Journal of the Nigerian Association of Mathematical Physics
Volume 11 (November 2007), 403 - 410
© *J. of NAMP*

Groundwater potential investigation using combined VLF and VES

K.O. Ozegin, D.O. Isiwele and S.O. Azi
Department of Physics, Ambrose Alli University, Ekpoma, Nigeria.
e-mail: solocastmd@yahoo.co.uk, 08034953007

Abstract

This work is an assessment of groundwater in Oke-Agbe High School field located in Akoko North-West Local Government Area of Ondo State. The goal is to establish groundwater viability in this location based on a clear-cut relationship between Electrical Resistivity (VES) and Electromagnetics methods (VLF). Both methods were jointly used for investigation to determine overburden thickness, geo-electric layers and groundwater potential.The advantage of this combination is that the VLF technique was used as a reconnaissance survey to identify the best VES locations. The computer iterated data from the study area enabled us to delineate the area into high, medium and low water potential zones Results obtained in this study clearly showed the depth to the bedrock beneath the VES stations. The field was contoured to demarcate areas with thick overburden (> 10m), areas with medium overburden (between 5-8 m) and areas with relatively thin overburden (≤ 5m) marked as A, B, and C respectively. VES station 4 with infinite overburden thickness and VES station 6 with fractured basement are the only aquifer units within the entire school field where groundwater could be exploited and therefore, serve as high groundwater potential zones. However, it must be stated here that VES station 6 is the surest bet within the priority area for groundwater development. . This result from combined technique is more reliable than the investigation based on only one method of investigation for groundwater feasibility studies, especially were the subsurface is doubtful.

1.0 Introduction

Water is the most common substance on earth. It covers more than 70% of the earth's surface. The average amount of water used domestically each day by every person is about 50-100 litres. Surface water has been one of the easiest and most convenient ways to meet public demand for water but unfortunately, it has not been free of contamination, hence, the need for groundwater exploration. Groundwater is fairly distributed over the globe and provides a reasonable constant supply, which is not likely to dry up under natural conditions such as surface sources may do and is often of quite high quality. However, groundwater is usually located well below the surface. Electrical resistivity method has been used extensively in groundwater investigation especially in the basement complex terrains [1,2,6]. This method is commonly used in getting detailed information about hydro geological setting for groundwater, geologic mapping and foundation study. Some of these include aquifer delineation, subsurface lithology, subsurface mapping, lithological boundary differentiation and geothermal exploration. Ground water studies or assessment is not limited to the study of ground water quantity but also to aquifer characteristics and even the general groundwater conditions of an area. VES methods may be enough in some cases to determine the groundwater potential of an area separately, yet it is worth the while to complement it with VLF [2], as the combined technique usually gives a better delineation, proper zoning and near zero error prediction of borehole sites based on clear and precise interaction and an accurate interpretation borne from a robust data set.

In general, Resistivity surveying technique involves passing current into the ground by means of two electrodes called current electrodes and measuring the potential drop through a second pair of electrodes called potential electrodes. Hence in Schlumberger array depth probing, current is passed into the subsurface through the current electrodes and the potential difference is measured through the potential electrodes. While the potential electrode spacing remains fixed for a considerable number of probes, the current electrode spacing is expanded symmetrically about the centre of the spread for a common factor K (λ).

Although groundwater as it were is one of the many areas of geophysical application, it is quite fair to say that it is the meeting point of all the geophysical methods, as this gives room for composite interpretation. In this paper, the VLF and Schlumberger VES were jointly used for the geophysical survey of the study area. The need for a more dynamic approach to groundwater borehole site location has become paramount in the daily water exploration techniques, thus it preempted this study with the following objectives in mind: to differentiate the lithological boundaries, study the hydro geophysical condition of the area using the aforementioned methods, measure the thickness of the overburden or depth to bedrock, determine the aquifer and their geo-electric characteristics and also present a 3-D view of the mapped bedrock based on the symbiosis between Electrical Resistivity VES and Electromagnetic VLF methods and its hydro-geologic implications.

