Applied geophysics in groundwater mapping and water resource management

More than 20 years of experience in applied geophysics.

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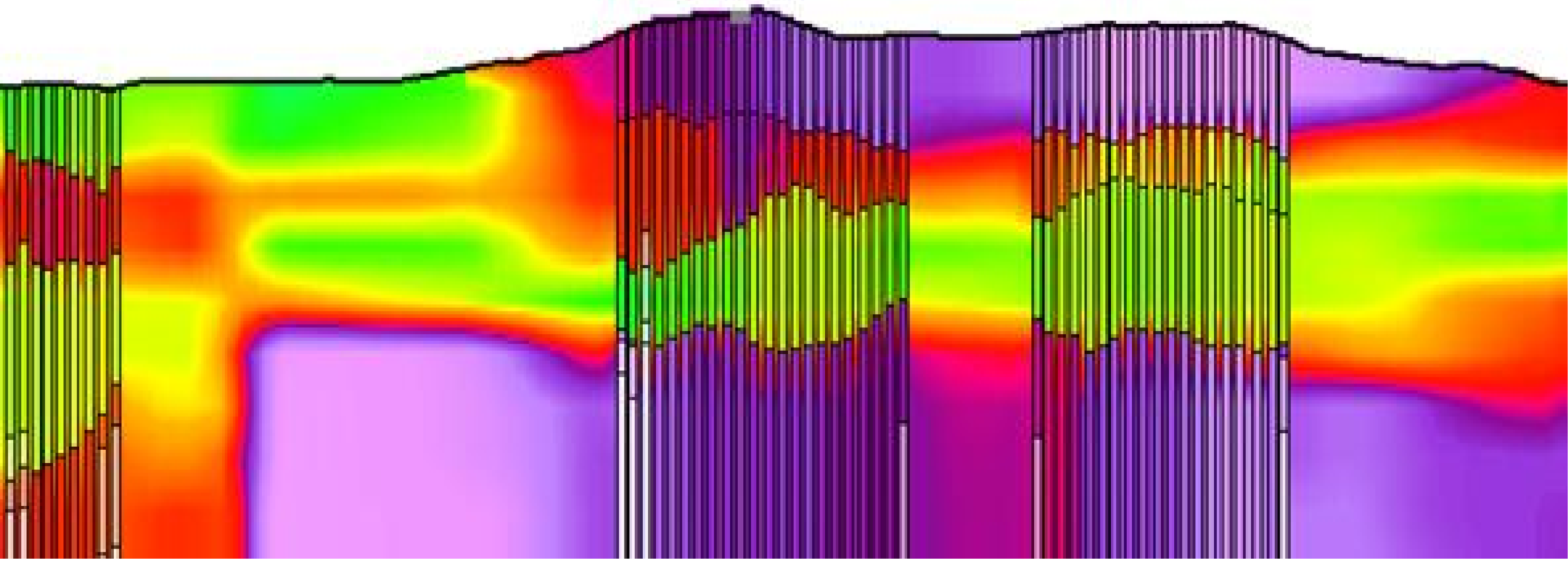
Ramboll is a company with more than 12.300 employees and 300 offices located worldwide. The group of geophysicists offers a wide range of geophysical survey techniques. With a long history of success and experienced staff – we are capable of undertaking the most demanding geophysical challenges.

For details on the various survey technologies please visit our website www.ramboll.com/Geophysics



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Growth in population, industry and irrigation, combined with the effect of climate change, causes increasing demand for water.

The key challenges of contemporary water management can only be understood within the very broad context of the world's socio economic systems. It is widely accepted that sustainable and equitable water management only can be achieved using an integrated approach. Assessment of the resource is the basis for rational decision-making, and authorities that use such assessments must be further supported and expanded from local to international levels.

Ramboll's integrated approach to water resources ensures that the management, development and utilisation of water resources, satisfies socio economic, environmental, sustainability and multi-sectoral water demands. Advanced technical solutions are applied and stakeholders are encouraged to participate.

Ensuring Safe Drinking Water

Access to safe drinking water is a basic human right and a key component of an efficient policy for health protection. Managing water resources to ensure satisfying drinking water quality is a global concern and a priority for sustainable development - the supply of drinking water of good quality is the basis for the proper functioning society.

Surface water is used as the primary drinking water resource in most countries. Around the world, Ramboll has supported many utilities and authorities manage surface water and river catchment areas to ensure a sustainable future drinking water resource and provided the overview of the available resource.

Uneven distribution of surface water and the deterioration in quality is likely to result in an

Figure 1 Drinking water

increasing reliance on groundwater resources during the coming decades. Increasing industrialization and thereby increasing risk of pollution is added to the risks of over-abstraction of groundwater, potential given subsidence or saline intrusion. When combining surface and groundwater, an integrated approach to water resources management will become ever more important.

