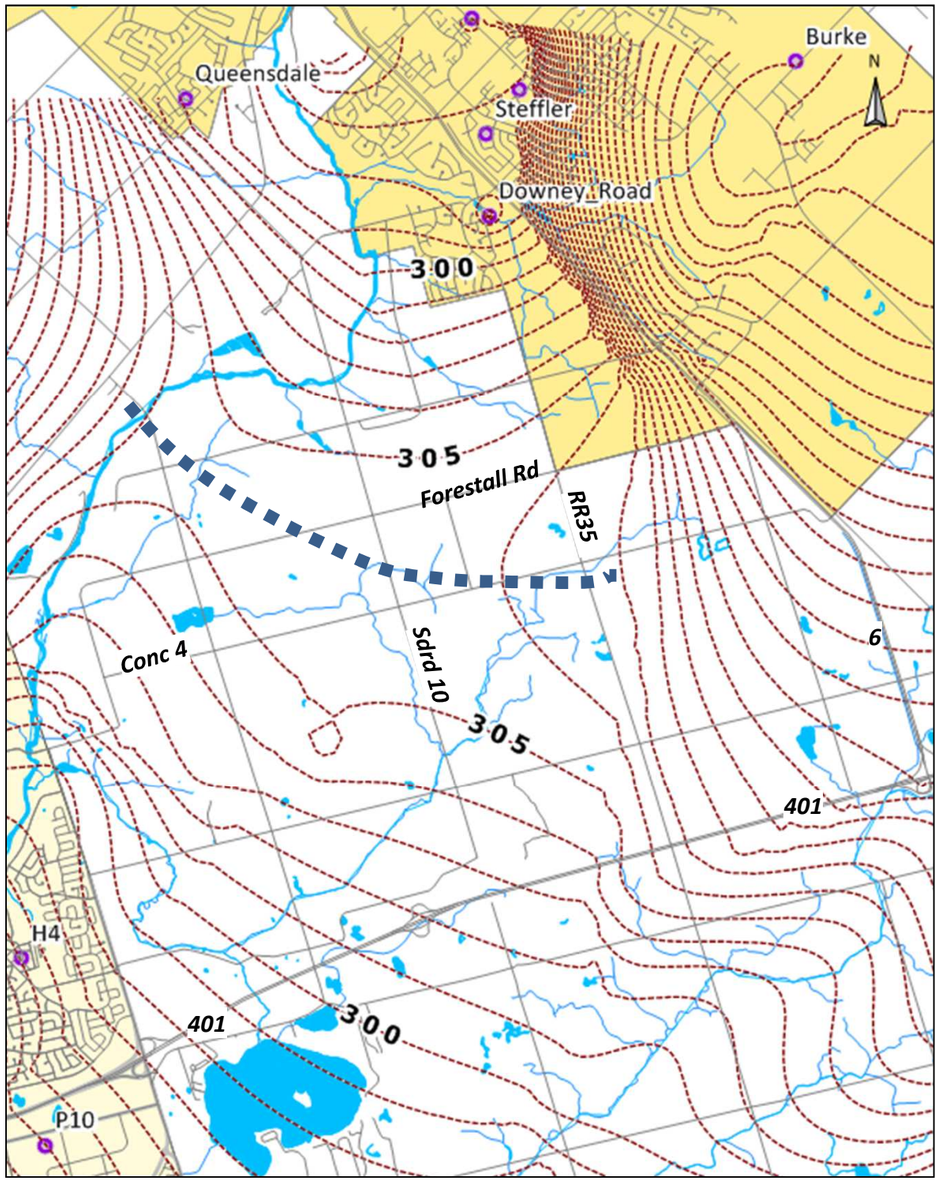
Figure 3: Region of Waterloo Local Area B

Simulated Water Levels – Guelph/GET Model



Simulated Water Levels – Cambridge Model



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Lakes
- Roads
- Streams
- City of Guelph Boundary
- Region of Waterloo Boundary
- Municipal Wells
- Cambridge Model Boundary
- Groundwater Level Elevations (masl)
- Interpreted Groundwater Flow Divide

