APPLICATION OF ELECTRICAL RESISTIVITY METHOD TO DELINEATE CONSTRUCTION SITES AT GIDAN KWANO CAMPUS, FUT, MINNA, NIGER STATE, NIGERIA

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***Abstract**:*
Vertical Electrical Sounding (VES), using ABEM SAS 4,000 Terrameter was carried out on a 500 x 500 m area of land located between latitude 09°32'21.4'' N to 09°32'37.8'' N and longitude 06°27'29.2'' E to 06°27'45.5'' E at the northern part of Gidan Kwano Campus, Federal University of Technology, Minna, Niger State. The study was aimed at investigating the subsurface structures of the study area with a view to delineating the sites suitable for civil engineering work. A total of 36 VES points at 100 m interval were sounded with a 100 m maximum half inter current electrode spacing (ab/2). Result revealed that the study area is underlain by three (3) geoelectric/geologic layers which include: the top soil with 10.6 to 1679.8 Ωm, 0.5 to 4.2 m and 0.5 to 4.2 m as its range of resistivity, depth and thicknesses respectively; the weathered layer having resistivity of 4.8 to 61.5 Ωm, depth of 2.7 to 23.0 m and thickness of 2.1 to 21.1 m; and the fractured/fresh basement which has 158.7 to 1421.5 Ωm as its resistivity value with undefined depth and thickness. The observed curve types include: A (3%) and H (97%). The points delineated for civil engineering works are VES stations A6, B1, B6, C5 and F1 having shallow depth to basement.

Keywords. Resistivity, Basement, Depth, Geoelectric layer.

A) INTRODUCTION

The growth of any community is highly dependent on the availability of infrastructures like roads electricity and industries among others (Salako *et al.*, 2010) and according to Nnamdi, 2010, there are three important requirements for human survival, they are Food, Clothing and Shelter. Well-structured shelter is of significant importance to Nigeria where building collapse has become a familiar occurrence (Alamu and Gana, 2014). Due to improper site investigation and poor foundation, there have been several cases of building collapse in Nigeria for some decades now (Alhassan *et al.*, 2015); according to Alamu and Gana, 2014, Nigeria recorded the highest report of structural failures between 1980 and 2014. It has resulted to the loss of several lives and valuables over the years.

Vertical electrical sounding (VES) was employed to investigate the competence of the subsurface layers of the study area for civil engineering activity. Improper founding of foundation and substandard quality building materials have been the most cause of structural failure (Akintorinwa & Abiola, 2011). Sitting buildings on incompetent earth layers also affects buildings aside design error (Alhassan *et al.*, 2015). A good foundation should sustain structures erected on it in such a way as not to cause any damage to the whole or part of a building due to earth movements or vibrations.

Electrical resistivity method is widely used in preliminary site investigation to show the materials existing in the subsurface (Omowumi,2014).

The study area is located at the northern part of the Gidan Kwano Campus, Federal University of Technology, Minna. It is defined by latitude 09º32′21.4″N to 09º32′37.8″N and longitude 06º27′29.2″E to 06º27′45.5″E. The population of staffs and students are increasing within the campus as more faculties are being relocated from the Bosso campus to Gidan Kwano campus, consequently, more buildings are being built to accommodate the growing population of the area. As such, there is need to delineate the areas where the fresh basement has shallow depth and high resistivity values which can provide strong base for building construction.

Several geophysical methods have been employed over the years in determining the depth to basement, electrical resistivity method is the most effective (Alhassan *et al*., 2017). It is a reliable and an effective tool in probing into the earth's interior, its advantages includes non-destructive effect on the environment, cost effectiveness, rapid and quick survey time and less ambiguity in analysis and interpretation of data. (Todd, 1980). The Vertical Electrical Sounding (VES) technique provides information on the vertical variation in the resistivity of the subsurface layers with depth (Obiora *et al*., 2016). Wide variety of problems like determination of depth, thickness and boundary of aquifer can be solved using the vertical electrical sounding (Bello & Makinde, 2007).

GEOLOGY OF THE STUDY AREA

The study area is located at the northern part of the Gidan Kwano Campus, Federal University of Technology, Minna. It is defined by latitude 09º32′21.4″N to 09º32′37.8″N and longitude 06º27′29.2″E to 06º27′45.5″E. The study area (Minna) is underlain by Basement Complex rocks consisting of medium-grained biotite granite interbanded with coarse-grained leucocratic granite and intruded in places by quatzo-feldspar pegmatite dykes. The dykes strike parallel to the strike of the foliation, and they range from 0.5 m to 3.5 m in diameter. Outcrops are found along the river valleys as flat-lying bodies. They range in sizes from 3x5 m to about 8x15 m. Pinkish feldspar (i.e potassium feldspar) is the dominant mineral in the granite gneiss and the pegmatite. This implies that its weathered product will be rich in clay.

