

## 1.0 Uncertainty

Based on the Technical Rules, the uncertainty assessment of WHPA is to include:

- an evaluation of the uncertainty associated with the assessment of the vulnerability of groundwater within the area of interest (low, medium, high vulnerability),
- an evaluation of the uncertainty associated with the delineation of the WHPA and
- an assignment of an uncertainty rating (high or low) for each vulnerable area.

The *technical rules* also state that an analysis of the uncertainty, characterized by 'high' or 'low', shall be made with respect to the delineation and assessment of *wellhead protection areas*. The factors to be considered in the analysis include:

- the distribution, variability, quality and relevance of data used;
- the ability of the methods and models used to accurately reflect the flow processes in the hydrological / hydrogeological system;
- the quality assurance and quality control procedures applied;
- the extent and level of calibration of models
- the accuracy of the groundwater vulnerability categories to effectively assess the relative vulnerability of underlying hydrogeological features.

The evaluation of uncertainty is a very subjective process and varied between studies. The key considerations of the evaluation in each study are discussed below by topic area and study. This includes the uncertainty in the delineation of the WHPA, the assessment of the vulnerability in the WHPA and the consideration of transport pathways. The uncertainty associated with the delineation of HVA and SGRA are also considered in this appendix and summarized in the appropriate subsection of Section 4.0 of the Assessment Report.

## **1.1 WHPA Uncertainty**

### **1.1.1. Uncertainty in the Delineation of WHPA**

The uncertainty in the delineation of the Wellhead Protection Areas (WHPA) is evaluated in each study. This is discussed by study in the following sections in many cases by direct quotations from the studies.

#### **1.1.1.1. London, Middlesex Centre & Thames Centre (Birr, Dorchester, Kilworth- Komoka, London - Fanshawe and Hyde Park back up wells, Melrose and Thorndale)**

As summarized in Source Protection Study, London, Middlesex Centre & Thames Centre Wellfield Source Protection Study Vulnerability Assessment Report Final Draft Report (October 16, 2009):

"The delineation of the *wellhead protection areas* comprises a number of assumptions and estimates based on point data such as lithology described in water well records and hydrogeological information provided from technical reports. Each model was developed making the most use of the available data, and therefore the results represent the best estimate that can be made based on that data. Improvements in the models can be made based on any additional information that becomes available in the future. Even with this uncertainty, the wellhead delineation process provides a good indication of the source of the water for the water supply system, which can facilitate a good water resource protection policy.

Overall, significant data gaps are identified if observed. These gaps include information on groundwater recharge values and the heterogeneity in the hydraulic conductivity of the aquifer and aquitard. In addition, better information on the hydraulic levels in the aquifer in the local/regional area would be beneficial, and could be used to improve the model. Should future pumping rates differ than those used in the model, then a reassessment of the modeled capture zones should be performed.

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Groundwater recharge values used in the model greatly control the width of the modelled capture zone. This value is often used to calibrate the model, and is not measured directly. The uncertainty associated with this factor is considered high.

The static water levels recorded in the water well records are notably erratic in nature. Improvement to the model would involve installation of several monitoring wells in key areas and additional hydrogeological studies (including pumping test).

For many of the systems there are no observation wells. When available hydraulic head levels used during model calibration were taken from water levels at different times of the year and over several decades, a more recent and comprehensive survey of hydraulic head levels would provide for a more accurate calibration in all areas. The hydraulic head levels used for calibration, while useful for comparison, could be offset by as much as 2 to 3 m due to seasonal fluctuation or other influences. Nevertheless, it is not expected that the variation would cause significant changes in the interpreted direction of the capture zones. As a result, the uncertainty associated with this factor is considered low.

The heterogeneity of overburden aquifer hydraulic conductivity could only be evaluated at a precursory level. Since hydraulic conductivity and other parameters can vary by as much as two orders of magnitude within the same hydraulic unit, it is likely that significant variation exists within these systems. This heterogeneity could not be completely identified based on the data available for the development of the model. Uncertainty associated with this factor is considered high.

