Volume estimate of granular deposits and groundwater reserves of the Abitibi-Témiscamingue eskers, Québec

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INTRODUCTION

The contribution of Quaternary studies to the economic geology of Nordic countries was convincingly demonstrated in several papers published in a special number of the journal Striae (1990). These document the expansion of the granular materials extraction industry in Scandinavian countries and stress the need for effective management of the resource to protect groundwater reserves and accommodate activities on eskers. With numerous large eskers laid out for the most part in a subaqueous environment, the Abitibi-Témiscamingue region has a glacial history similar to that of several areas in Scandinavia and consequently faces the same land use problems. Abitibi eskers support a wide variety of activities; logging, sand and gravel extraction, recreation and locally contain high-quality groundwater reserves. Several municipalities draw their supply of drinking water from wells located in nearby eskers. However, the region lacks at this time the basic information to properly manage the resource. Based on the distribution of eskers known from surficial geology maps, this study presents the first regional quantitative estimate of the Abitibi-Témiscamingue granular reserves and their groundwater potential.

SEDIMENTATION ENVIRONMENTS OF ABITIBI ESKERS

The accuracy of the method used to estimate the volume and the aquifer potential of Abitibi eskers is closely related to the sedimentation environment of Abitibi eskers. The depth of proglacial lake Barlow-Ojibway was a major controlling factor of the sedimentation process. Clay (varves) sedimentation occurs in water depths exceeding 30 to 50 m (Veillette, 1996).

Maximal depth of Barlow-Ojibway submersion

A model was derived from empirical measurements of the maximum level reached by the glacial lake to produce a map showing variations in the depth of proglacial lake waters over the region. The model was generated by *trend analysis* in ArcGIS 9.3 with maximal level (100 elevation points) compiled by Veillette (unpublished data). The model uses the same tilt axis as used before (Veillette, 1994).

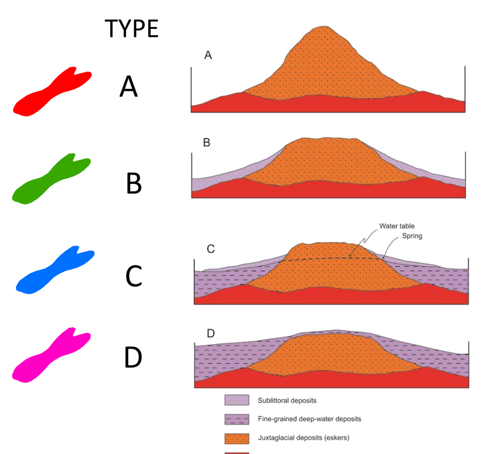
- Depth of proglacial water 0 - 50 m
- Depth of proglacial water 50 - 100 m
- Depth of proglacial water more than 100 m
- 425 Isoline of maximal level reached by Barlow-Ojibway submersion
- Clay plain boundary
- Area not included in submersion model

Types of sedimentation environments

Veillette et al. (2004) subdivided the eskers of the region into four broad types according to their sedimentation environments.

TYPE

- A — The esker lies above or outside the area submerged by proglacial waters
- B — The esker was submerged but lies at a depth located above the level of deep-water fine-grained deposition (varves)
- C — The esker lies within the deep-water facies and is partly buried by fine-grained deposits
- D — The esker is nearly or totally buried by fine-grained deposits



