Adamawa State University Journal of Scientific Research
ISSN: 2251-0702 (P)
Volume 6 Number 1, April, 2018; Article no. ADSUJSR 0601013
http://www.adsujsr.com

Geo-Electrical Study over Gella and Environs, Northeastern Nigeria

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Abstract

Geo-electrical study of Gella and Evirons using vertical electrical Sounding method was carried out to investigate the groundwater potentials of selected areas in Gella and environs Northeastern, Nigeria. The study area is located within latitudes 10°6'0"N and 10°17'0" N and longitudes 13°8'30"E and 13°30'30"E The area is underlain by the Precambrian basement complex of North-eastern Nigeria with Local geology of porphyritic granite. Ten (10) Vertical Electrical Soundings were carried out across the area using schlumberger electrode array configuration, with current electrode separation (AB) varying from 100 m to 150 m. The interpretation of the VES data helps in the characterization of three to four geo-electric layers from which the potential areas for ground water exploration were delineated. The geo-electric section obtained from the sounding curves revealed three layers and four layers models respectively. The three layer model with 90% occurrence while the four layers model with 10% show that the subsurface are categorized into topsoil layer, weathered/fracture layer and fresh basement layer. The weathered/fracture basement are the potential areas for ground water exploration. The thickness of the weathered aquifer varies from 5.5m to 40.2m in the area. On the basis of geo-electric parameters, the study area is zoned into high, intermediate and low potential zones.

Keywords: Geo-electrical; Resistivity; Groundwater, Curve-types; Weathered Basement; Gella and Environs.

Introduction

Geophysical methods are used for studying the structure and composition of the earth's interior using measurements based on its physical properties. For example, gravity, magnetic, and electrical surveys respond to density, magnetic susceptibility and electrical conductivity of the subsurface and provide information about the nature of the concealed structures that could be used for locating desired targets. Hence, geophysical methods can be used in exploration for minerals, hydrocarbons, groundwater and other subsurface targets. Detection of these subsurface deposits depends on those contrasting physical characteristics, which differentiate them from the surrounding rocks. The choice of geophysical methods to locate a certain type of deposit is dependent on the nature of the deposit and of its host rock (Reynolds, 1997).

Geophysical methods based on the use of electric fields, include a large variety of techniques such as direct current (DC) resistivity, self-potential (SP), induced polarization (IP), magneto telluric (MT), ground penetrating radar (GPR) and electromagnetic (EM) methods (Shahid and Nath, 2003). Among these, DC resistivity methods are often the best for determining the distribution of electrical conductivity or resistivity of the subsurface formation and also for detecting subsurface bodies, which have high or relatively high electrical conductivity contrast with the surrounding. Hence electrical studies in geophysics may be understood in the context of current flow through a subsurface medium consisting of layers of materials with individual resistivity. The electrical resistivity method measures the bulk resistance of earth materials to the passage of electricity. Measurements of resistivity are commonly used for evaluation of the variation in the subsurface resistivity related to lateral and vertical changes in geologic materials. Measurement of resistivity in the earth is defined as apparent resistivity because it is unlikely that the material into which the electrodes are inserted and of which measurements are taking homogeneous. The applied current and the resultant measured voltage, provide information about the subsurface apparent resistivity.

Electrical resistivity surveys are usually very useful and convenient when searching for ground water and in the exploration of minerals. It can also provide information about the subsurface formations when potential measurements are taken at the surface. The electrical resistivity method as a tool for geophysical exploration, is based on the fact that the underlying rock materials can impose resistance to the flow of current and as such ohm's law could be applied to them if the earth is homogenous, the resistivity measured is called true resistivity otherwise, the term apparent resistivity is used and this is a weigh average of the resistivity of the various formations.

The need for the development of ground water resources to meet up adequate domestic demand in local communities and residents in Gella and environs, called for this study. Gella and Environs suffer from shortage of water in season and out of season. At the peak of the rainy season, most of the area becomes marshy due to the impermeable nature of the rocks the yield from springs is little and vanishes during the dry season. Hence, the need for resistivity survey, to identify areas that have potentials for groundwater and therefor groundwater exploration through the evaluation of the physical properties of the area using vertical electrical sounding (VES), The interpretation of the resistivity data, in the study area will provide information for better understanding of the drilling depth to the water table and the aquifer thickness. This will aid in the optimum design and construction of boreholes, which will then provide access to portable water sources in the study area. This study will provide information that will serve as a guide for the success rate of any future groundwater exploration in the study area.

