GEOELECTRIC INVESTIGATION OF GROUNDWATER POTENTIALS OF GIDAN-WAYA, MAIKUNKELE, MINNA, NIGER STATE

Mannir, Muhammad,[1] Markus, Uti Ikitsombika,[1] Jamilu, Shehu[1] and Jimoh, M.O[2]
Department of Physics, Federal University of Technology, Minna
Department of Geology, Federal University of Technology, Minna
Corresponding author email: muhammadmannirtsf@gmail.com

ABSTRACT

A geoelectric investigation of Groundwater potential at Gidan-Waya, Maikunkele, Minna, Niger State Nigeria, was carried out using Electrical Resistivity method, by employing both Vertical Electrical Sounding (VES) and Electrical Resistivity Profiling ERP). The aim of the survey was to determine the ground water potentials of Gidan-Waya. Geosensor Terrameter Model DDR1 was employed for the survey. The study area lies within the basement complex region of Northern Nigeria. A total of ten profiles (A-J) with twenty stations along each profile at intervals of 50 m were investigated. Electrical Resistivity Profiling (ERP) was first employed using Wenner array configuration of equal electrode spacing of 30 m, probing the depth of 45 m for each station. The ERP results were used to produce an apparent resistivity contour map from which the promising points were obtained for Vertical Electrical Sounding (VES). Twenty two points were found to be promising and twenty were fully subjected to Vertical Electrical Sounding as two points were affected by electrical noise due to presence of high tension. The VES has a maximum current electrode separation (AB/2) of 100 m. The results obtained from VES plots reveal three distinct geoelectric layers; the top soil, the weathered/fractured layer, the fractured/fresh basement layer. Three distinct curve types were observed for the entire VES plotted curves. H-type was observed for VES A_{17}, A_{18}, C_{11}, C_{19}, D_{13}, E_9, E_{18}, F_9, F_{19}, G_{14}, G_{17}, H_3, H_{12}, I_{18}, I_{19}, J_{14} and J_{19}. A-type was observed for B_2 and D_{17} while K-type was observed for only B_{12}. The best points delineated as groundwater potentials are E18, A18, G14, D13, G17 and F9 with aquifer thickness of 23.9m, 21.4 m, 18.3 m, 25 m, 13.5 m and 11 respectively. Other points possessing groundwater potential are C19, I19, I18 and J19 with aquifer thickness of 9.1 m, 8.7 m, 8.5 m and 8.2 m respectively.

Keywords: Geoelectric, Vertical Electrical Sounding (VES), Electrical Resistivity Profiling (ERP), Ground water potential, Gidan-Waya, Resistivity, Aquifer, Geosensor terrameter, Basement

INTRODUCTION

Groundwater is a tremendous major economic resource, particularly in most cities of Nigeria where potable water is scarce (Nwankwo *et al*, 2013) and is basically required for prosperous development of any habitation. Many homes, industries and institutions pump their required quantities of water from the ground because it is commonly less polluted and more economical to use than surface water (Plummer *et al.*, 1999). Groundwater has a natural protection against pollution by the covering layers of the ground and it requires less treatment for direct consumption and other domestic activities.

Groundwater refers to the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formation. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water (Udensi, 2013). Groundwater is found almost everywhere but to get this resource in some areas is very difficult and complex (Ejepu *et al*., 2014).

A majority of fresh water is locked away as ice in the polar ice caps, continent ice sheets and glaciers beneath the ground. Water in rivers and lakes only account for less than 1% of the Worlds' fresh water reserves (Dogara, 1995). It is among natural resources bestowed on the human race. Groundwater makes-up about twenty percent (20%) of the world's fresh water supply which is about 0.61% of the entire world's water including ocean and permanent ice (Alhassan *et al*,. 2017).

Electrical resistivity method was used for this research and is based on the response of the earth to the flow of electrical current passed to the ground by use of electrodes.

The Electrical Resistivity Profiling (ERP) and Vertical Electric Sounding (VES) techniques were integrated in this survey.

ERP and VES techniques were integrated in the work in order to obtain detailed information on the groundwater potentials of the study area (Gidan-Waya).

Hence, it has been chosen for this work because it has proven to be an economic, quick and effective means of solving most groundwater problems in different parts of the world.

The thickness of the overburden can also be determined using VES technique as presented in this work.

Geology of the study area

The study area lies in the Basement Complex of North Western Nigeria. In Basement Complex, the rocks are of the Precambrian age, they are groups of crystalline rocks generally represented by granites, schist, migmatite, gneiss, quartzite and a host of other rocks (Tsepav *et al*., 2008).

The target zones for groundwater development in Basement Complex are mainly fractures like faults and deeply weathered zones where the unstable minerals have been removed by denudation processes. Fractures aid in enhancing secondary porosities (Ejepu *et al*., 2014). The fractures are caused by the displacement of the earth crust, and most of these geological features can be revealed in the form of anomalies in the geophysical investigations. Sedimentary Basement comprises of sandstone, which overlies uncomfortable in the Basement Complex, this formation consists of the Campanian deposits which are slightly cemented coarse to fine sandstones and siltstones with thin lenses of carbonaceous shale and clays, the deposits are highly aquiferous, the yields of boreholes in this area have been reported to be considerably high.

Climate and Temperature of the study area

The area has a typical Guinea savannah climate with distinct wet and dry seasons: a dry season which usually last from December to March and a rainy season which last from April to October.

Temperatures vary between 24°C around December/January and 32°C in March/April. Average annual rainfall for a thirty year record in the area is about 1270 mm. (Ejepu *et al*., 2014).

The period between November and February are marked with the NE trend wind called the harmattan, which often causes poor visibility during this period. Geology of Niger state is given in Figure 1.

