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SUBSURFACE INVESTIGATION OF CLIFFORD UNIVERSITY USING GEOELECTRIC METHOD: IMPLICATIONS FOR GROUNDWATER POTENTIAL

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ABSTRACT
Vertical Electrical Sounding (VES) survey was carried out in six different locations in Clifford University campus to ascertain the subsurface properties in relation to its viability for groundwater exploitation. The campus has a relatively even topography with the elevation range being 96 m – 112 m above sea level. Schlumberger array was used in the study to measure the resistance which was used to obtain the apparent resistivity of the subsurface. The maximum electrode spacing during the survey is 250 m. Upon analysis using the winResist computer software, four geo-electric layers were observed in five of the VES stations while VES station 2 has five geo-electric layers with the respective corresponding curve type being QH, HKA, KQ, KQ, HK and HA types. The lithology of the subsurface was observed to be mainly of sand and sandstone with minor clay intercalation thus implying a highly permeable aquifer with the thickness ranging from 34.5 – 72.3 m at depths ranging from 65 – 100 m. Clifford University is therefore viable for abundant groundwater with an average drilling depth of 72 m.

Keywords: Aquifer; VES; Resistivity; Groundwater; Schlumberger; Clifford University

1. INTRODUCTION

Earth's subsurface is chiefly made of rocks, minerals, hydrocarbon and water. A knowledge of the subsurface is essential in subsurface exploration, geotechnical, engineering and geological studies (Anbazhagan, 2018). -Subsurface studies in determining the rock strata, groundwater quality and soil type is quite indispensable in project design and execution. Such investigation helps in identifying the geophysical and geological properties of the subsurface components such as porosity, thickness, stress, overburden, weathering condition, tectonic activities, faults and cracks (Anbazhagan *et al.*, 2017).

Groundwater is one of the major components of earth's subsurface. It is the main source of water in rural and urban areas used for domestic industrial and agricultural purposes (Ebong *et al.*, 2017). It is the major source of portable water because it is relatively free from chemical and biological contaminants and when it is saved properly there will not be any need of purification before it can be consumed or used for industrial purposes (Ahamed et al., 2016). Groundwater occurs in subsurface geological formations under hydrostatic pressure as in the pores and cracks of rocks (Prabhu and Sivakumar, 2018). It makes up to 30% of earth's freshwater while rivers, lakes and glaciers make up 70% of the total amount of freshwater on earth (Salas *et al.*, 2014). Groundwater is the most extracted resource in the world and it accounts for about half of the world's drinking water, 40% of its irrigation water and a third of the water used for industrial purposes

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(Lall, 2017).

In tropical areas, groundwater is most useful during the dry season when there is no rainfall. The occurrence, storage and groundwater flow are dependent on a number of factors like geology and subsurface properties like faults, joints, fractures and weathering of hard rock beneath the surface of a particular area. Groundwater can also be affected by Climate change (Shakib and Shojarastegari, 2017). These factors have made groundwater to be abundant in some areas while it is deficient in other areas. Aquifers are rocks or unconsolidated sediment which can collect, store and transmit significant amount of groundwater to wells and springs. Examples include: Sands, pebbles, gravels, fractured hard rocks and cavernous limestone. Aquifer is composed of materials that are porous with sufficient level of permeability to allow water to flow through it (Todd, 2001).

Since the quantity and quality of groundwater depends on the variation in sub-surface properties, geophysical survey plays an indispensible role in ascertaining the occurrence and distribution of groundwater in different hydro-geological circumstances. Geophysical surveys are environmentally friendly as they are conducted on the surface of the earth with no disturbance of sub-surface materials. They are also cost-effective (Reynolds, 2011). The principal methods used in geophysical exploration include seismic, gravity, magnetic, electrical resistivity, self- potential, induced polarization and electromagnetic methods which are used based on the physical property of the subsurface investigated (Reynolds 2011, Kearey and Brooks, 2002).

The geoelectric method is the electrical geophysical survey aimed at determining the surface effects produced by the flow of electric current inside the earth. The electrical technique has wide range of application in; groundwater and mineral exploration, structural engineering studies, geothermal studies, permafrost mapping, archeological investigations and geological mapping (Sampath Kumar and Swathi, 2015). Geoelectrical resistivity techniques are reliable and can provide sufficient contrast in subsurface structures and variations in rock properties which can be exploited during groundwater investigations (Ebong, 2014) Vertical Electrical Sounding (VES) is a geoelectric method which studies the variation of earth's resistivity with depth. The electrical resistivity and conductivity of rocks depends on its porosity, water content, composition (clay mineral and metal content), salinity of pore water and grain size distribution (Azunna and Chukwu, 2018).

