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CONTENTS	Page
Olatunji S. and Abubakar H.O Electrical Probe of The Subsurface Geology For Groundwater Exploration In Irewolede Estate, Ilorin Kwara State.	1-16
A. O. Adesanya, A. M. Alkali, and D. Umar One Step Second Derivative Block Method For Stiff Initial Value Problems	17-27
Abdullahi, S. A., Momoh, A. A., Alhassan A. and Sajoh, D. I. The Impact of Asymptomatic Infection on the Transmission Dynamics of Hepatitis C Virus Infection	28-43
A.O. Adesanya, A. M. Alkali, R. O. Onsachi, K. M. Fasasi One Step Continuu's Trigonometrically- Fitted Method for Stiff and Oscillatory Initial Value Problems.	44-61
R. Katso, A. A. Momoh, A. Alhassan and S. A. Abdullahi Mathematical Modeling Of Unemployment Dynamics In The Presence Of Migration and Self-Employment.	62-77
K.M. Fasasi An Extended Taylor Series Transformations Techniques For System Of Second Order Initial Value Problems of Ordinary Differential Equations.	78-85
Mbaga, Yohana Vandi & Jibasen Danjuma Population Growth, Temperature and Carbon Dioxide Emissions: A Multivariate Time Series Analysis.	86-103
J. Sunday, R. O. Onsachi, and M. R. Odekunle On New Proves of Existence and Uniqueness of Solutions of Initial Value Problems and Boundary Value Problems of Class M.	104-112
Aishatu Shuaibu System and Functional Requirements For Implementing E-Voting System in Nigeria.	113-122
A.A Maidamisa, Asta Musa and Nathan Nachandiya Application of Queueing Theory in Anye Natal care Clinic for Pregnant Women in Gombe State.	123-132
Kadzai, M. T. Y. Lie Algebra And Lie Group On Paraletrix	133-139

ELECTRICAL PROBE OF THE SUBSURFACE GEOLOGY FOR GROUNDWATER EXPLORATION IN Irewolede Estate, Ilorin Kwara State

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Abstract

Resistivity Method involving electrical resistivity survey was carried out using vertical Electrical Sounding in Irewolede Estate of Ilorin west Local Government, Kwara State. This is to map the depth, thickness and the general resistivity distribution of the study area with high ground water potential. The survey was carried out with a Terrameter model DDC-8; a total of eleven VES points and three profiles respectively were covered. The survey lies within the crystalline basement complex of western central Nigeria and bounded by latitudes $8^{\circ}27'40''\text{N}$, $8^{\circ}27'45''\text{N}$ and longitudes $4^{\circ}33'11''\text{E}$ $4^{\circ}33'14''\text{E}$. The resistivity value obtained between $2\Omega\text{m}$ to $3000\Omega\text{m}$ for profile 1-3. Four prominent geoelectric layers with varying resistivity and thickness were delineated on all the VES points. The first layer has a resistivity value ranging from $48\Omega\text{m}$ to $934\Omega\text{m}$ with their thickness ranging from 0.5m to 1.0m. This layer is the top soil which contributes to the development of groundwater because it is the passage for the flow of surface water to the fractured subsurface layers. The resistivity value of the second layer, dominated by laterite, ranges between $7.39\Omega\text{m}$ to $2479\Omega\text{m}$ while the thickness varies between 1.0m to 11.4m. The third layer resistivity values range between $23.4\Omega\text{m}$ to $255\Omega\text{m}$ with variations in their thickness that range between 3.7m to 29.7m. This and the next layer are believed to contain the aquiferous layer. The fourth layer is the fractured basement, which is believed to be a porch for the underground water. The depth to aquifer in the area ranges between 3.7m to 29.7m. Overburden is thickest (about 30m) around the southern part of the area.

Keywords: Vertical Electrical Sounding, Geoelectric Section, Aquifer, Irewolede Estate.

1. Introduction

Water is required for various purposes, which include domestic, municipal, industrial and agricultural endeavours, but the quality required for groundwater supply depends on its purpose or intended use (Anudu *et al.*, 2008). Water occurs as both groundwater and surface water. Sources of portable water include rivers, lakes, rainfall, groundwater etc. Most fresh water is locked away as ice in the polar ice caps, continental ice sheets and glaciers. Water sourced from rivers and lakes account for less than 1% of the world's fresh water demands. However, groundwater is a major source of clean drinking water and it accounts for about 98% of the world's fresh water (Badmus & Olatinsu, 2010). Hence, groundwater is the largest available reservoir of fresh water. Groundwater is important because of its availability, low cost of development and its reliable quality. The early part of the 20th century saw a rapid expansion of the exploration of groundwater supplies due to industrialization and increase in demand for water. Groundwater comes from precipitation such as rain, snow and hailstone that soak into the ground and become the groundwater. Search for groundwater requires detailed geophysical investigations.

