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Application of Schlumberger Method to Investigate Sub-Soil Formation in Tudun Wada Area of Maiduguri Metropolis, Northern Nigeria

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Abstract: *The geophysical survey, using Vertical Electrical Sounding (VES) adopting Schlumberger configuration were conducted using ABEM SAS Terrameter, across Tudun Wada area of Maiduguri Metropolis Northeast Nigeria to evaluate the soil potential of the area. Based on interpretation by Computer software Interpex IX1D. All of the sounding points sample revealed three geo-electric layers/geologic units. The geologic units with hydro geologic significance include; first layer, second layer and third layer and characterized resistivity values range from 11.057-2044 Ωm, 1.7731-65.851 Ωm respectively. The layer thickness of the first and second layer vary from 6.1081- 0.50383 m and 0.71006-18.326 m.*

Keywords: *Resistivity, Delineate, Lithology, Maiduguri, Vertical Electrical Sounding*

I. Introduction

Site investigation and estimation of soil settlement characteristics are essential parts of a geotechnical design process. Geotechnical engineers must determine the average values and variability of soil properties (Al-Jabban M.J.W (2013).

Geophysical methods are used for the delineation of subsurface sequence, identification of geological structures and determination of physical parameters of rock formations. These information enhance rapid characterization of subsurface formations, identification of competent subsurface layers, determination of thickness and depth required for the design of civil engineering foundation. Virtually all civil engineering structures (e.g roads, dams, runways, bridges e.t.c) are sited on earth materials (soils, regolith or rocks). Investigating the subsurface at a proposed site to ascertain fitness of the host earth materials is important prior to the design of such structures (Olorunfemi et al., 2004). Geotechnical and civil engineering structure failure could result from the nature of the subsoil, undetected near-surface/subsurface geological structures, features induced by anthropogenic activities or inhomogeneities in soils and geomaterials constituting the foundation (Olorunfemi et al., 2000a; Olorunfemi et al., 2000b, Oladapo et al., 2008; Akintorinwa et al., 2011 and Fatoba, 2012). Such anomalous features are amenable to geophysical delineation (Olorunfemi, 2008).

Soil will be threatened if losses it water during drought causing foundation to settle near the perimeter where the soil dries most quickly. The interaction between soils and solid materials is one of the main problems encountered in civil engineering practice, such as: retaining walls, pile foundations, shallow foundations, earth reinforcement and earth dams. The friction between different construction materials and soils postulating that the most important factors affecting the friction are: normal stress level, moisture content, roughness and soil composition.

II. Material And Methods

Tudun Wada area is situated few maters behind the Department of Security Services (DSS) and bordered from east and west by Yerwa Government Girls Secondary School and PHCN Bulunkuttu Unit Maiduguri respectively. It is located between latitudes $11^0 50`$ and $50^0 24`$ N and longitudes $13^0 06`$ and $13^0 07`$ E. Lateritic soil is usually considered as a good natural foundation and building material.