Variations in the resistivity of earth materials either vertically or laterally, produce variations in the relations between the applied current and the potential distribution as measured on the surface thereby revealing something about the composition, extent and physical properties of the sub-surface materials. It is upon this principle that VES is employed. This research therefore uses the VES method to investigate the subsurface properties and their implication for groundwater abundance in Clifford University campus.

1.1 The Study Area

The Study area is located in Isiala-Ngwa North Local Government Area of Abia State Nigeria bounded in the South and by Umuahia South and Isiala-Ngwa South Local Government Areas Respectively. Clifford University is within the study area with latitude $5^0 22'.0'' – 5^0 25'.0''$ N and longitude $7^0 20'0''$ E - $7^0 23'0''$ E (Figure 1). The Climate of the study area is relatively humid being part of the sub-equitorial belt with an average rainfall of 4000 mm annually (Amos-Uhegbu *et al.,* 2012). The vegetation of the study area is mainly of the rainforest type while the surface temperature varies from 20 ^{0}C – 32 ^{0}C (Azunna *et al.*, 2020). The study area has a dendritic drainage pattern and it is drained by a distributary of Imo river and the elevation ranges from 96 m to 112 m above sea level thus having a relatively even topography as shown in figures 3 and 4.

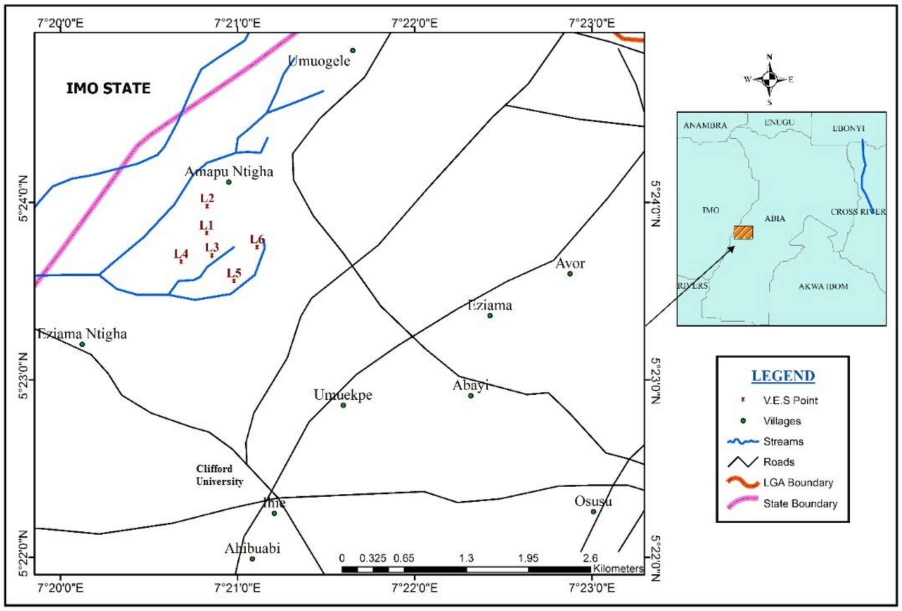


Figure 1: The location map of the study area showing the VES points

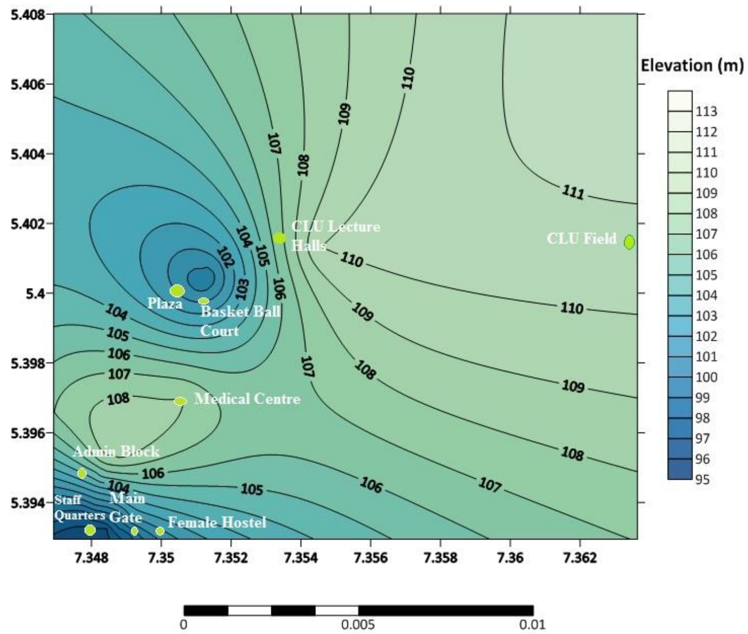


Figure 2: Elevation contour map of Clifford University Campus.

