Delineation of Groundwater Potential Zones in Basement Terrain at Oke Odan Apete Ibadan, Southwestern Nigeria.

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ABSTRACT

Delineation of groundwater potential zone in Basement terrain of Oke Odan area, Apete, Ibadan has become highly imperative due to the perennial water shortage being experienced in some parts of Apete community. This attempt was aimed at determining the variation in resistivity with depth, the thickness of the subsurface layers and determining the hydrologic characteristics of the subsurface layers, and thus, evaluate the groundwater prospects of the study area. The principles of electrical difference of natural earth magnetic field and Vertical Electrical Sounding (VES) were employed. Six profiles were carried out which is based on the field source of earth's electromagnetic field and differences in conductivity of geological profile. Ten (10) VES were carried out, the points were chosen based on the results obtained from profiling, using the Schlumberger electrode array configuration with current electrode separation (AB/2) varying from 1m to 100m. The field data were plotted on bi-logarithm graph and interpreted quantitatively by partial curve matching techniques and computer iteration. All the eleven modeled curves were within K-type, A- type, KH- type and AH- type. The result of interpreted curves delineated three to four geoelectric subsurface layers comprising the top soil, lateritic clay, weathered basement and fresh basement. The topsoil showed resistivity values of 32.8Ωm – 111.7Ωm and thickness ranged between 0.1m – 0.5m. The lateritic clay resistivity ranged from 280.8Ωm – 628.5Ωm and thickness ranged from 1.1m- 10m. The weathered basement resistivity ranged from 100.8Ωm - 4905Ωm and the thickness ranged from 0.3m – 32.3m.The fresh basement ranges from 247.2Ωm to 1727Ωm and thickness of infinity. Generally, the area showed good potential for groundwater exploration. Findings of this study showed that integration of magnetic and vertical electrical sounding is effective in delineation of groundwater potential zones in basement terrain.

Keywords: *Basement terrain• Resi7stivity• Geoelectric-subsurface• Vertical Electrical Sounding •weathered basement•*

INTRODUCTION

Groundwater is any water that is found beneath the surface of the earth and it is important to human life. Water occurs as both groundwater and surface water. Ground water consists of all subsurface water trapped in the pores and other open spaces in rocks, sediment and soils. It is a significant part of hydrogeologic cycle containing about 21% of the earth fresh water (Akinpelu et al., 2013). The expanding demand for water and the cost involved in drilling boreholes therefore require the application and the proper use of groundwater investigation techniques to locate high yielding aquifers (Adagunodo et. al., 2018). Groundwater potential mapping in basement terrain is complex due to the geological nature of the terrain especially where aquifers are compartmentalized (Abudulawal et al., 2015; Bayewu et al., 2017).Identification of fractures in the bedrock and/or thick overburden, as well as the degree of pore spaces and interconnectivity of the subsurface rocks have been described as the most relevant variables to understand groundwater accumulation in Precambrian basement terrain (Adagunodo et al., 2013a; Adelusi et al., 2014; Akinrinade and Adesina, 2016). For the purpose of this study, detailed geophysical survey was employed. The electrical geophysical method is the detection of the surface effects produced by the flow of current inside the earth. The electrical techniques have been used in a wide range of geophysical investigation such as mineral exploration, engineering studies, geothermal exploration, and geological mapping. Electrical methods are generally classified according to the energy source i.e., natural or artificial. This method is widely applied in basement areas for ground water exploration because they are less expensive than other geophysical techniques. They can also be used to locate fractured and weathered part of basement complex rocks. This method also has the capability of identifying water bearing formation. (Zohdy,1974). This research is aimed at establishing the usefulness of electrical resistivity method as potential tool in solving the complex hydrological problems associated with groundwater occurrences and development in typical hard rock formation, mapping the bed rock to delineate the fractured zone in the subsurface area, determining the thickness of the various subsurface layers and hence determine the variable areas or points suitable for groundwater exploration.

MATERIALS AND METHODS

The Study Area

Okeodan and some of its adjoining environs constitute the study area (Figure 1). The area is characterized by good roads networks, motorable and footpath. The area is underlain by complex rocks of south western Nigeria. It lies between latitude 7^0 28” 45’N and longitude 3^0 51”35’E in Oyo state, the network of minor roads links every parts of the town hence making accessibility very easy. The general physiography of the mapped area is that of a general low lying area with hills that are generally steep and distributed unevenly, and situated at the North eastern and western extremes of the mapped area. The study area falls in the tropical and climate and the tropical wet and dry (also known as tropical savanna climate). The region experiences a fairly high uniform temperature, moderate to heavy seasonal rainfall. The town is seen to be a low land forest area with agricultural activities been the major activities carried out on it. The regions are within Ibadan has four seasons like most of the other area in the southern Nigeria.