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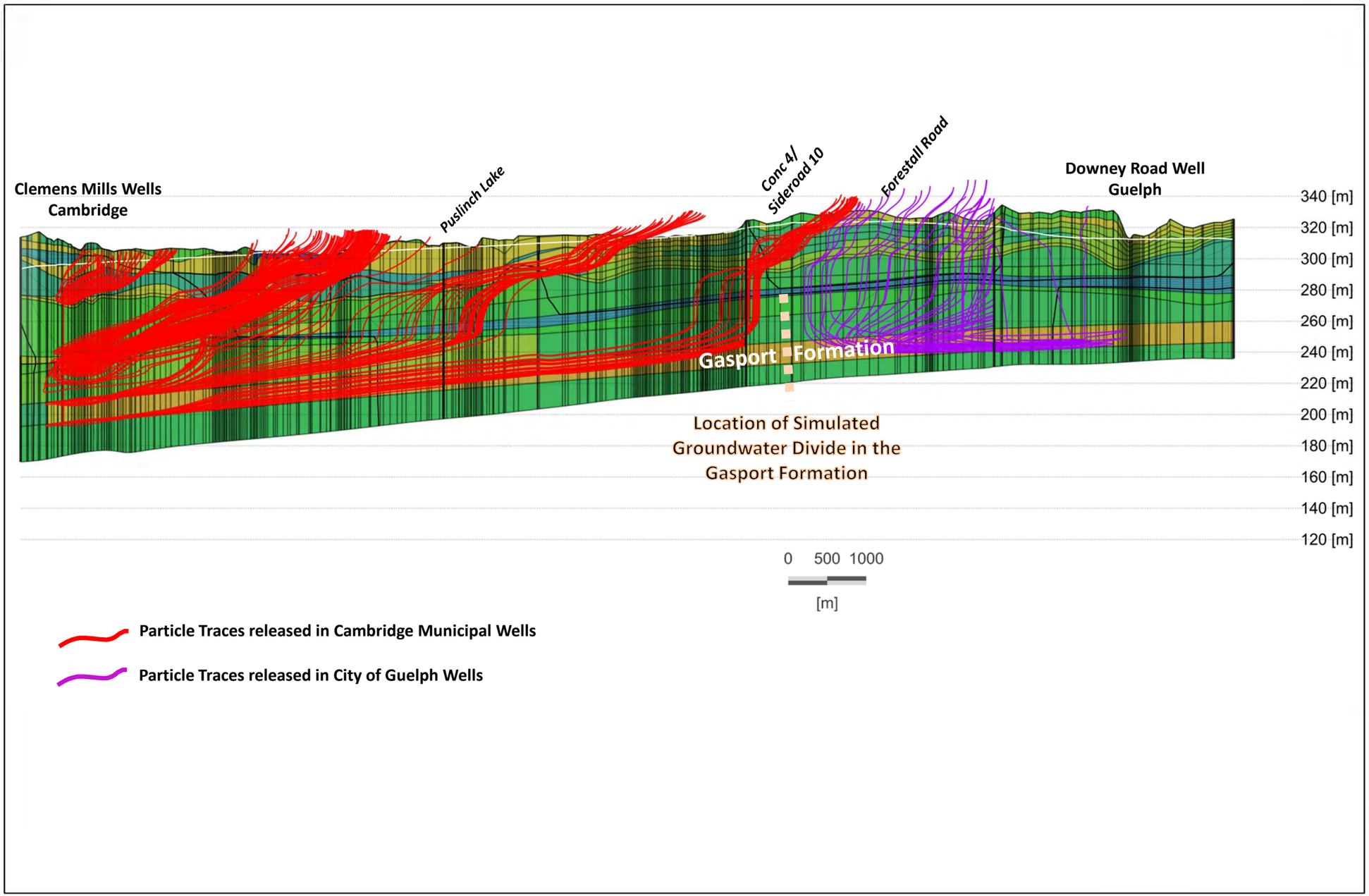
Figure 4: Simulated Groundwater Level Elevations – Gasport Formation



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

Simulated Hydraulic Conductivity (m/s)

- 0.01
- 0.001
- 0.0001
- 1e-05
- 1e-06
- 1e-07
- 1e-08
- 1e-09
- 1e-10

Simulated Hydraulic Head Contour (m)