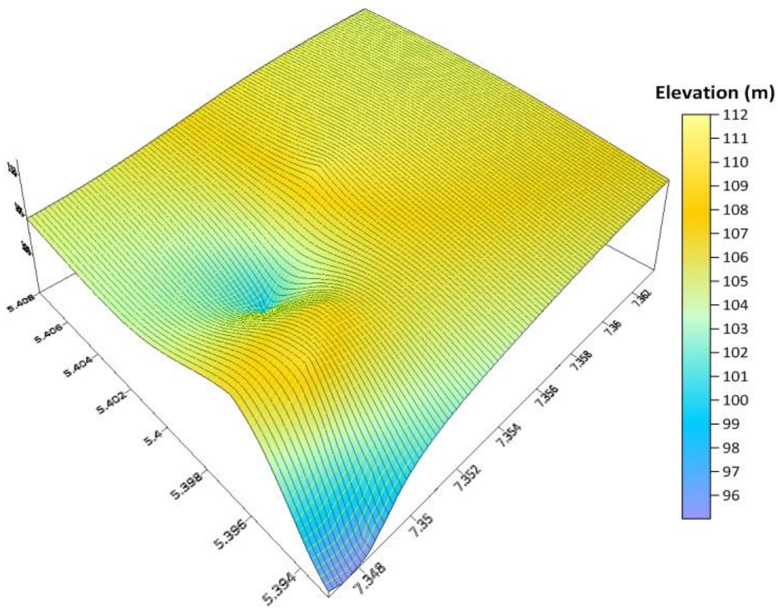


Figure 3: 3D Elevation map of Clifford University Campus.

Geologically, the study area is underlain by the Benin formation which is the youngest stratigraphic unit of the Niger-Delta Basin of Miocene to recent age (Short and Stauble, 1967, Azunna *et al.*, 2021). The Benin formation is made of continental deposits which included alluvial and upper-coastal deposits of about 2 km thick. Basically, Benin formation consists of sand and shale with an intercalation of thin clay beds (Anyadiegwu *et al.,* 2019)

2.0 REVIEW OF RELATED LITERATURE

Many studies have been done using geo-electric method to study the sub-surface as it relates to groundwater exploration. Abbey and Digbani (2018) understudied the groundwater potential of Rumuolumini town of Rivers state Nigeria using two VES soundings with the Schlumberger array. They discovered that the area is composed of top soil, clay, mud and sand with two aquiferous zones. The first zone has good quality groundwater while the second zone is shallow. There is therefore a sustainable groundwater water supply at a depth of 40 – 55 m.

On their own study, Victor *et al.,* (2014) understudied the groundwater potentials of Lokpaukwu, Abia State, using ten VES points using the schlumberger array configuration and observed six geo-electric layers showing a sequence of shale/clay-sand. The predominant VES curve was the H-curve showing a predominant water table depth of 40 m. However, with the variations in iso-resistivity, Isopach and traverse resistance, the occurrence of groundwater was observed to be at a depth of 100 m.

Sixty VES points were used by Doris et al. (2019) to obtain the aquifer depth of Ehime Mbano to be 90 m. They also used the Schlumberger array in the study. They also observed occasional truncation of the lateral continuity of the sands and sandstones by the shaly sediments in the study area and the aquifer parameters they estimated in some regions of their study permitted groundwater circulation thus possessing groundwater exploration prospects.

Amos-Uhegbu *et al.* (2012) also used the schlumberger array to obtain ten VES data sets in Umuahia South and they used the geo-electric section of different VES stations and compared it with some lithologs which gave a good geo-electrical description of the study area revealing a multi-aquifer hydrogeologic system where some stations in the study area will likely have a failure in bore-hole exploration. Chukwu *et al.*(2015) also used the Schlumberger array of VES to understudy the causes of bore-hole failure in Ikwuano/Umuahia area of Abia State, Nigeria and they discovered that the Imo shale formation and the total drill depth of 120 m make bore-hole drilling a waste of resources thus not being viable for ground water abundance.

In the Nandi River Basin of India, Prabhu and Sivakumar (2018) used the schlumberger array to obtain twenty-seven VES data sets up to a depth of 150 m and they identified potential zones of groundwater resources using true resistivity and sub-surface thickness obtained. Sampath and Swathi (2014) also studied the subsurface properties of Kanigiri area, Prakasam district, Andhra Pradesh, India using fifteen VES stations and the Schlumberger array and discovered that the subsurface of the study area has heterogeneous geologic sequence.

