Groundwater Exploration Using Electrical Resistivity Method A Case Study In Federal Capital Teritory (FCT) Abuja. Nigeria

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Abstract— **Eighteen resistivity data points were sounded in the study area with ABEM Terrameter, Maximum electric current half spacing attained for each point 100m away. Schulumbergers array was used for acquisition of data after which two methods of interpreting the data were used, qualitatively and quantitatively the raw data were interpreted with IXD1 software. Possible groundwater potential areas were detected. Out of the 18 VES points, VES 1, 5, 7, 9, 11, 12, 15, 16, 17 and 18 have groundwater potentials at depth ranging from 40 m – 80 m. The thickness of the aquifers with such potentials ranges from 37 m – 65 m. VES 2, 3, 4, 6, 8, 10, 13, 14, and 15 lacks fractured zone as such groundwater cannot be explored at these VES points. The X, Y, Z, data file was imported into Surfer9 software for resistivity mapping and contouring using kriging interpolation algorithm. The resistivity of the first layer of these points with groundwater potentials ranges from 500 ohm –m to 9000 ohms – m. While the resistivity value of the second layer ranges from 50 ohm – m to 800 ohm – m, and the resistivity value of the third layer ranges from 80 ohm – m to 700 ohm – m. The maps that were plotted was done using the resistivity values of the first, second and third layer of VES points with groundwater potentials while the elevation above sea level was used to produce map of the study area and VES points.**

***Index Terms*— Ground water, IXD interpex, Krigging, Qualitative, Vertical Electrical Sounding(VES)**

I. INTRODUCTION

Water is one of the most important ingredients to the survival of life. Groundwater has always been important supplement to the non availability of surface water which has become a scarce resource in most areas of Nigeria. Surface water where available are usually seasonal and prone to contamination by human beings and animals [5].

Water serves as an important substance for plant and animal existence but also plays a vital role in the technological advancing world. It is very important factor in maintenance of life, health and social stability. Water exists in three states: Solid as Ice, liquid as ground or surface water and gas as vapor. Water is renewable through precipitation, melting, infiltration and percolation depending on the environment. On the earth surface, water is principally found in streams, lakes, rivers, oceans, etc. It exists in crystalline rocks in the weathered mantle or in the joints and fracture system in the unweathered rocks[14],[2], [10],[11].

Subsurface water is that part of water cycle that is housed in sediments or along fractures, fissures or weathered part of indurate rocks under considerable hydrostatic pressure in some areas. The occurrence of groundwater in recoverable quantity as well as its circulation is controlled by geological factors [4] Groundwater forms only a minimum amount of the earth water but constitutes a significant amount of the total volume of fresh water on the Earth.

Groundwater plays an important role in the basement complex of Federal Capital Authority (FCT) Abuja where surface sources are either inadequate, intermittent or polluted, since domestic and industrial supply depends on the groundwater sources. Unfortunately groundwater does not occur everywhere on the Earth. Full and proper management is desired and necessary for social stability and even human survival. Large water supply of such commodities also widens. The full and proper development of our water resources becomes inevitable despite its complications and expenses.

Geophysics is the application of the principles of physics in understanding and finding solution of geological problems. Groundwater exploration employs a varieties of techniques in which the most widely used are electrical resistivity, seismic refraction and electromagnetic methods. Electrical resistivity method is commonly used because it is efficient, cheap and also gives valuable information about the aquifer potential.

Resistivity method operates by employing an artificial source of current, which is introduced into the subsurface using resistivity setup. Electrical sounding gives information on water bearing structures and easily determine the vertical variation of the earth electrical properties which can be related to the geology of the area.

[15] carried out a vertical electrical sounding on the basement complex terrain of Gwarinpa -Kafe area of Abuja Metropolis, Central part of Nigeria with the aim of assessing the groundwater potential of the area. The result shows that groundwater resources are available in both weathered overburden and fractures zone of the basement complex rocks in the area. Subsurface fractures are identified at depths ranging 20.0m - 36.0m which serve as a good reservoir of water.

Yield of water from the wells varies from 3.33m^3/hrs to 6.70m^3/hr. Among the 28 boreholes developed, 50% the wells had yield of 3.33 to 5.0m^3/hr, while 28.6% had yield that range from 5.1to 6.0m^3/hr, whereas 21.4% had yield between 6.1 and 6.70m^3/hr. Wells located on weathered basement alone had yield that range from 5.0m^3/hr indicating that more prolific wells are associated with saturated fractures within basement terrain.

