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Hydrogeological Implication of Electrical Resistivity Sounding in Ita-Eku, Ado Ekiti, Nigeria

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Authors' contributions

This work was carried out in collaboration of the authors. Author GOB designed the study, correlated the results and made the first draft. Authors OSO and OFO made the literature review, manage the analyses of the study and made the final draft. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Electrical resistivity prospecting method was used in evaluating the groundwater potential of Ita-Eku, southeastern part of Ado-Ekiti, Ekiti state, Nigeria using the vertical electrical sounding technique. A total of seven electrical soundings were conducted using the Schlumberger electrode array. The data acquired were interpreted qualitatively and quantitatively and were presented as tables, charts and section. The interpreted models revealed three to four geo-electric layers namely; topsoil, clay/lateritic soil, weathered/fractured layer and fresh basement. The topsoil which is relatively thin has thickness ranging between 0.8 and 2.5m while the resistivity values range from 26 to 171 Ω-m. The second layer has thickness ranging from 2.5 – 5.9 m and resistivity values from 5 to 19 Ω-m. The third layer is the weathered/fractured layer with thickness ranging from 5.9–35.3 m and the resistivity values range from 171 to 404 Ω-m. The basement resistivity values range between 711 and 3466 Ω-m. First and second order (Dar Zarrouk parameters) data were used to generate the geo-electric section, overburden thickness chart and longitudinal conductance chart. These section and charts were considered in generating the groundwater potential table. The groundwater potential table shows that about 28% of the entire study area falls within zone rated as having high groundwater

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potential, while about 28% of the study area constitutes the low groundwater potential rating and the remaining 44% has moderate groundwater potential rating.

Keywords: Hydrogeological; groundwater; Ita-Eku; geo-electric; aquifer; Dar Zarrouk.

1. INTRODUCTION

Geophysical methods especially the resistivity technique have been successfully used in groundwater exploration, since it is usually a non-invasive, relatively cheap and a quantitative evaluation technique [1]. Electrical resistivity measurements in geophysical survey using the vertical electrical sounding (VES) technique is a well-established approach for solving a variety of geotechnical, geological, hydrological and environmental problems [2]. In recent years, there has been an increased awareness that subsurface characterization using standard drilling methods which offers a point measurement does not provide sufficient information to accurately evaluate the true distribution of geologic parameters beneath ground surface at many sites [3]. Hence as complement to drill-hole, geophysical technique can provide broad composite images of the subsurface over large areas at relatively lower cost and higher speed. Geophysical techniques make sitting of buried utilities, massive engineering structures and recreation facilities easier and convenient [4]. In this study, only seven (7) vertical electrical soundings were carried out to cover a particular area in Ita-Eku area of Ado-Ekiti (Fig. 1). The data obtained were processed and their outputs were presented as table, chart, section and maps. According to [5], earth resistivity can be related to important geologic parameters of the subsurface such as type of rocks and soils, porosity and degree of saturation. This study highlights the geo-electric properties of rocks within the study area, in terms of the electrical resistivity of the underlying layers, their thicknesses, thickness of potential aquiferous horizon and depth to bedrock. These properties were used in determining the groundwater potential and desirable points for optimal groundwater exploitation.