This study is focused on the analysis of the subsurface geology to evaluate the groundwater budding of Irewolede housing estate in Ilorin metropolis because of increasing demand for water by the inhabitants using vertical electrical sounding resistivity (VES) technique. Electrical resistivity survey is one of the most relevant geophysical methods for groundwater

exploration (Olasehinde, 1999). The vertical electrical sounding technique was chosen based on the recommendations of experts in addition to the facts that the instrumentation is simple, field logistics are easy and straightforward and the analysis of data is less tedious and economical. Irewolede housing estate houses about 500 people who use water for various purposes. The main source of water within the estate is a borehole which dries up during the harmattan season. This study will help to solve this problem by providing a good knowledge of the subsurface geology of the estate and map the structures which may enhance ground water exploitation in the study area. The study area is located within Ilorin West Local Government Area of Kwara State Nigeria (Fig.1), whose coordinates lie between latitudes, $08^{\circ} 27' 37.7''\text{N}$ - $08^{\circ} 27' 45.5''\text{N}$ and longitudes $04^{\circ} 33' 18.9''\text{E}$ - $04^{\circ} 33' 25.5''\text{E}$, and is accessible through network of roads and well developed footpaths.

2. Geology, Climate and Geomorphology

The study area lies within the crystalline basement complex in the North-central Part of Nigeria (Fig. 2). The rocks are mainly banded gneiss, shared gneiss and augen gneiss bounded by granodiorites and granites at the Southeast, the structural fabrics is mainly a North-South trending fracture system dominated by Southerly plunging ($6-10^{\circ}$) anticlinorium with a gentle westernly dipping limb is depicted (Olasehinde *et al.*, 1986). As shown in the Figure 3 (Olasehinde *et al.*, 1986); the common rock types include migmatite gneiss, augen gneiss, quartzite, older granite (extensively weathered) and superficial deposit. Migmatite-gneiss is most extensive of the rocks in Ilorin occupying more than 90% of the study area. The difficulty encountered in categorizing the migmatitic rocks appears to be quite persistent over the entire basement complex of Nigeria (Oluyide *et al.*, 1998). These rocks generally belong to those classified as lit-par-lit magmatite which are conventional migmatite with their components disposed in parallel order encompassing banded gneiss. They are found around the dumpsite along Asa dam – Offa garage road, Oko-Erin, Sobi area and along Jebba road within the Ilorin metropolis. They are noted for their high colour index dominated by dark coloured minerals.

The hydrological setting of the area is typical of what is obtained in other Basement complex area where the availability of water is a function

of the presence of thick-little clay overburden material and presence of water filled joints, fracture or faults within the fresh Basement rocks.

The humid tropical climate of the area has particularly encouraged relatively deep weathering of the near surface rocks to produce porous and permeable material that allows groundwater accumulation as shallow aquifer which is recharged principally through infiltration of rainwater. The area is characterized by two climatic seasons: a wet season during which the groundwater is usually recharged by precipitation and a dry season. The wet season usually extends from April to October while the dry season lasts from November to March. The annual temperature is $26-27^{\circ}\text{C}$ and the area is well drained by river Asa and its Tributaries (Nwankwo, 2011). The direction of flow is westerly and the drainage pattern is dendritic. Rock exposures are most predominant along the river valleys although few were seen outside the river on the river on ridges and hills. The host rock occurs as flat lying rock and is cross cut by intrusive such as quartz vein, pegmatic dyke and granite. It lies around the arid region within the Guinea Savannah belt of Nigeria. However, due to increase at which house are built, most of the forest was cleared. Recent economic developments have seen that most part of the area was developed.