The rapid growing industrialization recently witnessed by the Gwagwalada metropolis has resulted in population increase and has resulted in urbanization of satellite villages and settlements of which the ancient Dagiri settlement is one

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Rapid population growth of Dagiri occasioned by the influx of people from nearly congested city has made the sources of water inadequate for its dwellers, and the need for good quality and readily available portable groundwater in this area forms the basis for this research. Dagiri town is underlying by Basement Complex rocks of the northcentral Nigeria and groundwater in this environment is usually contained in the weathered and/or fractured basement rocks or alluvial deposits within flood plains as mentioned by some authors among whom are [19] and [13]. The geophysical methods employed in the investigation of shallow features of the earth's crust vary according to the physical properties of the rocks, [3]. The basement aquifers are often limited in extent both laterally and vertically [16]. This discontinuous nature of the basement aquifer system makes detailed knowledge of the subsurface geology, its weathering depth and structural disposition through geological and geophysical investigations inevitable [1]. The most commonly applied geophysical technique for ancient river channel exploration is the electrical resistivity method [8]. This is a consequence of the usually significant resistivity contrast between the deposit within the channel and the underlying bedrock [2]. The resistivity profiling method has found useful application in groundwater investigation in basement terrain, most especially in understanding the lateral variation [4], [12]. This method was employed for groundwater investigation in Barkumbo valley, Gudun hill area and Tambari valley, very close to Bauchi state, from which highly weathered basement materials were revealed, leading to the suggestion that parts of the Barkumbo valley are best suited for a borehole programme.

II. LOCATION AND ACCESSIBILITY

The study area lies within latitude $8^0 25^1$ and $9^0 20^0$ N of the equator and longitude $6^0 45^1$ and $7^0 39^1$ E of Greenwich Meridian (Fig 1.). Abuja is geographically located in the center of the country with a landmass of approximately 7,315 km². It is situated within the Savannah region with moderate climatic condition the study area is accessible throughout the year.

Fig. 1: Location map of study area

III. GEOLOGY AND STRUCTURES

The study area is located within North Central Nigeria. The geology of the area has been studied and discussed by previous workers like, [7] etc. They described the rocks as comprising mostly granite, gneisses, mica schists, hornblende and feldspathic schists and migmatites. The rocks are highly fractured and jointed showing essentially two fracture patterns, NE – SW and NW – SE. These fractures control the drainage and flow patterns of rivers in the area, however, minor Cretaceous deposits of Nupe Sandstones occur in the southern part of FCT between Kwali and Abaji, extending to Rubochi and the border with Nassarawa State. Similarly, metasediments have also been mapped along a general NNE-SSW direction through the west of Kusaki (in the south) and east of Takushara (in the north) [18]. Mica schists and amphibolites schists occur around Kusaki and Buze villages outside the study area. He emphasized the need for the presence of joints and fracture sets in crystalline rocks if the basement rocks are to act as good indicators of groundwater sources and sites of tube-well drilling for potable water supply.

The F.C.T (Abuja) is almost predominantly underlain by high grade metamorphism and igneous rocks of Precambrian age generally trending NNE-SSW. These rocks consist of gneiss, migmatites, granites and schist belt outcrops along the eastern margin of the area. The belt broadens southwards and attains a maximum development to the southeastern section of the area where the topography is rugged and the relief is high. In general the rocks are highly sheared (fig 2.).

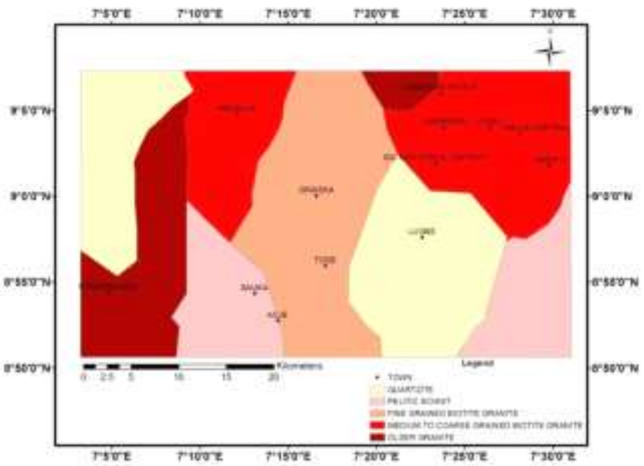

Fig 2. Geologic map of study area

IV. METHODOLOGY

A. *INTRODUCTION*

The most common and widely used geophysical survey method is the electrical resistivity method. In groundwater exploration, depth to bedrock determination, sand and gravel exploration etc, and the electrical resistivity method can be used to obtain quickly and economically details about the location, depth and resistivity of subsurface formation[9]

The basis of the method is that when current is applied by conduction into the ground through electrodes, any subsurface variation in conductivity alters the current flow within the Earth and this in turn affects the distribution of the electric potential. The degree to which the potential at the surface is affected depends upon the size, location, shape and

conductivity of the materials within the ground. It is therefore possible to obtain information about the subsurface distribution of these materials from measurements of the electrical potential made at the surface.
This usual practice is to pass current into the ground by means of two electrodes and to measure the potential difference between a second pair placed in line between them. From the values of the potential difference, the current applied and also the electrode separation a quantity termed the apparent resistivity can be calculated. In homogeneous ground, this is the true ground resistivity but usually it represents a weighted average of the resistivity of all the formation through which the current passes. It is the variation of this apparent resistivity with change in electrode spacing and position that gives information about the variation in subsurface layering.

