INVESTIGATION OF GROUNDWATER POTENTIAL USING ELECTRICAL RESISTIVITY METHOD AT GARATU SECONDARY SCHOOL, NIGER STATE, NIGERIA

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Abstract
Evaluation of groundwater potential was carried out at Garatu Secondary School, Garatu, Niger State Nigeria. Schlumberger electrode configuration was adopted with maximum current electrode spacing (AB/2) of 100 m. The profile separations was 100 m with inter vertical electrical soundings (VES) point spacing of 100 m from profile A to F. Total of thirty-six vertical electrical soundings station were covered. The interpretation revealed three distinctive geologic layers. The first layer which is the top layer has resistivity value ranging from 907.1 – 1605.2 Ωm, its depth and thickness varies between 1.3 – 1.8 m and 1.3 – 1.8 m respectively which corresponds to the geo-electrical parameters of fadama loam, weathered laterite and fractured basement. The second layer has resistivity value of 205.4 – 322.2 Ωm, depth of 12.0 – 17.8 m and thickness of 10.5 – 16.0 m; this layer refers to the weathered/fractured basement. The resistivity of the third layer ranged from 858.4– 4777.2 Ωm, its depth and thickness are undefined. The results clearly showed that the electrical resistivity method is suitable for and very efficient in investigating groundwater potential. The parameters (resistivity, depth and thickness) of the layers were employed to delineate the aquifer potential of the study area, their weathered/fractured layer with resistivity value varying from 148.9 to 218.9 Ωm while the depth and thickness ranged from 22.8 to 30.4 m and 21.0 to 27.3 m respectively. Five VES points C3, C4, D2, E4, and F2 were delineated as groundwater potential points of the area.

Keywords: Groundwater, Electrical Resistivity, Garatu, Aquifer, vertical electrical soundings

Introduction
Water is one of the most important substances for life on earth. All living creatures including plants and animals must necessarily require water to survive. The absence of water would mean the absence of life on earth. Apart from drinking water to survive, humans have many other uses for water for day to day activities. All through the ages and especially in recent times human activities have shown an ever increasing trend in fresh water exploration, meanwhile land use for various reasons shows also changes as development progresses. To meet this daily demands, many people rely on land-based exploration and exploitation. Hence, Groundwater is one of nature's most valuable and inseparable resources for life on earth (Eva & Dwita, 2018).

Water is an essential resource required for the day to day running of human activity. Hence the demand for water due to the ever increasing human population is a major problem of the Garatu community. The community has come to the spotlight due to its strategic positioning as a center of commercial activities. The location of the community just by the major road linking Niger State and other South Western state keeps attracting traders to the location, consequently, there is an increasing demand to compliment the already existing water supply sources in the community and this has informed the need to delineate aquifer potential of the study area. More also, availability of good quality drinkable water has been a major challenge characterised with issues such as pollution and lack of requisite information to exploit clean water for use. For instance, exploration and exploitation for oil in the Niger Delta region of Nigeria has brought about polluted water which is still being used by the people for drinking and other purposes (Anomohanran, 2013).

Research has it that nearly all the water in the ground originates from precipitation that has permeated into the earth. It is also observed that a great amount of rainfall runs-off on the surface of the earth while the other part permeates into the underground and becomes the groundwater that results into the springs, lakes and wells (Oseji, et al. 2006). Hence, Electrical resistivity was employed to delineate aquifer potentials of the study area as a remedy for getting portable and clean water for human consumption from groundwater which are available in most places on the face of the earth.

Location of the Study Area

Garatu Secondary School is situated at the northern part of Garatu, just at the right hand side of the entrance from Minna. Garatu is a growing community along Minna – Bida road at about 21 km from Minna; located within the Basement Complex terrain of North-Central Nigeria and is underlain by Pre-Cambrian basement rocks of which granites are predominant. The community lies within 9.5083° N (9° 30' 29.88 " N), 6.4290° E (6° 25' 44.4" E). It is largely known for its commercial activities. As farm produce traders from across the country converge to transact business in the sale of mainly Yam tubers and other commodities from farms around the community.

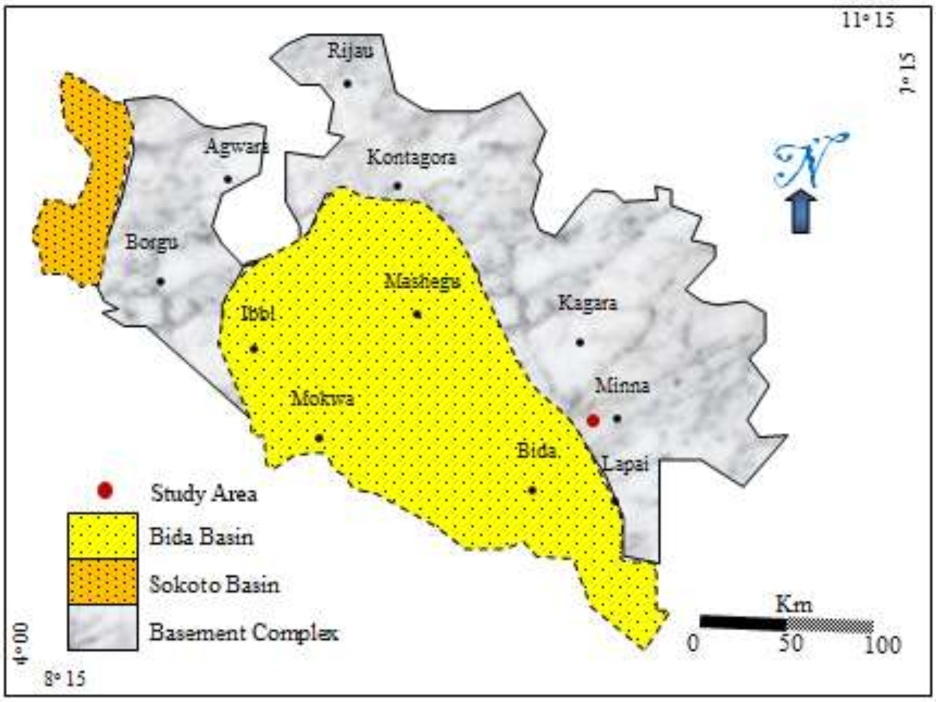

Figure 1: Geological Map of Niger State Basement Complex and Sedimentary Basins (Nwanosike, et al., 2012)

Geology of the Study Area

Nigeria's geology is made up of three (3) major litho-petrological components and they are namely; the Basement Complex, Younger Granites, and Sedimentary Basins. The Basement Complex is Precambrian in age and is made up of the Migmatite-Gneiss-Quartzite Complex, the Schist Belts, the Older Granites and the PanAfrican Migmatite-Gneiss-Quartzite ComplexThe Sedimentary Basins, containing sediment fill of Cretaceous to Tertiary ages, comprise the Niger Delta, the Benue Trough, the Chad Basin, the Sokoto Basin, the Mid-Niger (Bida/Nupe) Basin, and the Dahomey Basin. (Abdullahi, et al., 2017). Garatu is about 21 km away from the main city of Minna; it shares a common geologic features with the city of Minna. It occupies the central portion of the Nigerian basement complex. About half of the landmass of Niger State is underlain by the Basement Complex rocks while the remaining half is occupied by the Cretaceous Sedimentary rocks of the Bida Basin (Figure 2.1). It lies within the north-central portion of the Nigerian Basement complex. The geological mapping revealed that the area is underlain by granite and gneiss which in most locations are undifferentiated granite-gneiss-complex.

