



Geophysical Evaluation of Groundwater Potential Using Electrical Resistivity Method in Nigerian Defence Academy, Kaduna, Nigeria

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Received on: September 2019

Revised and Accepted on: November 2019

Published on: December 2019

ABSTRACT

The groundwater potential of the (NDA, Kaduna) was investigated using vertical electrical sounding (VES) method. A total number of 40 vertical electrical sounding VES points were used for the investigation using Schlumberger array and data obtained were analyzed using curve matching and computer iteration techniques. The data revealed a 3-layer (A, KH and H Curve type) and 4-layer (A and H-curve type). In the 3-layer system, the apparent resistivity of the first layer ranged from 18.9 Ωm to 183.2 Ωm with a corresponding thickness of 0.7 m to 14.8 m. The second layer has apparent resistivity value ranged from 13.5 Ωm to 423.8 Ωm with a corresponding thickness in the range of 4.5 m to 14.7 m while the third layer has resistivity values ranging from 1156.4 Ωm to 3732.7 Ωm with an infinite depth. For the four (4) layered model curves, first layer's resistivity ranged from 29.5 Ωm to 244.7 Ωm , with a corresponding thickness ranging from 0.8 m to 13.0 m. The resistivity of the second layers ranged between 25.2 Ωm to 183.4 Ωm with a corresponding thickness ranging from 8.0 m to 14.2 m. The third layer resistivity ranged from 119.4 Ωm to 586.7 Ωm with a corresponding thickness ranging from 8.1 m to 20.4 m. The forth layer has a resistivity value ranging from 1318.3 Ωm to 3240.9 Ωm with an infinite depth. An integration of both isopach and iso-resistivity maps for both the 3- layer model curves and 4- layer model curves indicates that most of the northwest parts of the study area have low apparent resistivity values and thick overburden which implies good groundwater potential while, the southern portion has a little higher resistivity values and shallow overburden, an indication of poor groundwater potential. Future boreholes in the area should reached an expected depth of 40 m to 60 m depth

Keywords: Evaluation, Groundwater Potentials, Resistivity, Depth, Aquifer.

1.0 INTRODUCTION

The growth of any locality (NDA, Kaduna) depends on availability of basic infrastructural needs such as roads, water, electricity and industries among others. A general case of northern Nigeria where the amount of rainfall is limited to very few months of the year with annual rainfall of about 1000-1500mm (Eduvie, 1998). Surface water sources are often inadequate or non-existent (Baimba,1978, Perez and Barber,1965).

There is need for scientific identification of parameters governing ground water resources, investigation of groundwater potential and management, particularly, if satisfactory living conditions of the inhabitants are to be catered for. This is paramount, due to the presence increase in groundwater demand for various human activities. The New Nigerian Defence Academy Kaduna, Nigeria was designed originally for over 8,000 cadet and staff but currently has a population of over 15,000 people and basic amenities are over-stretched. This high population has resulted in acute water shortage in

the area, the inhabitants now rely on water vendors for their daily water needs. Groundwater accounts for greater percentage of the world's fresh water and it is fairly distributed throughout the world. It is the need to delineate the areas that would be suitable for groundwater potential and need to conduct hydrological and geophysical survey of the area in order to provide useful information on the possible sites for ground water exploration. Since the object of sound is to determine the variation of electric conductivity with depth, vertical electrical sounding (VES) has been the most important geophysical method of water prospecting in area of deep in situ weathering of fresh bedrock. The geo-electric resistivity method, particularly the (VES) method has been chosen for this particular work basically, because it has proven to be an economic, quick and effective means of solving most ground water problems in different parts of the world (Breusse,19631969 and Frohlich, 1974).

2.0 MATERIALS AND METHODS

The equipment that were used for the resistivity method is reasonably cheap and easy to use. The resistivity field data were acquired with the aid of the following equipment: -

Terrameter (Geopulse campus Tiger)- This is the major power source of the whole set-up. It measures the resistance of the subsurface layers and can also measure the voltage of the power source. The equipment has an in-built system of reducing the effect of noise. The instrument is portable and fixed with a rechargeable battery. It has a maximum power of 18 watts, manual selection of current in steps up to 100mA, a choice of sample time/ signal length averaged three frequency settings.