The study area is located within latitudes 10°6'0"N and 10°17'0" N and longitudes 13°8'30"E and 13°30'30"E and covers an aerial extent of about 810.4338 square kilometers in Gella and Environs (Fig.1). The area has an undulating topography and the elevation varies between 592m and 1035m above sea level. The mean annual rainfall ranges from 900mm to 1050mm (Adebayo, 2004). The climate is tropical with average temperature of about 32.9°c in dry season and relative humidity ranging from 10-45%, the mean annual rainfall is about 1050mm which usually starts around May and lasts for six (6) months (Adebayo and Tukur, 2004). The dominant drainage, system in the study area, is the Yedzeram River which takes its source from Gella Hills, South of Mubi, flows through the region in a South-North direction, it eventually drains into Lake Chad. Temperatures are usually slightly cool between November and February and a gradual increase in temperature from January to April with seasonal maximum occurring in April (Adebayo and Tukur, 2004).

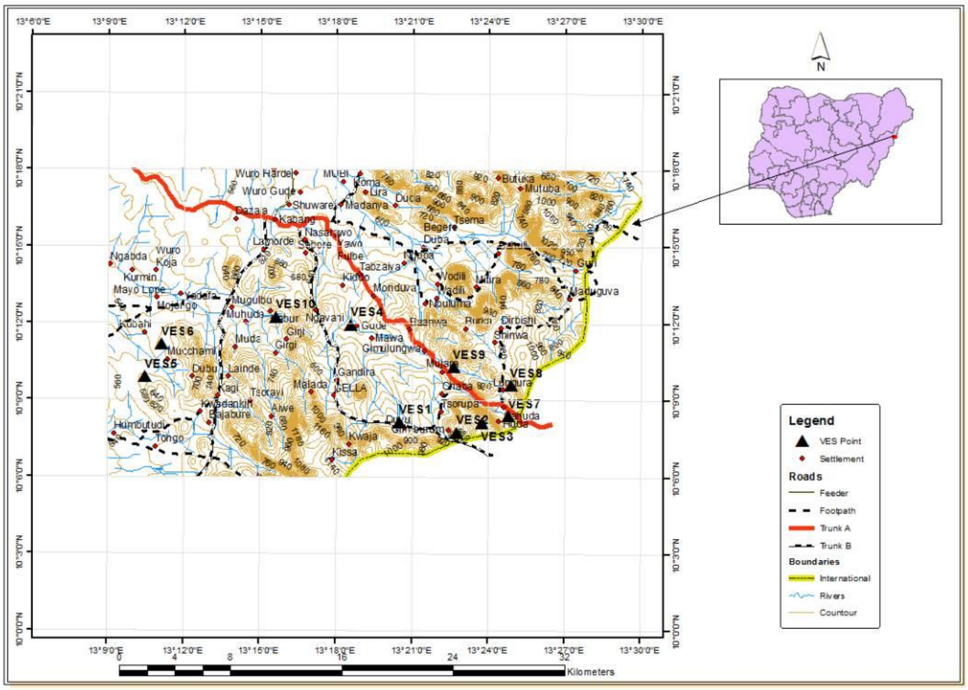

Figure 1: Topographic map of the study area
Source: Digital Elevation Model (DEM), 2006

The geology of the study area is unified into Precambrian basement complex rocks (Fig.2), which are considered to be undifferentiated basement mainly Porphyritic. Porphyritic rocks are aphanites with large crystals or phenocrysts floating in a fine-grained groundmass of non-visible crystals, as in a porphyritic basalt, or phanerites or intrusive, with individual crystals of the groundmass easily distinguished with the eye, but one group of crystals clearly much bigger than the rest, as in a porphyritic granite (Adebayo and Umar, 2004). The basement complex rock mineralogically consists of quartz, feldspars, Biotitic, Hornblende, Diorite and Granodiorite.