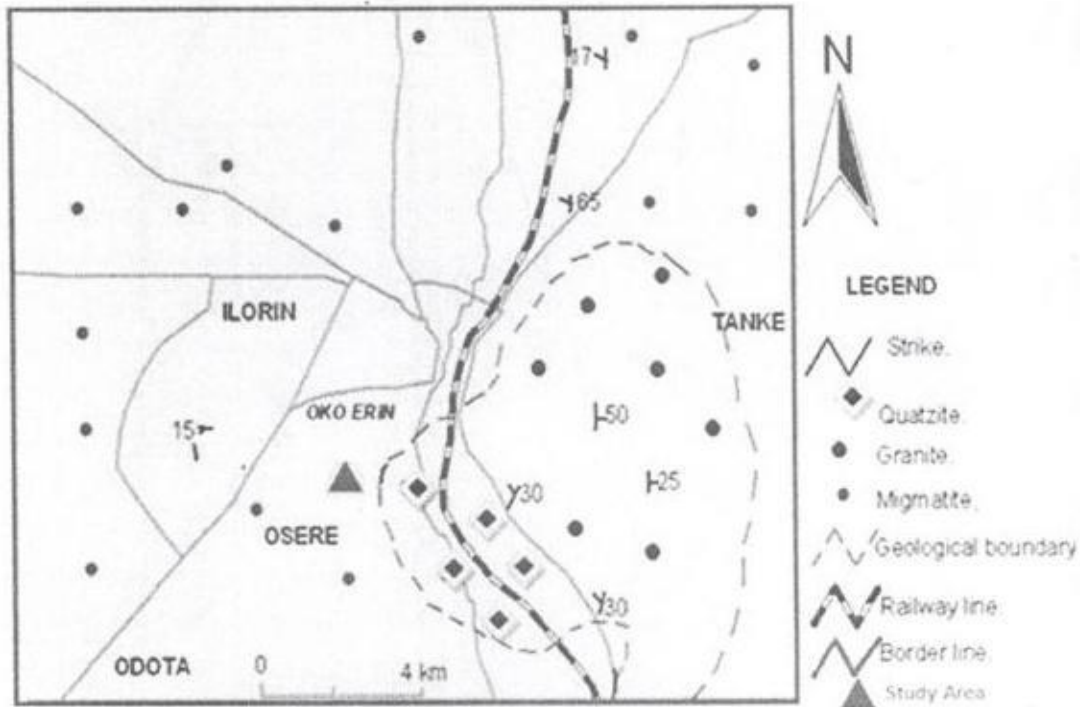


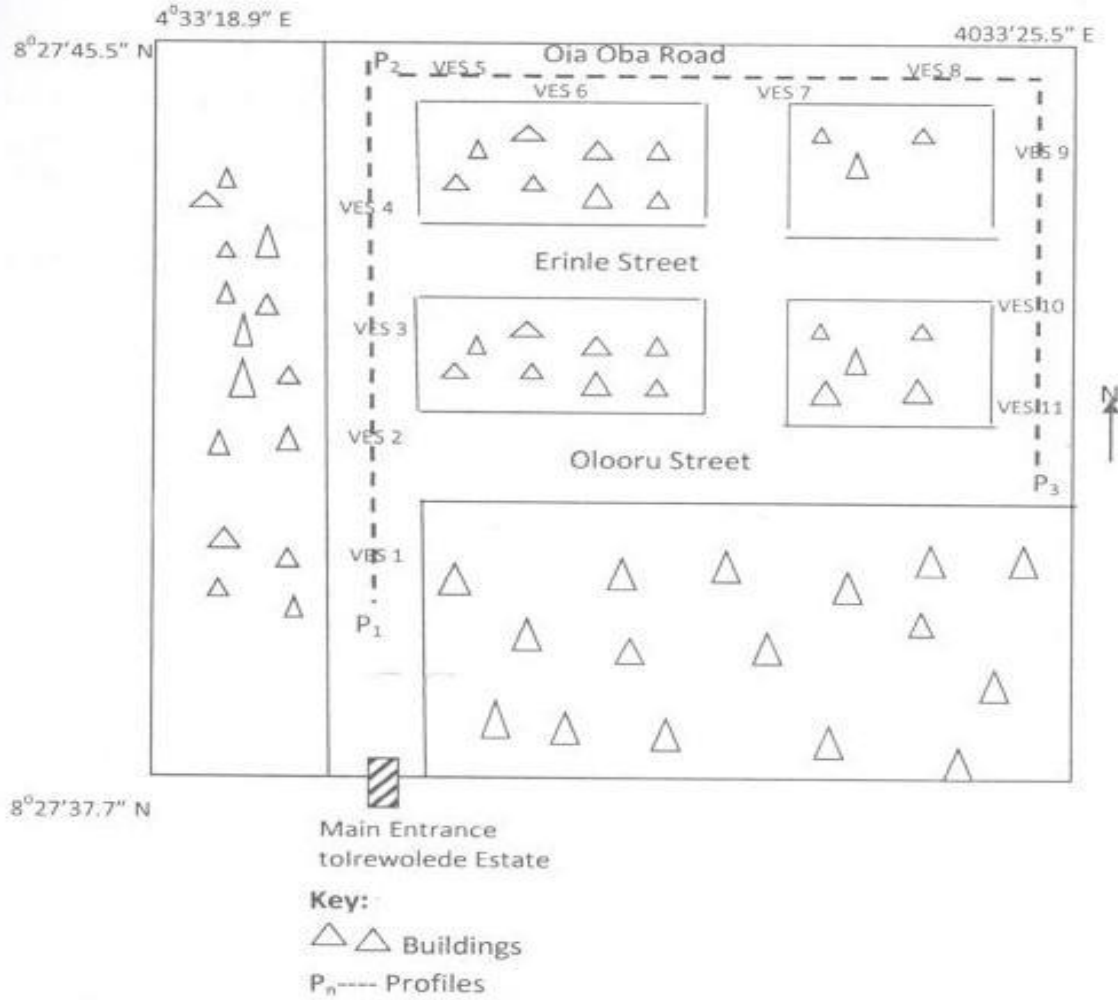
Fig.3: Local Geology of the Study Area

3. Materials and Method of Study

Three Multi-VES profiles were established with 11 VES points distributed on them (Fig. 4); P_1 contains VES 1– 4, P_2 contains VES 5 – 8 while P_3 contains VES 9 – 11. Schlumberger configuration was adopted in all. The basic field equipment used for the study is resistivity meter which display apparent resistivity value digitally as computed from Ohm's law. Other accessories that accompany the equipment are the measuring tape, 4 hammers, 4 metal electrodes, Compass clinometer and Global Positioning System were used for locating the cardinal directions and global coordinates of the stations. In the Schlumberger array, the four electrodes were positioned symmetrically along a straight line, the current electrodes on the outside and the

