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INVESTIGATION OF THE LAYERED SEAWATER-FRESHWATER INTERFACE: A STUDY FROM KALEKÖY-GÖKÇEADA, TURKEY

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ABSTRACT *Two-dimensional electrical resistivity tomography survey was conducted to determine layered seawater-freshwater interface which is under natural conditions through a semipervious layer in a coastal alluvium of Gökçeada-Turkey. The site is in the northeastern part of Gökçeada. Two electrical resistivity profiles, with using dipole-dipole configuration, were surveyed during the investigation. The interpretation of the two-dimensional inversion of the acquired resistivity data delineated the seawater-freshwater interface. Additionally to the resistivity data, two-dimensional seismic refraction tomography survey was also conducted to characterize the alluvium properties in terms of saturation conditions. It was found that the soil could be characterized with unconsolidated sediments. This study yielded useful information about the geometry of seawater body under the freshwater. The interface was found at the depth of 7-8 m, approximately, and presented an undulated surface. Seawater intruded far distant than the length of the survey area (>150m).*

INTRODUCTION

Coastal aquifers comprise prominent parts of freshwaters in regions where border the sea, especially in arid, semi-arid zones and islands. Providing that groundwater is withdrawn or pumped from a coastal aquifer, it causes rearranging of natural balance, that is seawater-freshwater interface intrudes into the coastal aquifer or even to usable parts of it. This phenomenon is called seawater intrusion, encroachment or encroachment of seawater (Bear, 1979; Domenico and Schwartz, 1990). Under natural conditions (without pumping or withdraw), the flow of freshwater can limit landward encroachment of seawater. By pumping water upwards of replenishment from a coastal aquifer, phreatic surface lowers in vicinity of the coast, hence a new seawater–freshwater interface develops. For instance, hydrogeology at many coastal locations is characterized by a layer of freshwater that is replenished from rain, and which overlies a deeper seawater layer intruding from the ocean and sea (Unsworth et al, 2007).

In this paper, a study from Gökçeada is presented. Two-dimensional (2D) electrical resistivity tomography (ERT) technique was conducted to determine layered seawater-freshwater interface which is under natural conditions through a semipervious layer in a coastal alluvium of Gökçeada. ERT is one of the most commonly applied geophysical technique for groundwater exploration and seawater intrusion and it is also capable of determining the quality of groundwater i.e., whether the water is saline, brackish, fresh or contaminated (e.g. Barker, 1980; Rogers and Kean, 1980; Urish, 1983; Abdul Nassir

et al., 2000). Additionally to the ERT, seismic refraction tomography (SRT) technique was also conducted in order to determine the unconsolidation rate of alluvium. The profiles surveyed during the study are shown in Figure-1.

Water saturation is a key point for both liquefaction analysis and supplying potable water in coastal regions. The shallower the water level is the higher the liquefaction risk is. Thus, especially settlement areas in coastal regions need to be surveyed carefully in terms of seawater intrusion which also contaminates the drinkable water wells. Our result showed that the soil in survey area could be characterized with unconsolidated sediments due to very low S-wave velocities (result not presented because of the noisy data). The boundary between seawater and freshwater was found at the depth of ~7-8 m, according to the ERT results. Due to the geological conditions it presents an undulated interface. On the contrary to expectations the sea water intruded far distant than the length of the survey area (>150m). These results confirm that the area also has a high liquefaction risk due to high water level and unconsolidated alluvium.

DESCRIPTION OF THE SITE

Gökceada island locates between latitudes 40^0 05' 12'' N and 40^0 14' 18'' N and longtitude 25^0 40' 06'' E and 26^0 01' 05'' E. The island is the largest island of Turkey and comprises 289.5 km^2 and has a population of ~9000. Gökçeada has also rich water resources and ranked 4th island of the world from the point of plenty of freshwater sources in the world. The depth to the water level is approximately 2 m below the ground level in plain parts of the island.

The name of the site surveyed is Kaleköy and it is in northeastern part of Gökçeada (Figure-1). Western and eastern parts of the region, much higher altitudes than alluvium plain, are hilly and represented by sandstone-shale sequence named Mezardere formation (Temel and Çiftçi, 2002). Hill slope allows rapid surface runoff wherefore infiltration occurs easily into alluvium. For this, the site is appropriate to investigate seawater-freshwater interface shape due to the fact that freshwater resulting from surface runoff limits seawater beneath itself.

Figure-1 The location map of site and the tomography profiles surveyed (not to scale)

THE METHODS AND FIELD APPLICATIONS

ERT technique was performed using dipole-dipole electrode configuration with Iris Syscal-R1+ resistivity meter. In order to investigate both the shallow and deeper part of the subsurface two profiles were surveyed. Electrode spacing of 4 m was selected for the profile ERT1 and 10 m for ERT2 (Figure-1). The measurements were conducted using a maximum dipole separation of 7 electrodes spacing. The processing and interpretation of the measured data were performed using the 2D inversion algorithm of Loke and Barker (1996). The algorithm is based on the smoothness constrained least squares and produce a geoelectrical section for a profile data. The optimization adjusts the 2D resistivity model by reducing the difference between the calculated and measured apparent resistivity values in each iteration. Additionally to ERT profiles, SRT technique was also applied with a Geometrics ES-300, 12-channel seismic recorder. SRT profile was surveyed with a total length of 64 m and with a geophone spacing of 4 m. 5 shot points were selected: one in the middle, two close to first and last geophone and two far offsets. First arrivals picked and the travel time curves were used in the calculation of the model velocities and depths to the interfaces with the package of Plotrefa 2.67. The method starts with a user selected initial velocity model and iteratively traces rays through the model with the goal of minimizing the RMS error between the observed and calculated travel times. The result of the S-wave survey did not produce good result since the data quality was very low. First arrivals could hardly be picked in noisy data. It also indicates the unconsolidated nature of the survey area.