Electrodes- These are steel rods of about 30cm with a base and a pointed end. The pointed end is use to penetrate the ground. The material makes it a good conductor. Four electrodes were used;

3.0 METHODOLOGY

In this particular work, the data collected were basically collected from main measuring mode of the Terrameter (Resistivity). The profiling data were collected using Wenner electrical profiling method. 10 m-electrode spacing was used and this corresponds to 15 m probe depth. Care was taken to ensure that the electrode layout follow a

the first pair is the potential electrode while the second pair is the current electrode. Their basic function is to pass current into the ground and measure potential between two points. Two-third of the length of the electrodes was driven below the earth surface.

Cables- They are made of conducting material (copper). There were four reels of cables used during the geophysical survey. The cables were connected to the terrameter on one end and the other is connected to the electrodes.

Clips- These are objects used for passing the currents from the cables to the electrodes by clipping the electrodes after wounding the cable on it. The mouth is made of conducting materials while the base (handle) is made of insulating material to prevent electrocution. The clips ensure good electrical contact

Hammer and Cutlass-These were used to drive the electrodes into the ground. It consists of a relatively slim wooden cylindrical handle embedded into a metallic head. While the cutlass was used to clear the path along which measurement are to be taken.

Tapes- These are used for making measurements of length on the field as they have been calibrated in metric units. The tapes used were of 100m in length. They were used in measuring electrode spacing on the field.

Global Positioning System and Compass-Clinometer- this equipment was used for taking coordinates and bearing. GPS will be used for taking the longitudes, latitudes and elevation of various locations. It is portable and handy. The compass-clinometer was used to take direction of the profiles.

Field Stationery- These are writing materials that were used to record all observation and field data. The stationery consists of pencils, pens, recording sheets, rulers and so on.

straight line along the N-S profile layout. Similarly, Schlumberger method of electrical sounding was employed for electrical drilling (VES data). The maximum current electrode separation of 200 m and potential electrode separation of 30 m were reached and this corresponds to 100 m probed depth (i.e. AB/2). There was no need for data reduction or repeated measurement since the receiver of meter

discriminates noise and measures voltages corrected with transmitted signal current. The system has the built-in function to average the best measurement of maximum of four staking

with the standard deviation of unity or even less (ABEM instrument AB, 1999). The field layout is shown in table 1.

Table 1: Show the Profile Layout along which the Data were collected

	A1	A2	A3	A4	A5	A6
NDA.	B1	B2	B3	B4	B5	B6
N	C1	C2	C3	C4	C5	C6
	D1	D2	D3	D4	D5	D6
	E1	E2	E3	E4	E5	E6
AIRPORT ROAD.	F1	F2	F3	F4	F5	F6

3.1 Pre-drilling Geophysical Investigation

A total spread of 100 m was covered with maximum current electrode separation (AB/2) of 50 m. An ABEM SAS 1000 Terrameter with schlumberger electrode configuration were used for the electrical resistivity survey. The array

consists of 2 currents (C_1 and C_2) and 2 potential (P_1 and P_2) electrodes (Fig 4). According to (Olasehinde and Awojobi, 2004), It method works under the principles of the wider the current electrodes, the deeper the current penetration.

