The interrelation between multi layered aquifer and the sea, examples from Gaza and the Carmel coastal areas

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ABSTRACT

The interrelation between multi layered aquifer and the sea was studied in several locations in the coastal area of Gaza Strip (near Gaza city and near Rafah) and in the coastal area of the Carmel (Dor Bay).

In the Rafah area (southern Gaza Strip), the interface was found at very shallow depths in both upper sub-aquifers (~9 and 16 meters) at 150 m from the sea. The interface was sharp, especially in the confined unit, with the change from 20% to 90% seawater occurring within ~2 meters. Preliminary results show evidence for current seawater intrusion by the increase in the EC (Electrical Conductivity) of bottom water from 36 mS/cm to 48 mS/cm from January to June 2013, probably due to over-pumping in this area. Hydrological simulations were conducted with SEAWAT showing seawater intrusion in the different sub-aquifers in Gaza to be in 700-1100 m.

At Dor, several boreholes were drilled through three aquifer units, phreatic, semi-confined and confined (A, B and C, respectively), all within a section of 40 meters thick. In the confined units, the water level fluctuates tidally in phase with sea level, possibly indicating on good connection between the sea and the aquifers.

INTRODUCTION

The problem of salinization of coastal aquifers due to seawater intrusion is extremely severe in the east Mediterranean coastal aquifer, especially in the Gaza Strip. In several cases, the extent of the seawater intrusion reach a distance of more than 2 km (Mellol and Zeitoun, 1999) and still moving inland.

The relationship between the coastal aquifer and the sea depends on the hydraulic parameters of the aquifer and its connection to the sea, which can be studied by the response of the aquifer to tidal changes (e.g. Nielsen, 1980).

METHODS

Drilling was conducted in both regions to different depths in order to monitor the rate of seawater intrusion by tracking the location of the fresh-saline water interface in the various sub-aquifers.

The location of the interface was monitored by EC profiles. These measurements were conducted several times in order to follow the changes with time.

The effect of seawater intrusion in Gaza is farther studied by numerical simulation of different parts of the aquifer, using SEAWAT code.

The interrelation between multi layered aquifer and the sea was also studied by the effect of tide, using continuous data of water level in the Dor area (measured with divers). These data were compared to preliminary results of simulations in the different sub-aquifers using the FEFLOW code.

RESULTS

In the Rafah area (southern Gaza Strip), the interface was found at very shallow depths in both upper sub-aquifers (~9 and 16 meters) at 150 m from the sea. The interface was sharp, especially in the confined unit, with the change from 20% to 90% seawater occurring within ~2 meters (Fig. 1). Preliminary results show evidence for seawater intrusion by the increase in the EC of bottom water from 36 mS/cm to 48 mS/cm from January to June 2013.The boreholes in Gaza showed an interesting pattern of increasing nutrient concentrations (mainly nitrate) with salinity (=depth), which is the opposite trend of that anticipated and observed further north, along the Israeli coast. This should be further studied.

The simulations in Gaza were conducted for a model domain in south Gaza (Rafah and Khan Yonis; Fig. 2, 3). The transient simulation for the salinity of the shallow phreatic aquifer indicate that the seawater concentration extend to 700 meters inland while in the deep confined aquifer it extends to 1100 meters inland (Fig. 4).

At Dor, the boreholes were drilled through three aquifer units, phreatic, semi-confined and confined (A, B and C, respectively). In B, a two-step interface was found between 15-21 m and bottom water reached 60% seawater salinity. In the confined C, bottom water reached >90% seawater salinity, and the interface was sharp, at 36-38 m. In the semi confined unit (B), the water level fluctuates tidally in phase with sea level, possibly indicating on good connection between the sea and the aquifers. Interestingly, the hydraulic head in C is 50 cm higher and its tidal amplitudes are somewhat larger than in the shallower unit B. EC was also found to fluctuate in response to tide. Preliminary simulations imply good connection of the semi confined aquifer (B) according to the relatively fast response to the sea tide (Fig. 5).

DISCUSSIONS AND CONCLUSIONS

The hydrogeological relations between coastal aquifer and the sea are quite complex both in Gaza and Dor area due to the division of the aquifer into several sub-aquifers.

The increase in salinity in the Rafah area is probably due to over-pumping which is expected to enhance seawater intrusion. This needs to be farther studied to rule out seasonal effects. The simulations show intrusion to a distance of ~ 1000 meters which is expected to increase due to the extensive over pumping in Gaza Strip.

