KARST GEOLOGY AND IMPACTS ON GROUNDWATER QUALITY IN AN AGRICULTURAL AREA IN HURON AND PERTH COUNTIES, ONTARIO

Alge M. Merry, Waterloo Hydrogeologic Inc., Waterloo, Ontario.
Patricia A. Meyer, Waterloo Hydrogeologic Inc., Waterloo, Ontario.
Alec M. Scott, Ausable Bayfield Conservation Authority, Exeter, Ontario.
Davin Heinbuck, Ausable Bayfield Conservation Authority, Exeter, Ontario.
Daron G. Abbey, Waterloo Hydrogeologic Inc., Waterloo, Ontario.

ABSTRACT
The identification of sinkholes located in Perth and Huron Counties during recent groundwater studies, provided the motivation for this study. Over 50 sinkholes (within ~100 km^2) were identified during a sinkhole investigation and characterization study. Surface runoff from agricultural lands often drains directly to sinkholes, providing a link to the bedrock aquifer necessitating the need to understand the interaction between surface water and groundwater in this area. Field surveys were conducted and a sinkhole information system was developed to identify the extent of the karstic environment and characteristics of its drainage area. Preliminary study findings indicate sinkholes were identified in topographically low-lying areas covered by glaciolacustrine sediments. Each sinkhole cluster is located within a closed drainage system, which promotes the erosion and subsidence of overburden, the dissolution of the rock, and the subsequent surface expression of the sinkholes. Two sites were selected for further investigation and a monitoring well was drilled to aid in the evaluation of groundwater quality. Monitoring of water levels and water quality in one of the sinkholes, and the study monitoring well have provided information on loading to the aquifer. This information and the study information system have been used to develop draft policies for the protection of groundwater resources in the study area.

RÉSUMÉ
L'identification des sinkholes à Perth et Huron pendant des études récentes d'eaux souterraines, si la motivation pour cette étude. Plus de 50 sinkholes (dans ~100 km^2) ont été identifiés pendant une étude de recherche et de caractérisation de sinkhole. Les eaux de surface des régions agricoles s'écoulent souvent directement aux sinkholes, fournissant un lien à la couche aquifère de roche en place rendant nécessaire la nécessité de comprendre l'interaction entre l'eau de surface et les eaux souterraines dans ce secteur. Des enquêtes de champ ont été conduites et un système d'information de sinkhole a été développé pour identifier l'ampleur de l'environnement et des caractéristiques karstiques de son secteur de drainage. Les résultats préliminaires d'étude indiquent que des sinkholes ont été identifiés dans des domaines topographiquement bas-menteur couverts par des sédiments de glaciolacustrine. Chaque faisceau de sinkhole est situé dans une canalisation fermée, qui favorise l'érosion et l'affaissement des terrains de recouvrement, la dissolution de la roche, et l'expression extérieure suivante des sinkholes. Deux emplacements ont été choisis pour davantage de recherche et un puits de surveillance a été foré à l'aide dans l'évaluation de la qualité d'eaux souterraines. La surveillance des niveaux d'eau et de la qualité de l'eau dans un des sinkholes, et l'étude surveillant bien ont fourni des informations sur charger à la couche aquifère. Cette information et le système d'information d'étude ont été employés pour développer des politiques d'ébauche pour la protection des ressources d'eaux souterraines dans le secteur d'étude.

1. INTRODUCTION

The Ausable-Bayfield Sinkhole Investigation Study was initiated to improve the understanding of local groundwater conditions surrounding a series of sinkholes located in the municipalities of Huron East and West Perth. These municipalities, located west of the city of Stratford, Ontario, rely on groundwater to supply nearly 100% of their drinking water needs. Previously completed groundwater studies improved the understanding of the hydrogeology and groundwater system throughout this area, however they also noted that the interaction between sinkholes and the underlying groundwater system required further characterization. Within the study area, sinkholes represent conduits whereby contaminated surface water can be rapidly transmitted to the groundwater system.

The sinkhole investigation study focused on sinkholes identified in the former townships of Hibbert (Perth County) and Tuckersmith (Huron County). The 400 square kilometre area included in the sinkhole investigation study is presented in Figure 1.