The study area is underlain by undifferentiated Migmatized Biotite and Biotite – hornblende gneiss and Quartzite and quartz schist (Figure 2). The Migmatite is mostly widespread in the basement complex of southwestern Nigeria which comprises of gneisses, quartzite, calc-silicate rocks, Biotite (Hornblend Schist) and Amphibolite. The slightly Migmatized to unmigmatized Paraschist and meta-igneous rock are described as younger or newer metasediments. Charnockites occur west of Ibadan as dyke like bodies scattered over a wide area, Jones and Hockey (1964) recognized three main groups of granites ; an early phase comprising granodiorites and quartz diorites, a main phase comprising coarse Phophyrite, Hornblende granite syenite and coarse porphyritic Biotite granite and a late phase comprising homogenous granites , dykes and Pegmatites and Aplite.

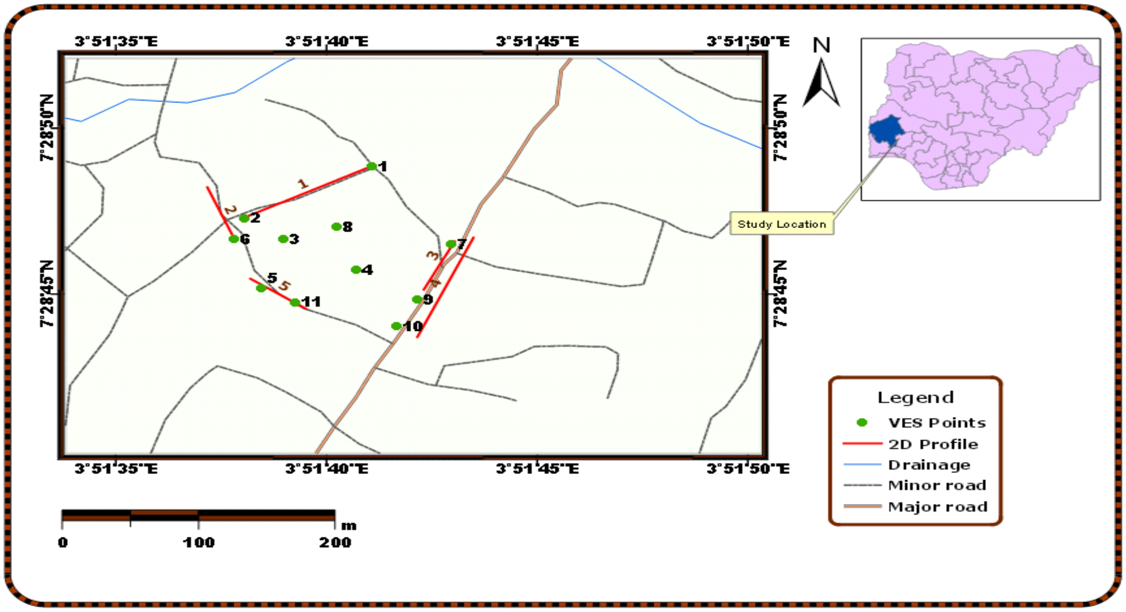


Figure 1: Location of the study area and the VES Points

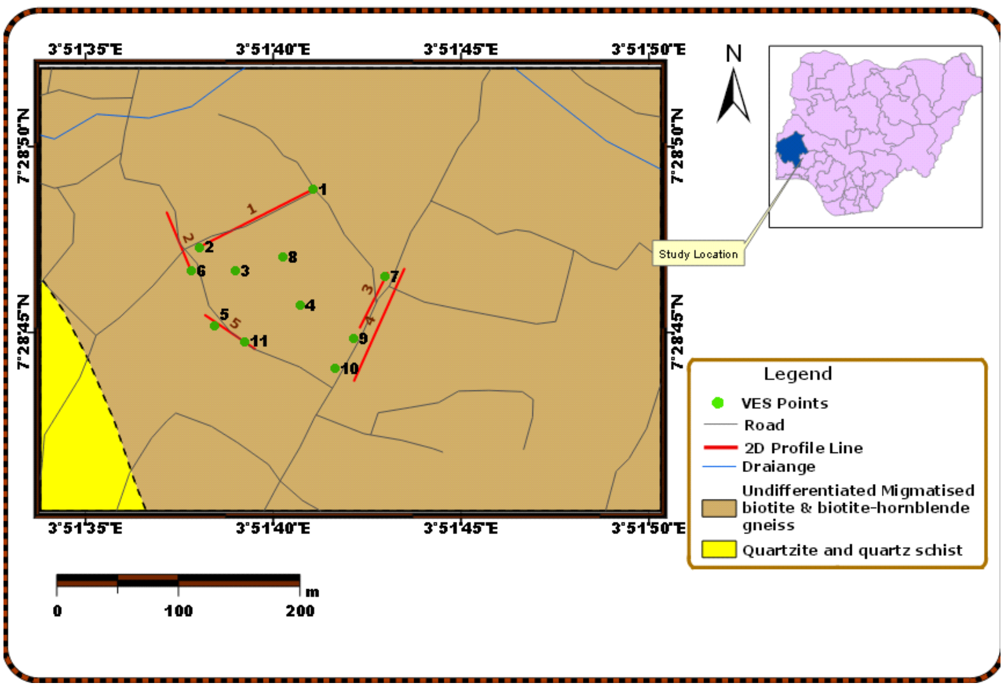


Figure 2: Geological Map of the Study Area

MATERIALS AND METHODS

Data Acquisition and interpretation

The paper explains how electromagnetic profiling method and Vertical Electrical Sounding (VES) were used in exploring for groundwater in basement terrain at Oke-Odan Apete, Ibadan, Southwestern, Nigeria. The electromagnetic method was used for reconnaissance survey. Points on the electromagnetic profiles that show adequate conductivity were considered for electrical resistivity sounding. Among the techniques that are globally adopted for groundwater exploration, Very Low Frequency Electromagnetic (VLF-EM) and VES have been the most utilized geophysical tools (Adagunodo *et. al*., 2018).

PQWT, one of the new geophysical instruments, working on the principle of electrical difference of natural earth magnetic field (frequency 0 – 30 KHZ), the several different frequencies of electromagnetic field changes is the law to study the underground field or material changes. The natural electrical magnetic resistance abnormalities and changes with depth are useful tools to study and interpret subsurface rock properties. The instrument can automatically draw curve graph and profile map, through which geological structures and also the location of the ore bodies could be determined.