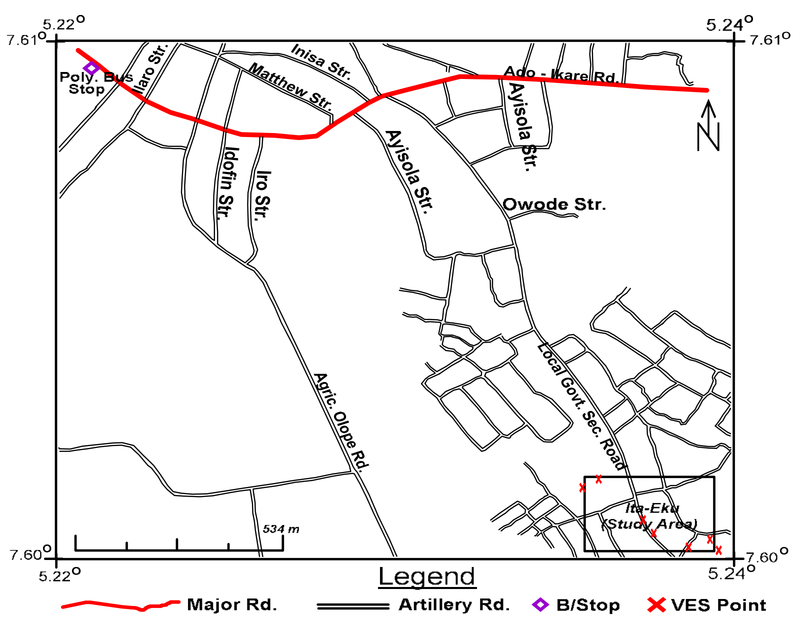

Fig. 1. Map of part of Ado Ekiti showing the study area

1.1 Geological and Geographical Setting of the Study Area

The study area is located around Odo-Ado area of Ado-Ekiti within Latitude 7.60 $°E$ to 7.61 $°E$ and Longitude 5.22 $°N$ to 5.24 $°N$. It is situated within Igirigiri village along Ado-Odo Local Government Area, Ado-Ekiti. The topography is approximately flat with elevation ranging from 1374.7 to 1450.1 ft above sea level. The geology of the study area can be explained within the context of the geology of the Precambrian basement Complex of southwestern Nigeria which form a part of the basement complex of Nigeria [6]. The major rock type within the area is typically Migmatite-gneiss comprising of undifferentiated Granite and Charnockite. The vegetation in the area is typical of rainforest type, characterized by short dry season and long wet season, with high annual rainfall of about 1,300 mm. Annual mean temperature is between 18ºC and 33ºC with relatively high humidity [7].

2. METHODOLOGY

The acquisition of geophysical data involving the use of vertical electrical sounding technique in Ita-Eku area of Ado-Ekiti was carried out with the aid of Geo-pulse^{TM} resistivity meter. The resistivity meter is a high quality earth resistance meter capable of accurate measurements over a wide range of conditions. It contains both the transmitter unit, through which current enters the ground and the receiver unit, through which the resultant potential difference is recorded. Other materials include: two current electrodes and two potential electrodes, two black coloured connecting cables for current electrodes and two red coloured cables for potential electrodes, two reels of calibrated ropes, hammer for driving the electrodes in the ground, compass for finding the orientation of the traverses, cutlass for cutting traverses and data sheet for recording the field data. In the study area, the electrode spread of AB was varied from 1 to a maximum of 200 m (Fig. 2). The electrical resistivity data were processed by plotting the apparent resistivity values against the half of electrode spread (AB/2). This was subsequently interpreted quantitatively using the partial curve matching method and computer assisted 1-D forward modelling using Win-Resist 1.0 version software [8].

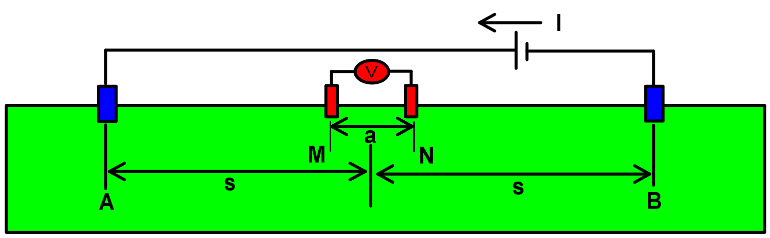

Fig. 2. A sketch diagram of Schlumberger array

Second order geoelectric parameters called Dar Zarrouk parameters were determined from the iterated geoelectric parameters [9]. The second order parameter of interest in this study is the longitudinal conductance (Si). This second order parameters are derived using equations developed by [10]. For *n* layers, the total longitudinal unit conductance is given by:

$$S = \sum_{i=1}^{n} \left(\frac{h_i}{\rho_i}\right) \quad (1)$$

Where, S = longitudinal unit conductance,
n = number of layers,

h_i= layer thickness,
ρ_i= layer resistivity.

3. RESULTS AND DISCUSSION

3.1 Table and Chart

Table 1 shows the summary of results obtained from the resistivity data inversion, while the pictorial statistical analysis of the result is presented in Fig. 3. Curve types identified were A, H, KH and HA (Table 1). The predominant curve type is the HA curve type having percentage frequency of 57.1% while the H, A and KH curve types has 14.3% each respectively. The high percentage recorded by the HA curve type within this study area is an indication of a predominant low groundwater potential of the study area as shown in Fig.3.