The rock types present in the area are part of the old granitic suite which are mostly exposed along the stream channels (Udensi *et al.,* 1986).

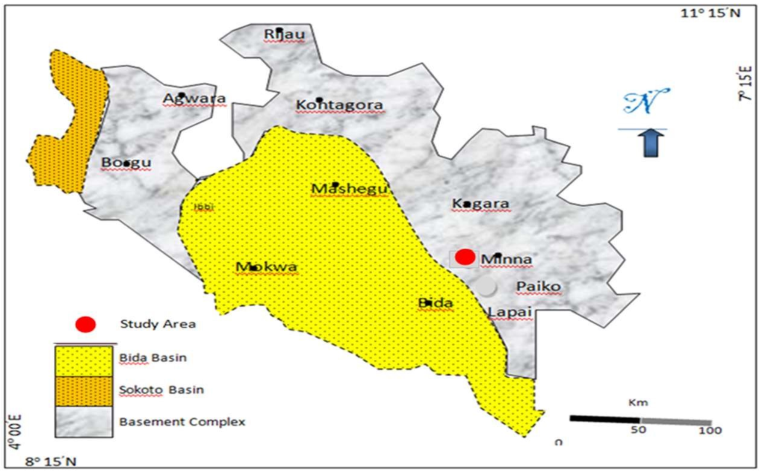


Figure 1: Geological Map of Niger State (Amadi *et al.,* 2012)

METHODOLOGY

The research employed the electrical resistivity method in delineating the shallow consolidation basement of the study area. Thirty six vertical electrical sounding (VES) points were probed using ABEM SAS 4000 model Terrameter and its accessories. Schlumberger array electrode configuration pattern with half inter current electrode spacing (AB/2) varying from 1 to 100 m was adopted. The apparent resistivity was computed using equation 1

$$\rho_a = KR \qquad (1)$$

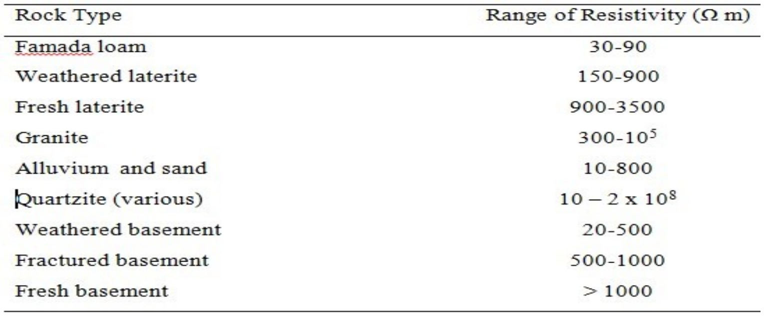
where ρ_a is apparent resistivity, R is the earth`s resistance and K is a geometric factor expressed as

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

where AB is inter current electrode spacing and MN is inter potential electrode spacing.

The apparent resistivity values obtained were plotted against AB/2 using winResist software and from the plots; the resistivity, depth and thickness of each of the subsurface layer were deduced; also, geologic cross sections were made.

Table 1: Ranges of resistivity of various rocks component in basement complex (Esimai, 2017).



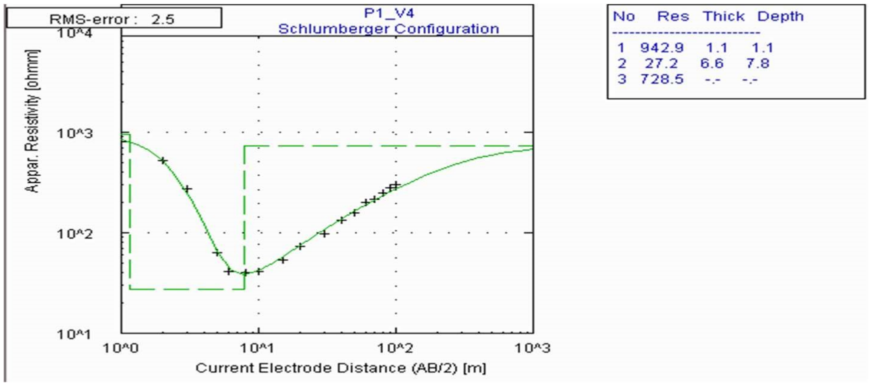
Rock Type	Range of Resistivity (Ω m)
Famada loam	30-90
Weathered laterite	150-900
Fresh laterite	900-3500
Granite	$300\text{-}10^5$
Alluvium and sand	10-800
Quartzite (various)	$10 - 2 \times 10^8$
Weathered basement	20-500
Fractured basement	500-1000
Fresh basement	> 1000

RESULTS AND DISCUSSION

The Geoelectric section (VES curve) as shown in Figure 1, provides information about the subsurface layer resistivity, depth and thickness as summarised in Table 2.