Simulated Water Table

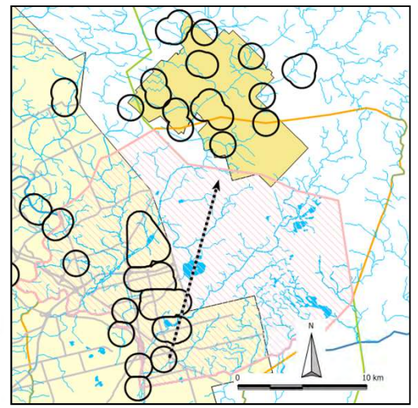


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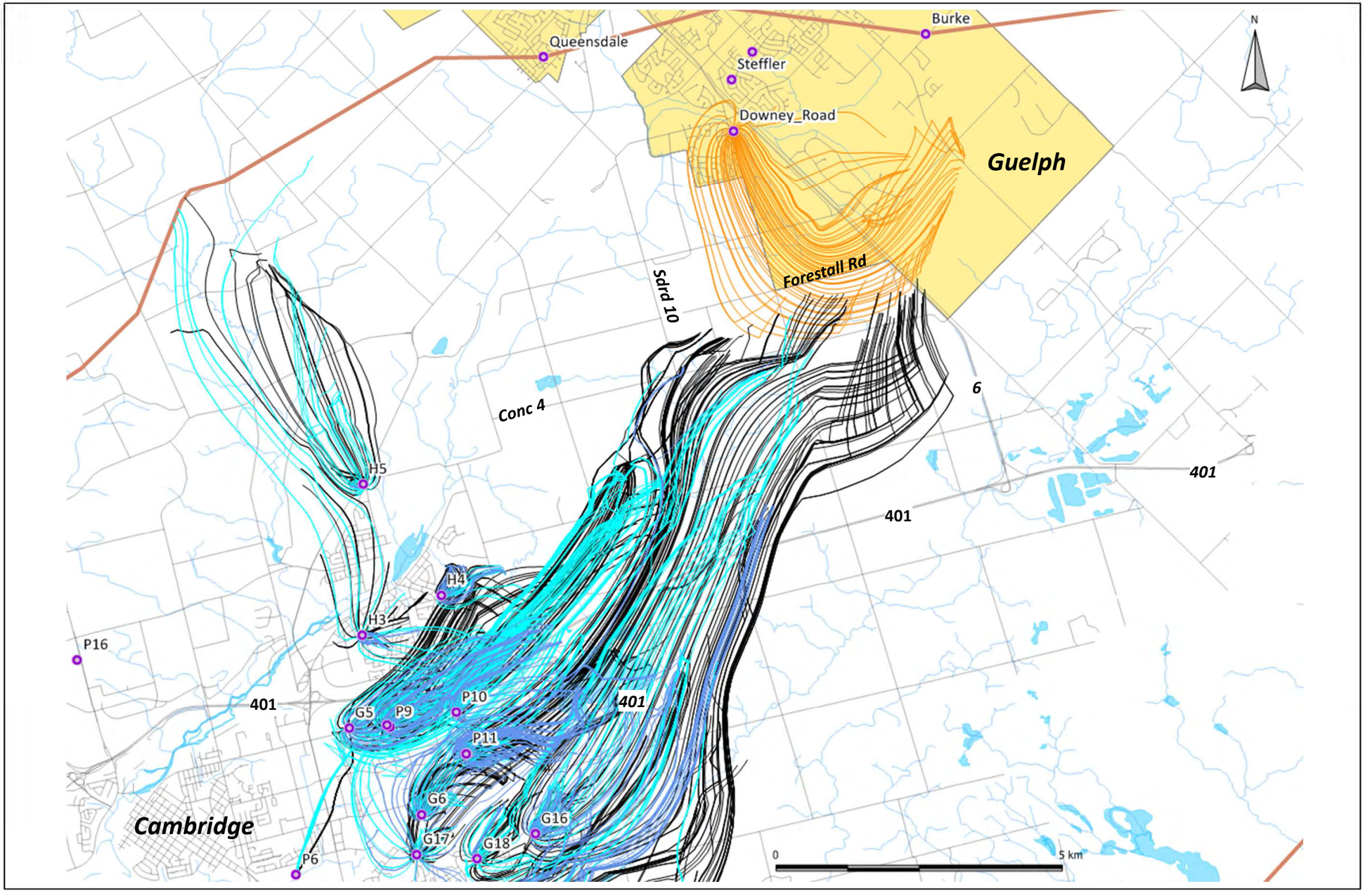
Figure 5: Backward Tracking Particle Traces – Cross-Section Through Cambridge Model



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers and Streams
- Lakes
- Cambridge Model Domain
- City of Guelph Municipal Boundary
- Region of Waterloo Municipal Boundary

Region of Waterloo Model

- Particle Pathlines 1
- Particle Pathlines 2
- Particle Pathlines 3
- Particle Pathlines – Downey Well