Included in the study were several study partners selected to reflect the regional and local relevance of groundwater in this study. They include provincial and municipal levels of government, conservation authorities, local landowners, the agricultural community, rural organizations and other agencies. The Ministry of the Environment (MOE) was the

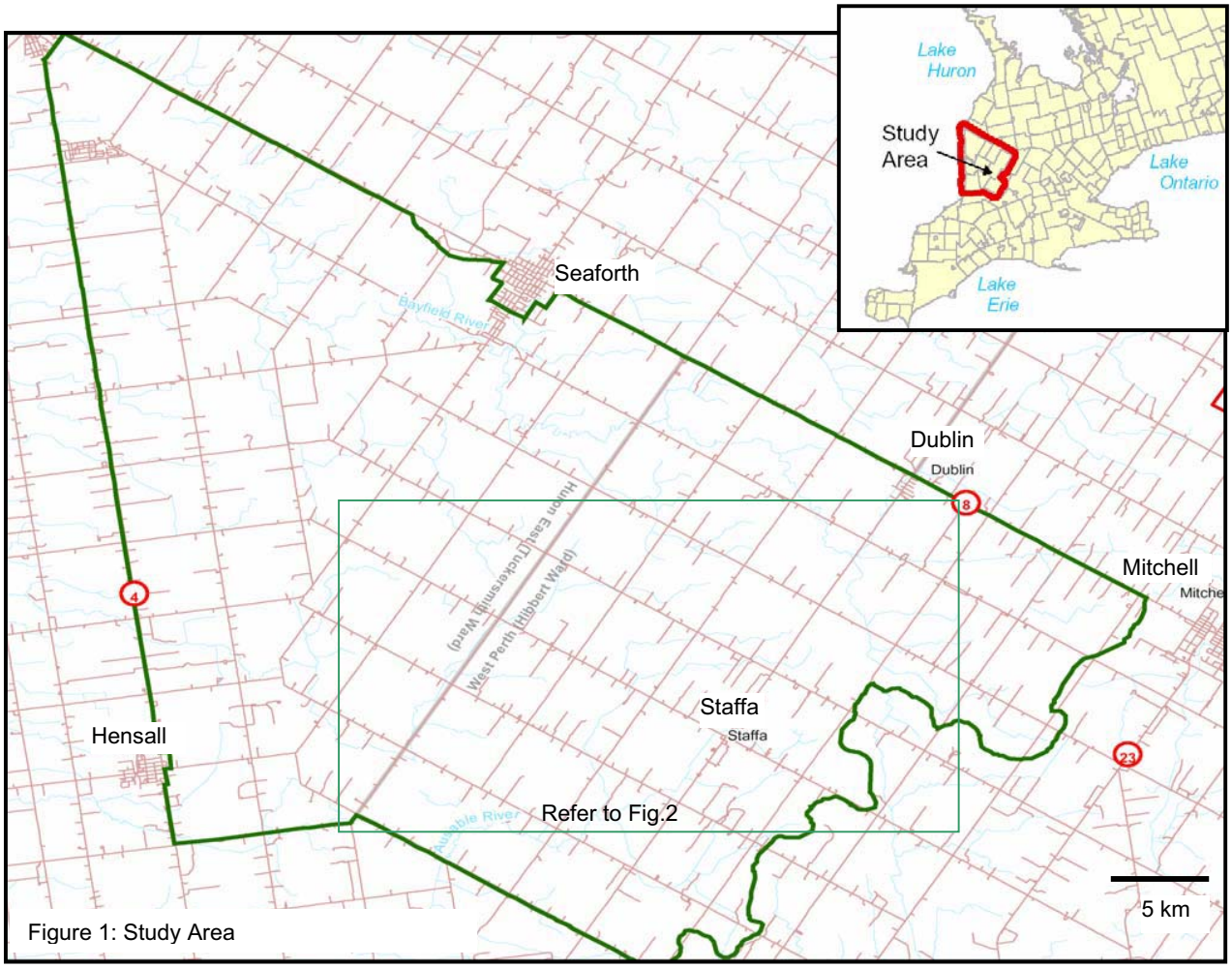


Figure 1: Study Area

project's primary funding organization and provincial partner. The Ausable Bayfield Conservation Authority (ABCA), the Municipality of Huron East, and the Municipality of West Perth were also major partners to the study and have provided funding and in-kind contributions of technical staff and project management resources.