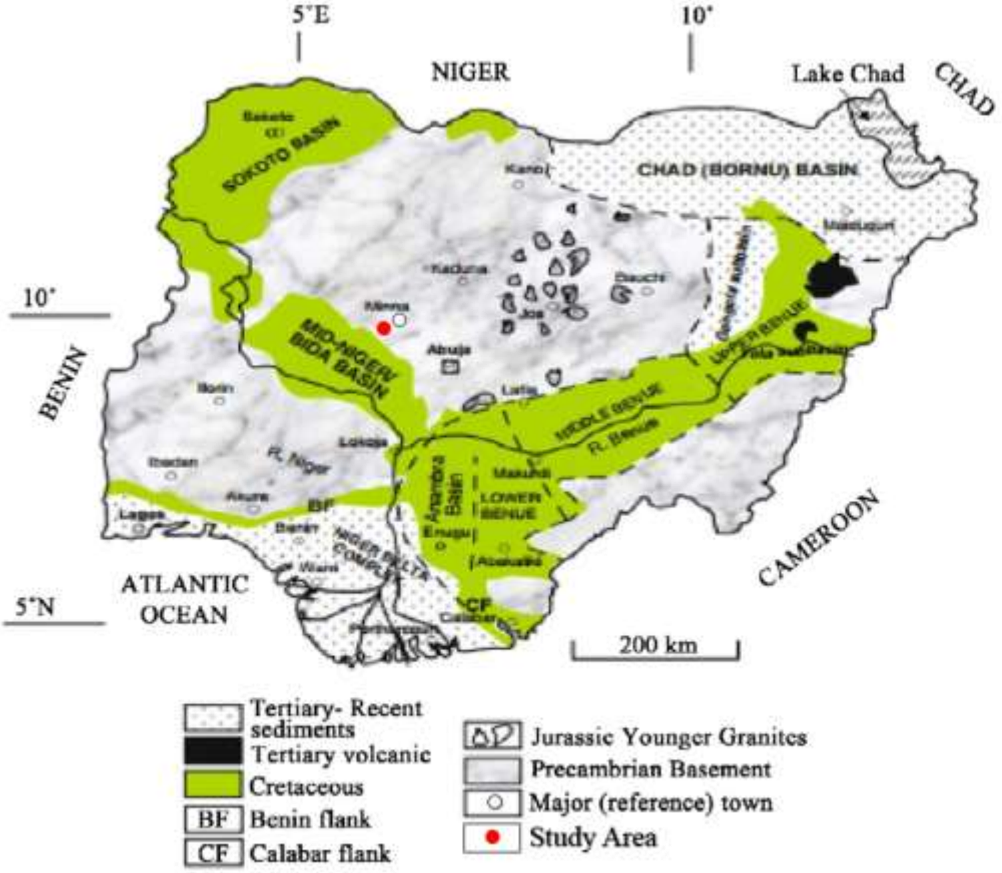

Figure 2.1: Geological map of Nigeria showing the basement complex, younger granites and sedimentary basins (Abdullahi et al., 2017)

Alhassan *et al*. (2015) in their paper titled "Electrical Resistivity survey for ground water" at EL-HALAL Farms. The area revealed three lithological formations in some places while in some place five. With the lowest resistivity found to be 6.85 Ωm and the highest resistivity was 12,774.46 Ωm. Since this is a sedimentary area drilling was expected to be deep down to a depth of about 70-75m. Obiajulu *et al*., (2015) employed the electrical resistivity method to determine the groundwater potential of Ihiala and its environ. The lithostratigraphic units within the study area include: Benin Formation and Ogwashi Asaba Formation. VES stations along BB1 profile drawn through North-South direction which comprise of VES 4, 7, 9 and 10 were chosen as the areas that hold the best prospect for sustainable groundwater development.

Methodology

Electrical Resistivity survey method was used to carry out this study in order to determine the parameters for the subsurface structures of the study area. Haven, adopted the vertical electrical sounding technique, the Terrameter (ABEM SAS 4000) was used to measure the earth's resistance. This was achieved by making a total of six (6) profiles or traverses with six (6) VES points trailing each of the profiles (A_1-A_6, B_1-B_6 …, F_1-F_6) making it a total of thirty-six (36) VES points. These sounding points had inter-profile spacing and inter VES point spacing of 100m. Then, Schlumberger array was adopted having half inter electrode spacing (AB/2) ranges from 1 – 100m. Using a pair of electrodes A and B for the supply of direct current into the ground while another electrode pair M and N were used as the potential electrodes. While carrying out the exercise, the current electrode spacing was continually increased as the potential electrode separation was kept constant. Hence, the geometric factor K, was evaluated for all the electrodes spacing via the use of the equation (1).

$$K = \pi\left(\frac{\left(\frac{AB}{2}\right)^2-\left(\frac{MN}{2}\right)^2}{MN}\right) \quad (1)$$

Thereafter apparent resistivity (ρ_a) values were derived as K is multiplied by resistance (R) values

$$\rho_a = KR \quad (2)$$

The values of the apparent resistivity obtained were plotted against AB/2 using the software called winResist. Furthermore, resistivity, thickness and depth of each of the subsurface layer were all obtained respectively.

Result and Discussion

Geoelectric Section

The Geoelectric section (VES curve) as shown in Figure 3, provides information about the subsurface layer resistivity, depth and thickness across the entire study area as summarised in table 1.