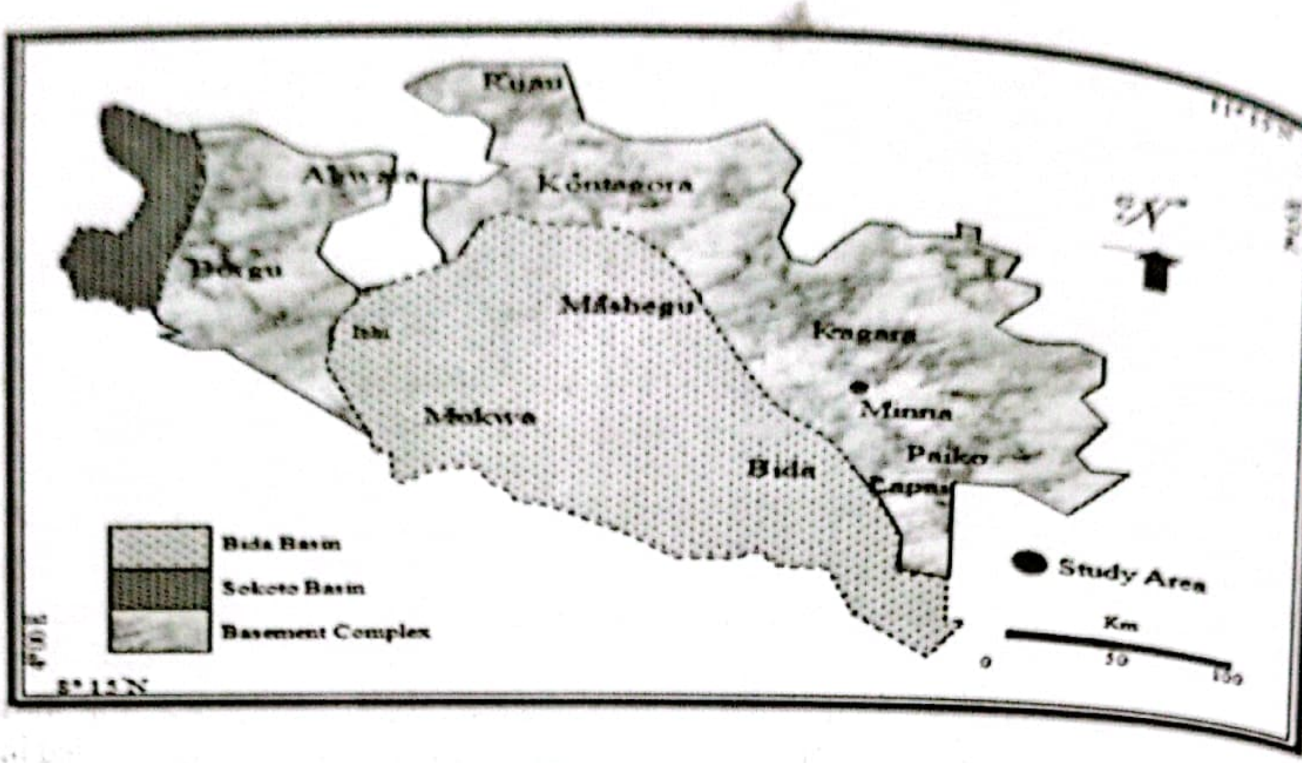

Figure 1: Geology map of Niger state (Basement Complex and Sedimentary Basin) (Alabi, 2011).

Description of the study area

Gidan-Waya is a settlement in Maikunkele, Bosso local government of Niger state about 1km from Bosso Local Government Secretariat. The study area is about 300 meters from the main road along Minna-Zungeru-Kontagora Highway. The study area extends to the airport housing estate about 500 meters from the main road. The size of the study area is 1km by $\frac{1}{2}$km. It lies between latitude 09⁰ 40ˡˡ 05.2ˡˡ N and 09⁰ 40ˡ 37.4ˡˡ N and longitude 006⁰ 27ˡ 13.9ˡˡ E to006⁰27ˡ28.3ˡˡ E. The study area lies within the north eastern part of Minna. The area has distinct dry season which usually last from December to March and a rainy season which last from April to October with a typical Guinea savannah climate. The observed rock types in the study area are granite and are mostly exposed at the eastern part of the study area. A stream crosses through the study area from about 180 meters eastward at points D1, D2 and D3 to about 250 meters westward at point F20. The geology map of the study area is given in Figure 2.

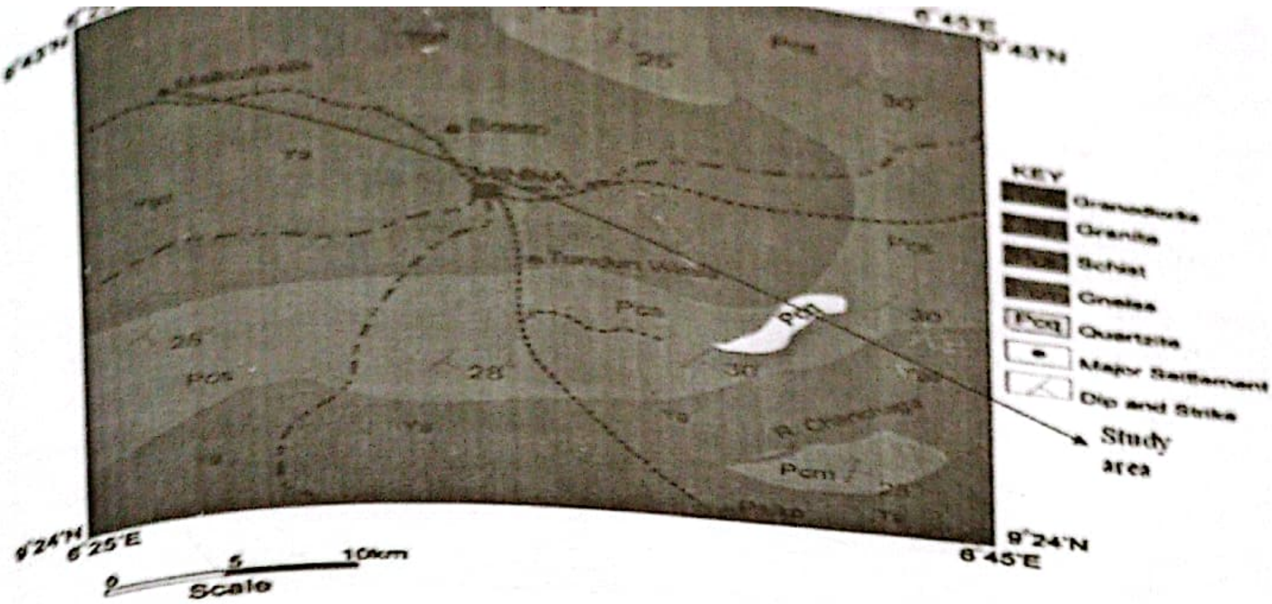

Figure 2: Geology Map of the Study Area (Alabi, 2011)

MATERIALS AND METHOD

Electrical method was employed for data collection using both ERP and VES techniques. The most important equipment used in during this research work is the Geosensor Terrameter, model DDR1 for collection of both ERP and VES data. The instrument is packaged in a potable box and contains the following components:

a. Power source: The power is from d.c. source of the equipment of the battery.
b. Current and voltage display screen: The Meter Model has digitized meters capable of displaying the values of current flow, the voltage for each measurement.