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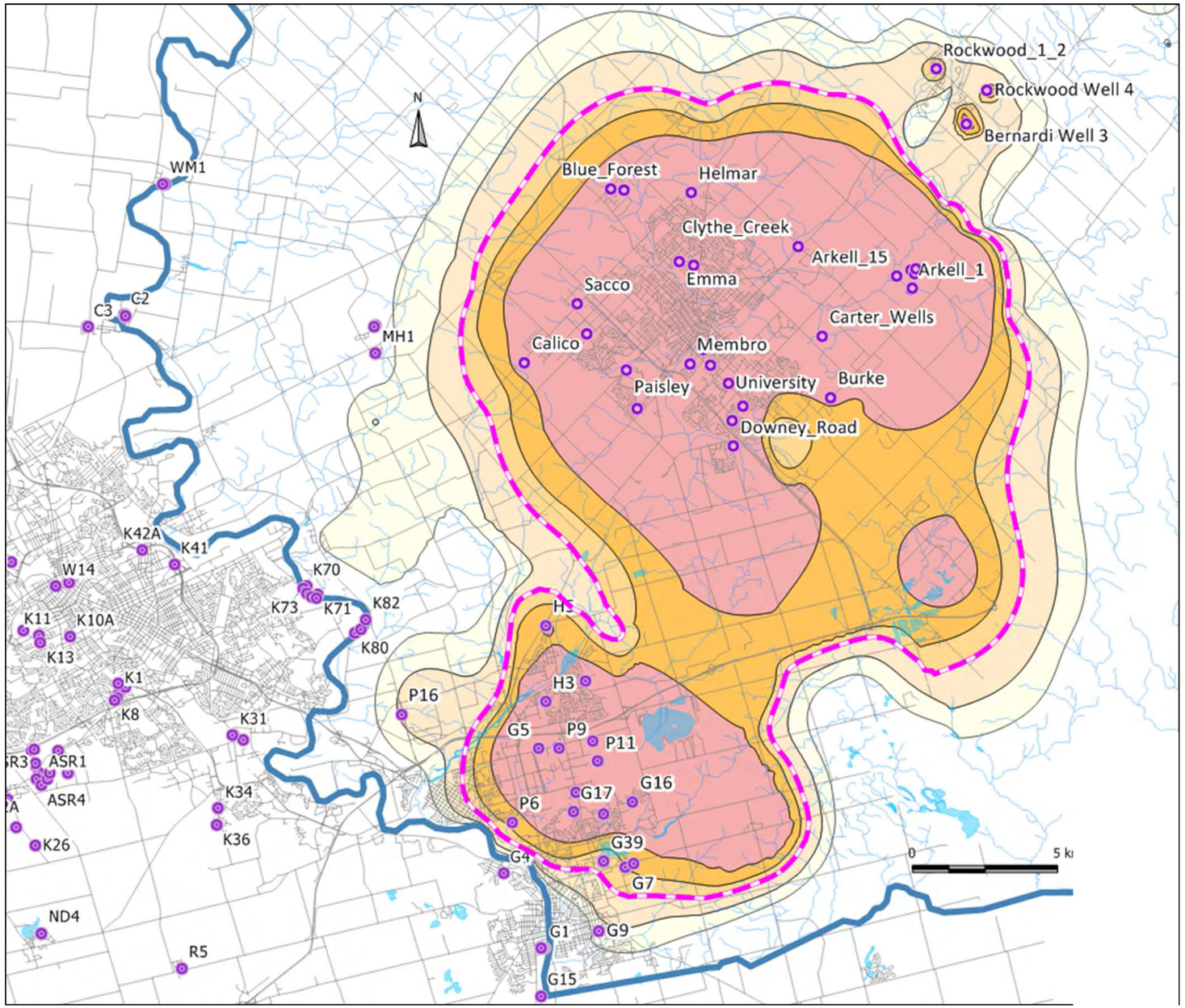
Figure 6: Backward Tracking Particle Traces in Cambridge Model



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers/ Streams
- Lakes
- Guelph FEFLOW Model Boundary

Simulated Drawdown in Gasport Fm

- 0.50 - 1.00 m
- 1.00 - 2.00 m
- 2.00 - 3.00 m
- 3.00 - 5.00 m
- > 5.00 m
- Guelph WHPA-Q1/Q2

