GROUNDWATER VULNERABILITY ASSESSMENT PEER REVIEW

AUSABLE BAYFIELD MAITLAND VALLEY
SOURCE PROTECTION REGION

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1. INTRODUCTION AND SCOPE

WESA Inc. (WESA) and karst expert Daryl Cowell were retained by the Ausable Bayfield Maitland Valley (ABMV) Source Protection Region (SPR) to complete a peer review of the groundwater vulnerability assessments for their region.

The peer review comments and opinions outlined below pertain to the municipal technical study completed by Waterloo Numerical Modelling Corp. (WNMC), International Water Supply (IWS) and B.M. Ross and Associates (B.M. Ross), documented in the *Draft Report for Well Head Protection Area Delineation Project* (WNMC, draft 2009). The following documents received subsequently were not provided with the original document and were also included in our review:

- Appendix G;
- New figures (21 smaller scale figures to provide additional details supplementing Figures 4-1-1 to 4-1-6); and
- A technical memorandum (Golder, 2010) containing new analyses for the Harriston drinking water system (DWS).

The general objectives of the peer review were to (1) assess compliance to the Ontario Ministry of the Environment (MOE) Technical Rules (December 12, 2008); and (2) to provide oversight on decisions made during the development of the groundwater vulnerability analysis which required professional judgment. With respect to the above study, this was confined to the development of the groundwater flow models and focused on the data and assumptions that were used in developing, calibrating and running the models.

The specific objectives of the groundwater vulnerability assessment peer review were to address the following questions:

- Does the vulnerability assessment conform with the requirements of the provincial Technical Rules?
- Was the adopted methodology adequate, in particular with respect to the local settings and data availability?
- Is the documentation adequate of the analyses and results, including discussion of the assumptions and limitations?
- Are the study results, interpretations and recommendations reasonable?

2. APPROACH AND REPORT ORGANIZATION

The peer review focused primarily on the following elements: (1) Data sets used to characterize hydrogeologic conditions within each model domain; (2) Conceptual geological model that forms the basis for the numerical model; (3) Appropriateness of boundary conditions established for each model domain; (4) Calibration of each model relative to the ability of the model to reasonably represent observed groundwater conditions; (5) Application of the model in order to develop wellhead protection areas (WHPAs); (6) Appropriateness of any modifications of vulnerability scores from those stipulated in the guidance; and (7) Appropriateness of the level of uncertainty (as defined in MOE Guidance) outlined in the report.

3. SUMMARY OF DRINKING WATER SYSTEMS

Table 1 lists the DWS for each municipality included in the study (WNMC, draft 2009), including:

1) Township of Ashfield-Colborne-Wawanosh
2) Municipality of Bluewater
3) Municipality of Central Huron
4) Municipality of Huron East
5) Municipality of North Huron
6) Municipality of Morris-Turnberry
7) Township of Minto
8) Municipality of North Perth

A total of 25 DWS including 43 individual water supply wells were included in eight separate groundwater flow models, in order to delineate the WHPAs.

The details about each well, extracted from WNMC (draft 2009) are summarized in Table 1, along with the model where they were simulated, relevant report sections and figures, as well as any additional pertinent information. Table 2 also lists each of the DWS and corresponding supply wells included in the WNMC (draft 2009) study, but organized according to the groundwater flow model they are included in.

4. DOCUMENTATION AND REFERENCING

4.1 GENERAL

In general, the WNMC (draft 2009) report requires a detailed review to address a significant number of editorial issues in the text, including numbering and referencing of tables and figures, as well as content such as map legends and scales. Appendix B (*Municipal Well Information*) and Appendix C (*Municipal Well Decommissioning Information*) were not available for review.

The general comments provided below apply to the document reviewed as a whole, followed by comments and issues related to individual models which are provided in separate subsections, where issues such as missing or incomplete documentation as well as inconsistencies in the text are outlined.

The general issues outlined below should be addressed as a priority to ensure that the work complies with the MOE Technical Rules (December 12, 2008). However, more specific issues identified throughout the report should also be addressed. The priority issues include:

- The status of each of the wells in the study with respect to groundwater under the direct influence of surface water (GUDI) is not presented or discussed. The GUDI status is needed to determine if WHPA-E are needed as part of the vulnerability assessment, in order to comply with the MOE Technical Rules; and
- Modifications to the vulnerability score associated with preferential transport pathways within each WHPA is not presented or discussed. Vulnerability scores need to take into consideration anthropogenic transport pathways to conform with the MOE Technical Rules;

Additionally, the following cross-referencing discrepancies or omissions were noted in the draft report and should be addressed in the final report:

- Figures: the legends and labels should be verified for accuracy and clarity; several legend entries are labeled generically as “Lines”, “Areas”, “Yes”, “No”, etc.

- Section 7.0 (*References*) is missing some of the documents that are referenced in the report in the following sections:
    - Section 1.1.1, Section 1.2.3, Section 1.1.3, Section 1.2.7, Section 2.1, Section 2.5.3, Section 2.7.1, Section 2.7.2, Section 2.7.4, Section 2.7.5, Section 2.8, Section 3.2.1, Section 3.2.2, Section 3.2.5, Section 3.4.1, Section 3.4.2, Section 3.4.3. Section 3.4.5, Section 3.5.1, Section 3.5.2, Section 3.6.1, Section 3.7, Section 3.8 and Section 3.9.
- Section 2.4 states that the physiographic regions are shown in Figure 2-4-1; however this figure appears to show the surficial quaternary geology (presented on Figure 2-5-1), rather than the physiography of the region;
- Section 2.7.2 refers to Section 3.5.1 as describing karst bedrock features; however this is inconsistent with Section 3.5.1 in this report.
- Section 2.7.5 refers to Figure 3.1 and Figure 3.2 under Watertable Susceptibility and Bedrock Susceptibility but this is inconsistent with the figures and figure numbers of this report. Similarly, a reference to Section 2 is inconsistent with Section 2 of this report.
- Table 3-1 (in Section 3.1) does not include the Brussels (North Huron model) and Harbour Lights (Huron West) municipal well fields.
- Section 3.3.4 refers to Table 3.3-1 but there is no such table in the report. It likely should refer to Table 3-5.
- Figure 4-1-5 (in Section 4.5) and Figure 4-1-6 (in Section 4.6) are identical; similarly Figure 5-1-5 (in Section 5.5) and Figure 5-1-6 (in Section 5.6) are identical. Reference to Figure 4-1-6 in Section 4.5 should be referenced as Figure 4-1-7 and reference to Figure 5-1-6 in Section 5.5 should be referenced as Figure 5-1-7.
- The title of Appendix G and the titles on the figures in Appendix G should read "Huron West" instead of "West Huron" to be consistent with the rest of the report and model nomenclature.

4.2 TOWNSHIP OF ASHFIELD-COLBORNE-WAWANOSH (ACW)

There are no specific documentation and referencing issues.

4.3 MUNICIPALITY OF BLUEWATER

Section 1.2.2 states that the Municipality of Bluewater has three communities that are serviced by a total of seven wells. However, upon closer examination these three communities appear to be serviced by only four wells.

4.4 MUNICIPALITY OF CENTRAL HURON

There are no specific documentation and referencing issues.