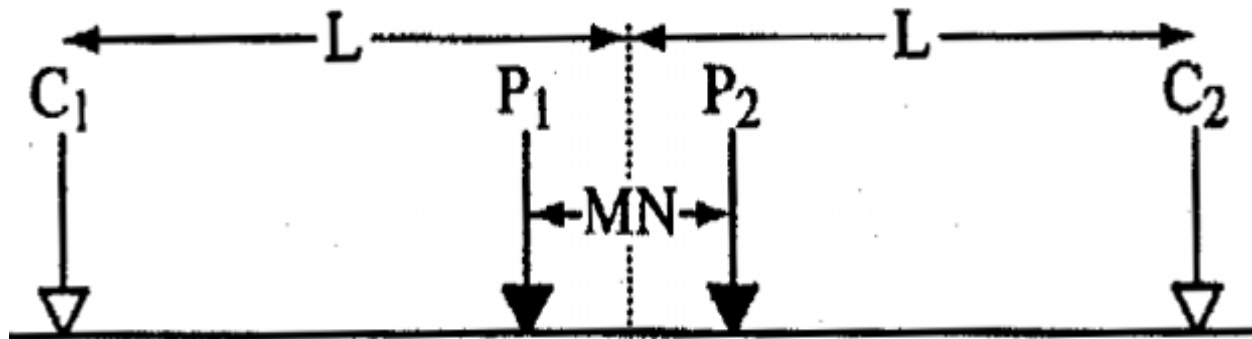


Figure 3.1: Schlumberger Array

The apparent resistivity values acquired from the measurement were plotted against half the current electrode spacing on a bi-logarithmic graph in order to determine the apparent resistivity and thicknesses of various layers penetrated. This software performs automatic interpretation of the Schlumberger sounding curves which gives the equivalent n-layer model input from the apparent resistivity data of each sounding point. It converts the apparent resistivity as a function of electrode spacing to the true resistivity as a function of depth in two dimensions. The profile data were processed using computer iterative window-based application software called surface 8.0, from Golden software and Minitab 14, which

gives a graphical presentation of the contour map. The software generates the resistivity contour map of both contour map and profiling data.

3.2 Study Area Description

Nigeria Defence Academy, Kaduna, Nigeria, is located along Kaduna airport -Mando road.. The Nigeria Defence Academy, lies in the north-western part of Nigeria with latitude of $10^{\circ}35''$ N and longitude $07^{\circ} 19''$ E, with elevation of 648 m, (Fig. 1). The study area is accessible through major roads, Kaduna airport road, shows geological maps of Nigeria showing the study area.



