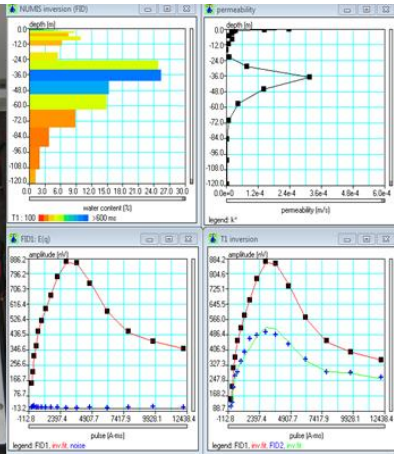

MAGNETIC RESONANCE SOUNDING (MRS)

The MRS method is the only non-invasive geophysical method that directly estimates water content and permeability without drilling

Most non-invasive geophysical methods map physical properties of the subsurface, such as electrical resistivity or velocity of sound, which can be interpreted into geological properties and structures. The MRS method differs significantly from all other non-invasive geophysical methods by assessing and estimating the water in the subsurface directly. This makes the MRS method extremely relevant in several cases.

The MRS method

The MRS method is based on the principle that protons in subsurface water pose a non-zero magnetic moment controlled by the geomagnetic field. By applying alternating electrical pulses (in a cable placed on the ground in a loop) at the resonance frequency (Larmor frequency), an additional electromagnetic field is established, and the orientation of the magnetic moment is changed. When the current in the loop is turned off, the protons return to the original equilibrium, which generates a magnetic field, also oscillating at the Larmor frequency, which is recorded by the equipment. By stepwise increasing the applied pulse moments the recorded data is collected as depth-related series of water content, permeability and transmissivity.

Relevant applications

Applying MRS-soundings are relevant in all cases where information on the subsurface water conditions is useful:

- Mapping of hydrogeological conditions in ground water mapping programmes.
- Correlation of mapped resistivities to hydrogeological conditions.
- Optimised borehole locations among several possible; either water withdrawal or thermal energy storage boreholes.
- Improved coverage of hydraulic parameters to groundwater modelling.
- Mapping of geological compositions that cannot be resolved by traditional resistivity methods.
- Aquifer locations determination crucial when performing flux risk assessment in contamination studies.
- Water content determination useful when assessing dewatering or ground water table lowering in construction projects.

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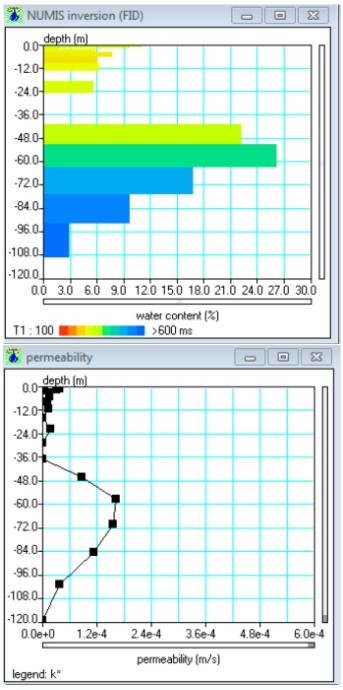
Magnetic Resonance Sounding (MRS) specifications:

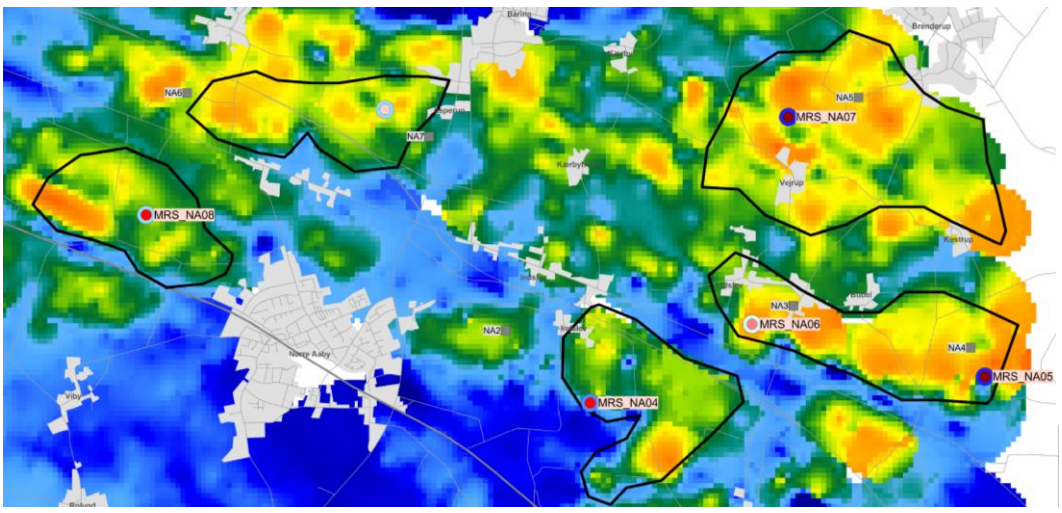
- **Maximum penetration depth: 80-120 m depending mainly on noise conditions.**
- **Approximate resolution: Approx. +/- 10 m in 60-70 m depth with traditional setup, but resolution can be improved in certain depth intervals if a certain focus depth is given.**
- **Field production: 1-3 soundings per day, depending on noise conditions and necessity for improved resolution.**
- **Strengths: Only geophysical method that directly assesses and estimates hydrogeological conditions such as water content and permeability as function of depth. What is assessed is the free water and not ex. water bound in clay, i.e. it is the water available for withdrawal.**
- **Weaknesses: Distance must be kept to all power lines (approx. 250 m to 10-60 kV and 650 m to 400 kV).**

Case example

The main MRS equipment available on the marked is shown in the middle photo on the top of the previous page. On the right top figure of previous page is shown an example of a MRS-sounding, and another example is shown to the right on this page. The first graphs show the interpreted water content (x-axis) as function of depth (y-axis). The colour indicates the estimated decay constant of the resonance signal, which is used to estimate the permeability shown in second graphs. The two additional graphs, in the top of previous page, show the resonance data amplitude as function of pulse moment, i.e. the data points are the recorded signal and the lines are the model response.

The example to the right estimates minor secondary aquifers and one deep main aquifer from 41-109 m depth with up to 26 % water.
The MRS sounding example shown on the right is part of a larger SkyTEM and MRS survey, where the results are summed up in the figure on the bottom of this page. The contour grid illustrates the resistivities mapped with SkyTEM, and colours of the circles indicate water content and permeability mapped with MRS-soundings. High resistive areas (yellow and orange areas) are identified as possible aquifers and before drilling, MRS-soundings are performed to confirm the presence of water. It is seen that the hydrogeological conditions are different within the same resistivity levels which gives an optimal background for prioritising the future borehole locations.





Contour grid (SkyTEM)
elevation -50 m to -60 m:

1 10 100 1,000
Resistivity [Ohmm]

MRS water content
(inner circles):

- 20 to 30 %
- 15 to 20 %
- 10 to 15 %
- 0 to 10 %

MRS permeability [m/s]
(outer circles):

- 5e-4 til 1e-3
- 5e-5 til 1e-4
- 1e-5 to 5e-5
- 0 to 1e-5