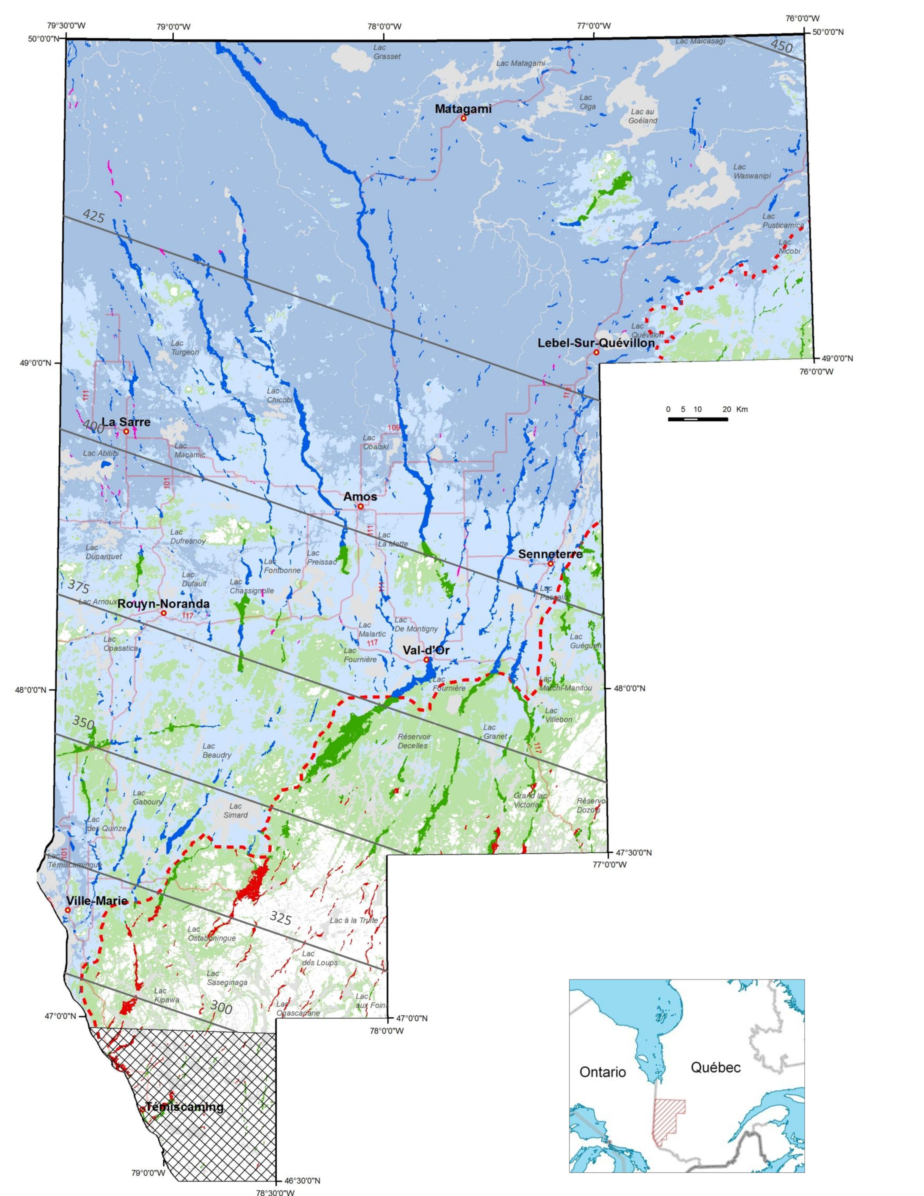


Figure 1. Sedimentation environments and maximum depth of proglacial lake Barlow-Ojibway in the study area

ESKER SEDIMENTATION IN DEEP PROGLACIAL WATERS (TYPE C): A CONCEPTUAL MODEL

A large part of the study area was submerged by the deep proglacial waters of Lake Barlow-Ojibway (see Type C, Figure 1). The morphology, internal structure and surficial characteristics of eskers result from a combination of glaciofluvial, glaciolacustrine and postglacial processes. Figure 2 illustrates the sequence of events that led to the formation of a large part of Abitibi eskers as they appear today. The model is derived from photo-interpretation, field observations, drill holes and published works.