4.5 MUNICIPALITY OF HURON EAST

Section 1.2.3 states that there are three wells that supply the community of Seaforth but Figure 1.2 well labels show two wells that are not part of the Seaforth DWS. The three new wells that are part of the Seaforth DWS are TW1, PW1 and PW2 and WESA (2009) should be referenced since the report has been finalized.

4.6 MUNICIPALITY OF NORTH HURON

Section 1.2.5 (*Belgrave* subheading) states that the "Jane and McCrae Well" was decommissioned in 2008. This is inconsistent with Section 1.2.6 *Belgrave*, where two active wells are identified (Jane Street Well and McCrae Street Well).

Section 3.2 "North Huron and Molesworth" (the name of the model) is inconsistent with the rest of the report including Tables 3-1, 3-2, 3-3 and 3-4 where the model is referred to as "North Huron".

4.7 MUNICIPALITY OF MORRIS-TURNBERRY

Section 1.2.5 (*Belgrave* subheading) states that the "Jane and McCrae Well" was decommissioned in 2008. This is inconsistent with Section 1.2.6 *Belgrave*, where two active wells are identified (Jane Street Well and McCrae Street Well).

4.8 MINTO TOWNSHIP

Section 3.7 "Town of Minto" (the name of the model) is inconsistent with the rest of the report including Tables 3-1 where the model is referred to as "Minto Township".

4.9 MUNICIPALITY OF NORTH PERTH

Section 3.9 "Listowel & Gowanstown" (the name of the model) and Table 3-18 and 3-19 is inconsistent with the rest of the report including Tables 3-1 where the model is referred to as "North Perth".

5. REVIEW OF VULNERABILITY ASSESSMENT

In this section, comments are provided in relation to the groundwater vulnerability assessment presented in Section 3.0 and subsections in WNMC (draft 2009). General comments are presented in the next section that are pertinent to the entire study area and/or apply to all models, while the following sections provide our comments specific to each individual model.

5.1 GENERAL COMMENTS

The following observations apply to the study as a whole, while comments pertaining to the individual groundwater models are provided in the subsequent subsections.

- Given the relatively large scale of most figures it is often difficult to determine if a WHPA A (100 m zone) was delineated for each of the wells in various drinking water systems (DWS). A WHPA A is needed in order to be compliant with the requirements of the MOE Technical Rules (December 12, 2008).
- As noted above in Section 4.1 (Documentation and Referencing), a vulnerability score adjustment to account for constructed preferential (transport) pathways does not appear to have been completed within the WHPAs. This should be completed in order to be compliant with the requirements of the MOE Technical Rules (December 12, 2008).

- It is difficult to differentiate between the vulnerability scores presented in the figures contained within the report reviewed and the WHPAs as presented in the figures subsequently provided by WNMC for review since the colour schemes are the same.
- Revised figures presenting the vulnerability scoring for each DWS on a smaller scale would be useful – review of the vulnerability scoring has been limited to what can be discerned at the relatively large scale of the figures provided.
- A map of the interpreted potentiometric surface would be useful to compare against the boundary conditions defined for each model, and also against model results (simulated heads and groundwater flow directions and velocity).
- The approach used to generate WHPAs, by combining results from several sensitivity scenarios to create "composite WHPAs", produced in some cases results that may be somewhat unrealistic and may have produced WHPAs that are overly conservative; a better approach may have been to present the "best estimate" WHPA developed using the calibrated model which corresponds to the best match to the hydrogeologic conditions, as observed from the available water level data.
- It is not clear which surficial geology mapping has been used in each of the studies but reference to "Quaternary" mapping suggests the 1:50,000 Quaternary/Surficial mapping (available for entire area) rather than 1:1 million Quaternary and/or 1:1 million Chapman and Putnam Physiography of Southern Ontario mapping – this should be confirmed as the models include several surficial layers.
- Individual well studies should be considered for future work at all systems with potential for karst influence; these studies should consider water quality, chemistry (temperature and specific conductance); and bore hole characteristics (well logs; video logging [where possible]).
- The Huron County study (WNMC et al., 2003) considered the Bois Blanc and Dundee Formations as having low permeability but the Lucas being karstic; the Perth County study (WHI, 2003) noted a sharp decrease in well water levels at the contact between the Lucas and Dundee Formations which they equated to karst; the Wellington County study (Golder, 2006) considered bedrock as a single unit to the base of the Amabel Formation (to the Cabot Head).
- The WNMC report identified the presence of karst sinkholes from former karst studies but did not seem to incorporate this into the ISI – "should be given special consideration"; conversely the Perth County ISI incorporated known sinkholes including surface and bedrock layers (higher susceptibility). A consistent approach should be adopted to map

the ISI across the study area, in particular within the WHPAs where any available local data should be utilized.

- Although commonly used and probably reasonable in most layers, it is uncertain if the ratio of 10:1 specified in the models for the horizontal to vertical hydraulic conductivity of the bedrock is appropriate; given the karst nature of some bedrock units, this may not be appropriate. It should be noted that a ratio of 1:1 was used in the Zurich model, but no justification or rationale was provided.

5.2 NORTH HURON MODEL

The general approach in the North Huron model development appears to be reasonable. Although references to model details were provided in WNMC (draft 2009), it should be noted that there were no specific model details available for review. The following comments are based solely on text and the available model output as presented in the figures provided.

5.2.1 COMMENTS ON MODEL

The following are summary comments on the North Huron Model:

- The conceptual model incorporated 5 overburden layers and 1 bedrock layer representing the depth interval from the upper bedrock to the bottom of the screens. The bottom of the model was set in bedrock at 100 m below ground surface. However the bedrock formation(s) are not specified. The Bedrock Geology of Ontario map (Map 2544) and corresponding report figure (Figure 2-5-2) indicates that the Dundee Formation forms the uppermost bedrock unit to the west and south of Blyth and the Detroit River Group (possibly Onondaga) at Blyth as well as to the north and east.
- Model calibration included estimated recharge rates between 20 and 100 mm/yr which appear reasonable given the range of surficial materials in the area.
- The NRMS of 2.423% is excellent, however the calibration plot of observed vs. simulated heads and associated geological cross-sections were not available for review. Hydraulic conductivity for the bedrock unit(s) represented in Layer 6 of the model was reported as 2×10^{-5} to 1×10^{-4} m/s, but it is not clear how this was assigned, for example was it based on lithology.
- The Lucas Formation is known to be karstic and as such it is possible that the pumping wells may draw their supply from karst conduits; this may imply that the hydraulic conductivity values in the immediate vicinity of the wells may be higher locally compared

to locations where karst conduits are not present. Since the model is well-calibrated, we can conclude that any karst conduits that may be present are represented adequately in the bulk hydraulic conductivity estimated from model calibration.

5.2.2 Karst Aspects

The Dundee Limestone contains chert and bituminous partings and tends to have a lower permeability than other carbonate units in the area. The Huron County report (not fully available for review) assigned a lower permeability to the Dundee than the Lucas which they considered to be karstic.