VES has proven easy and useful in the study of groundwater because of its ease of use. Plethora of studies have been done in groundwater and subsurface studies using VES in various parts of Nigeria and the world at large as can be seen in the works of Ibeneme *et al.* (2014), Okonkwo and Ujam (2013), Ezeh (2012), Webb *et al.* (2011), Akaolisa (2006), Adiat et al. (2009), Adepelumi *et al*. (2001), Bala and Ike (2001), Ozebo *et al*. (2008) and Udom *et al.* (2002). Nevertheless, there seems to be insufficient information as regards the sub-surface properties and groundwater potential in Isiala-Ngwa North which is the focus of this paper with Clifford University being the central point.

3. MATERIALS AND METHODS

Field survey was carried out in March 2022 on the campus of Clifford University to obtain VES data from six VES stations in different locations of the University. Schlumberger array method was employed where a pair of current electrodes and a pair of potential copper electrodes connected to a resistivity meter powered by a DC-battery were used to obtain the apparent resistivity of the subsurface under investigation. The schematic diagram of the connection is as shown in Figure 4 and the current distribution in the subsurface is shown in Figure 5. The maximum spread of the current electrode AM = ½AB is 250m on each of the VES stations.

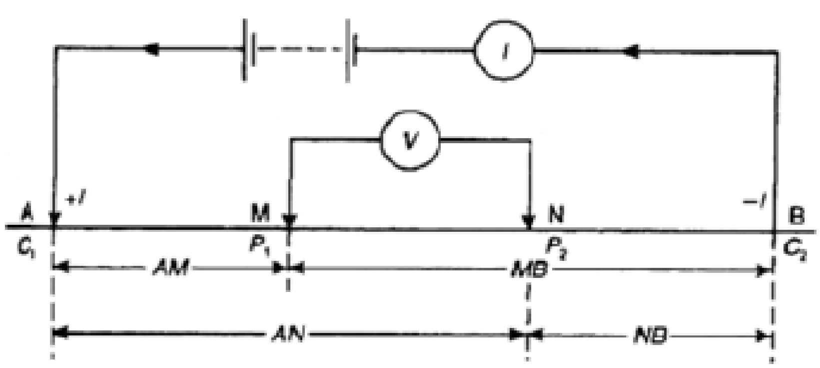


Figure 4: Electrode Configuration for Electrical Resistivity (Keller and Frischknecht, 1996)

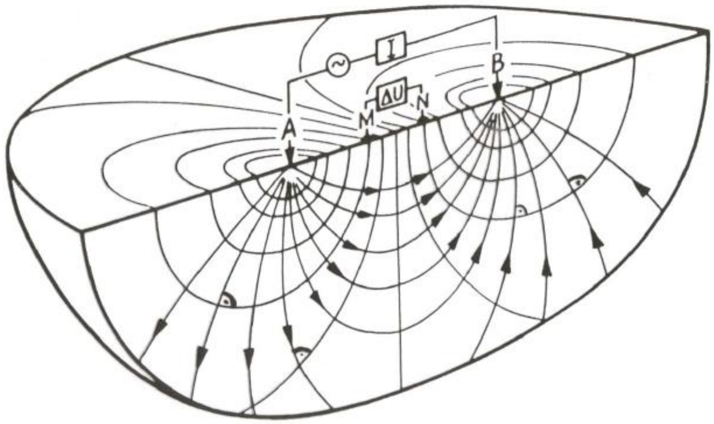


Figure 5: Two current electrode spacing for electrical resistivity survey for homogenous isotropic earth model. (Keller and Frischknecht, 1996)

From figure 4, the two electrodes A and B inject current into the ground using a direct current source and the other two electrodes M and N measure the resulting voltage. From Ohm's law, the electric potential V at any point P at a distance r from a point electrode emitting an electric current I depends on the current and the resistivity ρ of the medium as given in equation 1 (Singh and Sharma, 2022).

$$V_r = \frac{\rho I}{2\pi r} \qquad (1)$$

For an infinite homogenous isotropic medium, the resistivity is constant. The potentials at points M and N are given in equations 2 and 3 while the change in potential between the two electrodes is given in equation 4

$$V_M = \frac{\rho I}{2\pi}\left(\frac{1}{AM} - \frac{1}{MB}\right) \qquad (2)$$

$$V_N = \frac{\rho I}{2\pi}\left(\frac{1}{AN} - \frac{1}{NB}\right) \qquad (3)$$

$$\Delta V_{MN} = V_M - V_N = \frac{\rho I}{2\pi}\left(\frac{1}{AM} - \frac{1}{MB} - \frac{1}{AN} + \frac{1}{NB}\right) \qquad (4)$$

