
SUBSURFACE INVESTIGATION USING ELECTRICAL RESISTIVITY METHOD

By

Adegbola R.B. and Abidoye O.E.

Department of Physics,

Lagos State University, Ojo, Lagos, Nigeria

P.O. Box 0001, LASU Post Office, Ojo, Lagos State, Nigeria

Email: adegbolaji@yahoo.com and olanike.abidoye@gmail.com

ABSTRACT

A geophysical investigation using the vertical electrical sounding (VES) and 2D electrical resistivity methods were carried out at Iba Estate Nursery and Primary School, Iba, Lagos State, Nigeria to determine the subsurface layer parameters which are resistivity values and thicknesses to categorize the ground-water potential of the study area. The Instrument used was PASI Terrameter. Vertical Electrical Sounding (VES) with Schlumberger array was conducted at ten (10) VES stations. The data obtained were analysed using computer software (WinResist) which gives an automatic interpretation of the apparent resistivity. The results showed that four to five geologic layer formations dominated the study area. The resistivity values were of range between 14.7 to 6460.0 ohms-meter and their thickness values vary from 0.4 to 123.2 m. 2-D resistivity structures were also obtained to further affirmed two dimension natures of the subsurface. It can be inferred that the suitable aquifer will be at the third layer of the subsurface.

Keywords: Geologic, Schlumberger array, Terrameter, Subsurface, Win Resist.

INTRODUCTION

One of the nature's hidden treasures is Groundwater. Its exploitation remains an important issue due to its unavoidable needs. Other sources of water are streams, rivers, ponds, to mention a few, none is as hygienic as groundwater because groundwater has an excellent natural microbiological quality and generally adequate chemical quality for most uses (Okafor & Mamah, 2012). The use of geophysics for both groundwater resource mapping and for water quality evaluations has increased dramatically over the years. The Vertical Electrical Soundings (VES) has proved very popular with groundwater studies due to simplicity of the technique. Groundwater is very important for human water supply in urban and rural areas (Sunmonu & et.al, 2012). Exploration of groundwater in sedimentary terrain is a very challenging task when the promising groundwater zones are associated with porous media.

In this environment, the groundwater potentiality depends mainly on the thickness of the weathered/fractured layer overlying the basement (Mansour, 2009). The electrical geophysical survey method is the detection of the surface effects produced by the flow of electric current inside the earth. The electrical techniques have been used in a wide range of geophysical investigations such as mineral exploration, engineering studies, geothermal exploration, archaeological investigations, permafrost mapping and geological mapping (Jatau, 2013; Oyedele & Olorode, 2010). Using this method, depth and thickness of various subsurface layers and their water yielding capabilities can be inferred. Measurement of resistivity is, in general, a measure of water saturation and pore space connectivity (G.VenkataRao, P.Kalpana, & Rao, 2014) which can be interpreted qualitatively and quantitatively in terms of a lithologic and/or geohydrologic model of the subsurface (Amadi,

2011). Therefore, evaluation of groundwater potential at Iba Estate area was done in order to know the groundwater yielding capabilities or groundwater conditions of the study area.

Many different electrode spreads have been used in the past but only few are still in use today. These include; Schlumberger array, Wenner array and double – dipole array. However, the most widely and commonly used arrays are Schlumberger array and Wenner array. The choice of array and its dimension largely depend upon the target; its size, depth and resistivity contrast with its surroundings (Saleh, Sule, Ahmed, & Murana, 2014). Similarly for arriving at suitable decisions regarding usage of different types of recording configurations, experience has shown that, if the survey is in a noisy area and there is need for good vertical resolution with limited survey time, the Wenner array should be used. If good horizontal resolution and data coverage is important, and the resistivity meter is sufficiently sensitive and there is good ground contact, use the dipole-dipole array. If there is need for both reasonably good horizontal and vertical resolution, use the Wenner-Schlumberger array with overlapping data levels. If there is a system with a limited number of electrodes, the pole-dipole (three-electrode) array with measurements in both the forward and reverse directions might be a viable choice. For surveys with small electrode spacing and good horizontal coverage is required, the pole-pole (two-electrode) array might be a suitable choice. In the case of Self Potential (SP) Methods, where no subsurface energisation using external artificial source is done; we simply make use of two non-polarisable electrodes for subsurface investigations for mineral detections. It has got extensive applications for massive sulphide investigations. Presently, ground water investigations are also carried out using SP. Induced Polarisation (IP) is yet another method where measurements are carried out during 'off time' and this method is extensively used for investigations of 'disseminated sulphides'. An indirect application of IP includes detecting clay (being ground

