Estimation of underground fractured aquifers in the region of Eskişehir, Turkey, by using 1D inversion in electrical resistivity data (VES).

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Abstract

The present work has as its main objective the estimation of underground aquifers in Eskişehir Province, Turkey by using the electrical resistivity method. In order to interpretate de data collected, it was used an interactive program inversion for 1D interpretation of Schlumberger sounding curves. The program, written in Matlab, optimizes the gap between the measured and the calculated apparent resistivity data. The work consists of real data, where shallow aquifers were observed based on resistivity's values variation. Data used were based on the Schlumberger array and the VES (Vertical Electrical Sounding), where the center point of the array is kept at a fixed point, while the spacing between the current or potential (or both) electrodes are gradually increased.

Introduction

The problems with the lack of water for human consumption and for use in agriculture has been growing worldwide. In the region of Eskisehir province, more precisely in the regions among the villages of Topkaya, Fahriye and Şerefiye, the problems occur especially during the summer due to increased consumption and lack of groundwater recharge. The wells drilled in these regions (around 50-55m deep) have a relatively low flow rate of water (54 to 140.4 m^3 / h) and capture it mainly from sedimentary aquifer related to the conglomerate unit, from Hamitabat Formation. In this path, the studies developed in this work will be done by using 1D inversion of resistivity data (VES) in order to map the shallow sedimentary aquifer. This procedure employed can contribute effectively to the development of hidrogeophysics researchs in the Eskisehir province and Turkey. The results to be obtained will help to minimize the ambiguities inherent in the interpretation of geophysical data, and it will have important implications for hydrogeological studies, for example, the mapping of shallow sedimentary aquifer, the location of subhorizontal fractures zones, the layer thickness estimation and in the orientation of wells drilling in the exploration of groundwater research in the sedimentary aquifer system.

Data analysis of electrical research was conducted based on quantitative interpretation, which allows to characterize the subsurface material, determining the thicknesses and resistivities of horizontal layers, adjusting the apparent resistivity data by using the 1D inversion algorithm ''A Damped Least-Squares Inversion Program for the Interpretation of Schlumberger Sounding Curves''

The apparent resistivity values obtained in the field were used to adjust the geoelectrical model of Earth 1D, in order to obtain a compatible geologic-geoelectrical model.

Method

The electrical resistivity method is used in the study of horizontal and vertical discontinuities in the electrical properties of the soil and also in the location of three-dimensional bodies with a electrical conductivity anomaly. It is routinely used in hydrogeology and engineering geology investigations in order to investigate the shallow subsurface. The resistivity method consists in injecting current in the subsurface by two current electrodes(often called A/B or C1/C2) and measuring the voltage difference by two potential electrodes(often called M/N or P1/P2). This will give you the value of an apparent resistivity (resistivity that will change when changed the location and separation of the electrodes, that's the reason to be called apparent resistivity), that can be calculated by diving the voltage(V) by the current injected(I), and multiplying by a factor that changes for each array.

Schlumberger array is commonly used in Vertical Electrical Sounding surveys, which consists of keeping the current and potential electrodes (or both) in the same relative spacing, and the whole arrangement is gradually expanded around a fixed central point. Consequently, the data being measured are taken as current reachs greater depths. 1D electrical method using Vertical Electrical Sounding has been employed over the years to characterize aquifer in different geologic environments and to map fractures in basement areas (Koefoed, 1979, McDowell, 1979, Ayolabi et al, 2003). The technique is also extensively used in geotechnical survey to determine the thickness of overburden and in hydrology to define horizontal zones of porous stratum. The data inversion of vertical electrical sounding assumes an one-dimensional (1D) earth model to determine the model parameters, which are: resistivity and layer thickness. It is assumed, implicitly, a stratified plane, formed by horizontal layers laterally infinite, homogeneous and isotropic, which the electrical resistivity varies only with depth.

Methodology

In the work, the example used for interpretation of Schlumberger sounding curves was based on actual data from Turkey. The studied area is located in the Eskisehir province, more precisely among the villages of Topkaya, Fahriye and Serefiye, in the northwestern part of Turkey. The profile survey done, using Schlumberger array (VES) had north-south and had a total of 13 sounding sections, as shown in figure 1. The geology of the studied region is composed of Paleozoic marble, Neogene conglomerate, mixture of sand, Pliocene clay and pebbles and alluvium. The top layer, mostly alluvial, has limited water, while the main aquifer occurs in the conglomerate layer, which reaches the surface at north of the survey area and has unit larger than 200m, acting as a good reservoir. The marble bedrock appears as the metamorphic unit. During the work, the drilling of a well found marble after 6-7 m and continued until a depth of 50-55m, with water flow rate of 54-140.4 m^3/h approximately.
The maximum and the minimum half-current electrode separation used were, respectively, 700 and 400 m.