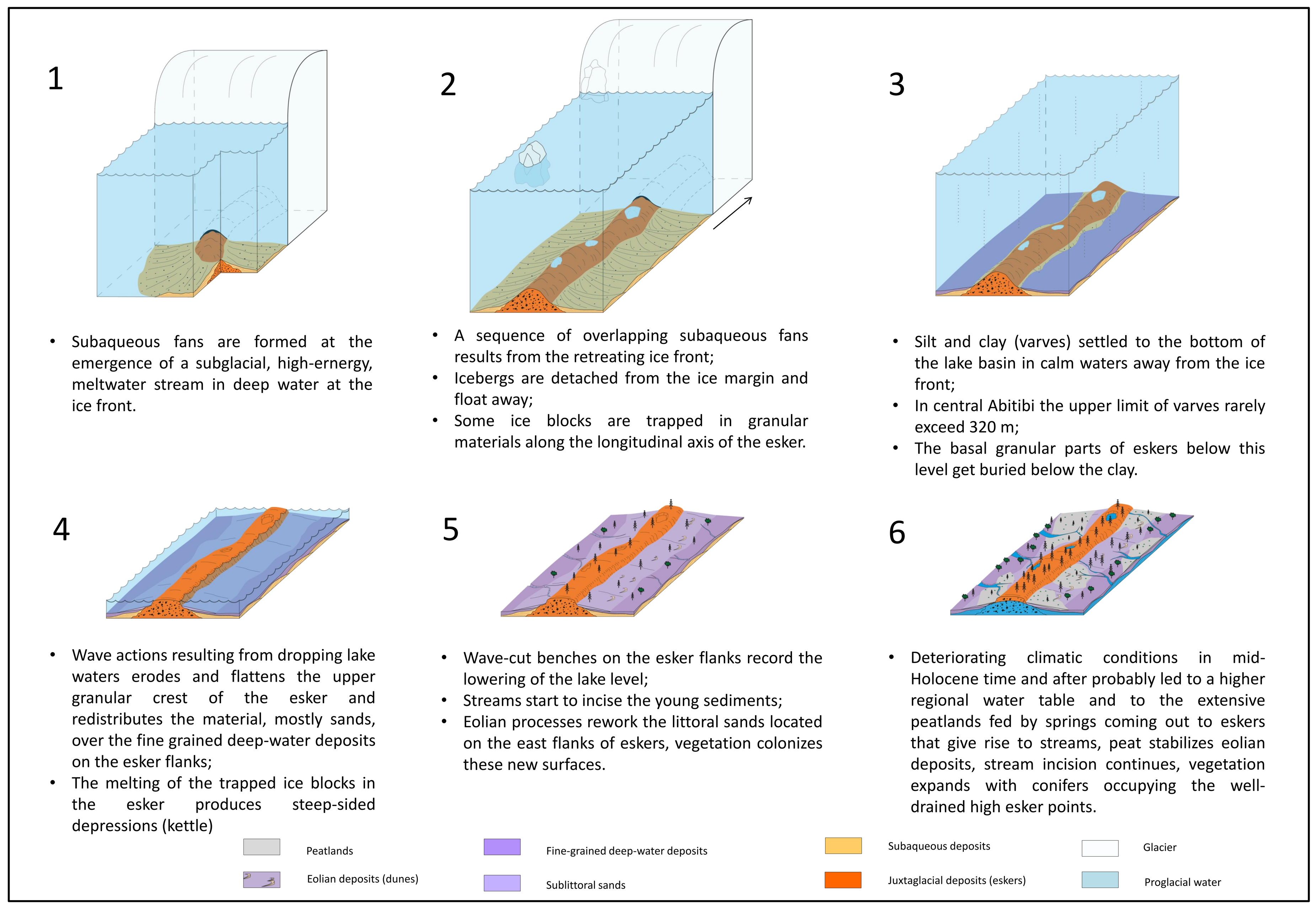


Figure 2. A conceptual model for esker formation in deep glaciolacustrine waters.

