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Extended Abstracts

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Environmental and artificial tracers in hydrogeology

title: **Investigation of well vulnerability in a river bank infiltrated aquifer using high resolution surface and groundwater temperature measurements**

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Larger waterworks in Norway using groundwater are typically based on river bank infiltration in shallow fluvial- or glaciofluvial deposits. Often, short distance between the river course and the wells, in addition to steep gradients and high permeability, give short residence time in the subsurface for extracted groundwater. These water supplies may therefore be vulnerable towards surface water contamination. Nevertheless, the water quality from water works based on river bank infiltration is normally surprisingly good, and based on reports from the Norwegian health authorities on drinking water quality in Norway, there are few reported cases of pathogen bacteriological contamination of groundwater.

Due to the normally good drinking water quality in river fed aquifers in Norway vulnerability assessment of these water supplies is seldom performed. Long term analytical records, showing good bacteriological groundwater quality, are often used as the only documentation for assuming that the aquifers and wells have acceptable hygienic protection against contamination of nearby surface water. Due to economical limitations, more comprehensive investigations, like tracer tests and groundwater modelling, are rarely performed to assess the aquifer vulnerability.

A commonly used method in Norway to estimate the residence time on groundwater from riverbed infiltration to extraction in production wells is to monitor the temperature fluctuations in surface water and extracted groundwater over a longer period of time. Recorded delays in temperature response in groundwater relative to surface water give evidence of groundwater residence time between infiltration and arrival at the wells. In order to obtain large contrasts in measured surface water temperatures the monitoring period covers normally the summer period and at least one of the colder seasons.

Although this method is commonly used in Norway, the validity of the method is not very well documented under Norwegian conditions, and there has until now not been reported any field experiments where long time temperature measurements have been combined with tracer tests.

In a river fed aquifer in the glaciofluvial fan at Mølleneset, near Alta in Northern Norway, NGU has, in close collaboration with Alta municipality, preformed long term surface- and groundwater temperature measurements in addition to a tracer test to evaluate the residence time for groundwater in the aquifer. The field site is display in Figure 1.

High frequent temperature measurements (each hour) over a period of more than a year using temperature loggers where performed in the Mølle river and three nearby wells. During the monitoring period well 1 and 2 were pumped with a capacity of 10–12 l/s while well 3 was only used as a monitoring well. The flow in the Mølle river change from app. 700 l/s during the spring flood to as low 60–70 l/s in the winter period. Based on monthly water sampling during the monitoring period, the groundwater from the pumped wells was found to have good drinking water quality.

As shown in figure 2, the temperature record for the river water showed both large and rapid temperature changes over the year. Similar temperature changes were also recorded in well 2 and 3, and the recorded groundwater temperature changes appeared almost simultaneously with the changes in the river temperature. Notably, the recorded water temperature changes in well 1 displayed a totally different pattern over the year compared to the river and the two other wells, with relatively slow seasonal temperature variation with no rapid temperature changes.

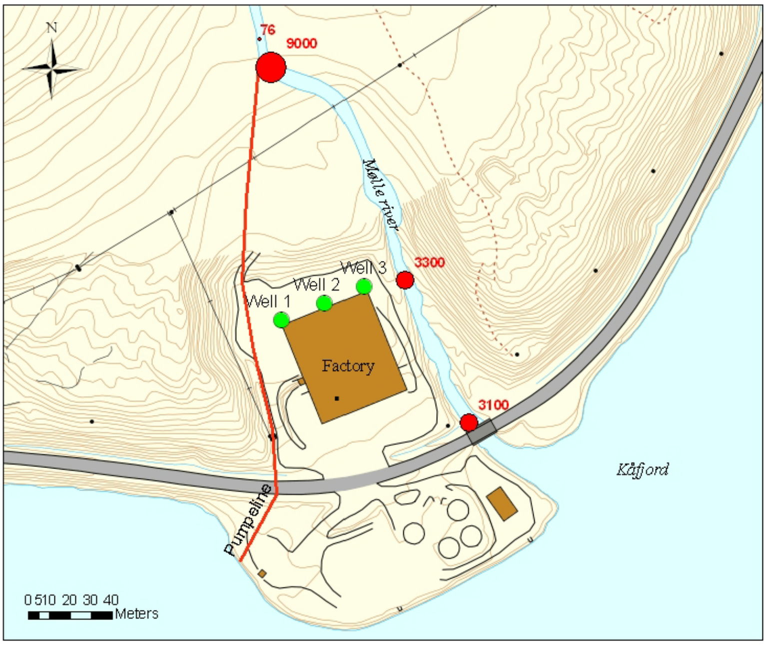

Figure 1. Field site with wells, pump line for seawater and measured EC in red (us/cm) in Mølle river after 5 hours of seawater pumping (20 l/s).