water indicators) formations that possess relatively high apparent chargeability/polarizability. This is an indirect application of IP for ground water investigations. Spectral Induced Polarisation (SIP), where measurements are carried out over a full spectrum both in time domain (TD) and frequency domain (FD) is extensively in use for mineral detection. It is also used for mineral discrimination like graphite and sulphide. Tomography is yet another significant tool in Electrical Resistivity (ER), Self-Potential (SP) and Induced Polarisation (IP). Multi-electrode systems are in use for Tomography application for the investigations of natural resources and for subsurface geological architecture. Tomography studies give better resolution, high accuracy and more precision. The electrical techniques are regularly used by vast number of geoscientists (Sarma, 2014).

For this present work, Schlumberger and Wenner arrays were adopted because of the following advantages;

- 1) The relatively small separation of the potential electrodes reduces noise due to ground current (from industrial and telluric sources) which may limit the useful depth of penetration.
- 2) In general VES method with Schlumberger array has considerable importance in the groundwater exploration because it is easy to operate (only the current electrodes need to be frequently moved), relatively low cost and its capacity to distinguish between saturated and unsaturated layers
- 3) The Schlumberger array has a greater depth of penetration and the Wenner array is good in resolving vertical changes (i.e. horizontal structures) (Hadi, 2009; Loke, 2000).

In Schlumberger symmetrical array the current and potential pairs of electrodes have a common mid- point. All the four electrodes are arranged collinearly, the current electrodes are usually much further apart than the potential electrodes as shown in Figure 1. The smallest current -

potential electrode distance is always much greater than the distance between the two potential electrodes. In depth probing the potential electrodes are fixed while the current electrode separation is increased symmetrically about the centre of the spread. However, when expansion of the current electrodes causes the potential difference to become so small that it cannot be measured precisely, the

potential electrodes are moved further apart, while keeping the current electrodes fixed, and then further readings are taken by expanding the current electrodes using the new potential electrode positions. The apparent resistivity is plotted against electrode spacing on log-log scale to obtain a sounding curve (Saleh et al., 2014).

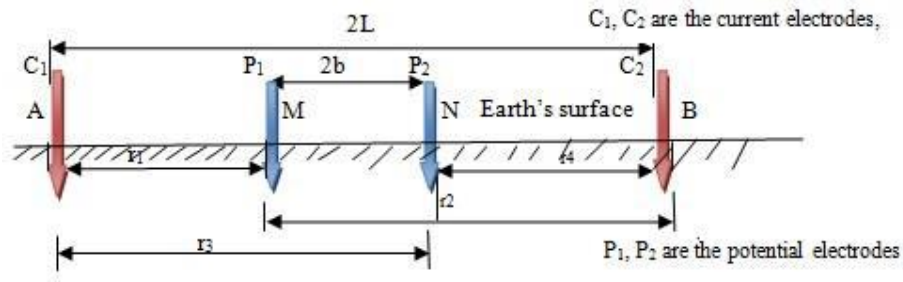


Figure 1: Schematic diagram of Schlumberger Array

Vertical Electrical Sounding (VES) is a geoelectric common method that measures vertical variation of electrical resistivity (Kelly, 1993). It is well known that resistivity methods can be successfully employed for groundwater investigations where a good electrical resistivity contrast exists between the water-bearing formation and the underlying rocks. Vertical Electrical Sounding (VES) also called depth sounding or sometimes electrical drilling is used when the subsurface approximates to a series of horizontal layers each with uniform but different resistivity. The goal is to observe the variation of resistivity with depth. Schlumberger configuration is most commonly used for VES. The mid-point of the array is kept fixed

while the distance between the current electrodes is progressively increased. This causes the current lines to penetrate to ever greater depth depending on the vertical distribution of conductivity.