The eastern and northern communities including Wingham, Molesworth, Belgrave and Auburn Hills, likely draw water from the Detroit River Group whereas the other communities may draw water from the Dundee or the Detroit River Group. Although the mapping indicates that the Detroit River Group is represented by the Onandaga Formation, this is unlikely as this unit occurs in the Niagara Peninsula area whereas the study area contains the Lucas and Amherstburg formations (Johnson et al. 1992). The Lucas is the uppermost Formation in this area and, given the depth of the wells, could potentially supply all systems with the exception of the Dungannon well which only penetrates the upper portion of the bedrock unit.

It is not clear from the information provided to what degree any of the wells may be influenced by karst, but those wells completed to the Lucas Formation should be considered karstic until proven otherwise. Interestingly, recent sinkhole mapping studies undertaken in Huron and Perth counties in the early 2000's identified a number of sinkholes in the Brussels area to the east of Blyth. These sinkholes are free-draining which suggest they must "window" somewhere down gradient in the direction of Lake Huron (the ultimate base level).

5.2.3 Critical Issues and Deficiencies

Based on the information available for review, the following are critical issues and deficiencies that should be addressed:

- Given the relatively large scale of Figures 4-1-1-C and 4-1-4-E it is difficult to determine if a WHPA A (100 m zone) was delineated for the Century Heights, Benmiller and Wingham drinking water systems (DWS). A WHPA A is needed in order to be compliant with the requirements of the Terms of Reference (December, 2008);

- The location of the well for Molesworth DWS is not consistent with the WHPA in particular for WHPA A (100 m zone); and
- WHPA B seems very small for Brussels Well No. 2 (Turnberry St). This may be reasonable but it is difficult to verify this based on the data and documentation available for review.

5.2.4 Opportunities for Improvement

Based on the information available for review, the following are opportunities for improvement that should be addressed in any future initiatives:

- Figures similar to those provided for other models in Appendices D to G would be useful additions to summarize the model construction details and results, without having to refer to previous reports where the original model was documented.
- Address the issues raised in the Critical Issues or Deficiencies section (Section 5.2.3).
- Address the issues identified in the Documentation and Referencing section (Section 4.1, 4.6 and 4.7).
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- The areas surrounding the wells should be investigated for karst surface features, including the determination of potential karstic recharge and/or discharge to surface streams. Water quality testing of stream flows into the sinkholes in the Brussels area conducted by the Conservation Authority should be checked against all municipal well chemistry down gradient (including Blyth) to determine the potential for karstic interaction with the well supply.

5.3 Zurich Model

5.3.1 Comments on Model

The following are summary comments on the Zurich Model (Section 3.3 and Appendix D):

- The general approach in the Zurich model development appears to be reasonable.

- The Zurich model includes five overburden and three bedrock layers. Bedrock hydraulic conductivities (bottom three model layers) ranging between $5x10^{-5}$ to $1x10^{-4}$ m/s were assigned based on layer thickness of 25 m, 25 m, and 50 m, respectively. It is not clear how these were assigned in the model but Figure D8 shows only one bedrock layer with the lower conductivity value covering most of the model domain and the higher conductivity occurring in the southwest corner of the domain.
- The calibration plot of well heads had a NRMS of 6.3% which is reasonable, however there appears to be very few bedrock wells included in the calibration plot (Figure D11).

5.3.2 Karst Aspects

Zurich is underlain by the Dundee Formation which was considered to be of lower permeability than the Lucas in the Huron County modeling. The same study considered the latter to be karstic and this has been confirmed by others (D. Brunton, Ontario Geological Survey, personal communication to D. Cowell). The Zurich wells may be deep enough to draw water from the Lucas Formation beneath the Dundee Formation. Interestingly, recent sinkhole mapping studies undertaken in Huron and Perth counties in the early 2000's identified a number of sinkholes in West Perth to the east of Zurich. These sinkholes are free-draining which suggest they must "window" somewhere down gradient in the direction of Lake Huron (the ultimate base level). However, surface karst in the area surrounding the Zurich wells are not likely significant given the presence of up to 30 m thick overburden materials.

It is not clear from the information provided to what degree the wells may be under the influence of karst but if completed to the Lucas Formation should be considered karstic until proven otherwise. The assigned hydraulic conductivities may be too low for the Lucas Formation, particularly if karst conditions occur within the supply zone.

5.3.3 Critical Issues and Deficiencies

Based on the documents reviewed there are no critical issues or deficiencies in relation to the hydrogeologic conceptual model, numerical model design, calibration or uncertainty analysis. The model, modelling results and vulnerability analysis completed are based on reasonable professional judgment and are technically defensible decisions.

5.3.4 Opportunities for Improvement

Based on the information available for review, the following are issues that should be addressed:

- Address the issues identified in the Documentation and Referencing section (Section 4.1 and 4.3).
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- Actual hydraulic conductivities should be determined for each well completed in the Lucas Formation. In addition, the areas surrounding the wells should be investigated for karst surface features, including the determination of potential karstic recharge and/or discharge to surface streams. Water quality testing of stream flows into the sinkholes in West Perth area conducted by the Conservation Authority should be checked against all municipal well chemistry down gradient (including Zurich) to determine the potential for karstic interaction with the well supply.
- The Lucas Formation is known to be karstic and as such it is possible that the pumping wells may draw their supply from karst conduits; this may imply that the hydraulic conductivity values in the immediate vicinity of the wells may be higher locally compared to locations where karst conduits are not present. Since the model is well-calibrated, we can conclude that any karst conduits that may be present are represented adequately in the bulk hydraulic conductivity estimated from model calibration.

5.4 Clinton Model

5.4.1 Comments on Model

The following are summary comments on the Clinton Model (Section 3.4 and Appendix E):

- The general approach in the Clinton model development appears to be reasonable in that the Clinton model includes three overburden and four bedrock layers. The hydraulic conductivities for the Lucas Formation were set to $2x10^{-4}$ m/s around the wells and $1x10^{-3}$ in the southwestern zone of the domain. The Dundee Formation which overlies the Lucas Formation is represented as one bedrock layer with a significantly lower conductivity value of $1x10^{-12}$ m/s and covers the whole model domain.
- The calibration plot (Figure E11) of well heads had a NRMS of 3.70% which is good, as is the absolute residual mean of 2.70 m.

- A vertical recharge rate of 10 mm/year seems a bit low when compared to the adjacent model for Brucefield where the recharge rate is sited to be estimated at 50% greater (15 mm/year).

5.4.2 KARST ASPECTS

The conceptual model for Clinton included an open bedrock interval through the Dundee and Lucas formations. The Lucas is confined and is believed to have higher transmissivity associated with karst features aligned northeast to southeast. Surface karst in the area surrounding the wells is not likely significant given the presence of more than 50 m of overburden materials.

Although the nature of the underlying evidence for karst is not confirmed, the Clinton water supply model has appropriately incorporated karstic flow conditions within the main supply zone. The predicted versus observed heads within the bedrock zone are reasonable and appear to confirm the assumptions.

5.4.3 CRITICAL ISSUES AND DEFICIENCIES

Based on the documents reviewed there are no critical issues or deficiencies in relation to the hydrogeologic conceptual model, numerical model design, calibration or uncertainty analysis. The model, modelling results and vulnerability analysis completed are based on reasonable professional judgment and are technically defensible decisions.