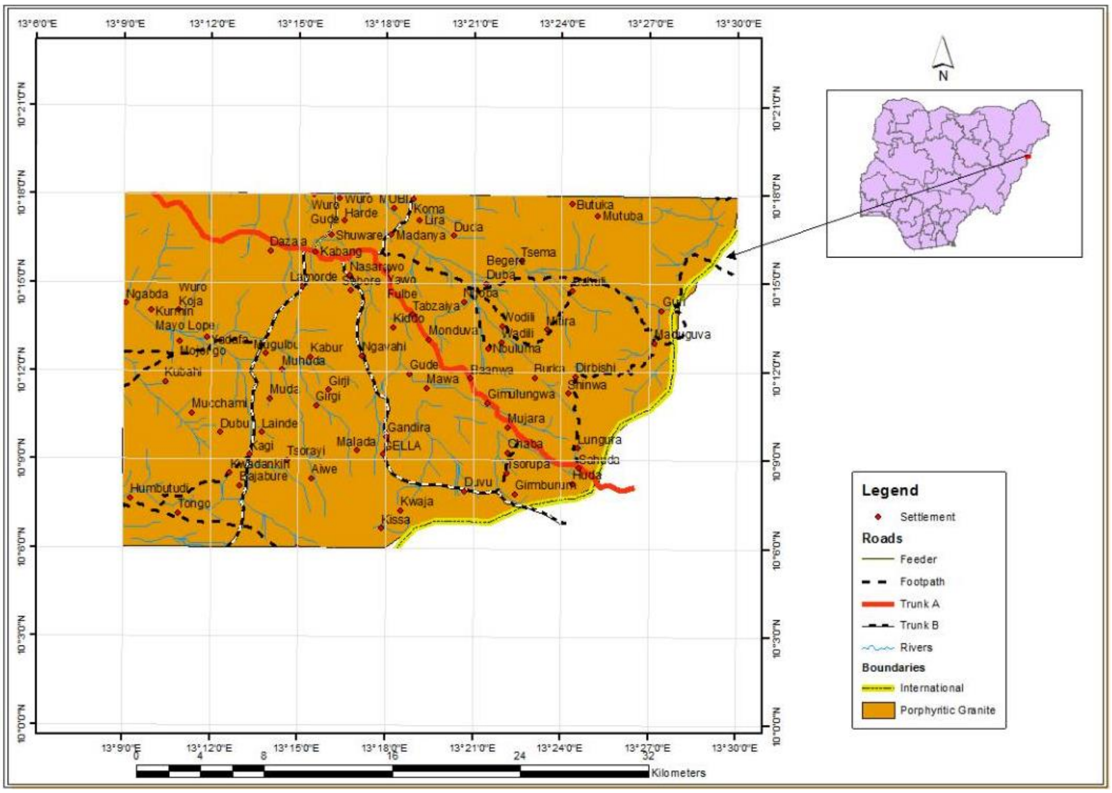

Figure 2: Geologic map of the study area
After Nigeria geologic survey, 2006

Opeloye and Dio (1999) asserted that Mubi encounter passes parts of an ancient craton that was active in geological past and the hard crystalline cratonic basements are ancient Precambrian rocks formed from series of orogenic cycles within the mobile belt of Central Africa. The granitisation by intrusion of Granite, Granodiorites and Syenites during this period transformed the older rocks into oriented Biotitic-granite, Biotitic and porphyria–granite and alkaline granite. These recycled crystalline rocks are outcrop at Mubi as prominent ridges consequent to compression during the orogeny events. Most rock within the area are Gneisses, Migmatities and Quartzite's, but later obliterate by the late Proterozoic and pan-Africa events. The predominant geological structures in the area are quartz veins, folds, dykes and shear zones (Bassey, 2006a and 2006b). The dominant tectonic directions in the area are NW-SE making pre-Africa deformation and NE-SW making the thermo tectonic event (Adebayo and Dayya, 2004).

Materials and Methods

Data Collection and Interpretation

The data used for this study was obtained from Umar Bahago (UB) Water Engineering Service Limited, FCE Corner shop. A total of Ten (10) Vertical Electrical Sounding (VES) stations were acquire within the study area, using Schlumberger configuration with ABEM SAS 1000 Terrameter. In carrying out the survey, the potential electrodes remain fixed and the current electrodes are expanded simultaneously about the center of the spread. The maximum electrode separation used was 100 - 150m which are arranged in a straight line, with the potential electrode placed in between the current electrodes. This configuration is mostly used as it provide sub-surface information considering the depth of penetration which ranges 1/3 and 1/4 of the total separation (Mallarn and Ajayi, 2000).

From the sounding acquired in all locations, the data obtained were analyze by a suitable computer resistivity software known as (INTERPEX). Electrical resistivity interpretation involves the use of curves matching techniques and computer applications, which invert the observed data to a model of true resistivity of the subsurface. The mathematical analysis for quantitative interpretation developed via method of' images are most highly developed for electrical sounding technique and dealing with single overburden problems. This process involves the comparison of field profiles with characteristic curves. The first step in interpretation of VES measurement is to plot the field data on a double logarithmic coordinate graph. For Schlumberger VES data (considered in this work), the apparent resistivity is plotted as the ordinate while the electrode spacing is plotted as the abscissa of the logarithmic graph. There are several methods employed in the interpretation of VES data. These include both qualitative analysis as well as quantitative interpretation.

Qualitative analysis of the field profile is geared towards understanding the characters of the beds between surface and the under lying beds (Telford *et al.*, 1990). For convenience in selecting the method of interpretation of resistivity sounding data, the curves are classified into four basic shapes for three horizontally layered earths with resistivity. A curve which has a definite minimum at the intermediate depth is classified as a type H curve while that with a definite maximum at the intermediate depth is classified as a type K curve. These indicate the presence of a three-layer bed sequence with the resistivity ratios varying as respectively. Curves that show uniform increase or decrease in resistivity value with depth are classified as type A or Q respectively. The resistivity ratios are therefore the classification above is made on the assumption that each of the curve types in their crudest form is for two beds over a basement although in general, these characteristics of sounding curves represent multiple layers. Similarly, some ideas also of the relative bed thicknesses may be obtained from the horizontal extent of the maxima and minima as well as the flanking portions in all cases (Telford *et al*. 1990). When there are more than three layers with different resistivity apparent on a field curve, several letters are used to classify the curve. A type-HK curve indicates a sequence of resistivity's (Keller and Frischkneit, 1996). Similarly, use can also be made of the maximum and minimum point to estimate the resistivity and layer thickness.