The electrical resistivity employing VES configuration is effective due to its simplicity (Sunmonu*et al.,* 2012) and its effectiveness in understanding subsurface geology (Tizro et al., 2012; Anomohanran*et al.,* 2017).In prospecting for groundwater, the interest is in the vertical variations resistivity which is achieved by carrying out depth sounding survey. A total number of sixteen (12) VES by applying the Schlumberger array were randomly acquired along four (5) traverses, one along each traverse. The electrode separation (AB/2) varied from 1 to 50 m. Current was passed into the ground through the current electrodes using Ohmega 127/179 terrameter, and the resulting potential was measured through the potential electrodes. The method is implemented by incrementing the electrode array about a fixed point for deeper subsurface probing and to establish the resistivity variations with depth (Adagunodo*et. al*. 2017)

The Vertical Electrical Sounding technique measures the vertical variations in ground apparent resistivities with respect to a fixed center of array. The VES technique employs the collinear arrays designed to output a one- dimensional (1-D) vertical apparent resistivity versus depth model of the subsurface at a specific observation point (Figure 3).

RESULTS AND DISCUSSIONS

Table 1 Shows number of layers, resistivity values, thickness, curve types and possible lithologies expected. The 2D geosections obtained are also presented in figure 9.

Geoelectric Characteristics

The qualitative interpretation involves detailed analysis of the curves in order to infer the number and the resistivity of layers which involves pseudo-sections among others. The main objective of the quantitative interpretation of VES curves is to obtain the geoelectric parameters and geo-sections (Nejad*et al*., 2011). Qualitative interpretation of the Vertical Electrical Sounding (VES) curves obtained from the study area can be classified based on curve shapes into K, H, A, KH and HA types.The curve types consist of three (3) three-layer models (that is, K, H and A-type) and two (2) four-layer earth model (that is, KH and HA-type). K-type covered 20%, H-type covered 10%, A-type covered 30%, and KH-type covered 30% while HA-type covered 10% of the total VES stations in the study area (as presented in Figure 4).Therefore, A and KH types are the most dominant sounding curve types in the study area.60% of the study area showed three layers lithology varying from topsoil, sandy clay or laterites, and bedrock (weathered fractured or fresh bedrock). However, the remaining 40% belong to four-layer lithologic group varying from topsoil, laterites, weathered bedrock (saprolite), and fresh bedrock.

Generally, the weathered gneiss/granite bedrocks (saprolite) and fractured gneiss/granite bedrocks (saprock) constitute the aquifers or aquiferous units in the area.