Figure 3.2. Map of Kaduna showing the accessibility of the study area

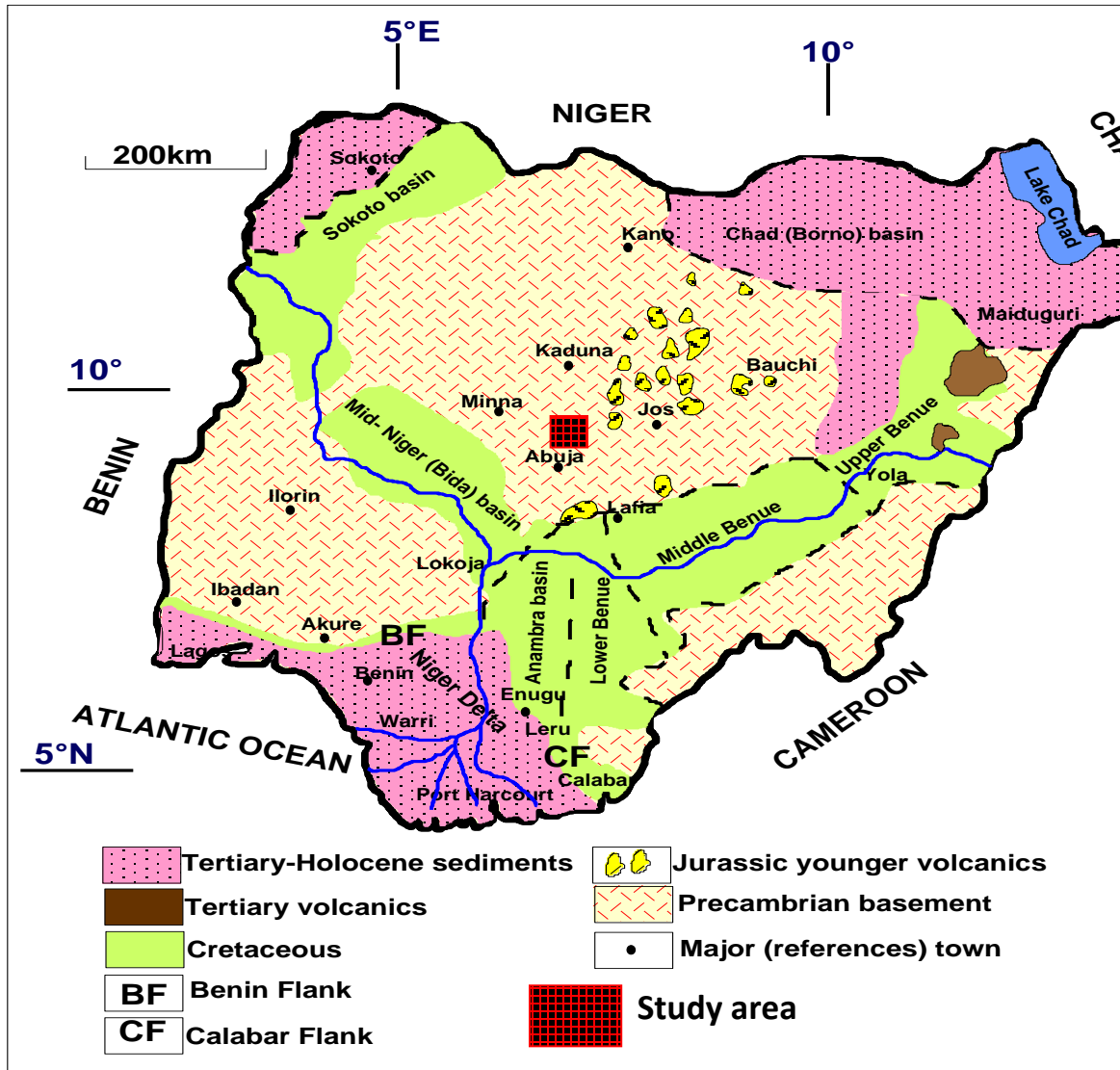


Figure 3.3 Geologic map of Nigeria showing the Study Area (NGSA., 2000)

3.3 Geology and Hydrogeology of The Area

The study area lies within the Basement Complex of Northern Nigeria (figure 2). The Basement Complex includes all rocks older than the late Proterozoic (McCurry, 1976). It is composed mainly of gneisses, migmatite,

granites, and some extensive areas of schist, phyllites and Quartzites (Baimba,1978),(Preez and Barber.,1965) according to (McCurry,1976).The whole Basement has been through at least two tectonic-metamorphic cycles and consequent metamorphism, magnetization and

granitisation have extensively modified the original rocks so that they generally occur as relict rafts and xenoliths in migmatite and granites. Two groups of granites are present and these are the Older Granites and the Younger Granites. The Older Granites are widespread and often give rise to smoothly domed hills which typically rise to about 170 m above the surrounding plains,(Russ,1957).The Younger granites which include granites,syenites and rhyolites cover extensive areas in the plateau ,(Russ,1957).

The topsoil varies in composition, colour and texture at most places. They are predominantly laterite and quartz grains (deep browns or reddish brown soil). Geophysical investigation reports of (Eduvie., 2005) and (Dan –Hassan., 1999) showed that Kaduna is underlain by 3 to 5 geologic layers; the top lateritic soil, clayey sand/sandy clay, weathered transition zone, the fractured bed rock and the fresh bedrock. Geophysical investigation and borehole drilling reports have clearly established two major aquifers. These are the overburden weathered aquifer

and the fractured crystalline aquifer (Dan-Hassan and Olarufemi.,1999) at some locations these aquifers are interconnected and form a hydrogeological unit of water table surfa

4.0 RESULTS AND DISCUSSION

Two different categories of model curve types were identified in the study area. The first category is those with four layers which represent about 60% of VES curves (Fig. 4.1) while the second category consists of three layers (figure 4.2), which representing about 40% of the sounded points within the study area (Figure. 4.2). The geo-electric section of the study area displayed that the subsurface lithologies of the area are not uniformly distributed from the interpretation. Area with thick regolith materials shows great potential for groundwater exploitation (Ako, 1996). The regolith are product of weathering which induces the geological materials to be porous and permeable, which qualifies them as aquifers, since they can store and transmit groundwater in economic quantity (Momoh et al., 2012). From geoelectric sections for 3 Layer system below, show clearly that VES5, VES 7 and VES 18 are more good for groundwater development

