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Protecting coastal abstraction boreholes from seawater intrusion using self-potential data

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We investigate whether the presence and transport of seawater can influence self-potentials (SPs) measured within coastal groundwater boreholes, with a view to using SP monitoring as part of an early warning system for saline intrusion.

SP data were collected over a period of 18 months from a coastal groundwater borehole in the fractured Chalk of England. Spectral analysis of the results shows semi-diurnal fluctuations that are several orders of magnitude higher than those observed from monitoring of the Chalk more than 60 km inland, indicating a strong influence from oceanic tides. Hydrodynamic and geoelectric modelling of the coastal aquifer suggests that observed pressure changes (giving rise to the streaming potential) are not sufficient to explain the magnitude of the observed SP fluctuations. Simulation of the exclusion-diffusion potential, produced by changes in concentration across the saline front, is required to match the SP data from the borehole, despite the front being located some distance away.

In late summer of 2013 and 2014, seawater intrusion occurred in the coastal monitoring borehole. When referenced to the shallowest borehole electrode, there was a characteristic increase in SP within the array, several days before any measurable increase in salinity. The size of this precursor increased steadily with depth, typically reaching values close to 0.3 mV in the deepest electrode. Numerical modelling suggests that the exclusion-diffusion potential can explain the magnitude of the precursor, but that the polarity of the change in SP cannot be replicated assuming a homogeneous aquifer.

Small-scale models of idealised Chalk blocks were used to simulate the effects of discrete fractures on the distribution of SP. Initial results suggest that comparatively large reductions in voltage can develop in the matrix ahead of the front, in conjunction with a reduced or absent precursor in the vicinity of a fracture. Geophysical logging indicates the presence of a fracture zone near the base of our measurement array, and when included in the numerical modelling we find an apparent increase in SP prior to saline breakthrough consistent with the field observations.

Several challenges remain in accurately simulating all of the observed SP components at our study site and in identifying the presence or absence of these phenomena across a range of aquifer types. Nonetheless, this work represents an important step in the development of a new borehole geophysical monitoring tool for groundwater managers to identify impending seawater intrusion and adapt planned abstraction regimes accordingly.