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Desbarats, A J; Hinton, M J; Logan, C E; Sharpe, D R

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Geostatistical Mapping of Leakance in a Regional Aquitard, Oak Ridges Moraine Area, Ontario

A.J. Desbarats, M.J. Hinton, C.E. Logan, and D.R. Sharpe
Geological Survey of Canada, 601 Booth St.
Ottawa, ON, K1A 0E8

The Oak Ridges Moraine and the underlying glacial lake deposits within the Lower Drift (e.g Thorncliffe and Scarborough Formations) are important aquifers supplying domestic and municipal water supply within the Greater Toronto Area. The interbedded sands and silts of the Oak Ridges Moraine form a thick (50-150 m) upper aquifer system which is largely unconfined. The sandy texture of these deposits and their elevated topography provide a high groundwater recharge potential. Some of this recharge is transmitted down to the lower aquifers within the Thorncliffe and Scarborough formations although the flow paths are unclear. These lower deposits are between 10 and 100 m thick and consist of sandy and clayey sediments. The sandier sediments form confined aquifers that are used locally for municipal supply. They are confined by adjacent clayey sediments and the overlying Newmarket Till (Fig. 1).

The areally-extensive low-conductivity Newmarket till sheet forms an important regional aquitard that is believed to have a profound effect on groundwater flow patterns in the Greater Toronto Area. Far from a uniform confining unit, the Newmarket Till is incised by a complex network of sand, silt- and gravel-filled channels based on seismic profiles and continuous cores. These channels can form extensive aquifers which represent highly productive sources of groundwater. In some places, the channels cut through the till entirely and create high-conductivity windows that allow groundwater flow between the upper and lower aquifer systems. Recent investigations have also shown that there are large variations of hydraulic conductivity within the till itself due to geological inhomogeneities. Therefore, groundwater recharge of the lower aquifer system may take place by slow downward leakage over wide areas and by faster, more focused flow through windows in the till. As part of its broader investigations of groundwater resources in the Oak Ridges Moraine Area, the Geological Survey of Canada has undertaken a study of the hydrogeological significance of the Newmarket Till aquitard and the relative importance of these two recharge processes.