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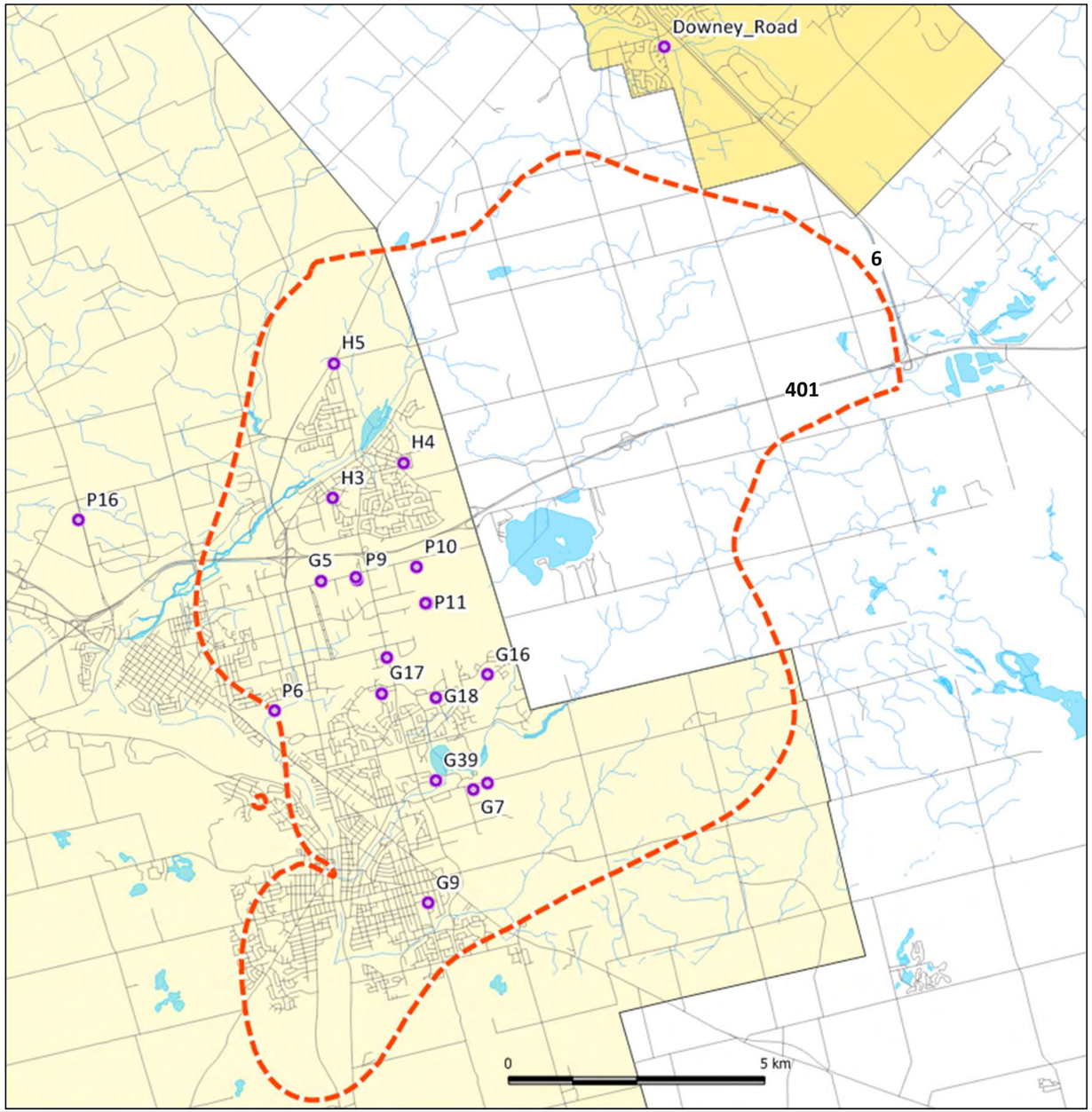
Figure 7: Simulated drawdown in the Gasport Fm (Guelph Model)



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- ROW Local Area B

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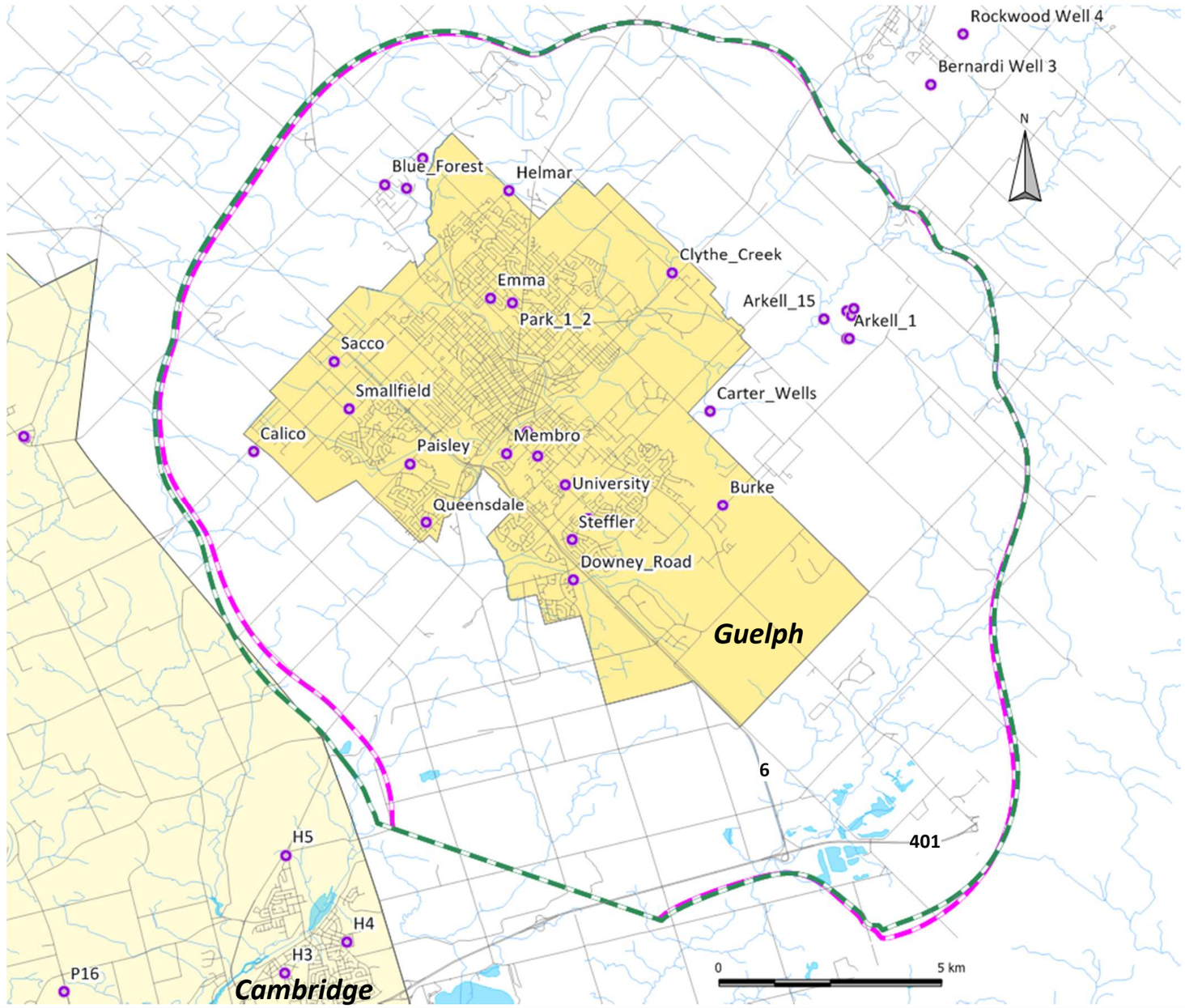
Figure 8: Region of Waterloo Local Area B