Table 1. Summary of geo-electric parameters obtained from VES within the area

VES No.	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	Northing	Easting	Curve Types
1	55	18	360	1471	1.0	5.4	14.8	735998	514626	HA
2	26	300	3467	-	2.5	5.9	-	735954	514802	A
3	60	19	363	1772	1.4	7.1	13.6	735944	514954	HA
4	54	15	384	2756	0.9	6.8	13.4	735979	514910	HA
5	50	5	171	711	1.2	5.8	22.3	736040	514572	HA
6	92	404	237	2544	1.2	4.8	30.5	736169	514348	KH
7	171	19	962	-	0.8	5.8	-	736142	514266	H

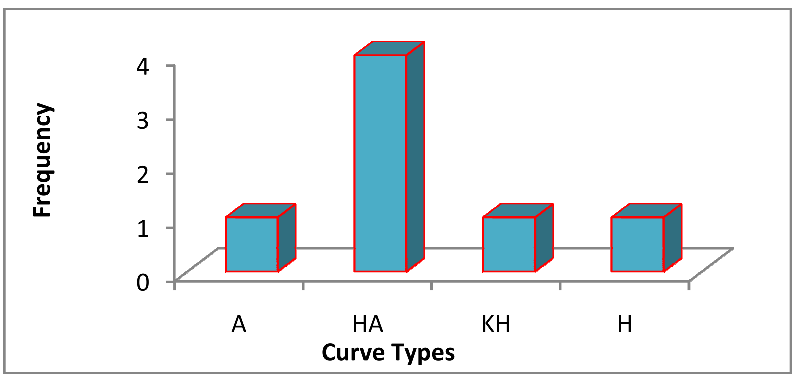

Fig. 3. Frequency of curve types within the study area

3.2 Geo-electric Sequences

Fig. 4 is a geo-electric section generated to connect all the VES points within the study area. The geo-electric section shows the variations of resistivity and thickness of geo-electric layers below VES 7, 6, 5, 1, 2, 4 and 3 in that order. The geo-electric sections revealed three to four subsurface geo-electric layers consisting of topsoil, clay/lateritic soil, weathered/fractured layer and fresh basement. The topsoil which is relatively thin has thickness ranging between 0.8 m and 2.5 m while the resistivity values range from 26 to 171 Ω-m. The low resistivity values obtained within this layer indicates that the topsoil is composed of clay and vegetable soil. The second layer has thickness ranging from 2.5–5.9 m and resistivity values from 5 to 19 Ω-m. This layer predominantly composed of clayey soil. The third layer is the weathered/fractured layer with thickness ranging from 5.9 – 35.3 m and the resistivity values range from 171 to 404 Ω-m. This contains weathered and fractured rocks that are partially saturated with water. This layer forms the major aquifer unit within Ita-Eku area. The basement resistivity values range between 711 and 3466 Ω-m, it is partially fractured under VES 5 but very fresh under VES 7, 6, 1, 2, 4 and 3. The bedrock also form basement ridges under VES 7 and 2 with a depression which underlain VES 6, 5 and 1. The depth to bedrock within this study area ranges between 6.6 m and 36.5 m.