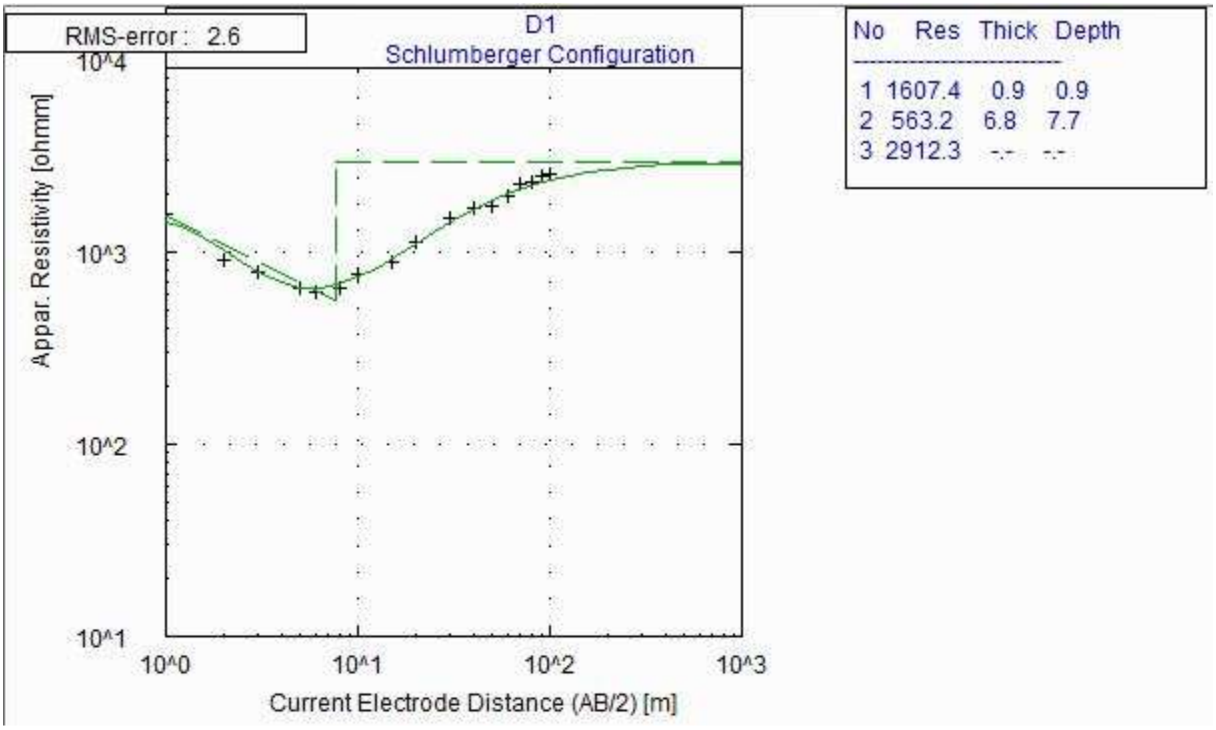

Figure 3: Geoelectric section of VES point D_1

Table 1 shows the summary of results obtained from each geoelectric section across profile A to F which reveals that the study area is underlain by three (3) geoelectric subsurface layers. The first layer which is the top layer has resistivity value ranging from 158.2 – 2344.9 Ωm, its depth and thickness varies between 0.9 – 7.7 m and 0.9 – 6.8 m respectively which corresponds to the geoelectrical parameters of fadama loam, weathered laterite and fresh laterite. The second layer has resistivity value of 46.6 – 563.2 Ωm, depth of 2.5 – 27.3 m and thickness of 3.1 – 30.4 m; this layer refers to the weathered/fractured basement. The resistivity of the third layer ranged from 858.4– 4777.2 Ωm, its depth and thickness are undefined.

Table 1: Resistivity, coordinates, thickness and depth of the study

VES Stations	Latitude (°)	Longitude (°)	No. of Layers	Layer Resistivity, ρ (Ωm)			Layer Depth d (m)			Layer Thickness, h (m)			Curve Type
				ρ1	ρ2	ρ3	d1	d2	d3	h1	h2	h3	
A1	9.416620	6.618310	3	907.1	205.4	1309.9	1.8	17.8	∞	1.8	16	∞	H
A2	9.416614	6.617400	3	1138.0	268.4	1621.6	1.3	16.6	∞	1.3	15.4	∞	H
A3	9.416608	6.616490	3	1555.4	213.4	1481.3	1.7	16.3	∞	1.7	14.6	∞	H
A4	9.416602	6.615580	3	1605.2	207.1	1657.6	1.6	15.9	∞	1.6	14.3	∞	H
A5	9.416595	6.614670	3	1100.8	176.6	2521.8	1.4	12.0	∞	1.4	10.5	∞	H
A6	9.416589	6.613760	3	1227.7	322.2	2614.0	1.5	14.1	∞	1.5	12.6	∞	H
B1	9.415716	6.618316	3	1446.2	188.8	1461.5	2.0	17.9	∞	2.0	15.9	∞	H
B2	9.415710	6.617406	3	1381.9	209.6	1750.3	2.5	18.8	∞	2.5	16.3	∞	H
B3	9.415704	6.616496	3	925.9	269.7	1752.4	1.7	22.7	∞	1.7	21.0	∞	H
B4	9.415698	6.615586	3	690.5	224.9	1505.4	1.6	16.9	∞	1.6	15.3	∞	H
B5	9.415692	6.614676	3	901.5	283.1	2066.9	1.6	18.2	∞	1.6	16.6	∞	H
B6	9.415685	6.613766	3	473.6	269.0	1525.5	1.1	22.5	∞	1.1	21.4	∞	H
C1	9.414813	6.618322	3	1251.8	262.1	1314.5	1.9	25.3	∞	1.9	23.4	∞	H
C2	9.414806	6.617412	3	1944.6	186.5	2124.4	1.4	17.9	∞	1.4	16.5	∞	H
C3	9.414800	6.616502	3	1343.0	172.2	1248.3	1.8	22.8	∞	1.8	21.0	∞	H
C4	9.414794	6.615592	3	694.4	148.9	880.9	2.1	28.7	∞	2.1	26.5	∞	H
C5	9.414788	6.614682	3	158.2	46.6	4777.2	0.6	3.1	∞	0.6	2.5	∞	H
C6	9.414782	6.613772	3	1009.5	168.8	1793.9	0.7	5.1	∞	0.7	4.3	∞	H
D1	9.413909	6.618329	3	1607.4	563.2	2912.3	0.9	7.7	∞	0.9	6.8	∞	H
D2	9.413903	6.617419	3	1337.1	196.6	1255.8	2.1	24.0	∞	2.1	21.9	∞	H
D3	9.413897	6.616508	3	1801.0	121.6	1308.3	1.9	17.6	∞	1.9	15.7	∞	H
D4	9.413890	6.615598	3	1518.1	210.4	1173.8	1.4	19.8	∞	1.4	18.3	∞	H
D5	9.413884	6.614688	3	1916.5	218.3	1089.0	1.6	21.7	∞	1.6	20.2	∞	H
D6	9.413878	6.613778	3	1178.0	264.0	976.2	1.6	21.9	∞	1.6	20.3	∞	H
E1	9.413005	6.618335	3	2008.6	111.4	1193.2	1.2	6.7	∞	1.2	5.5	∞	H
E2	9.412999	6.617425	3	2344.9	107.1	858.4	1.4	17.2	∞	1.4	15.7	∞	H
E3	9.412993	6.616515	3	1154.7	196.1	1006.5	2.6	25.5	∞	2.6	22.9	∞	H
E4	9.412987	6.615605	3	922.0	218.9	1052.7	1.8	28.0	∞	1.8	26.1	∞	H
E5	9.412981	6.614694	3	1459.9	208.1	1404.5	1.7	22.7	∞	1.7	21.0	∞	H
E6	9.412974	6.613784	3	1447.2	213.1	1411.9	1.7	21.7	∞	1.7	20.0	∞	H
F1	9.412101	6.618341	3	1382.7	103.3	2586.9	1.5	9.1	∞	1.5	7.5	∞	H
F2	9.412095	6.617431	3	915.0	196.3	1012.2	3.1	30.4	∞	3.1	27.3	∞	H
F3	9.412089	6.616521	3	2091.8	184.4	1417.2	3.2	24.9	∞	3.2	21.7	∞	H
F4	9.412083	6.615611	3	1052.1	178.0	1604.8	3.1	22.0	∞	3.1	19.0	∞	H
F5	9.412077	6.614701	3	1526.8	210.8	1789.9	2.7	21.3	∞	2.7	18.7	∞	H
F6	9.412071	6.613791	3	1755.2	321.1	1253.3	1.9	25.8	∞	1.9	23.9	∞	H

