Title: **Time Domain Electromagnetic Induction Survey of the Sandstone Aquifer in the Lake Winnebago Area**

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Background/Need: The Cambrian and Ordovician sandstone aquifer of eastern Wisconsin is a major source of water for municipalities and industry in eastern Wisconsin. This aquifer has been developed heavily in the Lake Winnebago area, particularly along the northern and southern ends of the lake. The rate of development has intensified over the last decade in response to strong economic growth and an increase in the population of the City of Fond du Lac and the developed corridor from Neenah to Kaukauna and surrounding areas (The Fox Cities). Declining water levels and deteriorating water quality has created concerns over the long term viability of the aquifer.

Objectives: The objective of this study is to perform the first regional time domain electromagnetic induction survey (TEM) of the sandstone aquifer around Lake Winnebago. The goal is to map the thickness of the Cambrian and Ordovician Sandstone aquifer and identify areas of saline ground water. The results of this study will provide critical information needed by several water utilities to make informed water supply planning decisions.

Methods: A geophysical survey consisting of 55 Time Domain Electromagnetic Induction (TEM) soundings was conducted in Fond du Lac, Winnebago, Outagamie, and Calumet Counties using a Geonics EM57 system. The layout of the soundings was optimized to measure the electrical resistivity of the sandstone aquifer at depths of about 500 to 1,000 feet. The data were interpreted using the TEMIX modeling software by Interpex. Ltd.

Results and Discussion: The TEM data detected significant changes in the salinity and geometry of the sandstone aquifer. The patterns detected in the Fond du Lac County portion of the study area are different than the pattern detected in the Fox Cities area. Significant topography was found on the Precambrian surface in the Fond du Lac area. Steep sided mounds and steep walled basins were found. The sandstone interval adjacent to the mounds or within the basins was found to be significantly more electrically conductive, suggesting more saline water in those areas. Areas with anomalously high resistivity in the sandstone section were also detected. These areas may represent thick carbonate sequences with relatively thin sandstone sections.

In the Fox Cities area, most TEM soundings detected high electrical conductivity in the sandstone section, indicating elevated total dissolved solids levels in the ground water. A few areas with higher resistivity in the sandstone section were

detected. These areas could represent areas with better water quality. The pattern of the conductive zones in the sandstone indicated that the saline water was migrating upward from the lower portion of the aquifer in response to heavy pumpage and declining head. In some areas, the vertical contact between fresh water and more saline water in the aquifer appears to be relatively sharp. In many areas the contact could not be detected by the TEM data. This could indicate the transition is more gradational, possibly as a result of vertical migration after decades of heavy pumpage. Only a few soundings detected Precambrian rock, probably due to signal attenuation in the high conductivity sandstone section and from higher noise levels due to the developed nature of mush of the survey area. The data indicated that two previously unknown mounds on the Precambrian surface may be present.

Conclusions: The results of the TEM survey strongly suggest the presence of the high TDS water in the lower portion of the sandstone aquifer in portions of both areas. Saline water seems to be associated with structural features on the Precambrian surface in Fond du Lac County. High TDS water appears to be migrating upward in response to heavy pumpage in the Fox Cities area.

Implications: The data suggest that the topography of the Precambrian surface should be considered when siting wells in Fond du Lac County. The data also suggests that some of the area designated for future well sites for the City of Fond du Lac may not be suitable for potable wells.

The data also suggests that water quality may continue to deteriorate in the Fox Cities area as a result of vertical migration from a saline water zone in the lower portion of the sandstone. Water quality could probably be improved by drilling shallower sandstone wells, backfilling the lower portion of existing wells, and pumping less. Additional investigation and ground water modeling will be needed to estimate the rate of change in water quality in the area for a variety of development scenarios. Alternate water sources may ultimately be needed to make up the loss in capacity. These alternate sources could include additional sandstone wells north or west of the area, a major sand and gravel aquifer approximately 15 miles to the northwest, or Lake Winnebago.

Publications: Jansen, J., R.W. Taylor, and T. Powell. 2003. A regional TEM Survey to Map Saline Water in the Cambrian-Ordovician Sandstone Aquifer of Eastern Wisconsin, abstract submitted for consideration, Proceedings of the Environmental and Engineering Geophysical Society.

Key Words: Sandstone aquifer, TDS levels, Water quality, TEM surveys

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Final Report: A final report containing more detailed information on this project is available for loan from Wisconsin's Water Library, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.