The greatest limitation of the resistivity sounding method is that it does not take into account horizontal changes in the subsurface resistivity. A more accurate model of the subsurface is a two-dimensional (2-D) model where the resistivity changes in the vertical direction, as well as in the horizontal direction along the survey line (Loke, 2000; Deyemi, Aizebeokhai, & Oladunjoye, 2015; Sarma, 2014). A typical subsurface current distribution is illustrated in Figure 2.

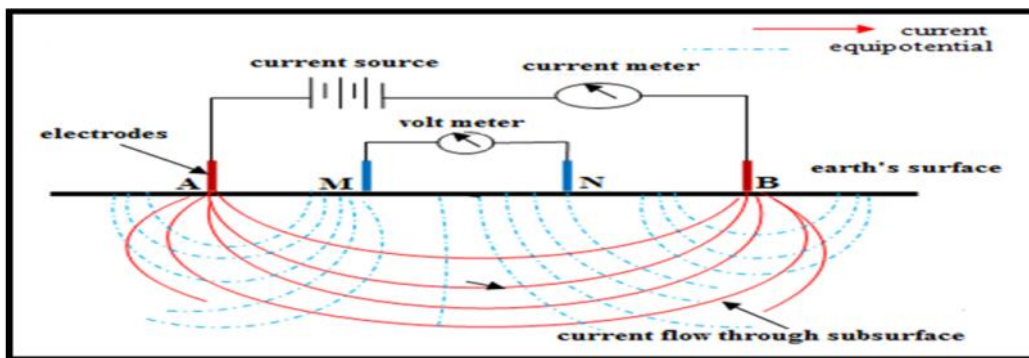


Figure 2: Schematic illustration of Basic Concept of Electrical Resistivity Measurement (Saleh et al., 2014)

LOCATION AND GEOLOGY OF THE STUDY AREA

Site Description

The area of study is located in Iba, Alimosho Local Government Area. It is 1.7km from Lagos State University, Ojo, Lagos. It is situated between Latitude 06°29' 33.7" and Longitude 03°11' 36.7" as shown in figure 3. The geographical location of Iba where the school is located could be understood within the context of its surrounding communities. To the South of Iba is the kingdom of Ojo, a settlement located right on the fore shore of the Badagry Creek. To the West, is the town of Ishasi, a part of the Iba kingdom, where it shares boundary with Ketu and Ijanikin. To the north, is

Obadore, a community considered to be more contemporaneous with Iba in terms of settlement, while Ijeododo and Ijegun constitute its eastern neighbours (Adeyeri & Sanni, 2013).

Geological settings

The area is sedimentary terrain comprises of Top soil, Sandy clay, Sand and Clayey sand. Ground water occurs in these formations under semi-confined and confined conditions (Ogundana & Talabi, 2014). In general these formations have resulted to moderate productive aquifers. The school has 2 wells out of which one is polluted.

