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Estimation of overburden thickness of industrial estate Ogbomoso, Southwestern Nigeria

***Theophilus Aanuoluwa Adagunodo and Lukman Ayobami Sunmonu**

Department of Pure and Applied Physics, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Oyo State Nigeria.

ABSTRACT

Vertical Electrical Sounding (VES) geophysical method was used to delineate Oyo State Industrial Estate, Ogbomoso South Local Government Area, Southwestern Nigeria. The study area falls within latitude $08^0\ 06^{'}\ 07.4^{''}$ and $08^0\ 06^{'}\ 25.4^{''}$ and longitude $004^0\ 15^{'}\ 03.3^{''}$ and $004^0\ 15^{'}\ 49.0^{''}$. The research was conducted with a view to estimating the overburden thickness and to know the competent zones with respect to engineering purpose in the study area. Ten Vertical Electrical Soundings (VES) were carried out across the area using the schlumberger electrode array configuration with current electrode separation (AB) varying from 130m to 200m. Nine out of the ten modeled curves were H-type where the remaining one was KH-type. The geoelectric sections obtained from the sounding curves revealed 3-layer and 4-layer earth models respectively. The models showed the subsurface layers categorized into the topsoil/first layer, second layer, third layer (which only revealed beneath one VES station), and the last layer (which is either fractured basement or fresh bedrock). Areas with thick overburden and those with fractured basement are the areas that factories making use of heavy machines should not be built on it. This is because the continual vibration of the heavy machines might cause subsidence in the factories in the future which might lead to loss of life and properties.

Keywords: Vertical Electrical Sounding, Thin Overburden, Thick Overburden, Industrial Estate, Fresh Bedrock, Fractured Basement.

INTRODUCTION

Collapses of buildings have become more intense and devastating in Nigeria today. Many buildings have collapsed because of the subsurface pattern, contrary to opinion which favours insufficiency or lack of genuine building materials. These happened as a result of little or no idea of the people about the subsurface pattern. If the factories are located on the fracture zones, the vibration of the heavy machines present in the factories will cause little but a very appreciable increment in the lateral extent of the fractures over a long period of time. As the fracture zone increases, there might be deformation in the foundation of the factory due to the continuous vibration of the heavy machines. That is the reason why factories should not be built on the fractured zone. It is therefore imperative to carry out geophysical survey before the building construction commences to avoid collapses which lead to loss of life and properties that are unquantifiable.

Geophysical methods are often used in site investigation to determine depths to the basement and map subsurface characterization prio to excavation and construction. Vertical Electrical Soundings have been used by different authors to determine overburden thickness and Geoelectric parameters of subsurface [1, 2, 3, 4, and 5]. The resistivity method has its origin in the 1920's due to the work of Schlumberger brothers. For the next 60 years, for quantitative interpretation, conventional sounding surveys were normally used [6]. In this method, vertical electrical soundings (VES) were conducted using Schlumberger electrode array [7]. The method is suitable for engineering and hydrogeological investigations [2].

This study aimed at providing detailed geophysical signatures for overburden thicknesses of the VES stations with a view to determining the average depth to basement of the site with respect to engineering purposes of the area.

SITE DESCRIPTION AND GEOLOGICAL SETTING

The studied area lies within the crystalline Basement Complex of Nigeria [8]. It lies within latitude $08^{0}\ 06^{'}\ 07.4^{''}$ and $08^{0}\ 06^{'}\ 25.4^{''}$ and longitude $004^{0}\ 15^{'}\ 03.3^{''}$ and $004^{0}\ 15^{'}\ 49.0^{''}$ (Figure 1). The study area is located at the outskirt of Ogbomoso South Local Government and shares boundary with Surulere Local Government Area along old Oshogbo road. The study area is accessible with network of roads that surrounds it and very close to Aarada market.

The rock groups in the area include quartzites and gneisses [9]. Schistose quartzites with micaceous minerals alternating with quartzo-feldsparthic ones are also experienced in the area. The gneisses are the most dominant rock type. They occur as granite gneisses and banded gneisses with coarse to medium grained texture. Noticeable minerals include quartz, feldspar and biotite. Pegmatites are common as intrusive rocks occurring as joints and vein fillings [2 and 10]. They are coarse grained and weathered easily in to clay and sand-sized particles, which serve as water-bearing horizon of the regolith. Structural features exhibited by these rocks are foliation, faults, joints and microfolds which have implications on groundwater accumulation and movement [2].

The extent to which the rocks have been weathered or fractured determines the amount of water to be found and these in turn govern the electrical resistivity values. This forms the basis of using electrical resistivity values and pattern of distribution to work out the different rock types and structures in this study.