potential electrodes on the inside. To change the depth range of the measurements, the current electrodes are displaced outwards while the potential electrodes are maintained at the same position. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes was also displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy (Koefoed, 1979; Alile *et al.*, 2008; Olatunji & Osazuwa, 2012).

Schlumberger array involves measuring the potential difference ΔV at both electrodes, caused by the passage of current at the current electrodes (Fig. 5). Potential at electrodes M and N due to the applied current at A and B are obtained as follow:



$$\text{From } \frac{V}{I} = R = \frac{\rho L}{A} \quad (1)$$

A, being an area of a spherical earth material in the portion considered, thus

$$V = \frac{\rho L I}{A} = \frac{\rho L I}{4\pi L^2} \quad (2)$$

But, the current flow pattern in the subsurface is semi- spherical, then (2) becomes

$$V = \frac{\rho I}{2\pi L} \quad (3)$$

Now by proper resolutions in Fig. 5, potential at M is

$$V_M = \frac{\rho I}{2\pi} \left\{ \frac{1}{a-b/2} - \frac{1}{a+b/2} \right\} \quad (4)$$

And potential at electrode N is

$$V_N = \frac{\rho I}{2\pi} \left\{ \frac{1}{a+b/2} - \frac{1}{a-b/2} \right\} \quad (5)$$

Hence, potential difference is given by

$$\Delta V = V_M - V_N \quad (6)$$

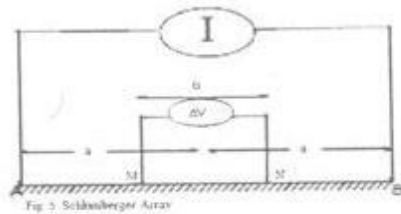
That is

$$\Delta V = \frac{\mu I}{2\pi} \left\{ \frac{8b}{4a^2 - b^2} \right\} \quad (7)$$

Thus, potential difference obtained here and the current I would yield resistance of the formation in question, which could be combined to give the apparent resistivity of the rock concerned. So, for the inhomogeneous rock

$$K = \pi \left\{ \frac{a^2}{b} - \frac{b}{4} \right\} \quad (9)$$

Thus, a and b are as shown in Fig. 5.



body concerned here the apparent resistivity is given by:

$$\rho_a = \frac{\Delta V}{I} K \quad (8)$$

where K is the Geo-electric factor obtainable by applying (7) in (8), as

The electrodes' spacing configurations used for the data collection are shown in Table1.

Table 1: Electrode Configurations

S.N	$\frac{AB}{2}$ (m)	$\frac{MN}{2}$ (m)	S.N.	$\frac{AB}{2}$ (m)	$\frac{MN}{2}$ (m)
1	1	0.5	15	20	2.0
2	1.5	0.5	16	20	4.0
3	2	0.5	17	25	4.0
4	2.5	0.5	18	30	4.0
5	3	0.5	19	35	4.0
6	4	0.5	20	40	4.0
7	5	0.5	21	40	8.0
8	5	1.0	22	45	8.0

4. Results and Discussion

The result of the vertical electrical sounding (VES) was interpreted using IPI 2 WIN software and the output are shown in figures 6 to 16.