V. RESULTS

VES 1

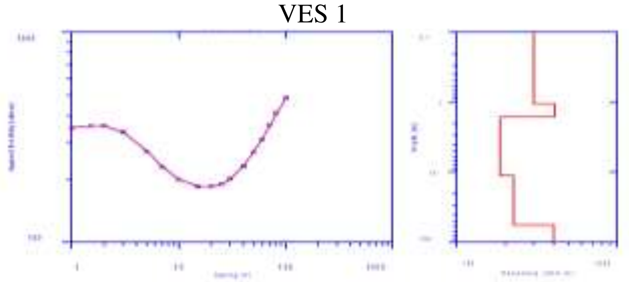

Fig 3. curve matching with model of VES 1

Table 1. VES 1 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth(m)	Geo-electric section
1	350	1	1	Topsoil
2	200	20	21	Weathered basement
3	550	90	111	Fresh basement

VES 2

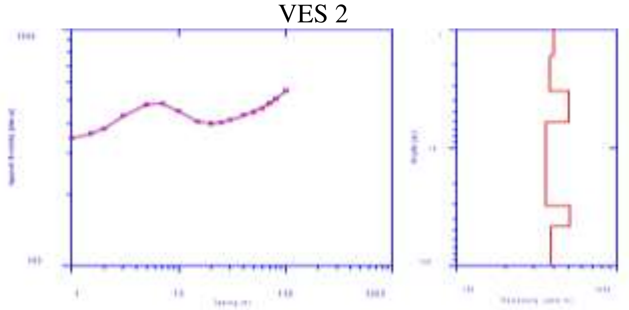

Fig 4. curve matching with model of VES 2

Table 2. VES 2 Results

Layer No	pa(Ωm)	Thickness(m)	Depth (m)	Geo-electric section
1	350	1	1	Topsoil
2	500	5	6	Consolidated sandstone
3	420	20	26	Weathered basement
4	600	90	116	Fresh basement

VES 3

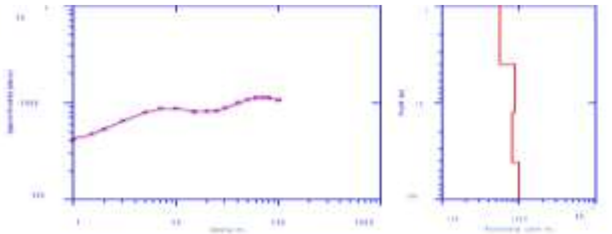

Fig 5. curve matching with model of VES 3

Table 3. VES 3 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	400	1	1	Topsoil
2	800	7	8	Consolidated sandstone
3	700	20	28	clay
4	1000	80	108	Fresh basement

VES 4

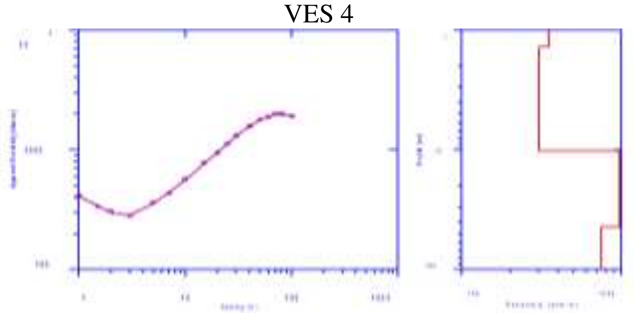

Fig 6 curve matching with model of VES 4

Table 4. VES 4 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	400	1	1	Topsoil
2	300	3	4	Weathered basement
3	300	60	65	Fresh basement

VES 5

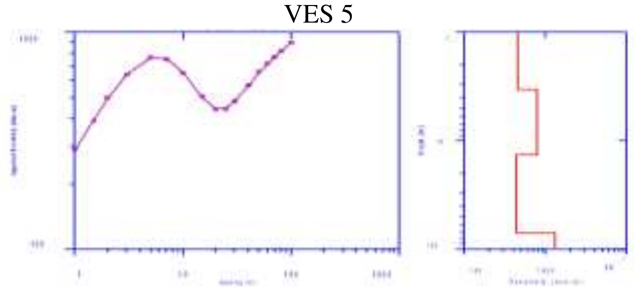

Fig 6. Curve matching with model of VES 5

Table 5 : VES 5 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	290	1	1	Topsoil
2	780	5	6	Fresh basement
3	450	25	31	Fractured basement
4	1000	90	121	Fresh basement