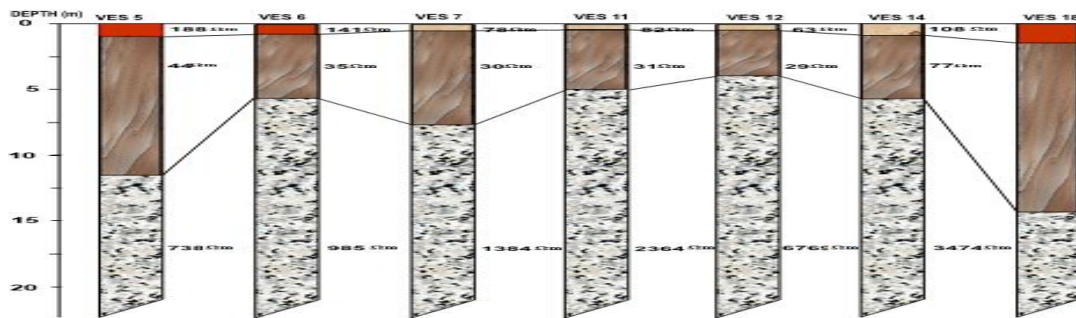


Fig 4.1: Geoelectric Sections for 3 Layer System

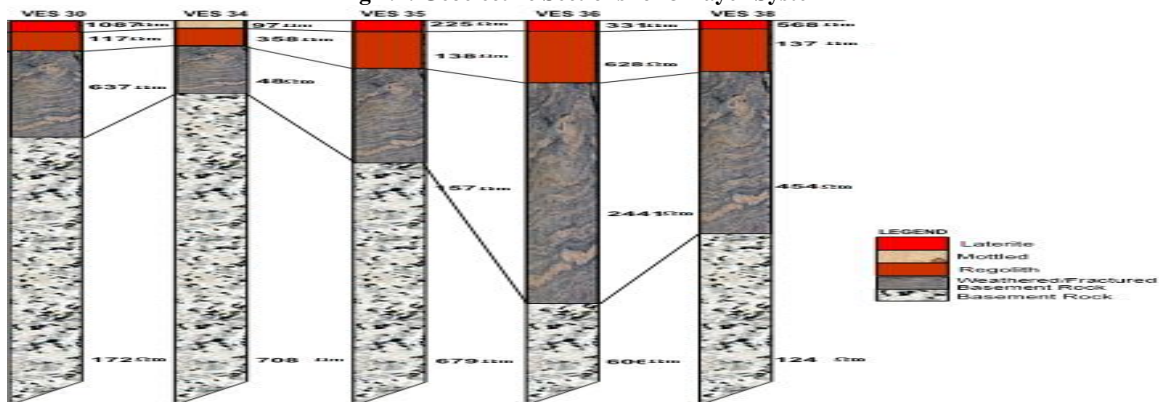


Fig. 4.2: Geoelectric System for 4 Layer System

LEGEND
 Laterite
 Mottled
 Regolith
 Weathered/Fractured
 Basement Rock

The geoelectric sections with the 3 layer show laterite, mottled zone, regoliths/saprolith and basement rock as the lithologies (Fig. 4.1) while the the four layer curves shows laterite, molted zones, regoliths/saprolith, fractured basement and fresh basement rocks (Fig. 4.2). The subsurface lithology varies from place to place within the study area and the finding conformed to the work done by other researchers such as Mbonu et al.,(1991; Olorunfemi and Okakune, (1992); Ikpokonte, (2010); Aiyegbusi and Akujieze, (2010; 2013), Omeji et al., (2013).