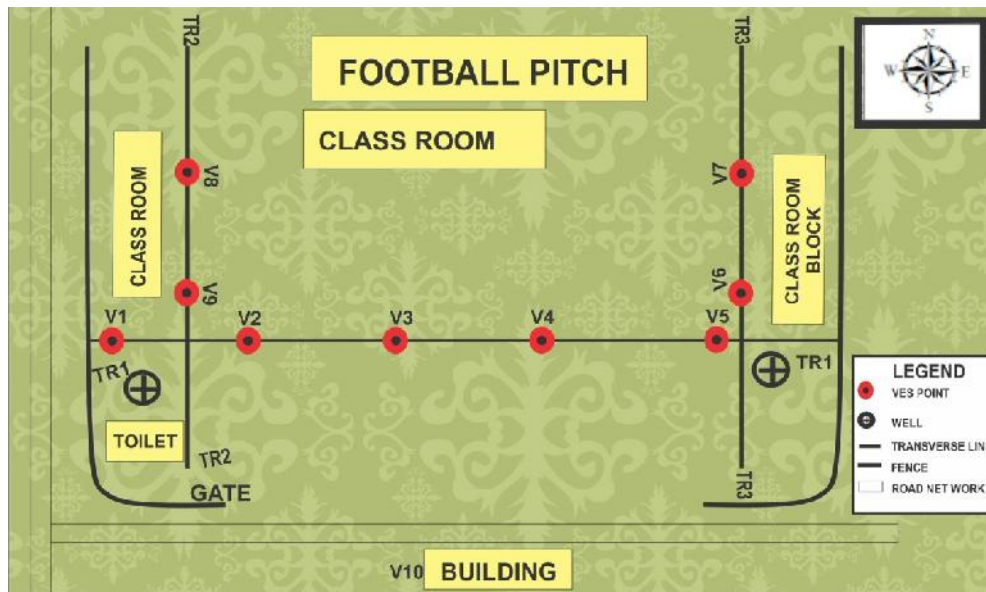


Figure 3: Location map of the study area showing positions of the profiles

MATERIALS AND METHODS

In this work the instruments used for data collection are; Terrameter PASI system and its components such as magnetic compass, field hammer, cutlass, ranging pole, pegs, electrodes, cables and reels, measuring tape, global positioning system (GPS), and other accessories. The consecutive readings were taken automatically and results were averaged continuously and presented automatically on the display. Vertical Electrical Sounding (VES) using D.C resistivity method was carried out in the study

area. The data were acquired using Schlumberger array. Profiles of 500 m length that are not necessarily parallel to each other were established at different locations to cover the whole area under study as shown in Figure 3. Measurements were taken at each VES point by expanding the current electrodes symmetrically about the centre of the spread.

Data Processing

The data were reduced, and the computed apparent resistivity values were then plotted against

their corresponding $AB/2$ values on log-log graph paper using computer software (Win Resist) and DiproWin for the curves and Pseudo-sections

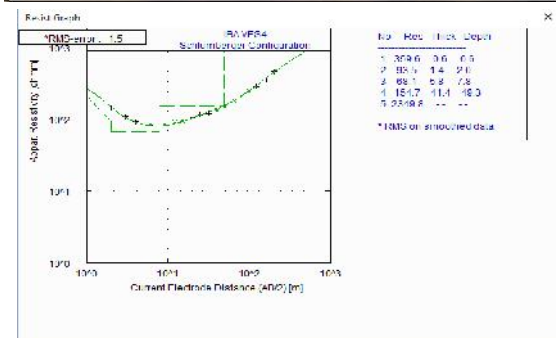
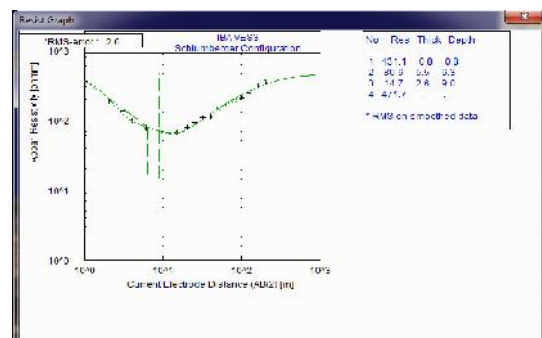
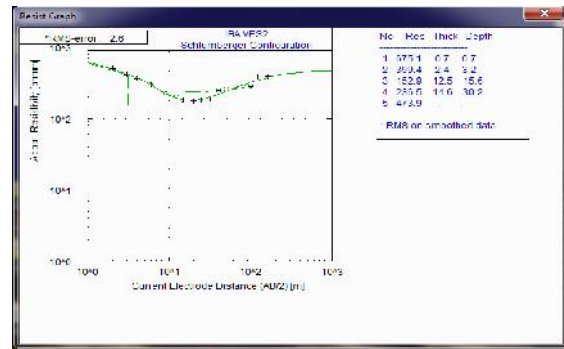
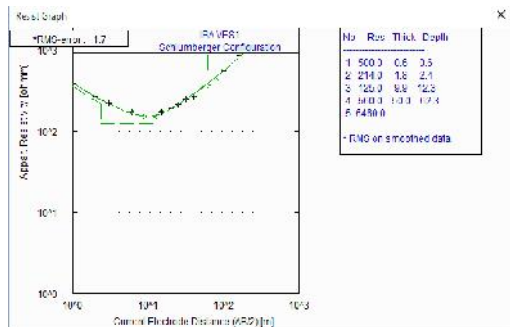
RESULTS AND DISCUSSION

