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Groundwater and Surface Water Interactions Assessed with MRS

Mette Ryom Nielsen
Ramboll Denmark
Olof Palmes Allé 22, Aarhus
mrn@ramboll.dk

Marianne Jeppesen
Lyngby-Taarbæk Supply Company
Hjortekærbakken 12, Kgs. Lyngby
mje@ltf.dk

SUMMARY

The EU Water Framework Directive (WFD) has the objective that the entire aquatic environment achieves 'good status' by 2015. Interaction between groundwater and surface water can affect the quality of both water systems and therefore it is of great importance to be able to assess the degree of interaction between groundwater and surface water.

Various issues related to interaction between surface water and ground water can threaten one of the systems. The work presented here is related to assessments of the possibility that interaction could take place between groundwater and the water in protected ponds in the large nature park Jægersborg Dyrehave north of Copenhagen. The assessments are of great importance to the evaluation of whether a planned new water supply well field at the edge of the park could have any effect on the protected ponds.

Twelve Magnetic Resonance Soundings (MRS) and twelve ground based Transient Electromagnetic soundings (TEM) were conducted in the nature park Jægersborg Dyrehave of which seven are placed close to ponds. In six of the cases there appear to be a clear separation between the surface water and groundwater, and thus there are no signs that the new abstraction will affect the water in the ponds.

Key words: Interaction, groundwater, surface water, MRS.

INTRODUCTION

Interaction between groundwater and surface water in lakes, streams and wetlands are of great importance both for the entire aquatic environment and for nature. In order to meet the WFD (EU Water Framework Directive) environmental objectives of good condition throughout the aquatic environment in 2015 (European Parliament and Council, 2000), and for the authorities to be able to assess the impact on Natura2000 areas of nearby groundwater abstraction, there is a need for methods to estimate the degree of interaction between surface water and groundwater.

The MRS (Magnetic Resonance Sounding) method is the only surface-based method to directly estimate the water content in the subsoil in different depth levels without drilling. Therefore, the relevance of using MRS to evaluate the possibility for interaction between surface water and groundwater is obvious.

Lyngby-Taarbæk Water Supply Company wants to establish a new water supply well field at the edge of the park Jægersborg Dyrehave north of Copenhagen. In the park several protected ponds are found. Lyngby-Taarbæk Water Supply Company wants to ensure that water abstraction at the new well field will not have any effect on the protected ponds. Additionally, the water supply company is unsure about the exact location of the well field, since it depends on which location has the most optimal aquifer conditions. All of this information will be of great value in the application to the municipality for the drilling and abstraction permit.

With the purpose of assessing the possibility of interaction between groundwater and the water in protected ponds, and pointing out the most optimal well field location, Rambøll has conducted twelve MRS (Magnetic Resonance Sounding) and twelve ground based TEM (Transient Electromagnetic) soundings in the nature park Jægersborg Dyrehave for Lyngby-Taarbæk Water Supply Company. Within the same project 9.4 km of high resolution land streamer seismic was conducted but will not be presented here.

METHOD

The MRS method is based on the principle of Nuclear Magnetic Resonance (NMR) and allows the non-invasive detection of free water in the subsurface. The MRS method is well described by Legchenko, A. et al. (2002 and 2013b). For this survey we used the NUMIS^{poly} equipment by Iris Instruments. We used different loop setups according to the purpose and depth target. For the MRS performed to evaluate the optimal location for the well field, we used large loops, to assess the whole aquifer. For the MRS performed to evaluate interaction between groundwater and surface water, we used smaller loops to focus on the shallow parts.

The Jægersborg Dyrehave is located close to Copenhagen and the park is surrounded by densely populated areas. As expected the noise level was very high in certain areas (~15.000 nV in a square loop, side 62,5 m, 2 turns), but also surprisingly low in others (~100 nV in an eight-shape-square loop, side 50 m). At the locations with a high level of noise it seemed to originate from very mixed sources, and different solutions were applied to reduce the noise influence as much as possible during data acquisition. For these specific locations what was experienced to be the most efficient noise reduction was a spike filter as well as increasing stack numbers and measuring during the night.

The use of the TEM method in Denmark is well known (Christiansen, A. V. and Christensen, N. B., 2003). For this project we used PROTEM 47/TEM47 instrument by Geonics with the 40 m x 40 m setup.

The MRS data was preprocessed in Proview by J. F. Girard, 2013 and flowingly processed and inverted in Samovar v. 11x45 (Legchenko, A., 2013a), using both smooth and block inversion. TEM data was processed and inverted in SiTEM/SEMDI v. 2.1.10.81 (Hydrogeophysics Group, 2010), and used to determine the Kernel.

RESULTS

Twelve MRS were performed in Jægersborg Dyrehave at strategic locations; seven were placed close to ponds and five were placed where the Water Supply Company is considering placing the well field, Figure 1. The survey was conducted in August 2013.

