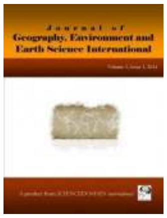

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Application of Electrical Resistivity in Building Foundation Study around Led School Area in Bishini, Northwestern Nigeria

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Authors' contributions

This work was carried out in collaboration by all the authors. All authors participated in the data acquisition. Author OFO designed the study, participated in interpretation of the data and wrote the protocol. Author AOT prepared the site map, participated in interpretation of the data, wrote the introduction, conclusion and abstract of this paper. He was responsible for the editing/formatting of the manuscript. He is the corresponding author responsible for all correspondences. Author LOA managed the literature searches and editing of the draft manuscript. Author AAO participated in the interpretation of the field data as well as editing the draft manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the structural competence of the subsurface geological materials around Led School Area in Bishini, NW Nigeria to delineate the area that is suitable for building development. Twenty Seven vertical electrical soundings (VES) points were occupied in the study area employing ABEM Terrameter SAS 300C with Schlumberger electrode configuration of maximum electrode separation AB/2=150 m. The field resistivity data were interpreted using Win RESIST software. The results from the 2-D interpretation of the VES data were used to prepare the geoelectric sections along four cross sections. The interpreted results showed that the geoelectric sections consist of

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three to five layers, which are: Top soil, Laterite, Lateritic clay, weathered layer and Fresh basement. The resistivity value and subsurface layer thickness for the top soil varied from 191.7 Ω m to 8146 Ωm and 0.3 m to 7.0 m respectively. The Laterite layer had resistivity values ranging from 1000 Ωm to 1627.3 Ωm and thickness between 1.8 m and 2.5 m. The weathered layer resistivity varied from 33.5 Ω m to 850 Ω m with thickness of 3.6 m to 44 m. The bedrock resistivity ranged from 1238.3 Ωm to 33438.6 Ωm. Geoelectric sections along profile 4 and 1 revealed the thinnest sequence of loose overburden materials and fresh basement at the shallowest depth. The area covered by these profiles is suitable for building development. Building development should not be located along profiles 2 and 3 due to relatively thick weathered layer. However the area may be considered for citing borehole to harness its groundwater potentials.

Keywords: Competence; geological materials; geoelectric sections; bedrock; building development.

1. INTRODUCTION

Non availability of potable water and accommodation of staff and students constitute challenges in most boarding schools warranting the need to develop housing structures around the school areas that will conveniently accommodate enough people. Construction of buildings for students' accommodation need cautious approach to avoid the incidence of building failures and collapses that constitute major issues of concern, affecting urban development in Nigeria and the world at large. Although ground conditions rarely prohibit development entirely, they do introduce material planning considerations including flood risk, development of contaminated land, and capacity of subsurface infrastructure [1,2].This study is intended to serve as a pre-construction investigation for evaluation of site condition at Led School, Bishini, Northwestern Nigeria, as an aid to geotechnical engineers. A building constructed at a site without properly considering the underground strata or its load-bearing capacity may settle excessively or differentially, causing development of cracks in building which may ultimately lead to its failure and collapse. Subsurface geological features such as fractures, voids and nearness of water table to the surface are among the inconveniences that pose considerable constraints to building constructions especially to their foundation [3]. Geophysical methods, particularly geoelectrical resistivity techniques, have been extensively used for a wide variety of engineering and environmental problems [4-11]. The use of electrical resistivity measurements has been a favorite tool of geophysicists because of the wide range of resistivity values found in nature which represents a greater dynamic range for this technique than most other commonly used methods. Electrical resistivity survey is relatively easy to perform and can be used to identify geological structures. The application of electrical resistivity survey has become a prime choice, as a result of the cheap cost that is involve and the fact that it saves time and easy to carry out and can also be used to determine geological structures [12]. In this study, a non-invasive geophysical technique involving Vertical Electrical Sounding using Schlumberger array was adopted to investigate the subsurface conditions at the possible areas for construction of building for staff and students around the school premises.

2. SITE LOCATION AND GEOLOGY

Bishini lies between co-ordinates 10.433° to the North and 7.867° to the East within the Basement Complex of Nigeria (Fig. 1). The area is a little less than half square kilometer. Bishini falls within the geologic terrain underlain by the Precambrian Basement Complex rocks of Nigeria characterized by the Migmatite-gneiss complex, older granites, charnockites, quartzite and minor intrusive lithologies. The local geology showed that the area is underlain by rocks of the Basement Complex (migmatites, gneisses and granite). Outcrops are rare except for a few Laterite capping the bedrock. The Laterite consists of different horizons with distinct petrographic characteristics which may have significant influence on the shape of the VES curves. The surface terrain is fairly uniform permitting easy stretch of the Schlumberger array.