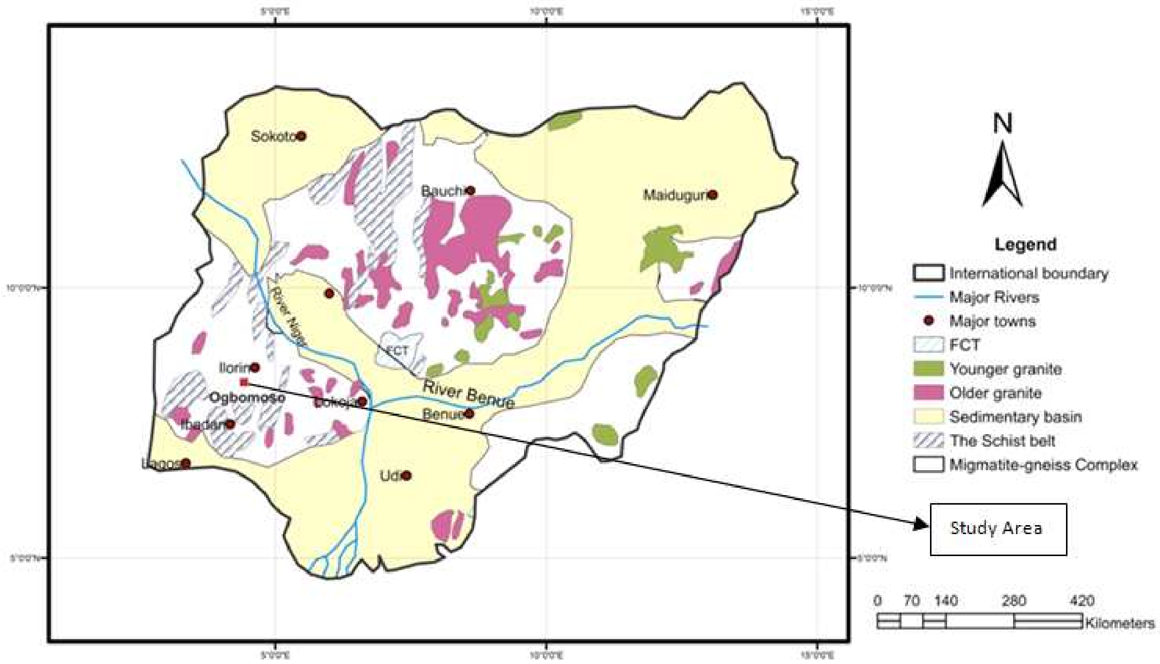

Figure 1: Geological map of Nigeria showing the study area. (Modified after Ajibade et al, 1988).

FIELD SURVEY

A four day survey was carried out in October, 2011 using the electrical resistivity method. The survey was conducted with R 50 Resistivity meter. A total of 10 Vertical Electrical Sounding (VES) stations were occupied randomly to cover the area of study (Figure 2). The schlumberger array with maximum electrode spacing (AB) of 130 to 200m was used for the field resistance measurements.

The resistivity values were determined and plotted on a double logarithmic graph paper for quick check on the field.

RESULTS

Parameters such as apparent resistivity and thickness obtained from partial curve matching were used as input data for computer iterative modeling using the WinResist software [11]. The modeling produced series of curves as shown in Figure 3a-j. Almost all of curves were H-type ($\rho_1 > \rho_2 < \rho_3$) except at one station which showed KH-type ($\rho_1 < \rho_2 > \rho_3 < \rho_4$). Surfer 8 software [12] was further used on personal computer to develop geoelectric sections of four profiles (Figure 4a-d) from layer parameters.

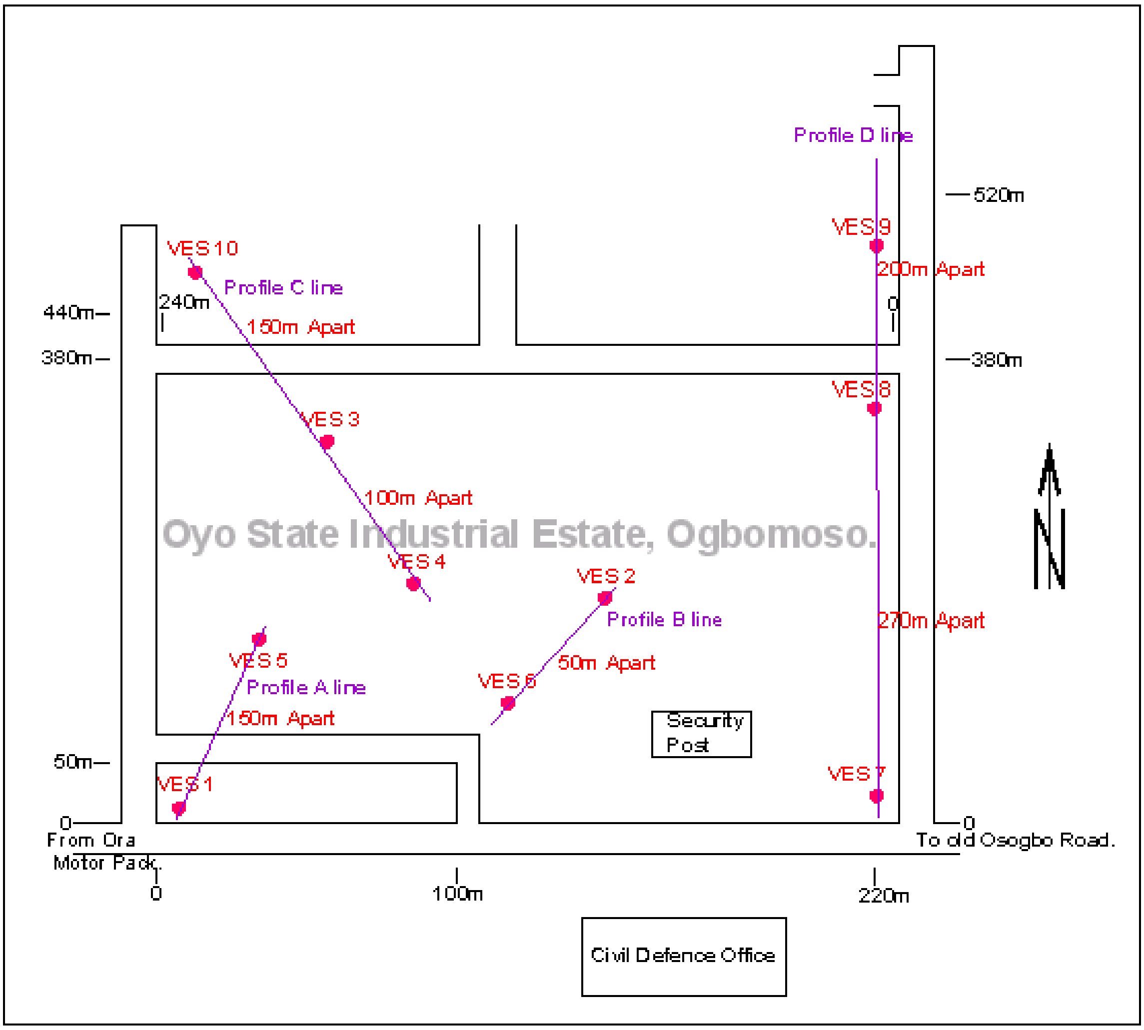

Figure 2: Layout map of Vertical Electrical Sounding stations.