VES 6

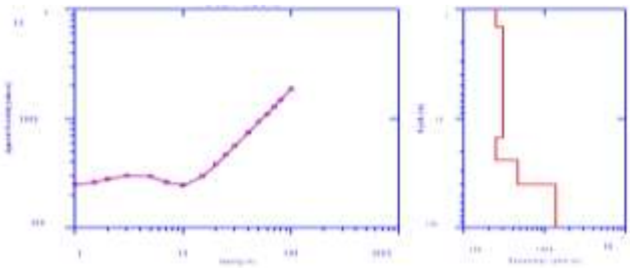

Fig 7 curve matching with model of VES 6

Table 6 : VES 6 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	250.	1	1	Topsoil
2	300	4	5	Consolidated sandstone
3	250	9	14	Weathered basement
4	2500	90	104	Fresh basement

VES 7

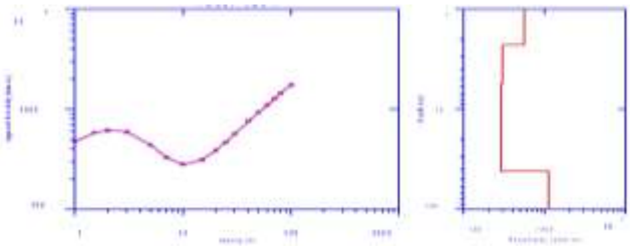

Fig 8. Curve matching with model of VES 7

Table 7. VES 7 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	500	1	1	Topsoil
2	600	2	3	Consolidated Sandstone
3	300	10	13	Weathered basement
4	2000	90	103	Fresh basement

VES 8

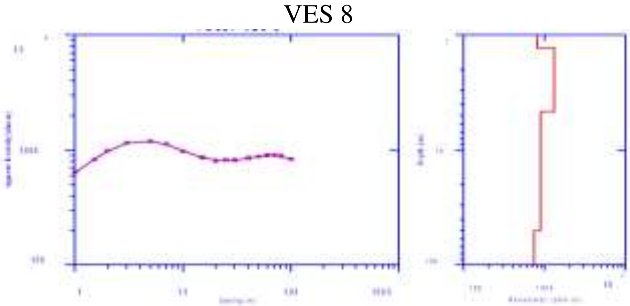

Fig 9. Curve matching with model of VES 8

Table 8. VES 8 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	20	1	1	Topsoil
2	1200	5	6	Fresh basement
3	800	20	27	Partial fractured basement
4	1100	80	107	Fresh basement

VES 9

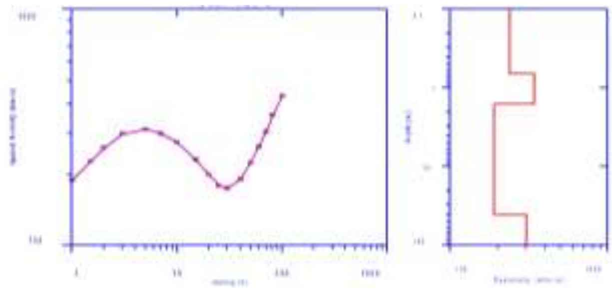

Fig 10. Curve matching with model of VES 9

Table 9. VES 9 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	190	1	1	Topsoil
2	200	5	6	Fresh basement
3	180	30	37	Weathered basement
4	500	80	117	Fresh basement

VES 10

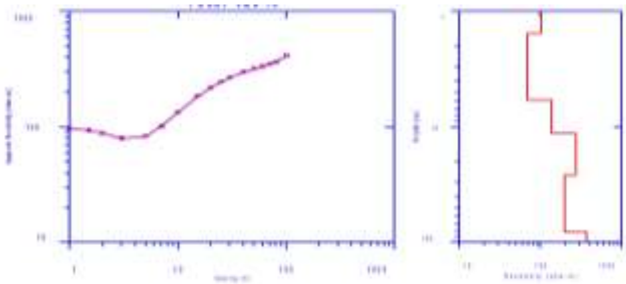

Fig 11. Curve matching with model of VES 10

Table 10. VES 10 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	100	1	1	Topsoil
2	80	3	4	Clay
3	500	90	95	Fresh basement

VES 11

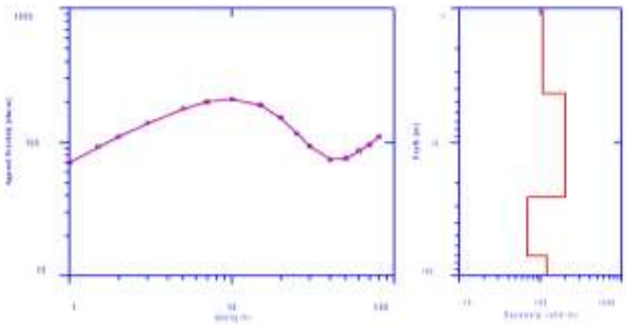

Fig 12. Curve matching with model of VES 11

Table 11. VES 11 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	70	1	1	Topsoil
2	200	10	11	Fresh basement
3	90	40	51	Weathered basement
4	150	90	141	Fresh basement