The experimental work was carried out at Oke-Agbe High School field in Oke-Agbe. Oke-Agbe is located in Akoko North-West Local Government Area of Ondo State in the Southwestern basement complex of Nigeria. It lies within longitude $5^0\ 45^1$ and $5^0\ 50^1$ and latitude $7^0\ 35^1$ and $7^0\ 40^1$. The altitude of Oke-Agbe is about 200ft above the sea level. Oke-Agbe lies within the tropical climate. The annual rainfall is about 1500mm. Rock exposure are very common within the study area as many outcrops are seen beside the road. A syncline was observed close to the school field based on the geological mapping carried out. (This is a depression observed from the data obtained from the outcrops on both sides of the school, it is sometimes favourable to groundwater).

2.0 Theoretical background

The theory of VLF techniques has been presented elsewhere [2,4,5]. The theory of electrical resistivity of a layered earth is well known and has been also described in [2,7]. For Schlumberger array used in this work, the apparent resistivity, ρ_a, is given as

$$\rho_a = \frac{kV}{I} \tag{2.1}$$

where k is the geometrical factor, defined as $k = \pi\left(\frac{L^2}{l} - \frac{l}{4}\right)$, L is half the current electrode spacing and l is half the potential electrode spacing

3.0 Methodology

VLF involved transversing profiles of given intervals with the receiver and antenna held at right angles to each other and readings taken. Schlumberger depth probing, involved expanding the current electrode spacing symmetrically about the centre of the spread while the potential electrode spacing remained fixed over a range of readings until it was necessary to increase the current (I) in other to maintain a measurable potential for large values of lateral displacement between the potential electrodes. Four (4) VLF profiling and Eleven (11) VES were taken on the school field for the purpose of this study. The ABEM WADI and RESISTIVITY METER (STRATAMETER) were used for the VLF and Schlumberger investigations respectively.

4.0 Results and discussion

The VLF profiles gives information of the conductive and non-conductive zones and the location of the target. Figure 1 shows a typical VLF reconnaissance profile along H – H section for locating the optimum VES stations on the Oke-Agbe high school field. The figures for locating VES stations along other sections are omitted.

Vertical Electrical Sounding (VES) data are presented as depth sounding curves. The sounding curves are obtained by plotting the apparent resistivity values against electrode spacing AB/2 on log-log graph sheet. The various sounding curves obtained are shown in Figure 2- 4. Resistivities and thicknesses of the layers from computer iteration were used to present the geo-electric sections. The layer sequence, resisitivity thickness and lithology classification are also given in the geo-electric sections. The Geo-Electric sections are represented as F-F', G-G' and H-H'.

In all, two sounding curves types are obtained from eleven vertical electrical sounding (VES) stations. They are ; H, and QH. The H curve is the most dominant.

4.1 Geo-electric section ($F – F^1$)

The total length of this section is about 70m long. It has four VES stations on it namely VES 11, 8, 9 and 10; it is in $N10^0E$ direction (Figure 2) A minimum of three layers were identified beneath the VES stations. The VES data interpretation delineates three major geologic units in this section; the topsoil, the weathered layer and fresh basement. In the topsoil, the resistivity value ranges from 39.6 – 141.6 Ωm. The low resistivity (< 50 Ωm) is characteristic of clay while the high resistively (> 50 Ωm) may typify sandy clay. This layer thickness ranges from 0.5 – 0.9 m. In the weathered layer, resistivity values ranged from 14.9 to 70.7 Ωm. Its thickness varied from 2.7 m to 6.6 m. The Fresh basement has resistivity values of 906.8 Ωm and above. In all, no aquifer was delineated in VES stations (11, 8, 9 and 10), This makes them unproductive zones.