Table 1: Geoelectrical Sequence of Oke-Odan Community

VES NO.	Curve Type	Number of Layer	Resistivity (Ωm)	Resistivity Model	Layer Thickness (m)	Layer Depth (m)	Inferred Lithology
1	K	3	111.7	ρ1< ρ2 > ρ3	1.4	1.4	Top soil
			490.5		26.5	27.9	Weathered basement
			172.7		∞	∞	Fractured basement
2	H	3	121.4	ρ1 > ρ2 < ρ3	2.1	2.1	Top soil
			737.8		19	21.1	Weathered basement
			247.2		∞	∞	Fractured basement
3	K	3	67.6	ρ1< ρ2 > ρ3	0.3	0.3	Top soil
			1415.0		3.3	3.6	Weathered basement
			471.6		∞	∞	Fractured basement
4	A	3	34.3	ρ1< ρ2 < ρ3	0.3	0.3	Top soil
			269.3		6.3	6.6	Weathered basement
			620.7		∞	∞	Fresh basement
5	A	3	88.4	ρ1< ρ2 < ρ3	0.9	0.9	Top soil
			522.0		11.4	12.3	Weathered basement
			704.0		∞	∞	Fresh basement
6	A	3	59.4	ρ1 < ρ2 < ρ3	0.9	0.9	Top soil
			381.5		11.1	12.0	Weathered basement
			501.8		∞	∞	Fresh basement
7	KH	4	133.8	ρ1< ρ2 > ρ3 < ρ4	0.9	0.9	Top soil
			628.5		10.3	11.2	Lateritic soil
			567.6		32.3	43.5	Weathered basement
			692.0		∞	∞	Fresh basement
8	KH	4	61.7	ρ1< ρ2 > ρ3 < ρ4	0.6	0.6	Top soil
			549.6		10.7	11.3	Lateritic soil
			274.3		23.1	34.4	Weathered basement
			1017.4		∞	∞	Fresh basement
9	KH	4	32.8	ρ1< ρ2 > ρ3 < ρ4	0.1	0.1	Top soil
			290.8		1.1	1.2	Lateritic
			100.9		0.3	1.5	Weathered basement
			491.8		∞	∞	Fresh basement
10	HA	4	158.3	ρ1> ρ2 < ρ3 < ρ4	2.5	2.5	Top soil
			42.3		1.0	3.5	Lateritic soil
			280.8		1.8	5.3	Weathered basement
			2286.0		∞	∞	Fresh basement

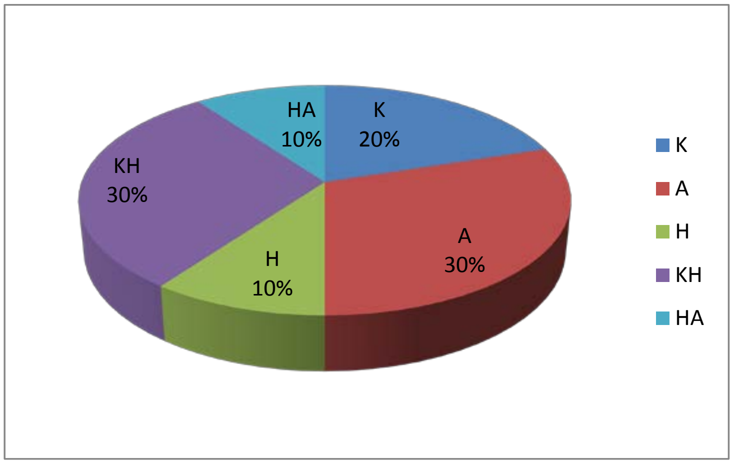


Figure 3: Percentage Distribution of vertical electrical sounding Curves types in the Study Area.