Iso-Resistivity Contour Maps

Iso-resistivity contour map of the first layer

An interval of 100 Ωm was used to generate the iso-resistivity contour of the first layer (Figure 4.). The range of the resistivity values is 100 – 2400 Ωm. The contour reveals that the study area is characterised by high top soil resistivity value aside the north-western portion which has low top soil resistivity value. The topsoil is dominantly weathered and fresh laterite.

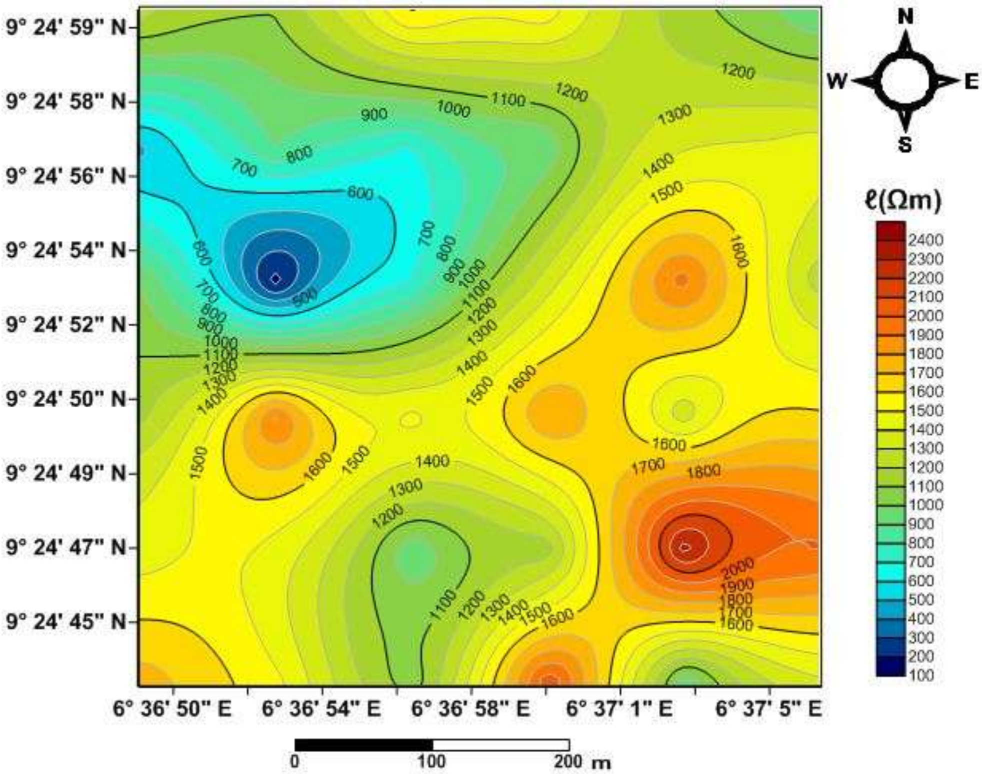

Figure 4: Iso-resistivity contour map of the first layer.

Iso-resistivity contour map of the second layer

The iso-resistivity contour of the second layer (Figure 5) was generated at an interval of 20 Ωm. It's resistivity value ranges from 40 – 560 Ωm which corresponds to the resistivity of a weathered basement. The contour shows that the resistivity of this weathered zone is higher at the northern, north-western, south-western and the eastern parts of the study area while the south-eastern and central parts are characterised by low resistivity value.

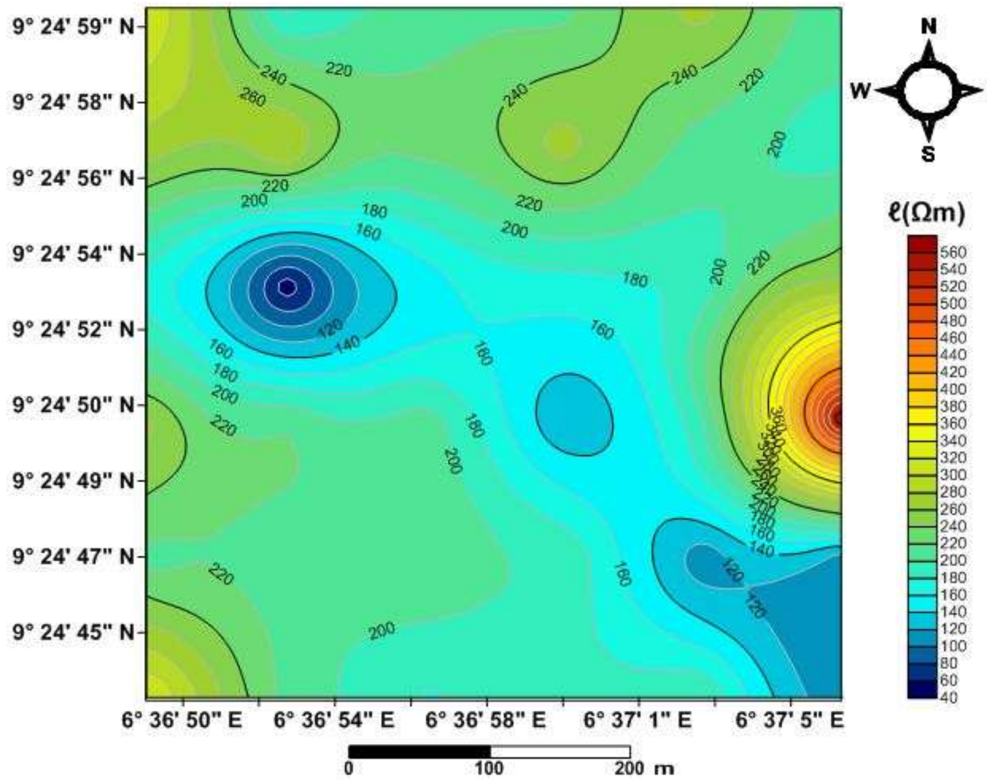

Figure 5: Iso-resistivity contour map of the second layer.