4.2 Geo-electric section ($G – G^1$)

This geo-electric section has a length of 50 m with three VES stations on it VES 5, 6 and 7 as shown in Figure 3. It is in $N10^0E$ direction. Four geologic units were delineated namely; the topsoil, the weathered layer, the fractured basement and the fresh basement. The topsoil has resistivity values ranging from 105.1 – 240.6 Ωm, its thickness ranged from 0.4 – 0.6 m. In the weathered layer, resistivity values varied from 15.8 – 17.9 Ωm and thickness ranged from 5.3 to 6.6 m. The fractured basement has resistivity value of 744.7 Ωm while the fresh basement had its resistivity value from 1236.4 Ωm and above. Groundwater potential area can be obtained around VES station 6. This is due to the fractured basement depression overlain by thick overburden. The overburden of this groundwater potential area is made of clay material, which could serve as a natural screening material and prevent the aquifer from being polluted. Other VES stations (5 and 7) is overlain by thin over burden and underlain by basement ridge.

4.3 Geo-electric section ($H - H^1$)

This section is about 85 m long. It is in $N10^0E$ direction, it has a total of four vertical electrical sounding stations on it VES 1, 2, 3 and 4 (Figure 4). Three sub surface layers were identified beneath the VES stations. The VES data interpretation delineated three major geo-electric sections; the topsoil, the weathered layer and fresh basement. In the topsoil, the resistivity value ranged from 95.6 to 311.5 Ωm. The low resistivity (< 150 Ωm) is characteristic of clay and sandy clay while the high resistivity (> 150 Ωm) typifies clayey sand and laterite. The layer thickness ranged from 0.6 m to 1.9 m. In the weathered layer, resistivity values varied from 18.7 to 277.0 Ωm. The low resistivity (<50 Ωm) suggested that the lithology in the layer suites clay. The thickness of this layer ranged from 5.1 to 5.9 m. The fractured basement had resistivity of 737.7 Ωm while the fresh basement had resistivity values of 1593.4 Ωm and above. Groundwater potential areas could be obtained around VES 4 because of the presence of aquifer while in other VES stations no aquifer was delineated. Figure 5 shows the mapped region of the school field and the respective VES stations and potential groundwater zones. Figure 5(a) as depicted by the isopach map and Figure 5(b) shows the 3-D view.

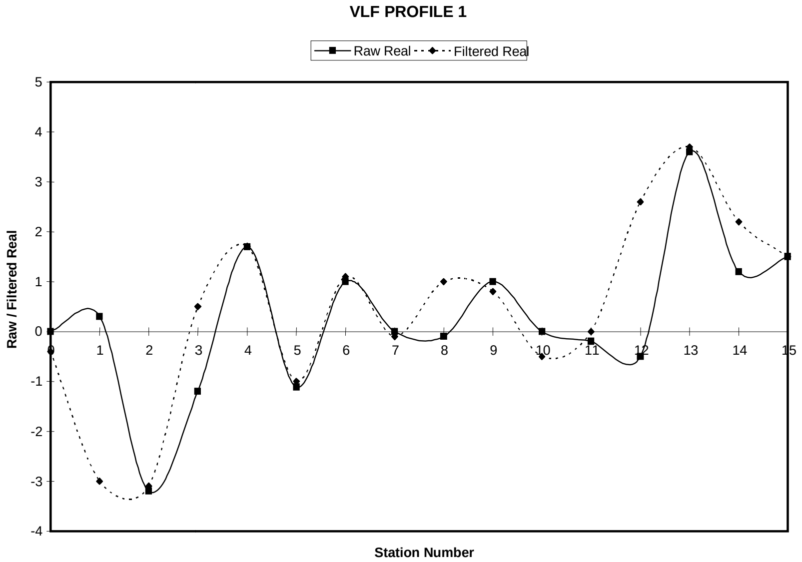
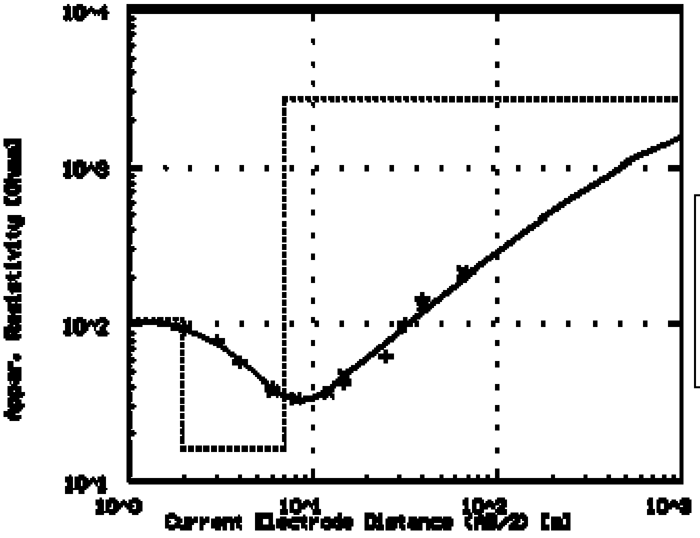