VES 12

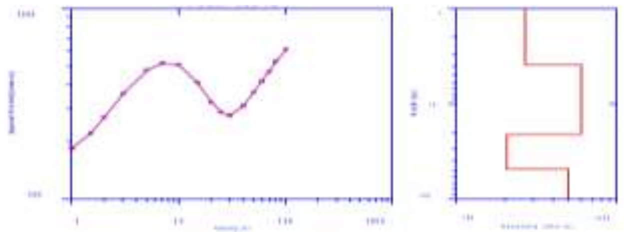

Fig 13. Curve matching with model of VES 12

Table 12. VES 12 Results

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	180	1	1	Topsoil
2	600	8	9	Fresh basement
3	300	25	34	Fractured basement
4	700	100	134	Fresh basement

VES 13

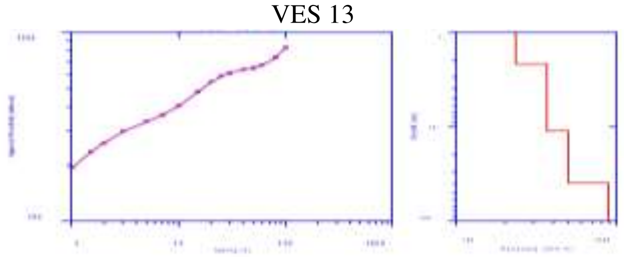

Fig 14. Curve matching with model of VES 13

Table 13. VES 13 Result

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	180	1	1	Topsoil
2	90	80	81	Fresh basement

VES 14

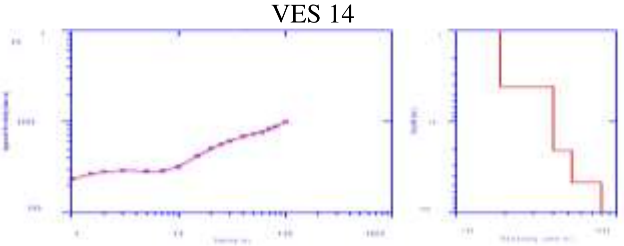

Fig 15. Curve matching with model of VES 14

Table 14. VES 14 Result

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	200	1	1	Topsoil
2	300	7	8	Clay
3	1000	80	89	Fresh basement

VES 15

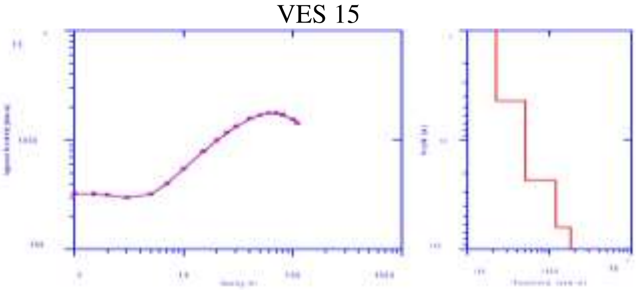

Fig 16. Curve matching with model of VES 15

Table 15. VES 15 Result

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	220	1	1	Topsoil
2	230	4	5	Clay
3	2000	60	66	Fresh basement

VES 16

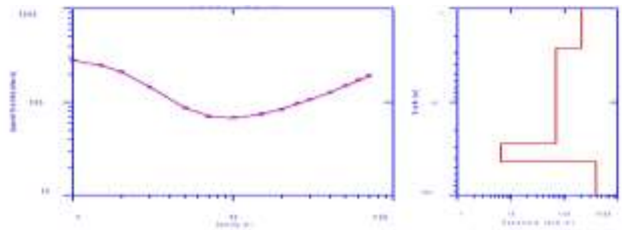

Fig 17. Curve matching with model of VES 16

Table 16. VES 16 Result

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	280	1	1	Topsoil
2	90	9	10	Weathered basement
3	250	80	90	Fresh basement

VES 17

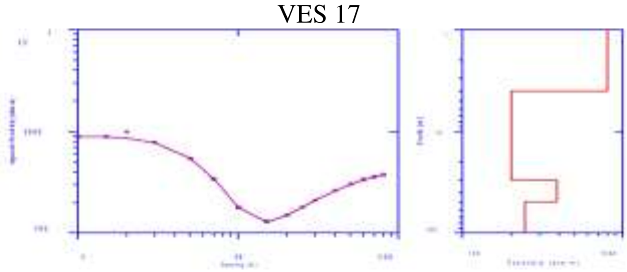

Fig 18. Curve matching with model of VES 17

Table 17. VES 17 Result

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	9000	1	1	Topsoil
2	110	15	16	Weathered basement
3	500	80	96	Fresh basement