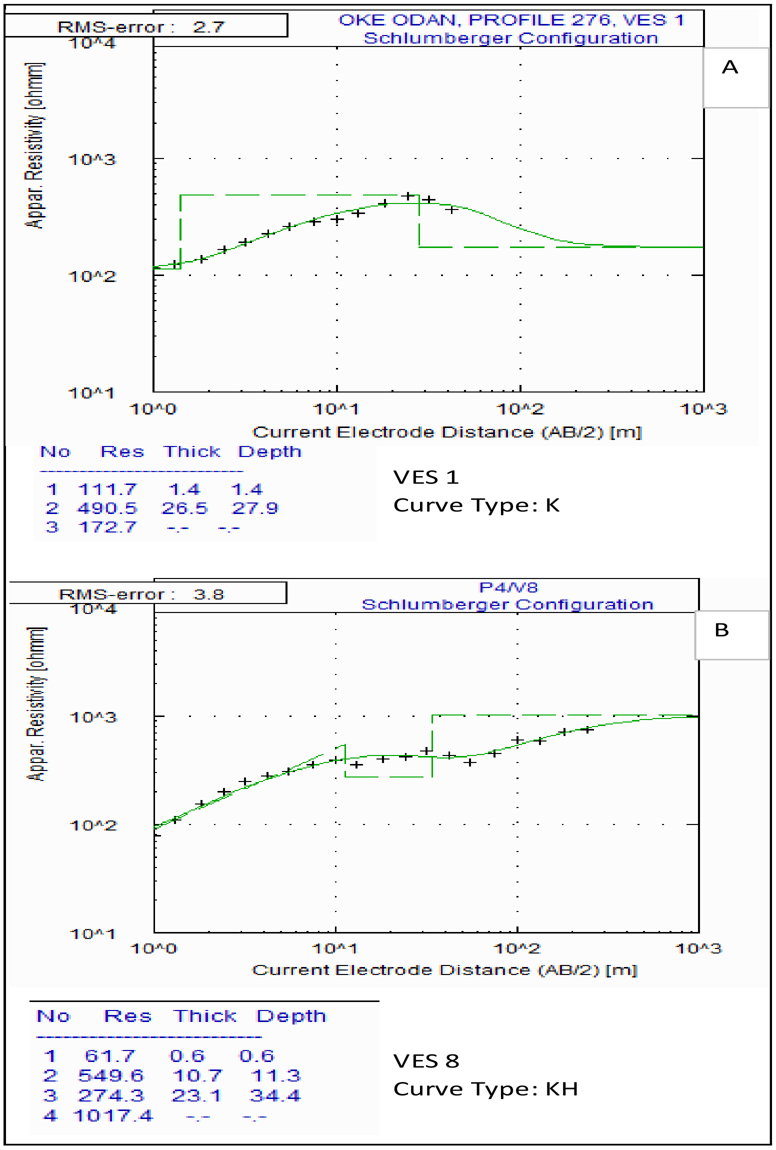


Figure 4: Plots of Apparent Resistivity against Ab/2 for VES 1 and 8

Profile Sections

Profile 1: This section shows the layers of the earth of 300m depth and lateral distance at 49m (Figure 5). The apparent low resistivity region covers about 20% of the total area of the section, to depth of about 120m is inferred to be composed of weathered basement, saturated or aquiferrous zone with resistivity ranging from (0.00-0.76Ωm). Underlying the low resistivity layer is the fresh basement rock which occupied about 85% of the total area of the section and characterized by high resistivity ranging from (0.92- 2.60Ωm).Vertical Electrical Sounding was conducted on preferred points at 5m and22m along the traverse.

Profile 2: This section shows the layer of the earth at 300m depth and lateral distance at 24m (Figure 6). The section shows a layer of high resistivity which covers about 80% of the section. The low resistivity region constitutes about 15% of the section with values ranging from (0.00 -

0.82Ωm) up to depth of about100m and is inferred to be a saturated zone. Vertical Electrical Sounding was conducted on points at 16m, 21m and 22m along the traverse.

Profile 3: This section shows a profile of the earth up to 300m depth, dominated by high resistivity materials (Figure 7).The low resistivity (0.00 - 1.07Ωm) regions occur at the surface with greater concentration of points at 9m and 20m along the traverse and depth of about 20m and 10m respectively. A weathered to fresh basement with a little sign of saturation as depicted in the section shows poor groundwater development potential.

Profile 4: This section shows majorly four different layers as depicted by the section (Figure 8). The low resistivity regions (0 - 70m) and (about 270m beneath) depict saturation due to its low magnetic resistivity from (0.00-0.77Ωm). Vertical Electrical Sounding (VES) was carried out on points at 3m and 18m along the traverse. Point at 3m shows more aquifer potential due to its further depth of saturation of about (90m) than point at 18m (about 55m).

Profile 5: This section shows four layers with resistivity values ranging from 0.0 to 2.7Ωm (Figure 9).The Saturation zones: 0 - 95m depth, and from depth 270m and beneath). At the surface, low resistivity extends to both ends of the section as it does at 270m and beneath. Vertical Electrial Sounding was conducted at locations 7m and 21m, along the traverse, which shows the highest degree of saturation and good prospects for gound water development.