From the isopach map of regolith thickness for three layered curves (Fig. 4.3), it can be

established that the northern central portion of the area shows deep/thick overburden/regolith thickness, while south-western portion shows shallow overburden. This corresponds to the iso-resistivity map, as the shallow overburden materials are seen around the ridge which shows lower resistivity values. The thicker the overburden materials the better chance for groundwater storage and this implies that the northern sector correspond to groundwater discharge zone while the southern portion are areas of groundwater recharge. The average thickness of regolith/overburden materials for the three layered curve is about 11m.

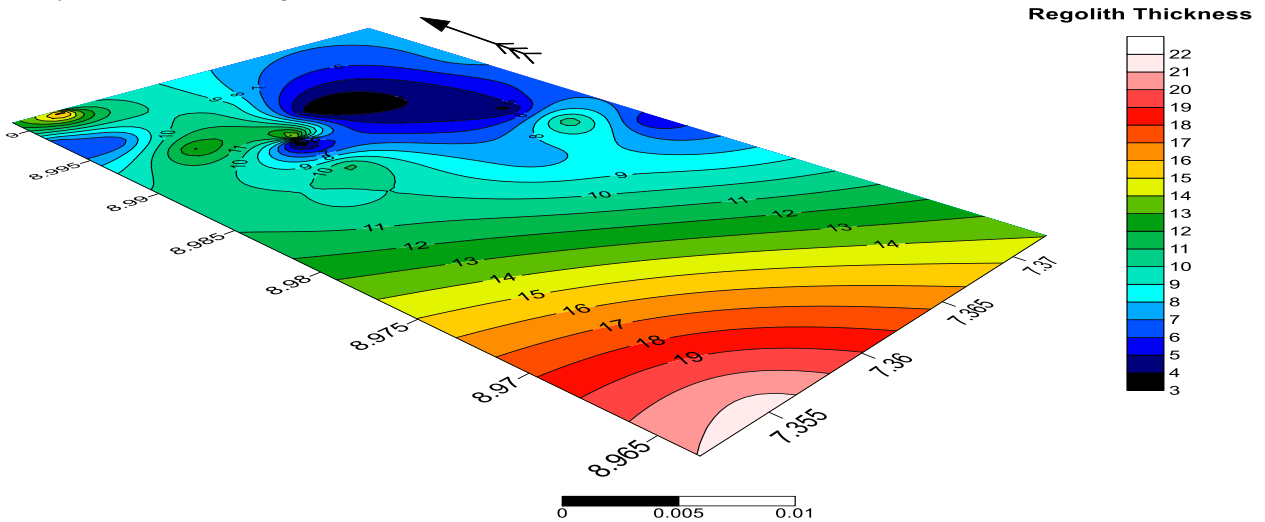


Fig. 4.3: Isopach map of regolith thickness for three layered model curves

The iso-resistivity map of the three layer model curves indicates that the resistivity value is lower at the northern central portion of the area compared to the southern portion of the area (Fig. 4.4). From the countour map the area with higher resistivity values indicate presence of no water or conducting materials while lower resistivity values are indicative of a thick overburden. For

the 3 layer system, the weathered/fractured zone is the second layer which is regarded as the regolith aquifer zone (Amadi et al., 2015b; Olasehinde et al., 2016). It is characterized by low resistivity values (high conductivity) compared to the first and third layers as illustrated in Figure 4.4.