The coordinates of the extreme points in curve types H and K (i.e. maximum or minimum and electrode separation) are used with certain characteristic curves for three layer employing a particular electrode spread. For Schlumberger array in which is plotted against for various values of z2/zl and the ratio is plotted against z2/zl for various values of, L (rnax) being the electrode spacing at which is maximum or minimum. Thus horizontal lines drawn across the characteristic curve gives two sets of possible values of z2 and z2/zl, corresponding to the intersection. If values of z2/zl are plotted against, we obtain two curves which intersect at one point. The point of intersection therefore represents the correct values of z2 and z2/zl (Telford *et al.*, 1990). A total of four profiles were also drawn to connect the sounding points, which were used to produce the geo-electric sections by plotting depth of resistivity values against distance.

Results and Discussion

The results obtained from this study have been very useful in the determination of topsoil, weathered/fractured basement rocks in Gella and environs. This research finding contained ten (10) different Vertical electrical soundings (VES), which have three to four layers: VES 1 curve (Fig.3), has four layers with thickness ranging from 1.5m to 40m and resistivity ranging from 310Ωm to 740 Ωm. VES 1 has an H-type curve; VES 2 and 4 curve have a thickness ranging from 1.5m to 40m with three layers (Fig. 4 and 6). The resistivity of these layers ranges from 300 Ωm to 678 Ωm. VES 2 and VES 4 have K-type curve; Thus for the rest of the VES (i.e. VES 3, 5, 6, 7, 8, 9, and 10 respectively) they both have three layers with thickness ranging from 1.5m to 60m and resistivity ranging from 32 Ωm to 740 Ωm respectively (Fig. 5, 7, 8. 9, 10, 11 and 12). They all have lower resistivity and therefor higher conductivity. VES 5, 9 and 10 shows anomalous conductivity at the depth of 8m to 10m. The curve types are H and HA types respectively. VES 3, 6 and 7 shows anomalous conductivity at a depth of 30m to 40m. The curve types are Q and K-type. The areas with high conductivity could be possible areas for groundwater potentials. Table 1 shows the summary of the vertical electrical sounding of the ten sounding points,

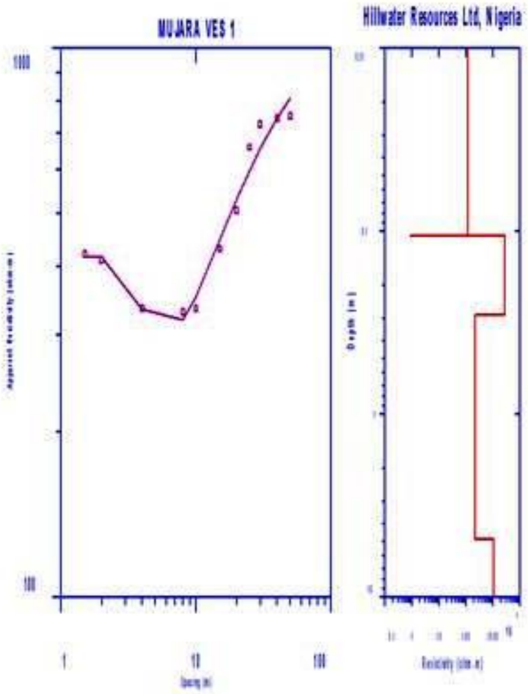

Figure 3: VES 1 curve.

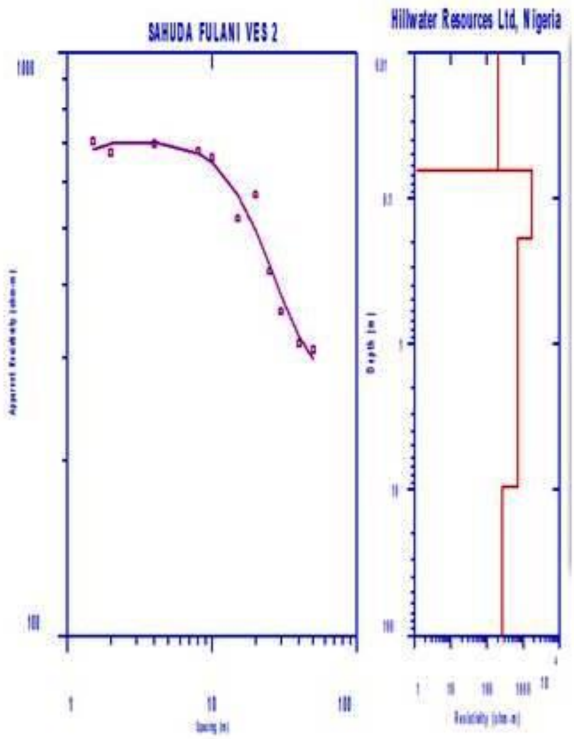

Figure 4: VES 2 curve.