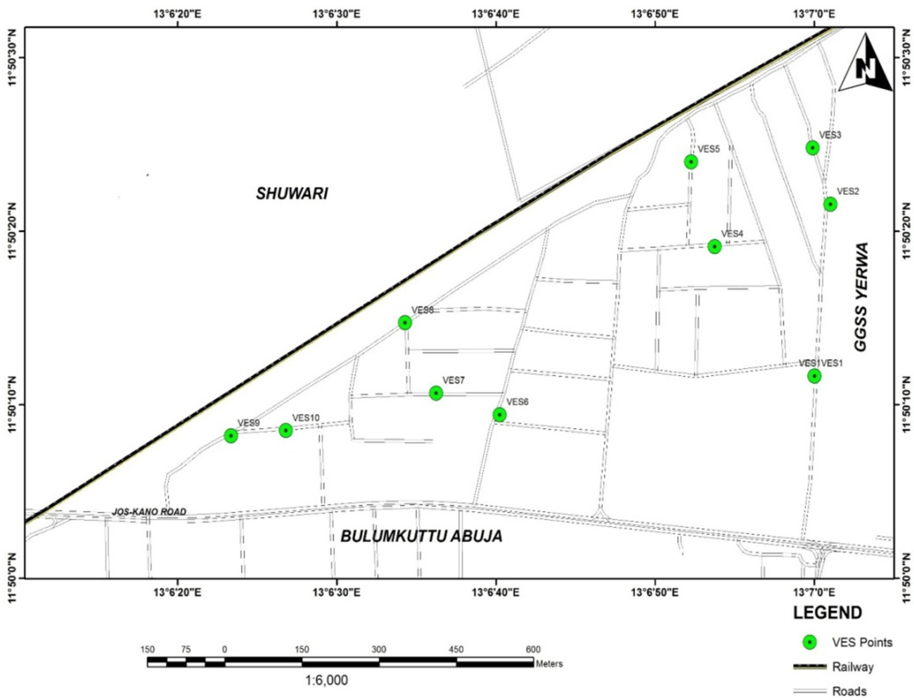


Figure 1: Map of the study area indicating sounded 10 points

Data Collection: In geophysical surveys, the Terremeter SAS 300 permits natural or induced signals to be measured at extremely low power consumption. Moreover, it can be used in a wide variety of application where effective signal noise discrimination is needed. In the resistivity mode, it comprises a battery powered, deep-penetration resistivity meter with an output sufficient for a current electrode separation of 2000 *m* under good surveying condition. Discrimination circuitry and programming separates DC voltage, self-potential and noise from the incoming signal. The resistance V/I is calculated automatically and displayed in digital form in kilo-ohms ($k\Omega$), or milli-ohms ($m\Omega$). The Terremeter SAS 300 contains three main units, all housed in a single casing: the transmitter, the receiver and the microprocessor. The electrically isolated transmitter sends out well-defined and regulated signal currents. The receiver discriminates noise and measures voltage correlated with transmitted signal current (resistivity surveying mode).

Table 1: Apparent Resistivity Data for the Ten VES Points

AB/2	MN/2	VES1	VES2	VES3	VES4	VES5	VES6	VES7	VES8	VES9	VES10
1.0	0.2	70.01	71.01	800.0	55.01	50.01	30.01	70.01	58.01	900.5	25.86
1.5	0.2	67.83	37.54	558.6	53.54	45.47	28.31	10.72	32.48	492.4	26.30
2.0	0.2	60.84	37.74	498.1	52.22	40.30	22.38	10.74	18.35	146.5	25.93
2.5	0.2	49.15	36.87	373.3	52.08	38.27	19.98	10.30	13.83	79.29	25.44
3.0	0.2	38.66	37.44	257.9	54.75	36.42	18.98	10.82	12.97	72.26	26.07
4.0	0.2	30.11	35.58	149.0	54.64	34.41	16.88	9.460	12.56	60.41	25.55
5.0	0.2	27.15	34.69	97.71	52.51	31.45	15.01	9.980	12.14	47.90	24.41
6.5	0.2	25.15	35.06	76.79	53.33	32.45	16.72	11.23	13.24	47.86	25.06
8.0	0.2	23.01	30.13	77.69	51.83	33.46	18.09	5.690	17.56	50.29	22.9
10	0.2	20.82	28.65	65.72	49.23	37.60	20.49	14.03	16.88	50.18	22.30
8.0	1.5	20.15	25.00	64.75	48.23	36.78	20.23	15.23	15.98	50.29	21.45
10	1.5	19.26	25.18	63.69	48.89	37.18	21.89	16.78	18.21	49.98	23.43
13	1.5	20.03	25.02	68.99	47.13	40.81	26.74	15.52	19.95	49.85	22.49
16	1.5	20.95	25.62	70.34	47.13	41.22	32.88	16.52	23.36	51.23	24.33
20	1.5	25.82	30.79	75.92	40.71	43.26	35.17	19.73	28.01	50.60	24.67
25	1.5	28.3	32.99	75.69	38.92	47.87	52.67	24.08	36.56	51.83	27.95
30	1.5	29.45	34.00	75.04	35.38	45.31	55.11	31.65	45.42	55.25	37.42
40	1.5	30.94	33.23	90.81	30.61	49.50	68.92	40.32	58.65	70.74	46.91
50	1.5	32.28	32.81	96.10	29.46	48.89	87.15	45.22	65.53	83.75	47.40
65	1.5	30.44	30.89	100.1	27.94	52.16	95.99	50.07	77.95	88.04	60.35
80	1.5	33.56	29.93	110.2	28.04	53.91	100.8	50.06	82.71	90.32	61.63
100	1.5	35.12	35.56	120.2	35.02	52.93	131.0	48.20	89.38	100.2	63.61