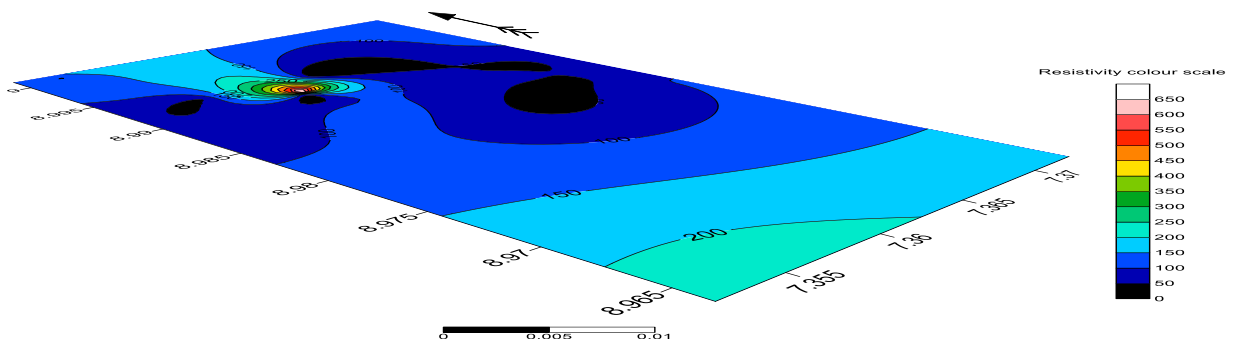


Fig. 4.4: Isoresistivity map of three layered model curves

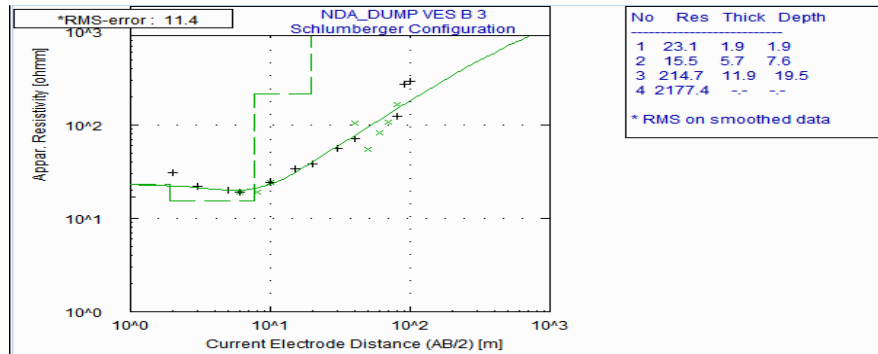


Figure. 4.2: A typical VES curve for 4 layer system in the area

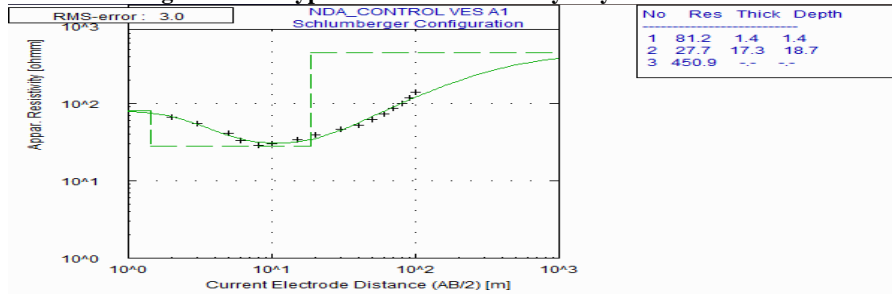


Fig. 4.3: A typical VES curve for 3 layer system in t

The geo-electric sections with the 4 layer show topsoil or laterite, weathered/ fractured basement and fresh basement (Fig. 4.2) while the the 3 layer curves shows laterite, fractured basement and fresh basement rocks (Fig. 4.3). The subsurface lithology varies from place to place within the study area and the finding conforms to the work done by other researchers (Olorunfemi and Olayinka, 2002; Osazuwa, I. B., & Abdullahi, N. K. (2008). Dan-Hassan, M. A., & Olarinfemi, M. O. (1991).

5.0 CONCLUSION AND RECOMMENDATION

The study investigates Geophysical Evaluation of Groundwater Potential in Nigerian Defence Academy, Kaduna, Nigeria using Vertical Electrical Sounding of the Electrical Resistivity

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method. The study became necessary due to the increase in population of the area as the results of personnel moving from old site to new site. A total number of 40 VES points were conducted and the data obtained were analysed through curve matching and computer software. The area comprises of both 3 layer and 4 layer system. The 3 layers were predominantly H-type curve while the 4 layer system was mainly HA-curve type and are typical of the basement complex terrain. The field data, geoelectric section, isopach and isoresistivity maps of both the 3 and 4 layer model curves show that the northern parts of the study area correspond to discharge zone while the southern portion correspond to recharge zone. A total drill depth of 40 to 60 m is recommended for optimum groundwater yields in the area.

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