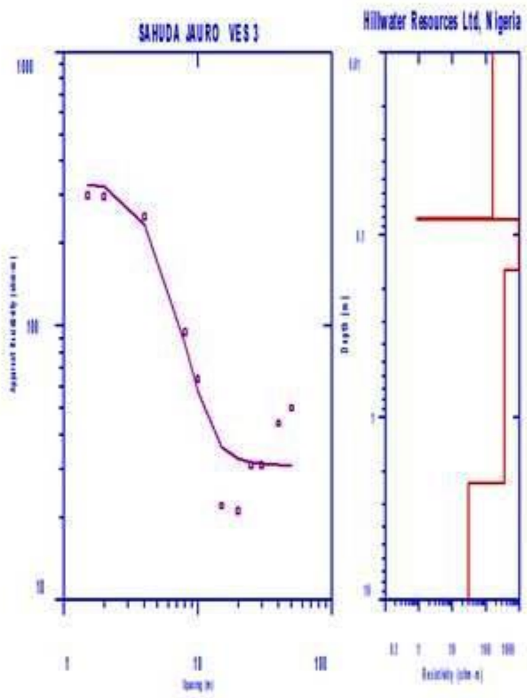

Figure 5: VES 3 curve

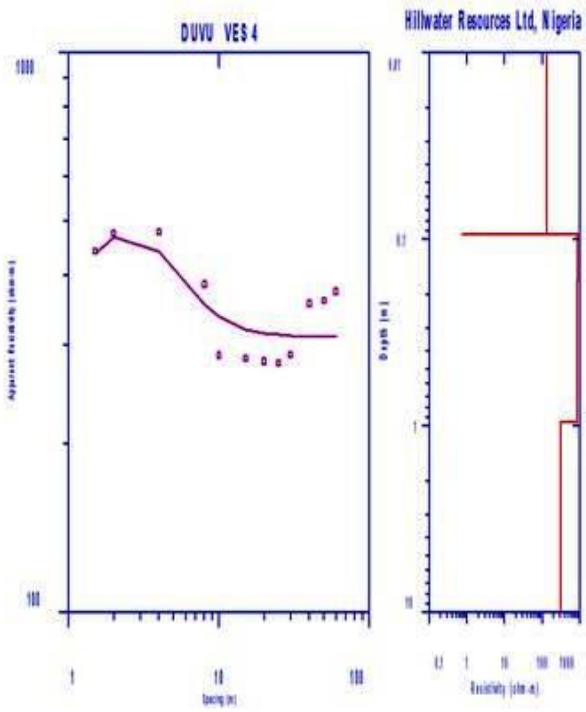

Figure 6: VES 4 curve

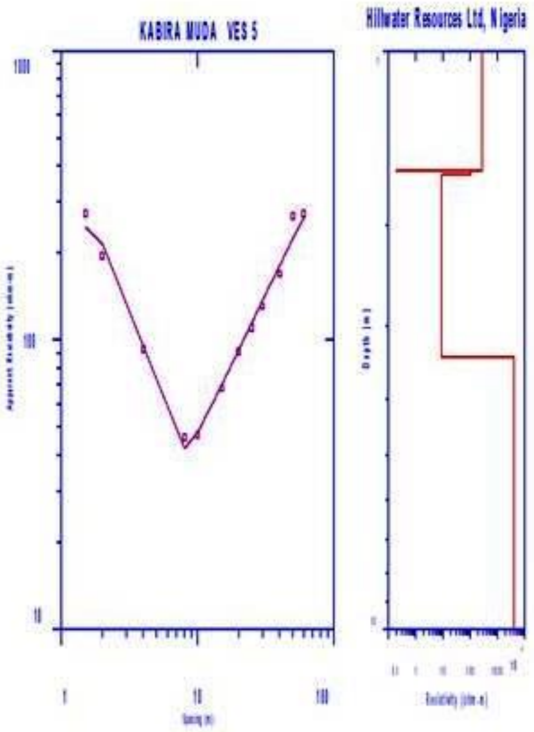

Figure 7: VES 5 curve

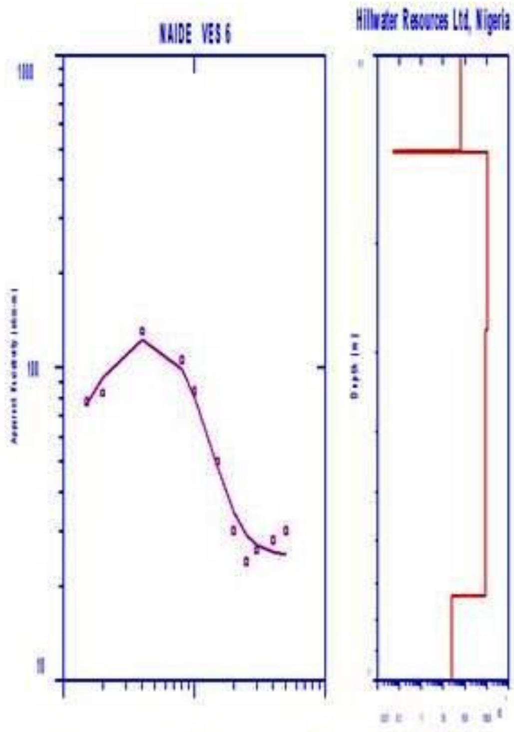

Figure 8: VES 6 curve

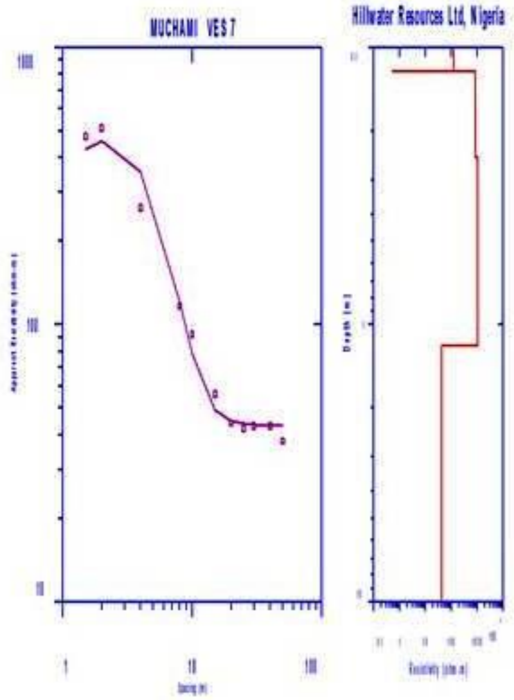

Figure 9: VES 7 curve

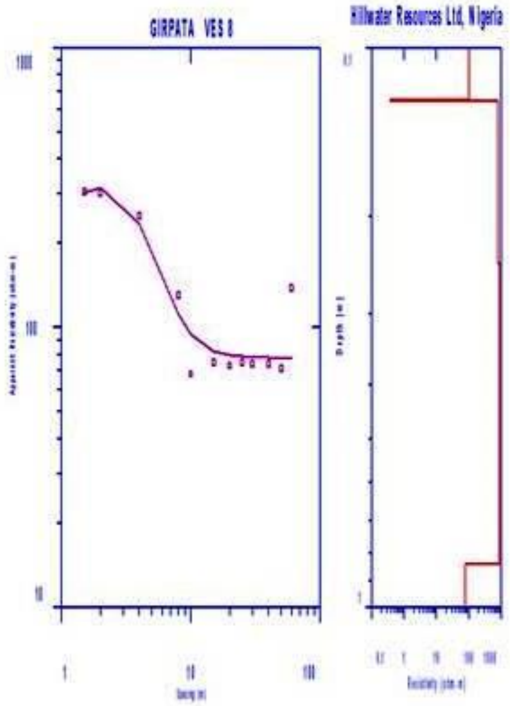

Figure 10: VES 8 curve

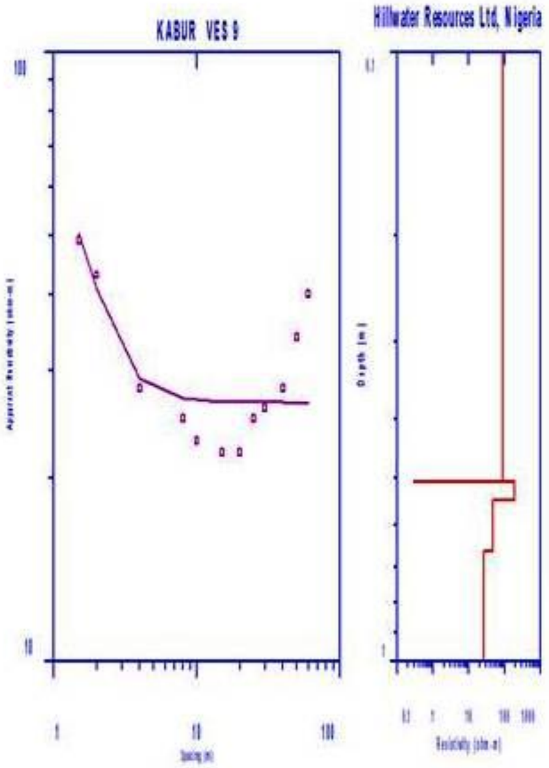

Figure 11: VES 9 curve

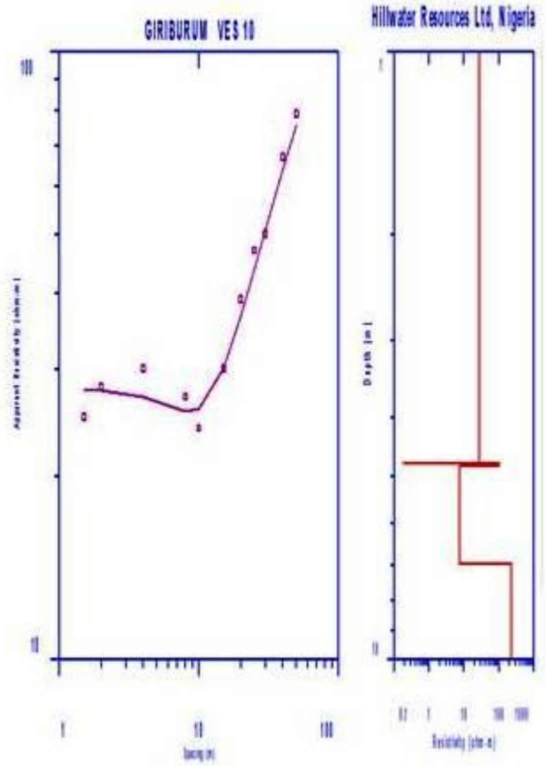

Figure 12: VES 10 curve

Four profiles were drawn to connect the sounding points, which were used to produce Geo-electric sections otherwise known as electro-stratigraphy of the study area. The result of the electro-stratigraphy of VES 5 and 6 show a section of top soil, weathered basement and fresh basement (Fig. 13); VES 4 and 10 show a section of two layers of top soil and a weathered basement (Fig. 14); VES 9 and 8 show a section of two layers with a top soil and weathered basement (Fig. 15) and VES 1, 2, 3 and 7 show a three layer section, with