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Research Article

Electrical Resistivity method for groundwater/borehole development, Owo LGA, Ondo State, Nigeria

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ABSTRACT

Electrical resistivity method has been identified to be one of the most suitable geophysical method/technique for groundwater or borehole development. Therefore, this research work was carried out using Vertical Electrical Sounding (VES) to recommend a suitable location for borehole drilling in Unity secondary school compound, Owo LGA, Ondo state with the specific objectives of delineating lithological unit that contributes the overburden using resistivity parameters, to identify the aquifer units and delineate the thickness and lateral existent. The Schlumberger electrode configuration was adopted for the field investigation. Two Vertical Electrical sounding stations were occupied during the survey in the area. A and H curve types were obtained from the field data. Quantitative and qualitative interpretation was carried out that reveals Topsoil, Lateritic hardpan/clay, Fresh basement and fractured basement that underlie the area. The resistivity of the topsoil varies from (114 – 1100) Ωm. Its thickness varies from (0.89m – 2.48m). The resistivity of the Lateritic hardpan/clay varies from (269 – 484) Ωm and its thickness varies from (1.47m – 2.20m). The resistivity of the Fresh basement layer varies from (1210 – 1646) Ωm and its thickness varies from (8.72m – 21.39m). Hence, since the overburden constitute the hydrogeological unit of VES 1 and VES 2, are 4.67m (15ft) and 2.37m (8ft) thick with resistivity values 484Ωm and 68Ωm layer beneath respectively, therefore, the site is feasible for groundwater development and VES 1 & VES 2 are recommended for boreholes drilling to a depth between 45m and 50m, with an anticipation of moderate groundwater yield.

Keywords: Electrical resistivity; schlumberger; borehole/groundwater; vertical electrical sounding

INTRODUCTION

Water is the most common and abundant resource on Earth. Generally, water is known as the basis of the existence of life. Man greatly depends on water for both domestic and industrial usage so therefore the quest for water for all purpose in life has drift from ordinary search for water to prospecting for steady and reliable subsurface or groundwater from boreholes. In Nigeria, presently, groundwater exploration has rescued the citizenry from acute shortage of water. Groundwater can be described as the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. It is derived primarily from percolation and tension free interface of impermeable rock formation. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers. Aquifers are geologic formation that can store water and can be extracted in commercial/economic quantities. They are typically made up of gravel, sand, sandstone, or fractured rock etc. water can move through these materials because they have large connected spaces (porous) that make them permeable. The speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well the spaces are connected, water in the aquifers is brought to the surface naturally through a spring or can be discharged into lakes and streams. Groundwater can also be extracted through a well drilled into the aquifer. In other to determine the groundwater bearing formations (aquifer zones), geophysical methods are employed. The electrical resistivity method (ERM) has been found to be very reliable for groundwater studies over the years. Among the geophysical methods commonly employed in subsurface investigations, the electrical resistivity method (ERM) has particular advantage in

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hydrogeology as it responds to variations in conductivity of the groundwater bearing formations. The objectives of this method in the groundwater studies are to locate groundwater bearing formations, estimation of depth to the water table, thickness and lateral extent of aquifers, depth to bed rock, delineation of weathered zone etc. Electrical resistivity method has gained considerable importance in the field of groundwater exploration because of its low cost, easy operation and efficacy to detect the water bearing formation. Drilling of boreholes for groundwater exploration has been of improvement to the common hand-dug wells that do dry up during the dry season and solution to get safe and portable water free from contaminants [1].

STUDY AREA AND GEOLOGY

The study area is Unity Secondary School Compound, Owo, Owo Local Government which is a plain terrain located within the North Senatorial District of Ondo State (figure 1). Its topographic elevation is between 318m and 321m above sea level located within the rainforest belt of Nigeria with a climate of long wet season (April to October) and a short dry season (November to March). Groundwater recharge is mostly through meteoric precipitation (rainfall) and lateral base flow. The pre-Cambrian Basement complex rocks (Igneous and Metamorphic) of southwestern Nigeria (Rahaman 1976) underlie the study area. The lithological units identified to be migmatite gneiss are mostly concealed by the unconsolidated basement regolith in the area. The unconsolidated regolith underlain by fractured/ fresh bedrock generally occurs in a typical basement terrain [2].