In addition to the Geosensor terrameter, the following tools were used:

i. Four (4) steel electrodes of about 0.7m long each, two as potential electrode, two as current electrode.
ii. Hammers with rubber handle, which are used to peg electrodes into the ground to ensure proper contact with the ground.
iii. Four (4) reels of cables that connect the terrameter to the current and potential electrode.
iv. Tape rule/survey tape which is used to measure the distances at the field.
v. Recording sheets: used in taking the values displayed on the screen of the terrameter.
vi. G.P.S. for taking the location (i.e. the latitude and longitude) of the study area.
vii. Crocodile clip for ensuring tight connection on the steel electrodes.
viii. Calculator to compute the resistance from the obtained voltage and current.

The Geosensor Terrameter used for the survey is shown in Plate 3.4 along with other tools employed for the research.

This research has utilized Electrical resistivity method in delineating groundwater potentials of the study area using both Electrical Resistivity Profiling (ERP) and Vertical Electrical Sounding (VES) techniques by determining the subsurface layer parameters (resistivity, thickness and depth). Electrical resistivity method was employed for the research due to its ease and flexibility in obtaining sound information of the proper points suitable for groundwater exploration. The method determines the subsurface resistivity distribution of the ground which can be related to the physical conditions of interest such as degree of water saturation, lithology, porosity and presence or absence of fracture in rocks. Resistivity measurements of the ground are normally done by injecting current through two current electrodes and measuring the resulting voltage difference at two potential electrodes. The basis for electrical resistivity measurement is Ohm's law which is given by equation 1.

$$V = IR \quad (1)$$

$$\text{Or} \quad R = \frac{V}{I} \quad (2)$$

Where V = voltage in volts and I = current in amp. The apparent resistivity was computed using equation 3.

$$\rho a = \frac{KV}{I} \quad 3$$

Substituting $\frac{V}{I}$ for R in equation 3 we have our apparent resistivity as;

$$\rho a = Rk \quad 4$$

$$K = 2\pi a \quad 5$$

Where "R" is the resistance value and "K" is the geometric factor which depends on the electrodes arrangements and "a" is the spacing between electrodes. The unit of apparent resistivity is Ohm-meter (Ωm) while geometric factor K is in meter (m).

Ten (10) profiles; A-J were mapped on the area of study each of 1000 meters (1k) length, the distance between one profile and the other is 50 meters. Twenty points were obtained on each profile at the interval between of 50 m. Two hundred ERP points were probed at 45 m depth after which twenty two were found to be promising and were subjected to Vertical Electrical Sounding in order to achieve the aim of getting sound and detail information of the subsurface with respect to groundwater potentials of the study area.

RESULTS AND DISCUSSION

The ERP resistance data collected directly from the field for 200 points were processed to apparent resistivity using the standard conversion factor obtained from the electrode geometry ($\rho a = Rk$ and $K = 2\pi a$). The ERP data was collected along 10 profiles (A-J) at spacing of 50 m while probing the depth of 45 m. The apparent resistivity data for ERP was used to generate an Iso-resistivity contour map of the study area from which the promising points for groundwater were obtained on the basis of low resistivity closures and later subjected to Vertical Electrical Sounding (VES). Figure 4 shows the contour map for apparent resistivity of the entire study area (ERP contour map) upon which the promising points were obtained. From the Electrical Resistivity Profiling (ERP) contour map, twenty points were established to be promising and were probed for groundwater potentials using Vertical Electrical Sounding (VES). The Vertical Electrical Sounding (VES) data were modelled using WinResist software which plots the VES curves with the corresponding resistivity, depth and thickness.

The interpretation was done using a computer program called WinResist version 1.0, this program performs automatic interpretation of the Schlumberger sounding curves. This curve gives the equivalent n-layer model from the apparent resistivity of each sounding. The program plots the VES curves with the corresponding resistivity, depth and thickness.Further analyses of the interpreted VES data was done using Surfer11.

The profile layout of the study area is given in Figure 3 while the Electrical Resistivity Contour map (ERP) of the study area is given in Figure 4.

The general results obtained from the VES plots were presented in Table 1. The depth column indicates the beginning of a layer.

The parameters (resistivity, depth and thickness) obtained from the VES curves were used in generating the resistivity contour maps using computer iterative window based software called Surfer package (Surfer 11.0). Four distinct transverses were established out of the sounded promising points as shown in figure 5 in order to produce the geologic and geoelectric sections these transverses are:

(i) Transverse A' (A17, D17 & G17)
(ii) Transverse B' (A18, E18 & I18)
(iii) Transverse C' (C19, F19, I19 & J19)
(iv) Transverse D' (B12, C11 & E10)

The promising fitting points are colored green, promising non-fitting are colored red, noise affected points are colored black while non-promising are colored white as given in the key of Figure 4.