Data Processing: Interpex is a software company dedicated to the production of high quality affordable software for the processing, interpretation and display of geophysical data. The Model Entry dialog box allows for dynamic column and row manipulations to make model entry more convenient. Either the layer thickness (or depth) and/or the resistivity can be fixed in the inversion process. Forward and inverse model calculations can be carried out using buttons on the model entry dialog. Models can be inverted using either the layer depth or layer thickness. Graphics are presented as the Sounding data on the left hand side with the model on the right hand side. Interactive property sheets allows for user configuration of displayed data. For DC and IP data, the model can be displayed on the same axes as the data. Menu commands and toolbar buttons are available for estimating a layered model (DC and IP data only), estimating a smooth model or analyzing equivalence of the layered model. Forward modeling, inverse modeling, smooth model estimation and equivalence analysis can be carried out individually. Profiles and soundings can be selected by name or by point and click at a map location. Soundings on a profile can be selected by point and click on a profile location. A model can be copied to the model clipboard and then back to an individual sounding, all soundings on a profile or to every sounding in the database. Consequently, data obtained was apparent resistivity of the area under study though the data was characterized by some errors. In order to obtain better model or near precise data were smoothened and alternative model was displayed alongside the original curve and each time the curves smoothened, the raw data was also adjusted to the required values. The data afterward was fed in to computer for interpretation, analyses and credible conclusion

III. Result

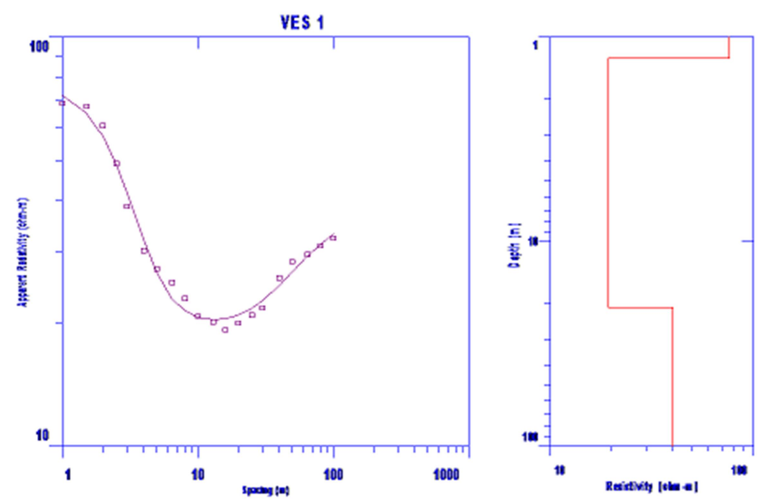
Data generated from the Vertical Electrical Sounding using Schlumberger configuration were presented as Geoelectric sounding curve and Geoelectric section. Geoelectric section shows the subsurface layers, resistivity, depth and thickness while Geoelectric Sounding Curves were obtained by plotting the apparent resistivity value against the electrode spacing using Computer software IX1D for interpretation. All of which were iterated thereafter on the computer with the same software program, to minimize as much as possible the errors which yield near better curves.