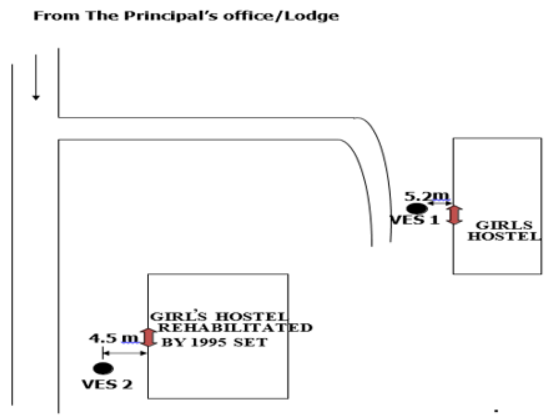

Figure 1: Site Description

METHODOLOGY AND FIELD WORK

Principle of Electrical Resistivity Method

The electrical resistivity method is an active geophysical method. This method utilizes differences in electric potential to identify subsurface material. It employs an artificial source which is introduced into the ground through a pair of electrodes, the electrodes by which current is introduced into the ground are called current electrodes and the electrodes between which the potential difference is measured are called the potential electrodes. An accurately known current from a resistivity meter is caused to flow from one outer electrode to the other into the earth and a measurement is taken of the voltage between the two inner electrodes. Having measured voltage and current, a simple formula is used to establish depth and composition of the strata the ground apparent resistivity is calculated from parameters (I), (V) and the geometric factor (K) of the electrode array used. Electrical resistivity method is fundamentally based on Ohm's Law measuring resistance. Resistance is defined as the voltage divided by the current (R= V/I), where V is the potential difference across the wire and I is the electric current through it, the value of a material's resistance depends on the resistivity of that material. Resistivity is the value of resisting power of a certain material to the flow of a moving current. Resistivity values of rocks are controlled by chemical composition of the minerals, density, porosity, water content, water quality and temperature. Resistivity varies to a large extent in different rocks. Igneous and metamorphic rocks show a range of 102 and 106 Ohm-m and the sedimentary rocks show 100 to 105 Ohmm. However, in the porous formations such as highly weathered and fractured rocks and unconsolidated sediments, the resistivity is controlled more by the amount and quality of water present than the actual rock resistivity. These resistance values are converted to apparent resistivity values using the formula [3-5].

pa = kV/I

The true resistivity of a formation is calculated based on the apparent resistivity values obtained. By plotting apparent resistivity values as ordinate and electrode spacing as abscissa on double logarithm paper, a smooth curve can be obtained passing through different points. This curve is called vertical electrical sounding curve or field curve. From these field curves, layer parameters can be determined and subsurface hydrogeological conditions can then be interpreted by using anyone of the interpretation techniques. The electrical resistivity method is carried out using a set of geophysical instrument which are resistivity meter, electrodes, cable wires, engineering hammer, measuring tapes etc., quantitative and qualitative interpretation is done to interprete field data [6].

A current I flowing through a cylindrical conductor of length L and cross sectional area A

R α L/A .... (1)

$R = \frac{PL}{A}$ .... (2)

Where P =resistivity From ohm's law DV α I

V = IR

Electrode configuration

There are many electrode configurations used in electrical resistivity survey. The choice of a particular array in preference to others is dependent on the aim of the survey and depth of information required. The most common are the Wenner Arrangement, Schlumberger Arrangement, Dipole-Dipole Arrangement; Pole-Dipole Arrangement, etc. The schlumberger and wenner arrays are used for shallow investigations. Dipole systems are usually employed for deeper studies. However, Schlumberger electrode configuration was employed in this research work because of its advantage over other methods both in the field survey as well as in the interpretation of data. In schlumberger electrode configuration, four electrodes are used and are placed on a straight line on the earth but with AB= 5MN i.e. the potential electrodes (M&N) are closely spaced in a way that it does not exceed one-fifth of the spacing of the current electrodes while the current electrodes (A&B) are widely spaced until the observed voltage becomes too small to measure. The schlumberger sounding generally have better resolution, greater probing depth and less time-consuming field deployment [7].

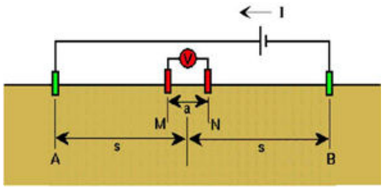

Figure 2: Schlumberger electrode configuration

Field work

The basic setup for a resistivity survey involves using a resistivity meter and electrodes. The resistivity meter acts as both a voltmeter (measuring V) and an ammeter (measuring I) and records resistance values (V/I) and the resistance values are converted to apparent resistivity values. The survey was carried out on 22nd December, 2016. Two vertical electrical soundings (VES) were conducted at the location. The schlumberger electrode array was utilized. Total electrode spread (AB/2) was varied from 1.0m to a maximum of 65m.The DDR2 Resistivity Meter was utilized for the data acquisition. The field data were interpreted qualitatively and quantitatively [8].

Instrumentation

DDR2 resistivity meter

5 steel electrodes

2 Current cable reels

2 Potential Cable reels

3 Hammers

2 Measuring Tapes

Recording (data) sheet

Cutlasses

RESULTS AND DISCUSSION

The field data are presented as sounding curves (fig. 2). The electrical resistivity sounding curve obtained is A in VES 1 and H in VES 2. The curves were interpreted qualitatively and quantitatively. The qualitative interpretation involved partial curve marching using two-layer schlumberger master curves and the auxiliary K, H, Q AND A curves. Outputs were modeled using computer iteration (DC software). The interpreted results are presented in Table 1.