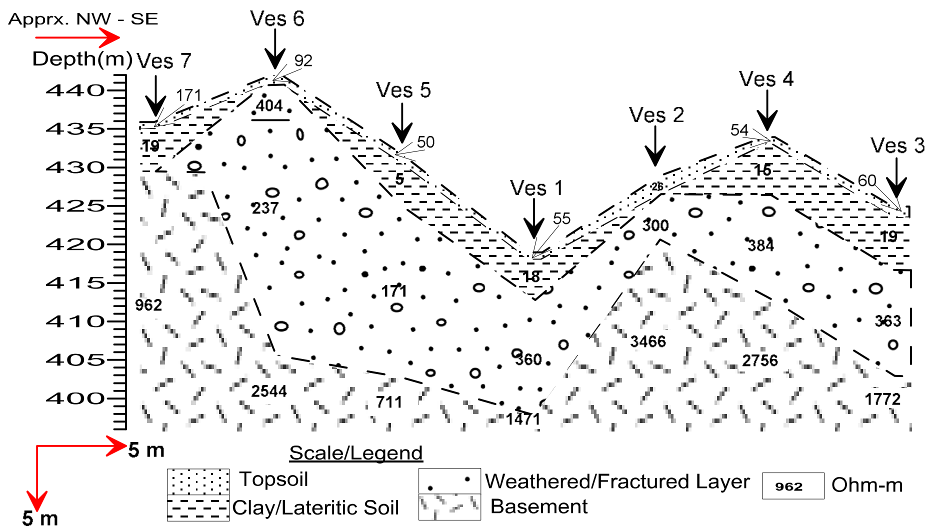

Fig. 4. Geo-electric section within the study area

3.3 Overburden Thickness Chart

The chart shows variation in thickness of the overburden from points where the vertical electrical sounding was conducted within the study area (Fig. 5). It varies from 6.6 to 36.5 m, with a mean of 20.7 m and standard deviation of $\pm$ 9.83. The regions around VES points 2 and 7 have thin overburden (6.6 to 8.4 m), while areas which underlain VES 1, 3, 4, 5 and 6 have relatively thick overburden (21.1 to 36.5 m). Zones within the study area whose overburden thickness is less than 10 m are considered in this study to have limited (low) groundwater potential, since it also show near-surface basement ridges, high aquifer protective capacity (thick clay layer above the aquifer) and low values of total longitudinal conductance (0.12 – 0.31mhos) as shown in Fig. 6. On the other hand, zones identified as having overburden thickness ≥ 21 m are considered to have moderate to high groundwater accumulation potential, due to the favourable basement structure and relatively high longitudinal unit conductance values (0.32 to 1.23 mhos). The low groundwater potential zones cover about 28% of the entire study area, while the remaining parts fall within the medium to high groundwater potential (about 72% of the study area).

