How helicopter-borne electromagnetic models can help to improve the hydrogeological understanding of a saltwater-rising zone

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Helicopter-borne electromagnetic investigations provide a high potential for a comprehensive mapping of the upper hundred metres of the subsurface. The relevance for hydrogeological questions lies in the determination of resistivity models to distinguish between sand and clay as well as between saltwater and freshwater saturated sediments.

Groundwater salinization

The problem of groundwater salinization in the North German Plain is becoming increasingly important within the context of groundwater extraction and treatment, and is a latent risk for the sustainable use of aquifers in Northern Germany.

Project D-AERO

In 2008 and 2009, BGR carried out airborne geophysical measurements for saltwater-freshwater investigations in cooperation with LIAG in the context of the project D-AERO (Steuer et al., 2010; Steuer et al., 2012; Wiederhold et al., 2010).

One of the survey areas covers the estuary of the Elbe river to the north-west of Hamburg (red box in Figure 1). Here, the aquifers and their salinization were mapped using the BGR helicopter-borne electromagnetic (HEM) system. Parts of the results of this survey were contributed to the project KLIMZUG-NORD, where the Technical University Hamburg-Harburg investigates environmental effects of climate change on the estuary of the Elbe river.

Inversion results

Based on 1D inversion results, resistivity maps at selected depths of 1, 10, 20 and 40 m below sea level (bsl) show the resistivity structure of the entire survey area (Figure 4). The moraine ridge (high-lying hinterland (Figure 2) consisting of Pleistocene moraine sediments) appears resistive, whereas the marsh (plain Holocene wet land, alluvium) appears conductive. In the northern part of the survey area the extent of the saltwater intrusion along the Elbe river into the Quaternary aquifer was mapped.

Water-table salinization

In this region, salinizations of the Miocene aquifer are known at some places. The Miocene aquifer is locally in hydraulic contact with the upper Quaternary aquifers due to Quaternary valleys. At those places a rise of highly mineralized groundwater may occur depending on the groundwater potential differences. The digital elevation model (Figure 2) and the Quaternary base map (Figure 7a) indicate, that the necessary conditions for saltwater risings are given. Figure 8 shows this hydrological situation schematically. In the Elbe estuary region some of such risings are documented by Gruke et al. (2000).

Hydrogeological interpretation

In the northwestern part of the survey area (black circle in Figure 5) at a place where anthropogenic sources could be excluded. This anomaly could be caused by clay or saltwater saturated sediments. The latter is presumed as analyses of waters from drainage channels and rain ponds in this area show high NaCl concentrations (150-724 mg/l). The 1D inversion result of a TEM measurement (Figure 6b) corresponds to the HEM results. The transmitter moment, however, was too low to penetrate the conductive zone.

Conclusions

HEM proved to be an efficient tool for resistivity mapping and revealed following results at the Elbe estuary. The moraine ridge and the marsh area are characterized by high resistivities and low resistivities, respectively. In the northern part of the survey area the extent of saltwater intrusion was mapped. In the southern part of the survey area a significant resistivity low obviously not affected by anthropogenic sources was detected by HEM and identified as saltwater-rising zone by water analyses and hydrogeological considerations.

References


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