APPARENT VOLUME OF GRANULAR DEPOSITS

The volume of granular deposits was estimated using GIS methods. A DEM (digital elevation model) was generated by *topo to raster* in ArcGIS 9.3 for each esker from a 1: 20 000 topographic data base (Figure 3). The apparent granular mass of the esker, which is the outcropping median ridge(s), that stands above the confining littoral/eolian sands, clay or peat as depicted on surficial geology maps (see references) was measured (Figure 3). It follows that this volume represents a minimum value since it does not allow for the buried basal parts of eskers that may extend laterally below the confining deposits. Field observations and drilling show that sandy subaqueous fans extend well beyond the outcropping predominantly coarse-texture median part of eskers. The thicker and most extensive the confining deposits the smaller the volume estimates (Figure 4.). Figure 5 illustrate apparent height of eskers in the study area.

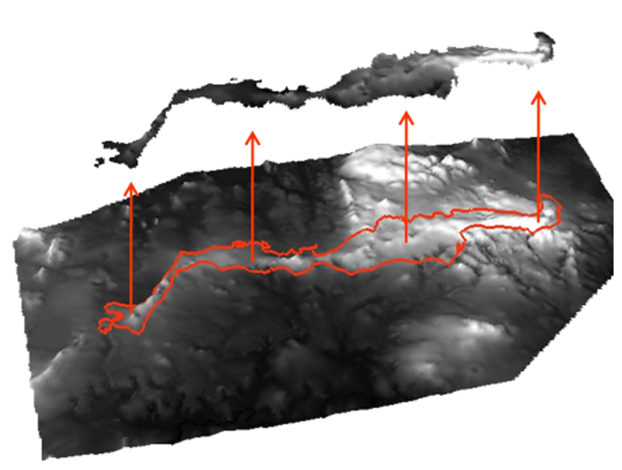


Figure 3. Esker segment boundary (red) as it appear in surficial geology map and DEM used to estimate the apparent volume of granular material in an esker segment.

Figure 4. Example of apparent section (green) calculated to estimate the apparent volume of granular materials in an esker segment.

Volume of regional granular reserves = 10,6 km³

(5700 Stade Olympique)