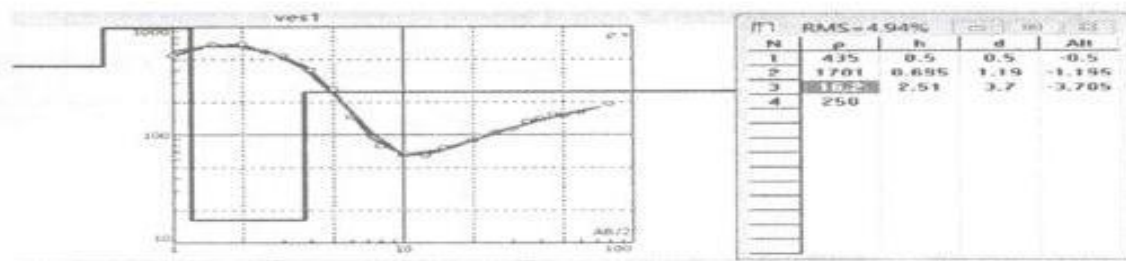


FIG 6 : Field curve for VES 1, Profile 1

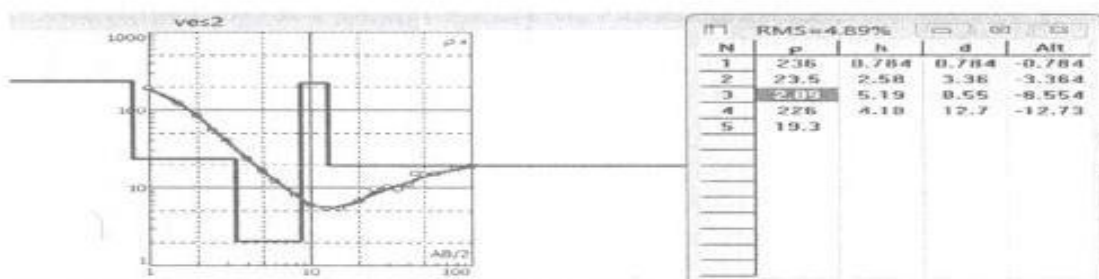


Fig. 7: Field Curve for VES 2, Profile 1

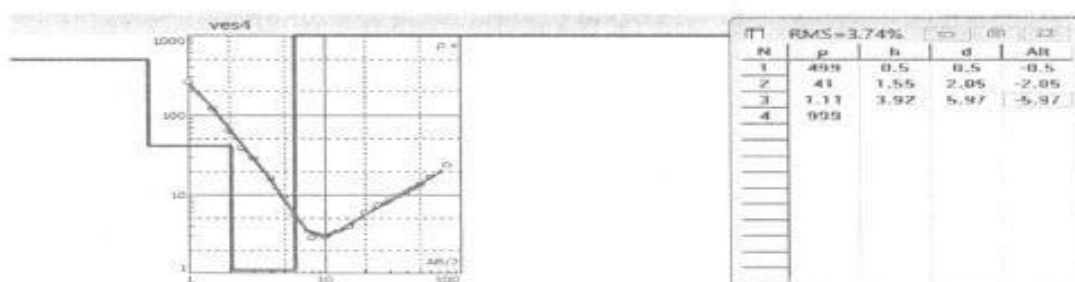


Fig. 9: Field Curve for VES 4, Profile 1

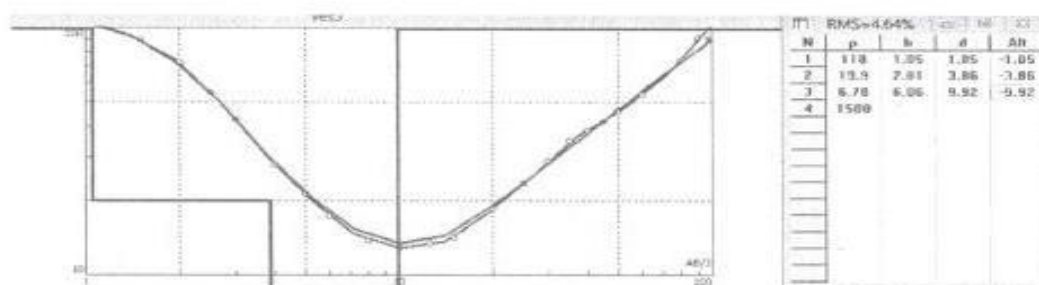


Fig. 10: Field Curve for VES 5, Profile 2

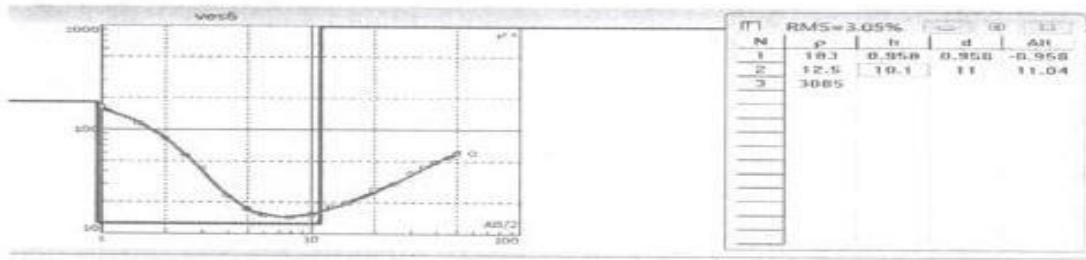


Fig. 11:Field Curve for VES 6, Profile 2

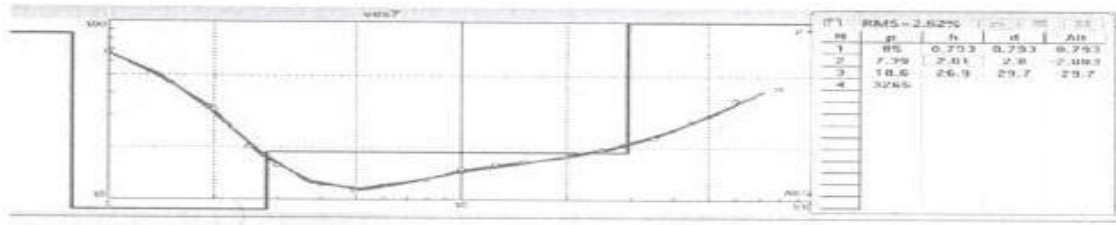


Fig. 12:Field Curve for VES 7, Profile 2

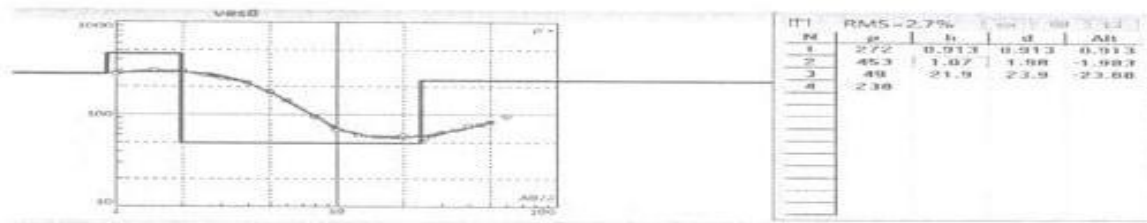


Fig. 13:Field Curve for VES 8, Profile 2

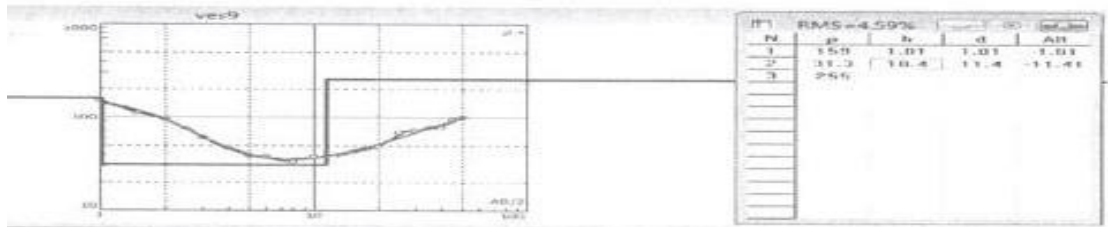


Fig. 14: Field Curve for VES 9, Profile 3

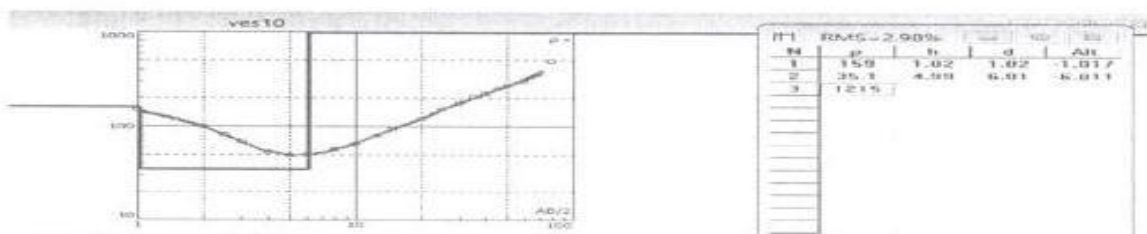