Table 2 shows the summary of results obtained from each geoelectric and geologic section (Fig. 3) and (Fig. 4) respectively 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 10.6 – 1679.8 Ωm, its depth and thickness varies between 0.5 – 4.2 m and 0.5 – 4.2 m respectively which corresponds to the geoelectrical parameters of fadama loam, weathered laterite and fresh laterite (Table 2). The second layer has resistivity value of 4.8 – 61.5 Ωm, depth of 2.7 – 23 m and thickness of 2.1 – 21.2 m; this layer refers to the weathered/fractured basement. The resistivity of the third layer ranged from 158.7 – 1421.5 Ωm, its depth and thickness are undefined.

The observed frequencies in curve types include 97% of H and 3% of A. The weathered/fractured layer in the H-curve type is usually characterized with low resistivity value made up of clayey or sandy clay (Olorunfemi *et al*. 1999).

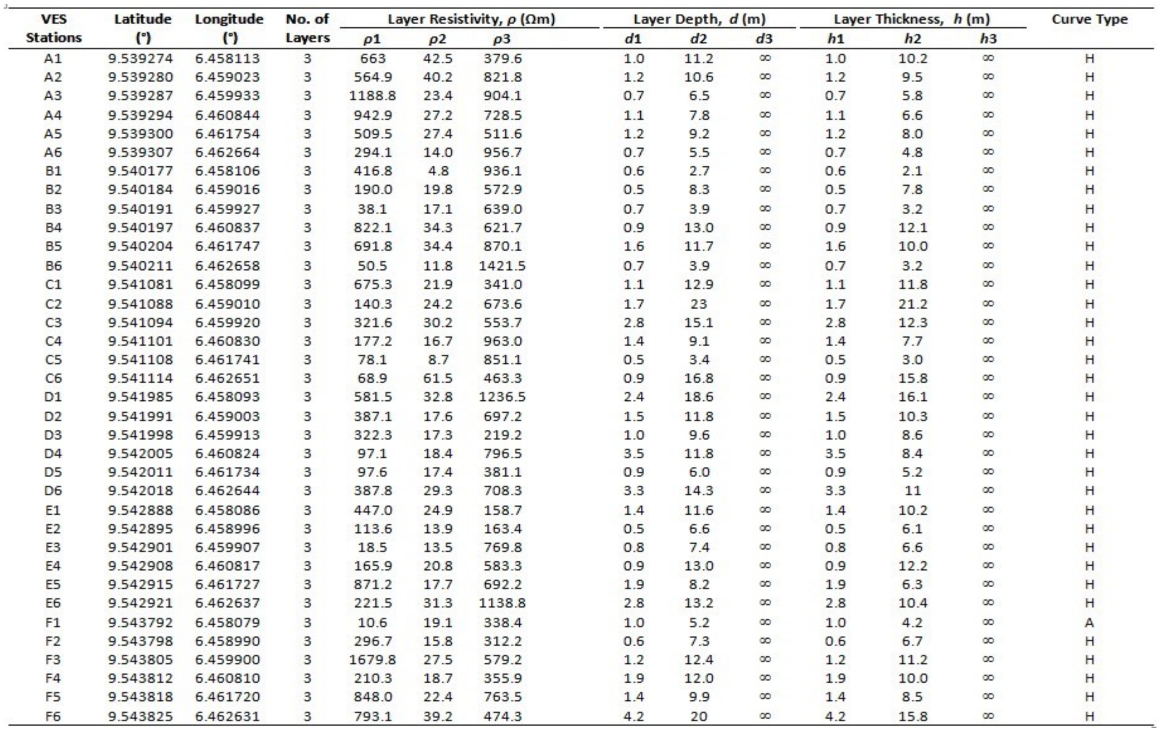


No	Res	Thick	Depth
1	942.9	1.1	1.1
2	27.2	6.6	7.8
3	728.5	-.-	-.-

Figure 2: Geoelectric section of VES point A_4

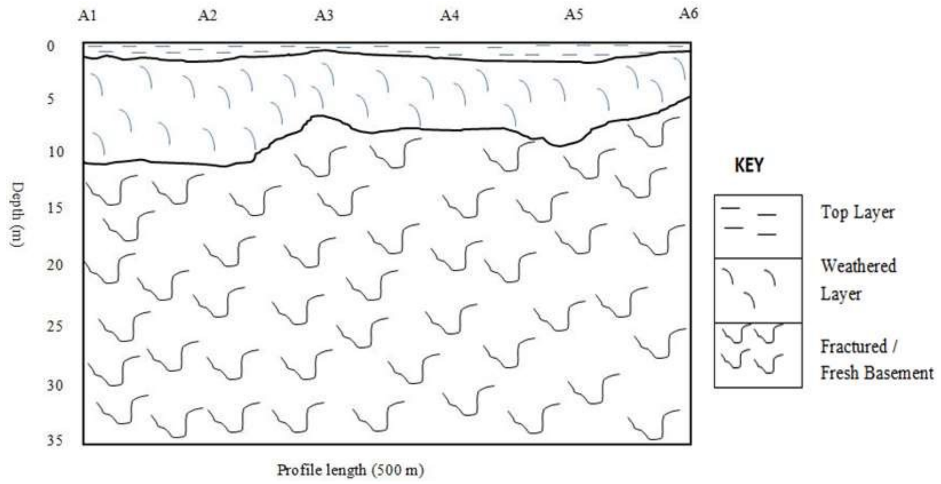
In basement complex terrain, areas with fresh basement layer depth less or equal to 4 m are favourable and good for building construction (Alhassan *et al*., 2015)