Based on these observations the groundwater in well 2 and 3 have very short residence times from river bed infiltration to the wells, whereas the groundwater in well 1 has a residence time closed to two months.

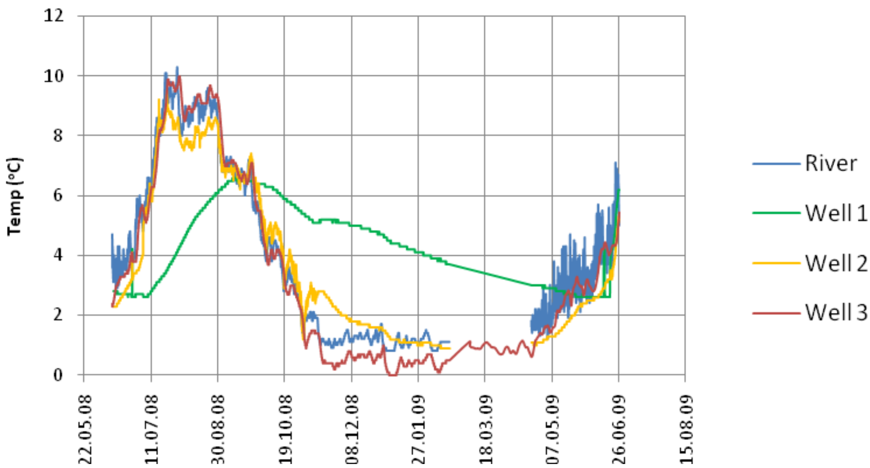

Figure 2. Long time temperature measurements in Mølle river and groundwater at Møllenes.

To validate the estimated residence time for groundwater based on temperature measurements a tracer test was performed at the well site. As the alluvial fan is close to the fjord, seawater was used as an ionic tracer and pumped into the river upstream of the groundwater wells. The seawater injection resulted in a major change in the river water's electrical conductivity (Figure 1). The seawater injection continued for a whole day with concurrent automatic logging of electric conductivity in the three wells. A quick arrival for the salt pulse and nice breakthrough curves were recorded in the well 2 and 3 (Figure 3), the same wells that displayed simultaneous temperature fluctuations in groundwater as the river water. Well 1, that displayed a slow temperature variation compared to the river water, did not show any significant change in the electrical conductivity that could be related to the seawater injection.

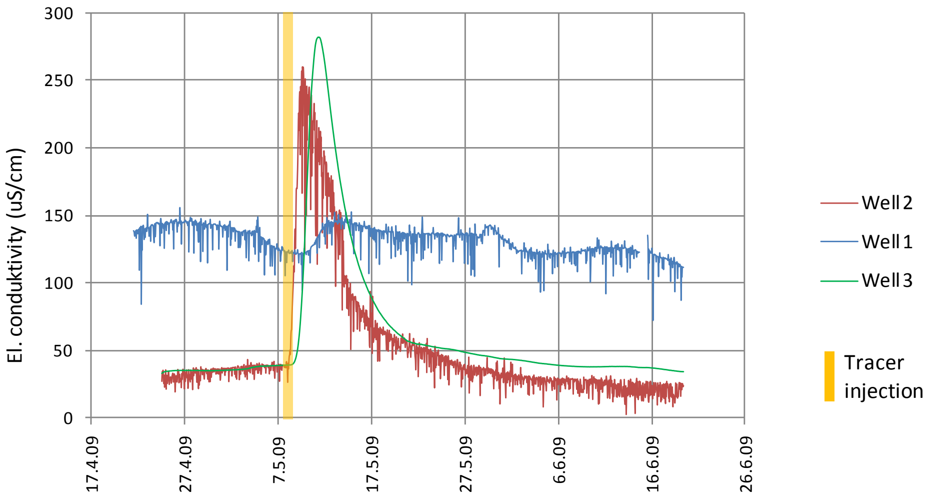

Figure 3. EC measurements in groundwater wells before, during and after seawater introduction to the Mølle river.

This experiment clearly demonstrates that there is a very good correlation between residence times estimated on river- and groundwater temperatures, and estimations based on the ionic tracer test at Mølleneset well site. The experiment supports therefore the use of the more simple methodology based on long term surface- and groundwater temperature measurements, instead of using more complicated and costly tracer test, in evaluating residence time for groundwater in an aquifer.

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