Table 2: Summary of Interpretation of data

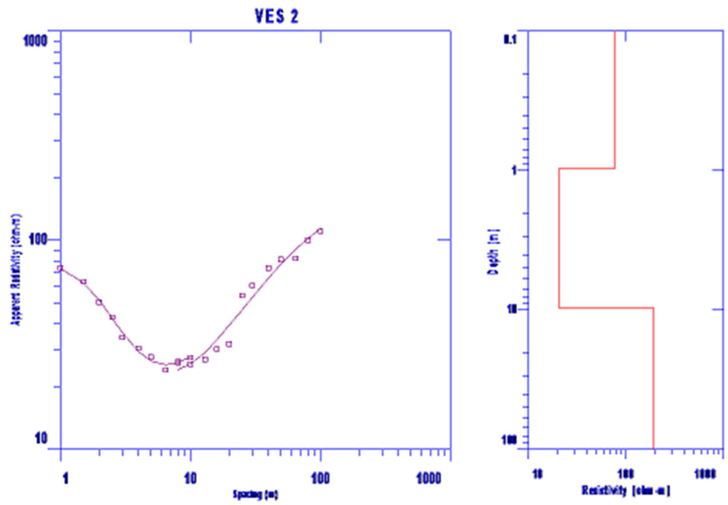
VES	$\rho(\Omega m)$	Thickness (m)	Depth (m)	Lithology	Curve type	Elevation (m)	Error %
1	76.292	1.2654	1.2654	-clay	H	-1.2654	4.94
	19.445	19.651	20.916	-unconsolidated wet clay		-20.916	
	40.231			-sandy clay			
2	38.145	4.9732	4.9732	-clay sand	H	-4.9732	2.95
	9.0897	2.6503	7.6235	Wet clay		-7.6235	
	36.254						
3	831.42	1.1162	1.1162	-laterite	H	1.1162	4.38
	65.815	18.326	19.442	-sandy		19.442	
	142.86			-silty			
4	53.221	11.959	11.959	-sandy clay	Q	-11.959	2.89
	21.875	57.263	69.222	-clay		-69.222	
	214.80			-sand			
5	49.913	1.1381	1.1381	-sandy clay	H	-1.1381	2.63
	25.633	3.2314	4.3695	-clay		-4.3695	
	53.082			-sand			
6	29.115	1.5769	1.5769	-clay fresh water	H	-1.5769	5.92
	5.1829	1.9252	3.5021	-fresh ground water		-3.5021	
	229.79			-sand and gravel			
7	11.057	2.5005	2.5005	-fresh ground water	K	-2.5005	17.58
	2.3597	1.2811	3.7816	-fresh ground water		-3.7816	

	89.647			-dry clay			
8	118.17 11.058 169.29	0.48792 6.1081	0.48792 6.5961	-laterite -fresh ground water -laterite	H	-0.48792 -6.5961	6.46
9	2044.0 48.653 146.87	0.50383 20.614	0.50383 21.118	-dry clay -laterite	H	-0.50383 -21.118	9.50
10	26.208 1.7731 100.06	5.4963 0.71006	5.4963 6.2063	-clay -dry clay	H	-5.4963 -6.2063	4.95

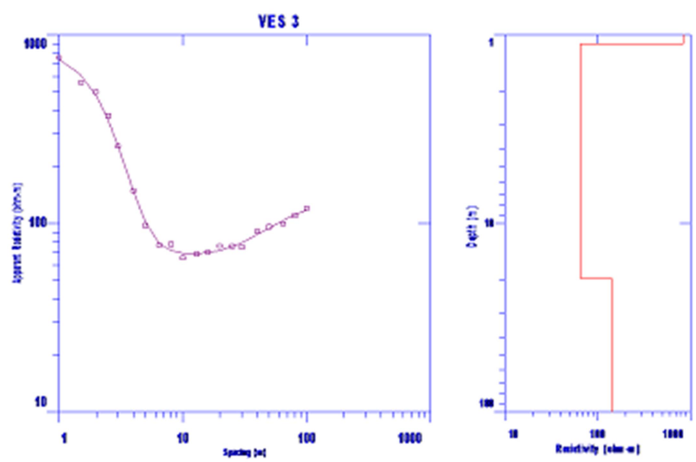
The interpretation of vertical electrical sounding (VES) data for the survey is quantitative. The following are display of the interpreted data.