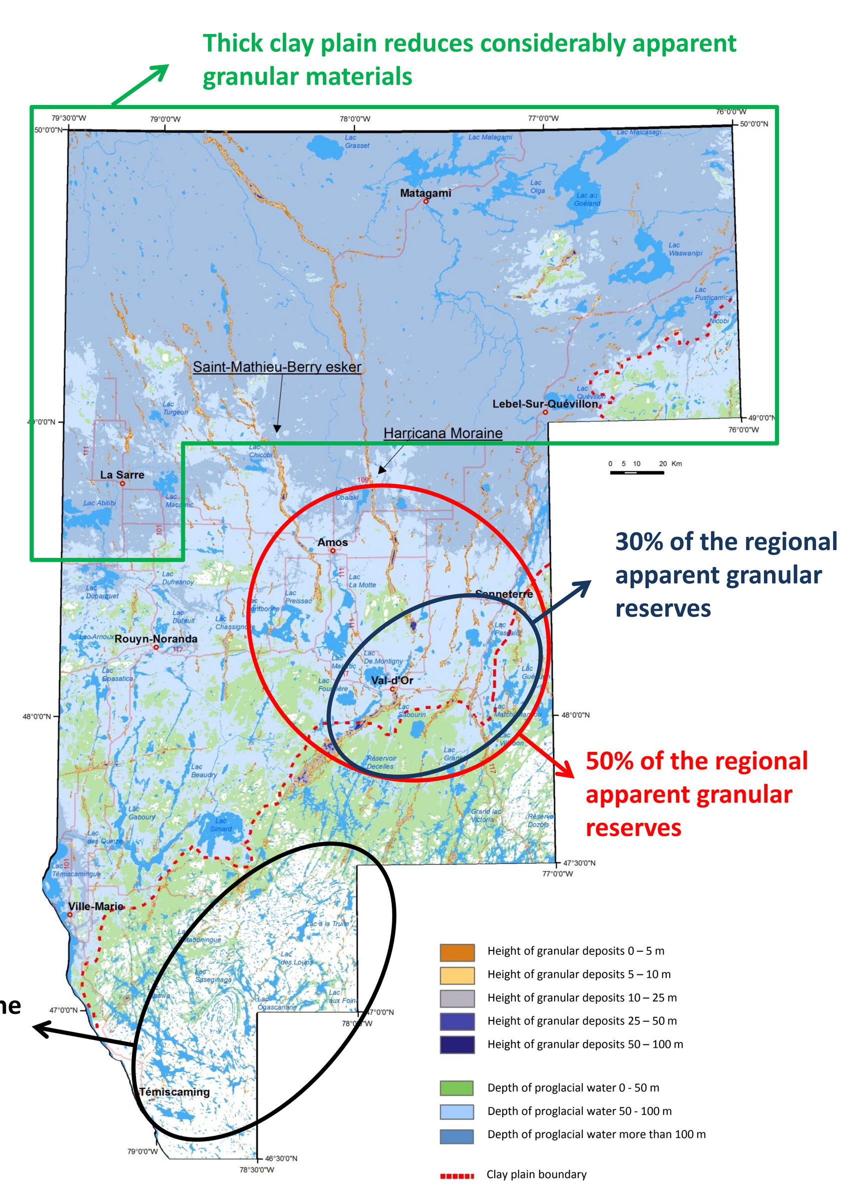


Figure 5. Height of eskers and maximum depth of proglacial lake Barlow-Ojibway in the study area.

AQUIFER POTENTIAL OF ABITIBI ESKERS

The presence of an aquifer in an esker is closely related to its sedimentation environment and to site-specific conditions such as the bedrock topography below the esker. Springs and seepage zones on esker flanks are reliable indicators of groundwater. These parameters were used to assess the aquifer potential of esker segments according to the classification outlined below; 0 for unfavourable conditions, 1 and 2 for favourable conditions. The integration of these parameters produces four different levels of aquifer potential (Figure 6).

Sedimentation environments

Value: 0: Type A and B; 1: Type C

Allow the classification of all esker segments into one of Type A, B, C or D since water depth is the key factor controlling clay sedimentation. Fine-grained deposits of low permeability resting on the flanks of an esker, as is the case with Type C esker, confine groundwater within it. These eskers contain most of the municipal and industrial groundwater facilities of the region. They have the highest aquifer potential of the region. The aquifer potential of Type D esker cannot be determined as part of this study due to a lack of geomorphological criteria visible on airphotos.

Outcropping bedrock

Value: 0: Presence; 1: No presence

Presence of rock outcrops (or thin till cover) within and in the vicinity of eskers imply the absence of major bedrock depressions, hence of natural groundwater reservoirs, below the eskers.

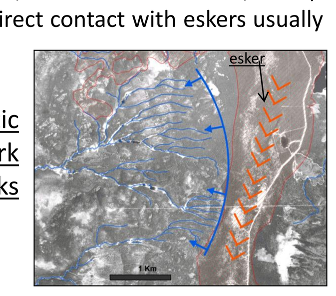
Outcropping bedrock within an esker

Springs and seepage zones

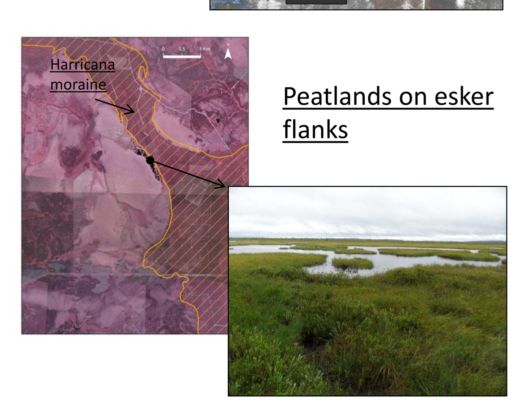
Value: 2: Presence; 1: No presence

The presence of springs, identified from airphoto-interpretation and field visits, emerging at the contact between the upper level of the confining clays and the granular flanks of eskers were taken as positive indicators of groundwater (Champagne, 1988: Veillette et al., 2004). Dendritic drainage network on esker flanks and peatlands in direct contact with eskers usually correspond to seepage zones.