VES 18

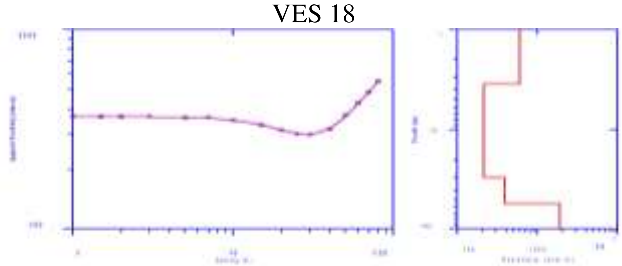

Fig 19. Curve matching with model of VES 18

Table 18. VES 18 Result

Layer No	Pa (Ωm)	Thickness (m)	Depth (m)	Geo-electric section
1	370	1	1	Topsoil
2	350	30	31	Weathered basement
3	7000	90	21	Fresh basement

Table 19. Summary of Results

VES No	Depth to ground water (m)	Thickness (m)	Recommendation
1	70 ± 5	65	Good yield of groundwater
2	NIL	NIL	No Fracture/ Weathered zone
3	NIL	NIL	No Fracture/ Weathered zone
4	NIL	NIL	No Fracture/ Weathered zone
5	50 ± 5	40	Low groundwater
6	NIL	NIL	No Fracture/ Weathered zone
7	30 ±	25	Shallow groundwater
8	NIL	NIL	No Fracture/ Weathered zone
9	70 ± 5	59	Can provide groundwater
10	NIL	NIL	No Fracture/ Weathered zone
11	80 ± 5	52	Can provide groundwater
12	70 ± 5	52	Can provide groundwater
13	NIL	NIL	No Fracture/ Weathered zone
14	NIL	NIL	No Fracture/ Weathered zone
15	NIL	NIL	No Fracture/ Weathered zone
16	40 ± 5	37	Can provide groundwater
17	50 ± 5	43	Can provide groundwater
18	60 ± 5	40	Can provide groundwater