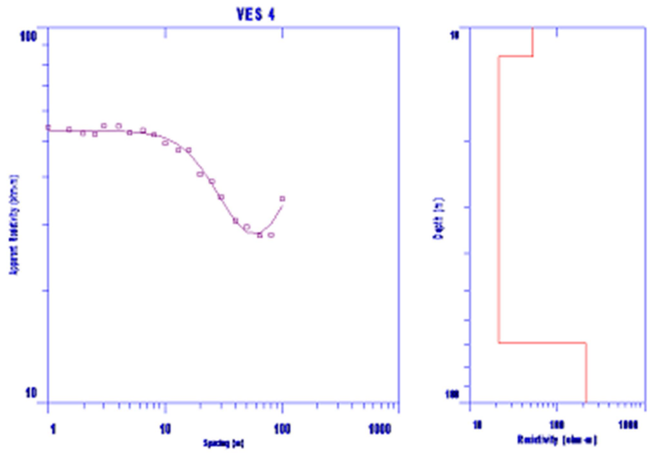
VES 1: The VES show a three layer succession with first two layers having thickness of 1.2654 m and 19.651 m respectively, and the last layer of infinite thickness. This is a type H curve indicating a dry layer under laid by water saturated layer. If the first and second layer made up of same materials will they have the resistivity in this range 19.445 Ωm? But the other section is saturated. If in the same vein the material of third layer with resistivity of 40.231 Ωm which is over laid by moist region is same as layer two, can they have low resistance but only part of it is saturated with water. The sounding point has a fitting error of 4.94%.



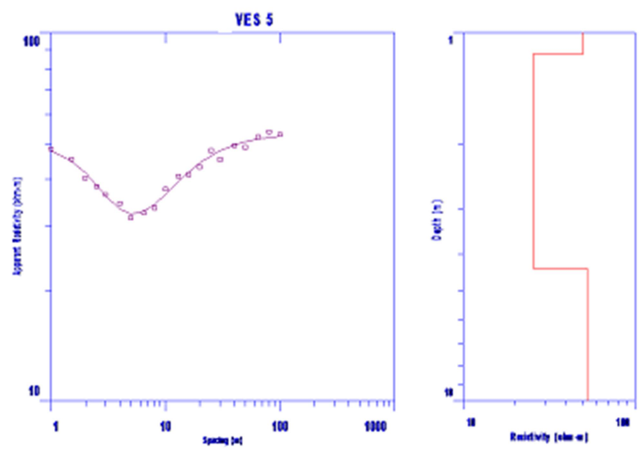
VES 2: This VES point with a fittings error 2.95% is related to the last layer but thickness of first layers differs the former is thinner with value 1.265 *m* while the latter is thicker with 4.9732 *m*. It has a three-layer case revealing a high resistance of 38.145 **Ω***m* in the first layer under laid by moisture layer with resistivity of 9.0897 **Ω***m*. If both layers contain the same material will they have same low resistivity? But with one section saturated with water, would they have same formation if the resistivities of third and second layer are the same low resistance with one part saturated with water? The lithologies in this sounding point are sandy clay, wet clay and claye sand. It is *H* type curve.