For shallow overburden systems (e.g. Dorchester), the *WHPA* -B, and *WHPA* -C receive a low uncertainty. The rationale for this decision is that the hydrogeology of the overburden aquifer is not complex (shallow relatively homogeneous unconfined aquifer, with good quality calibration wells). A high uncertainty is given to *WHPA* -D in the overburden aquifer as the uncertainty of the model is higher at large travel times.

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The most significant limitations for the confined overburden groundwater flow models are the assumption that the aquifer is continuous over the entire model area. Confined overburden aquifers are known to be discontinuous and coincide with the depositional environment that occurred during interstadial periods in which the aquifers were formed. However, considering the limited extent of the 25-year time of travel area and the correlation of the intermediate aquifer at other wells in an area, the uncertainty associated with this factor is considered low.

For bedrock aquifers the delineation of the *wellhead protection areas* comprise a number of assumptions and estimates based on point data such as lithology described in water well records and hydrogeological information provided from technical reports. The most significant limitations for bedrock groundwater flow model are that there is little information on the geology of the area and few monitoring wells to calibrate the model.

As a result of these factors, there is significant uncertainty associated with the modelled capture zones. Even with this uncertainty, the wellhead delineation process provides a good indication of the source of the water for the water supply system, which can facilitate a good water resource protection policy."

## **1.1.1.2. Oxford**

As outlined in the draft 'County of Oxford Source Protection Technical Studies Program Report on the Groundwater Vulnerability Assessment for the Wellhead Protection Areas Draft (October 2009):

"The WHPA for the Embro, Ingersoll, Lakeside, Mount Elgin, Tavistock, Thamesford, and Woodstock production wells appear to be reasonable approximations and can be considered as having a relatively low level of uncertainty. The WHPA for Beachville, Hickson, and Innerkip all appear to have relatively long and narrow shapes. The WHPA for Beachville also has two distinct and separate long and narrow shapes oriented at approximately 90 degrees from each other. Several factors affect the shape of the WHPA's. The forecast pumping rates used to delineate these WHPA's are low and range from 0.1 – 2.5 L/s, and is the largest control on the shape of the WHPA. It is questionable whether these WHPA represent the real capture area (capture zone

projected to surface) for these municipal well systems. However, with the exception of the Beachville WHPA, it is reasonable to classify the WHPA for these systems as having a relatively low level of uncertainty with respect to the modelling methodology used in their development. In the opinion of the consultant, there is not enough high quality data available to support classifying the Beachville WHPA as having a low uncertainty.”

### **1.1.1.3. Perth**

The most significant limitation for the groundwater flow models is the assumption that the aquifer is continuous over the entire model area. However, considering the limited extent of the 25-year time of travel area and the correlation of the contact aquifer at other wells in the area, the uncertainty associated with this factor is considered low. The most significant limitation for a groundwater flow model is the unpredictable/unknown nature of the regional groundwater flow at the site of the municipal well.

For all groundwater systems, there is a high uncertainty associated with hydraulic head levels (taken at different times of the year over several decades), groundwater recharge values (which are not measured directly), and the heterogeneity of both the overburden and bedrock aquifer hydraulic conductivity (could not be completely identified based on the data available).

### **1.1.2. Uncertainty associated with Vulnerability Assessment**

The groundwater vulnerability assessment was based on the Intrinsic Susceptibility Index (ISI) methodology in Perth and Middlesex. Overall, the uncertainty associated with the groundwater vulnerability map is deemed low, as there appears to be a consistent regional trend in the ISI results. However, uncertainty associated with the vulnerability assessment of the individual system using *ISI* varies between high and low.