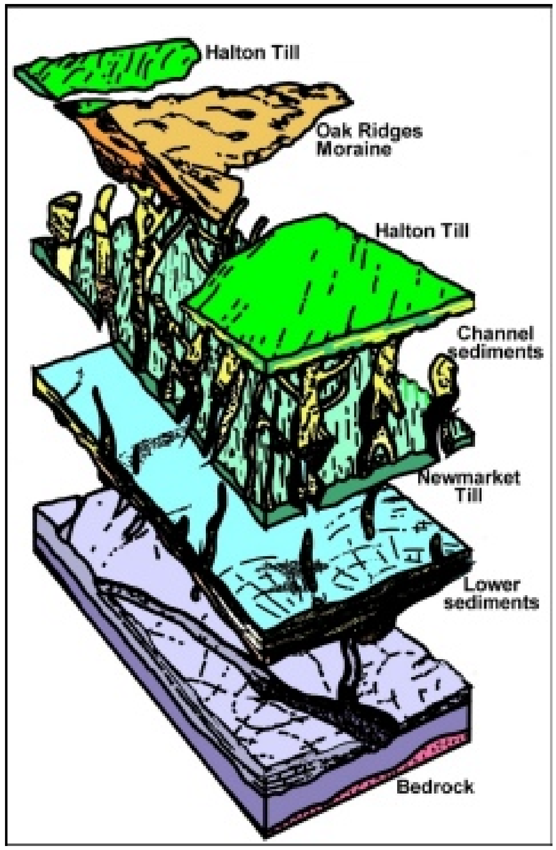

Figure 1. *Geological model of the Oak Ridges Moraine area.*

The objective of this study is to map spatial variations of the aquitard's leakance. Leakance is defined as the ratio of the hydraulic conductivity to the thickness of an aquitard and is a measure of its integrity as a flow barrier. The mapping exercise is based on over 9000 thickness measurements derived from water well records, supplemented with continously-cored boreholes, outcrop observations and seismic data (Fig. 2) that provide constraints on thickness where well control is inadequate. A small number of hydraulic conductivity measurements, gathered in the course of investigations of prospective landfill sites, are also used in the leakance calculations. Because of the considerable spatial variability in aquitard thickness and the uncertainties involved in both thickness and conductivity measurements, mapping is performed using a geostatistical approach. Thickness values on a square 250 m grid are interpolated using the Sequential Indicator Simulation method (Gomez-Hernandez and Srivastava,1990). This method is particularly powerful in that it produces thicknesses that honour the spatial statistics of observations. The method can also be used to estimate the uncertainty in mapped values. Indeed, Figure 3 shows a map of the probability of encountering thicknesses of zero, or windows in the aquitard. This map reveals that windows in the till occur over approximately 20 % of the study area. It also suggests patterns and trends associated with the incised channels that can be used to guide the targeting of new water supply wells in tunnel aquifers. Conversely, areas of zero window probability, in the uplands between incised channels, may be more suitable for siting landfills. At each of the grid locations where thicknesses are simulated, corresponding conductivities are generated by randomly drawing a value from the among the measurement data. Although somewhat simplistic, this approach is justified given the short spatial correlation ranges typically observed in conductivity data (Fogg et al., 1998), and given the number of measurements available for characterizing such a large area. From the simulated thickness and conductivity values, leakances are calculated at each grid point. Where the till is absent, leakances are assigned a default value based on the hydraulic conductivity of channel-fill deposits and the average thickness of the till layer.

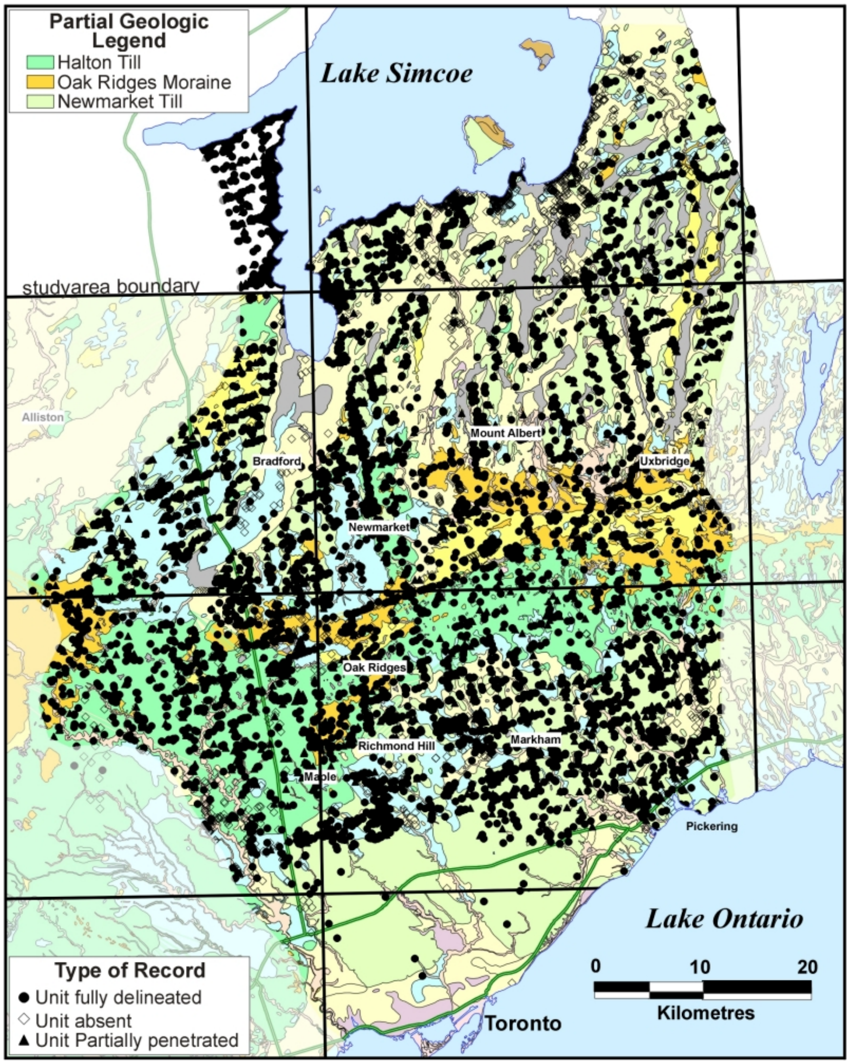

Figure 2. *Geological map of the study area showing the distribution of data points used in this study.*

The map of aquitard leakance shown in Figure 4, represents grid node values averaged over cells of 1 x 1 km so that mapped quantities are less erratic and more representative of their local surroundings. These leakances fall into two groups, one consisting of low values and associated with cells where the till is present throughout, and another consisting of very high values and associated with cells where the till is partially or completely absent. The contrast in leakances between the cells with continuous and discontinuous till averages over four orders of magnitude. This contrast, together with the areal extent of

