

## **Mapping of groundwater reserves in Finland: the present status and aspects for future work**

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The population of Finland relies heavily on groundwater as a source for potable water. Particularly, the rural population relies almost entirely on groundwater for their domestic water needs. About 60% of potable water distributed by communal and private water works is derived from natural or artificial groundwater. Altogether in Finland there are more than 2,300 water intake plants serving more than 10 people, and there are about 600,000 private wells usually serving one single household or a summer cottage (Korkka-Niemi 2001). The vast majority of wells are finished in unconfined, shallow, and porous gravelly and sandy surficial deposits. Geologically the aquifers are located in end moraine complexes, eskers, outwash plains or littoral beach ridges and terraces, deposited during or immediately after the deglaciation of the last Weichselian (Wisconsinan) glaciation.

There are no nation-wide databases of wells, their lithologies or hydraulic properties. However, a systematic mapping of groundwater areas was conducted in early 1990's by the Finnish Environmental Institute (Britshgi & Gustafsson 1996). This database contains files from 7,141 groundwater areas. The groundwater areas have been delineated on the basis of surficial geology, observations on the elevation of the groundwater table, and location of wells. Some of the areas include more specific additional information such as borehole logs or yield estimations based on pumping tests. This systematic mapping has been very useful because it has provided a practical tool for groundwater protection actions. More importantly, it also has indicated that groundwater is capable of supplying the national water supply in the future; at present only about 10% of the estimated total yield of the mapped groundwater reserves is in daily use.

The next phase of the survey for managing Finland's groundwater resources is presently going on. A project called VIRMA was launched three years ago in order to construct a groundwater flow model (Modflow) for at least one important aquifer at each of the 13 environmental districts of Finland. The project is being conducted in cooperation with the Finnish Environmental Institute, local environmental agencies, the Geological Survey of Finland, geology departments at the University of Turku and University of Helsinki, and local water companies. Presently, there are 10 areas that have been targeted for groundwater modeling projects and these areas represent some of the largest and best known aquifers in Finland. It has been a learning experience to construct geological models for the aquifers and to connect them with the flow models. The geological model of the Virttaankangas area (Artimo et al. 2002) is a good example of the progress that has been made in aquifer mapping.

Except for the Virttaankangas area, and for an additional half a dozen of reasonable well known groundwater reserves, the present knowledge of Finland's aquifer systems is based on traditional mapping of surficial deposits, and does not include any three-dimensional (3-D) information of aquifer thicknesses, water tables, sedimentological aspects, etc. This paper attempts to indicate this gap by comparing an independent hydrogeological data set with the existing small-scale aquifer map for Finland.

There are some characteristic geological properties common to nearly all Finnish aquifers:

1. The aquifers contain considerable variability. They normally include sediment units of very high hydraulic conductivity in close contact with units of very low permeability. In addition, the location of superconductive zones is related to core zones of eskers.
2. Esker sedimentology is controlled by deglaciation rates and a strong annual cyclicity of sedimentation, resulting in an architecture of imbricated fans (Mäkinen & Räsänen 2002). Coarse-grained proximal zones often lend themselves as the most suitable locations for water intakes. They usually are separated from each other by sequences of sandy and fine-grained sediments. The distance between individual fans depends on the rate of deglaciation being about 100 meters in the southern part of the country and about 1000 meters closer to the ice divide.
3. The bedrock surface controls groundwater flow and the location of groundwater reserves. Known fracture zones indicate the deepest bedrock depressions (Vuorela 1992), which often coincide with the largest aquifer systems.

The combination of these geological elements - esker chains (Kujansuu & Niemelä 1984), annual deglaciation rates, and location of the most prominent fracture zones - resulted in a predictive map indicating the location of potential sand and gravel aquifers. This map subsequently was compared with the map of 7,100 classified groundwater reserves. The results indicate that the mapping of national groundwater resources does reflect the general pattern of where the highest yielding sand and gravel aquifers are located. However, in areas where aquifers are not well known, particularly in areas with a high groundwater storage potential, the nationwide assessment falls short, indicating a need for further research. The VIRMA-project will answer some of the questions along with additional 3-D geological modeling and subsequent groundwater flow modeling.

## References

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