5.4.4 OPPORTUNITIES FOR IMPROVEMENT

Based on the information available for review, the following are issues that should be addressed:

- Address the issues identified in the Documentation and Referencing section (Section 4.1).
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- Actual hydraulic conductivities should be determined for each well completed in the Lucas Formation and the model adjusted as may be necessary.

- The Lucas Formation is known to be karstic and as such it is possible that the pumping wells may draw their supply from karst conduits; this may imply that the hydraulic conductivity values in the immediate vicinity of the wells may be higher locally compared to locations where karst conduits are not present. Since the model is well-calibrated, we can conclude that any karst conduits that may be present are represented adequately in the bulk hydraulic conductivity estimated from model calibration.

5.5 BRUCEFIELD MODEL

5.5.1 COMMENTS ON MODEL

The following are summary comments on the Brucefield Model (Section 3.5 and Appendix F):

- The general approach in the Brucefield model development appears to be reasonable in that the Brucefield model includes three model layers representing the overburden and six model layers representing the bedrock. The hydraulic conductivity for the Lucas Formation was set to $1x10^{-4}$ m/s. The Dundee Formation which overlies the Lucas Formation is represented as three bedrock layers which all have significantly lower conductivity values of $1x10^{-12}$ m/s and covers the whole model domain although the layer thins out towards the west.
- The calibration plot (Figure F9) of well heads had a NRMS of 4.83% which is good, as is the absolute residual mean of 3.66 m.
- A vertical recharge rate of 15 mm/year seems reasonable given the description of the overburden but is 50% greater than the recharge rate in the Clinton model (10 mm/year).

5.5.2 KARST ASPECTS

The conceptual model for Brucefield included an open bedrock interval through the Dundee and Lucas formations and the latter is confined. The model incorporated six bedrock layers including three for the Dundee Formation.

Recent sinkhole mapping studies undertaken in Huron and Perth counties in the early 2000's identified a number of sinkholes in West Perth to the southeast of Brucefield. These sinkholes are free-draining which suggest they must "window" somewhere down gradient in the direction of Lake Huron (the ultimate base level). However, surface karst in the area surrounding the

Brucefield well is not likely significant given the presence of 30 to 40 m thick overburden materials.

The bedrock conductivity for the Brucefield water supply model has hydraulically separated flow in the Lucas Formation from the overlying Dundee Formation. It is the reviewer's opinion that a realistic hydraulic conductivity value for the Lucas Formation has been used.

5.5.3 Critical Issues and Deficiencies

Based on the documents reviewed there are no critical issues or deficiencies in relation to the hydrogeologic conceptual model, numerical model design, calibration or uncertainty analysis. The model, modelling results and vulnerability analysis completed are based on reasonable professional judgment and are technically defensible decisions.

5.5.4 Opportunities for Improvement

Based on the information available for review, the following are issues that should be addressed:

- Address the issues identified in the Documentation and Referencing section (Section 4.1 and 4.5).
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- Actual hydraulic conductivities should be determined for each well completed in the Lucas Formation and the model adjusted as may be necessary. Water quality testing of stream flows into the sinkholes in West Perth conducted by the local Conservation Authority (CA) should be checked against all municipal well chemistry down gradient (including Brucefield) to determine the potential for karstic interaction with the well supply.
- The Lucas Formation is known to be karstic and as such it is possible that the pumping wells may draw their supply from karst conduits; this may imply that the hydraulic conductivity values in the immediate vicinity of the wells may be higher locally compared to locations where karst conduits are not present. Since the model is well-calibrated, we can conclude that any karst conduits that may be present are represented adequately in the bulk hydraulic conductivity estimated from model calibration.

5.6 HURON WEST MODEL

5.6.1 COMMENTS ON MODEL

The following are summary comments on the Huron West Model (Section 3.5 and Appendix G):

- The general approach in the Huron West model development appears to be reasonable in that the Huron West model includes five model layers representing the overburden and one model layer representing the upper bedrock with a uniform thickness of 50 m.
- The hydraulic conductivity for the Lucas Formation was set to $1x10^{-4}$ m/s. The Dundee Formation which overlies the Lucas Formation is represented as three bedrock layers which all have significantly lower conductivity values of $1x10^{-12}$ m/s and covers the whole model domain although the layer thins out towards the west.
- The calibration plot (Figure G7) of well heads had a NRMS of 8.552% which is acceptable, and the absolute residual mean of 4.921 m is also acceptable.
- Vertical recharge rates of 2 mm/year (tile drained fields), 50 mm/year (non-tile drained areas with low permeability surficial geology) and 200 to 300 mm/year (surficial sand and gravels) are reasonable however the greater recharge rates of 200 and 300 mm/year may be high compared to other similar settings in Ontario.
- The model description in Section 3.6.1 of the text and Table 3-14 are inconsistent with the information presented in Appendix G. Appendix G was received as a separate submission on a later date than the draft report so is assumed to be more current but given this inconsistency it is not possible to describe the model with any degree of certainty since we cannot discern if there are 6 layers or 8 layers in the model and which layers are overburden versus bedrock. Therefore the text should be updated to match the information in Appendix G. Furthermore, the format of the model information in Appendix G should be made consistent with the model information presented in Appendices D, E and F.

5.6.2 KARST ASPECTS

All of these water supply systems consist of single wells completed into bedrock along the shore of Lake Huron. The model domain includes two bedrock layers with an assigned hydraulic conductivity of $2x10^{-5}$, based on a well performance test. The report does not specify if there was only one test. The bedrock unit(s) within the supply zones are not indicated but all locations are underlain by the Dundee Formation which in turn overlies the Lucas Formation.

The model calibration data in Appendix G suggest karstic conditions and at least one well (Huron Sands) was noted to have "karst" from 77.7 m to 94.3m. This is a rather significant interval.

The Huron Sands well is likely completed into the Lucas Formation which is known to be a karstic aquifer (as identified in the original Huron County hydrogeological report). Lake Huron is the ultimate base level for surface streams and bedrock aquifers but karst conditions could drive subsurface flows even lower than the lake level. This is suggested by the Huron Sands well where karst was found almost 100 m below the level of the lake.

5.6.3 Critical Issues and Deficiencies

Based on the documents reviewed there are no critical issues or deficiencies in relation to the hydrogeologic conceptual model, numerical model design, calibration or uncertainty analysis. The model, modelling results and vulnerability analysis completed are based on reasonable professional judgment and are technically defensible decisions.

5.6.4 Opportunities for Improvement

Based on the information available for review, the following are issues that should be addressed:

- Address the issues identified in the Documentation and Referencing section (Section 4.1).
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- Surface karst in the area surrounding the wells is not likely significant in these areas given the presence of 30 to 40 m thick overburden materials. However, each of the wells should be considered to be under the influence of karst within the supply zone. Actual in-well hydraulic conductivities should be obtained and applied to the model as necessary.
- The Lucas Formation is known to be karstic and as such it is possible that the pumping wells may draw their supply from karst conduits; this may imply that the hydraulic conductivity values in the immediate vicinity of the wells may be higher locally compared

to locations where karst conduits are not present. Since the model is well-calibrated, we can conclude that any karst conduits that may be present are represented adequately in the bulk hydraulic conductivity estimated from model calibration.