Figure 1: Very Low Frequency (VLF) Profile for H – H section (a = 10m).
Raw real data ——■—— Filtered real data - - - - -◆- - - - -



*RMS-error: 2.5

No	Res	Thick	Depth
1	265.8	0.7	0.7
2	28.7	6.3	6.9
3	1567.5	-.-	-.-

* RMS on Smoothed Data

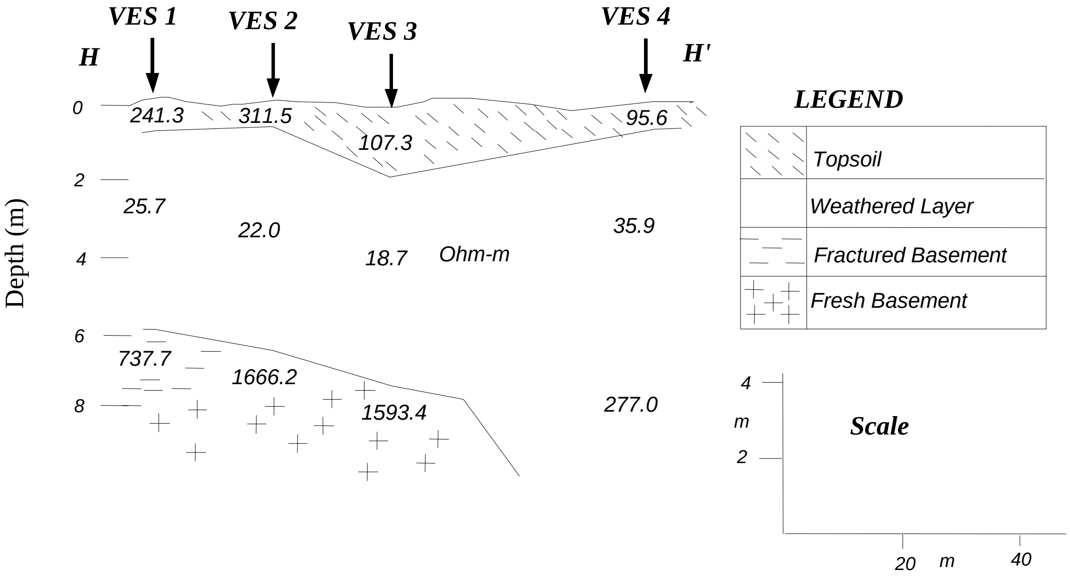
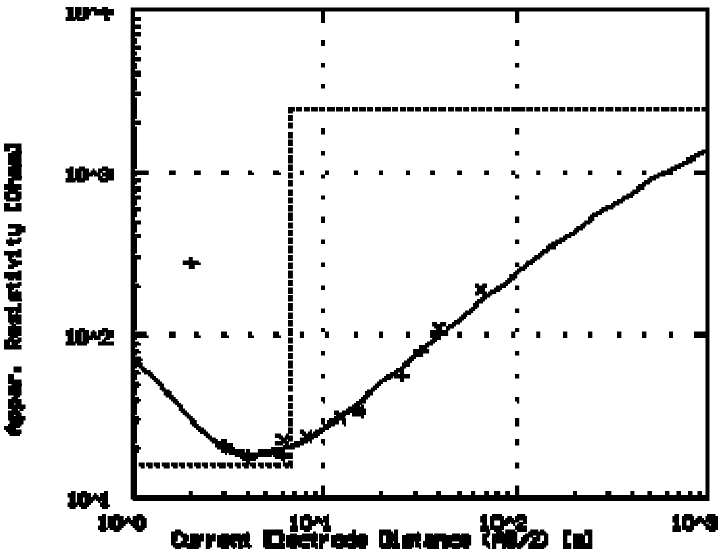