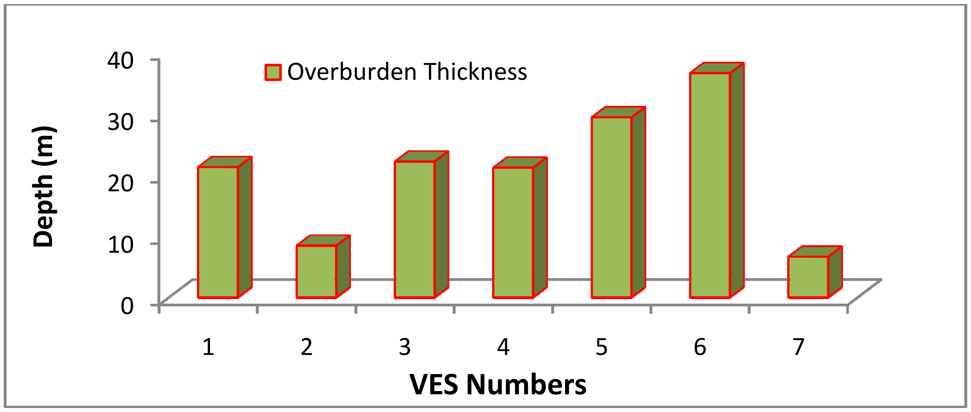

Fig. 5. Overburden thickness chart of the study area

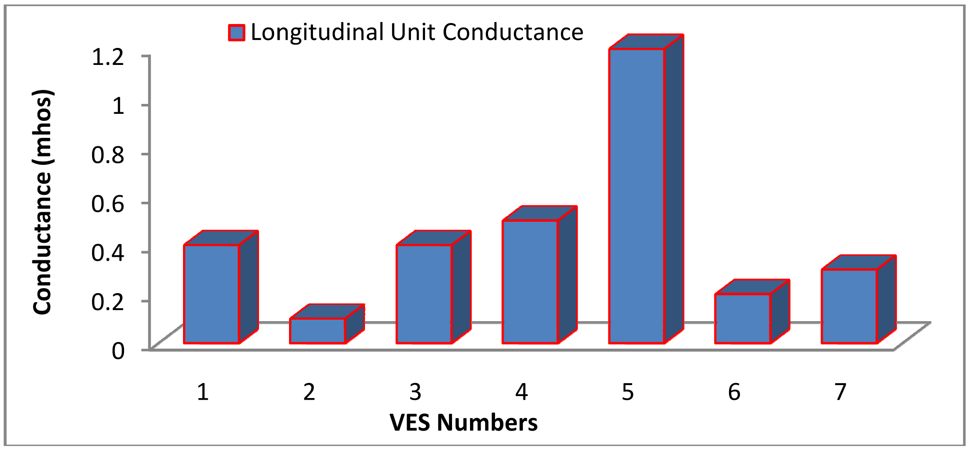

Fig. 6. Longitudinal conductance chart of the study area

3.4 Evaluation of Groundwater Potential

Table 2 shows the groundwater potential table of the study area. Important parameters to be considered when evaluating groundwater potential of an area within the basement complex are the thickness of the overburden, the resistivity and thickness of the weathered layer [11,12]. A horizon is regarded as significant with respect to its water-bearing potential, if it is relatively thick and has low resistivity values which suggest a saturated condition [13]. The groundwater potential of the study area can be classified into high, moderate and low potentials. Zones under VES 5 and 6 with thick overburden (29.3 – 36.5 m) with high longitudinal conductance values ranging from 0.32 to 1.23 mhos (Fig. 6), significantly thick weathered layer of resistivity values between 171 and 237 Ω-m and within the basement depression are classified as high groundwater potentials. Zones under VES 2 and 7 with thin overburden (thickness between 6.6 and 8.4 m), near-surface basement ridges, high aquifer protective capacity (thick clay layer above the aquifer) and low values of total longitudinal conductance (0.12 – 0.31mhos) are considered to have low groundwater potential. While zones under VES 1, 3 and 4 having overburden thickness between 21.1 to 22.1 m with thin weathered layer of resistivity values between 19 to 300 Ω-m and longitudinal unit conductance value between 0.36 to 0.50) are considered to have moderate groundwater potential. The groundwater potential table shows that about 28 % of the entire study area falls within zone rated as having high groundwater potential, while about 28 % of the study area constitutes the low groundwater potential rating and the remaining 44 % has moderate groundwater potential rating. The aquifer in this area occurs within a basement depression, highly localized and is protected against infiltration of polluting fluid (delineated beneath VES 5 and 6).

Table 2. Groundwater potential table of the study area

Characteristics	Low	Moderate	High
Overburden Thickness (m)	6.6 – 8.4	21.1 – 22.1	29.3 – 36.5
Longitudinal Unit Conductance (mhos)	0.21 – 0.31	0.36 – 0.50	0.32 – 1.23
Basement Feature	Near-surface basement	Depression	Depression
Weathered Layer Thickness (m)	0 – 5.7	13.4 – 14.8	22.3 – 30.5
VES Number	2 and 7	1, 3 and 4	5 and 6
Resistivity of weathered layer	0 - 300	360 - 384	171 - 237
Potential Rating (%)	28	44	28

4. CONCLUSION

Electrical Resistivity Method involving Vertical Electrical Sounding (VES) has proved useful in the delineation and characterization of aquifer unit as part of the preliminary investigations to assess groundwater resource potential and development in Ita-Eku, Ado-Ekiti, south-western Nigeria. The first order geo-electric parameters obtained from the interpretation of the vertical electrical sounding data and the second order (Dar Zarrouk) parameter (longitudinal conductance, S_i) were used to generate the geo-electric section, overburden thickness and longitudinal conductance charts. These are reflective of the hydraulic properties of the aquifer unit in the study area. From the interpreted results, zones with high overburden thickness, high longitudinal conductance values and significantly thick weathered layer are classified as having high groundwater potentials, zones with thin overburden, near-surface basement ridges, high aquifer protective capacity and low values of total longitudinal conductance are considered to have low groundwater potential, while zones having moderate overburden thickness with thin weathered layer are considered to have moderate groundwater potential. About 28% of the area falls within the high groundwater potential rating, while about 44% constitutes the medium groundwater potential rating and the remaining 28% constitutes low groundwater potential rating. Hence the groundwater potential of the area is generally rated to be moderate. The VES stations underlain by high and medium groundwater potential zones are envisaged to be viable for groundwater development within the area. Thus, groundwater resource development and management can be effectively planned for in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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