3. MATERIALS AND METHODS

The site investigation involved Vertical Electrical Sounding (VES), which was carried out at 27 points with the aids of ABEM SAS 300C Terrameter, four electrodes (C1, C2, P1, P2), measuring tape and hammers. An electric current I (amperes, A) was injected into the ground through the current electrodes (C1, C2), while two other electrodes P1 and P2 are used to record the resulting potential difference V (volt, V) (Fig. 2). Schlumberger electrode configuration of maximum electrode separation, AB/2∆f 150 m was used. The potential electrodes remained fixed and the current electrodes were expanded simultaneously about the center of the spread (Fig. 2). When the distance between the current electrodes was large, the distance between the potential electrodes was increased to have a measurable potential difference. The apparent resistivity measurements at each station were plotted against electrode spacing (AB/2). The VES data obtained were subjected to partial curve matching using two-layer master curves and auxiliary curves as an initial stage of data interpretation [13,14]. The layered earth model thus obtained served as the input model for the inversion algorithm as a final stage in the quantitative data interpretation [15-17]. The results obtained (layer resistivities and thicknesses) were fed into a computer as a starting model in an iterative forward modeling technique using WIN RESIST. From the interpreted results (layer resistivities and thicknesses), geoelectric sections along direction N-S were produced, and results were also used to generate histogram.