top soil , weathered basement and a fresh basement (Fig.16). The result of the electro-stratigraphy was used to classify the study area into high (weathered basement) and low (fresh basement) groundwater potential zones. Therefor weathered basement areas should be accorded more preference as potential zone for ground water development. The result of this study relates well with the works of Alile *et al*. (2008) who confirmed the suitability of the electrical resistivity method in groundwater exploration since there was a high correlation between the VES results and the borehole values obtained from two sites in Edo State, Nigeria. Vertical electrical resistivity sounding method was successfully used in locating the site for suitable borehole drilling and for the confirmation of the Bende-Ameki formation in Agbede South-Western Nigeria (Adetola and Igbedi, 2000).

Table 1: Result of the computed output of the ten (10) VES of Gella and environs

S/N	VES	Thickness of layers (m)				Depth	Resistivity of layers (ohm-m)				Longitudinal conductivity (Siemen)				Transverse resistance (ohm-m)			
		h_1	h_2	h_3	h_4		ℓ_1	ℓ_2	ℓ_3	ℓ_4	δ_1	δ_2	δ_3	δ_4	T_1	T_2	T_3	T_4
1.	VES 1	1.50	4.00	8.00	40.00	9.50	425	330	310	740	0.00235	0.00303	0.00323	0.00135	637.5	1320	2480	29600
2.	VES 2	1.50	4.00	40.00		55.50	680	700	300		0.00147	0.00143	0.00333		1020	2800	12000	
3.	VES 3	2.00	4.00	30.00		35.50	320	230	32		0.00313	0.00435	0.0313		640	920	960	
4.	VES 4	1.50	2.00	50.00		27.50	440	470	310		0.00227	0.00212	0.00770		660	940	1760	
5.	VES 5	2.00	8.00	60.00		9.50	200	43	280		0.00350	0.0232	0.00357		400	344	16800	
6.	VES 6	1.50	4.00	40.00		40.50	79	135	25		0.0126	0.00741	0.0300		118.5	540	1000	
7.	VES 7	1.50	2.00	40.00		30.50	430	370	42.00		0.00233	0.00270	0.0238		645	740	1680	
8.	VES 8	1.50	4.00	40.00		35.50	300	240	80		0.00333	0.00417	0.0125		450	960	3200	
9.	VES 9	1.50	4.00	30.00		20.50	50	28	26		0.020	0.03571	0.03846		75	112	780	
10.	VES 10	2.00	10.00	40.00		12.00	28	26	67		0.03571	0.0385	0.0149		56	260	2680	

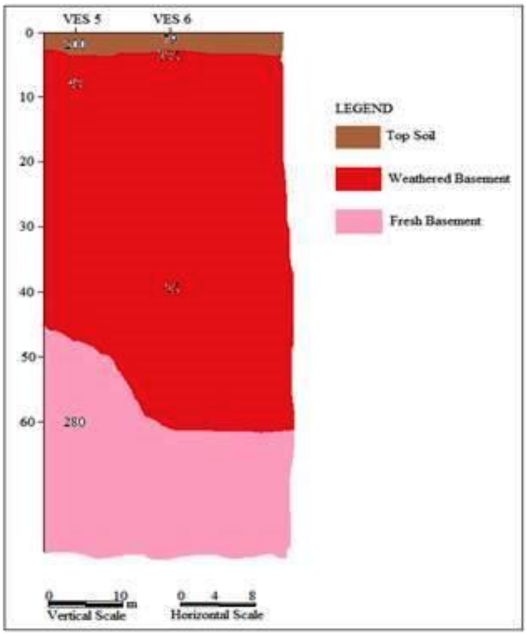

Figure 13: Geo-electric Section of VES 5 and VES 6.