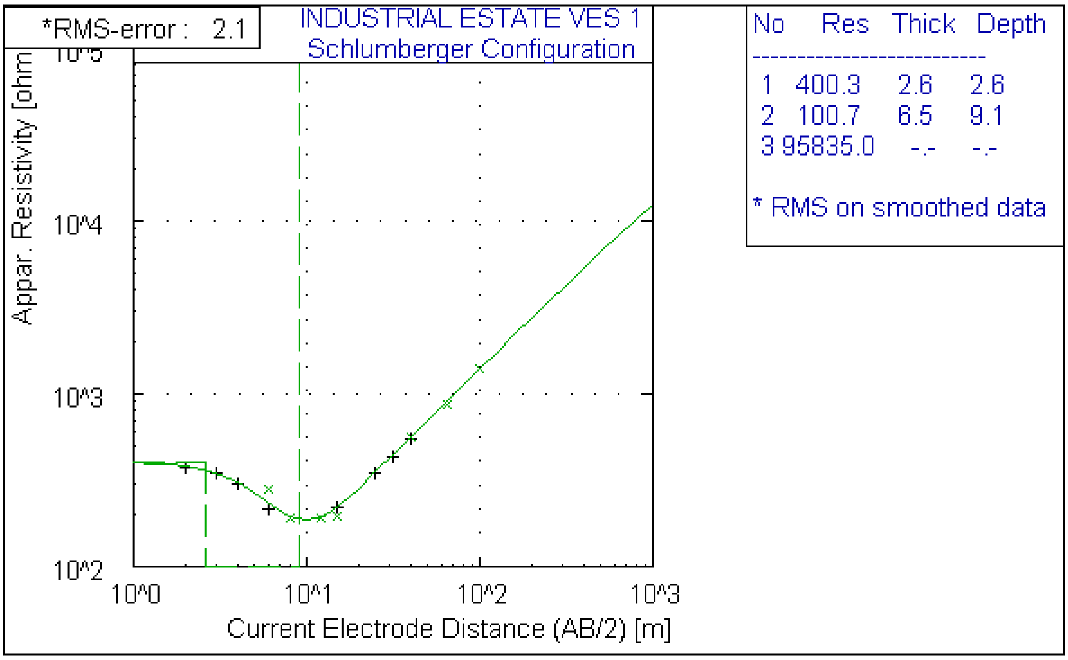

Figure 3(a): The modeled curve for VES 1.

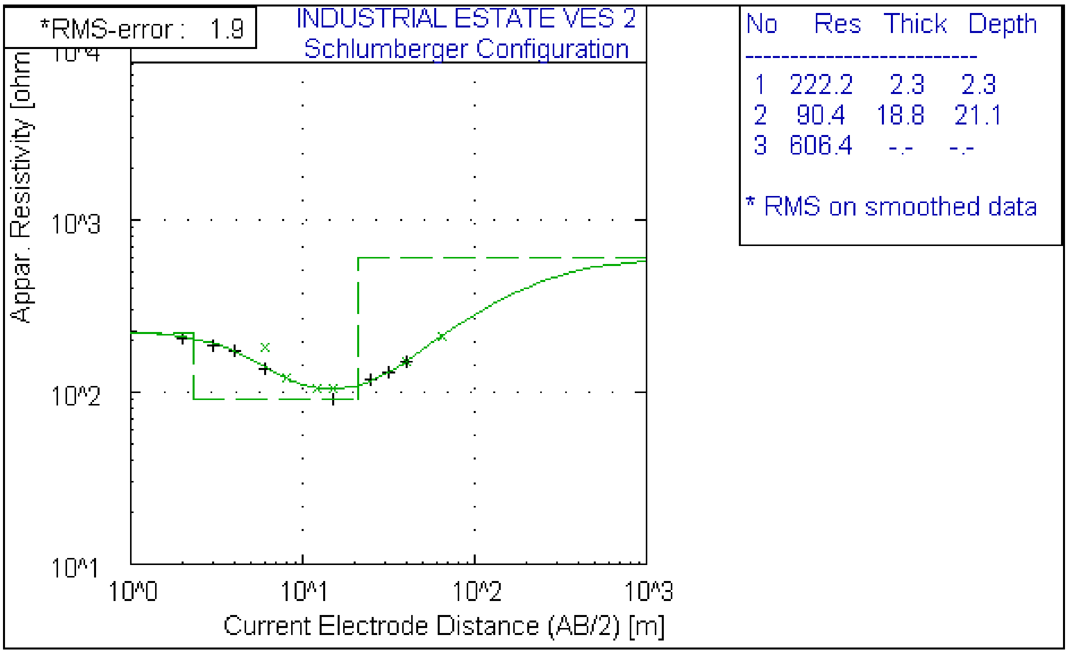

Figure 3(b): The modeled curve for VES 2.