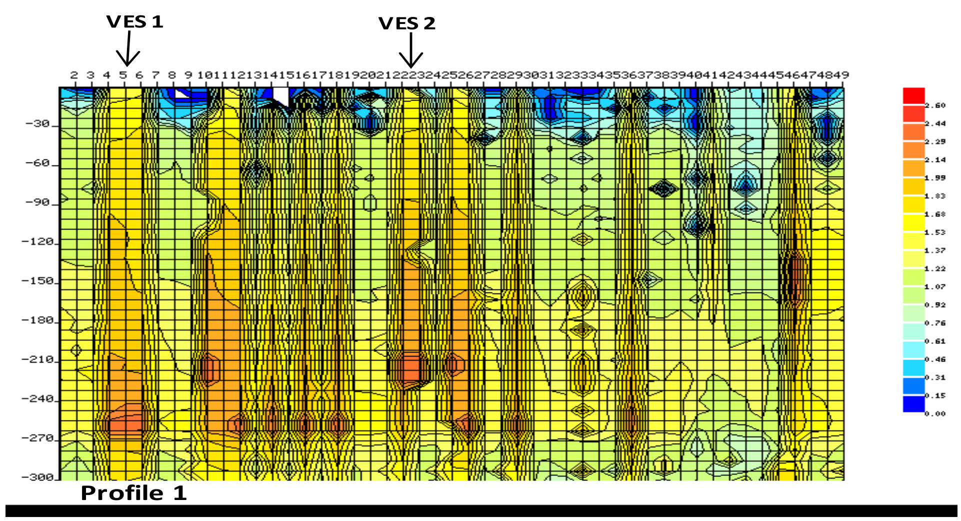


Figure 5: 2D Profile Sections along Traverse 1

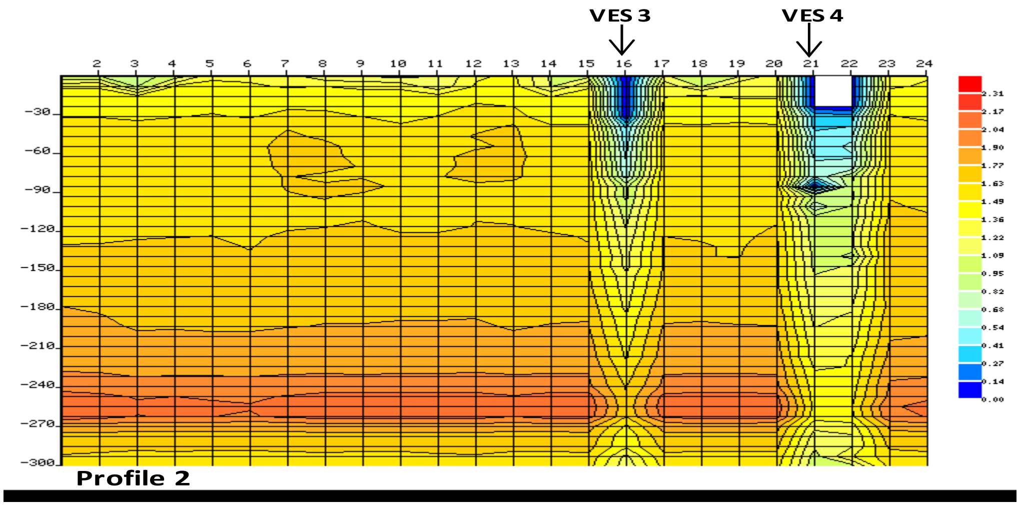


Figure 6: 2D Profile Sections along Traverse 2

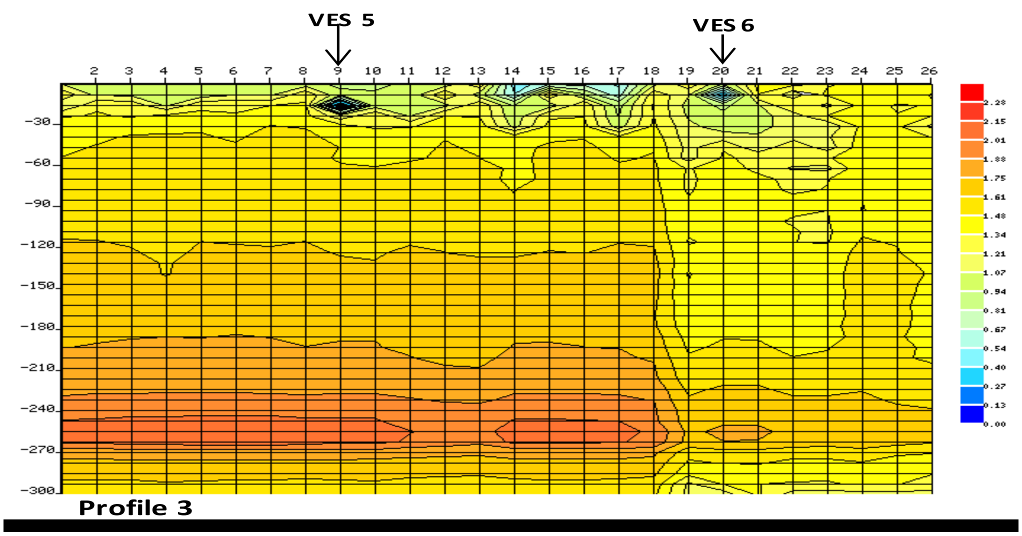


Figure 7: 2D Profile Sections along Traverse 3

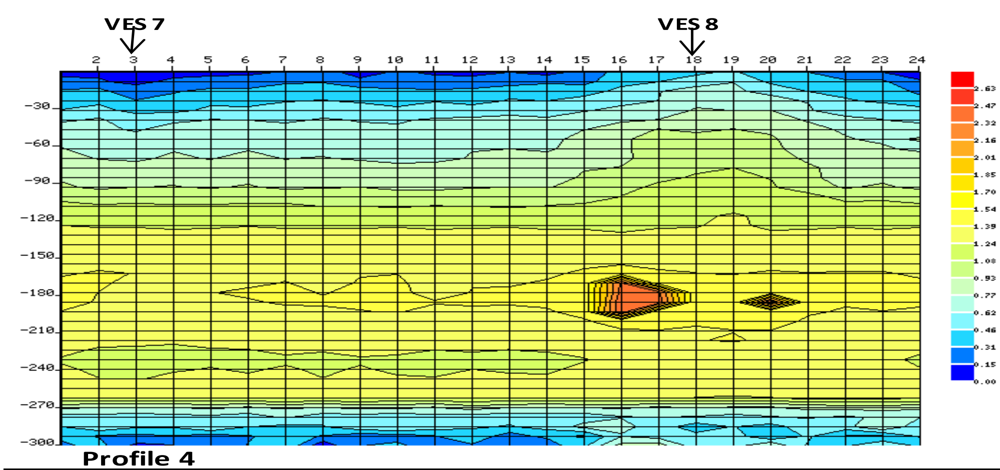


Figure 8: 2D Profile Sections along Traverse 4

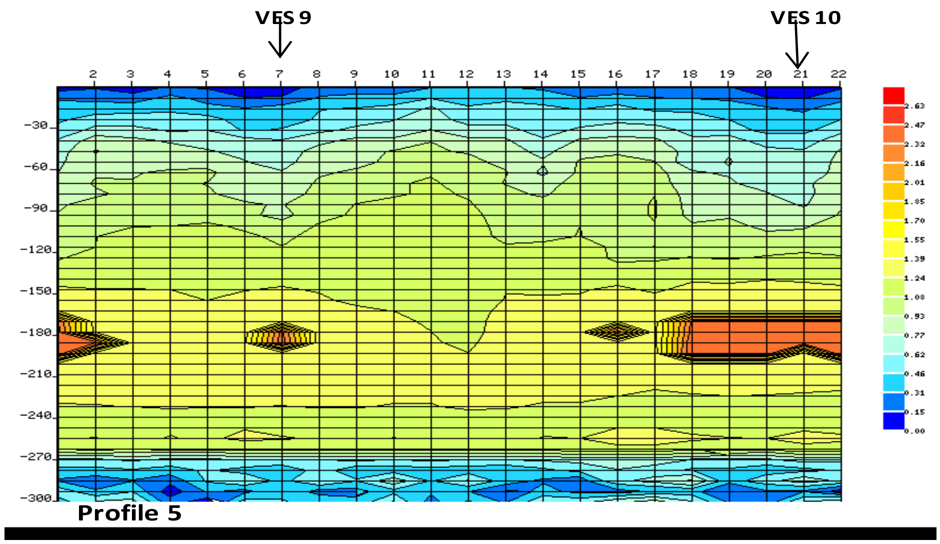
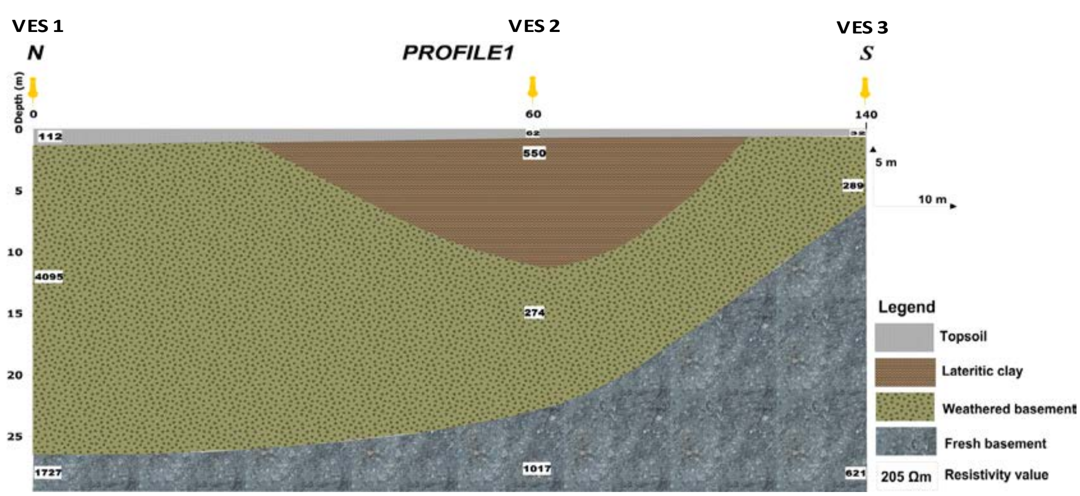


Figure 9: 2D Profile Sections along Traverse 5.

Geoelectric Sections

The geoelectric sections of Oke-Odan were produced from the geoelectrical parameters along Profile 1, 2 and 3 (Figures 10). This was done to depict the vertical and lateral distributions of ρa layer-by-layer in the subsurface (Adagunodo and Sunmonu, 2013), which is a revelation of the lateral and vertical facies changes inferred from the geoelectrical parameters (Adagunodo *et al.*, 2013a, b). A minimum of three and a maximum of four geoelectrical sequences were demarcated underneath these sections.

The lithologies demarcated are: topsoil, laterites, sandy clay/clayey sand/clay/weathered rocks, and bedrock. From the geoelectric section above, VES points 1, 4 and 8 have excellent potential for groundwater exploitation because of the presence of weathered basement which has low resistivity values and thereby indicates high conductivity. VES points 2 and 5 could also have good potential for groundwater exploitation because the considerable thickness of the weathered basement which has low resistivity values and imply high conductivity.