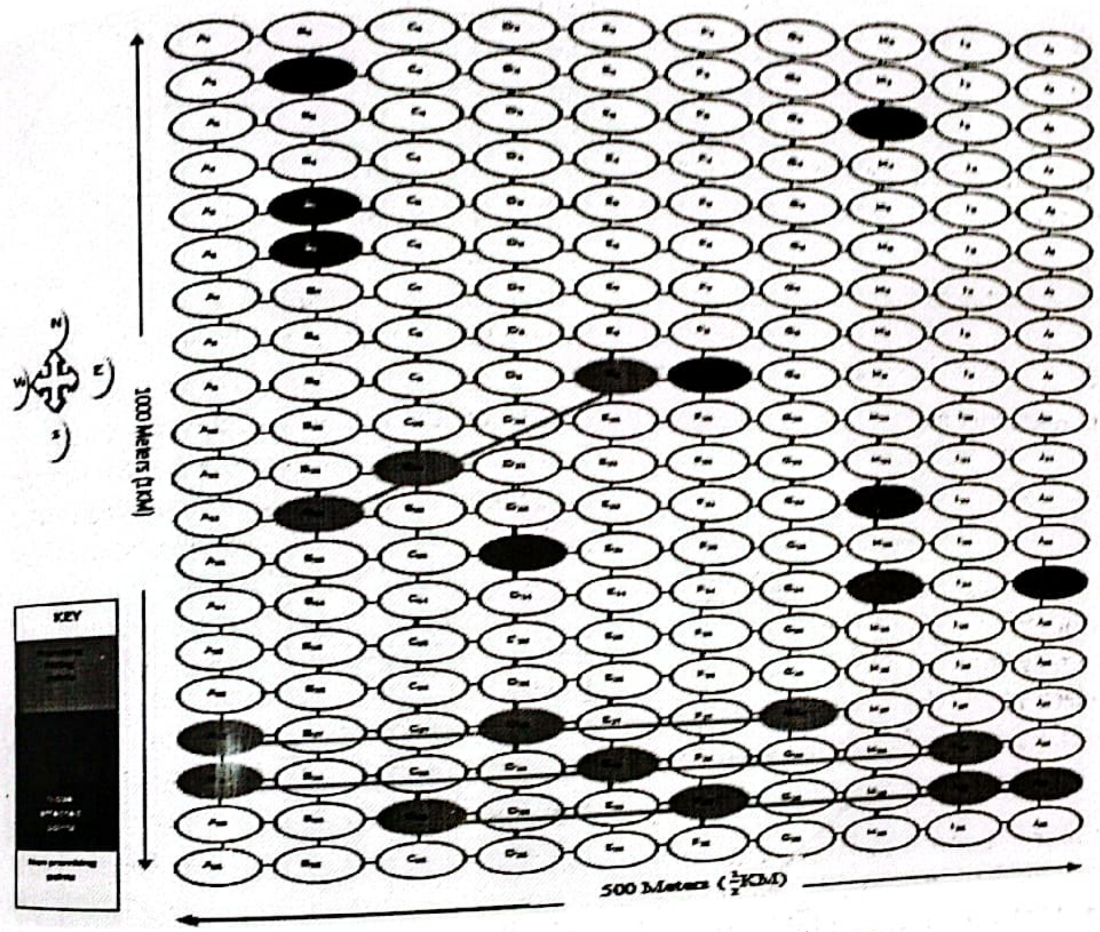

Figure 3: Profile layouts for the study area

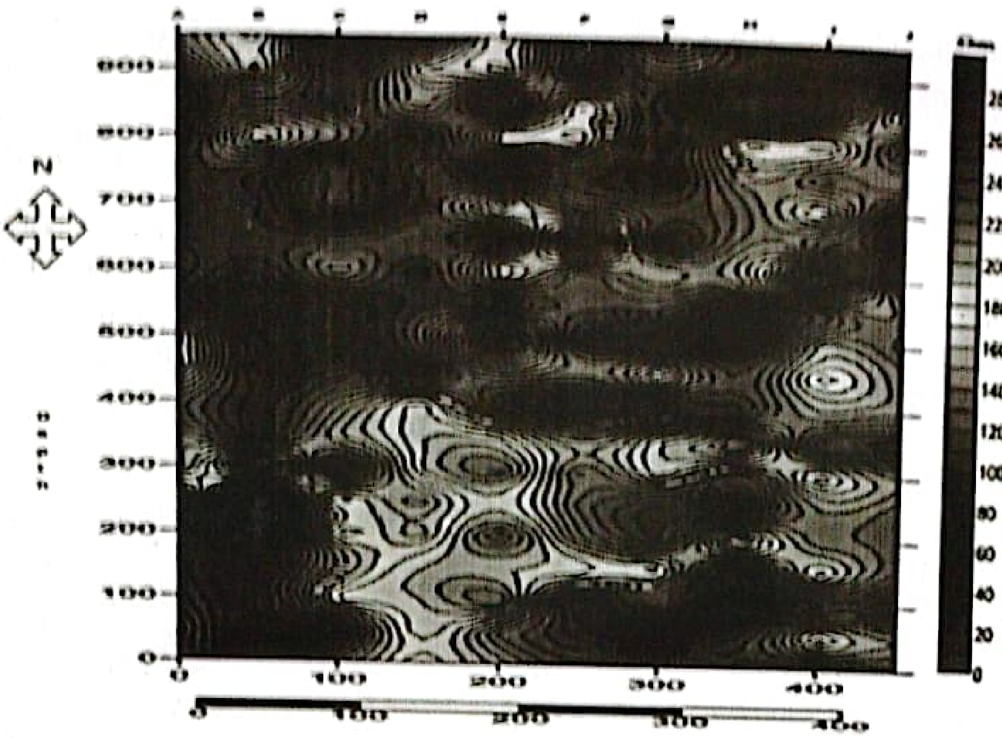

Figure 4: Electrical Resistivity Profiling (ERP) Contour map

Vertical Electrical Soundings (VES) results

The analysis of the VES plots along various transverses was summarized in tabular forms, giving information about the averaged resistivity values, depths and thicknesses of each layer. The average resistivity values show the variation of resistivity corresponding to depth and thickness of each layer.

Three distinct curve types were observed for the entire plotted curves. H-type was observed for VES A_{17}, A_{18}, C_{11}, C_{19}, D_{13}, E_9, E_{18}, F_9, F_{19}, G_{14}, G_{17}, H_3, H_{12}, I_{18}, I_{19}, J_{14} and J_{19}. A-type was observed for B_2 and D_{17} while K-type was observed for only B_{12}.

Interpretation and analysis for the VES along the transverses

The most essential parameters for the interpretation are: average resistivity, depth and thickness for each layer.

Interpretation of VES point along transverseA^1 (A17, D17 & G17)

Table 1 shows the summary of the resistivity result of transverse A^1. The entire transverse shows three layers model with two distinct curve types including H (A17 and G17) and A (D17). The first layer is top soil with resistivity values ranging from 32.4 Ωm to 242.4 Ωm which translates the presence of alluvium, sand and clay. The lowest resistivity value of 32.4 Ωm is found at D17 while the highest resistivity of 242.4 Ωm is found at G17. The layer has its highest thickness of 5.5 m at D17 while the lowest thickness of 0.6 m is found at A17. The transverse has its highest depth of 5.6 m at VES D17. The second layer is a weathered basement with resistivity values ranging from 11.6 Ωm to 165.3 Ωm. The lowest resistivity value of 11.6 Ωm is at VES A17 while the point with the highest resistivity value of 165.3 Ωm is at VES D17. The layer has thickness ranging from 4.7m at VES D17 to 13.5 m at VES G17 which serve as the best expected point for groundwater potential as it falls within the weathered zone of the transverse. The third layer is fractured/fresh basement layer is characterised by resistivity values ranging from 370.0 Ωm to 1052.4 Ωm.

the lowest resistivity value of 370.0 Ωm is located at VES A17 while the highest of 1052.4 Ωm is at VES G17. The layer's thickness is to infinity depth.