The good connection between the different sub-aquifers and the sea was exhibited in the Dor area by the relatively fast respond of the groundwater levels to the sea-tidal fluctuations. Indeed, the rocks of the semi-confined aquifer are quite permeable and are exposed very near the shoreline (~50 meters).

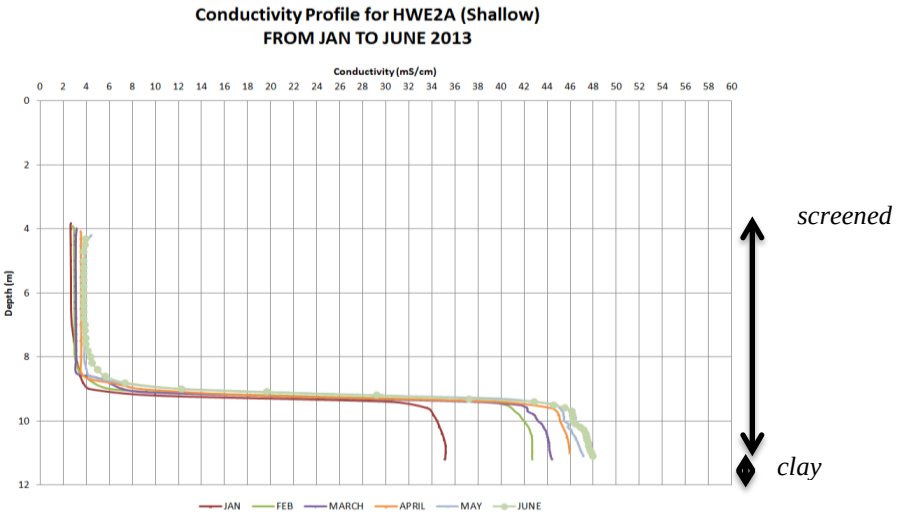


Figure 1. EC profile in well HWE2A, located at a distance of ~150 meter from the sea at Rafah area

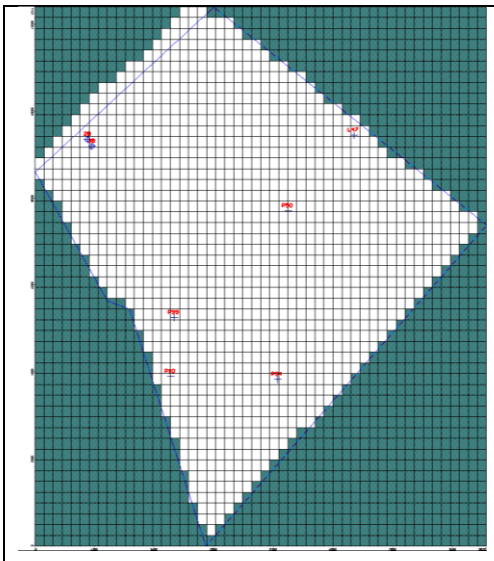


Figure 2. The model domain of the south Gaza area, of about 8 km x 12km. The wells shown in the figure are the ones used for calibration