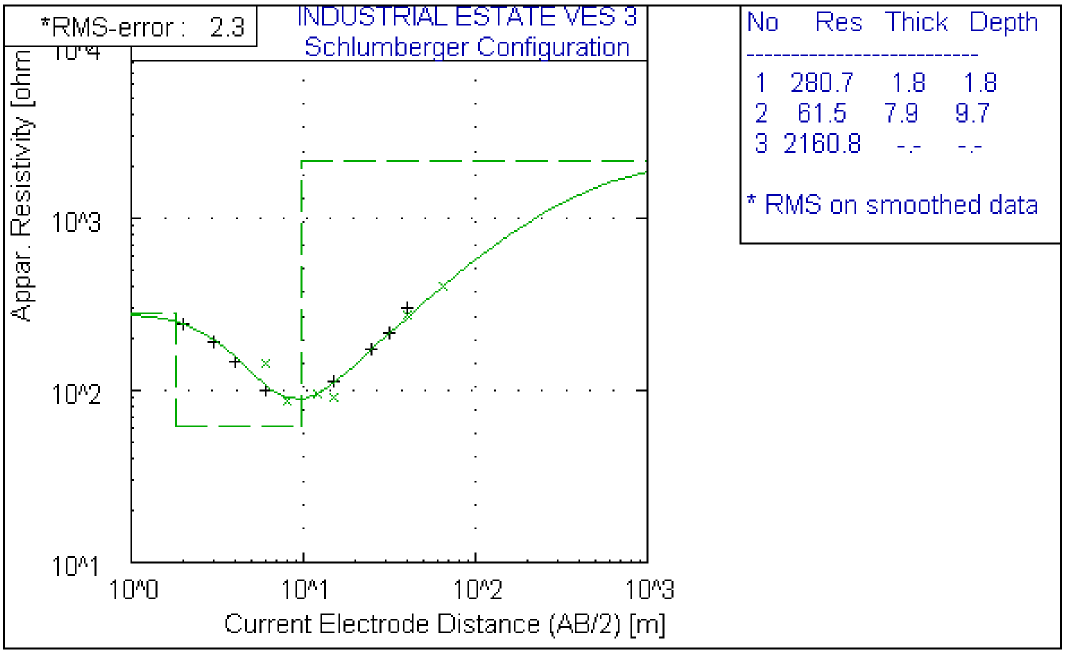

Figure 3(c): The modeled curve for VES 3.

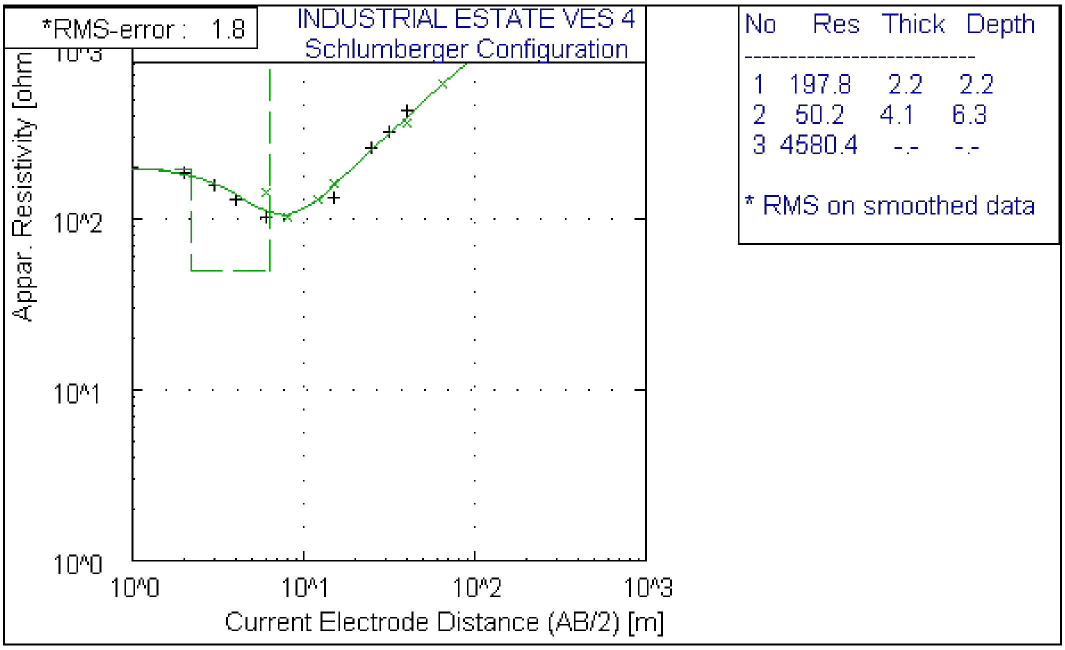

Figure 3(d): The modeled curve for VES 4.

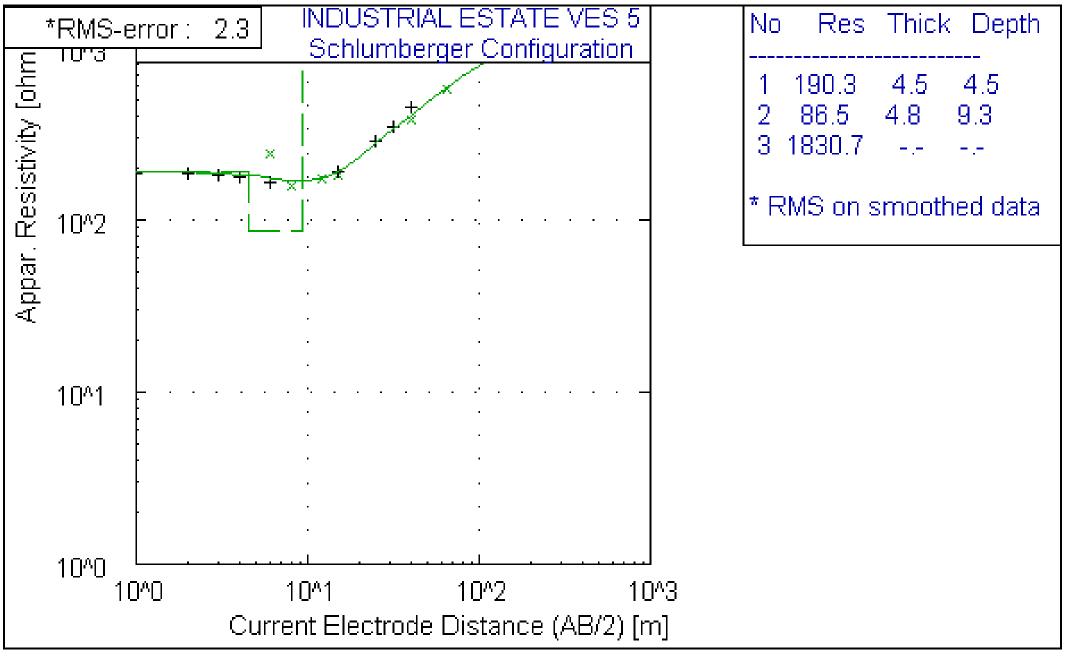

Figure 3(e): The modeled curve for VES 5.