The geoelectrical sections were obtained up to penetration depth of ~9 m for ERT1 and ~22 m for ERT2 (Figure-2). The zone from the surface to the depth of approximately 7 m corresponds to alluvium composed of gravel-sand-silt-clay. The resistivity values vary from 15 to 35 ohm-m in the zone. These low resistivity values for this kind of alluvium may be attributed two main factors: either high clay ratio or the water saturation in the alluvium. The existence of water saturation in this zone is suggested due to both hydrogeological conditions (shallow water level, rapid surface runoff) and the high P-wave velocity in the alluvium. It can be clearly seen that the velocities of P-waves are ~1450-1700 m/sec in that zone between the depths of 2-7 m (Figure-3). The bottom zone characterized by very low resistivities ranging from 3 to 0.7 ohm-m in both profiles corresponds to seawater (Figure-2). Because of the high resolution depending on small electrode spacing on ERT1 in comparison to ERT2, the intrusion of the seawater can be observed from ERT1 precisely and it indicates below the depth of ~7-8 m. At the bottom part of the very low resistivity zone observed on the profile ERT2 (>20 m), resistivity increases with depth (Figure-2). This may be interpreted to be decreasing porosity in response to increasing compaction and this compaction may indicate the Mezardere formation represented by sandstone-shale sequence.

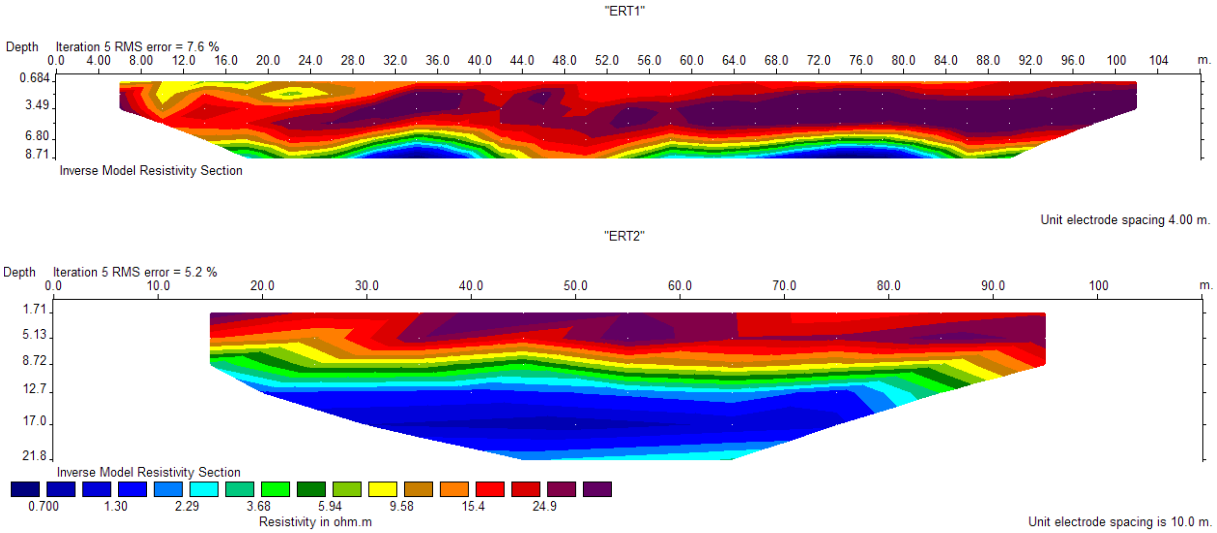

Figure-2. The inverse model resistivity sections for the profiles, ERT1 and ERT2.

CONCLUSIONS

The conducted ERT survey at the coastal alluvium in Kaleköy-Gökçeada identifies successfully the layered seawater-freshwater interface. The interpretation of resistivity sections with the combination of SRT section provides a meaningful existence of freshwater. We interpreted that the freshwater (15-35 ohm-m) exists over the denser seawater (0.7-3 ohm-m). The seawater-freshwater interface was observed below the depth of ~7-8 m. On the other hand, because of the shallow water table level and the existence of sand zones in the coastal areas of Gökçeada, there can be potentially liquefaction risk if the area opens for settlement.

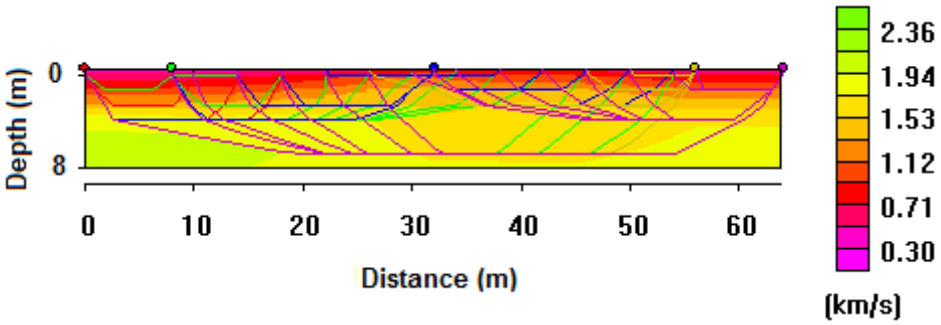

Figure-3. The seismic tomography section for the profile SRT with ray traces

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