The groundwater vulnerability within the County of Oxford has been assessed in previous studies using three methodologies (AVI, ISI and SWAT). Excerpts surrounding the discussion from the County of Oxford Source Protection Technical Studies Program Report on the

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Groundwater Vulnerability Assessment for the Wellhead Protection Areas (Draft, October 2009) are included below.

“The studies are well documented in the reports, and it is evident from the reports that considerable thought and interpretation went into the previous work. The resulting map products were reviewed as part of this groundwater vulnerability assessment, and some minor adjustments were made by a hydrogeologist based on professional judgment. The adjustments included infilling of apparent gaps within the vulnerability mapping of the WHPA, smoothing of contacts, and removal of relatively small anomalies that were not clearly supported by the available hydrogeological information. As a result, the intrinsic vulnerability map products (SWAT, AVI) used in the groundwater vulnerability assessment are considered to have a low uncertainty. The groundwater vulnerability assessments associated with the following municipal production well WHPA are considered to have a **low uncertainty**: Embro, Hickson, Ingersoll, Innerkip, Lakeside, Mount Elgin, Tavistock, Thamesford, and Woodstock.

The groundwater vulnerability assessment for the Beachville WHPA is considered to have a **high uncertainty** due to the uncertainty associated with the delineation of the WHPA. “

## ***1.2 Uncertainty associated with Transport Pathways***

Some uncertainty is associated with the approach to the mapping of transport pathway information for all well systems. Since information on the presence or absence of *transport pathways* did not involve confirmatory site visits and visual inspection alone would not be conclusive as to whether a transport pathway exists, the actual presence of the identified *transport pathways* is unknown. Therefore, the mapped extent of the area where these *transport pathways* exist is deemed conservative. Throughout all of the studies, the features of concern would be poorly maintained water wells or oil and gas wells and many of these locations are unknown. Where vulnerability has been adjusted based on an area of increased density of potential transport pathways the location of the individual pathways is less of a concern and therefore the uncertainty associated with adjusting the vulnerability of the area is limited as to whether the potential pathways are poorly constructed or maintained. As this methodology is

applied to an area rather than to individual features the number of features which are potentially transport pathways further reduces the uncertainty.

### **1.3 Overall WHPA Uncertainty**

Based on the discussion above, the uncertainty associated with the vulnerability assessment of the 22 groundwater systems *Wellhead Protection Areas* is to be identified as 'Low' or 'High', as required by the *technical rules*. The overall uncertainty is largely affected by the uncertainty associated with the *wellhead protection area* modelling rather than the aquifer vulnerability assessment for all systems or the adjustments due to transport pathways.

As discussed above, the peer reviewers have had considerable discussion about uncertainty with the consultants who have undertaken the studies for ground water vulnerability assessment. This was also consistent with the uncertainty associated with the Intake Protection Zones in the other Source Protection Areas of the region. Through that discussion it became apparent that there is considerable subjectivity to the assignment of the uncertainty factors. It has been suggested that upon completion of the peer review of all of the reports that an overall assessment and comparison of the uncertainty be undertaken so that relative comparison between studies can be made and priorities for future assessment can be identified. It is important to understand that a high uncertainty associated with any aspects of the work does not suggest that the conclusions are inappropriate for the purposes that the results are being used. This is merely an acknowledgement of the potential for a better understanding with further analysis or data. If it were identified that the uncertainty was too great, additional work would have been undertaken to reduce the level of uncertainty if data were available to support the additional work. Even with the completion of additional work, it is unlikely that all uncertainty can be eliminated.