Fig. 15:Field Curve for VES 10, Profile 3

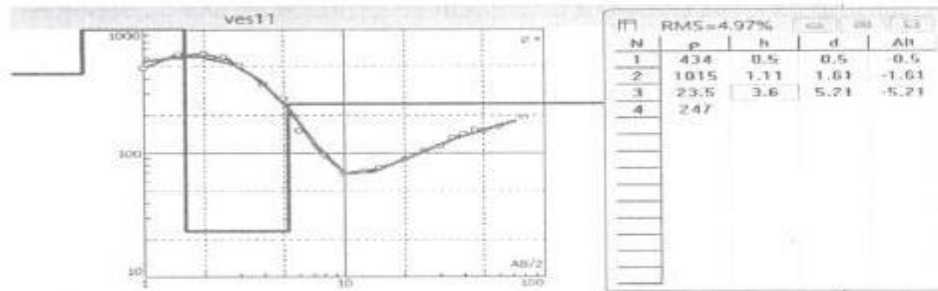


Fig 16:Field Curve for VES 11, Profile 3

The summary of the interpreted survey responses are presented in Tables 2 and 3. The result reveals that the area is characterized by 3 to 5 geo-electric subsurface layers. The 3-layer geo-electric section obtained is characterized by H curve type (Figures 11, 14 and 15) and is generally made up of top loose soil, laterite/clay and fresh basement rock from top to bottom with

minute variations. The 4-layer geo-electric section obtained is characterized by KH, QH and

HA curve types (Figures 6, 8, 9, 10, 12, 13, and 16). Finally, the 5-layer geo-electric section is characterized by HKH curve types (Figures 7).