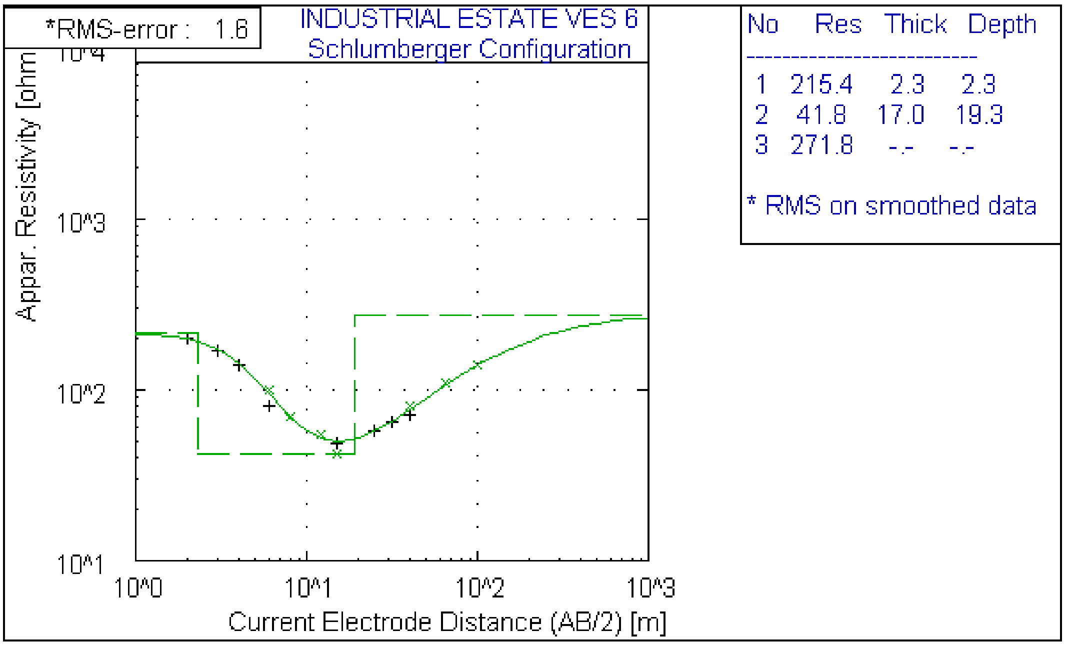

Figure 3(f): The modeled curve for VES 6.

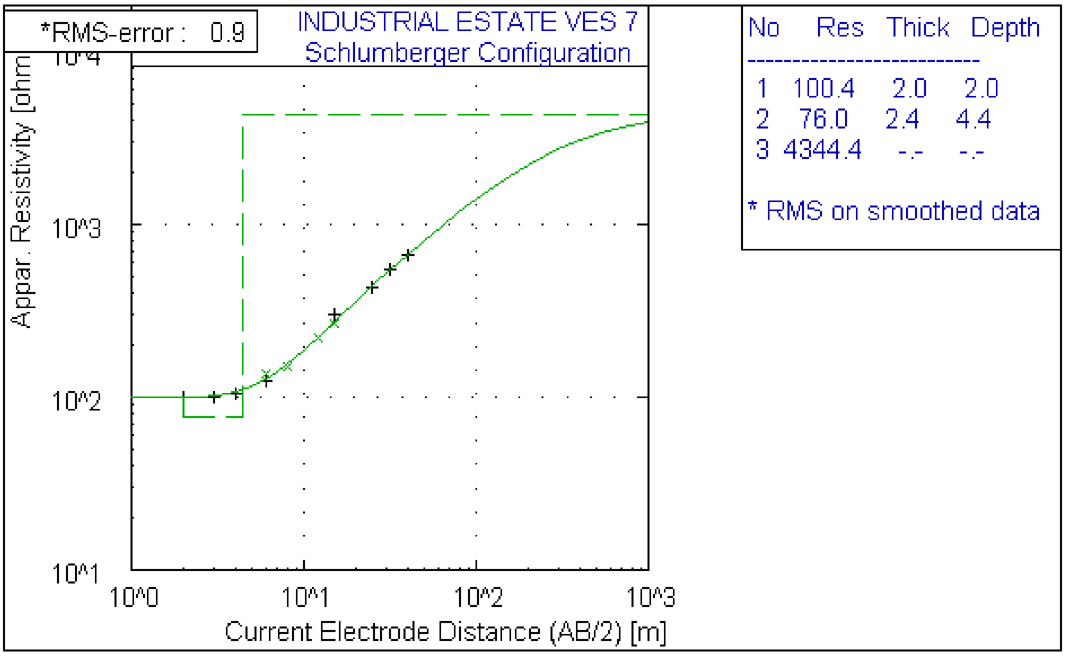

Figure 3(g): The modeled curve for VES 7.