Springs



Dendritic drainage network on esker flanks



Peatlands on esker flanks

High potential — Low potential

Level		
4.	High aquifer potential. All characteristics suggest the presence of a groundwater reservoir	39%
3.	Good aquifer potential. Some characteristics suggest the presence of a groundwater reservoir	32%
2.	Low aquifer potential. Some characteristics suggest the possibility of a limited groundwater reservoir	26%
1.	No geomorphological evidence of a groundwater reservoir were observed	3%

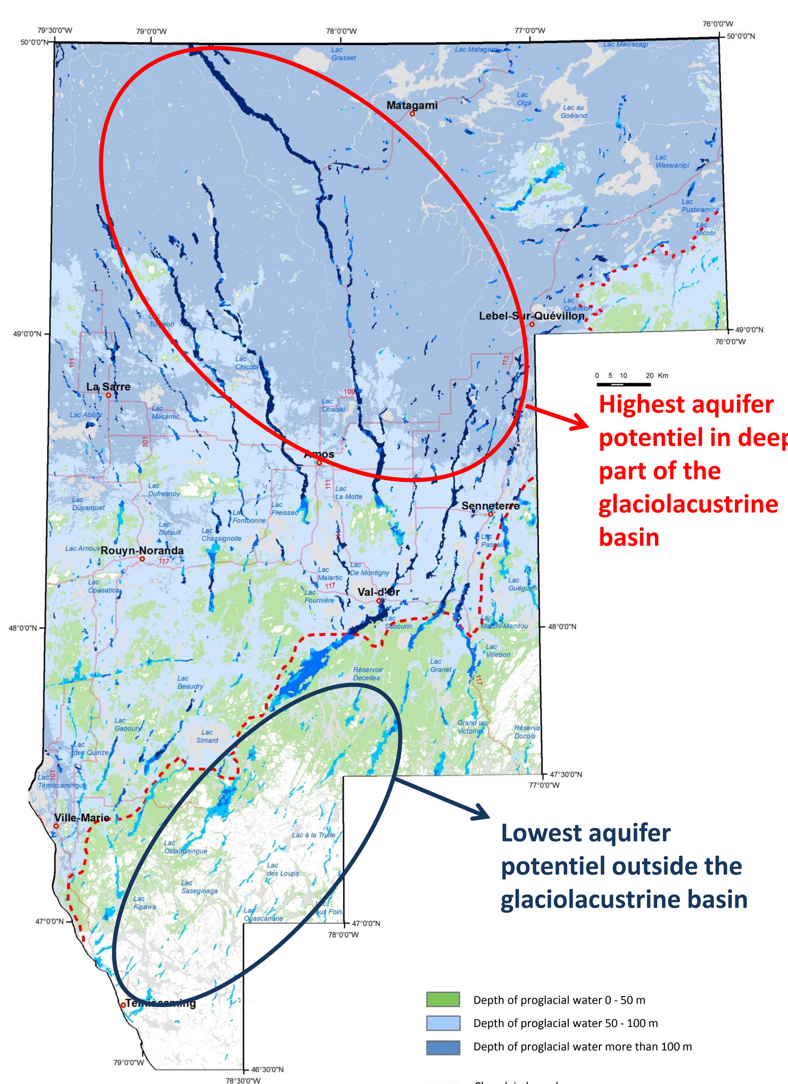


Figure 6. Aquifer potential and maximum depth of proglacial lake Barlow-Ojibway in the study area.

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CONCLUSION

Data presented constitute the first regional conservative estimate for the volume of granular reserves in the eskers of the region. The study shows the great variations in volume, grain-size and aquifer potential that can be encountered along the same esker and as such outlines the need for subdividing eskers into individual segments possessing different physical properties and consequently different land use objectives. This knowledge will allow physical planners to discriminate between esker segments with widely different land use vocations and lead to the protection and further investigation of segments showing favorable conditions for the retention of groundwater.