For schlumberger array, AM = NB; AN = MB,

However, the earth is inhomogeneous due to the presence of sub-surface materials. Therefore the resistivity varies with the relative spacing of the electrodes. Therefore the resistivity obtained is the apparent resistivity ρ_a which is a function of the nature of the inhomogeneity, electrode spacing and the surface location. Apparent resistivity is expressed in Ohm meter (Ωm) according to equation 5 where G is called the geometric factor (Singh and Sharma, 2022).

$$\rho_a = \frac{\Delta V_{MN}}{I} K = \mathrm{RG} \qquad (5)$$

R is the resistance of the earth path through which the current passed as recorded by the resistivity meter in Ohms. The Resistivity meter measures processes both the current and potential values and digitally processes it and outputs the result as resistance depending on spacing of the current electrode. The model of the resistivity meter used in the survey is SSR-MP-ATS.

For schlumberger array, the geometric factor is given in equation 6 (Singh and Sharma, 2022)

$$G = \pi\left(\frac{\left(\frac{AB}{2}\right)^2}{4MN} - \frac{MN}{4}\right) = \frac{\pi}{4MN}\left[AM^2 - MN^2\right] \qquad (6)$$

The electrode spacing for each of the VES stations were used to determine the apparent resistivity of the subsurface and modeled with a geophysical software WinRESIST to determine the geo-electric layers and the layer parameters when apparent resistivity is plotted against the current electrode spacing (AB/2) on a log-log graph.

4. RESULST AND DISCUSSIONS

In resistivity survey, the electrical resistivity distribution of the subsurface differentiates the different geo-electric layers and a plot of the apparent resistivity against the corresponding electrode spacing gives the standard VES curves. For a three layer section, the standard curves are A. H, K and Q as shown in Figure 6 (Zohdy, 1989). Depending on the number of layers, these letters can be used in combination to show the variation of resistivity with depth. Subsurface stratigraphy can also be delineated using the resistivity contrasts. The modeled VES curves for each of the VES station is as shown in Figure 7 and the geo-electric layer parameters for each of the VES stations tabulated in Table 1. For the VES stations under investigation, five of them each have four geo-electric layers while VES station 2 has five geo-electric layers. The corresponding curve types for VES 1 – 6 are QH, HKA, KQ, KQ, HK and HA types respectively where $\rho_1 > \rho_2 > \rho_3 < \rho_4$, $\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$, $\rho_1 < \rho_2 > \rho_3 > \rho_4$, $\rho_1 < \rho_2 > \rho_3 > \rho_4$, $\rho_1 > \rho_2 < \rho_3 > \rho_4$ and $\rho_1 > \rho_2 < \rho_3 < \rho_4$ respectively.

Table 1: Geo-electric layer properties of the VES Stations

VES STATION	*Geo-electric Layer*	*Resistivity (Ωm)*	*Thickness (m)*	*Depth (m)*
1	1	1245.4	3.4	3.4
	2	379.7	25.9	29.3
	3	237.0	57.8	87.1
	4	2313.4	-	-
2	1	3341.1	2.9	2.9
	2	423.1	6.4	9.4
	3	4644.4	16.3	25.7
	4	1024.3	46.2	71.9
	5	623.4	-	-
3	1	605.1	5.8	5.8
	2	2047.6	24.4	30.2
	3	1066.3	34.5	64.8
	4	188	-	-
4	1	556.0	0.8	0.8
	2	3418.9	44.1	44.9
	3	489.0	56.1	100.9
	4	363.3	-	-
5	1	745.6	1.3	1.3
	2	301.3	9.4	10.6
	3	1311.1	54.8	65.4
	4	423.8	-	-
6	1	1356.0	0.8	0.8
	2	358.3	6.1	7.0
	3	657.7	72.3	79.3
	4	989.9	-	-