Table 2: Layer resistivity, depth thickness and curve type



VES Stations	Latitude (°)	Longitude (°)	No. of Layers	Layer Resistivity, ρ (Ωm)			Layer Depth, d (m)			Layer Thickness, h (m)			Curve Type
				$\rho1$	$\rho2$	$\rho3$	$d1$	$d2$	$d3$	$h1$	$h2$	$h3$	
A1	9.539274	6.458113	3	663	42.5	379.6	1.0	11.2	∞	1.0	10.2	∞	H
A2	9.539280	6.459023	3	564.9	40.2	821.8	1.2	10.6	∞	1.2	9.5	∞	H
A3	9.539287	6.459933	3	1188.8	23.4	904.1	0.7	6.5	∞	0.7	5.8	∞	H
A4	9.539294	6.460844	3	942.9	27.2	728.5	1.1	7.8	∞	1.1	6.6	∞	H
A5	9.539300	6.461754	3	509.5	27.4	511.6	1.2	9.2	∞	1.2	8.0	∞	H
A6	9.539307	6.462664	3	294.1	14.0	956.7	0.7	5.5	∞	0.7	4.8	∞	H
B1	9.540177	6.458106	3	416.8	4.8	936.1	0.6	2.7	∞	0.6	2.1	∞	H
B2	9.540184	6.459016	3	190.0	19.8	572.9	0.5	8.3	∞	0.5	7.8	∞	H
B3	9.540191	6.459927	3	38.1	17.1	639.0	0.7	3.9	∞	0.7	3.2	∞	H
B4	9.540197	6.460837	3	822.1	34.3	621.7	0.9	13.0	∞	0.9	12.1	∞	H
B5	9.540204	6.461747	3	691.8	34.4	870.1	1.6	11.7	∞	1.6	10.0	∞	H
B6	9.540211	6.462658	3	50.5	11.8	1421.5	0.7	3.9	∞	0.7	3.2	∞	H
C1	9.541081	6.458099	3	675.3	21.9	341.0	1.1	12.9	∞	1.1	11.8	∞	H
C2	9.541088	6.459010	3	140.3	24.2	673.6	1.7	23	∞	1.7	21.2	∞	H
C3	9.541094	6.459920	3	321.6	30.2	553.7	2.8	15.1	∞	2.8	12.3	∞	H
C4	9.541101	6.460830	3	177.2	16.7	963.0	1.4	9.1	∞	1.4	7.7	∞	H
C5	9.541108	6.461741	3	78.1	8.7	851.1	0.5	3.4	∞	0.5	3.0	∞	H
C6	9.541114	6.462651	3	68.9	61.5	463.3	0.9	16.8	∞	0.9	15.8	∞	H
D1	9.541985	6.458093	3	581.5	32.8	1236.5	2.4	18.6	∞	2.4	16.1	∞	H
D2	9.541991	6.459003	3	387.1	17.6	697.2	1.5	11.8	∞	1.5	10.3	∞	H
D3	9.541998	6.459913	3	322.3	17.3	219.2	1.0	9.6	∞	1.0	8.6	∞	H
D4	9.542005	6.460824	3	97.1	18.4	796.5	3.5	11.8	∞	3.5	8.4	∞	H
D5	9.542011	6.461734	3	97.6	17.4	381.1	0.9	6.0	∞	0.9	5.2	∞	H
D6	9.542018	6.462644	3	387.8	29.3	708.3	3.3	14.3	∞	3.3	11	∞	H
E1	9.542888	6.458086	3	447.0	24.9	158.7	1.4	11.6	∞	1.4	10.2	∞	H
E2	9.542895	6.458996	3	113.6	13.9	163.4	0.5	6.6	∞	0.5	6.1	∞	H
E3	9.542901	6.459907	3	18.5	13.5	769.8	0.8	7.4	∞	0.8	6.6	∞	H
E4	9.542908	6.460817	3	165.9	20.8	583.3	0.9	13.0	∞	0.9	12.2	∞	H
E5	9.542915	6.461727	3	871.2	17.7	692.2	1.9	8.2	∞	1.9	6.3	∞	H
E6	9.542921	6.462637	3	221.5	31.3	1138.8	2.8	13.2	∞	2.8	10.4	∞	H
F1	9.543792	6.458079	3	10.6	19.1	338.4	1.0	5.2	∞	1.0	4.2	∞	A
F2	9.543798	6.458990	3	296.7	15.8	312.2	0.6	7.3	∞	0.6	6.7	∞	H
F3	9.543805	6.459900	3	1679.8	27.5	579.2	1.2	12.4	∞	1.2	11.2	∞	H
F4	9.543812	6.460810	3	210.3	18.7	355.9	1.9	12.0	∞	1.9	10.0	∞	H
F5	9.543818	6.461720	3	848.0	22.4	763.5	1.4	9.9	∞	1.4	8.5	∞	H
F6	9.543825	6.462631	3	793.1	39.2	474.3	4.2	20	∞	4.2	15.8	∞	H