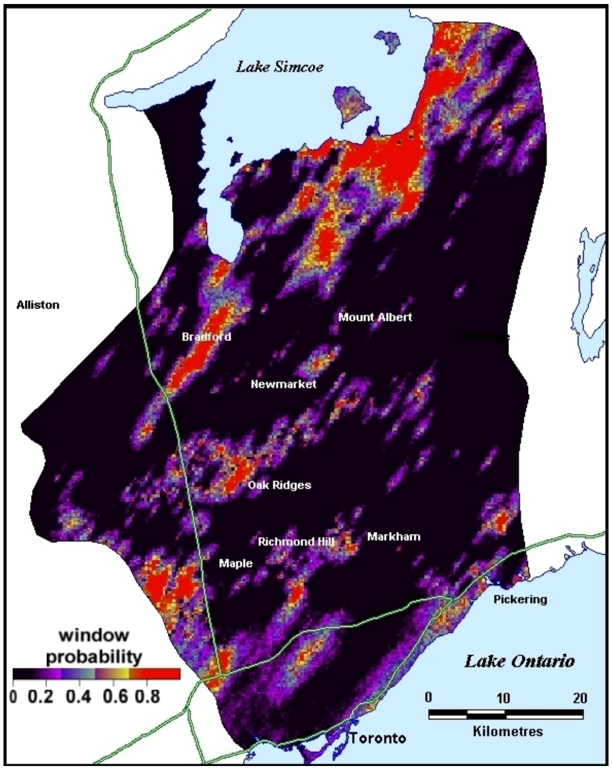

Figure 3. *Map showing probability of finding a window in the Newmarket Till.*

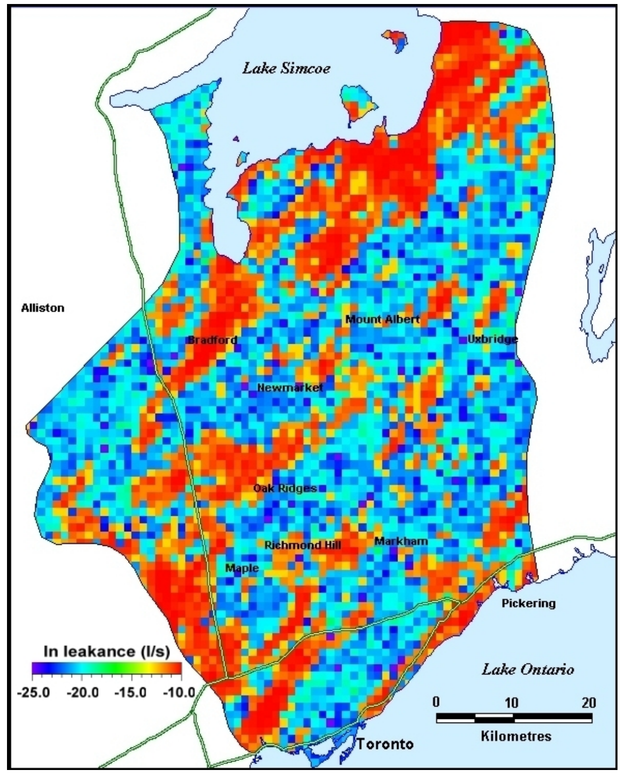

Figure 4. *Map of estimated leakance through the Newmarket Till based on 1 km block cells.*

the high-leakance group, strongly suggests that the most significant flow between the upper and lower aquifer systems takes place through windows in the Newmarket Till. However, leakage through the till itself may be significant locally, where the unit has been thinned by erosion or where its conductivity is enhanced by inhomogeneities such as sandy interbeds and/ or vertical fractures. The results of this study lend quantitative support to the current conceptual model for groundwater flow in the Oak Ridges Moraine area and the critical role of windows in the Newmarket Till aquitard in determining regional flow to lower aquifers.

Cited references

Gomez-Hernandez JJ and RM Srivastava 1990. ISIM3D: An ANSI-C three-dimensional multiple indicator conditional simulation program, Computers and Geoscience 16(4): 395-440.

Fogg GE, CD Noyes and SF Carle 1998. Geologically-based model of heterogeneous hydraulic conductivity in an alluvial setting, Hydrogeology Journal 6(1): 131-143.