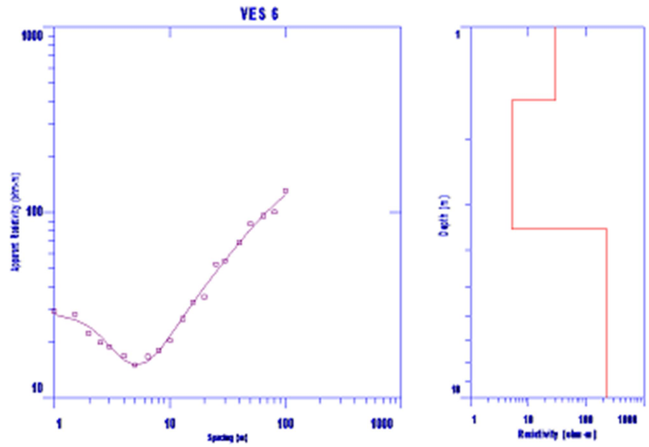
VES 3: Three layer cases were sample in this VES point with 4.38%. It is thinner with thickness of 1.1162 *m* than the previous two but related in same pattern with high resistivity of 831.42 **Ω***m* under laid by moist region with resistance of 65.815 **Ω***m* at just depth of 19.442 *m*. If these two layers have same materials will they have same low resistivity? But one part is moist. If in the same vein the second and third layers are dominated by same material, will they have similar resistivity but section of it is, saturated with water. This is *H* type sounding point with laterite, sandy and silty formation.



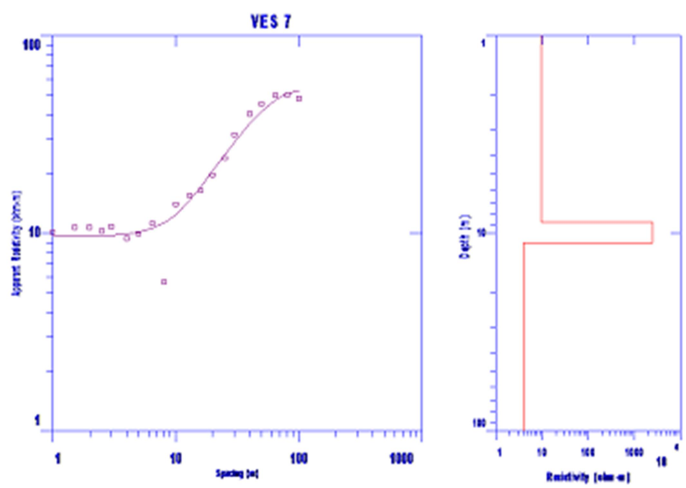
VES 4: The VES show a three-layer succession with first two layers having thickness of 11.959 *m* and 69.222 *m* respectively and the last layer of infinite thickness. This sample point is different from the previous ones in that it is *Q* type curve. Will the low resistivity of 21.875 **Ω***m* be attributed to all three layers if supposing made up of same material with one part saturated with water? This VES point has a lithology of sandy clay, clay and sand.



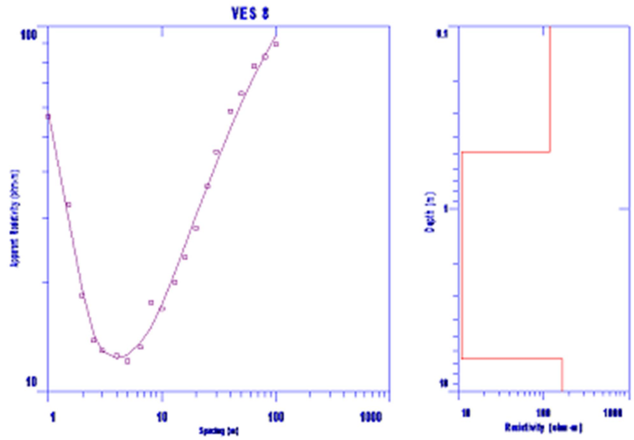
VES 5: This profile with less than 3% fitting error recorded three layers. It has a similarity with previous VES points but it is thinner in first layer which pervious with resistivity of 49.913 **Ω***m* under laid by moisture content layer with value 25.633 **Ω***m*. If the layer is occupied by same material will they have same low resistance with one part domicile with moisture? The infinitely layer with 53.083 **Ω***m*, if having a similar low resistance with the layer two, can the material in the sub surface be same with one part saturated with water? The formations are sandy clay, clay and sand. This is a type *H* curve.