5.7 TOWN OF MINTO MODEL

This model is also referred to as the "Minto Township Model" everywhere else including Table 3-1 in the WNMC 2009 report. A consistent name used throughout the report.

The general approach in the Town of Minto model development appears to be reasonable. Although references to model details were provided in WNMC (draft 2009), it should be noted that there were no specific model details available for review. The following comments are based solely on text and the available model output as presented in the figures provided.

5.7.1 COMMENTS ON MODEL

The following are summary comments on the Town of Minto Model:

- This model was not updated by WNMC (draft 2009) but was updated by Golder (2009) from the original Wellington County study (Golder, 2006). As such very little information on the model is available for review.
- The WHPA for Clifford as delineated in Golder (2006; Figure 3.31a) is quite different than the WHPA delineation in WNMC (2009; Figure 4-1-6-A). It is not clear why, except perhaps that the stand-by well (Clifford Well No 2) was modeled in WNMC (draft 2009) but not in Golder (2006). Some additional clarification is required to render a professional opinion on the vulnerability assessment for the Clifford DWS.
- The WHPA for Harriston as delineated in Golder (2006; Figure 3.31b) and Golder (2009; Figure 2) are both quite different from the WHPA delineated in WNMC (2009; Figure 4-1-6-B). It is not clear why, except perhaps that Harriston Well No. 2 appears to be missing in the WNMC (draft 2009) analysis. Some additional clarification is required to render a professional opinion on the vulnerability assessment for the Harriston DWS.
- The calibration plot (Golder, 2006; Figure A.1) of well heads had a NRMS of 6.6% which is acceptable for the entire data set but wells representing the lower Salina had a range of over +/- 30 m from the 1:1 calibration curve (Golder 2006, Figure A.1). The wells representing the upper Salina had a much narrower range of less than +/- 10 m.

5.7.2 KARST ASPECTS

Clifford

The Clifford Well Supply is derived primarily from an overburden well (Mill Street Well) which is 54.6 m deep. A nearby standby well (Well No. 4) is completed into the upper bedrock. The bedrock conceptual geological model employed for Minto Township includes the Salina, Bois Blanc and Detroit River formations; however the Clifford standby well likely penetrates the Salina. This formation includes a range of lithologies including halite, limestone, gypsum, and shale. The model employs one bedrock layer ("upper" Salina) with an assigned hydraulic conductivity of $5X10^{-5}$ m/s.

Because the primary water supply is taken from the overburden, karst is not likely a factor for this system. However, there is a potential for karst in the upper Salina which could impact the standby well.

Harriston and Palmerston

The wells are believed to have been completed into the upper part of the Salina Formation. This upper bedrock unit is represented as one bedrock layer with an assigned hydraulic conductivity of $5x10^{-5}$ m/s.

There is no reason to suspect karstic influence in the supply zone, however it is likely that karst flow does occur lower in the Salina. Thus, the bedrock unit supplying the wells should be confirmed and *in-situ* hydraulic conductivities should be obtained from each well. The surrounding overburden deposits are moderately thick (20 to 30 m), hence surface karst may not be significant.

5.7.3 CRITICAL ISSUES AND DEFICIENCIES

Based on the information available for review, the following are critical issues and deficiencies that should be addressed:

- The Vulnerability Scores have not been completed for the updated WHPA delineated by Golder (2009) for the Harriston DWS.

5.7.4 Opportunities for Improvement

Based on the information available for review, the following are issues that should be addressed:

- Figures similar to those provided for other models in Appendices D to G would be useful additions to summarize the model construction details and results, without having to refer to previous reports where the original model was documented.
- Address the issues identified in the Documentation and Referencing section (Section 4.1) and in the Critical Issues and Deficiencies section.
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- If the Clifford standby well becomes a primary supply well, *in-situ* hydraulic conductivity tests should be undertaken within the bedrock section. Also, a suite of general chemistry analyses (major ions, bacteria, nutrients) should be undertaken to determine the possibility of GUDI conditions.
- The Maitland River and its major tributaries in the area of the wells should be surveyed with respect to the possibility of karst discharge zones.

5.8 Atwood Model

The general approach in the Atwood model development appears to be reasonable. Although references to model details were provided in WNMC (draft 2009), it should be noted that there were no specific model details available for review. The following comments are based solely on text and the available model output as presented in the figures provided.

5.8.1 Comments on Model

The following are summary comments on the Atwood Model:

- The conceptual model incorporated one overburden layer, one overburden/ weathered bedrock contact zone layer and three layers corresponding to unweathered bedrock.
- Uniform hydraulic conductivities were assigned across each of the model layers.

- The WNMC (draft 2009) study updated the original Perth County report (WHI 2003) based on the addition of a new well and decommissioning of the original well.
- The upper, weathered bedrock layer is assigned a hydraulic conductivity of $1x10^{-4}$ m/s and the lower non weathered layer is $7.5x10^{-5}$ m/s.
- The calibration curve (WHI 2003; Figure 6.2.4) has a NRMS value of 7.4% and a total range in well heads in the order of +/-5 m, however the plot does not distinguish between aquifers.

5.8.2 KARST ASPECTS

Overburden in this area is in the range of 20 m so surface karst features may not be significant. The bedrock model includes the Detroit River Group (Amherstburg and Lucas Formations) overlying the Bois Blanc Formation and the well is believed to be completed to the latter. The model incorporates two bedrock layers extending 50 m below the overburden.

There is no direct indication of karst influence, however the Lucas (WNMC 2009) and Bois Blanc (Worthington et al. 2001) Formations are both considered to be karstic aquifers and should be treated as such unless otherwise proven.

5.8.3 CRITICAL ISSUES AND DEFICIENCIES

Based on the information available for review, the following are critical issues and deficiencies that should be addressed:

- Given the relatively large scale of Figure 4-1-5-A it is difficult to determine if a WHPA A (100 m zone) was delineated for the Atwood drinking water system (DWS) wells. A WHPA A is needed in order to be compliant with the requirements of the Terms of Reference (December, 2008);

5.8.4 OPPORTUNITIES FOR IMPROVEMENT

Based on the information available for review, the following are issues that should be addressed:

- Figures similar to those provided for other models in Appendices D to G would be useful additions to summarize the model construction details and results, without having to refer to previous reports where the original model was documented.

- Address the issues identified in the Documentation and Referencing section (Section 4.1) and in the Critical Issues and Deficiencies section.
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.
- The actual hydraulic conductivities in the supply zone(s) (note: casing presence/depth not recorded) should be determined.
- In addition, the area surrounding the wells should be surveyed for surface karst features and the Maitland River tributaries in the area should be evaluated for possible karst discharge.

5.9 North Perth Model

The heading for Section 3.9 in the report is "Listowel and Gowanstown", while the remainder of the document uses "North Perth" to refer to this model; the latter is adopted here.

The general approach in the North Perth model development appears to be reasonable. Although references to model details were provided in WNMC (draft 2009), it should be noted that there were no specific model details available for review. The following comments are based solely on text and the available model output as presented in the figures provided.