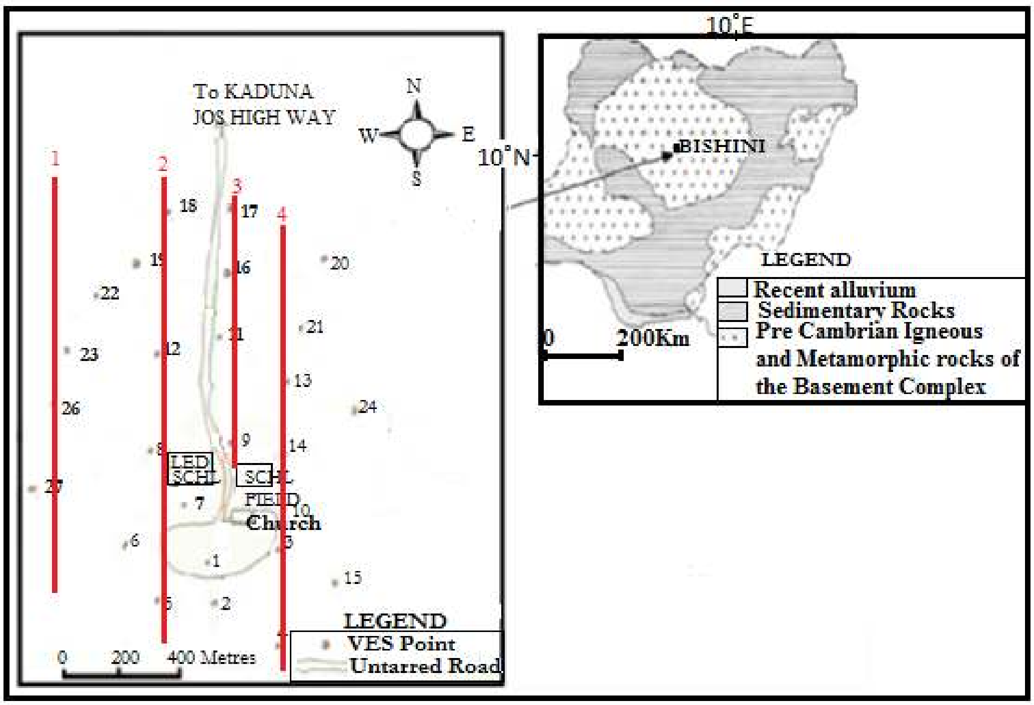

Fig. 1. Base map of the study area showing VES points and cross section lines

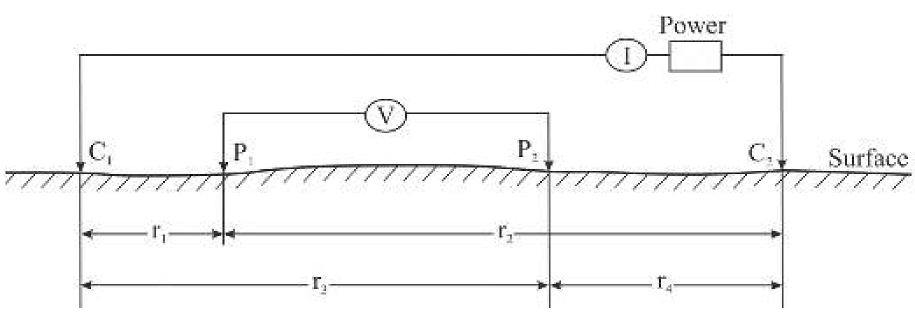

Fig. 2. Principle of VES; Two current (*C1* and *C2)* and two potential (*P1* and *P2*) electrodes in the standard configuration [17]

4. RESULTS AND DISCUSSION

The results of the study were presented as Sounding Curves, Histogram and Geoelectric sections. Five types of curves were identified in the area of investigation. The H curve occurred most in the area, accounting for about 89% of the total curves, followed by QH curve with about 33% degree of occurrence; HA and HKH constitute about 11% each; KH has the least occurrence with about 6% representation of the total curves (Table 1). Furthermore, representative of the VES curves (6H, 2QH, 1HA, 1HKH and 1KH) are presented in Fig. 3 while Fig. 4 illustrates the histogram of the curves which clearly showed that H type curve was predominant.

The VES results were used to prepare 2-D geo-electric sections (Fig. 5a-d) along cross-section lines 1, 2, 3 and 4 (Fig. 1). The sections revealed the geo-electric/geologic characteristics of the subsurface layers. Top soil, laterite, lateritic clay, weathered basement and the fresh basement constitute the five layer configuration while the three layer configuration consists of top soil/lateritic clay, weathered basement and fresh basement. The resistivity value and subsurface layer thickness for the top soil/lateritic clay varied from 191.7 Ωm to 8146 Ωm and 0.3 m to 7.0 m respectively. Laterite which form part of the second layer along profile 1(Fig. 5a) has resistivity values ranging from 1000 Ωm to 1627.3 Ωm and thickness between 1.8 m and 2.5 m. The resistivity value for weathered layer varied from 33.5 Ωm to 850 Ωm and its thickness varied from 3.6m to 44m. The bedrock resistivity ranged from 1238.3 Ωm to 33438.6 Ωm.

4.1 Geoelectric Section along Profile 1

Geolelectirc section along profile1 comprises of VES stations 27, 26 and 23 (Fig. 5a). The first layer constitutes the top soil with layer resistivity values ranging from 1200 Ωm to 2500 Ωm. The layer thickness ranges from 1.5m to 2.0m. The second layer varied in composition for the three

Table 1. Summary of resistivity values and layer thicknesses

VES no	ρ_1(Ωm)	ρ_2(Ωm)	ρ_3(Ωm)	ρ_4(Ωm)	ρ_5(Ωm)	h_1(m)	h_2(m)	h3(m)	h_4(m)	Curve types
1	8146.0	721.8	197.0	22401.9	-	1.3	4.7	28.1	-	QH
2	671.7	75.7	4418.9		-	6.0	12.4		-	H
3	232.7	121.8	155.3	3283.8	-	1.0	2.3	32.0	-	HA
4	1467.5	652.8	33.5	17906.5	-	2.3	0.7	6.0	-	QH
5	5514.3	1197.5	269.0	1344.6	-	1.3	9.3	17.0	-	QH
6	2177.7	120.7	34292.9	-	-	4.4	16.3	-	-	H
7	1089.6	173.3	23872.4	-	-	7.0	36.0	-		H
8	2935.9	349.7	33438.6	-	-	1.7	44.0	-	-	H
9	1074.2	72.2	12660.4	-	-	6.1	12.8	-	-	H
10	1201.5	133.1	3124.3	-	-	1.9	16.0	-	-	H
11	1299.7	137.7	10937.9	-	-	5.6	34.0	-	-	H
12	984.7	242.3	6570.0	-	-	4.5	38.3	-	-	H
13	2400.3	84.7	3637.8	-	-	3.7	22.4	-	-	H
14	566.8	55.6	31357.3	-	-	2.2	12.1	-	-	H
15	881.5	111.8	2698.2	-	-	2.4	8.2	-	-	H
16	2350.0	1800.0	1000.0	1950.0	-	1.7	7.7	23.0		HA
17	2599.9	246.3	6277.1	-	-	1.8	28.0	-	-	H
18	1133.2	96.5	5143.9	-	-	6.1	11.7	-	-	H
19	1233.8	179.1	3371.4	-	-	2.1	15.8	-	-	H
20	1572.5	1223.9	84.5	9299.6	-	1.4	7.7	19.6	-	QH
21	1162.5	302.7	2203.7	-	-	2.0	11.9	-	-	H
22	191.7	2666.2	60.0	2063.0	-	0.3	1.4	3.6	-	KH
23	2500.0	1670.0	850.0	1800	-	1.5	8.0	15.0	-	QH
24	6184.1	1209.5	259.1	1238.3	-	1.1	8.1	19.9	-	QH
25	1538.2	137.2	1719.8	-	-	2.5	14.1	-	-	H
26	1200.0	1000.0	2000.0	800.0	2000.0	1.5	2.5	7.0	20.0	HKH
27	1746.2	1627.3	1944.2	102.2	11164.3	2.0	1.8	1.4	6.7	HKH