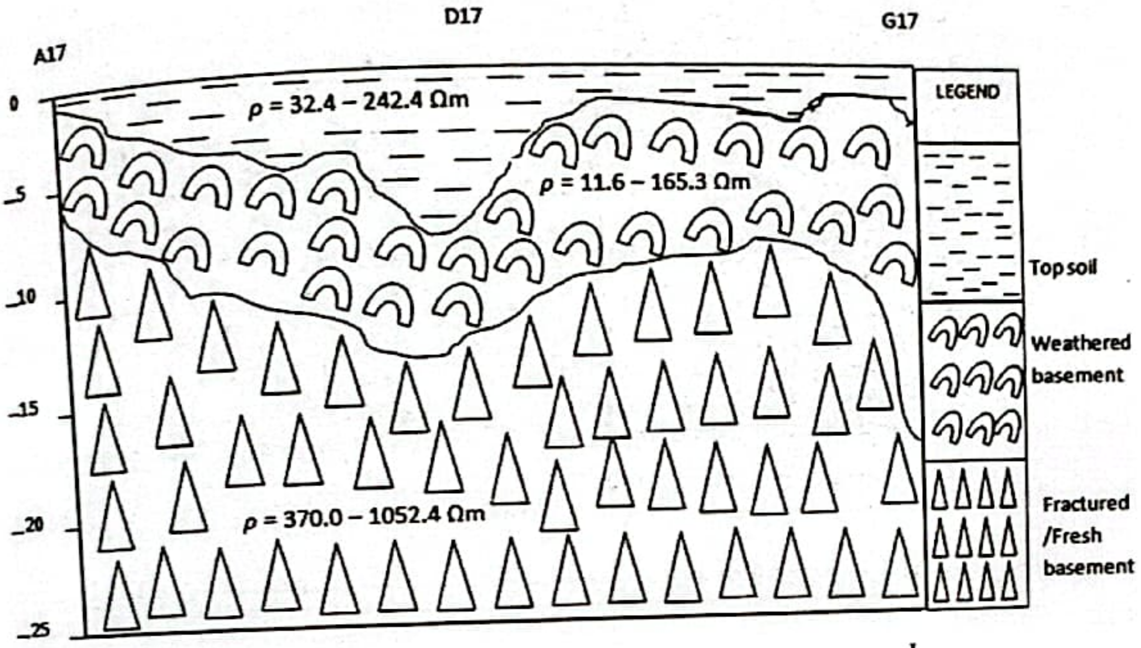

Figure 5: Geologic Section for Profile A[I]

Iso-resistivity contour maps

Iso-resistivity maps were produced for the most promising zone (southern part) of the study area in order to avoid much interpolation in producing the Iso-resistivity contour maps at surface, 5 meters, 10 meters and 20 meters depth as shown in figure 6a, 6b, 6c and 6d respectively. This gives apparent resistivity variation at various depths. Iso-resistivity maps show the resistivity pattern with depth through slicing of the entire study area horizontally. Surfer 11 software package was used to produce maps by contouring resistivity values beneath all the VES points at various depths of interests which are; 0 m (surface), 5 m, 10 m and 20 m.

Table 1: Summary table for general VES results

VES Points	Curve Type	No of Layers	Depth (m)	Thickness (m)	Resistivity (Ωm)
A17	H	1	0.0	0.6	58.9
		2	0.6	5.4	11.6
		3	6.0	∞	370.0
A18	H	1	0.0	0.8	1008.3
		2	0.8	21.4	35.2
		3	22.2	∞	355.6
B2	A	1	0.0	11.5	64.7
		2	11.5	6.5	96.6
		3	18	∞	2139.1
B12	K	1	0.0	8.1	28.0
		2	8.1	2.8	51.7
		3	10.9	∞	33.66.0
C11	H	1	0.0	1.1	67.7
		2	1.1	6.7	18.2
		3	7.8	∞	4052.0
C19	H	1	0.0	0.4	445.6
		2	0.4	9.1	16.6
		3	9.5	∞	265.4
D13	H	1	0.0	1.2	187.6
		2	1.2	25.0	32.2
		3	26.2	∞	534.6
D17	A	1	0.0	5.6	32.4
		2	5.6	4.7	165.3
		3	10.3	∞	662.7
E9	H	1	0.0	0.6	842.5
		2	0.6	6.5	41.3
		3	7.1	∞	302.1
E18	H	1	0.0	0.8	319.7
		2	0.8	23.9	40.5
		3	24.7	∞	212.4
F9	H	1	0.0	0.8	856.8
		2	0.8	11.0	47.8
		3	11.8	∞	6650.4
F19	H	1	0.0	0.4	615.7
		2	0.4	1.3	20.9
		3	1.7	∞	855.3
G14	H	1	0.0	1.7	803.9
		2	1.7	18.3	82.4
		3	20.0	∞	2352.4

Table 1: Summary table for general VES results (Cont'd)

VES Points	Curve Type	No of Layers	Depth (m)	Thickness (m)	Resistivity (Ωm)
G17	H	1	0.0	1.6	242.4
		2	1.6	13.5	47.9
		3	15.1	∞	1052.4
H3	H	1	0.0	1.3	132.1
		2	1.3	7.1	14.2
		3	8.4	∞	981.7
H12	H	1	0.0	0.7	547.9
		2	0.7	7.0	52.6
		3	7.7	∞	147.9
I18	H	1	0.0	3.7	405.6
		2	3.7	8.5	28.2
		3	12.2	∞	839.1
I19	H	1	0.0	1.6	355.0
		2	1.6	8.7	77.0
		3	10.3	∞	1193.9
J14	H	1	0.0	1.6	94.8
		2	1.6	3.3	10.8
		3	4.9	∞	8200.5
J19	H	1	0.0	5.6	277.9
		2	5.6	8.2	31.1
		3	13.8	∞	2243.5