5.9.1 Comments on Model

The following are summary comments on the North Perth Model:

- The conceptual model incorporated one overburden layer, one overburden/ weathered bedrock contact zone layer and two layers corresponding to unweathered bedrock.
- Uniform hydraulic conductivities were assigned across each of the model layers.
- The WNMC (draft 2009) study updated the original Perth County report (WHI 2003).
- The overburden aquitard is assigned a hydraulic conductivity of $5x10^{-8}$ m/s and the weathered bedrock is assigned a hydraulic conductivity of $8X10^{-4}$ m/s and the lower non weathered layer is assigned a hydraulic conductivity of $8x10^{-5}$ m/s.

- The calibration curve (WHI 2003; Figure 6.3.5) has a NRMS value of 7.8% and a total range in well heads in the order of +/-7m, however the plot does not distinguish amongst aquifers.

5.9.2 KARST ASPECTS

Overburden in this area is in the range of 20 m so surface karst features may not be significant. The bedrock model includes the Detroit River Group (Amherstburg and Lucas formations) overlying the Bois Blanc Formation and the well is believed to be completed to the former.
There is no direct indication of karst influence, however the Lucas (WNMC 2009) and Bois Blanc (Worthington et al. 2001) formations are both considered to be karstic aquifers and should be treated as such unless otherwise proven.

5.9.3 CRITICAL ISSUES AND DEFICIENCIES

Based on the information available for review, the following are critical issues and deficiencies that should be addressed:

- Given the relatively large scale of Figures 4-1-5-B and 4-1-5-C it is difficult to determine if a WHPA A (100 m zone) was delineated for the Listowell and Gowanstown drinking water system (DWS) wells. A WHPA A is needed in order to be compliant with the requirements of the Terms of Reference (December, 2008);

5.9.4 OPPORTUNITIES FOR IMPROVEMENT

Based on the information available for review, the following are issues that should be addressed:

- Figures similar to those provided for other models in Appendices D to G would be useful additions to summarize the model construction details and results, without having to refer to previous reports where the original model was documented.
- Address the issues identified in the Documentation and Referencing section (Section 4.1) and in the Critical Issues and Deficiencies section.
- Surface to aquifer advection time (SAAT) or surface to well advection time (SWAT) could be used as an alternative to the Intrinsic Susceptibility Index and Aquifer Vulnerability Index (ISI/AVI). Application of the physically based SAAT and/or SWAT approach would

make the calibrated three-dimensional model more defensible with little additional effort. To better understand the uncertainties of the model results.

- The actual hydraulic conductivities in the supply zone(s) (note: casing presence/depth not recorded) should be determined. It is possible that the pumping wells may draw their supply from karst conduits; this may imply that the hydraulic conductivity values in the immediate vicinity of the wells may be higher locally compared to locations where karst conduits are not present. Since the model is well-calibrated, we can conclude that any karst conduits that may be present are represented adequately in the bulk hydraulic conductivity estimated from model calibration.
- In addition, the area surrounding the wells should be surveyed for surface karst features and the Maitland River tributaries in the area should be evaluated for possible karst discharge.

6. SUMMARY AND OVERALL PROFESSIONAL OPINION

The peer review team, comprised of WESA and karst expert Daryl Cowell, completed a detailed review of the draft groundwater vulnerability assessment study completed for the Ausable Bayfield and Maitland Valley Source Protection Region (WNMC, draft 2009). The study was completed by WNMC, IWS and B.M. Ross, and consisted in the development of wellhead protection areas (WHPAs) and groundwater vulnerability scores for a total of 25 drinking water systems (DWS), comprising a total of 43 individual water supply wells, and included in eight separate groundwater flow models.

Our technical review focused on four key questions outlined earlier, namely:

- Does the vulnerability assessment conform with the requirements of the provincial Technical Rules?
- Was the adopted methodology adequate, in particular with respect to the local settings and data availability?
- Is the documentation adequate of the analyses and results, including discussion of the assumptions and limitations?
- Are the study results, interpretations and recommendations reasonable?

We found that the conceptual models used to develop the numerical models generally incorporated the available information adequately. In particular, the models were developed (or in some cases updated from previous studies) with particular attention to the hydrogeologic properties specific to each of the overburden and/or bedrock layers, derived from the available information. Where hard data were not available, assumptions were made and generally were documented adequately.

In our professional opinion, the groundwater vulnerability assessment was conducted based on defensible technical assumptions, and the results from the numerical analyses were found to correspond reasonably well with the available observed hydrogeologic conditions within the study area. No major concerns were identified related to the methodology adopted to delineate the WHPAs, and the results, interpretations and recommendations documented in WNMC (draft 2009) appear reasonable.

We understand that the documents reviewed are draft documents and therefore to a certain extent incomplete; however, assuming that the issues identified in previous sections of this review are addressed, the results from the analyses can be used in the on-going and developing Source Water Protection process.

A few issues were identified that we would consider significant. These relate to compliance with the MOE Technical Rules (December 12, 2008) in the following ways:

1) The GUDI status of the DWS is not discussed in the report (WNMC, draft 2009); a WHPA-E would have to be delineated for those municipal wells that are designated as GUDI. This will have to be addressed in order for the vulnerability assessment to comply with Technical Rules 47 (5) and 49;
2) The presence of constructed (transport) pathways within the delineated WHPAs should be identified and the vulnerability scores adjusted where warranted, as prescribed by Technical Rules 39, 40 and 41. Preferential pathways may include, for example, improperly abandoned supply wells, sink holes of karstic origin or other features that may constitute preferential conduits for surface contamination to reach the aquifer units supplying the DWS. It is our understanding that this aspect was not included in the terms of reference for the study (WNMC, draft 2009); and
3) For the Harriston water supply, Golder (2010) recently updated the groundwater model by increasing the pumping rate (technical memorandum dated March 1, 2010). The WHPAs have changed as a result, but the vulnerability scoring does not appear to have been completed for the areas outside of the original WHPAs. This should be done to comply with Technical Rule 83;

4) We are unable to confirm that WHPAs have been delineated for all stand-by / backup wells associated with the various DWS, as prescribed by clauses 15(2)(d) and 15(2)(e) of the Clean Water Act and Technical Rule 5(1). Appendix C in WNMC (draft 2009) (Municipal Well Decommissioning Information) will likely contain the necessary information in this regard, but was not available in the draft WNMC report ("to be added later"). This will need to be confirmed.

Other technical aspects that should be considered as key 'opportunities for improvement' and should be prioritized in future source water protection efforts within the ABSV SPR include:

1) Four of the models were updated from previous studies as part of the work completed by WNMC (draft 2009). Additional documentation of the models, with a level of detail similar to what has been provided for the other four models (figures for the Zurich, Clinton, Brucefield and Huron West models are provided in Appendices D to G, respectively) would be beneficial to the reader. In particular, we would like to see the model construction details (numerical grid, layers, boundary conditions) and calibration results (scatter plots of observed vs. simulated heads) without having to consult the previous study reports;
2) The fact that WNMC acknowledged in their report the presence of karst features, and where possible made some adjustments to account for these features, despite the limited amount of information available to constrain these modifications, is encouraging. We recommend that field studies be conducted where justified and feasible to adequately identify and characterize karst in the vicinity of some of the municipal wells. For instance, sinkholes can extend from surface to some depth into the bedrock, potentially creating preferential transport pathways into the subsurface;
3) The methodology used by WNMC to delineate 'composite' WHPAs by combining individual WHPAs produced for each uncertainty analysis scenario, while conservative, could result in artificially large WHPAs; in our opinion, a better approach would be to delineate the WHPAs using the 'best' calibrated model results, and to outline zones of higher uncertainty relative to these WHPAs based on the results from the uncertainty analysis. We do not consider this to be a critical issue; and
4) It is our understanding that the identification of Significant Groundwater Recharge Areas (SGRAs) is being completed as part of a parallel study. This is an aspect of

source water protection that is generally not included in this round of technical studies across the province, and that it was probably not included in the terms of reference provided to WNMC for the vulnerability assessment.