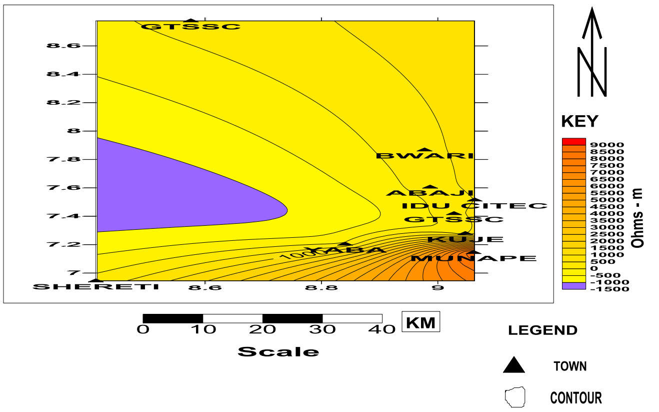

Fig 20. Iso- ohmic map of first resistivity layer of the study area

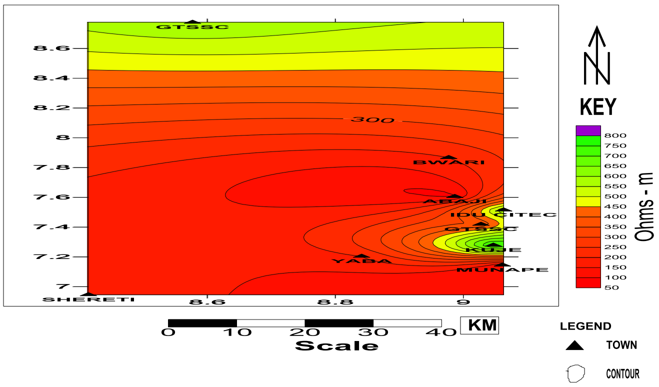

Fig 21. Iso- ohmic map of second resistivity layer of the study area

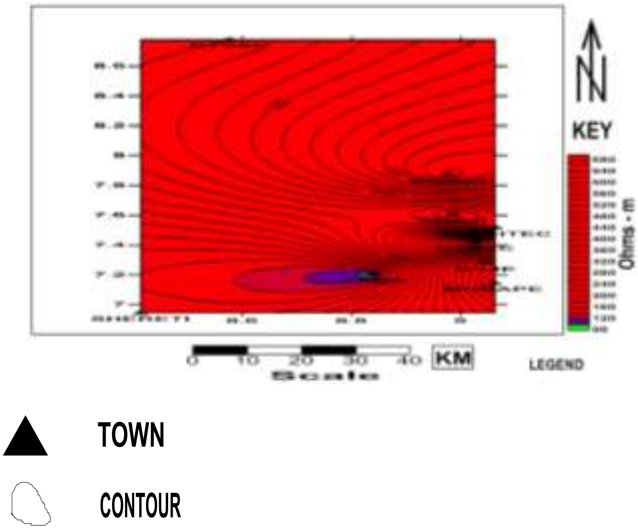

Fig 22. Iso- ohmic map of third resistivity layer of the study area

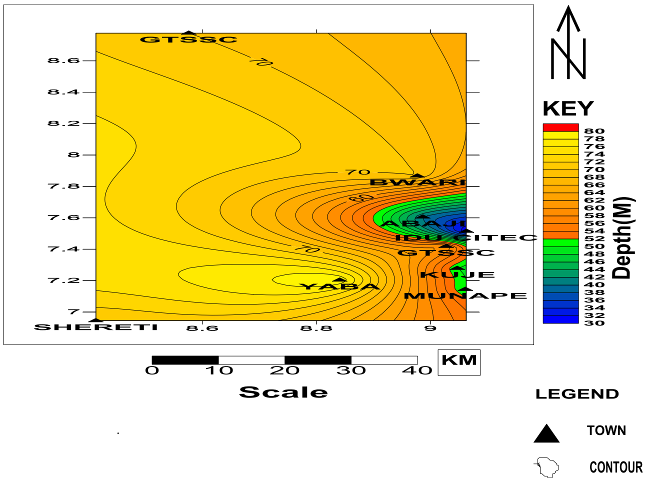

Fig 23. Possible depth of groundwater in the study area

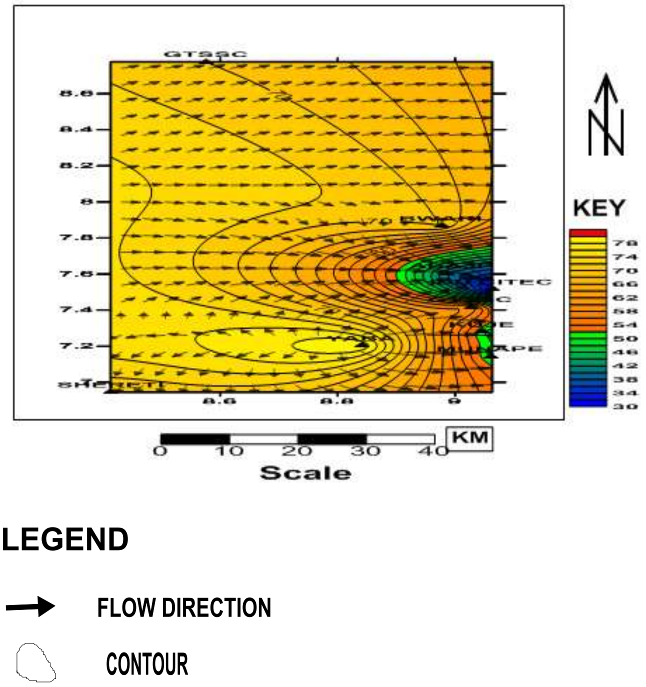

Fig 24. Direction of groundwater flow

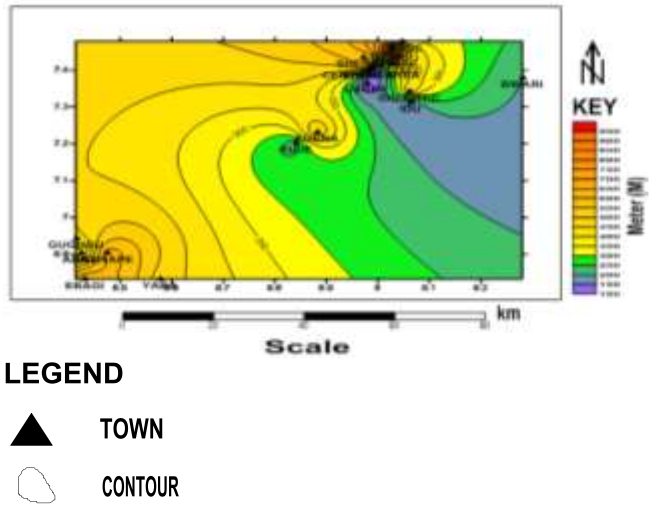

Fig 25. Contour map of the study area

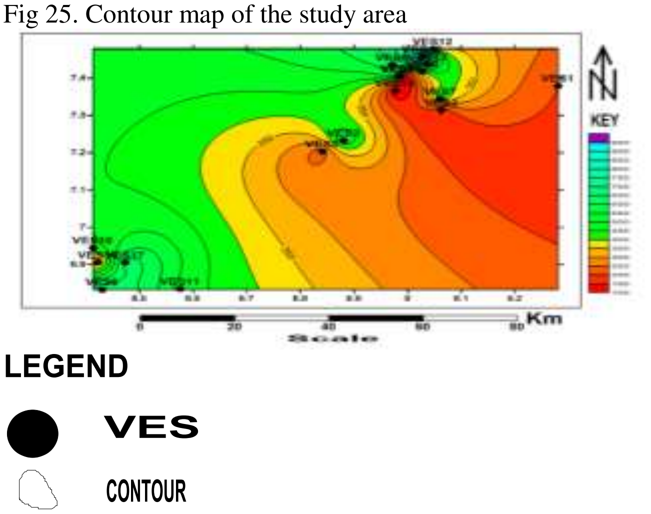

Fig 26. Location of vertical electrical soundings (VES) of the study area

VI. DISCUSSION OF RESULTS

Vertical electrical soundings (VES) randomly carried out at eighteen different location within the study area were plotted and smoothened with IX1D software. The result of the smoothened data were interpreted and explained as follows;

From the interpretation VES 1 is H type of curve, which is interpreted (in Table 1) to have three geoelectric section, Topsoil, Weathered basement, and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 70 m ± 5 m.