a

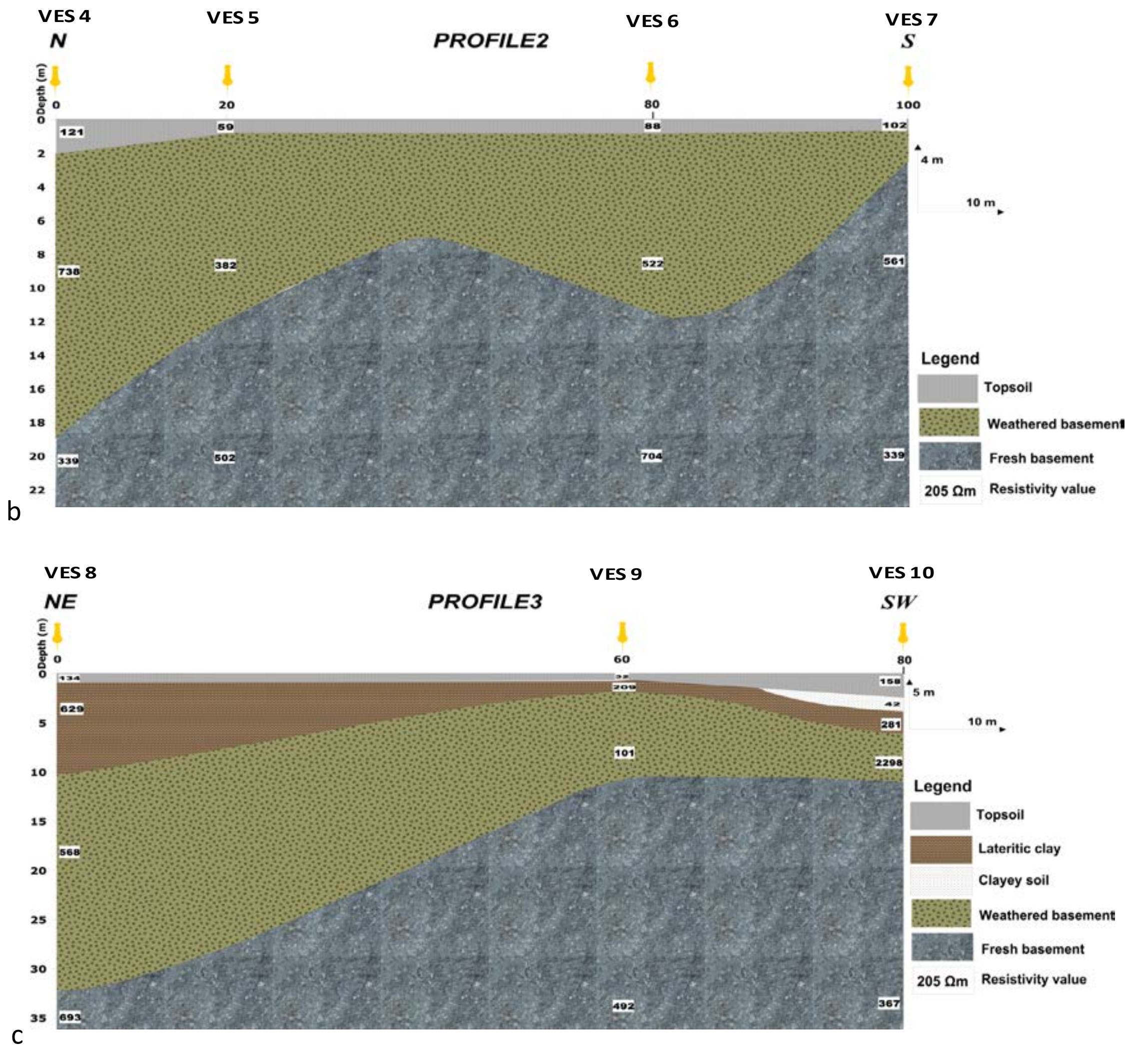


Figure 10 (a-c): Geoelectric sections along Profile

CONCLUSION

The study has been able to highlight the importance of resistivity method in effective hydrogeologic characterization and groundwater exploration. This study has proved to be quite successful for mapping outcrop types, structural formations and fractures which would not have been observed at the surface. The presence of weathered layer and fractured basement are key components of aquifer system and zone of groundwater accumulation in study area. A multidimensional approach through the integration of modeled curves and the geo electric section has made the study both very qualitative and quantitative as information missed by any of the methods is revealed by the other and thereby necessitating justifiable conclusions.It can be concluded that the low resistivity and significantly thick weathered rock and the fractured basement constitute the aquifer in this area.

The hydro-geophysical investigation of OkeOdan area, Apete Ibadan has contributed to a better understanding of groundwater development in this part of the basement complex of southwestern Nigeria. There are weathered basement and fractured basement which occurred in almost all the locations. Basement depressions and / or fractured/sheared bedrock may likely contain more groundwater compared with areas where such structural features or elements are absent, since water often accumulates in the fractured/jointed column of the bedrock. The technique has increased the rate of success for location of site for borehole drilling and consequently the cost effectiveness of groundwater exploration. Surface geophysical exploration of groundwater in Oke-Odan southwestern Nigerian therefore raises hope for water supplies in the area.

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