Figure 2: VES Curve and geo-electric section H – H′



*RMS-error: 3.6

No	Res	Thick	Depth
1	96.5	0.7	0.7
2	36.8	6.3	7.0
3	302.1	-.-	-.-

* RMS on Smoothed Data

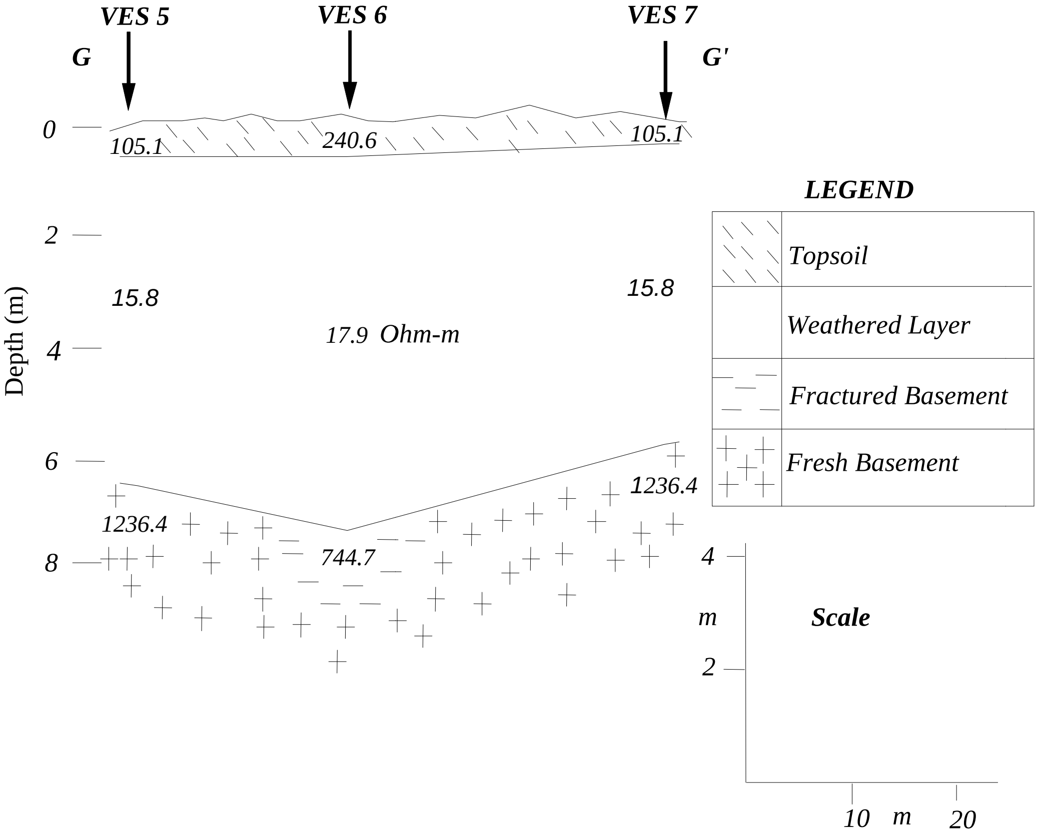
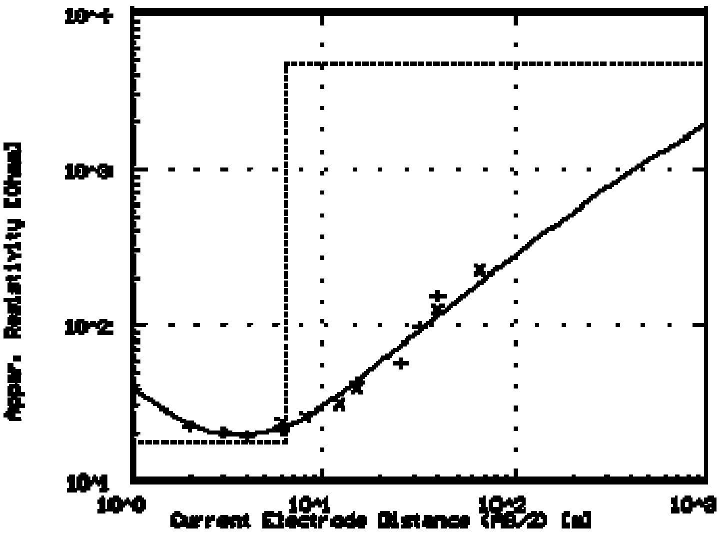