VES stations. While VES 26 and VES 27 have loose lateritic materials with resistivity values of 1000 Ωm and 1627.3 Ωm respectively as their second layer with average thickness of 2.2 m, hard pan lateritic clay of resistivity value 1670.0 Ωm form the second layer in VES station 23 and has a thickness of about 8 m. It extends to form third layer in VES stations 26 and 27. Weathered basement of average resistivity and thickness values of 451.1 Ωm and 13.4 m respectively forms the fourth layer in VES stations 26 and 27. It occurs as third layer in VES station 23 and has resistivity value of 850 Ωm and thickness of 15 m. Fresh basement with resistivity values varying from 1800 Ωm to 11164.3 Ωm is closer to the surface at VES station 27 than VES station 26 and 23. To construct high building that can accommodate large number of staff around this area, introduction of pilling for the structure to rest directly on the competent bed must be considered to avoid differential settlement of the building which may cause some major cracks on the building.

4.2 Geoelectric Section along Profile 2

This geoelectric section encompasses VES 5, 8, 12 and 18 (Fig. 5b). The resistivity of the top soil/Lateritic clay which form the first layer ranges from 984.7 Ωm to 5514.3 Ωm and its thickness varies from 1.3 m to 6.1 m. Weathered lateritic materials/weathered basement form the second layer with resistivity value ranging from 96.5 Ωm to 349 Ωm and its thickness ranges from 11.7 m to 44 m. The weathered layer along this profile is relatively thick especially at VES station 8 and 12. The last geoelectric layer beneath these VES points constitutes the fresh bedrock with resistivity ranging from 1344.6 Ωm to 33438.6 Ωm. This site may not favour construction of high building because of nearness of weathered layer to the surface and its high thickness, but borehole can be sited at VES stations 8 and 12 to take care of water challenges.

4.3 Geoelectric Section along Profile 3

Geoelectric section along profile 3 contains three VES stations – VES 9, 11, and 17 (Fig. 5c). It reveals three geoelectric layers. The first layer which is top soil/lateritic clay has resistivity ranging from 1074.2 Ωm to 2599.9 Ωm and its thickness varies from 1.8m to 6.1 m. Directly below the top soil is weathered layer with resistivity values ranging from 72.2 Ωm to 246.3 Ωm. The thickness of this layer ranges from 12.8 m to 34 m. The last layer detected along this profile is the fresh basement with resistivity varying from 6277.1 Ωm to 12660.4 Ωm. Weathered layer is closer to the surfce at VES stations 11 and 17 than VES station 9. Fresh basement seems to be the only competent layer that can sustain heavy structure along this profile. Due to the relatively thick weathered layer in this area, the area may not be able to support heavy structures, alternatively a groundwater abstraction facility e.g. a borehole may be suitably sited around the area to harness its groundwater potential.

4.4 Geoelectric Section along Profile 4

Six VES stations, VES 4, 3, 10, 14, 13 and 21, arranged in this order, are along this profile 4 (Fig. 5d). The resistivity of the top soil ranges from 232.7 Ωm to 2400.3 Ωm and its thickness varies from 1.0m to 3.7m. Lateritic clay underlay the topsoil from VES 4 to VES 3 along the section.