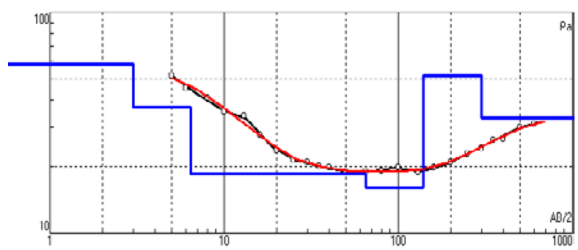
Figure 1- Area where soundings were made, among the villages of Topkaya (39°38'01.88"N/31°00'43.77"E), Fahriye (39°37'00.93"N/30°56'34.83"E) and Serefiye (39° 35'23.44"N/31°01'34.92"E). In total, 13 soundings were made.

In most graphs of each section (Figures 2, 3 and 4), the curves appear with an H form, with high resistivity values in the shallower layers of the region (low AB/2 values) and in the deeper layers (high AB/2 values). In the middle layer, it is observed a decrease in resistivity, which characterizes the sedimentary aquifer which can be formed due to the porosity of the conglomerate.

Results

The inversion method used in the 1D interpretation of the sounding curves obtained significant results, taking into account that the calculated apparent resistivity values are equal or very close to the measured apparent resistivity values. Among the 13 soundings made in the studied area, a total of 93 graphics were generated.From these 93 graphics, 3 of them, equally spaced along the studied area, were taken for observation. On the table beside the graphs, some of the model parameters(blue line) can be observed, these are: Number of layers (N), apparent resistivity values(p), layer thickness (h) and depth of the respective layer(d).

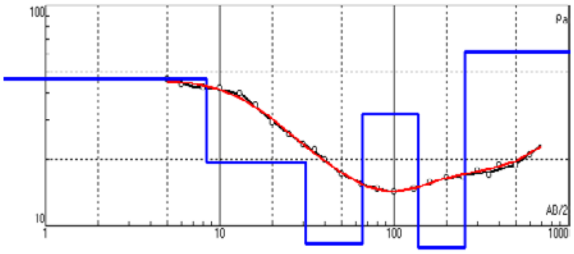
Sounding S



N	ρ	h	d	Alt
1	58.1	3	3	-3
2	37.1	3.46	6.46	-6.463
3	18.6	58.4	64.8	-64.83
4	16.1	74.6	139	-139.4
5	51.9	161	300	-300.2
6	33.3			

Figure 2- Apparent resistivity curves. The black and empty point represent the observed data, the red line is the calculated apparent resistivity and the blue line represents the layer's model. Sounding S was made in the North part of the studied area.

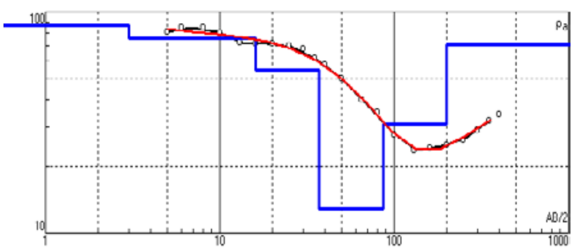
Sounding J



N	ρ	h	d	Alt
1	46.3	8.38	8.38	-8.377
2	19.3	22.6	31	-30.95
3	8.3	35.2	66.1	-66.15
4	32.1	71.5	138	-137.6
5	7.93	117	255	-255.1
6	61.6			

Figure 3- Apparent resistivity curves. The black and empty point represent the observed data, the red line is the calculated apparent resistivity and the blue line represents the layer's model. Sounding J was made in the middle part of the studied area.

Sounding A



N	ρ	h	d	Alt
1	86.6	3	3	-3
2	76	13.1	16.1	-16.1
3	54.7	21.2	37.3	-37.28
4	12.9	49.1	86.4	-86.35
5	31	114	200	-200
6	71.3			

Figure 4- Apparent resistivity curves. The black and empty point represent the observed data, the red line is the calculated apparent resistivity and the blue line represents the layer's model. Sounding A was made in the South part of the studied area.

Conclusions

The program used in the 1D inversion is suitable for shallow small scale investigations if the lateral changes in the in the study area are expected to be smooth. Since the prior geological knowledge from the the studied area is within the favorable parameters for 1D investigations, with smooth contacts between layers and horizontal to subhorizontal sedimentary packages, the methodology employed is satisfactory and is proven in the presented graphs.

The curves observed in all the three graphs from Figures 2, 3 and 4, respectively, have the same characteristics, which, for smaller depths, resistivity values are high, which matches the geology which is characterized by alluvial sediments. With increasing depth, it is observed a decrease in resistivity values representing the layer where the conglomerate is found, porous rock where possibly the aquifer is confined. Finally, in maximum depths, and thus, highest values of half-current electrode spacing (AB/2), these resistivity values increase again, representing the marble bedrock.

The results obtained from the geophysical methods, when compared to wells drilled in the region, confirm the results and validate the possibility of the existence of an aquifer.

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