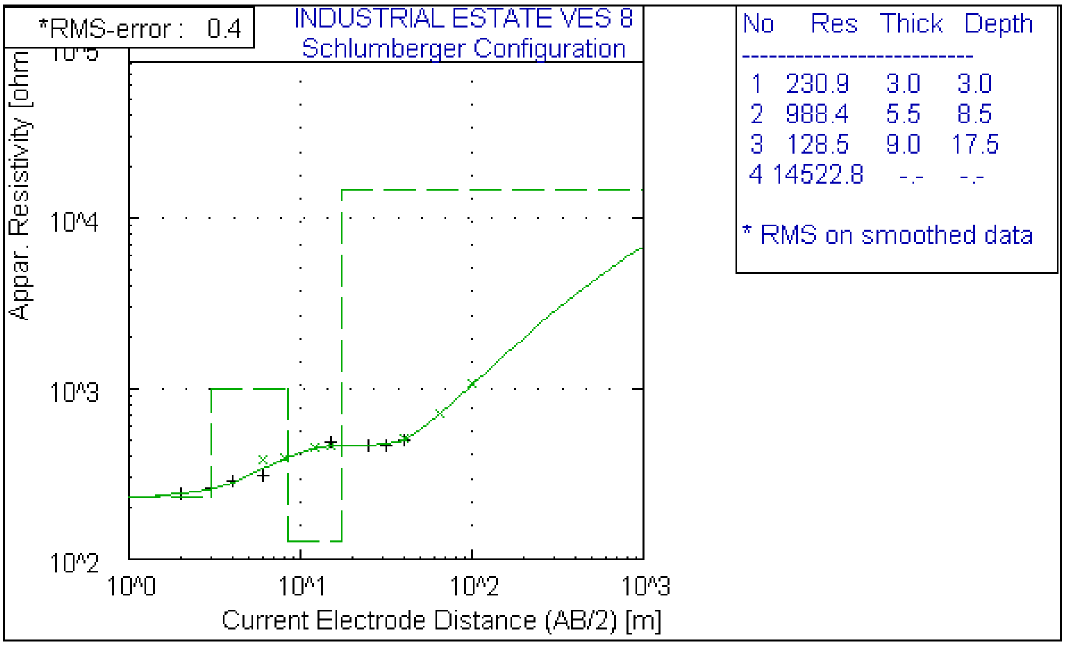

Figure 3(h): The modeled curve for VES 8.

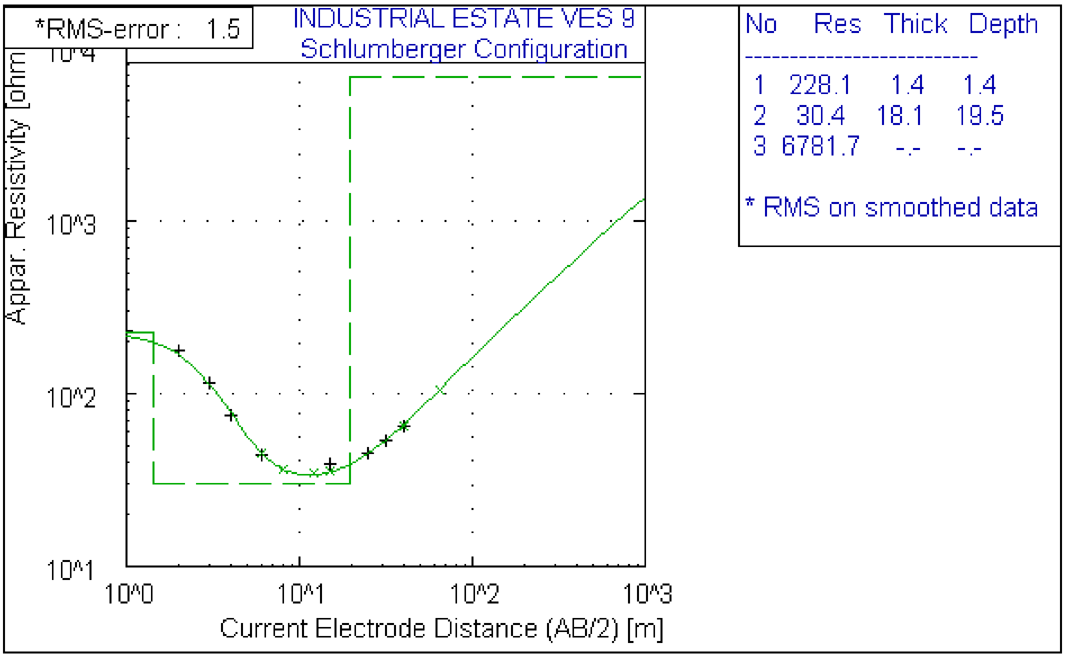

Figure 3(i): The modeled curve for VES 9.

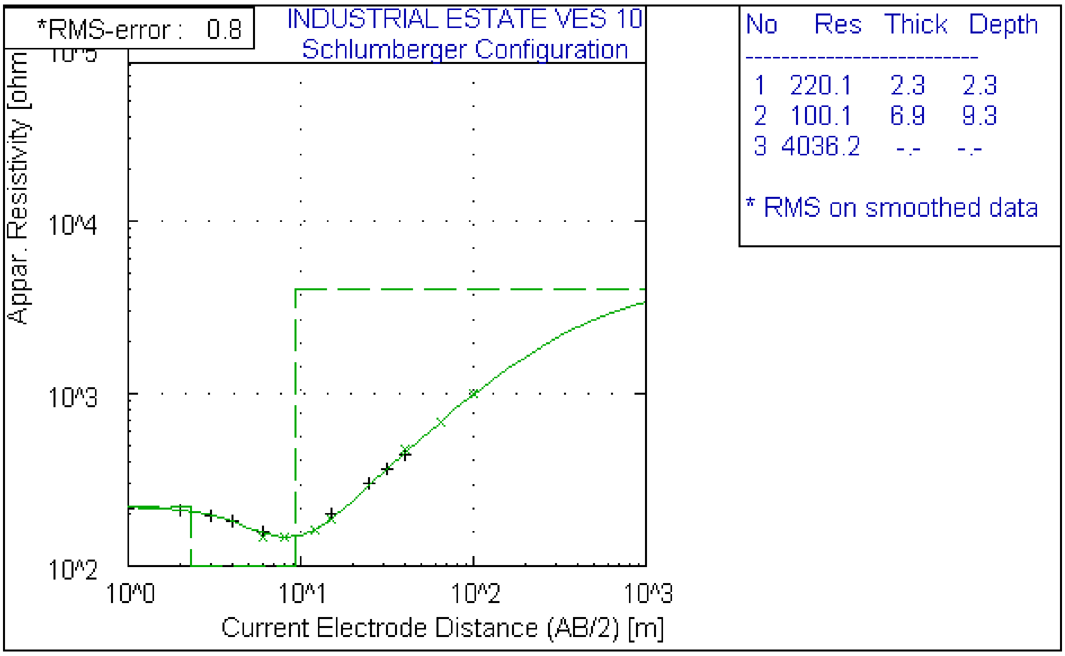

Figure 3(j): The modeled curve for VES 10.