Figure 3: VES Curve and geo-electric section G –G′



*RMS-error: 4.2

No	Res	Thick	Depth
1	101.3	0.9	0.9
2	22.4	6.6	7.5
3	4316..9	-.-	-.-

* RMS on Smoothed Data

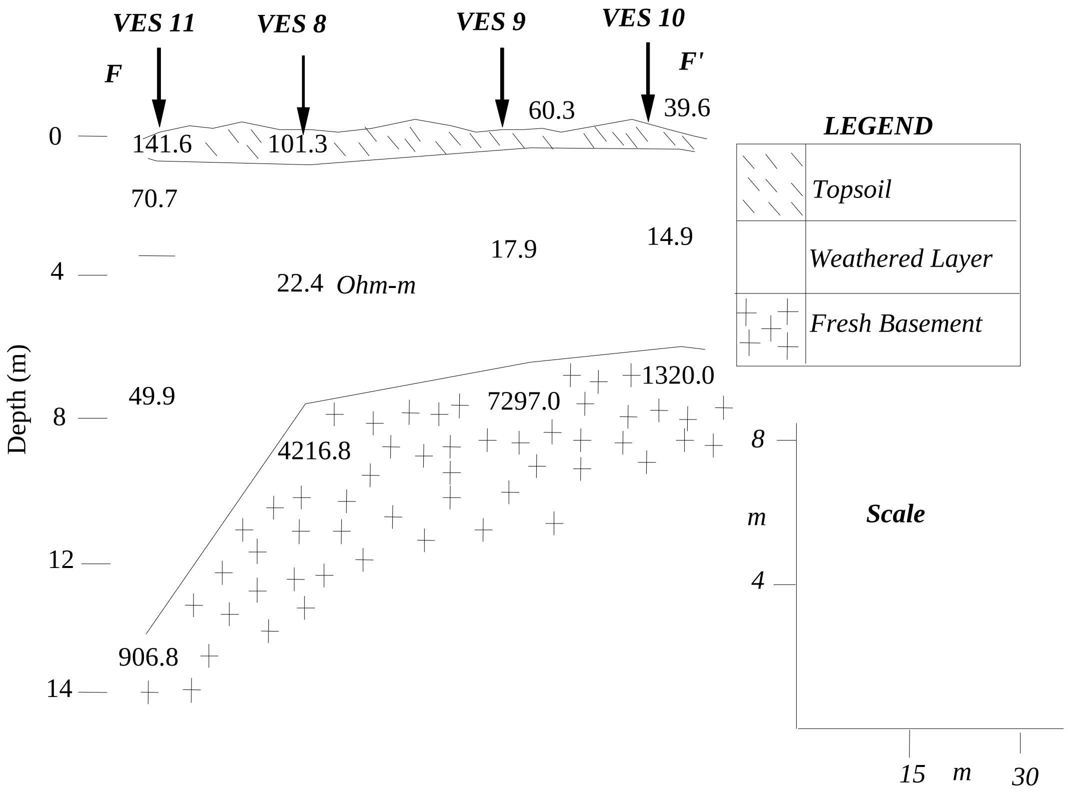
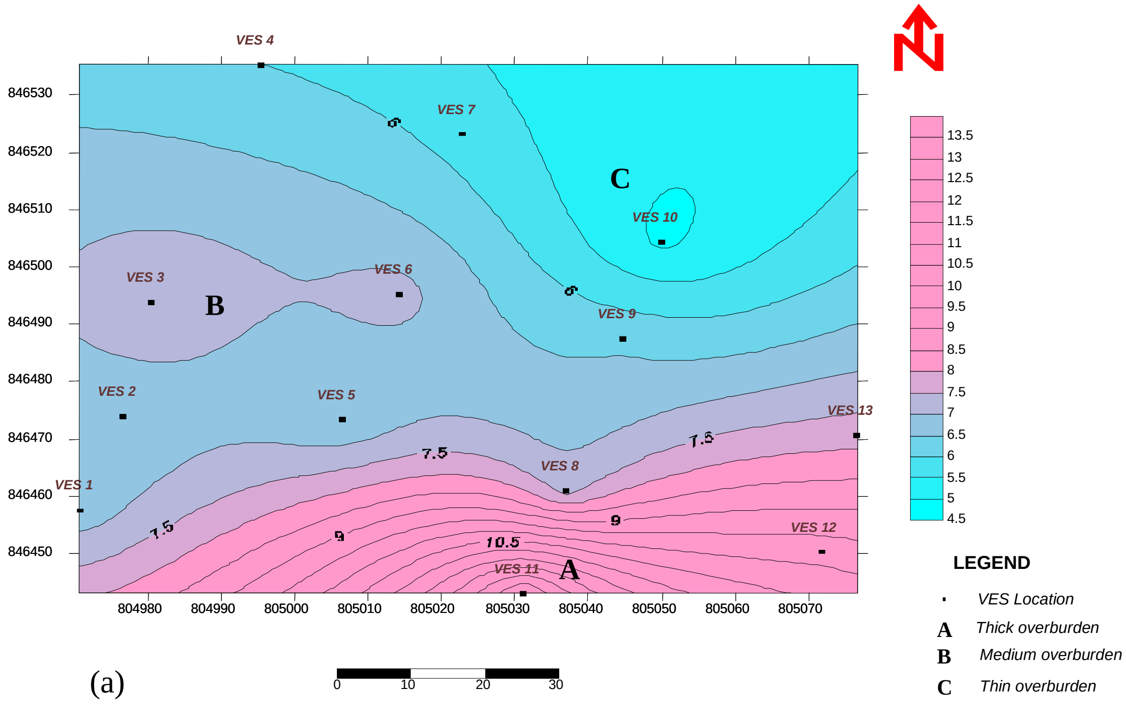
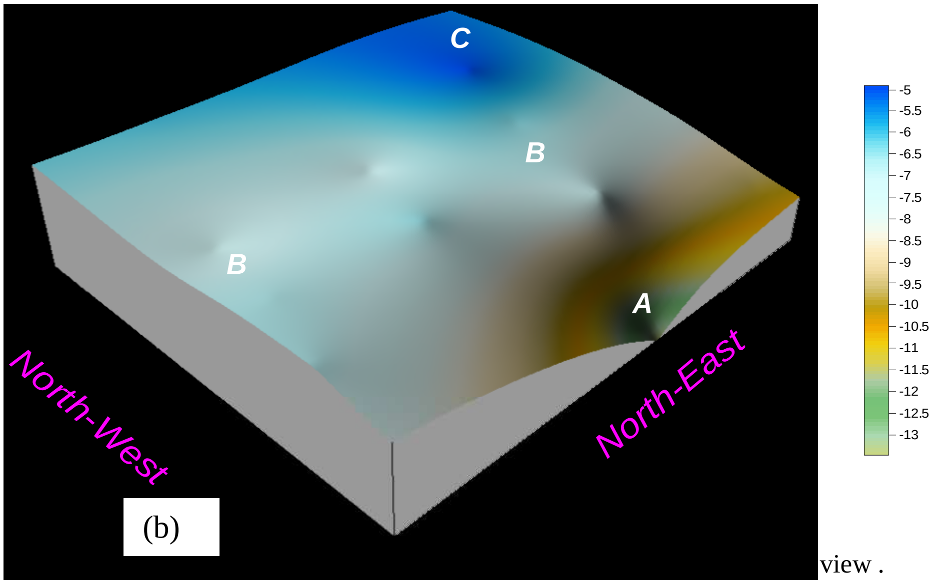


