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Groundbased TEM Survey in the Subsiding Mekong Delta

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Summary

The Mekong Delta in southern Vietnam is struggling with intensive use of the groundwater due to intensive irrigation of multicycle rice cultivation and aquaculture in the coastal zone. This has led to groundwater overexploitation and salt water intrusion of the fresh groundwater resources from the coast inwards. However, the picture in this enormous delta is much more complex with many of the groundwater resources still containing residual saline groundwater from previous transgressions. Furthermore, the lowered water table has led to high subsidence rates since the early 1990's. At present, the condition of the Mekong Delta groundwater system is poorly understood, mainly described by boreholes explaining about geology and salinity, with only few geophysical surveys to connect the geological observations. In this abstract we present the first results from a groundbased TEM survey. We have mapped a large, very conductive area, with depth of investigation reaching down to -200 m. The results can feed into geological and hydrogeological models of the area and provide a better understanding of the connection between groundwater resources.

Introduction

The Mekong Delta in southern Vietnam is struggling with intensive use of the groundwater due to the increasing size and living standard of the population, but mainly due to intensive irrigation of multicycle rice cultivation and aquaculture in the coastal zone. This has led to groundwater overexploitation and salt water intrusion of the fresh groundwater resources from the coast inwards. However, the picture in this enormous delta is much more complex with many of the groundwater resources still containing residual saline groundwater from previous transgressions. Furthermore, the lowered water table has led to high subsidence rates since the early 1990's. At present, the condition of the Mekong Delta groundwater system is poorly understood, mainly described by boreholes explaining about geology and salinity, with only few geophysical surveys to connect the geological observations.

To get a better understanding of the groundwater system in a small area of the Mekong Delta, a groundbased time-based electro-magnetic (TEM) survey was conducted in January 2017, in the Soc Trang Province of Vietnam (Figure 1). Here we present some data examples, and the findings of this survey.

Figure 1 Survey area in the Soc Trang Province, Mekong Delta, southern Vietnam.

Method and Theory

The HGG WalkTEM system with a 40 x 40 m transmitter loop and a 10 x 10 m receiver loop in the central loop configuration was used in this survey. The system was with a dual-moment configuration, with a low moment for early times and high moment for late times, using ~ 2 and ~ 20 A respectively. The receiver coil and the receiver instrument contains low-pass filters which are modelled accurately using first order low-pass filters. The high moment of 32 NAI and a stacking time at each station of 5 – 8 minutes allowed to run with a 40 ms period, hence the signal was gated using log-spaced gates with centre gate times from 10 μ s to 25.6 ms. A few examples can be seen in Figure 2. Prior to the survey the equipment was calibrated at the Danish national test site (Foged, *et al*, 2013). The test site reference data was reproduced to within 3%, after calibration of the equipment.

The soundings were carried out in rice paddies in the end of the growing season, which made setting up the loops and handling the geometry troublesome, but the local field crew ensured a high production rate, and in total 386 soundings were made during the survey. Two system were used concurrently by two field crews. The mean spacing between soundings were around 4-500 m in order to cover a large area. The field conditions required walking barefoot in up to half a meter of water/mud and rice plants to the waist. Near the end of the survey the fields were harvested, which made the fieldwork much easier but brought snakes to the area.

The software package SPIA was used for the processing of the TEM data, where data is stacked and averaged, and coupled or noisy data is culled, however only a few soundings were affected by noise or couplings and 372 soundings were usable after processing. Inversion of the data was by the inversion code AarhusInv (Auken *et al*, 2015), using spatially constrained 1D smooth models. The models had 30 layers with thicknesses logarithmically increasing from 2 m down to a bottom layer boundary at 300 m. To calculate the depth of investigation (DOI), it was calculated according to Christiansen and Auken (2012).

Figure 2 Examples of stacked TEM responses with low and high moment plotted red and blue, respectively. Here the signal spans up to seven orders of magnitude in three and a half orders of magnitude in time. The grey data points at very late times are influenced by noise and are discarded when the uncertainty exceed 25%.

Results

The inversion results can either be shown as profiles or as mean resistivity maps in depth or elevation slides. In Figure 3 is shown a mean horizontal resistivity map in the elevation interval -80 to -60 m. The interpolation of the mean resistivity values to regular grids is performed by Kriging interpolation (Pebesma and Wesseling, 1998), with a node spacing of 100 m and a search radius of 600 m. In general the entire area is very conductive with large areas down to 1 ohmm, and in this interval only up to 15-20 ohmm.

Figure 4 shows an East-West oriented profile, marked by a red line in Figure 3. The models have been blanked below the DOI, which in this profile ranges between elevations -70 to -170 m. The surface layer is resistive in almost all models, this a combination of a layer of freshwater present in most rice paddies, and the loops often being placed on top of the rice plants, a field procedure which greatly increased the production speed. Just below is a continuous, very conductive layer at around 1-2 ohmm, with a layer boundary around -20 to -30 m elevation for the most models. This layer most likely corresponds to Holocene marine clays. At both ends of the profile more resistive layers are below, with resistivities around 5-15 ohmm. In between, at profile coordinates around 9000 -12500 m, the layer

boundary is missing and the conductive layer from the top extends down below the DOI. This can be interpreted as an erosion structure filled with Holocene marine clays, as seen elsewhere along the Vietnamese Coast (Dung *et al*, 2014). The erosion structure continues southward as seen in Figure 4. The higher resistive areas may be either be less heavy clays or sandy formations containing saline groundwater. To distinguish between these, borehole information needs to be incorporated.

Figure 3 Mean resistivity map between elevations -80 to -60 m, with models blanked at DOI. Red line marks the profile shown in Figure 3.

Figure 4 East-west oriented profile, blanked at DOI.

Conclusion

In this abstract we have presented the first results from a groundbased TEM survey from the Mekong Delta, South Vietnam. We have mapped a large, conductive area, with depth of investigation reaching down to -200 m. In the profile shown, a large erosion structure filled with Holocene clays have been mapped. The inversion results can feed into geological and hydrogeological models of the area and provide a better understanding of the connection between groundwater resources.

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