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- Previous Guelph Local Area A
- Revised Guelph Local Area A

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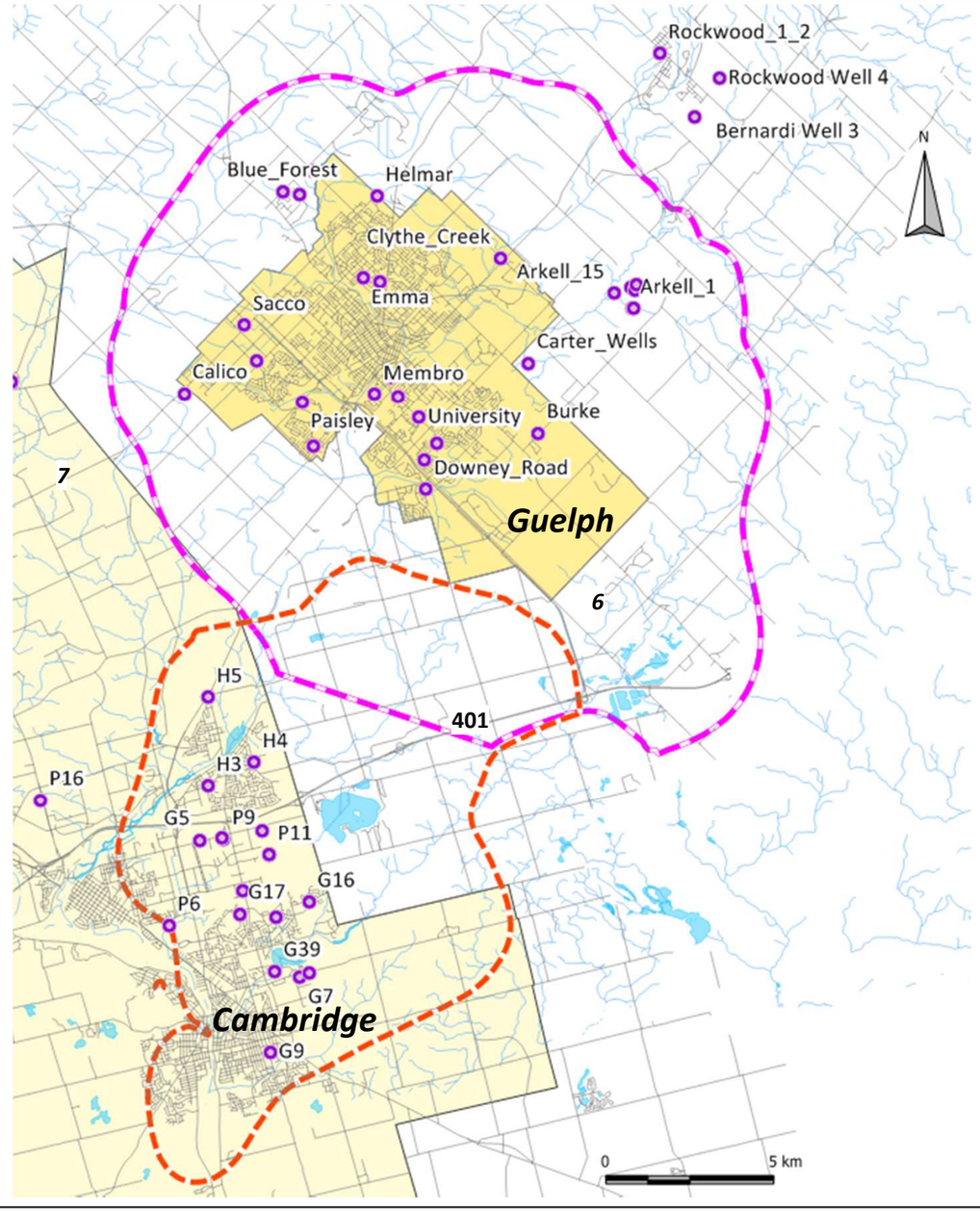
Figure 9: Guelph/GET Local Area A (2014 and 2016)