Figure 4: VES Curve and geo-electric section F – F′





view .

5.0 Conclusion

The results of the computer interated VES data interpretation and the VLF profiling enabled the delineation of the layers in the investigated area. It showed the depth to the bedrock beneath the VES stations occupied in Oke-Agbe high school field. The overburden thickness in the school field varied from 4.9 to 13.6*m*, and the isopach map shows the respective zones of thickness. (Area marked, A is thick overburden (>10*m*), areas with medium overburden is marked, B (between 5 - 8*m*) and areas with relatively thin overburden (≤ 5*m*) is marked, C. However the weathered material is mainly clay this could serve as a natural screening material which prevents an aquifer from being polluted. The VES stations within the area of medium overburden (between 5*m* to 8*m*) are V_1 - V_9, V_{12}, V_{13} while VES station 4 with infinite overburden thickness and VES station 6 with fractured basement overlain by thick overburden are the only aquifer units within the entire school field where groundwater could be exploited and therefore, serve as high groundwater potential zones. However, it must be stated here that VES station 6 is the surest bet within the priority area for groundwater development, this is as a result of its high amplitude shown by the VLF and subsequently confirmed by the VES. This result from combined technique is very reliable for groundwater feasibility studies especially were the subsurface investigation based on only one method of investigation is doubtful.

Acknowledgement

We are especially grateful to Applied Geophysics Department, Federal University of Technology, Akure-Nigeria for the equipments.

References

[1] Anhaeusser, C.R, 1969. A Reappraisal of some aspects of Precambrain shield geology bull, Geol. Soc. Amer., vol. 80, pp 2175 – 2200.

[2] Grant, F. S., West, G. F, (1965). Interpretation Theory in Applied Geophysics. New York, McGraw-Hill.

[3] Fischer, G., Le Quang, B.V., and Muller, I. 1983. Very Low frequency Ground Surveys, a Powerful tool for the study of shallow two – Dimensional structures. Geophys. Prosp. 31, 977-91

[4] Lowrie, W., and West, G.F. 1965. The Effects of a Conducting Overburden on Electromagnetic Prospecting Measurements. Geophysics 30 624-32

[5] Omosuyi, G. O , Ojo, J.S. and Enikanselu P.A. 2003. Geophysical investigation for groundwater around Obanla-Obakekere in Akure area within basement complex of southwestern Nigeria, J. Min. Geol. Vol. 39 (2), pp. 109-116.

[6] Sarpapathy, B.W. and Kanungo, B.N., 1976. Groundwater exploration in Hand-rock terrain – A case study, geoph. Prosp. Vol. 24 (4), pp. 725-736.

[7] Telford, W.M, Geldart, L.P., and Sheriff, R.E. 1990. Applied Geophysics. Second Edition, Cambridge University Press.