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An investigation of groundwater condition by geoelectrical resistivity method: A case study in Korin aquifer, southeast Iran

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Abstract

The Korin basin is located in Sistan and Baluchestan Province in the southeast of Iran. Rapid agricultural development in this basin has caused increase on demand for water supply. The basin is characterized by an arid climate with an average annual rainfall of 84 mm. The monitoring of the groundwater level exhibits a decreasing trend of water level. The main reason for this decline in the groundwater table is that wells pumping from groundwater resource has exceeded natural recharge in the recent years. In this research the aquifer of this basin has been studied by the geoelectrical method. The need for this research is studying groundwater conditions for protecting groundwater supplies as a unique source of water for this area.

A resistivity survey was carried out in order to study groundwater conditions in the shallow Korin aquifer such as depth, thickness and location of the aquifer and the type of water. Also zones with high yield potential have been determined based on the resistivity information. 596 vertical electrical soundings by Schlumberger array were conducted out at positions in 26 profiles. The resistivity Schlumberger sounding m was carried with half-spacing in the range of 200 m to 400.

The resistivity data confirm that the Korin aquifer consists mainly of an alluvial aquifer. These data were used to determine the depth and nature of the alluvium and the boundaries of the aquifer with a reasonable accuracy. The high resistivity in the southeast and northwest of the aquifer is due to higher water quality and the existence of alluvial fan with coarse grain materials. The lower resistivity in the central and northern parts of the aquifer is due to finer materials.

Key words: Resistivity, groundwater, aquifer, electrical sounding, Iran

Introduction

The Korin basin, which lies in the southeastern part of Iran is located in Sistan and Baluchestan Province (Fig.1). The basin is characterized by an arid climate and small amounts of precipitation (Average 84 mm/year), and covers about 3400 km^2. This area faces a serious water supply challenge driven by scare water resources and rapid population growth. The study area lies in the northern part of the basin about 100 km in the southwest of Zahedan city, the capital of Sistan and Baluchestan province.

The Korin aquifer is the major exploited aquifer in the region and it is an alluvial deposit aquifer. The purpose of this paper is to use the resistivity data and interpreting geoelectrical soundings to study the aquifer conditions such as depth and nature of the alluvium, boundaries and location of the aquifer and groundwater quality. This study can be used to protect groundwater supplies as a unique source of water for this area.

However, the use of geophysics for both groundwater resource mapping and for water quality evaluations has increased dramatically over the last 10 years in large part due to the rapid advances in microprocessors and associated numerical modeling solutions. The vertical electrical sounding (VES) has proved very popular with groundwater studies due to simplicity of the technique. Traditional methods for characterizing protective layers include test hole drilling and analyses of log, with the objective being to characterize thickness and/or lateral extent of the protective layer. Disadvantage of such investigations are that can be labor-intensive and expensive (Kalinski et al. 1993).

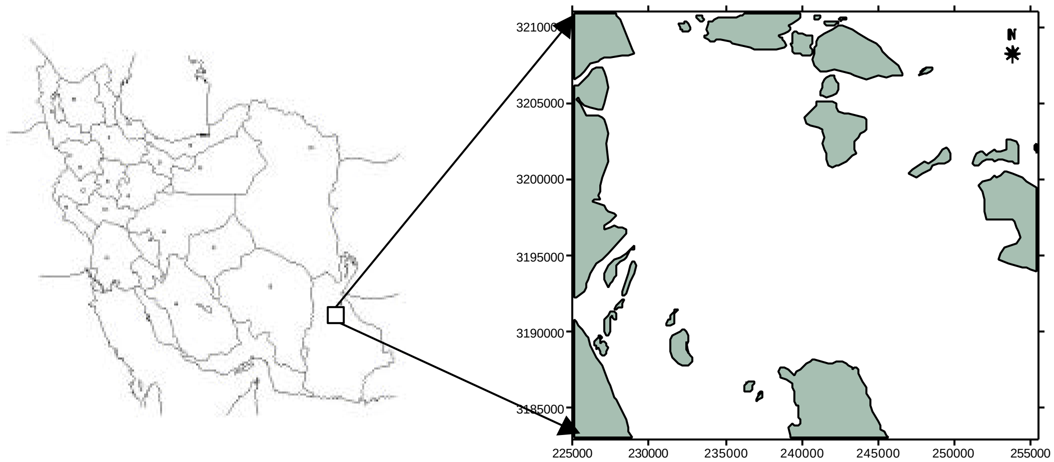

Fig. 1 Location of the study area

Vertical electrical sounding

The electrical resistivity survey involved VES was carried out at the survey area. The principle of Vertical electrical sounding was established in the 1920s (e.g. Gish and Rooney, 1925).