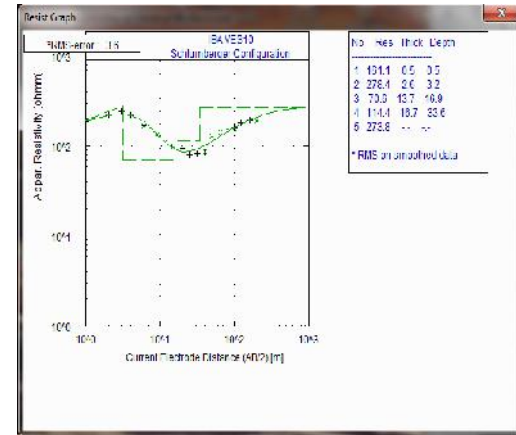
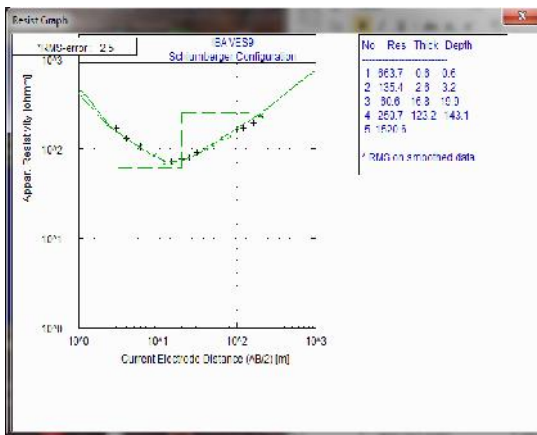
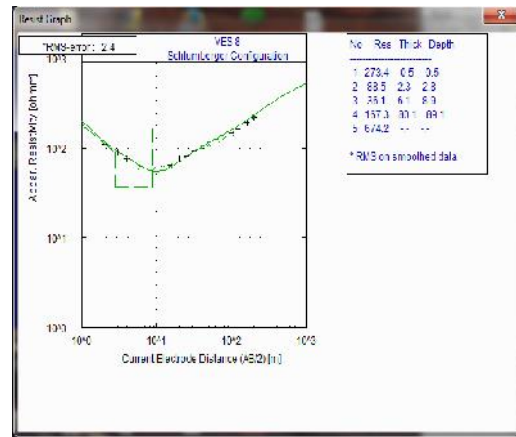
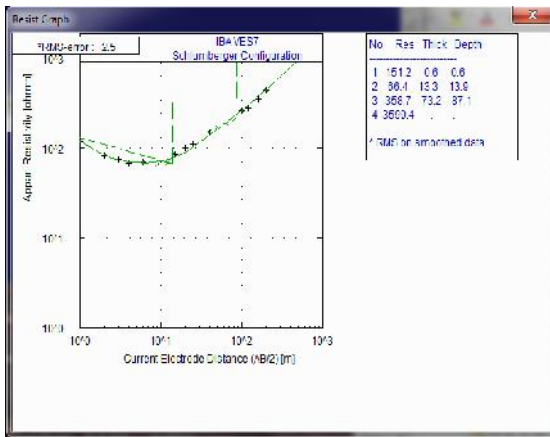
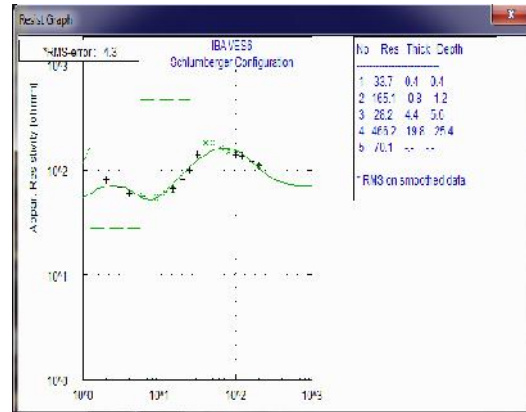
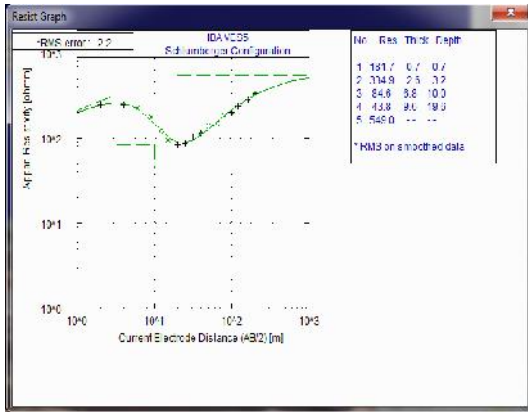
The data analysis for the Vertical Electrical Sounding (VES) was performed using computer software (win Resist) as stated above. Different geophysical and geologic works carried out in Iba Estate Primary School were considered in order to arrive at the resistivity values used for the interpretation of this present work. The area of study consists of five geo-electric layers successions in both 1-D and 2-D results as shown in Figures 4 and 5. The first layer is represented by Top soil of thickness subsurface space value ranges from 0.4 m to 0.8 m, depth from 0.4 m to 0.8 m with resistivity values from 151.1 Ωm to 675.1 Ωm . The second layer is represented by Sandy clay of thickness 0.8 m to 13.3 m, depth 1.2 m to 13.9 m with resistivity values from 66.4 Ωm to 399.4 Ωm . The third layer is Sand of thickness 2.6 m to 73.2 m, depth 5.6 m to 87.1 m with resistivity values from 14.7 Ωm to 358.7 Ωm . The fourth layer is Clay Sand of thickness 9.6 m to 123.2 m, depth 19.8 m to 143.1 m with resistivity values from