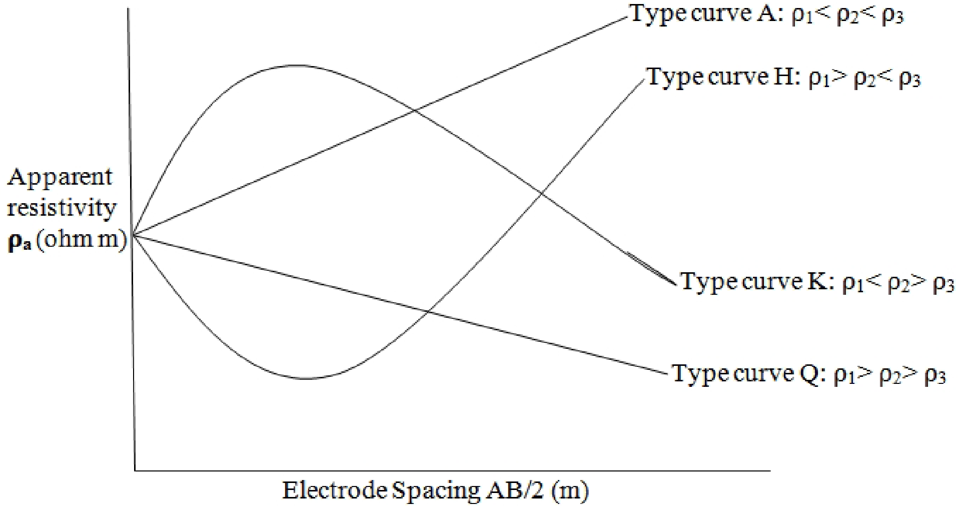
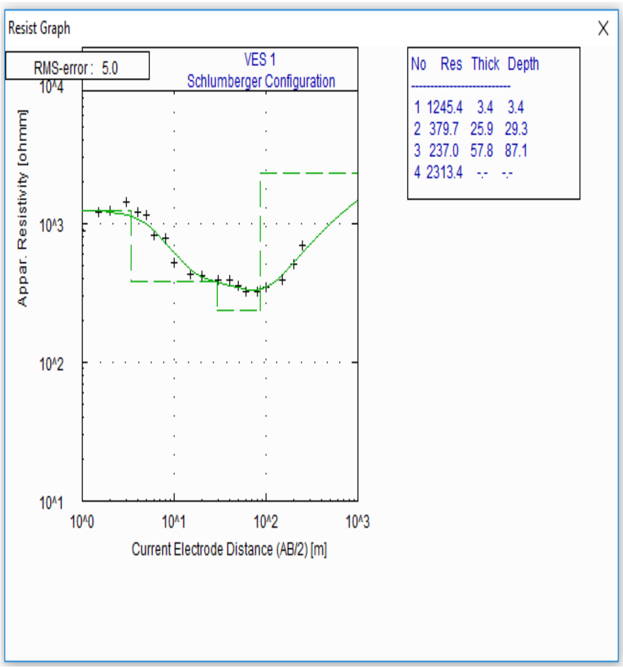
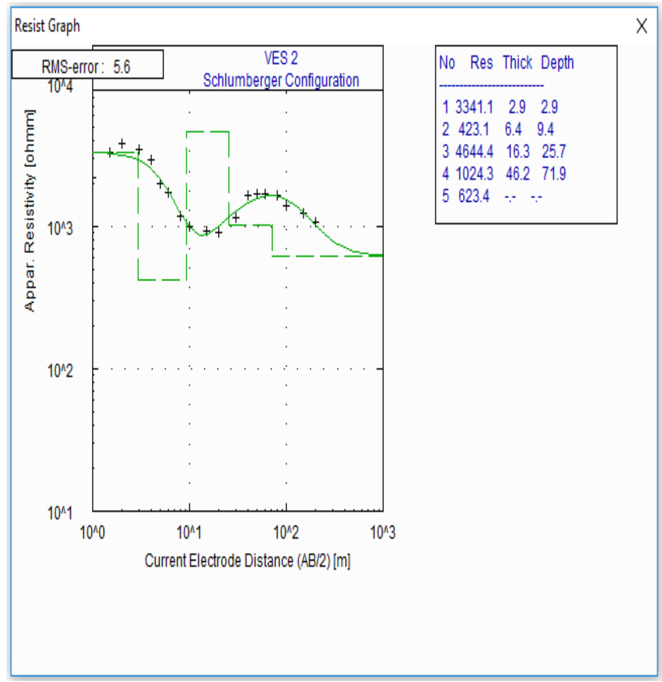