VES 2 is an A type curve and is interpreted (in Table 2) as Topsoil, Consolidated Sandstone, and weathered basement. In this case it can be deduced that it is not a potential area for groundwater exploration.

VES 3 is also A type curve and is interpreted (in Table 3) as Topsoil, Weathered basement and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 4 is an A type curve and is interpreted (in Table 4) as Topsoil, weathered basement and Fresh basement. In this case it can be deduced that it is not a potential area for groundwater exploration.

VES 5 is a K and H curve type, which is interpreted (in Table 5) to have three geoelectric section, Topsoil, Fresh basement, fractured basement, and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 50 m ± 5 m.

VES 6 is an A type curve and is interpreted (in Table 6) as Topsoil, Consolidated Sandstone, Weathered basement and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 7 is a K and H curve type, which is interpreted (in Table 7) to have three geoelectric sections, Topsoil, Consolidated Sandstone, Weathered basement and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 30 m ± 5 m.

VES 8 is a Q type curve and is interpreted (in Table 8) as Topsoil, partial fractured basement, and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 9 is a K and H curve type, which is interpreted (in Table 9) to have three geoelectric sections, Topsoil, fresh basement, weathered basement and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 70 m ± 5 m.

VES 10 is an A type curve and is interpreted (in Table 10) as Topsoil, Clay, and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 11 is a K and H curve type, which is interpreted (in Table 11) to have three geoelectric sections, Topsoil, fresh basement, weathered basement and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 80 m ± 5 m.

VES 12 is a K and H curve type, which is interpreted (in Table 12) to have three geoelectric sections, Topsoil, fresh basement, fractured basement and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 70 m ± 5 m.

VES 13 is an A type curve and is interpreted (in Table 13) as Topsoil and weathered basement, and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 10 is an A type curve and is interpreted (in Table 14) as Topsoil, Clay, and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 15 is an A type curve and is interpreted (in Table 15) as Topsoil, Clay, and Fresh basement. It can be deduced that it is not a potential area for groundwater exploration.

VES 16 is a H curve type, which is interpreted (in Table 16) to have three geoelectric sections, Topsoil, weathered basement and fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 40 m ± 5 m.

VES 17 is a H curve type, which is interpreted (in Table 17) to have four geoelectric sections, Topsoil, fresh basement, weathered basement, and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 50 m ± 5 m.

VES 18 is a H curve type, which is interpreted (in Table 18) to have three geoelectric sections, Topsoil, weathered basement, and Fresh basement. This VES point show a potential for groundwater exploration within weathered basement which could be at depth of 60 m ± 5 m.

The Iso – ohms of the first layer in (Fig 20) ranges from 500 ohms – m to 9000 ohms – m layers with low resistivity valves shows that there is high electrical conductivity and layers with high resistivity will give low electrical conductivity represent the topsoil. Fig 3 shows the Iso – ohms map of the second layer with resistivity value ranging from 80 ohms –m to 800 ohms – m are mostly weathered, fresh basement, clay and consolidated sandstone. Layers with low resistivity values shows high electrical conductivity and layers with high resistivity values shows low electrical conductivity. The Iso – ohms map of the third layer in Fig 4 shows resistivity value ranging from 80 ohms – m to 680 ohms – m. These layer with low resistivity value indicates high electrical conductivity, the layer have geo – electric section ranging from clay, weathered, partially fractured, fractured to fresh basement. Fig 5 shows the possible depth of groundwater which have being discussed above.

Fig 6 shows the direction of groundwater which flows mostly from NW to NE and SE respectively but the groundwater flow changes it direction in S as some water flow to small portion of SW and some flow toward N while some flow from S to SE these could be as a result o aquifer depths which varies from place to place.

VII. CONCLUSION

Groundwater is the common source of water within the study area. Eighteen (18) VES points were investigated. Out of these eighteen (18) VES points, nine (9) VES points have groundwater potentials which include VES 1, 5, 7, 9, 11, 12, 16, 17, and 18 at depth ranging from 40 - 80 m while VES 2, 3, 4, 6, 8, 10, 13, 14, and 15 do not posses groundwater potentials because they lack fractured/weathered zone. In view of that, 50% of the VES points are potential area for groundwater exploration.

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