The electrical resistivity survey involved VES is based on measuring the potentials between one electrode pair while transmitting direct current (DC) between another electrode pair. The depth of penetration is proportional to the separation between the electrodes, in homogeneous ground, and varying the electrode separation provides information about the stratification of the ground (Dahlin, 2000).

The resistivity method is carried out to solve more problems of groundwater in the types alluvium, karstic and another hard formation aquifer as an inexpensive and useful method. Some uses of this method in groundwater are: determination of depth, thickness and boundary of an aquifer (Zohdy, 1969 and Young et al. 1998), determination of interface saline water and fresh water (El. Waheidi et al., 1992, and Choudhury et al., 2001), porosity of aquifer (Jackson et al, 1978), hydraulic conductivity of aquifer (Yadav, 1998, Troisi et al. 2000), transmissivity of aquifer (Kosinski and Kelly, 1981), specific yield of aquifer (Frohlich and Kelly, 1987), hydrogeological mapping in karst terrains (Sumanovac and Weisser, 2001), contamination of groundwater (Kelly, 1976 and Kaya, 2001). Contamination usually reduces the electrical resistivity of pore water due to increase of the ion concentration (Frohlich and Urish, 2002). However, when resistivity methods are used, limitation can be expected if ground inhomogeneties and anisotropy are presented (Matias, 2002).

Data acquisition

VES was carried out in the study area with a KD Sound Terrameter Unit (Almas Toos Co.). The equipment is light and powerful for deep penetration. The resistivity survey was completed with 596 sounding stations in 26 profiles. Field survey was carried out between April to June 2001. The location of electrical profiles and soundings are presented in Fig. 2.

The electrical sounding in this study was conducted by using the Schlumberger array. This array is a popular method which is rather time consuming. The Schlumberger soundings were carried with maximum current electrode spacing (AB) ranging from 400 m to 800 m (AB/2= 200-400 m). The field data acquisition was generally carried out by moving two or four of the electrodes used, between each measurement.

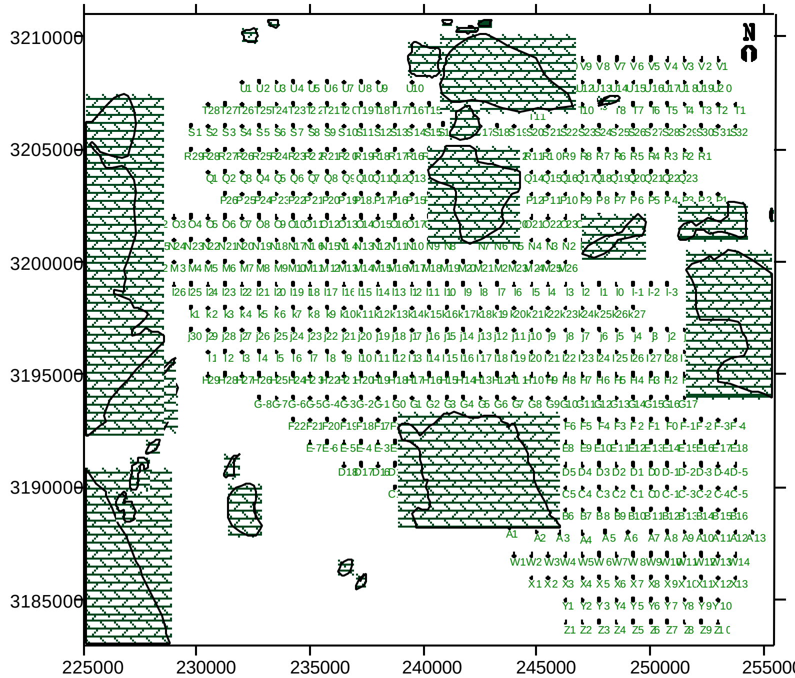

Fig.2 Location of electrical sounding

Results and discussion

VES curves of the 596 sounding stations obtained by plotting the apparent resistivity against electrode spacing. The resistivity for each of the VES was drawn on transparent double log graph paper and a smooth field curve. Computer programs for reducing geoelectrical sounding curves into values of thickness and resistivity of individual layers are described by Zohdy and Bisdorf (1989). The field curves were interpreted by the well-known method of curve matching with the aid of Russian software IPI7.63. However, thickness and characteristics of the aquifer are fairly well known due to the number of dug wells in the center of the aquifer. A number of geoelectric stations were purposely located near about the 16 wells. The key to success of any geophysical survey is the calibration of the geophysical data with hydrogeological and geological ground truth information.