respectively. The plots are shown as Figures 4a-j. The Pseudo-sections are shown as Figures 5a-b.

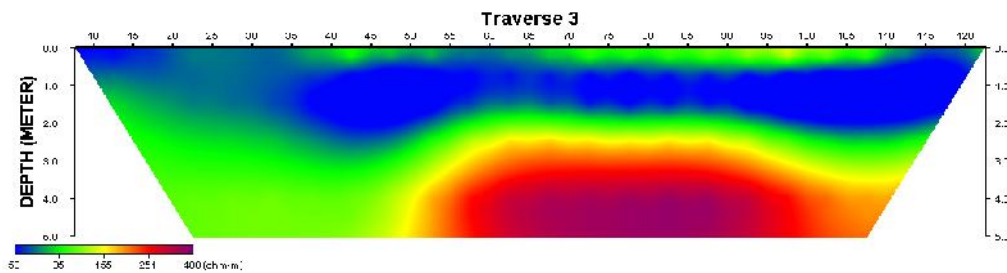
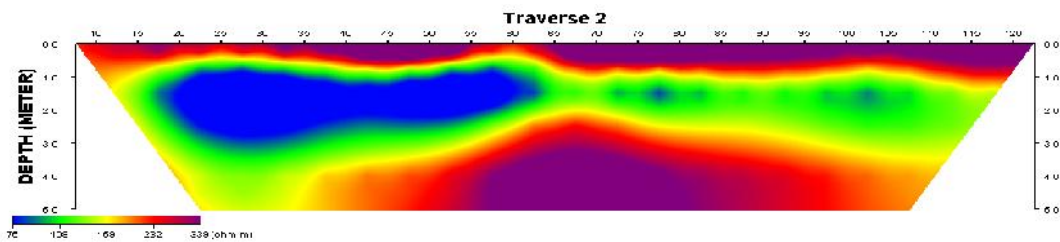
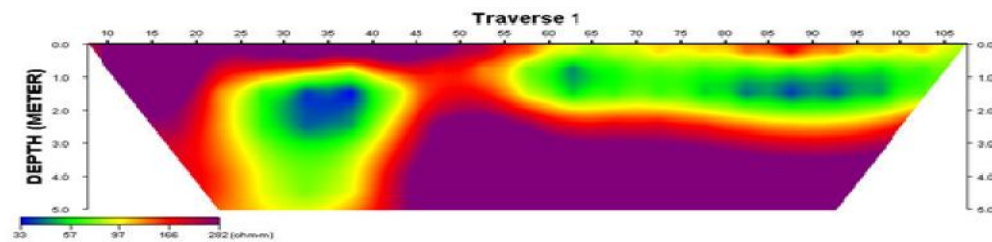
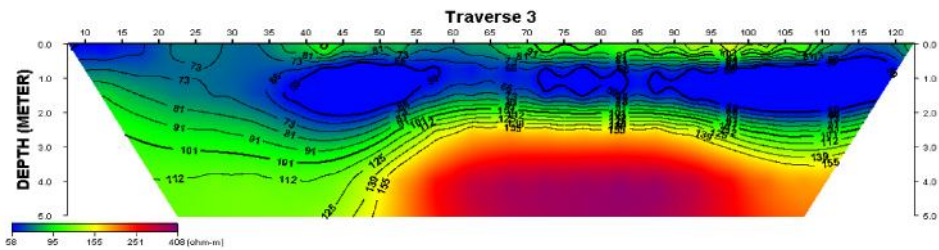
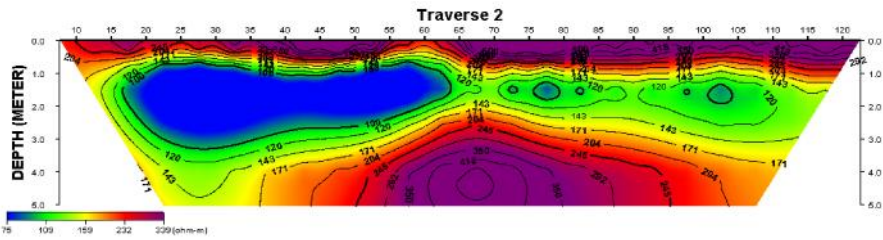
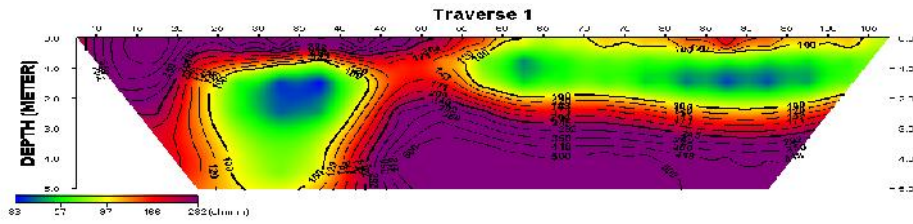
43.8 Ωm to 560.0 Ωm . The fifth layer has resistivity values from 70.1 Ωm to 6460.0 Ωm the current terminated in most of the VES points as shown in Figures 4, as this layer showing no value for thickness and the depth. Table 1 showed the summary of the values obtained from the VES plotting. It can be inferred that the suitable aquifer will be at the third layer.