Climate Change and Water Quality

Global climate change is likely to increase the frequency and severity of droughts and floods, and is becoming an ever more important factor for both the quantity and quality of groundwater and surface water resources. Water resources need to be managed in a holistic way for future generations.
With increasing abstraction rates the question of optimizing our use of water resources will become increasingly important to maintain good quality drinking water.

Combination of droughts and over-extraction can cause lowering of groundwater table, with eventually potential water scarcity. To prevent this, it is important to have a common administrative understanding, disregarded more arbitrary decisions.

The EU Water Framework Directive

In Europe, the Water Framework Directive defines European ambitions for the protection of our precious water resources. It aims to promote sustainable water consumption, reduce water pollution and to ensure the progressive reduction of groundwater pollution. The Directive takes a holistic approach to these topics, requiring public stakeholder involvement and socio economic studies to be part of the planning and implementation process. Ramboll's integrated expertise in water resources, river basin management, shareholder involvement and water economics enables us to assist our customers with new challenges posed by the Water Framework Directive.

Services

In relation to groundwater mapping and water resource management difference services can be applied. In the following there will be focus on the use of geophysical investigation in order to obtain as detailed information of the subsurface as possible.

Delineation of Aquifers

Due to the Danish national groundwater mapping program Ramboll has gained extensive experience in groundwater mapping. These competences include geophysical surveys, 3D geological modelling, groundwater modelling and well field exploration strategies.

Prior to setting up a groundwater mapping program it is highly important to carefully examine the purpose and expected outcome. In this phase a cost/benefit analysis should be included as a managing tool.

Borehole information contributes with valuable input about the subsurface but the boreholes are often of poor quality and they are expensive to install. To obtain extensive subsurface information in the early phase of a groundwater mapping project, experience has shown that optimal use of geophysical methods contributes with crucial information.

Combined with other available information such as water chemistry etc. boreholes and the geophysical investigation results will make up the data input for a hydrogeological model. This hydrogeological model will serve as a base for a groundwater model, describing the subsurface hydraulic conditions.

Aquifer Storage and Recovery (ASR)

Within the last decade reuse of water has been introduced many places as a new or additional source of water. Ramboll has carried out studies on integrating reuse of water in the overall water consumption and still ensuring safe drinking water.

ASR or artificial recharge plants have different designs for different proposes. Desalinated saltwater can be recharges and stored later to be exploited. Treated wastewater and storm water can be recharged and filtered through the subsurface and be recovered again down streams.

To obtain the most effective ASR plant it is extremely important to know the subsurface conditions. Different geophysical investigations can be applied to map the infiltration and the storage capacity.

Saltwater Intrusion Mapping

In many geographical regions saltwater intrusion has an important impact on the aquifer's suitability for domestic water supply. Especially electrical and electromagnetic geophysical investigation provides crucial information,

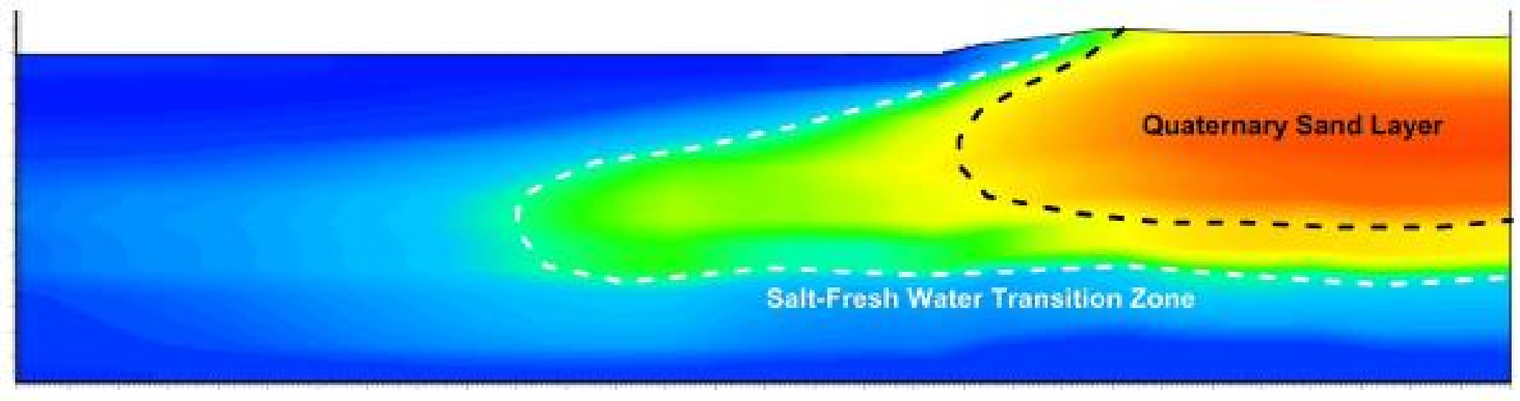

Figure 2 Geophysical mapping of salt-fresh water transition Zone

Figure 3 WalkTEM system for single site TDEM measurements

since the salinity has a strong impact on the subsurface conductivity, Figure 2.