Iso-resistivity contour map of the third layer

The iso-resistivity contour of the third layer (Figure 6) was generated at 200 Ωm interval, the contour has its resistivity values ranging from 800 – 4800 Ωm which depicts the resistive characteristics of fractured basement rocks. The third layer has its lowest resistivity value majorly at the southern, south-western, and central parts of the study area while those of high resistivity value occupy the north-western and north eastern part.

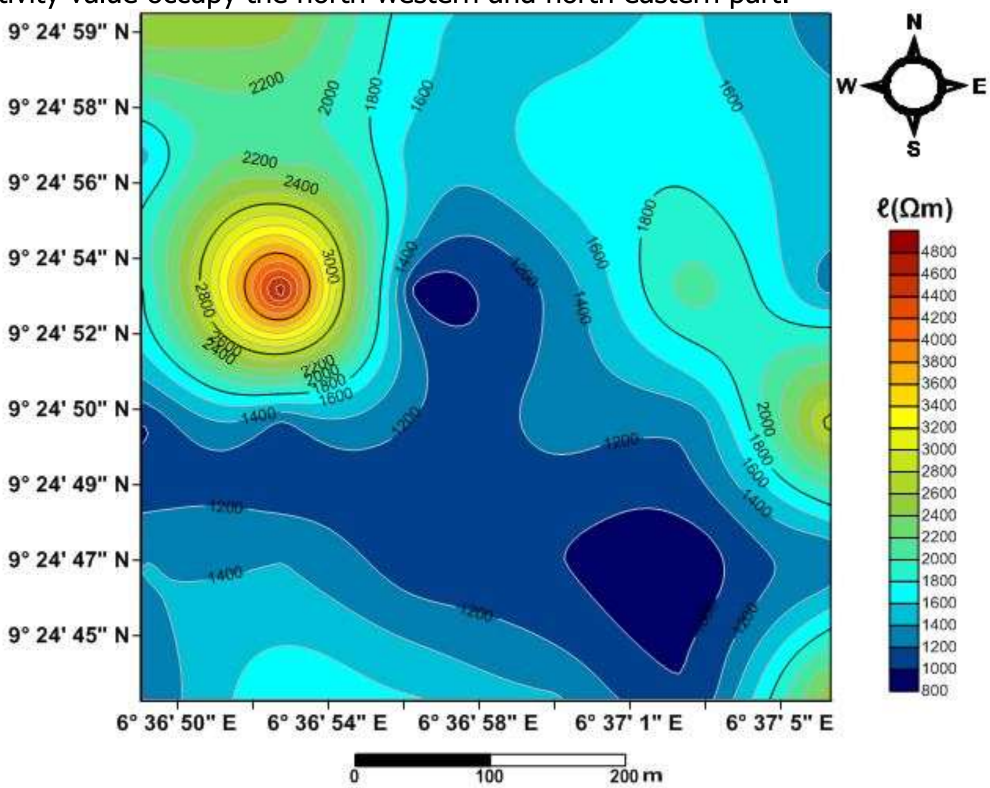

Figure 6: Iso-resistivity contour map of the third layer.

Isopach map

The Isopach (overburden contour map) was generated at an interval of 2 m, the values range from 2.5 to 27.3 m as shown in Figure 7. The contour reveals that overburden thickness is generally high within the study area and the points with overburden thickness less than ten meters only occupy a portion of the western and south-eastern parts of the study area.

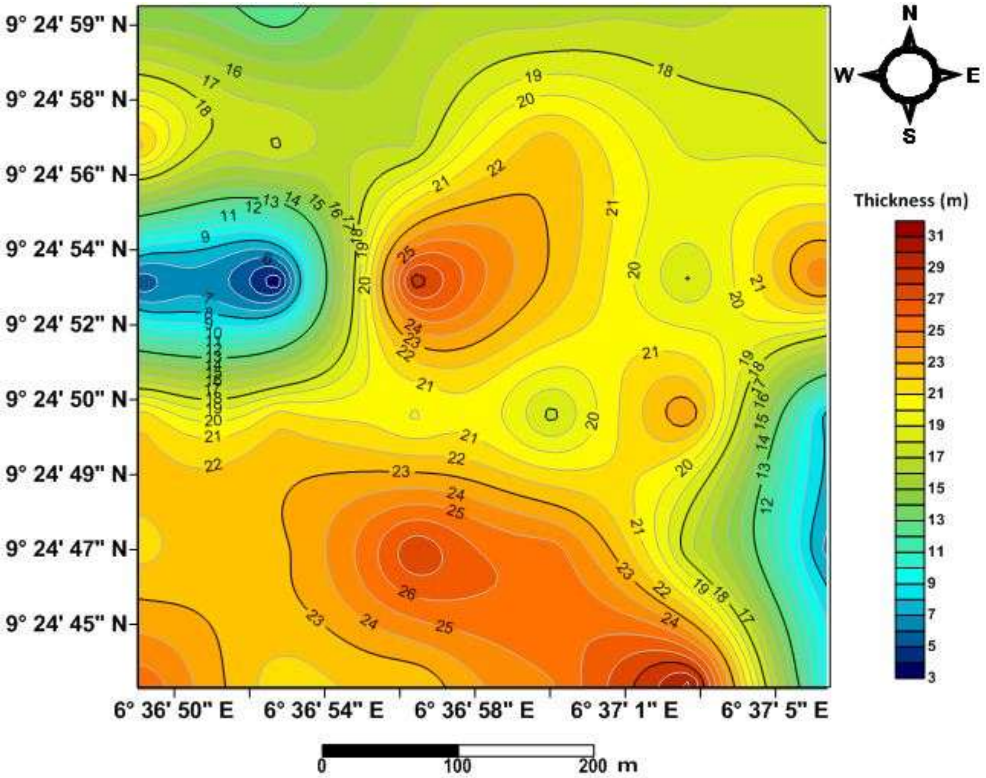

Figure 7: Overburden contour map of the study area

Geologic sections of the study area

Figure 4.6 to 4.11 reveals the vertical geologic section through profile A – F showing the layers of the subsurface structure, their depth and thickness.