TABLE 1: Ves Interpretation Results

VES NO	THICKNESS (m) d1/d2/d3/d4............dn	RESISTIVITY (Ωm) p1/p2/p3/p4............pn
1	2.48/2.20/21.39	114/484/1210/799
2	0.89/1.47/8.72	1100/68/1646/100

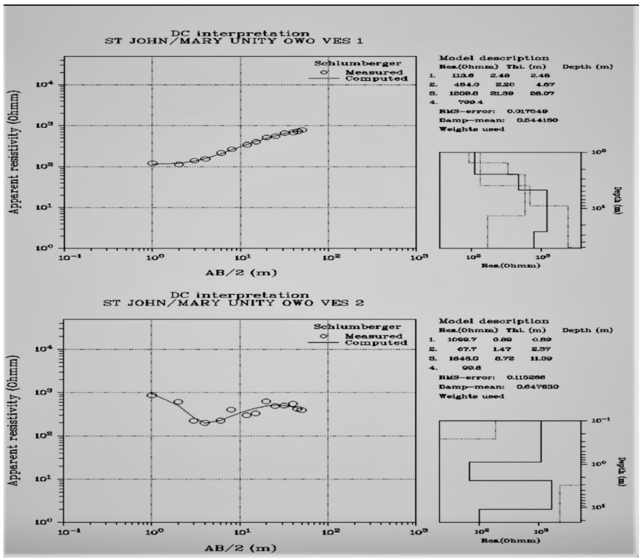

Figure 3: Ves Curves

Groundwater potential evaluation

The electrical resistivity interpretation of the VES stations shows that the overburden thickness of the site, VES 1 and VES 2 are 4.67m (15ft) and 2.37m (8ft) and the layer are characterized by resistivity values are 484Ωm and 68Ωm respectively. Thus, the overburden is of average hydro-geologic potential hence of good tendency for groundwater development.

Table 2: Summaries of Geoelectric Parameters Of Location

Ves No	No of Layers	Layers Resistivity	Layers Thickness	Depth	Curve	Interpreted Lithology
1	4	114	2.48	2.48	A	Top soil
		484	2.20	4.67		Lateritic hardpan
		1210	21.39	26.07		
		799	+			Fresh basement

						Fractured basement
2	4	1100 68 1646 100	0.89 1.47 8.72	0.89 2.37 11.09	H	Top soil Lateritic clay Fresh basement Fractured basement

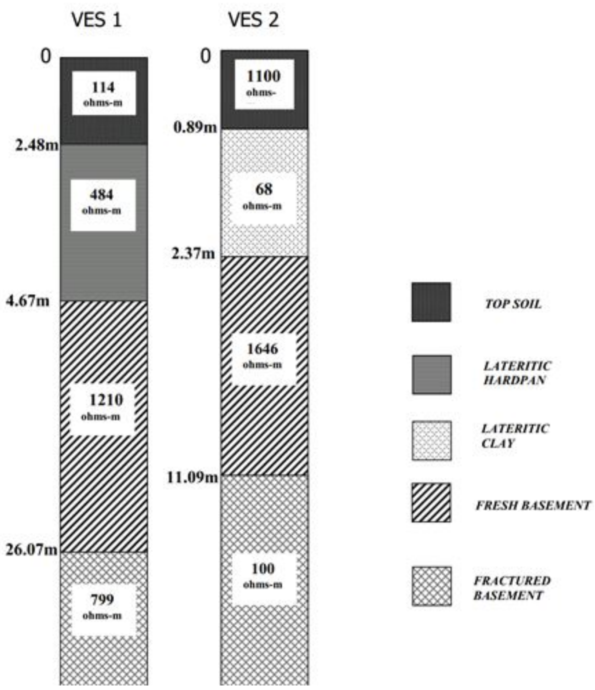

Figure 3: Geoelectric Section

Table 3: Ves Comparism

	VES 1	VES 2
YIEDING	LOW-MODERATE	MODERATE
RECOMMENDATION	RECOMMENDED	RECOMMENDED
DEPTH	45 – 50M	45 – 50M
REMARK	GOOD	GOOD

Table 4: Resistivity Sounding Field Record

Current Electrode Spacing (AB/2)	**Potential Electrode MN (m)**	**ρa = (KR) VES 1**	**ρa = (KR) VES 2**
1	0.5	121	875
2	0.5	113	619
3	0.5	140	225
4	0.5	155	200
6	0.5	205	226
6	1.0	225	225
8	1.0	267	400
12	1.0	344	301
15	1.0	388	235
15	2.0	422	469
20	2.0	513	627
25	2.0	560	490
32	2.0	657	502
40	2.0	685	502
40	5.0	683	601
45	5.0	725	423
50	5.0	725	392

CONCLUSION AND RECOMMENDATION

From this research study, the resistivity survey delineates four subsurface geoelectric layers; Topsoil underlain by Lateritic hardpan/clay, Fresh basement and Fractured basement. Hence, the site is feasible for groundwater development; both VES 1 and VES 2 are recommended for boreholes drilling to a depth between 45m and 50m, with an anticipation of moderate groundwater yield. The drilling of boreholes can be carried out in the study area, Unity Secondary School Compound, Owo, Owo LGA, Ondo State because it is feasible for groundwater development. The drilling should be supervised by a competent and experienced Geologist or Mining Engineer.

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