The results are presented as sounding curves as shown in Figures 4 a-j. From the inspection of the interpreted resistivity curves, it is apparent that some of the curves are HA curves and KHA curves. From the pseudo-sections it can be revealed that the NW and SW regions are comparatively more weathered than the other parts. The investigation of the study area has revealed the third layer to be the most competent for locating small to medium engineering structures due to the presence of sandy soil. Therefore, third layer can be considered to be highly promising water-bearing layer for well or borehole drilling based on its resistivity value.





Figures 4a-j: The resistivity Curves and interpreted models for VES stations I-10



Layer	Thickness (m)	Depth (m)	Resistivity (Ωm)
1 st	0.4 - 0.8	0.4 - 0.8	151.1 - 675.1
2 nd	0.8 - 13.3	1.2 - 13.9	66.4 - 399.4
3 rd	2.6 - 73.2	5.6 - 87.1	14.7 - 358.7
4 th	9.6 - 123.2	19.8 - 143.1	43.8 - 560.0
5 th	-----	-----	70.1 - 6460.0

CONCLUSION

Understanding the subsurface formation during the planning stages of the development of a site is the key to success. One of the most widely used geophysical survey methods is the measurement of electrical resistivity (Adegbola, Oseni, Sovi, Oyedele, & Adeoti, 2010). In this study, electrical resistivity method using VES and 2D surveys were carried out in the study area using the Schlumberger and Wenner electrode arrays with a view to understand the subsurface geologic settings that could guide the successful exploration of groundwater. Analysis of the interpreted results revealed the nature and composition of the subsurface lithologic units. Resistivity-sections and Pseudo-sections were generated. Both low and high resistivity anomalies have been demarcated in pseudo-section and resistivity sections. Majority of the VES curves are 'HA' type with multi layered geo-electrical sections. From the pseudo-sections it may be revealed that the NW and SW regions are comparatively more weathered than the other parts. The investigation of the study area has revealed the third layer to be the most competent for locating small to medium engineering structures due to the analysis of the curves. Therefore, third layer can be considered to be highly promising water-bearing layer for well or borehole drilling based on its resistivity value.