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- Region of Waterloo Local Area B
- Guelph Local Area A

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Figure 10: Region of Waterloo and City of Guelph/GET Local Areas

APPENDIX A

Assessment of the Impact of Updates to the Guelph/GET Model on the Cambridge Model

As part of the Guelph-Guelph/Eramosa Tier Three Assessment, updates were made in the Guelph/GET groundwater flow model in the Guelph and Puslinch Lake area after the Region of Waterloo Tier Three Assessment was completed. Consequently, some of the input parameters applied in the Cambridge Model and the Guelph/GET model are inconsistent; however, the inconsistencies in the parameters and boundary conditions lie over 5 km away from the Cambridge municipal water supply wells. However, as the WHPA-Q1 for Cambridge and Guelph overlap, the impact of these changes on the Cambridge water supply wells was evaluated.

A new groundwater flow model realization (herein termed the "Cambridge test model") was created using the calibrated base case Cambridge model as a starting point. The future Allocated Rates and the current land use (groundwater recharge) were assigned in the model to be coincident with Risk Assessment "Scenario G2". The parameters and boundary conditions in the Cambridge test model were updated so the model would contain all the recent changes made in the Guelph/GET model in 2015 and 2016. The following changes were made in the Cambridge test model:

1. Updates were made to the hydraulic conductivity values representing the Middle Gasport Formation layer of the model in the Dolime Quarry area of south-west Guelph. The areas where updates were made are illustrated on Figure A1. These updates are over 7 km away from the closest Cambridge water supply well (Well H5) and are separated by the municipal groundwater flow divide.

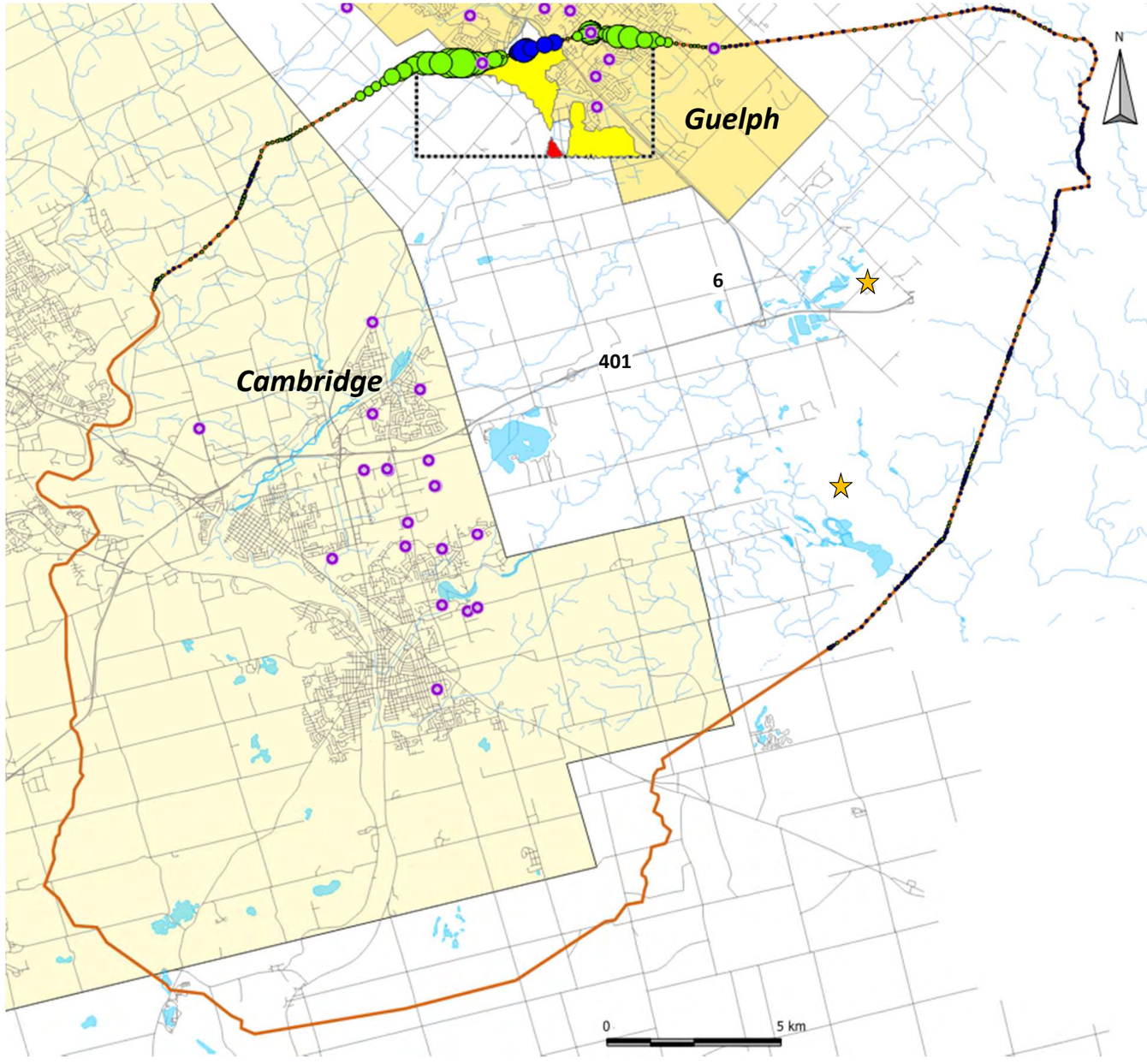
2. A hydraulic conductivity zone was added to the layer representing the Goat Island Formation in the Aberfoyle area to refine the representation of the Nestle water taking in this area. The well was previously simulated in the Gasport Formation and was updated to the Goat Island Formation, and a higher hydraulic conductivity area was added in the vicinity of the well. This change was over 13 km from the closest Cambridge water supply well (Well H4).