Geophysical Investigations

Geophysical investigation measures different subsurface properties. Often measured properties are electrical resistivity or conductivity and acoustic velocity. The following is a brief selection of the systems that Ramboll can apply.

Electrical and Electromagnetic Methods

Ramboll uses a variety of methods to map groundwater reservoirs and their vulnerability to pollution from saltwater, industries or agriculture. We hold a broad spectre of electrical and electromagnetic (EM) equipment; the choice of equipment is based on the geological setting and SoW.

Time-Domain EM (TDEM)

Single site TDEM has been applied for mapping the subsurface for the last three decades. TDEM provides us with a single point of information on the subsurface conductivity, and by doing multiple points, sections of 3D distribution can be obtained. Investigation depth varies depending on the different system setups and can be as deep as 500 m.

For single site TDEM measurements Ramboll uses ProTEM from Geonics and the WalkTEM system from ABEM, a stable and flexible system developed for measuring in harsh environments, Figure 3.

SkyTEM

SkyTEM is a helicopter airborne transient EM method, specially developed for accurate measurement of the conductivity of the subsurface, Figure 4

With the SkyTEM system large and remote areas can be mapped in a short time. Results obtained with the SkyTEM system are comparable with result from the TDEM soundings; however, an airborne system measures a continuous profile. Investigation depth varies depending on the system setup and can be as deep as 500 m.

Magnetic Resonance Sounding (MRS)

The MRS method is the only non-invasive geophysical method to estimate water content and permeability without drilling.

Ramboll uses the MRS method to map hydrogeological conditions and to correlate resistivity. The MRS method is also used to optimize borehole locations among several possible boreholes, to improve coverage of hydraulic parameters and to determine water content when designing dewatering or groundwater table lowering in construction projects.

Land-Based Seismic Surveys

Ramboll has developed a technique for seismic data acquisition called Pulled Array

Figure 4 The SkyTEM-system

Figure 5 The Pulled Array Seismic (PAS)

Seismic (PAS) using a towed land streamer instead of traditional cables and geophones planted in the ground, Figure 5.

The data quality of the new PAS method is fully comparable to traditional reflection seismics but PAS is faster and more cost-effective. PAS brings fast progress, low expenses and detailed information from 30 m to more than 500 m below ground level.

Refraction seismic surveys are applied by Ramboll in order to map shallow layering, for example the depth to bedrock, and also weak zones in bedrock.

The thickness and elastic properties of shallow layers are mapped using multi-channel analyses of surface waves (MASW). MASW is also used for pavement analyses and localization of buried structures.

Electrical Resistivity Tomography (ERT)

ERT is an electrical method to measure the electrical resistivity of the subsurface. Cables with multiple outtakes are laid out and current is injected to the subsurface by spears connected to the outtakes.

Sections or profiles with detailed variation of the resistivity are obtained with an investigation depth of up to 150 m depending of the system setup. Ramboll uses the equipment Terrameter LS from ABEM.

Ground Conductivity Meter (GCM)

The GCM method is applied to obtain very dense and detailed information of the shallow subsurface, which is useful for:

- Surface infiltration capacity
- Water Sensitive Urban Design (WSUD)
- Detailed geological mapping

Ramboll uses the DualEM421 system from Dualem.com, Figure 6

Through geophysical interpretation detailed information of the upper approx. 10 meter is obtained.

Borehole Logging

Ramboll conducts borehole logging when mapping fresh water resources and for construction purposes. Our logging program includes temperature, flow, resistivity, natural gamma, EM-induction, deviation, caliper, acoustical- and optical televiewers, magnetic susceptibility, density, porosity and full-wave-form sonic logs.
In addition to this we use cross-hole tomography for illustrating the structures and shear and pressure wave velocities in-between boreholes.

Figure 6 The DualEM421 - system

Services within the field of water resource management and groundwater:

We offer a well-executed start-to-end survey or the role as supervisor for specific tasks.

The various tasks are:

- Survey design and planning
- Training of field crew and processing and inversion personnel
- Calibration of instruments and data
- QA/QC in the field and in the office
- Field operation
- Processing
- Inversion and Interpretation
- Data management and presentation
- Capacity Building

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