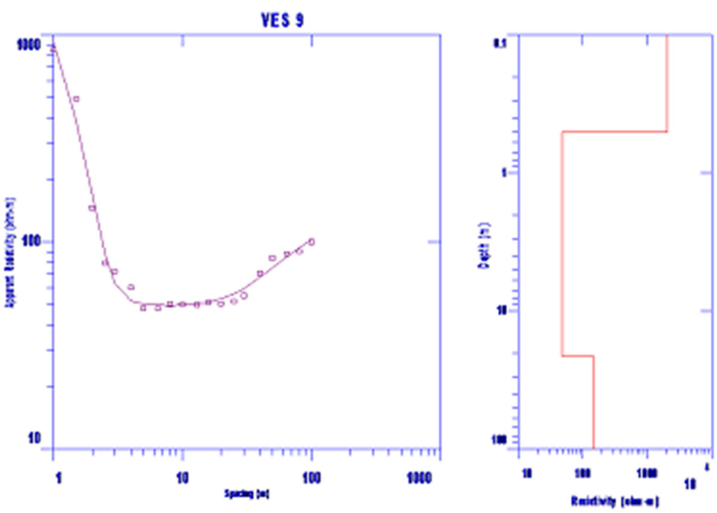
VES 6: This sounding point with fitting error of 5.92% has succession of three layers. It has similarity with above layers but the first and second layer with thin values 1.5769 *m* and 1.9252 *m* respectively. The first and second layers are dominated by low resistivity of 29.115 **Ω***m* and 5.1829 **Ω***m* material because both are water saturated region. In the other hand third layer is impervious because it has a very high resistivity of 229.29 **Ω***m*. The lithologies are clay fresh water, fresh ground water and sand and gravel. It is type *H* curve.



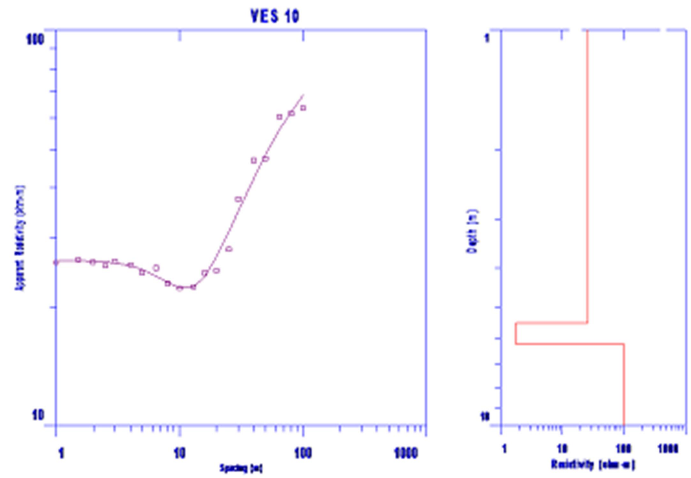
VES 7: Three-layer case profiled with fitting error up to 17.58%. The first and second layers have low resistivity of 11.057 **Ω***m* and 2.3597 **Ω***m* at a depth of 2.5005 *m* and 1.2811 *m* respectively. In third layer the resistivity gone up 89.647 **Ω***m* because of impermeable nature of the material. The first and second layers are made up of same materials which differ from the rest of the VES points discussed. This gives the evident for heterogeneity of the earth. It has a following formations fresh ground water, fresh ground water and dry clay. It is type *K* curve.



VES 8: This sounding point has a sequence of three layers profile with a fitting error of 6.46%. It is however, related to the rest of the sounding points because first dry layer with value 118.17 **Ω***m* under laid low resistance of 11.058 **Ω***m*. If supposedly, having the same material will the resistivity be conformed to low with one section of it is saturated with moisture. The infinite layer under laid by low resistance, has a high resistivity of 169.69 **Ω***m* dominated by laterite material while the first two are made up of laterite and fresh ground water. Layer two of the proceeding VES point is related to this second layer in the formation which fresh ground water.