The study developed from a base comprised of work previously completed at a regional scale across the Counties, local studies completed by the MOE, and a compilation of regional information sources. Previous recent initiatives such as the Perth County Groundwater Study (WHI, 2003) and the Huron County Groundwater Study (IWC, 2003) created an understanding amongst a core group of people within the Conservation Authorities and local municipalities.

2. SINKHOLE INVENTORY AND MAPPING

A review of literature was conducted to identify the potential locations of sinkholes near the county boundary between Huron and Perth. Several sinkholes were previously mapped prior to the commencement of this study (Cooper, 1979, Brown, 1981, Beukeboom, 1995, Karrow, 1997), and these reports were reviewed alongside orthophoto imagery, and maps of municipal drainage patterns. After soliciting and receiving permission from local landowners, field visits were conducted in May 2003 to identify, map and classify the sinkholes within the study area. Detailed characteristics of each sinkhole were recorded in the field, and this information was then transferred into an MS Access database, with a scanned copy of the original information and photographs of the sinkholes.

Figures 2 illustrates the locations, and diameters of the sinkholes studied (refer to Figure 1 for location within the study area). Several clusters of sinkholes were mapped within the study area, and two of these clusters (the Tuckersmith and Chiselhurst Clusters), contain the two largest sinkholes within the study area. Both of these large sinkholes receive water from 1 to 3 municipal drains, and each is believed to transmit considerable amounts of water to the underlying bedrock aquifer system.

3. HYDROGEOLOGIC CHARACTERIZATION

Information from various data sources, including the Ministry of Environment, Ministry of Natural Resources, Ministry of Northern Development and Mines, Geological Survey of Canada, Water Survey of