It has resistivity values that vary from 121.8 Ωm to 652.8 Ωm. Its thickness varies from 0.7 m to 2.3 m. Weathered layer forms second layer in VES 10, 14, 13 and 21. It extends from VES 3 to VES 4 as third layer with resistivity ranging from 55.6 Ωm to 302.7 Ωm and thickness ranging from 6 m to 32 m. The fresh basement along this profile is relatively close to the surface and it has resistivty ranging from 2203.7 Ωm to 17906.5 Ωm. The resistivity of the basement is a function of the degree of weathering and hence its strength [18-20]. This implies that basement rocks with low basement resistivity values <2000 Ωm within the study area should be avoided for siting any heavy structure. According to [20], regions with high fresh basement resistivity (>6000) Ωm) are areas of high competence, hence in this work, the regions coloured red are competent areas for civil works. Section along profile 4 which has the thinnest sequence of loose overburden materials spread over the longest lateral distance conforms with the findings of [18-20] and is most favourable and suitable for siting high building with large accommodation capacity; this is because the fresh basement is at the shallowest depth here, thus requiring the least excavatory work.

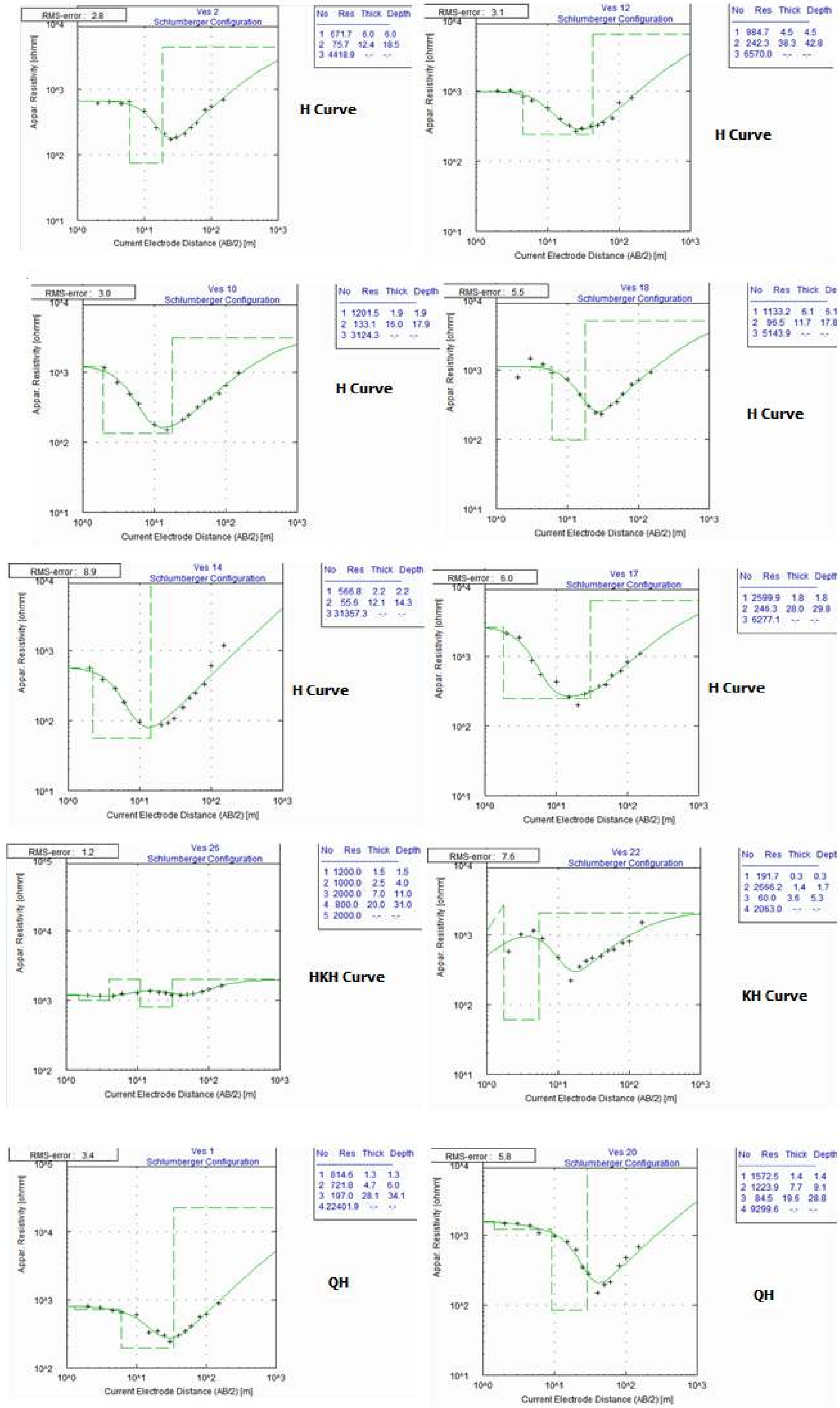

Fig. 3. Representative sounding curves from the study area

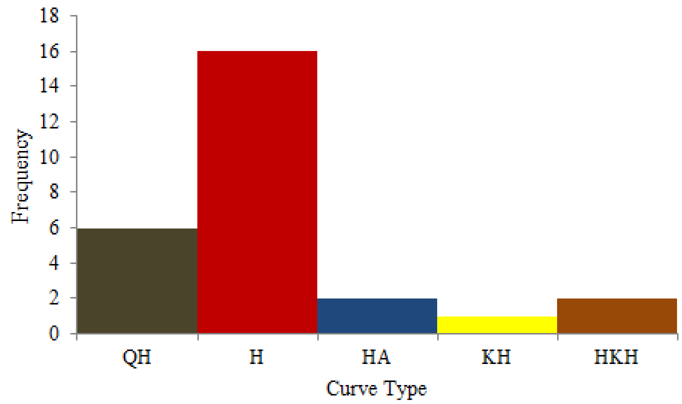

Fig. 4. Histogram of the VES curve types in the study

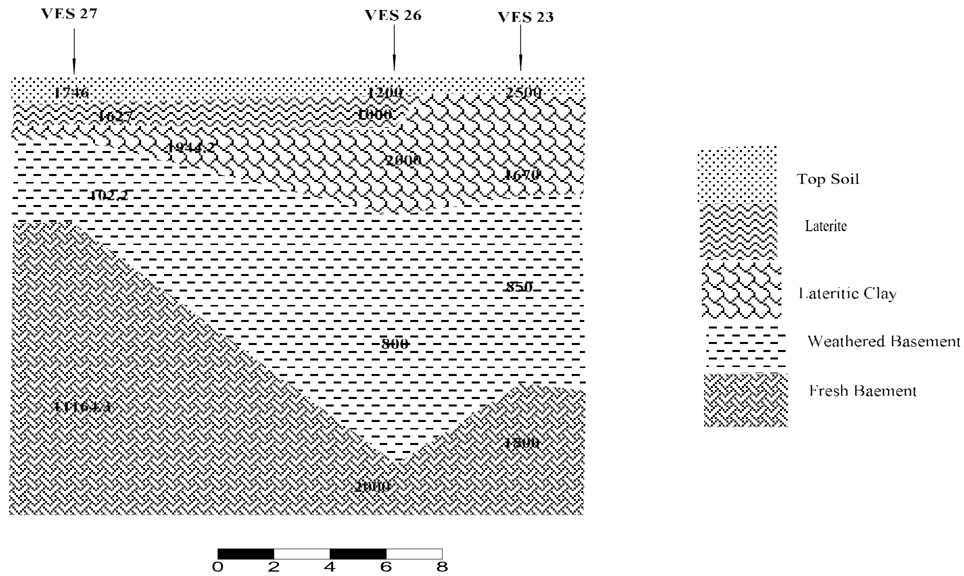

Fig. 5a. Geoelectric section of profile 1

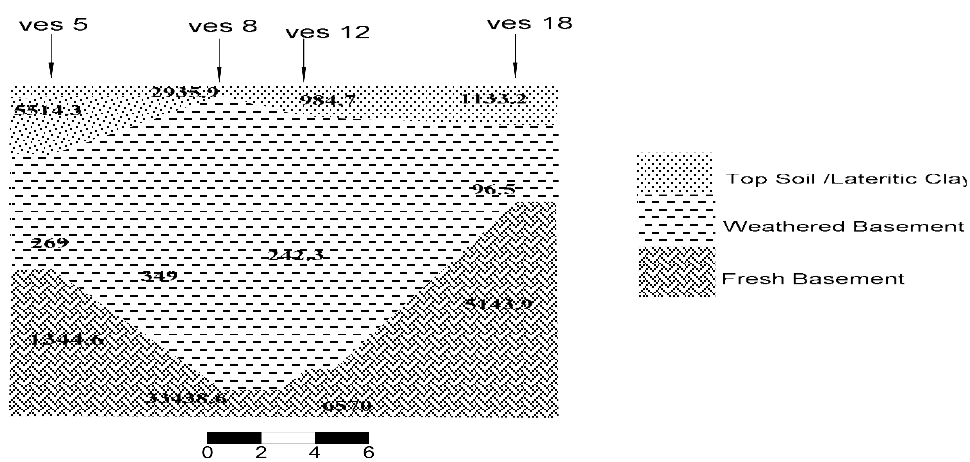

Fig. 5b. Geoelectric section of profile 2

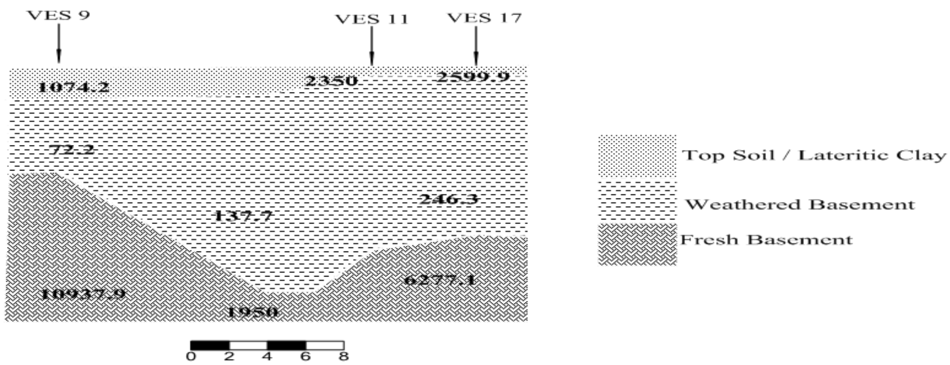

Fig. 5c. Geoelectric section of profile 3

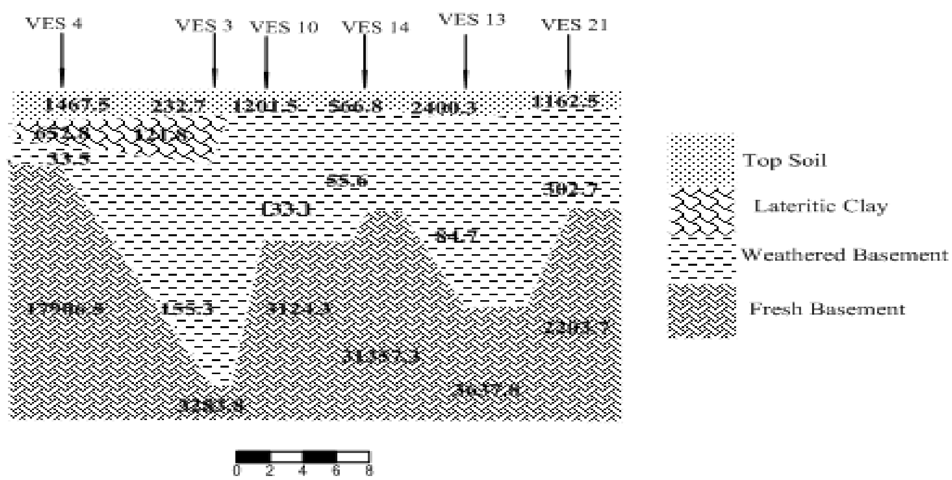

Fig. 5d. Geoelectric section of profile 4

5. CONCLUSION

Geophysical investigation involving Electrical resistivity method has been carried out in the study area to delineate the various lithological units at a proposed building site in Led School in Bishini, Northwestrn Nigeria. Twenty seven VES measurements were taken and the results obtained from the interpretation of the VES curves were used to prepare geoelectric sections along five cross sections so as to reveal the subsurface lithologic successions. Four major layers were delineated from the study area which comprises topsoil, laterite, lateritic clay, weathered basement and fresh basement. Geoelectric section along profile 4 revealed that the area has the thinnest sequence of loose overburden materials spread over the longest lateral distance and fresh basement is at the shallowest depth here. This makes the area to be most favourable and suitable for siting high building with large accommodation capacity. Geoelectric section along profile 1 also revealed that this area can be considered for high building when piling to competent rock is introduced. Owing to relatively thick weathered layer along Profile 2 and 3, the area may be considered for siting borehole to harness groundwater potentials.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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