We trust that the comments and recommendations provided herein, specifically the critical issues and opportunities for improvement, will be useful in providing guidance for future efforts aimed at ensuring adequate protection of the drinking water resource within the ABMV SPR.

Respectfully submitted,

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7. REFERENCES

Golder and Associates Ltd. (Golder), 2006. *County of Wellington Groundwater Protection Study*, Sept. 2006.

Golder and Associates Ltd. (Golder), 2010. *Technical Memorandum to Ms. Lorrie Minshall, GRCA, Updated Capture Zones for Wellington County*, March 1, 2010.

Johnson, M.D., D.K. Armstrong, B.V. Sanford, P.G. Telford, and M.A. Rutka, 1992. *Paleozoic and Mesozoic geology of Ontario*. Chapter 20 In ***Geology*** of Ontario, Geological Survey of Ontario, Special Volume 4, Part 2: 905-1008.

MOE, 2001. *Groundwater Studies. Technical Terms of Reference.* http://www.ene.gov.on.ca/envision/techdocs/4197e.htm

MOE, 2006. *Assessment Report: Draft Guidance Module 3, Groundwater Vulnerability Analysis.* October, 2006.

MOE, 2008. *Technical Rules: Assessment Report*. December 12, 2008.

MOE, 2009. *Technical Rules: Assessment Report*. Proposed Amendments. August 24, 2009.

Waterloo Numerical Modelling Corp. (WNMC), draft 2009. *Draft Report for Well Head Protection Area Delineation Project*. June 3, 2009.

WESA Inc., 2009. *Groundwater Vulnerability Assessment, Municipality of Huron East (Seaforth), Ausable Bayfield Maitland Valley Source Protection Region.*

Worthington, S.R.H., C.C. Smart, and W.W. Ruland. 2001. *Karst hydrogeological investigations at Walkerton*. Prepared for the Walkerton Inquiry on Behalf of the Concerned Walkerton Citizens.

Table 1
Summary of Drinking Water Systems (by Municipality)

Township/ Municipality	DWS	Well Names	Status	Date	(OB/ BR)	Depth (mbgs)	Casing Depth (mbgs)	PTTW Status	Maximum Rate (m^3/day)	Average Rate* (m^3/day)	Years for Average Rate	Model	Reference	Additional Information
Ashfield-Colborne-Wawanosh (ACW), Township of	Huron Sands	Huron Sands Well	In use	2001	BR	77.7	68.2	yes	328	20	2002-2005	North Huron	Section 1.2.1, Figure 1-2-1, Section 4.1, Figure 4-1-1, Section 5.1, Figure 5-1-1	Formerly Township of Ashfield
	Benmiller Estates	Benmiller Estates Well	In use	1977	BR	65.8	38.2	yes	196.3	59	2001-2005	North Huron		Former Township of Colborne
	Century Heights	Well 1	In use	1979	BR	68.8	34.4	yes	734.4	160	2001-2005	North Huron		Former Township of Colborne
		Well 2	In use	NA	BR	66	NA	yes						
	Dungannon	Well 1	In use	2002	BR	77.7	33.2	yes	438	90	2004 and 2005	North Huron		
		Well 2	In use	2002	BR	87.2	35.1	yes						
Bluewater, Municipality of	Carriage Lane Well	Carriage Lane Well	In use	1989	BR	60.9	39.6	exp. 2008	348.5	19	2002-2005	Huron West	Section 1.2.2, Figure 1-2-2, Section 4.2, Figure 4-1-2, Section 5.2, Figure 5-1-2	These are now separate DWS systems but were formerly part of the old Village of Bayfield.
	Harbour Lights Well	Harbour Lights Well	In use	1992	BR	32.9	28.6	exp. 2002	111.6	20	2002-2005			
	Zurich	Well 1	In use	1963	BR	88.4	66.4	yes	1152	546	2001-2005	Zurich		
		Well 3	In use	NA	BR	97.53	93.57	yes						
Central Huron, Municipality of	Clinton, Town of	Well 1	In use	NA	BR	99	30.5	no PTTW	NA	1968	2001-2005	Clinton	Section 1.2.3, Figure 1-2-3, Section 4.3, Figure 4-1-3, Section 5.3, Figure 5-1-3	No PTTW
		Well 2	In use	NA	BR	108	NA							
		Well 3	In use	1951	BR	109.7	29.3							
	Aubern Hall	Aubern Well	In use	1961	BR	56.4	36.6	yes	61.9	9	2003-2005	North Huron		
	McClinchey	McClinchey Well	In use	1967	BR	43.3	30.2	exp. 2004	100.8	8	2001-2005	Huron West		
	Kelly	Kelly Well	In use	1981	BR	45.7	31.7	exp. 2006	196.1	22	2001-2005	Huron West		
	S.A.M.	S.A.M. Well	In use	1979	BR	59.4	42.7	exp. 2007	164	9	2001-2005	Huron West		
	Van de Wetering	Van de Wetering Well	In use	1989	BR	42.1	27.1	yes	97.9	9	2001-2005	Huron West		
Huron East, Municipality of	Brucefield	Well 1	In use	1972	BR	88.4	23.5	yes	270	60	2001-2005	Brucefield	Section 1.2.4, Figure 1-2-4, Section 4.4, Figure 4-1-4, Section 5.4, Figure 5-1-4	
	Brussels	Well 1 (aka Church Street)	In use	1951	BR	60	NA	yes	1097	520	2001-2005	North Huron		
		Well 2 (aka Turnberry Street)	In use	1963	BR	60.4	12.4	yes		17				
North Huron, Municipality of	Belgrave	McCrae Street Well	Back Up	1976	BR	38.1	21.2	no PTTW	NA	20.5	1997-1999	North Huron	Section 1.2.5, Figure 1-2-5, Section 4.5, Figure 4-1-5 and Figure 4-1-6 (identical), Section 5.5, Figure 5-1-5 and Figure 5-1-6 (identical)	Decommissioning Report in Appendix C but no Appendix C. See Morris-Turnberry(?). In Section 4.5 Belgrave is included even though Section 1.2.5 indicates that there are two wells but then the name is singular (the "Jane and McCrae Well") and it states "the well" was decommissioned. Belgrave is half in M-T and half in the Mun. of N. Huron
		Jane Street Well	In use	1983	BR	42.4	19.7	no PTTW	NA	20				
	Blyth	Well 1	In use	1953	BR	73.2	19.6	exp. 2008	1776	527	1997-1999 and 2001	North Huron		
		Well 2	In use	1972	BR	79.25	20.1	exp. 2008		334.2	2001			
	Wingham	Well 3	In use	1973	BR	102.1	41.5	yes	6546.2	180	2001	North Huron		
		Well 4	In use	1996	BR	92.3	66.1	yes	5270	1797.3	1997-1999 and 2001			
Morris-Turnberry, Municipality of	Belgrave	McCrae Street Well	Back Up	1976	BR	38.1	21.2	no PTTW	NA	20.5	1997-1999	North Huron	Section 1.2.6, Figure 1-2-6	Municipality of Morris-Turnberry not included in subsequent Sections 3, 4 and 5. Belgrave is half in M-T and
		Jane Street Well	In use	1983	BR	42.4	19.7	no PTTW	NA	20				
Minto Township	Clifford	Well 1 (aka Mill Street)	In use	NA	BR	54.6	NA	yes	1310	300	(Golder,2006)/ (Golder 2010)	Minto Township	Section 1.2.7, Figures 1-2-7, Section 4.6, Figure 4-1-7 (text says Figure 4-1-6?), Section 5.6, Figure 5-1-7 (text says Figure 5-1-6?) and Golder (2010) for Harriston only	
		Well 3	In use	NA	OB	NA	NA	yes	655	416				In Golder, 2006 pumping rate is 417 m3/day
		Well 4	Back Up	NA	BR	NA	NA	yes	1309	0				
	Harriston	Well 1	In use	NA	BR	24	NA	exp. 2009	981	1374		Minto Township		Updates in Golder (2010)
		Well 2	Back Up	NA	BR	59	NA	exp. 2009	2100	0				
		Well 3	Back Up	NA	BR	26	NA	exp. 2009	1600	0				
	Palmerston	Well 1 (William St.)	In use	NA	BR	43.6	NA	yes	1964	512/ 354		Minto Township		
		Well 2 (William St.)	Back Up	NA	BR	43.6	NA	yes		0/ 306				
		Well 3 (Whites Rd.)	In use	NA	BR	53.4	NA	yes	2291	704/ 688				
North Perth, Municipality of	Atwood	Well 1 (aka Danbrook)	In use	NA	NA	NA	NA	exp. 2009	143	36	2001-2005	Atwood	Section 1.2.8, Figures 1-2-8, Section 4.7, Figure 4-1-8, Section 5.7, Figure 5-1-8	
		Well 2 (aka Smith)	In use	NA	BR	47.6	NA	yes	262	33				
	Listowell	Well 4	In use	1948	BR	92.6	NA	yes	3273	795	2001-2005	North Perth		
		Well 5	In use	1962	BR	92.66	NA	yes		693				
		Well 6	In use	1989	BR	118.57	NA	yes		819				
	Gowanstown	Well 1	In use	1964	BR	NA	NA	yes	71	11	2002-20058	North Perth		
	Molesworth	Well 1	In use	1976	BR	47.85	NA	no PTTW	NA	30	NA	North Huron		No PTTW, average pumping rate is estimated based on number of houses.