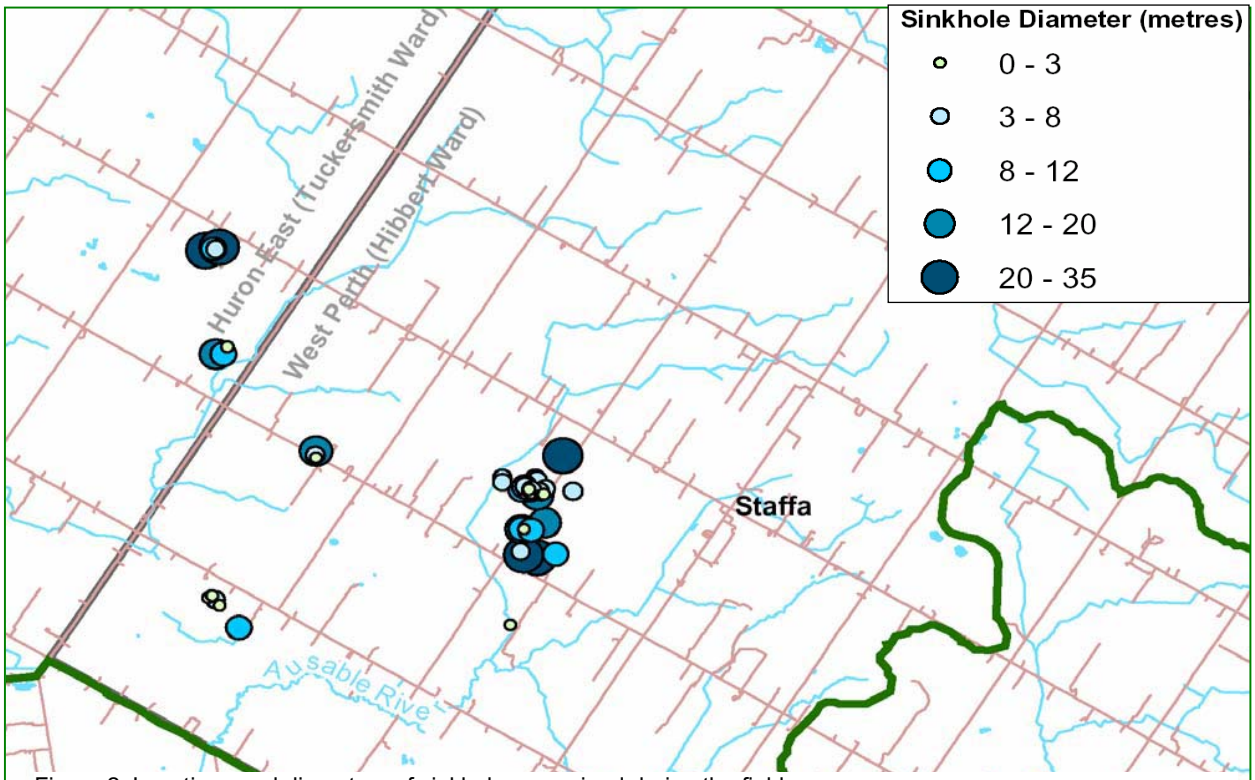


Figure 2: Locations and diameters of sinkholes examined during the field survey.

Canada, West Perth, Huron East, and the Ausable-Bayfield Conservation Authority was incorporated into a project database and GIS. The quality of the different sources of information was evaluated and data that was deemed inaccurate was not included in subsequent analyses. As part of the local analysis, water well locations, ground surface topography, Quaternary geology, bedrock geology, bedrock topography, and depth to bedrock were evaluated.

Geologic cross-sections were developed to examine the subsurface geology and gain an understanding of the groundwater dynamics throughout the study area. Thick sequences of fine-grained till overlie limestone and dolostone bedrock of the Lucas and Dundee Formations throughout most of the study area. The cross-sections also indicate that there are two hydraulically isolated bedrock systems that appear throughout portions of the study area. Where the shallow aquifer system is not in hydraulic connection with the deeper bedrock karst system, groundwater levels are locally perched. Shallow and deep bedrock water level mapping depict this relationship.

The location of sinkholes within the study area appears to be influenced by the local surficial geology, topography of the area, and the depth to bedrock. The majority of sinkholes examined were observed to lie in topographically low-lying areas that are covered with a thin veneer of glaciolacustrine sediments. Each cluster of sinkholes is typically located within a closed drainage system in which the depth to bedrock is between 5 and 15 m. This promotes the erosion of overburden, enhances the dissolution of the rock, and subsequently leads to the surface expression of the sinkholes. Based on discussions with local area landowners, sinkholes do not appear to be actively forming, and it is likely that the sinkholes mapped in this study have existed for long periods of time. This does not imply that new sinkholes are not presently forming, or that they could not develop in the future.

4. FIELD ACTIVITIES

Fieldwork was an integral part of this study and included the siting and installation of a long-term monitoring well. The well was drilled downgradient of largest sinkhole in the Chiselhurst cluster in an area accessible for a drilling rig. Groundwater levels in the long term monitoring well were not collected after the well was drilled as drilling foam present in the well would have yielded unreliable results. As part of the Provincial Groundwater and Monitoring Network, the well will be fitted with a data logger, and water levels will be monitored for years to come.

In addition to the installation of the long term monitoring well, water level monitoring also took place within the Tuckersmith Sinkhole. A transducer, placed 2 m from the base of the sinkhole, recorded the rise and fall of water levels in the sinkhole between June and October of 2003. Two large summer storm events were examined in detail, and estimates were made of the quantities of surface water discharged into the sinkhole. Figure 3 shows the Tuckersmith Sinkhole during a dry period (May 7, 2003),

Figure 3: Tuckersmith Sinkhole during a dry period

and Figure 4 shows the same sinkhole following a storm event (May 22, 2003).

Surface and groundwater quality samples were collected and analyzed as part of this study. Surface water (drain) samples were collected on two separate occasions at drains adjacent to the Chiselhurst and Tuckersmith sinkholes, to examine water quality prior to flow into the sinkholes. Groundwater samples were also collected from five wells; four located near the Chiselhurst Sinkhole, and the fifth well located near the Tuckersmith Sinkhole. The first round of sampling identified some trends that may be related to the proximity of wells in relation to the sinkholes, however fu should be drawn regarding water quality and the interaction between sinkholes and the underlying groundwater system.