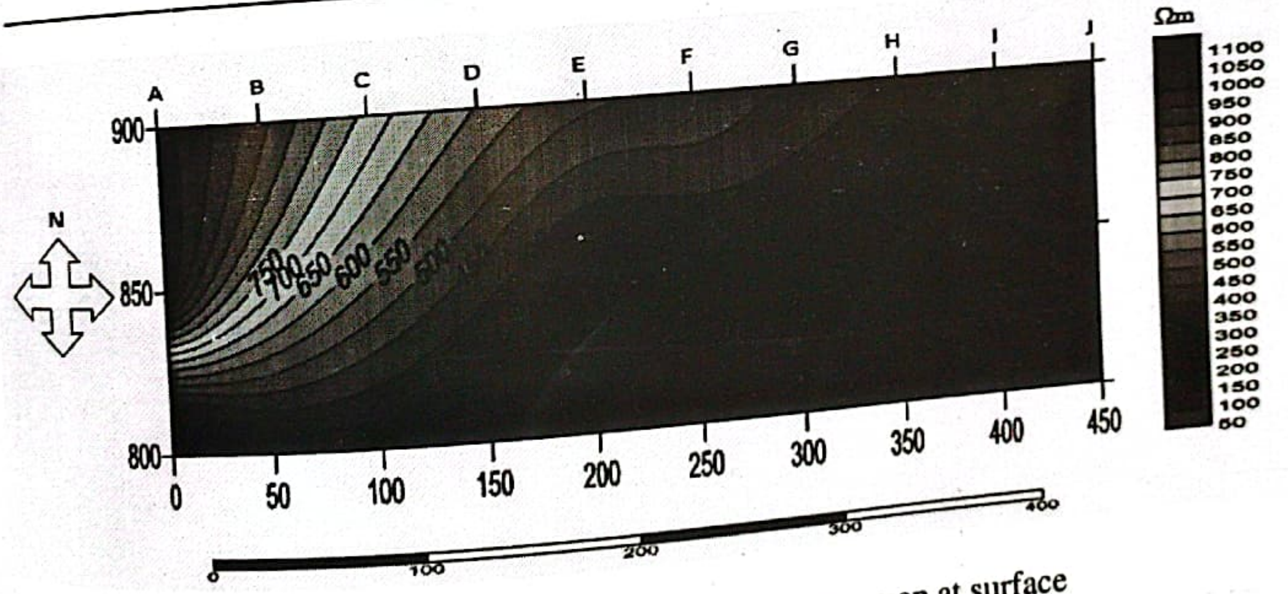

Figure 6a: Iso-resistivity contour map at surface

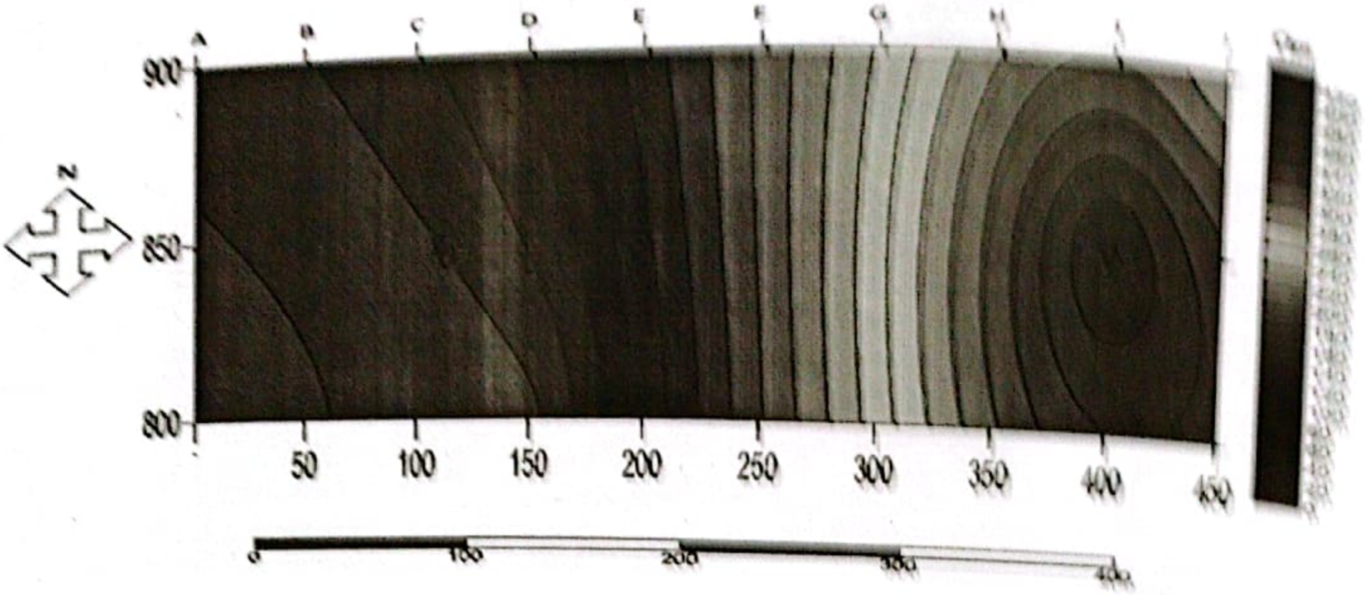

Figure 6b: Iso-resistivity contour map at 5 m depth

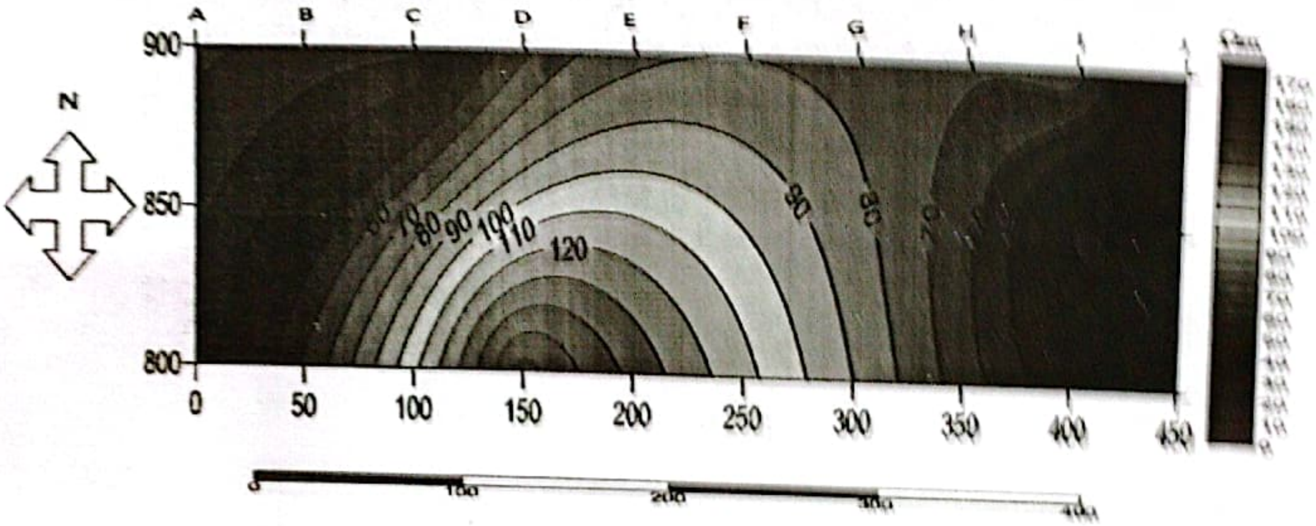

Figure 6c: Iso-resistivity contour map at 10 m depth

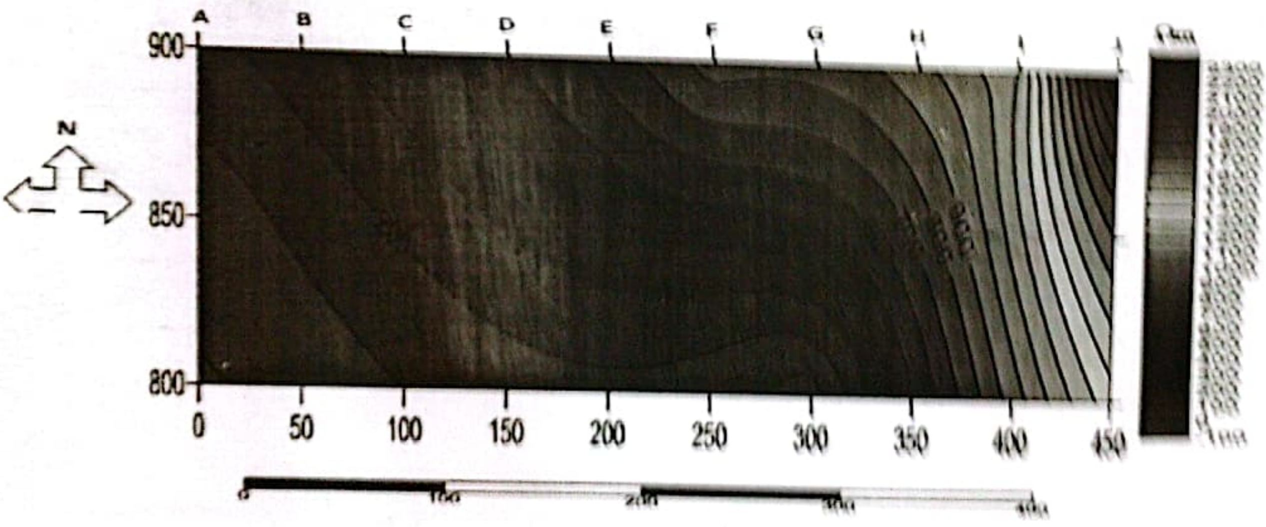

Figure 6d: Iso-resistivity contour map at 10 m depth

Resistivity contour on the Transverses

The Resistivity Contour maps for transverses A^{I}, B^{I}, C^{I} and D^{I} are shown in Figure 7a, 7b, 7c and 7d respectively.