B)



C)

Figure 3a: Vertical Geologic section through profile A

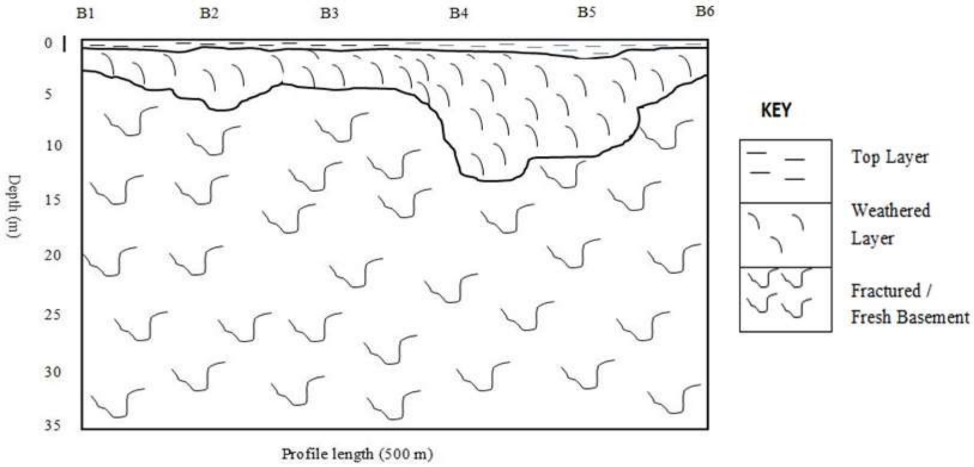


Figure 3b: Vertical geologic section through profile B

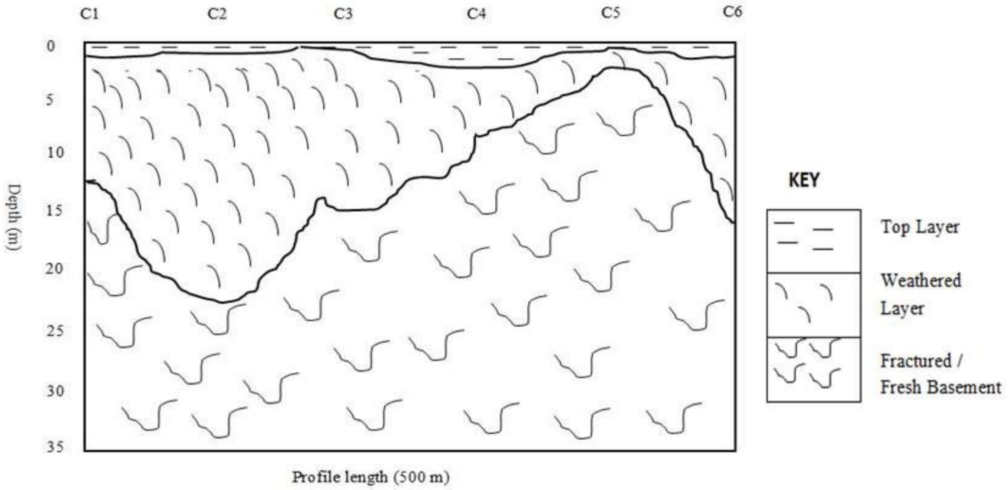


Figure 3c: Vertical geologic section through profile C

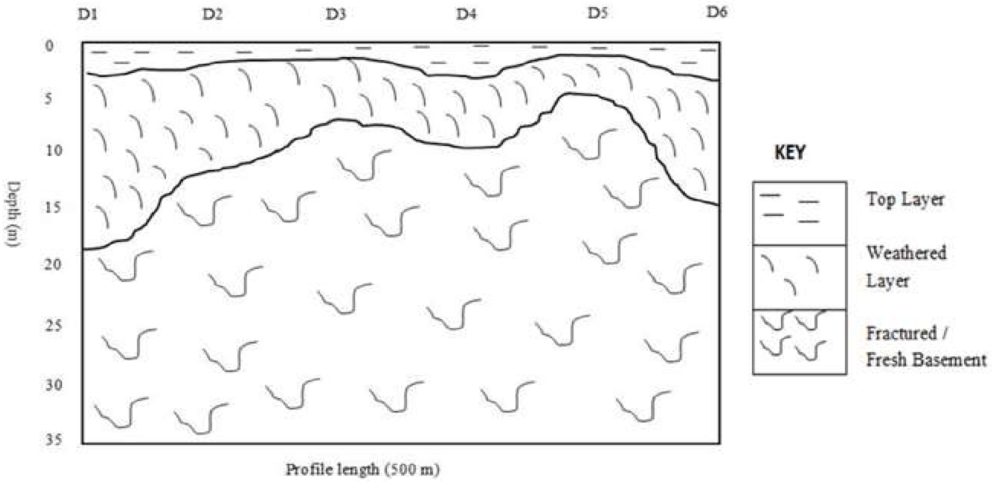


Figure 3d: Vertical geologic section through profile D

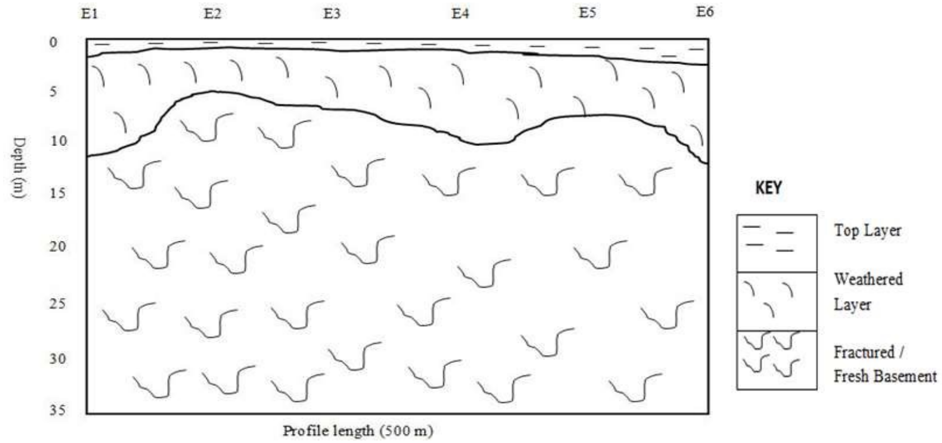


Figure 3e: Vertical Geologic section through profile E

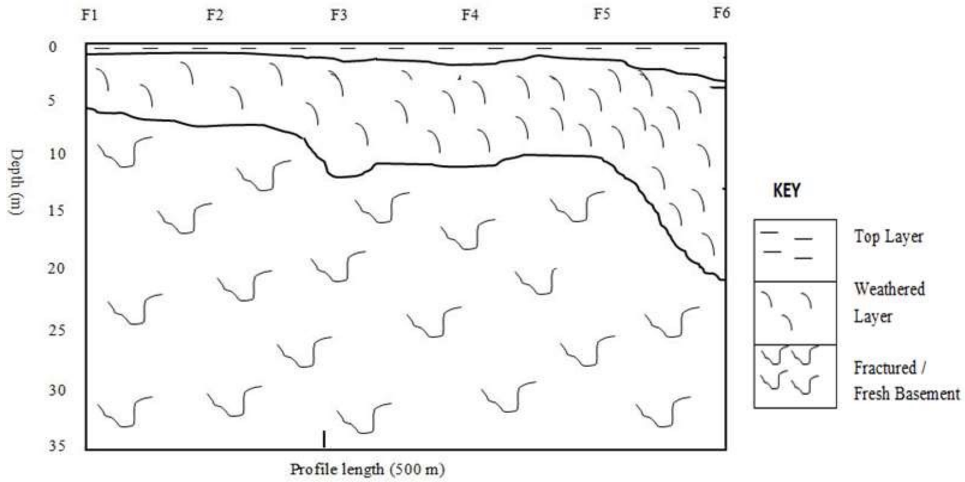


Figure 3f: Vertical Geologic section through profile F

Iso-resistivity map (Figure 4) were also obtained for the layers using the Golden Surfer software in order to investigate the continuous variation of resistivity with depth. An interval of 100 Ωm was used to generate the iso-resistivity contour of the first layer (Figure 4a). The range of the resistivity values is 10.6 to 1,679.8 Ωm. The areas with the lowest resistivity

the northern and southern parts.