ACKNOWLEDGEMENT

My gratitude goes to Mr Ponle, the Technician for the role played towards the completion of this field work.

REFERENCES

- Adegbola, R. B., Oseni, S. O., Sovi, S. T., Oyedele, K. F., & Adeoti, L. (2010). Subsurface Characterization and its Environmental Implications using the Electrical Resistivity Survey: Case with LASU Foundation Programme Campus Badagry, Lagos State, Nigeria. *Nature and Science*, 8(8), 146-151.
- Adeyeri, J. O., & Sanni, H. A. (2013). Social and Economic Development of Ibaland Up to 2000. *Global Journal of HUMAN SOCIAL SCIENCE*, 13(3), 17-24.
- Amadi, A. N. (2011). Evaluation of the Groundwater Potential in Pompo Village, Gidan Kwano, Minna Using Vertical Electrical Resistivity Sounding. *British Journal of Applied Science & Technology*, 3(3), 53-66.
- G.VenkataRao, P.Kalpna, & Rao, R. S. (2014). Groundwater Investigation Using Geophysical Methods- A Case Study Of Pydibhimavaram Industrial Area. *International Journal of Research in Engineering and Technology*, 3(16), 13-17.
- Hadi, T. N. (2009). Geoelectric Investigation of the Aquifer Characteristic and Groundwater Potential in Behbahan Azad University Farm, Khuzestan Province, Iran. *Journal of Applied Sciences*.
- Jatau, B. S. (2013). The Use of Vertical Electrical Sounding (VES) for Subsurface Geophysical Investigation around Bomo Area, Kaduna State, Nigeria. *IJSR Journal of Engineering*, 3(1), 10-15.

- Kelly, W. E. (1993). *Applied Geophysics in Hydrogeological and Engineering Practice*. Elsevier, Amsterdam.
- Loke, M. H. (2000). *Electrical imaging surveys for environmental and engineering studies: A practical guide to 2-D and 3-D surveys*.
- Mansour, A. A.-G. (2009). Geophysical Investigations for Groundwater in a Complex Subsurface Terrain, Wadi Fatima, KSA: A Case History. *Jordan Journal of Civil Engineering*, 3(2).
- Ogundana, A. K., & Talabi, A. O. (2014). Ground water Potential Evaluation of Ultra Modern Guest House, Afe Babalola University, Ado-Ekiti, Southwestern Nigeria. *The International Journal Of Engineering And Science*, 3, 41-45.
- Okafor, P., & Mamah, L. (2012). Integration of Geophysical Techniques for Groundwater Potential Investigation in Katsina-Ala, Benue State, Nigeria. *The Pacific Journal of Science and Technology*, 13(2).
- Oyedele, K. F., & Olorode, D. O. (2010). Site Investigations of Subsurface Conditions Using Electrical Resistivity Method and Cone Penetration Test at Medina Estate, Gbagada, Lagos, Nigeria. *World Applied Sciences Journal*, 11(9), 1097-1104.
- Oyeyemi, K. D., Aizebeokhai, A. P., & Oladunjoye, M. A. (2015). Integrated Geophysical and Geochemical Investigations of Saline Water Intrusion in a Coastal Alluvial Terrain, Southwestern Nigeria. *International Journal of Applied Environmental Sciences*, 10(4), 1275-1288.
- Saleh, S. D., Sule, P. O., Ahmed, A. L., & Murana, K. A. (2014). Subsurface Structural Characterization Using Dc Resistivity Method At Industrial Development Centre (Idc), Zaria. *Ozean Journal of Applied Sciences*, 3(3), 87-102.
- Sarma, V. S. (2014). Electrical Resistivity (ER), Self Potential (SP), Induced Polarisation (IP), Spectral Induced Polarisation (SIP) and Electrical Resistivity Tomography (ERT) prospection in NGRI for the past 50 years-A Brief Review. *J. Ind. Geophys. Union*, 18(2), 245-272.
- Sunmonu, L. A., & et.al. (2012). The groundwater potential evaluation at industrial estate Ogbomoso, Southwestern Nigeria. *RMZ - Materials and Geoenvironment*, 59(4), 363-390.