3. The constant head values along the perimeter of the Cambridge model were derived from the previous Guelph/GET groundwater flow model. As part of this memo, the constant heads in the Cambridge test model were updated to coincide with simulated heads in the updated Guelph/GET model. The differences between the groundwater level elevation in the current Cambridge Model and the updated test model are illustrated on Figure A1. The areas of the greatest updates to the groundwater level elevations in the Guelph area are over 10 km away from the closest Cambridge water supply well (Well H5).

4. Two large permitted water wells originally simulated in the Guelph/GET model, and subsequently removed as part of a detailed review of permits in Puslinch Township, were also removed from the Cambridge test model as the permits were in the correct locations and are expired. These two wells (Kraus Nurseries and Kats Okashimo Fish Farm) were over 10-15 km from the closest municipal water supply well (Well G16) and represent a reduction in total water taking of approximately 1,700 m^3/day (20 L/s) from the model. The locations of the two permits are illustrated on Figure A1.

To assess the potential impact of the above noted changes in model input parameters and boundary conditions on the Risk Assessment results in the Region, the Cambridge test model was run and the simulated groundwater level elevations at six water supply wells in Cambridge area were exported. The simulated groundwater level elevations in the current Cambridge model were also exported, and used to calculate the differences in elevations at the municipal wells between the two models. The changes made in the Guelph/GET model were negligible and led to negligible (1 to 4 cm) increases in groundwater level elevations at three water supply wells in Hespeler (Wells H3, H4 and H5) and three wells in the Pinebush Well Field (Wells P10, P11 and G5). The wells are located closest to the areas of model updates, and are completed across various bedrock aquifers, ensuring changes in simulated groundwater level elevations in various aquifers would be assessed by one or more wells.

In summary, inconsistencies between the model boundary conditions and hydraulic conductivity values in the Cambridge and Guelph/GET models in the Puslinch Township area exist; however, these were determined to have no impact on the groundwater levels at the municipal wells within the Cambridge area, and therefore, will not impact the Risk Assessment results in the City of Cambridge. Many of the changes are located near the northern boundary of the Cambridge model where it would be unfit to be applied to make predictions, as the boundary conditions in that area would influence the model results. The Guelph/GET model is recommended for use in this south Guelph area.



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Updated Guelph Model Area
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary

Revised Kx (m/s)

- Changed from 8e-5 to 5e-4
- Changed from 5e-4 to 1e-4

***Updated Guelph Model Heads - Existing Cambridge Model Heads**

Guelph/GET Model heads higher than Cambridge Model heads

- -6...-4 m
- -4...-2 m
- -2...-1 m
- -1...0 m
- 0...1 m
- 1...2 m
- 2...4 m
- 4...6 m
- 6...8 m

Guelph/GET Model heads lower than Cambridge Model heads

- Inactive Permit to Take Water

*Note: head difference calculation uses simulated heads in the Middle Gasport Fm.

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Figure A1: Differences between Cambridge Model and Revised Guelph/GET Model