Mapping possible flowpaths of contaminants through surface and cross-borehole spectral time-domain induced polarization

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In the Capitol Region of Denmark, a number of sites are contaminated due to various human activities. A large fraction of these sites are in clayey morainics, where the flow of polluting contaminants is slow and mostly towards depth. Boreholes are normally drilled in order to describe the geology, but boreholes alone do not always provide valuable information on the real groundwater flow. This is why the Capital Region initiated a project to evaluate different cross-borehole geophysical methods for mapping sand lenses/layers. A test site was established in an uncontaminated gravel pit near Hedehusene, Zeeland, Denmark (Kallerup grusgrav).

Our contribution was with spectral time-domain induced polarization (Fiandaca et al., 2012, 2013), due to its capability in lithotype discrimination (e.g. Chongo et al., 2015). The gravel pit was saturated with saltwater, which was introduced through the boreholes, resulting in a permanent decrease of contact resistance in the range of a few kΩ. Test TDIP acquisitions with borehole sequences showed poor data quality due to the high contact resistance. Consequently, around 100 litres of salt water were pumped in each borehole, resulting in a permanent decrease of contact resistance in the kΩ range. The added saltwater greatly reduced the noise in the IP decay, but also introduced a conductive anomaly at the bottom and near the boreholes.

Conclusion

The inversion results show a connected resistive sand layer seen to bury present at 1-3 m depth. The top of this resistive layer is seen on 2D DC inversion models retrieved from borehole-only data before adding saltwater are superposed to the cross-borehole inversion model. The dashed lines are the layer boundaries from the geological excavations. Despite of the alterations in the parameter distributions close to the boreholes, it was possible to retrieve the distribution of sand lenses/layers at the site, as confirmed by the geological excavations.

References


Data Acquisition

The measurements were carried out late in 2015. The electrode array consisted of a 2D 305-oriented surface profile with three boreholes. The surface profile was 65 m long with a minimum spacing of 1 m. The boreholes were drilled at 0.15 m, 1.25 m and 2.0 m along the surface profile with 51, 45, and 47 electrodes, respectively. Custom made tubes fitted with circular electrodes, with a vertical spacing of 20 cm, were inserted in each borehole, and the boreholes were backfilled with sand and watered.

Geochemistry

The site was dug out along four profiles A-D, and a geological model was constructed by superimposing high resolution photos together. The target formation in the gravel pit is the Hedeland Fm. which is overlain by 6-10 m of moraine clay.

Geological excavations showed a thin sand layer overlaying the moraine clay at 2 m depth. The top of a highly resistive layer is seen 2.5 m below the surface, which corresponds to the Hedeland Fm. Inverted models of the resistivity and chargeability and 7 m, with the DC and IP parameters suggesting the presence of thin conductive layers. The overall geology has been confirmed by the excavation performed for verifying the geophysical results.

The results will be compared in detail with the results obtained by the other geophysical methods.

Inversion Results

The contact resistances measured in the boreholes just after the borehole installation were in the order of a few kΩ, but after a few hours they increased to tens of kΩ due to the damage of the boreholes and the increase in the water table being well below the borehole depth. Test TDIP acquisitions with borehole sequences showed poor data quality due to the high contact resistance. Consequently, around 100 litres of salt water were pumped in each borehole, resulting in a permanent decrease of contact resistance in the kΩ range. The added saltwater greatly reduced the noise in the IP decay, but also introduced a conductive anomaly at the bottom and near the boreholes.

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Within the moraine clay, relatively thin sand layers were known to be present, and the purpose of the study was to determine if such thin layers could be detected by cross-borehole measurements. A geological profile along the DCP profile was constructed using the geological profiles A-D.

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Overview of null value electrodes (black dots), geological profile A-D (black-dotted line), and boreholes B0120, B1212 and B1720 (red dots).

Overview map of surface electrodes (black dots), geological profile A-D (black-dotted line), and boreholes B0120, B1212 and B1720 (red dots).