Table 2: Summary of Layer Resistivity, Thickness and Curve Type

VES NO	CURVE TYPE	LAYER NO	APPARENT RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)
1	KH	1	435	0.5	0.51
		2	1701	0.659	1.19
		3	16.2	2.51	3.7
		4	250		
2	HKH	1	236	0.784	0.704
		2	23.5	2.58	3.36
		3	2.09	5.19	8.55
		4	226	4.18	12.7
		5	19.3		

3	QH	1	118	1.05	1.05
		2	19.9	2.81	3.86
		3	6.78	6.06	9.92
		4	1500		
4	QH	1	499	0.5	0.5
		2	41	1.55	2.05
		3	1.11	3.92	5.95
		4	999		
5	KH	1	934	0.5	0.5
		2	2479	0.745	1.25
		3	41.1	10.9	12.1
		4	427		
6	H	1	183	0.958	0.958
		2	125	10.1	11
		3	3005		
		4			
7	HA	1	85	0.793	0.793
		2	7.39	2.01	2.8
		3	18.6	26.9	29.7
		4	3265		

Table 3: Summary of Layer Resistivity, Thickness and Curve Type

VES NO	CURVE TYPE	LAYER NO	APPARENT RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)
		1	272	0.913	0.913

8	KH	2	453	1.07	1.98
		3	49	21.9	23.9
		4	238		
		1	159	1.01	1.01
9	H	2	31.3	10.4	11.4
		3	255		
		1	159	1.02	1.02
10	H	2	35.1	4.99	6.01
		3	1215		
		1	434	0.5	0.5
		2	1015	1.11	1.61
		3	23.5	3.6	5.21
		4	247		
11	KH				

The first layers in the figures show resistivity values ranging from 85Ωm to 934Ωm with their corresponding thickness ranging from 0.5m to 1.05m. This section is considered as the top soil. The layer contributes to the development of groundwater because it is the passage for the flow of surface water to the fractured layers. The second layer, considered to be dominated by laterites, has resistivity range between 7.39Ωm to 2479Ωm while the thickness varies between 1.0m to 11.4m. The third layer has resistivity values lying

between 1.11Ωm and 255Ωm and the thickness range is 3.7m to 29.7m. The fourth layer has a resistivity value ranging from 226Ωm to 3265Ωm. In all the cases, there is an indication that the depth of groundwater in the study area is high as the low resistivity, that could be tantamount to the presence of underground water, occurs at great depth. This confirmed the challenge of borehole failure at the study area because most of the boreholes are not deep therefore the aquifers might not have been struck.

Figures 17 - 19 show the pseudo cross-sections obtained for the three profiles from the geo-electric data. The geo-electric sections here could be allied to the electrical responses from the rocks and their aquiferous constituents. In all the profiles the aquiferous areas with low resistivity values, i.e. dark blue portions exist in isolations. This could indicate presence of low or poor connectivity of pores. This can pose aquifer recharge challenges. This extends to about 100m depth on the profile

1, which is the only best promising environment.