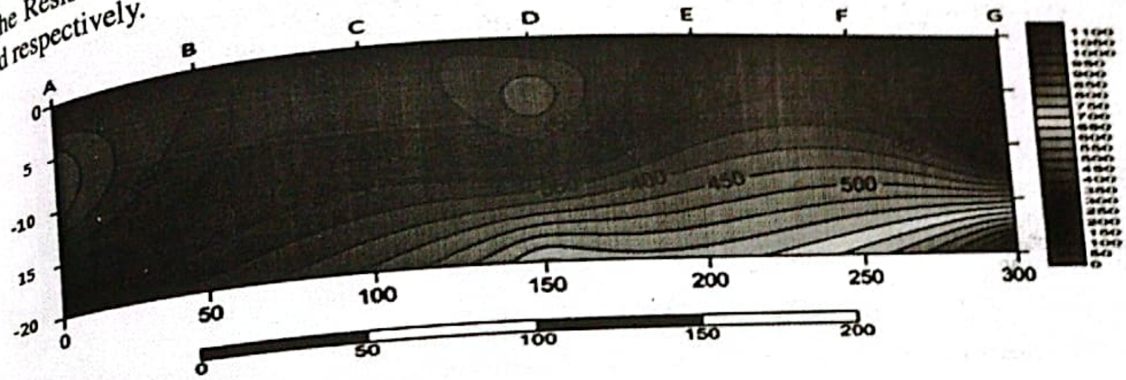

Figure 7a: Resistivity contour map for transverse A^{I}

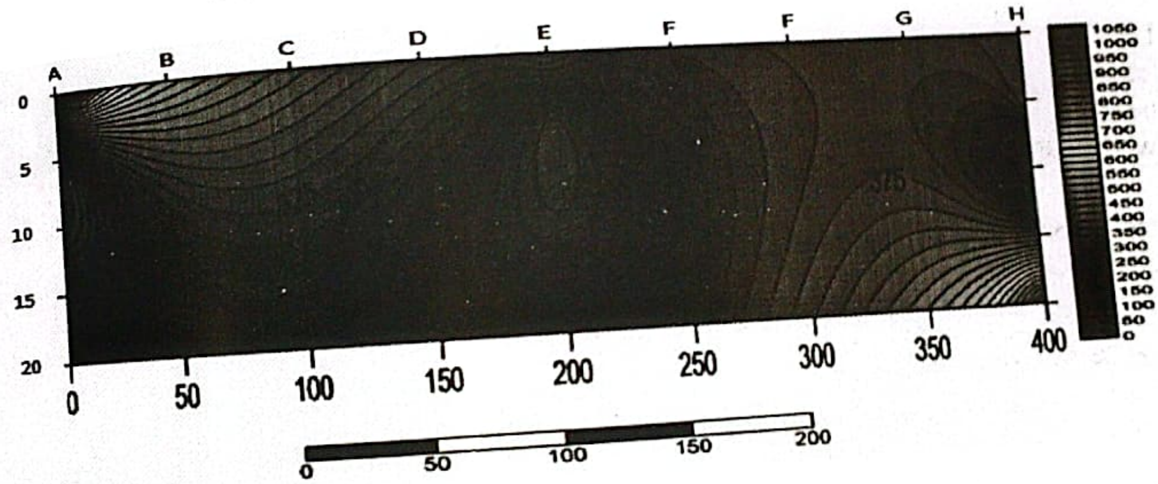

Figure 7b: Resistivity contour map for transverse B^{I}

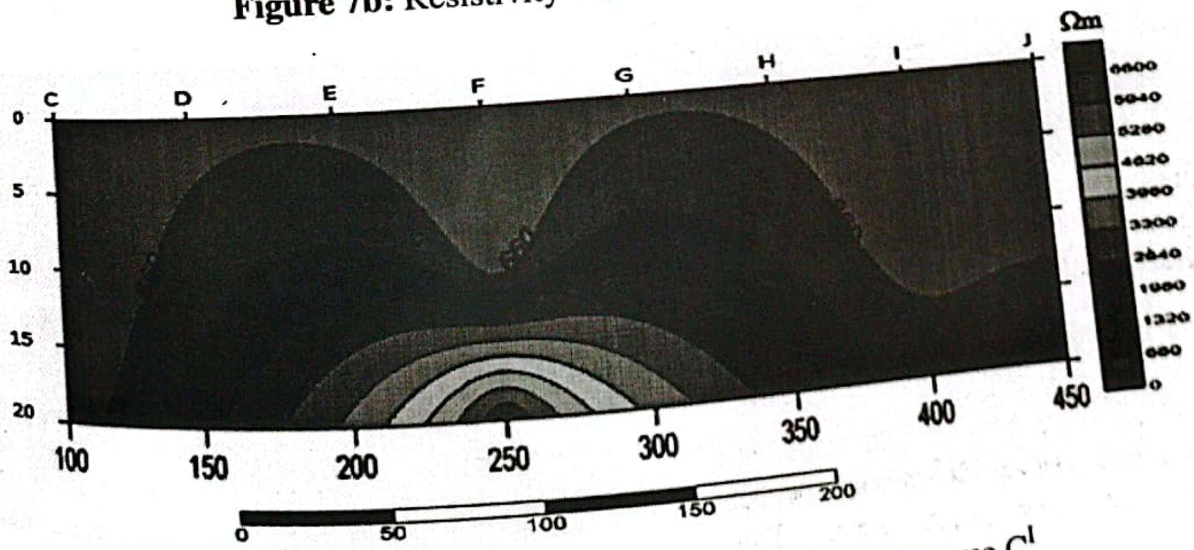

Figure 7c: Resistivity contour map for transverse C^{I}

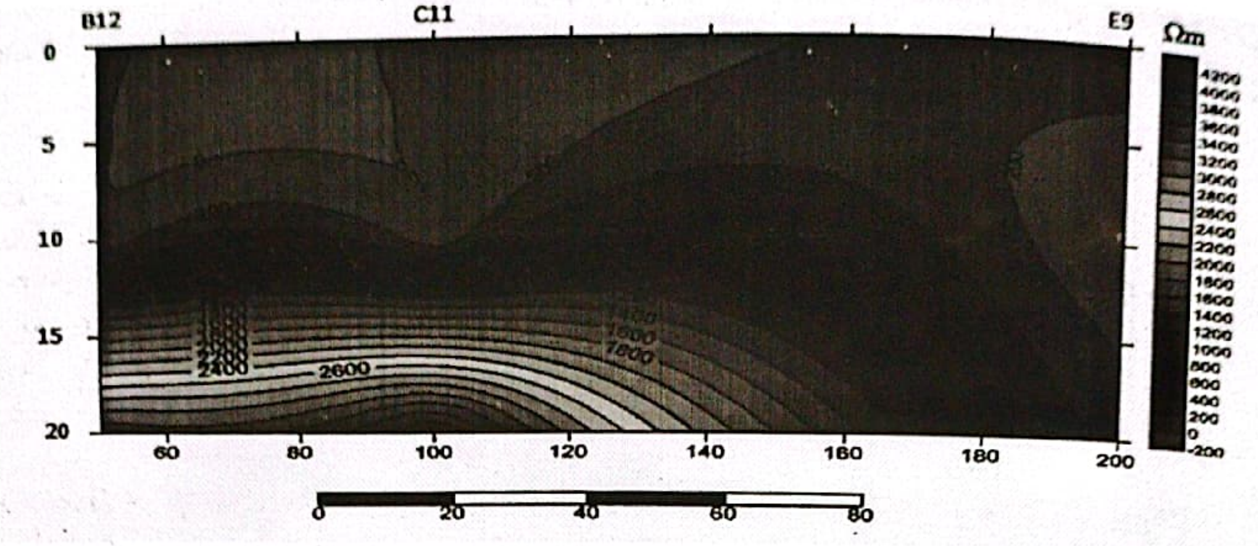

Figure 7d: Resistivity contour map for transverse D^I

CONCLUSION

Apparent resistivity values varying with depth and thickness were determined from the VES plots and were analysed in order to achieve the objectives of the research. The resistivity-depth curves were plotted using an iterative computer program known as WinResist version 1.0 for automatic interpretation of Schlumberger soundings.

Number of layers, depth, thickness and average resistivity for each VES points were determined from the plotted curves which were summarised in Table 1, 2 and 3.

Iso-resistivity contour maps, Vertical geoelectric contour maps and Geologic sections were also produced at various depths.

Three distinct geologic layers were observed for the study area which include; top soil, weathered/fractured layer and fresh basement.

The overburden thickness (depth to basement zone) and the range of resistivity values for each layer was also determined. The thickness contour map clearly gave indications of the nature of weathered layer with depth. This further aided the interpretation of areas with good aquifer potential.

The best points identified as groundwater potentials are E18, A18, G14, D13, G17 and F9 with aquifer thickness of 23.9m, 21.4 m, 18.3 m, 25 m, 13.5 m and 11 respectively. Other points possessing groundwater potential are C19, I19, I18 and J19 with aquifer thickness of 9.1 m, 8.7 m, 8.5 m and 8.2 m respectively.

RECOMMENDATIONS

1. Areas delineated as groundwater potentials may be drilled.