Geologic section of profile A

The geologic section through profile A (Figure 8) reveals that the profile is characterised by three layers. The first layer is the top soil which spreads through the entire profle; its resistivity, depth and thickness range from 907.1 – 1605.2 Ωm, 1.3 – 1.8 m and 1.3 – 1.8 m respectively.

The second layer is a weathered/fractured layer, its resistivity, depth and thickness varies between 205.4 – 322.2 Ωm, 12.0 – 17.8 m and 10.5 – 16.0 m respectively; it spreads across the entire profile. The third layer underlies the second layer, it is the fractured basement, it has a resistivity range of 1309.9 – 2614.0 Ωm and undefined depth and thickness.

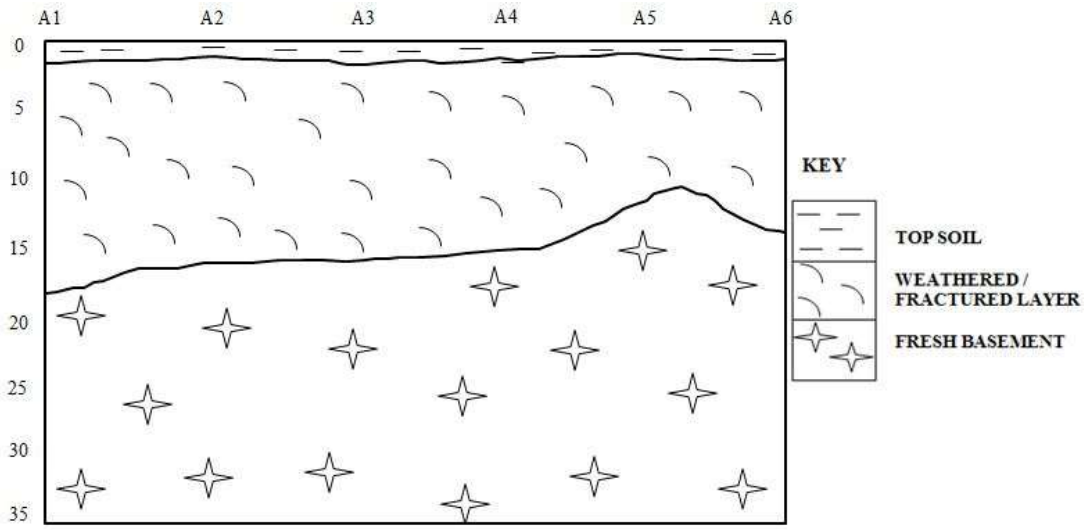

Figure 8: Vertical geologic section through profile A

Geologic section of profile B

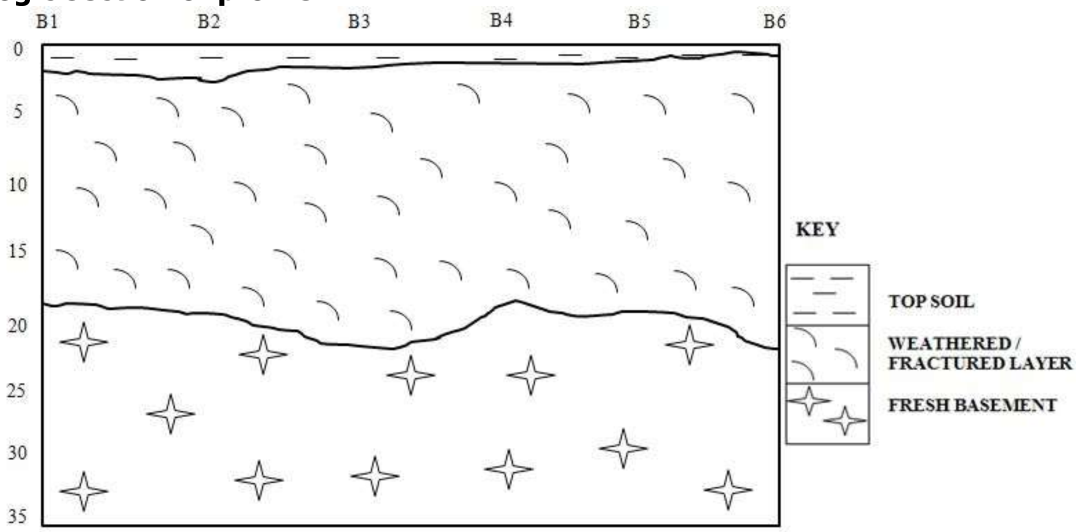

Figure 9: Vertical geologic section through profile B

The geologic section through profile B (Figure 9) shows that the profile is characterised by three layers. The first layer is the top soil which spreads through the entire profile; its resistivity, depth and thickness range from 473.6 – 1446.2 Ωm, 1.2 – 2.5 m and 1.1 – 2.5 m respectively. The second layer is the weathered/fractured layer, its resistivity, depth and thickness varies between 188.8 – 283.1 Ωm, 16.9 – 22.7 m and 15.3 – 21.4 m respectively; it spreads across the entire profile. The second layer is underlain by the third layer which is the fractured basement, it has a resistivity value of 1461.5 – 2066.9 Ωm and undefined depth and thickness.