Figure 4: Tuckersmith Sinkhole following a storm event

5.0 SINKHOLE CAPTURE MAPPING

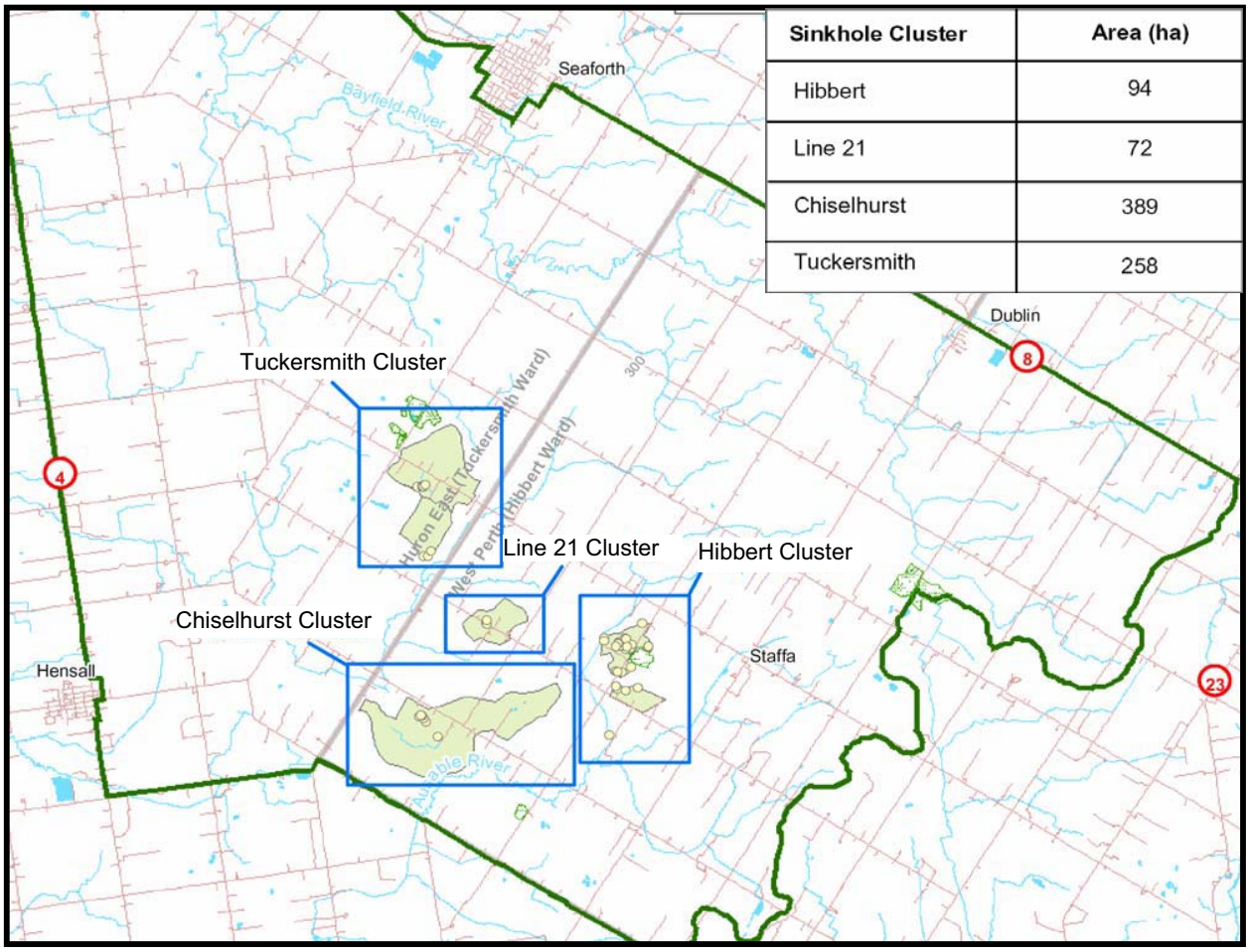
The area drained by each of the four sinkhole clusters identified in this study were estimated and are illustrated in Figure 5. The sizes of the capture zones for the different clusters varied between 72 and 389 ha, with the Chiselhurst and Tuckersmith clusters draining the largest spatial areas. The four capture zone areas total 813 ha, and based on an annual precipitation of 950 mm/yr, as much as 7.7 million cubic metres of water may be flowing through sinkholes to the underlying bedrock aquifer. Loses due to evapotranspiration and runoff interception would likely cause less water to flow to the sinkholes.