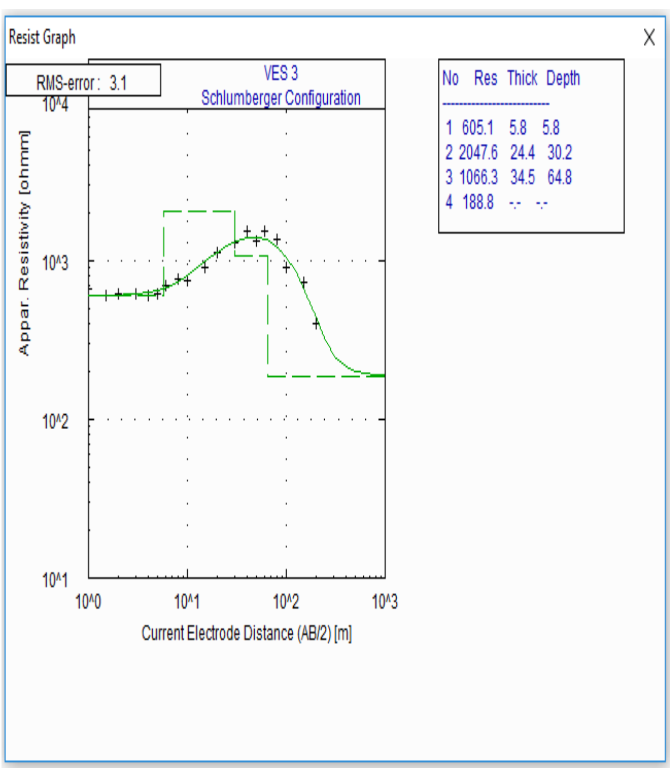
Figure 6: VES Curve types for layered structures (Zohdy, 1989).