2. Areas identified as groundwater potentials should be avoided for civil engineering work.

References

Alabi A. A. (2011). Geology and environmental impact assessment and benefit of granitic rocks of Minna area, North-western Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 2011; 4 (4): 39-45.

Alhassan, U. D., Obiora, D. N., Okeke, F. N., (2017). Geoelectrical investigation of groundwater potentials of northern Paiko, Niger state, central Nigeria.*Journal of Earth Science,* Vol. 28, No. 1.

Dogara, M. D. (1995). D. C. Resistivity Investigation of the groundwater potential in Romi, Chikun Local Government, Kaduna State, Nigeria. Unpublished M.Sc. Thesis ABU, Zaria.

Ejepu, S.J., Adebowale, T.A, Abdullahi, D.S., Yusuf, A. & Ochimana K. 2014: Subsurface Structural Mapping for Groundwater Resource Development of a Part of Tudun-Fulani North- Central Nigeria Using Radial Vertical Electrical Sounding Techniques.*International journal of engineering sciences & Research Technology*. 3(8).

Nwankwo, L.I., Olasehinde, P.I. and Osundele, O.E. (2013). Application of Electrical Resistivity Survey for Groundwater Investigation in A Basement Rock Region: A Case Study of Akobo, Ibadan, Nigeria. *Ethiopian Journal of Environmental Studies and Management Vol. 6 No.2 2013*

Plummer, C.C., McGeary, D. and Carlson, D.H., (1999), Physical Geology. 8th Edition. London. McGraw-Hill Book Company.

Udensi, E. E. and Chikwelu, E. E. (2013). Geoelectric determination of the groundwater potential of parts of Pompo village, Minna, Nigeria. *International Journal of Scientific Research and Management (IJSRM.)* Volume (1) Issue (3) 112-132.

Tsepav, M.T., Eminike, E.A., Mallam, A. (2008). Reconnainsance Resistivity survey for groundwater in some part of Dickwa Area, Gwalalada, Area council, FCT, Abuja. *Integrated Journal of Sciences and Engineering*, 7: 1.