Geologic section of profile C

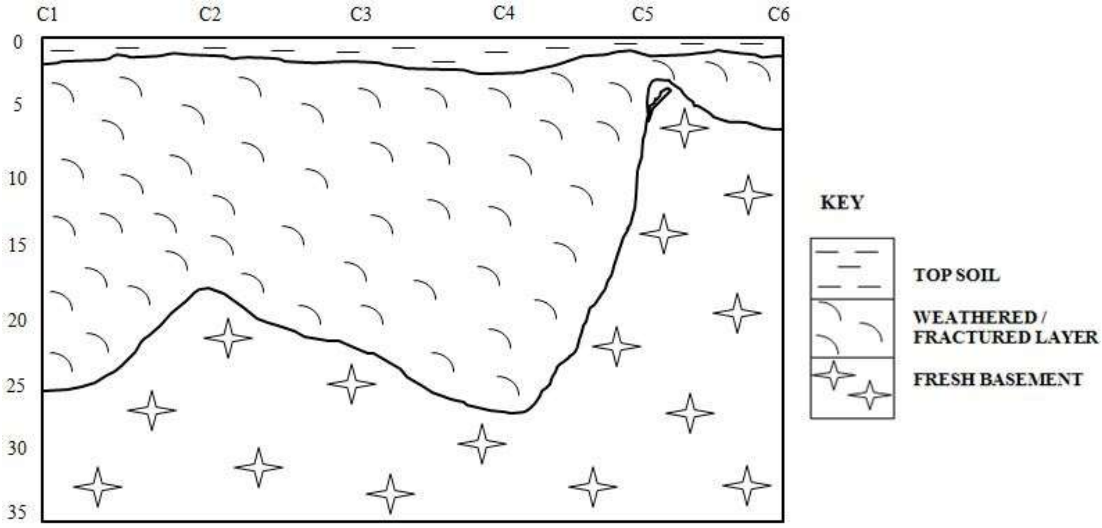

Figure 10: Vertical geologic section through profile C

Figure 10 shows the geologic section through profile C, it reveals that three distinct layers exist therein. The first layer is the top soil spreading through the entire profile; its resistivity, depth and thickness range from 158.2 – 1944.6 Ωm, 0.6 – 2.1 m and 0.6 – 2.1 m respectively. The second layer is a weathered/fractured layer which also spreads across the entire profile, its resistivity, depth and thickness varies between 46.6 – 262.1 Ωm, 3.1 – 28.7 m and 2.5 – 26.5 m respectively. The third layer which is the Fractured basement has a resistivity range of 880.9 – 4777.2 Ωm and undefined depth and thickness. There is a reservoir effect spreading from VES C_3 to C_4 which makes these points favourable for groundwater development.

Geologic section of profile D

The geologic section through profile D (Figure 11) reveals that the profile is characterised by three layers. The first layer which is the top soil spreads through the entire profile; its resistivity, depth and thickness range from 1178.0 – 1916.5 Ωm, 0.9 – 2.1 m and 0.9 – 2.1 m respectively. The second layer which is the weathered/fractured layer has resistivity, depth and thickness of 121.6 – 563.2 Ωm, 7.7 – 24.0 m and 6.8– 21.9 m respectively; it spreads across the entire profile. The Fractured basement which is the third layer underlies the second layer, it has a resistivity range of 976.2 – 2912.3 Ωm with depth and thickness undefined. VES point D2 is a good point for groundwater exploitation.

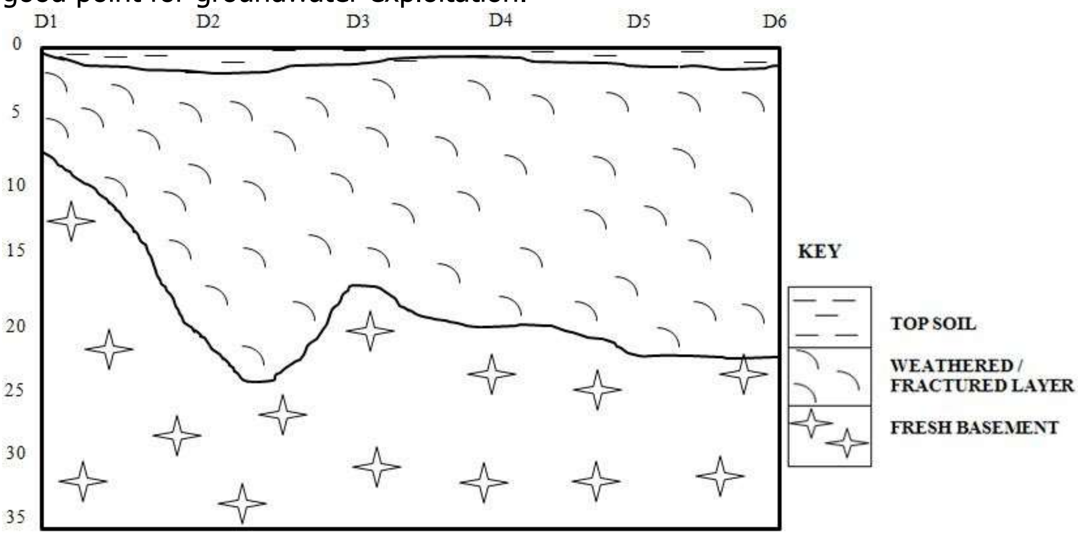

Figure 11: Vertical geologic section through profile D

Geologic section of profile E

Figure 12 shows the geologic section through profile E, it reveals that three distinct layers exist therein. The first layer is the top soil which spreads through the entire profile; its resistivity, depth and thickness range from 922.0 – 2344.9 Ωm, 1.2 – 2.6 m and 1.2 – 2.6 m respectively. The second layer is a weathered/fractured layer which also spreads across the entire profile, its resistivity, depth and thickness varies between 107.1 – 218.9 Ωm, 6.7 – 28.0 m and 5.5 – 26.1 m respectively. The third layer which is the Fractured basement has a resistivity range of 858.4 – 1411.9 Ωm with an undefined depth and thickness. VES point E_4 will be suitable for groundwater development.

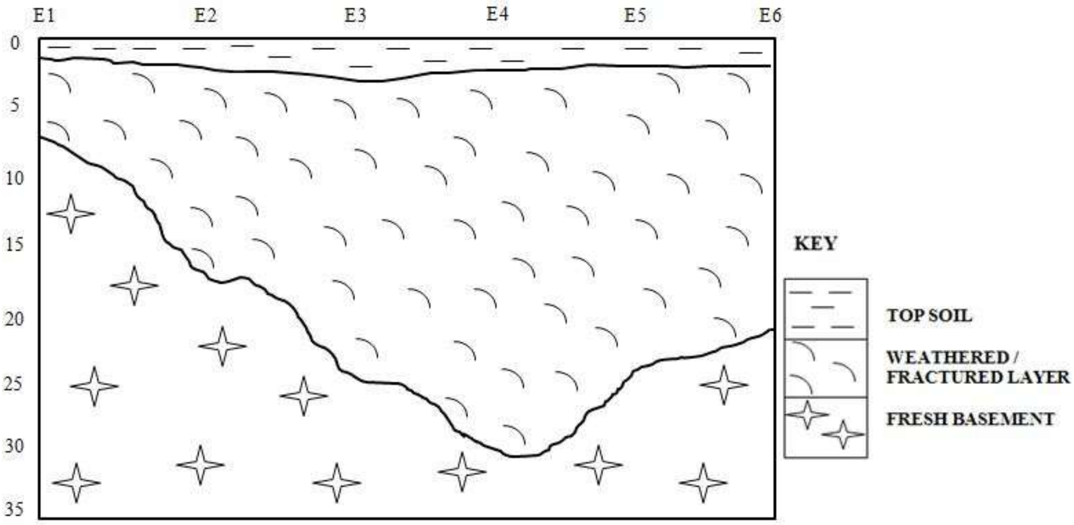

Figure 12: Vertical geologic section through profile E

Geologic section of profile F

Figure 13 shows the geologic section through profile F, it reveals that three distinct layers exist therein. The first layer is the top soil which spreads through the entire profile; its resistivity, depth and thickness range from 915.0 – 2091.8 Ωm, 1.5 – 3.2 m and 1.5 – 3.2 m respectively. The second layer is a weathered/fractured layer which also spreads across the entire profile, its resistivity, depth and thickness varies between 103.3 – 321.1 Ωm, 9.1 – 30.4 m and 7.5 – 27.3 m respectively. The third layer which is the Fractured basement has a resistivity range of 1012.2 – 2586.9 Ωm with an undefined depth and thickness. VES point F_2 will be a good point for groundwater development.