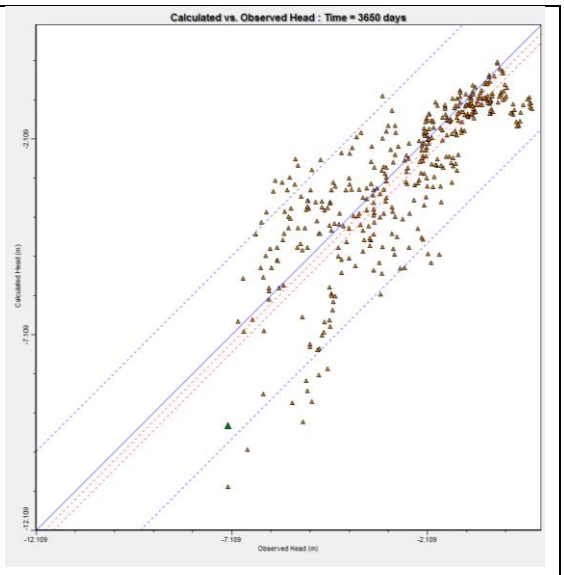
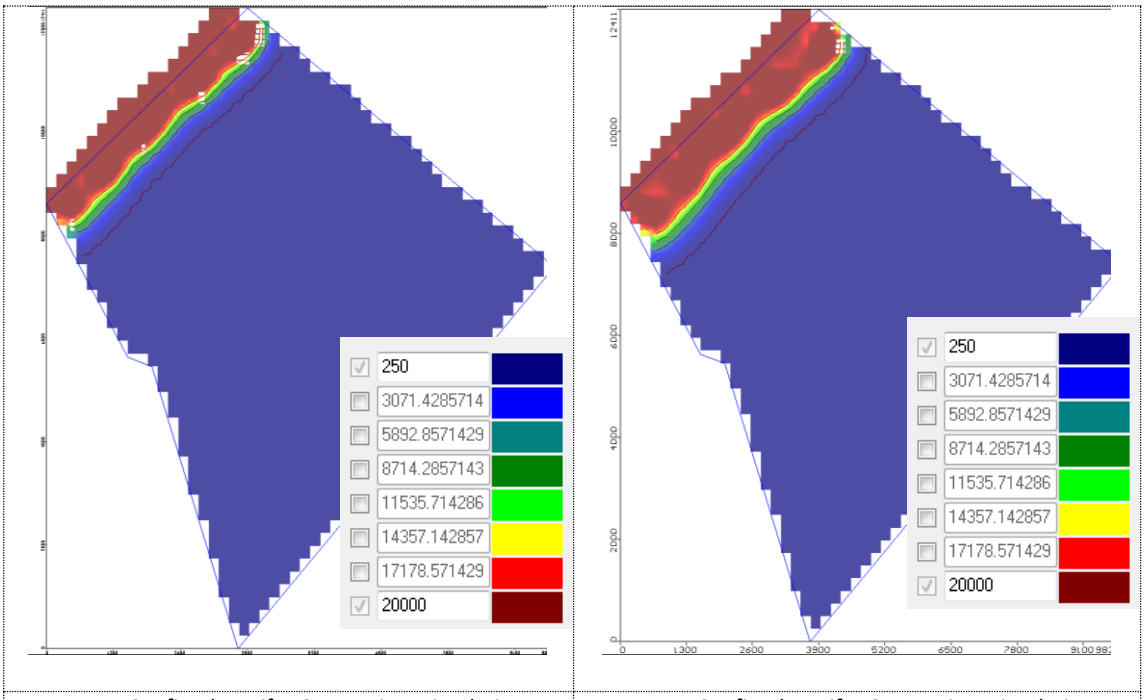


Figure 3. Steady state calibration for all the monitoring wells shown in figure 1, comparing the modeled water level and the measured water level in the aquifer. The correlation is about 85%.



Layer 7 – Confined Aquifer C– transient simulation – April 2008 – Cl Concentration (ppm)

Layer 7 – Confined Aquifer C– transient simulation – Oct 2013 – Cl Concentration (ppm)

Figure 4. Transient simulation for the salinity of the deep confined aquifer C. The dark red is the seawater concentration of CL (20,000 ppm)

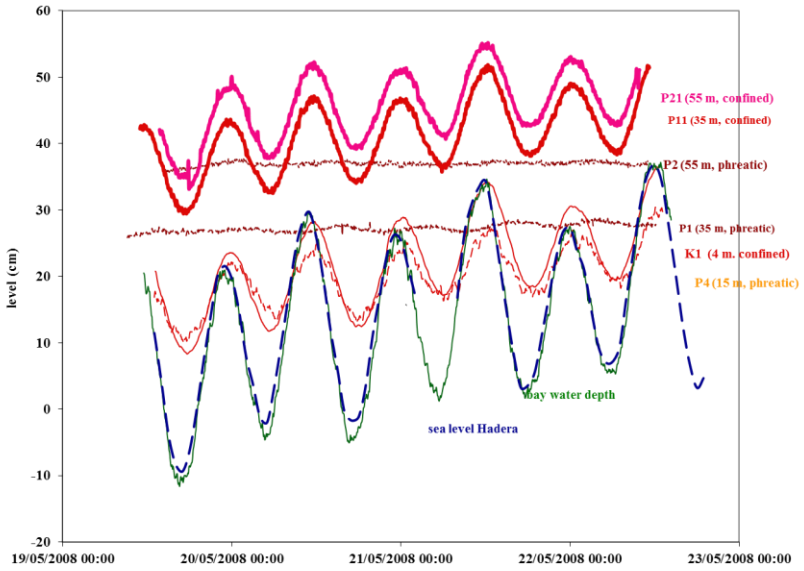


Figure 5.Water level fluctuations in several research boreholes at different distances from the sea in both phreatic and confined sub-aquifers

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Nielsen, P. 1990. Tidal dynamics at water table in beaches. *Water Resources Research* 26 (2127–2134).

Mellol A.J. and Zeitoun D.G. (1999), A semi-empirical approach to intrusion monitoring in Israeli coastal aquifer, In: Bear J.et al. Eds, 1999, pp. 543-559, Kluwer Academic Publishers, Netherlands.