6. GROUNDWATER PROTECTION PLANNING

A Groundwater Protection Strategy is a program of risk reduction to sustain the groundwater resource, both as a source of drinking water and an integral component of the ecosystem. The strategy should incorporate a number of different tools. These tools may include a combination of land use policies, regulatory controls, best management practices, public education, monitoring, land acquisition, and spills contingency planning.

The protection of water quality and quantity depends on the collective actions of individuals, private companies, government and other agencies. Policies, such as those in a municipal Official Plan, serve to identify the public interest in water quality and quantity. An Official Plan may establish goals, set objectives for water protection (aquifer and well head protection), and provide the framework for land use development and implementation measures. The policies may also provide the rationale for the use of other planning tools such as site plan control where applicable. These are regulatory mechanisms that may be used to control development on a lot-by-lot basis, or an area-wide basis. Planning applications, such as development or land use changes, largely drive the implementation process.

Best management practices may apply to a homeowner in the use and storage of solvents, pesticides, the operation / maintenance of septic systems, and the disposal of household hazardous wastes. For the agricultural industry it may include measures such as stream buffering from cattle grazing and the care with which manure and other fertilizers are applied.



Sinkhole Cluster	Area (ha)
Hibbert	94
Line 21	72
Chiselhurst	389
Tuckersmith	258

Figure 5: Sinkhole clusters, and drainage areas

Raising public awareness, through public educational programs, can have a major impact on water protection and may be more important than enforcement measures. It is through the voluntary actions and practices of people on a day-by-day basis that will help protect water resources (i.e. proper use, storage and disposal of fuels, solvents, and pesticides, regular water well maintenance, installation of water saving plumbing fixtures etc.) Municipalities can work towards developing a 'water ethic' in their communities. This means instilling a collective awareness, responsibility, and commitment to protect water on an ongoing basis.

7. RECOMMENDATIONS

The municipalities of Huron East and West Perth rely on groundwater to supply nearly all of their drinking water needs. More than 50 sinkholes were mapped throughout the study area, concentrated within four sinkhole clusters. The locations of sinkholes have been correlated to glaciolacustrine deposits off of the flanks of the Lucan and Seaforth Moraines in areas where the depth to bedrock is less than 15 m. The sizes of sinkholes and locations of sinkholes receiving drainage water is randomly distributed throughout the study area. The largest sinkholes were identified in the Tuckersmith and Chiselhurst clusters. Some municipal drains discharge to sinkholes, with more than 800 ha of land draining directly to sinkholes.

8. REFERENCES

Beukeboom, T. J., 1995. Sinkholes and Groundwater Quality, Investigation of Potential Impacts of Sinkholes on the Quality of Domestic Well Water in the Townships of Ashfield, Tuckersmith, and Hibbert. OMOEE, southwestern Region Technical Support Section Water Resources Assessment Unit, London.

Brown, D.R., 1981. Preliminary report on groundwater concerns resulting from the drainage of agricultural lands to sinkholes, Hibbert Township, Perth County, Tuckersmith Township, Huron County. OMOEE Southwestern Region Technical Support Section Water Resources Assessment Unit, London.

Cooper, A.J., 1979. Quaternary Geology of the Grand Bend- Parkhill Area, southern Ontario; Ontario Geological Survey Report 188, 70 p.

International Water Consultants, 2003. County of Huron Groundwater Assessment and Municipal Wellhead Protection Study, Final Report.

Karrow, P.F., 1977. Quaternary geology of the St. Marys area, southern Ontario; Ontario Division of Mines, Geoscience Report 148, 59p.

Karrow, P.F., 1993. Quaternary geology, Stratford-Conestogo area; Ontario Geological Survey, Report 283, 104p.

Upper Thames River Conservation Authority, Ausable-Bayfield C.A., Maitland Valley C.A., 2001. Perth County Groundwater Study, Final Report. Submitted to the County of Perth.

Waterloo Hydrogeologic, 2003. Perth County Groundwater Study, Final Report.