ABSTRACT

The detailed characterization of salt water intrusion is a key to understand both submarine groundwater discharge and manage often intensively exploited groundwater resources in coastal areas. With the objective to study the response of a coastal aquifer to a series of boundary conditions, a new experimental site has been developed through a clastic aquifer located north of Barcelona (Spain). This hectometer scale site is located 50 m from the seashore and equipped with 17 nearby shallow holes, with depths ranging from 15 to 26 m.

In order to study not only the sedimentary structure but also the response of the aquifer to a set of natural boundary conditions, downhole geophysical measurements have been deployed over the past 3 years in an innovative manner, either in a time-lapse or stationary manner. The downhole measurements are complicated by the unconsidered nature of the sediment, obliging to perform all measurements through PVC. Also, the generic nature of the sediment prevents clays identification from a direct use of gamma ray profiles. For this, constituting minerals (quartz, albite, feldspar, microcline, illite) were identified from X-ray diffraction on cores, and spectral gamma logs used to determine the ilite fractions from Th/K ratios.

In time lapse, high frequency electrical resistivity induction measurements show that preferential flow paths through the aquifer can be identified in a fast and reliable manner. Also, changes in depth of the fresh to salt water interface (FSWI) are precisely described, either in response to marine tides, or to a short but intense Mediterranean rain event. Changes on the order of than 0.78 m are obtained in less than a day of heavy rain. Overnight as well as seasonal changes such as months of dryness are also illustrated due to the variability of pore fluid salinity and temperature, even over short periods of time such as tens of minutes.

In stationary mode, the spectral natural gamma sensor located in front of the FSWI fluctuation zones records changes in front of all radioactive peaks (K, Tl, Bl, but also Ra with Rn) during intense rain events such as that of October 18-19, 2017. This places constraints on Ra and Rn production rate during such an event, leading to trace fresh water output into the sea.

Very High Frequency (VHF) Time-Lapse Logging (TLL) of Formation Electrical Conductivity

Induction Logging Tool (GeoVista)

Natural variability over night (N3 yellow hole)

Tidal forcing : 24 hours monitoring each 20 minutes (July 30, 2016) in N3 (yellow hole)

Formation Electrical Conductivity

Formation conductivity changes with respect to May 23 profile 23

Pore fluid conductivity changes between: May 11
profilles 1, 2, 3, 4 recorded with 10 minutes time lapse and May 12 (profile 23)

High frequency conductivity changes on May 11 due to fluid flow

Over 100 profiles were recorded on a plastic day. Little changes are observed in the salt water zone below 15 m depth. Significant changes are measured in the fresh water zone with cyclic pattern above 8 m depth.

Stationary Spectral Gamma Ray Logging (at 15 m in N4 green hole)

Spectrum Gamma Ray Tool (ANTAIRES and ALT)

Comparison between 4 min stacks (Oct 17 baseline / Oct 20) in N4 (green hole) at 15 m depth

Top: Comparison between energy spectra recorded during the baseline on October 17 (green curve) and, just after the rain event (blue curve). Significant changes are observed, even for a 4 minute stacking interval. Bottom: Changes over time of gamma ray log spectra during the rain event, using 15 minutes stacking intervals. Significant drop in the activity during the initial period due to flood increase the background level of the FSWI zone, when exposed to fresh water.