Notes:
NA Denotes Not Available
** Period used to average pumping rates shown in brackets*

Table 2
Summary of Drinking Water Systems (by Groundwater Flow Model)

Model	Township/ Municipality	DWS	Well Names	Status	Date	(OB/ BR)	Depth (mbgs)	Casing Depth (mbgs)	PTTW
North Huron	Ashfield-Colborne-Wawanosh (ACW), Township of	Huron Sands	Huron Sands Well	In use	2001	BR	77.7	68.2	yes
		Benmiller Estates	Benmiller Estates Well	In use	1977	BR	65.8	38.2	yes
		Century Heights	Well 1	In use	1979	BR	68.8	34.4	yes
			Well 2	In use	NA	BR	66	NA	yes
		Dungannon	Well 1	In use	2002	BR	77.7	33.2	yes
			Well 2	In use	2002	BR	87.2	35.1	yes
	North Perth, Municipality of	Molesworth	Well 1	In use	1976	BR	47.85	NA	no PTTW
	Central Huron, Municipality of	Aubern Hall	Aubern Well	In use	1961	BR	56.4	36.6	yes
	Huron East, Municipality of	Brussels	Well 1 (aka Church Street)	In use	1951	BR	60	NA	yes
			Well 2 (aka Turnberry Street)	In use	1963	BR	60.4	12.4	yes
	North Huron, Municipality of/ Morris-Turnberry, Municipality of (Belgrave)	Belgrave	McCrae Street Well	Back Up	1976	BR	38.1	21.2	no PTTW
			Jane Street Well	In use	1983	BR	42.4	19.7	no PTTW
		Blyth	Well 1	In use	1953	BR	73.2	19.6	expired 2008
			Well 2	In use	1972	BR	79.25	20.1	expired 2008
		Wingham	Well 3	In use	1973	BR	102.1	41.5	yes
			Well 4	In use	1996	BR	92.3	66.1	yes
Zurich	Bluewater, Municipality of	Zurich	Well 1	In use	1963	BR	88.4	66.4	yes
			Well 3	In use	NA	BR	97.53	93.57	yes
Clinton	Central Huron, Municipality of	Clinton, Town of	Well 1	In use	NA	BR	99	30.5	no PTTW
			Well 2	In use	NA	BR	108	NA	no PTTW
			Well 3	In use	1951	BR	109.7	29.3	no PTTW
Brucefield	Huron East, Municipality of	Brucefield	Well 1	In use	1972	BR	88.4	23.5	yes
Huron West	Bluewater, Municipality of	Carriage Lane Well	Carriage Lane Well	In use	1989	BR	60.9	39.6	expired 2008
		Harbour Lights Well	Harbour Lights Well	In use	1992	BR	32.9	28.6	expired 2002
	Central Huron, Municipality of	McClinchey	McClinchey Well	In use	1967	BR	43.3	30.2	expired 2004
		Kelly	Kelly Well	In use	1981	BR	45.7	31.7	expired 2006
		S.A.M.	S.A.M. Well	In use	1979	BR	59.4	42.7	expired 2007
		Van de Wetering	Van de Wetering Well	In use	1989	BR	42.1	27.1	yes
Minto Township	Minto, Township	Clifford	Well 1 (aka Mill Street)	In use	NA	BR	54.6	NA	yes
			Well 3	In use	NA	OB	NA	NA	yes
			Well 4	Back Up	NA	BR	NA	NA	yes
		Harriston	Well 1	In use	NA	BR	24	NA	expired 2009
			Well 2	Back Up	NA	BR	59	NA	expired 2009
			Well 3	Back Up	NA	BR	26	NA	expired 2009
		Palmerston	Well 1	In use	NA	BR	43.6	NA	yes
			Well 2	Back Up	NA	BR	43.6	NA	yes
			Well 3	In use	NA	BR	53.4	NA	yes
Atwood	North Perth, Municipality of	Attwood	Well 1 (aka Danbrook Municipal Well)	In use	NA	NA	NA	NA	expired 2009
			Well 2 (aka Smith Well)	In use	NA	BR	47.6	NA	yes
North Perth	North Perth, Municipality of	Listowell	Well 4	In use	1948	BR	92.6	NA	yes
			Well 5	In use	1962	BR	92.66	NA	yes
			Well 6	In use	1989	BR	118.57	NA	yes
		Gowanstown	Well 1	In use	1964	BR	NA	NA	yes

Notes:
NA Denotes Not Available