DISCUSSION

The Layer Parameters

The VES curves were modeled from computer and made sure that the RMS-error is as low as possible. It was observed that most of the modeled curves show three layers except in one station, where we have four layers (figure 3a-j). From the VES curves, the depth to basement of VES 1, 3, 4, 5, 7 and 10 are not up to 10m. The result shows that these areas have thin overburden thickness. Therefore, it is considered to be very good for building of factories. VES 8 and 9 show thick overburden thickness (depth to basement greater than 15m) but the basement at this region is unweathered, so if it is properly excavated, it could be considered for engineering purposes (building of factories). However, VES 2 and 6 should not be considered for engineering purpose because of the fracture present in the basement but could be used for groundwater prospecting which will serve the entire industrial estate (refer to figure 2 to see the location of each VES stations). The VES interpretation results are as summarized in table 1.

For the multilayer sounding curves obtained after curve matching and computer iteration, the type curves were determined by the relationship existing between the layer resistivity values; $\rho_1, \rho_2, \rho_3 \ldots \rho_n$. The classification of the sounding curves sample is as shown in table 2. It was discovered that the curves are mostly H-type (9 VES stations) except VES 8 that showed KH-type.

Table 1: Summary of the formation of layer thickness.

Location	Layer 1		Layer 2		Layer 3		Layer 4	
	ρ_1 (Ωm)	h_1 (m)	ρ_2 (Ωm)	h_2 (m)	ρ_3 (Ωm)	h_3 (m)	ρ_4 (Ωm)	h_4 (m)
VES 1	400.3	2.6	100.7	6.5	95835.0	-	-	-
VES 2	222.2	2.3	90.4	18.8	606.4	-	-	-
VES 3	280.7	1.8	61.5	7.9	2160.8	-	-	-
VES 4	197.8	2.2	50.2	4.1	4580.4	-	-	-
VES 5	190.3	4.5	86.5	4.8	1830.7	-	-	-
VES 6	215.4	2.3	41.8	17.0	271.8	-	-	-
VES 7	100.4	2.0	76.0	2.4	4344.4	-	-	-
VES 8	230.9	3.0	988.4	5.5	128.5	9.0	14522.8	-
VES 9	228.1	1.4	30.4	18.1	6781.7	-	-	-
VES 10	220.1	2.3	100.1	6.9	4036.2	-	-	-

Table 2: Classification of the resistivity sounding curves

Curve types	Resistivity model	Model frequency	VES Locations
H	$\rho_1 > \rho_2 < \rho_3$	9	1, 2, 3, 4, 5, 6, 7, 9, 10
KH	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	1	8
Total		10	

Geoelectric Sections

From figure 2, the 10 VES stations were grouped into 4 profiles (A, B, C and D) according to how convenient they can be located on a straight line to see an image representation of the subsurface. The results of the interpreted VES curves were used to draw 2D geoelectric sections (figures 4a–d) along profiles A, B, C and D to show the vertical distribution of resistivities within the volume of the earth in the investigated area. The sections consist of sequence of uniform horizontal (or slightly inclined) layers (horizons). Each layer (horizon) in a geo-electrical section may completely be characterized by its thickness and true resistivity. The geoelectric sections show both vertical and lateral variations in layer resistivity. One of the importances of 2D geoelectric sections is that it helps someone to see clearly where there is thin overburden as well as thick overburden within the sounding locations.

Profile A

Geoelectric sections of profile A shows that the area is divided into 3 regions (figure 4a). The first and second region shows low resistivity (high conductivity) values with thin overburden thickness which confirms the result gotten from groundmagnetic method to be true. The third region shows that the basement rock is fresh. This result has proved that southwestern part of the study area is good for engineering purposes.

Profile B

Geoelectric sections of profile B shows that it is divided into 3 regions (figure 4b). The first and second region show low resistivity (high conductivity) values with thick overburden thickness. The third region shows that the basement rock present in this profile is fractured. This result shows that the area is bad for engineering purposes because of the fractured basement that is present there but could be useful for groundwater prospecting which will serve the industries altogether.

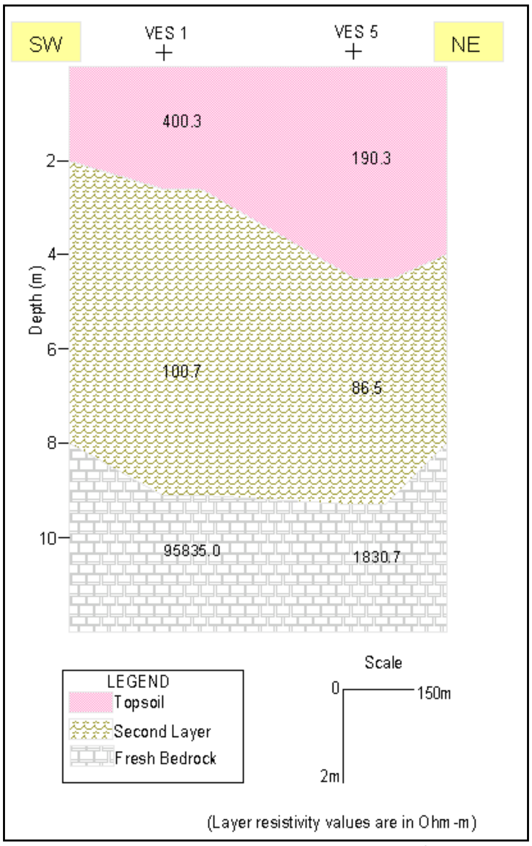

Figure 4a: Geoelectric section along profile A.