### **1.4 Highly Vulnerable Aquifers**

The *Highly Vulnerable Aquifer* area mapping product is a derivative product based primarily on ISI mapping. The ISI mapping is based on assigning an index based on aquifer, confining materials and water level information identified by drillers as recorded in the Water Well

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Information System (WWIS). The uncertainty in the *ISI* product is considered high due to a number of factors including:

- Uncertainty associated with the location information and therefore the accuracy of the elevation used in interpreting the description of depth in the *WWIS*
- Uncertainty associated with the material description in the *WWIS*
- Uncertainty associated with water table mapping
- The interpolation process associated with this mapping (and limited data in some areas)

In conclusion, the uncertainty is high in the use of the *WWIS*. The high uncertainty associated with individual data is offset to some degree by the high amount of data included in the *WWIS*. The location and presence of sand and gravel deposits in the Surficial Geology (OGS) mapping are based on a different data set from the *WWIS*. The level of uncertainty is reduced substantially due to the agreement of the two mapping products and the incorporation of professional judgement. The impact of the uncertainty in the low and medium vulnerability areas is minimal from a Source Protection Planning perspective. There is uncertainty related to the Highly Vulnerable Areas (HVA) although the product is acceptable for the purposes of delineating the Highly Vulnerable Areas. This uncertainty is associated with the data sets available for use in this analysis and would exist irrespective of whether the other methods identified in the rules were used to delineate the Highly Vulnerable Areas. Additional work to map the extent and thickness of aquifers in the region would greatly reduce the uncertainty.

## ***1.5 Significant Groundwater Recharge Areas***

The uncertainty associated with the delineation of the SGRA is discussed in the Significant Groundwater Recharge Area technical memorandum (UTRCA, May 2010).

“Groundwater recharge is one of the more elusive quantities to estimate at any level of water budget analysis. Recharge in the present analysis is derived from a continuous GAWSER model for each HRU/Climate zone combination within the UTRSPA. The GAWSER model relies on surficial geology mapping which is presented as a continuous surface, but clearly all areas are not sampled in the creation of the mapping, and some

interpolation is used in the creation of these maps. This interpolation carries with it a degree of uncertainty. In any modelling exercise there is an attempt to calibrate the model being used with observed field data with varying degrees of success. In the case of GAWSER modelling, median monthly flows derived from the model are compared with median monthly flows which have been measured, on the long term, at key Environment Canada hydrometric stations. A further discussion of the GAWSER calibration process is found in the SWS Tier 2 integrated model document (SWS 2010). Published stream flow values at these locations carry with them a certain degree of uncertainty, and this is discussed in detail in the TSR Tier 1 water budget report (TSR, 2010), Section 8.1.1.4.

We should keep in mind that inherent in the stream flow records are the effects of flow augmentation from upstream reservoirs (Wildwood and Pittock), as well as water added from other sources (i.e. Great Lake or groundwater) in the form of pollution control plant effluent. Furthermore, stream flow records are also affected by discharges from quarry dewatering operations, and also are somewhat reduced by surface water withdrawals, particularly in dry months. These numbers are accounted for in the modelling process as much as is possible, however we need to also realize that these numbers do affect the output and calculation of the recharge rates for the various HRU/climate zone combinations by GAWSER.

As the estimation of SGRAs are based upon the estimate of recharge, this also would have a degree of uncertainty associated with it.”

## **1.6 Summary**

The peer reviewers have had considerable discussion with the consultants who have undertaken the studies for both surface water and ground water vulnerability assessment in the Thames-Sydenham and Region. Through that discussion it has become apparent that there is considerable subjectivity to the assignment of the uncertainty factors. It has been suggested that upon completion of the peer review of all of the reports that an overall assessment and

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comparison of the uncertainty be undertaken so that relative comparison between studies can be made and priorities for future assessment can be identified. It is important to understand that a high uncertainty associated with any aspect of the work does not suggest that the conclusions are inappropriate for the purposes that the results are being used. This is merely an acknowledgement of the potential for a better understanding with further analysis or data. If it were identified that the uncertainty was too great, additional work would have been undertaken to reduce the level of uncertainty if data were available to support the additional work. Even with the completion of additional work, it is unlikely that all uncertainty can be eliminated. The Source Protection Committee is satisfied that the uncertainty of the vulnerability assessment is low enough for the purposes intended.