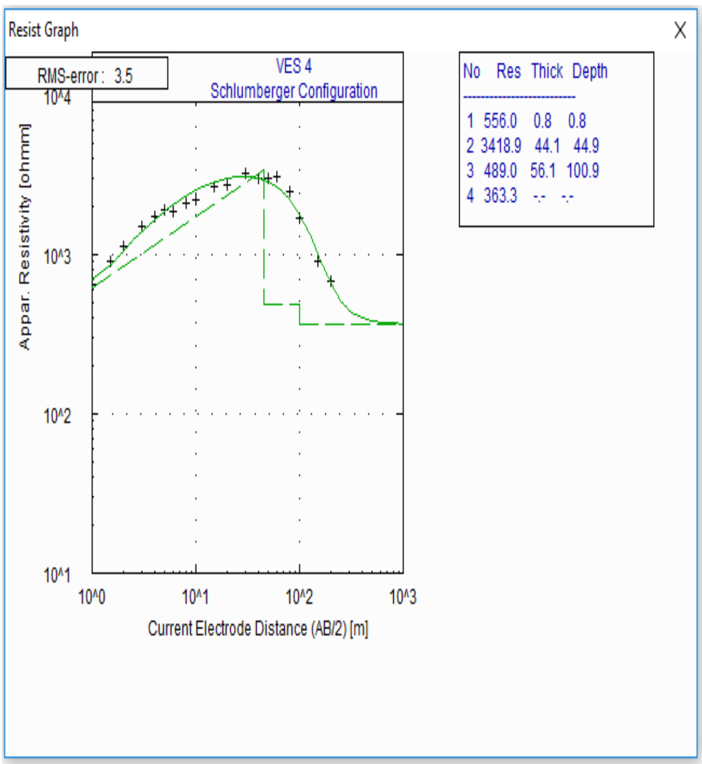
VES 1



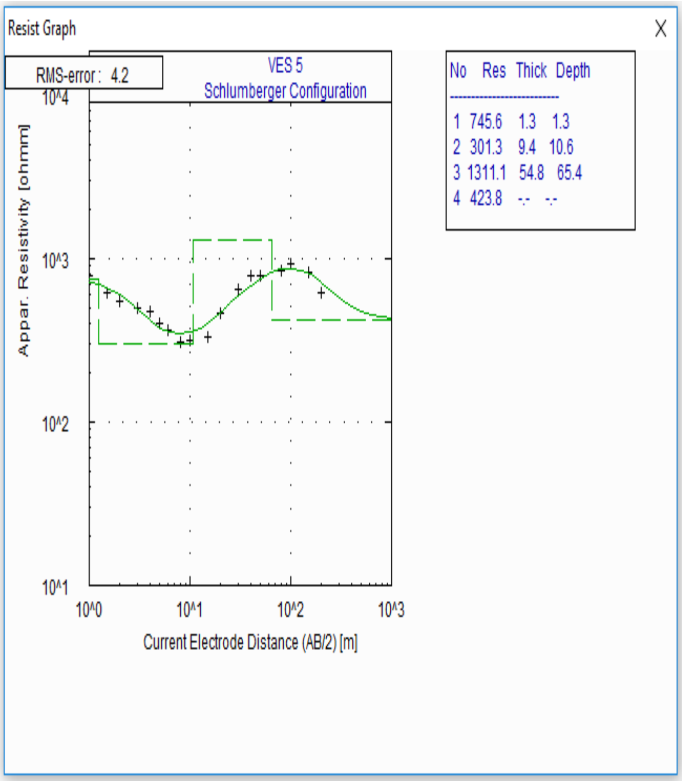
VES 2



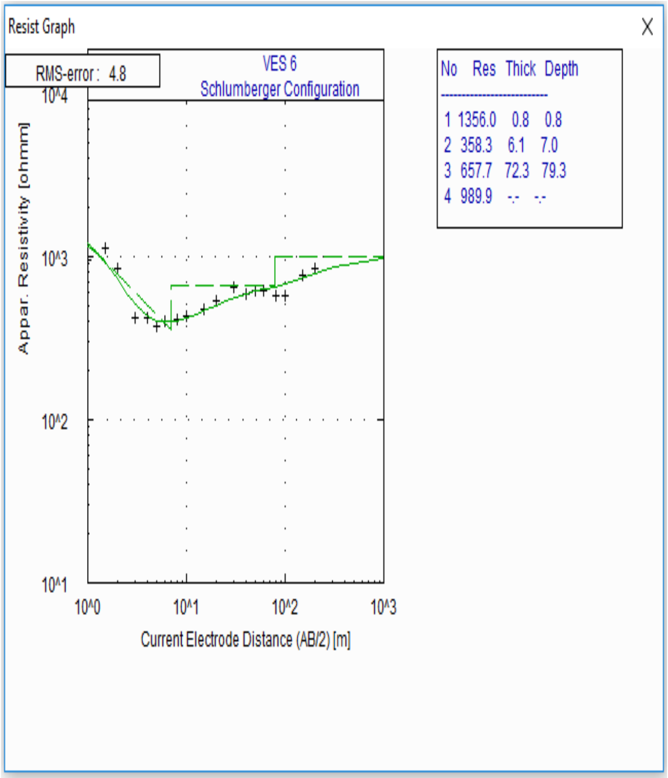
VES 3



VES 4



VES 5



VES 6

Figure 7: Modeled VES Curves and Layer Parameters for VES 1 - 6

Considering the geology of the study area being of the Benin formation, the subsurface lithology is mainly composed of fine to medium and coarse sands with clay intercalations. Comparing the resistivity values of the VES stations and the resistivity range of different lithologic units (Table 2), the study area is mainly composed of the top soil at the first layer, sand and sandstone in subsequent layers with minute clay intercalation noticed in VES 4. The high resistivity soil exhibits lack of moisture and clay content, and coarse-grained mineral constituents present in the soil while the low resistivity of topsoil depends on the proportion of clay mineral constituents in soil, the grain size, and moisture content.

Table 2: Resistivity Range of different lithologic units (Keller *et al.*, 1966)

Lithologic unit	***Resistivity (Ωm)***
Top soil	*70 – 300*
Clay	*1 – 100*
Sand	*60 – 1000*
Sandstone	*8 – 4000*

Aquifers with permeable materials allow groundwater to flow more than aquifers with impermeable materials because permeability describes how easily water can flow through the rock or unconsolidated sediment and how easily it will be to extract it for other purposes. Sand, sandstone and limestone are the more permeable materials compared to unfractured intrusive igneous rocks, metamorphic rocks clay and mudstone (Earle, 2015).

Considering the inferred lithology of the study area being composed mainly of sand and sandstone, groundwater will be abundant at a depth of 87.1 m, 71.9 m, 64.8 m, 100.9 m, 65.4 m and 79.3 m in VES stations 1 – 6 respectively while the respective thickness of the aquifer is 57.8 m, 46.2 m, 34.5 m, 56.1 m, 54.8 m and 72 m. This means that the average total drill depth for groundwater exploitation in Clifford University is 78m and the average aquifer thickness is 53 m.

COLNCLUSION

Vertical electrical Sounding is an electrical method of investigating the variation of the conductivity and resistivity of the subsurface material with depth. It has wide applications especially in groundwater studies. Six VES stations considered in this study show that the resistivity of the subsurface is between 188 – 4644 Ωm with the lithology is mainly made of sand and sandstone with minor clay intercalations. The thickness of the aquifer ranges from 34.5 – 72.3 m with an average of 53 m while groundwater is abundant at depths between 65 – 100 m with an average drilling depth of 72 m. Although groundwater is not easily contaminated like surface water, it is not entirely free of natural contaminants. There is therefore need to geochemically ascertain the purity level of the groundwater of the study area.

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