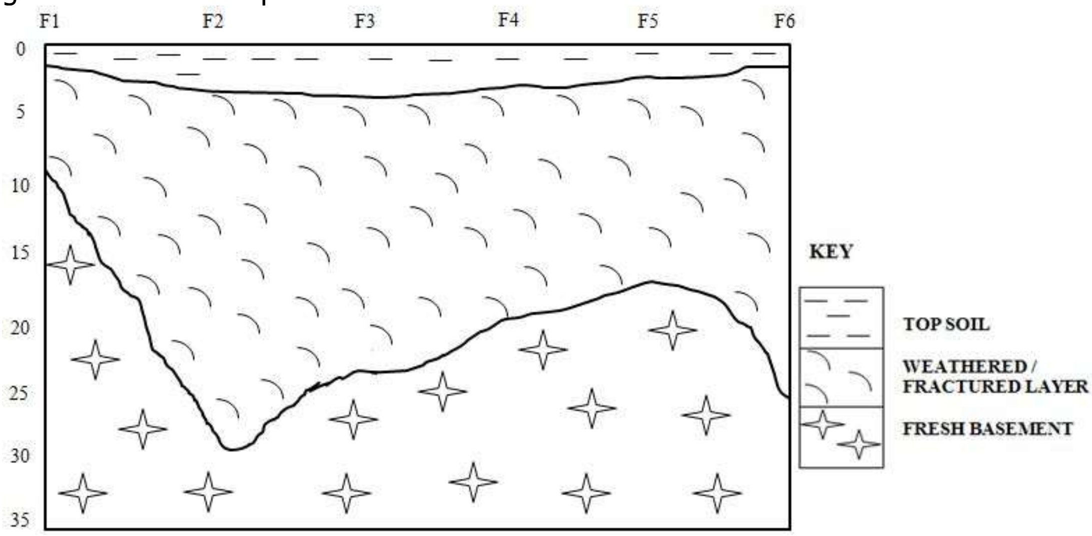

Figure 13: Vertical geologic section through profile F

Table 2: Delineated aquifer potentials of the study area

VES Stations	Latitude (°)	Longitude (°)	No. of Layers	Layer Resistivity ρ (Ωm)			Layer Depth (m)			Layer Thickness (m)			Curve Type
				ρ1	**ρ2**	**ρ3**	***d*1**	***d*2**	***d*3**	***h*1**	***h*2**	***h*3**	
C_3	9.414800	6.616502	3	1343.0	172.2	1248.3	1.8	22.8	∞	1.8	21.0	∞	H
C_4	9.414794	6.615592	3	694.4	148.9	880.9	2.1	28.7	∞	2.1	26.5	∞	H
D_2	9.413903	6.617419	3	1337.1	196.6	1255.8	2.1	24.0	∞	2.1	21.9	∞	H
E_4	9.412987	6.615605	3	922.0	218.9	1052.7	1.8	28.0	∞	1.8	26.1	∞	H
F_2	9.412095	6.617431	3	915.0	196.3	1012.2	3.1	30.4	∞	3.1	27.3	∞	H

Table 2 contains the VES points delineated as aquifer potential of the study area, the range of resistivity, depth and thickness of these aquifers are 148.9 to 218.9 Ωm, 22.8 to 30.4 m and 21.0 to 27.3 m respectively

Conclusion

The results obtained from the analysis of the data acquired in field of survey clearly showed that the electrical resistivity method is suitable for and very efficient in investigating groundwater potential. The study area is characterised by three (3) geoelectric layers as clearly revealed by the result, they are: the top layer which consist of fadama loam, sand and gravel; weathered/fractured layer and the fractured basement layer.

The resistivity of the top layer, weathered/fractured layer and Fractured basement layer varies from 158.2 to 2344.9 Ωm, 446.6 to 563.2 and 858.4 to 4777.2 Ωm respectively across the entire study area; the depth of the top layer ranges from 0.6 to 3.2 m, that of the weathered/fractured layer varies from 3.1 to 30.4 m while that of the Fractured basement layer is undefined across the six(6) profiles investigated; also, the study area has 0.6 to 3.2 m and 2.5 to 27.2 m as the thickness of its the top layer and weathered/fractured layer respectively, the Fractured basement layer has an undefined thickness.

Isoresistivity maps were produced for the top layer, weathered/fractured layer and the fractured basement layer. An interval of 100 Ωm was used to generate the isoresistivity contour of the first layer (Figure 4.). The range of the resistivity values is 158.2 – 2344.9 Ωm. The contour reveals that the study area is characterised by high top soil resistivity value aside the north-western portion which has low top soil resistivity value. The topsoil is dominantly weathered and fresh laterite; similarly, the iso-resistivity contour of the second layer (Figure 5) was generated at an interval of 20 Ωm. The contour shows that the resistivity of this weathered zone is higher at the northern, north-western, south-western and the eastern parts of the study area while the south-eastern and central parts are characterised by low resistivity value; also, The iso-resistivity contour of the third layer (Figure 6) was generated at 200 Ωm interval, the contour reveals that the third layer has its lowest resistivity value majorly at the southern, south-western, central and north-eastern parts of the study area while those of high resistivity value occupy the north-western part.
Also, The Isopach (overburden contour map) was generated at an interval of 2m, the contour reveals that overburden thickness is generally high within the study area as at the points with overburden thickness less than ten (10) only occupy a portion of the western and south-eastern parts of the study area.

The parameters (resistivity, depth and thickness) of the layers were employed to delineate the aquifer potential of the study area, five VES points C_3, C_4, D_2, E_4, and F_2 were delineated as groundwater potential points of the area, their weathered/fractured layer has resistivity value varying from 148.9 to 218.9 Ωm while its depth and thickness ranged from 22.8 to 30.4 m and 21.0 to 27.3 m respectively as indicated in table 2.

Recommendations

Government or individuals who wish to site boreholes within the study area should consider VES stations C_3, C_4, D_2, E_4, and F_2. More also, A further study should be carried out to investigate the protective capacity and the corrosiveness of the recommended VES stations.

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