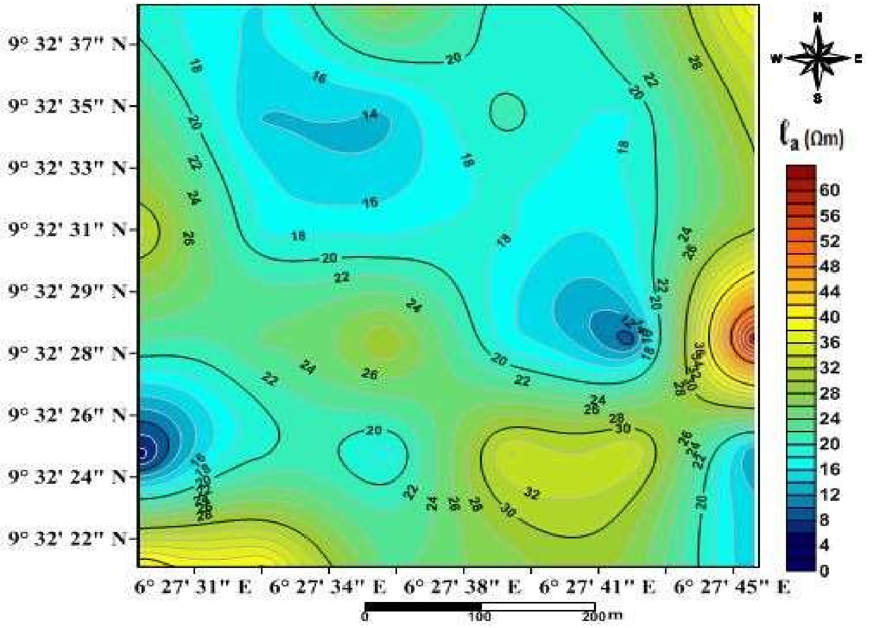


Figure 4a: Iso-resistivity contour map of the first layer

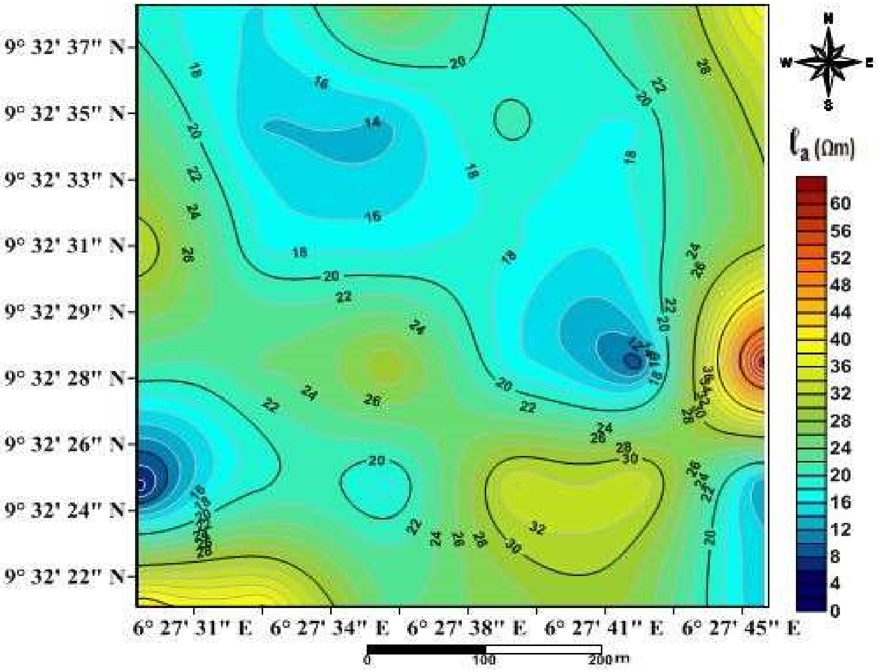


Figure 4b: Iso-resistivity contour map of the second layer

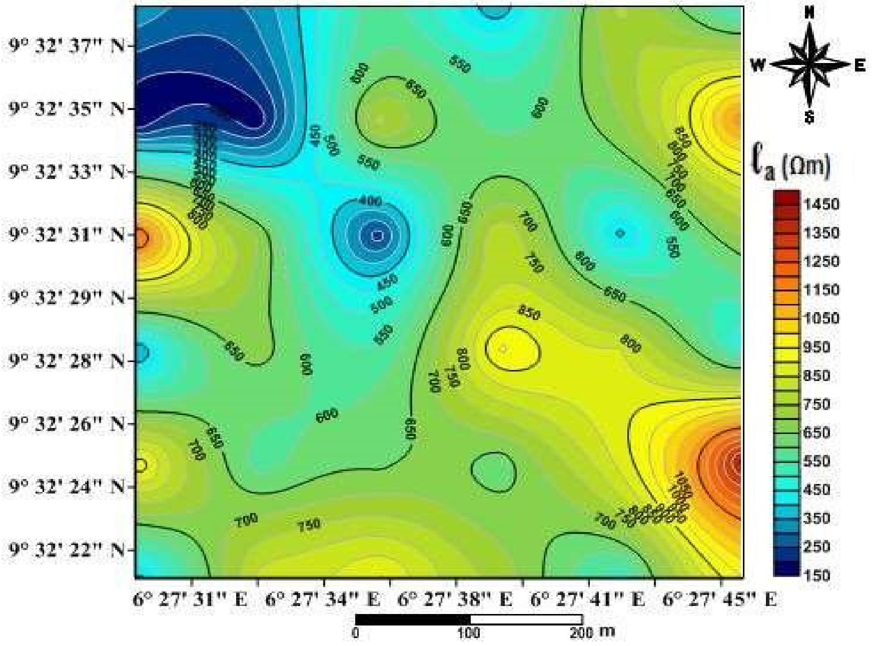


Figure 4c: Iso-resistivity contour map of the third layer

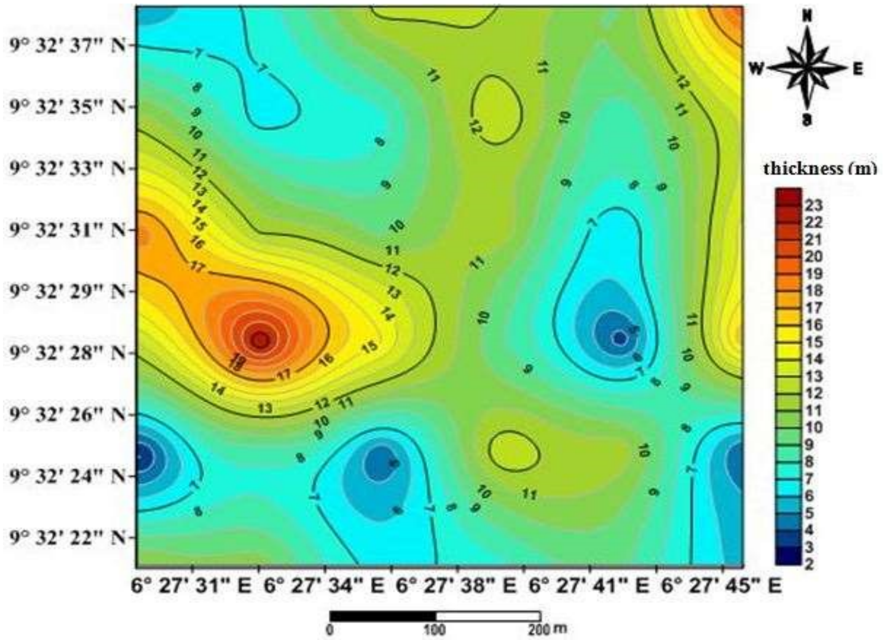


Figure 4d: Overburden contour map of the study area.

The iso-resistivity contour of the second layer (Figure 4b) was generated at an interval of 4 Ωm. The contour shows that the resistivity of the weathered/fractured zone is higher at the northeastern, eastern and southern part of the study area while the northern and central part are characterised by lower resistivity value. The iso-resistivity contour of the third layer (Figure 4c) reveals that the study area is highly weathered/fractured. The contour was generated at 100 Ωm interval with resistivity values ranging from 158.7 to 1421.5 Ωm. The third layer has its lowest resistivity value majorly at the north-western part of the study area while those of high resistivity occupy the north-eastern, south-western and south-eastern parts. The Isopach (overburden contour map) was generated at an interval of 1 m, the values range from 2.7 to 23 m as shown in Figure 4d. The contour reveals that overburden thickness is higher at the north-eastern and west-central parts of the study area while the north-western, southern, south-eastern and south-western parts are of lower overburden thickness.

Table 3: Recommended points for civil engineering works

VES Station	Latitude( )	Longitude( )	Number of layers	Depth to basement
A_6	9.539307	6.462664	3	5.5
B_1	9.540177	6.458106	3	2.7