VES success must rely on the careful interpretation and integration of the results with the other geologic and hydrogeologic data for the site. Therefore, litologic information obtained from log could be used to calibrate the VES field curves. Where test hole-log information was available, the solution to automatic interpretation procedure was constrained by keeping know layer thickness constant during the program computations. In final, the results of the Schlumberger electrical soundings have been compared with the geological sections have been obtained from the 16 dug wells. These results are in a good agreement with the geological sections.

The boundary of the aquifer, thickness and resistivity of subsurface layers also determined by the electrical survey in this research. From the interpretation of the resistivity curves, four subsurface layers indicated in the study area. These layers consisting of surface layer (topsoil), alluvium, saturated layer, and bedrock. Depth and thickness of subsurface layers were identified and dimension of the aquifer and type of bedrock were also indicated.

Average resistivity of the surface layer, alluvium, aquifer and the bedrock calculated in the range 3-800, 2-100, 8-25, >100 Ohm-m respectively. These data indicate that bedrock of the aquifer is the same (generally shale), but permeability and storage coefficient in the southeastern part and in the northwestern part is higher. The higher resistivity in the northwestern and southeastern parts is due to existence alluvial fan that consists of a mixture of gravel and sand and. The lower resistivity in the central and northern parts is due to finer materials of sand and silt mixed with clay.

RT map that shows the potential of the aquifer in the whole study area is shown in Fig. 3. The best part of the aquifer for future development and for choosing the drilling sites as mentioned above is southeastern and northwestern parts. Depth of the aquifer was measured in the range of 10-60m and average thickness of the aquifer is about 40m.

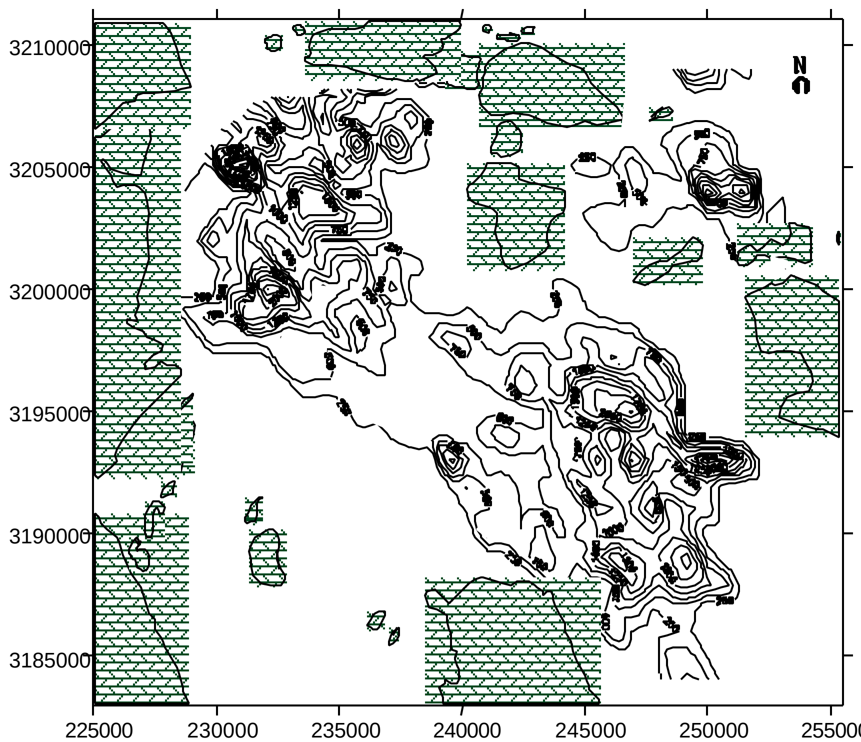

Fig. 3 RT map of the aquifer

Conclusions

Five hundred and ninety six VESs have been used to evaluate the subsurface hydrogeological conditions to a depth of about 200 m. Based on the interpretation of geoelectrical data, the following conclusions are drawn:

- The use of geoelectrical soundings provides an inexpensive method for characterizing on the groundwater conditions of the region.
- Interpretation of the VESs indicates the presence of an alluvial aquifer that mainly consists of gravel and sand in the southeastern and northwestern parts and sand and silt mixed with clay materials in the central and northern parts. The resistivity of the aquifer decreasing towards the north due to increasing salinity of water and/or clay content.
- VES tests also revealed four subsurface geoelectric layers; thin surface layer, alluvium, aquifer and the bedrock respectively. The aquifer thickness increases towards the south, the regional direction of increasing deposition in the basin. The average thickness of the saturated alluvial aquifer has been estimated about 40 m.
- The boundary of the aquifer has been estimated and zones with high yield potential have been determined for future development in the basin and for choosing the drilling sites.

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