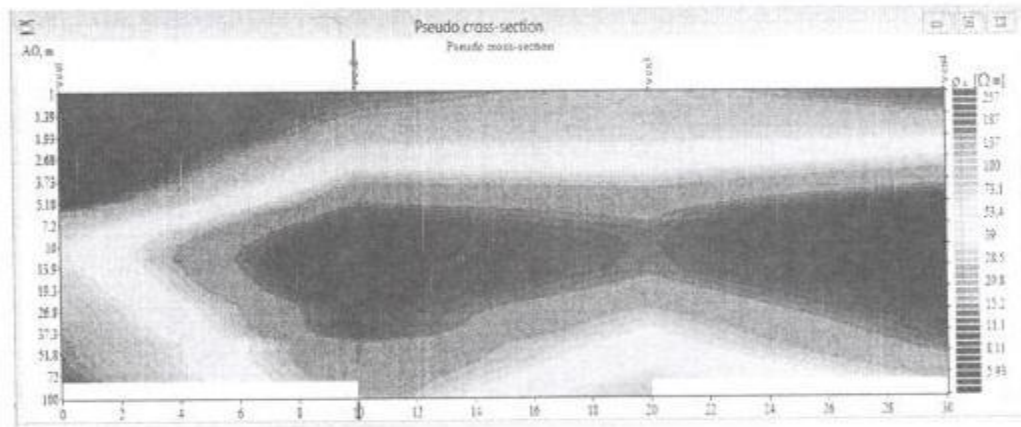


Fig. 17: Pseudo cross-section for Profile 1

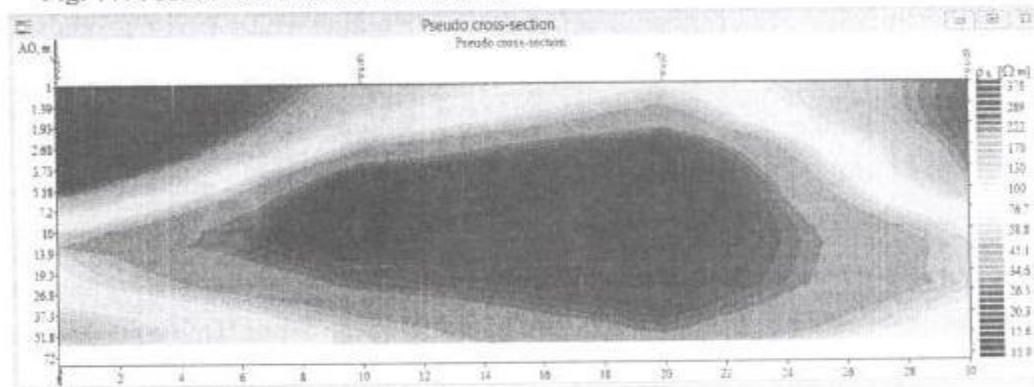


Fig. 18: Pseudo cross-section for Profile 2

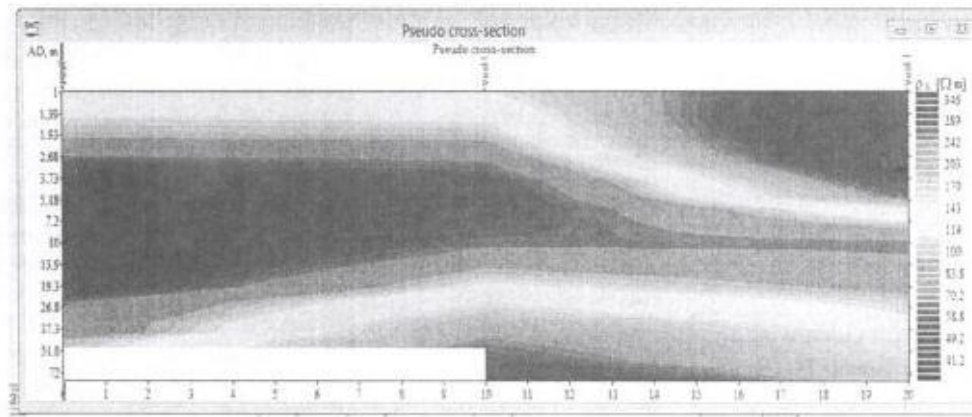


Fig. 19: Pseudo cross-section for Profile 3

An overburden hosts underground water and serves as a percolator especially during aquifer recharge. Thus, an aquifer located in a thick overburden is a good reservoir of underground water. A plot of overburden thickness (Fig. 20) indicated an increase down south in the area with the highest value of about 30m around the

south-eastern corner. Thus, aquifers in the south-eastern part could be more reliable. For the aquifers in the area to have extended to a depth of about 100m and the thickest aquifer being 30m it then means that the underground water here resides mostly in the fracture/ weathered hard rocks.

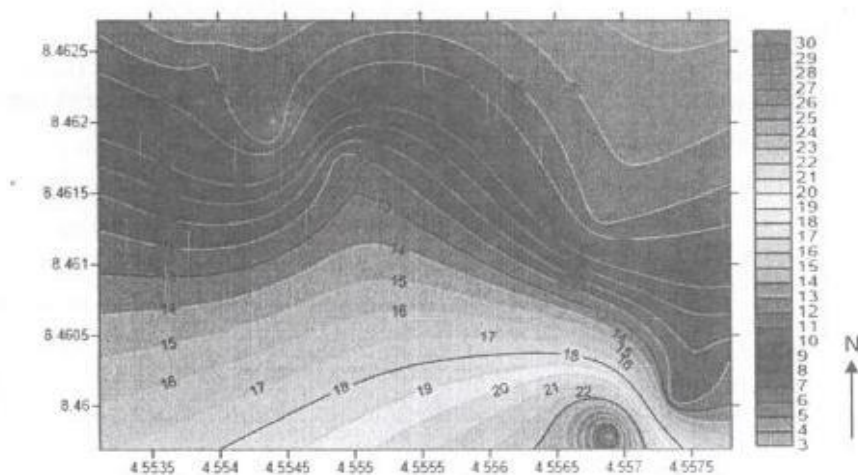


Fig. 20: Contour Map Showing the Distribution of Overburden Thickness

Conclusion

In conclusion, the main objective of this study is to determine the potential of groundwater and geological structure of the

study area. It can be concluded that the geological structure of Irewolede are as follows based on their layers. Layer 1 is Sand with resistivity value of approximately 499Ωm, layer

2 is Shale with approximate resistivity values that range between 23 Ω m and 1701 Ω m, layer 3 is Alluvium with approximate value of resistivity of about 1.11 Ω m to 225 Ω m. Furthermore, layer 4 is wet clay. The site of the best borehole can be located along the profile 1 around the southern part in the area where the largest and deepest aquifer coincides with thickest overburden. The borehole should be dug not less than a depth of 100 m (Fig. 17 and Fig. 20).

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