B_6	9.540211	6.462658	3	3.9
C_5	9.541108	6.461741	3	3.4
F_1	9.543792	6.458079	3	5.2

The sites suitable for structures within the study area were delineated after careful consideration was given to the resistivity, depth and thickness of the subsurface layers, five VES points having depth to fresh basement varying between 2.7 to 5.5 m were chosen; the points are: A_6, B_1, B_6, C_5 and F_1 as shown in Table 3.

D) CONCLUSIONS

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 the parameters of the subsurface structures. 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 layer and the fractured/fresh basement layer.

The resistivity of the top layer, weathered layer and fractured/fresh basement layer varies from 10.6 to 1,679.8 Ωm, 4.8 to 61.5 and 158.7 to 1,421.5 Ωm respectively across the entire study area; the depth of the top layer ranges from 0.5 to 4.2 m, that of the weathered layer varies from 2.7 to 23.0 m while that of the fractured/fresh basement layer is undefined across the six(6) profiles investigated; also, the study area has 0.5 to 4.2 m and 2.1 to 21.2 m as the thickness of its the top layer and weathered layer respectively, the fractured/fresh basement layer has an undefined thickness. Government and estate developers who wish to site structures within the study area should consider VES points A_6, B_1, B_6, C_5 and F_1. Quality excavation work should be carried out if structures must be built anywhere within the study area aside the afore mentioned points, more research work in this area would contribute immensely to solving the problem of building collapse completely.

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