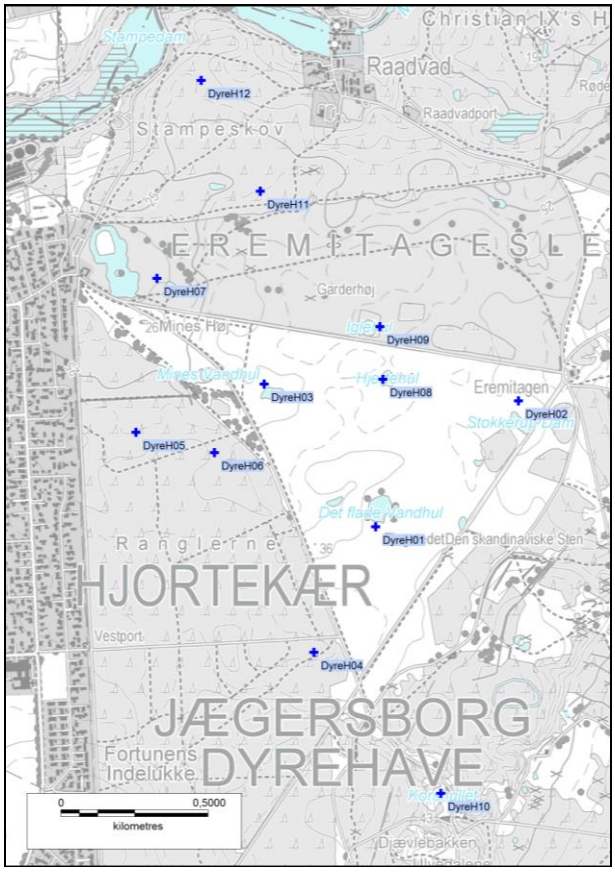
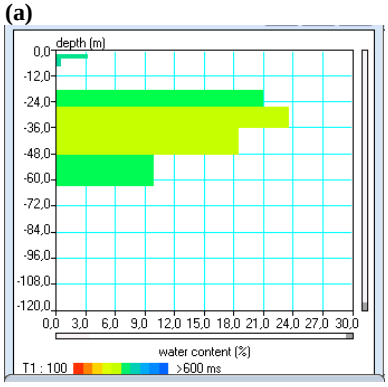


Figure 1. Location of the twelve MRS in Jægersborg Dyrehave. Seven MRS were placed close to the protected ponds.

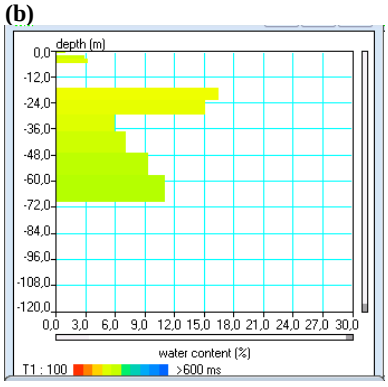
The collected data is all of good quality. In six out of the seven MRS placed close to the ponds, there appeared to be a clear separation between the surface water and groundwater. Examples of three MRS inversion results are presented in Figure 2. In all three examples the signal from the surface water is revealed as a small layer in the top 5 m. In a deeper and lager interval one or two layers are interpreted as the actual aquifers, which correspond well with the information from nearby boreholes (Jupiter, 2015). In the examples in Figure 1 (a) and (b) an unsaturated zone is observed between the surface water and aquifer, which indicate that any interaction is unlikely. In the third example in Figure 1 (c) there is also an indication of an unsaturated zone between the surface water and aquifer, but in this case the interval is narrow and a conclusion concerning possible interaction is more uncertain. However, this MRS is located the farthest away from the considered area for the new well field, and the influence from the new abstraction is therefore limited at this location.

In the examples in Figure 1 the longitudinal relaxation time, T_1, is estimated to approximately 350 ms in the aquifer, which corresponds with the aquifer described as sand and gravel above fractured limestone in the closest borehole (DGU nr. 194.8, Jupiter, 2015) (Legchenko, 2013b).

(a)



(b)



(c)

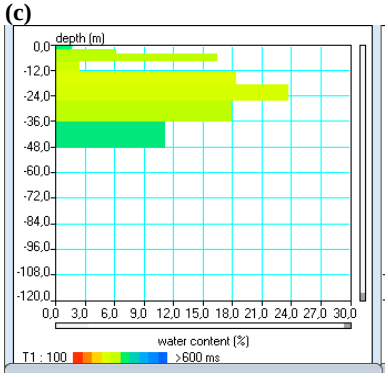


Figure 2. Examples of three MRS inversion results; Water content and Longitudinal relaxation time, T_1, used to estimate hydraulic conductivity (Legchenko, A., 2013), (a) MRS DyreH01 (S/N=9.82), (b) MRS DyreH09 (S/N=5.82), (c) MRS DyreH10 (S/N=12.94).

The second objective of the survey was to evaluate the most optimal well field location within locations in the western part of the survey area, where Lyngby-Taarbæk Water Supply Company is considering locating the new well field. Of the five MRS within this area, two locations, DyreH05 and

DyreH06, were estimated with the most optimal hydrological conditions of high water content (>25 %) and good hydraulic conditions (T_1 between 350 ms and 450 ms). The inversion results are not presented here, since this is not the main object of this paper.

CONCLUSIONS

The MRS results show an unsaturated zone between the surface water and groundwater, which indicate that any interaction is unlikely. Regarding the plans of establishing a new well in the area, there is no sign that the new abstraction well will affect the water in the ponds. This knowledge is crucial for Lyngby-Taarbæk Water Supply in their prioritization for future water supply well locations and any subsequent application for abstraction permission.

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