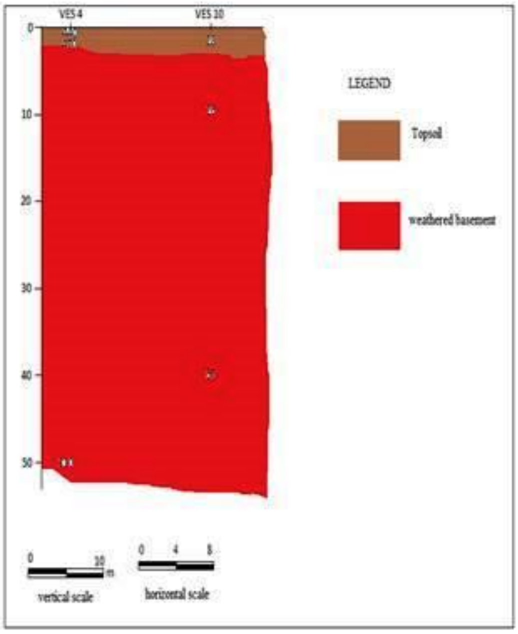

Figure 14: Geo-electric section of VES 4 and VES 10

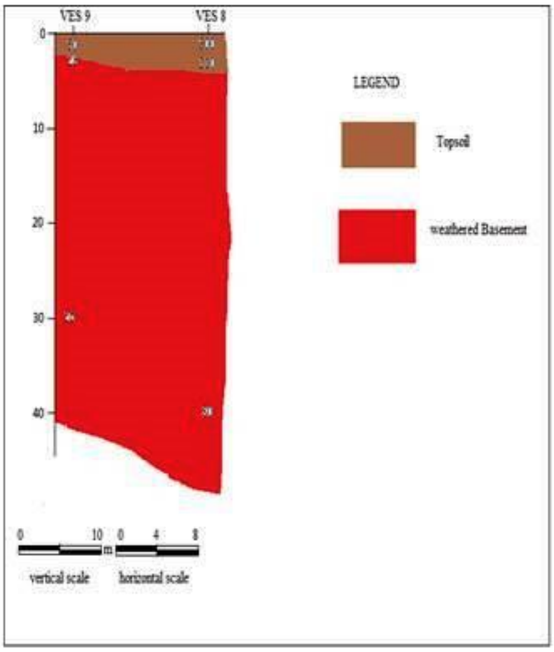

Figure 15: Geo-electric section of VES 9 and VES 8

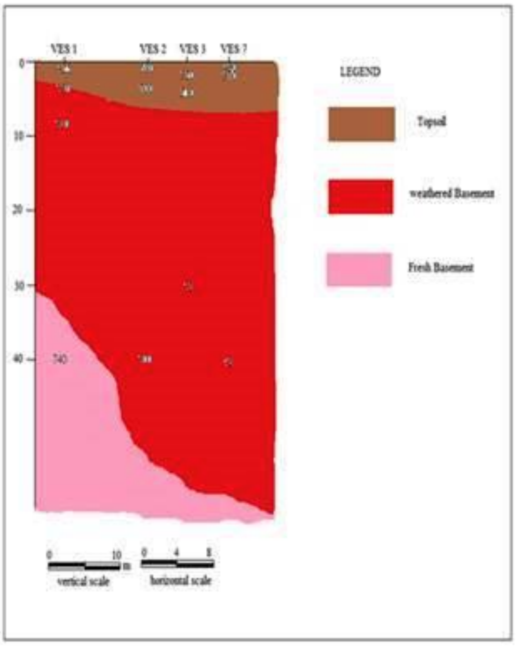

Figure 16: Geo-electric section of VES 1, VES 2, VES 3 and VES7

Conclusion

Vertical Electrical Sounding (VES) was used in this study to investigate the groundwater potentials of some selected areas in Gella Mubi South L.G.A, Adamawa State, Nigeria. A total of ten (10) vertical electrical soundings (VES), employing Schlumberger array configuration with current electrode spacing, AB of 100 - 150m were used. The interpreted resistivity data identified zones of high conductivity which could be fractures and/or weathered zones, and were considered as priority areas for vertical electrical sounding.

The interpreted VES data results also revealed one to three earth curve model (type) which varied from simple four layer H type to the complex three and four layers models K type curves and Q type curves. Type H and HA curves which are often associated with groundwater possibilities (Omosuyi, 2010) are pertinent in the area. The H type curve which is commonly obtained in a basement complex area, (Nur and Ayuni, 2011) constituted about 83.7% of occurrence in the area. Consequently, the electro-stratigraphic sections were used to categorize the study area into two hydric zones: high and low groundwater potentials.

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