VES 9: This shows a three layer with fitting error of 9.50%. Layer one has a high resistance of 2044.0 **Ω***m* at very thin thickness of less than 1 *m* indicating very dry zone under lay by moist layer at very lengthy depth of 21.118 *m*. beneath this layer is another dry section with high resistivity of 146.87 **Ω***m*. There is a similarity between this and the last sounding point. If layer one and two contain same material will they have same low resistivity with one section dominated by moisture? Same apply to layer second and third, if made up of same material can they have similar resistivity but only one part is moist. It has lithologies of dry clay and laterite and it is type *H* curve.



VES 10: In this VES point three layers sample having a fitting error 4.95%. This profile has a very good relationship but thicker than most of the VES points and has a resistivity of 26.208 Ω*m* with thickness of 5.4963 *m* under lain another water saturated zone at a depth of 6.2063 *m* with resistivity of 1.7731 Ω*m* but in third layer the resistivity gone up to 100.06 Ω*m*. if these three layers were made of same material will they have same low resistivity? But one section is dry. The lithologies are clay, wet clay and dry clay and a type *H* curve.

IV. Discussion

The Vertical Electrical Sounding modelling carried out in 10 VES stations was used to derive the geo-electric section of various profile; which indicate the existence of three geologic layers in the study area in each VES points where the survey was carried out. This comprised of first layer, second layer and third layer. The layer one consists of sandy soil or gravel with resistivity range from 11.057 Ω*m* to 2044.0 Ω*m* and thickness range from 0.48792 *m* to 11.959 *m*. There is some small content of moist material suspected to be clay indicated by the low value of resistivity which was referred to as VES 6, 7 and 10. All were drilled in the same side of the tar road in the west side. The layer two has a resistivity ranges from 1.7731 Ω*m* 65.815 Ω*m* thickness varies from 0.71006 *m* to 57.263 *m* which is highest layer in terms of thickness and it is in the VES 4, which is more appropriate for other geophysical activities especially Drilling of Boreholes, due to a probable high water content. The layer three has a resistivity ranges from 36.254 Ω*m* to 229.79 Ω*m* which move infinitely in depth. Therefore the bedrock from topsoil or earth`s surface ranges from 1.1162 *m* to 69.222 *m* respectively.

Furthermore, it is observe that the geo - electric curve type identified in the area with the exception of VES 4 and 7 which are *Q* and *K* respectively, the rest are *H*. Therefore, from the data analysis of the curve types, curve *H* is most dominants in the area. However, the resistivity distribution reveals that, the resistivity is lowest in the most part of the area with value 1.7731 *Ωm* at just less than 1 m which is found in the western part of the area. From the indication of the data analysis the study area is underlain by clay soil which has an adverse effect on foundation due it contraction and expanding nature thereby causing crack on building structures. Clear evidence of a structure problem is the appearance of cracks on column or beams. Vertical cracks are more problematic than horizontal ones. Cracks on walls appear in most new buildings which are the result of the settlement of foundations; although depending on circumstances they could appear also in the older buildings. Some cracks, which are classed as (hairings) can be repaired and should not create a serious problem if repaired with a coat of paint. If these cracks however continue to appear and the gap becomes larger, this is something more serious.

V. Conclusion

Vertical Electrical Sounding (VES) technique carried out at 10 VES stations in Tudun Wada area of Maiduguri Metropolis Northeast Nigeria to reveal the soil potential of the area. Computer aided interpretation of the VES data showed that the model curves consist of mainly *K*, *Q* and *H* with three geoelectric layers/geologic units. The result of successful Electrical Drilling indicates that top soils are mostly dominated by dry material suspected to be either sand or gravel while in the second layer significance amount of moisture content is observed base on the pattern of resistivity value ranges from 11.057-2044 Ω*m*, 1.7731-65.851 Ω*m* respectively. However by considering the result obtained it is an indication that the study area has a good land for boreholes and other Engineering and Architectural activities, due to the features that enhance. The geophysical investigation carried in the area using Schlumberger array further delineated that the area is underlain by clay soil manifest itself in form of cracks.

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