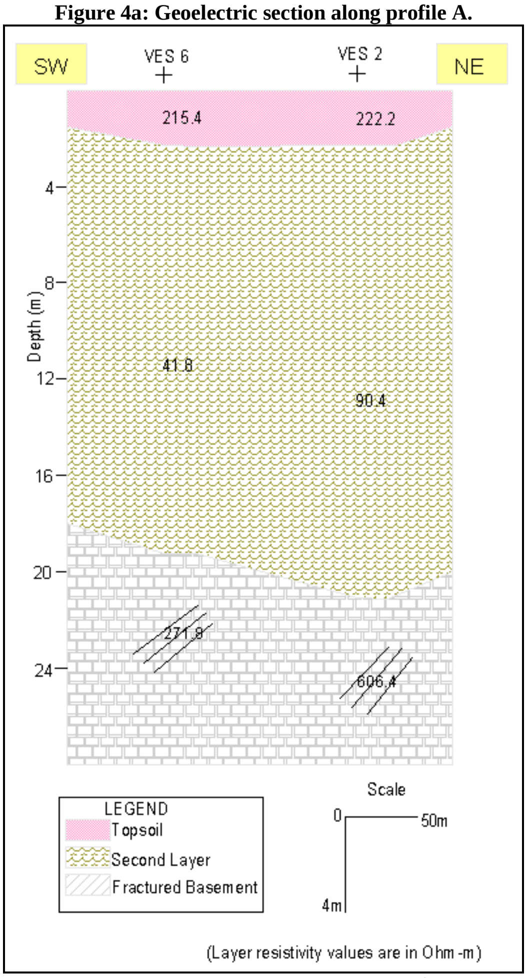

Figure 4b: Geoelectric section along profile B.

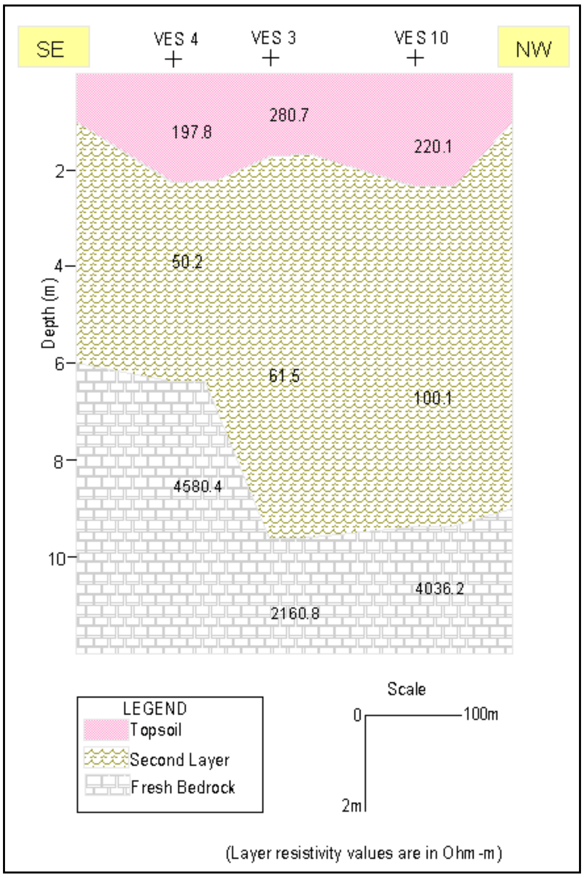

Figure 4c: Geoelectric section along profile C.

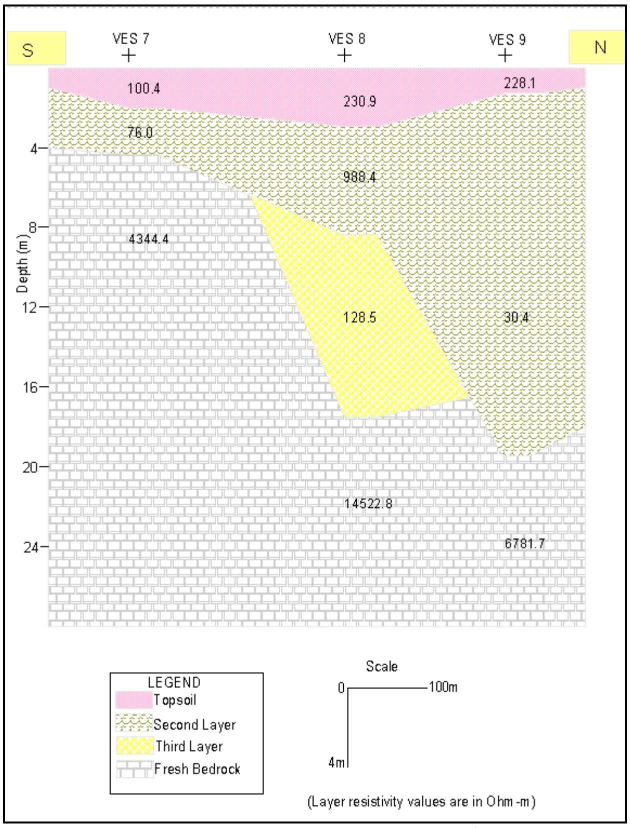

Figure 4d: Geoelectric section along profile D.

Profile C

Geoelectric sections of profile C shows that the area is divided into 3 regions (figure 4c). The first and second region show low resistivity (high conductivity) values with thin overburden thickness. The third region shows that the basement rock is fresh. This result shows that central and western part of the study area is good for engineering purposes.

Profile D

Geoelectric sections of profile D shows that the area is divided into 3 regions in two of the three VES and 4 regions in the remaining one (figure 4d). The first and second region as well as the third region from VES 8 show low resistivity. VES 7 shows thin overburden thickness while VES 8 and 9 show thick overburden thickness. The third region shows that the basement rock is fresh. This profile shows that the Northeastern and Eastern part of the study area are good for engineering purposes but with little excavation [13].

CONCLUSION

The study has been able to highlight the importance of electrical resistivity method in estimation of the overburden thickness. The study area is averagely competent for engineering purpose has revealed by the geoelectric sections (with overburden thickness ranging from 4.4 to 21.1m).

However, the areas with fractured basement (VES 2 and 6) will be good for groundwater prospects. Since the study area is from Precambrian basement. Quark building contractors must not be invited for building construction in the study area because the subsurface has proved its inhomogeneity from the interpretation. It has been showed that not all the areas are competent for the construction of factories that make use of heavy machines but the remaining area might be used for ware houses construction and hydrogeologic study as groundwater is also essential in industrial settings. It is recommended that detailed work be done in industrial estate Ogbomoso using other relevant geophysical methods to confirm the predictions in this work.

Acknowledgements

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