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ASSESSMENT OF GROUNDWATER POTENTIAL ZONES USING ELECTRICAL RESISTIVITY METHOD IN HONG, HONG LOCAL GOVERNMENT AREA OF ADAMAWA STATE NORTH EASTERN NIGERIA

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Abstract

Assessment of groundwater potential zones using the electrical resistivity method was carried out in Hong, Hong local government of Adamawa State, northeastern Nigeria, for the purpose of determining possible sites for drilling boreholes, the lithology of the area, and the thickness of the geo-electric layers. Ten Vertical Electrical Soundings (VES) were sounded in the area with ABEM SAS 1000 Terameter. The maximum electrode spacing was 100 m. The Schlumberger array was used for the geophysical survey and data acquisition. Qualitative and quantitative techniques were used for data interpretation of the raw data obtained from the fieldwork; 1XD Interpex software was used to interpret the data. Possible groundwater potential zones were detected out of ten (10) VES points. VES 5, 6, 7, 8, 9, and 10 were potential zones for groundwater exploration due to the presence of fractured/weathered basement zones and low resistivity values. It has depth ranging from 50 m to 30 m to aquifer level. While VES points 1, 2, 3, and 4 do not possess groundwater because they were of high resistivity values.

Keywords: Resistivity, Terameter, Schlumberger Array, Vertical Electrical Sounding (VES), Groundwater and Electrode.

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Introduction

Groundwater is one of the main sources of water for human existence, human beings rely on water for many things just to mention a few ; irrigation for agricultural purposes, drinking, cooking and industrial purpose. In search for groundwater geophysicist make use of geophysical techniques to locate the possible sites for groundwater exploration (Jatau *et al.,* 2022; Chunmada *et al.,* 2023; Lazarus *et al.,* 2020; Hassan *et al.,* 2017; Metwaly *et al.,* 2012; Abdullahi *et al.,* 2016 and Okolie *et al.,* 2010).

In most cases, people decide to site wells and boreholes without geophysical surveys, which has led to loss of financial resources and time wastage in different parts of the world. Groundwater exploration is a typical task of a hydro-geologist or an engineer. Identifying the location of its availability is a challenging task. Exploration of groundwater requires a basic understanding of its position in the subsurface geological set up. Groundwater Exploration is attempted through either by direct or indirect methods (Balsubramania, 2017).

Electrical Resistivity Method of Geophysical Survey: Vertical Electrical Soundings (VES) techniques have been used previously in research for locating aquifers for groundwater exploration. Geologists and geophysicists were able to establish a relationship between hydrological and geological parameters through the application of electrical resistivity techniques of geophysical survey (Zakari *et al.,* 2015). In practice, vertical electrical soundings (VES) have been employed to determine the resistivity variation with depth, geo-electric layers, and apparent resistivity of the area under study, thickness, and lithology. Since the sounding curves can be interpreted using a horizontally layered earth (1D) model, the apparent resistivity value has been measured using resistivity meters of different capacities. Resistivity meters normally give a resistance value, R = V/I. Resistivity value can be calculated by using the relation ρa = kR (Balsubramania, 2017).

The electrical resistivity method, alongside geophysical equipment and geo-soft for the purpose of interpretation of the collected field data, has been used by geophysicists over the years with proven positive results in different parts of the world (Shishaya and Abdi, 2016; Olatunji *et al.,* 2017; Sunday and Usman, 2021; Kasidi, 2017; Egbai, 2011; and Ezekiel, 2025).

Chunmada *et al.* (2023) in recent research on the assessment of groundwater potential in Adudu and its environs, part of the Akiri Sheet Middle Benue Trough, Central Nigeria. Vertical Electrical Sounding was employed; seventeen (17) vertical electrical soundings were carried out through the Schlumberger array. Resistivity of the study area was determined. The aquifer resistivity in the study area ranges from 80 Ωm to 457 Ωm, with an average value of 120 Ωm.

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Bello *et al.* (2022) identified potential zones for groundwater exploration in the Inkil area of Bauchi, northeastern Nigeria. The Schlumberger array was employed in the research; according to the findings, twelve (12) Vertical Electrical Soundings (VES) points were promising for groundwater exploration between the depths of 60 m and 70 m.

Due to the increase in population in Hong, the study area, there is a need to source more potential zones for groundwater exploration. Some of the existing boreholes in the area could not meet up with the water demand of the people living in the areas, and some boreholes even dried up during the dry season, which is the peak period when people living in the area need the water most for their existence. With the help of this research, some of the potential zones for groundwater exploration will be identified. Those points that are promising for groundwater exploration will be explored, such as hand-dug wells and borehole drillings, which will serve as a source of water supply in Hong and its environs.

The aim of this research is to assess groundwater potential zones using the electrical resistivity method in Hong, Hong local government area of Adamawa State, northeastern Nigeria.

The objectives are to determine the possible best site for drilling a borehole, the lithology of the area, and the thickness of geo-electric layers.

The Study Area

The study area is Hong, **Usoko Block, and Hildi Ijzakwa** Hong local government area of Adamawa State.

Hydrogeology of Hong Local Government Area, Adamawa State, Northeastern Nigeria.

The Hong Local Government Area (LGA) is situated in northeastern Nigeria's southern Adamawa State. Groundwater availability, transport, and quality are among the hydrogeological characteristics of the region that are influenced by its unique geology.

Geological Setting and Its Influence on Hydrogeology

Basement Complex: The local government area is largely covered by the Basement Complex, which is primarily made up of igneous (granites) and metamorphic (gneisses, schists) rocks. Because of their low primary porosity, these rocks tend to hold groundwater in worn and fractured areas (Olade, 1989). Aquifer yields from these cracks are often lower than those from sedimentary aquifers, although they do permit groundwater buildup, particularly along faults and tectonic zones. This massif has the Gongola Basin and the Yola Trough, two arms of the Cretaceous Benue rift, to the west and south, and the Chad Quaternary Basin to the north. The Mandara Hills, which

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represent the greatest elevation in the region at more than 850 meters above sea level, are the main geomorphologic features in the study area. The slopes go into the Cameroonian Republic. Bassey's (2006a, b) earlier work in the Hawal Basement Complex. Kwache and Ntekim (2015), Abdulahi et al. (2016), Unachukwu (2014), and a number of other authors. Although these authors had varying roles, they all noted the presence of Tertiary Basalt, Older Granites, Gneisses, and Migraites in the area. Pre-Cambrian gneisses predominate among these rocks.

Aquifer Types and Groundwater Occurrence

Different aquifers in Hong LGA contain groundwater, and each one has unique hydrogeological traits:

Fractures in Basement Aquifers: The worn and fractured zones of granites, gneisses, and migmatites are the main locations for the Basement Complex aquifers. When these rocks are not broken, they have poor permeability; however, tectonic activity-induced fissures allow water to build up and move. According to Olade (1989), the amount of water extracted from wells sunk into these aquifers usually ranges from low to moderate. Depending on surface infiltration into the fractures, recharge is a gradual process.

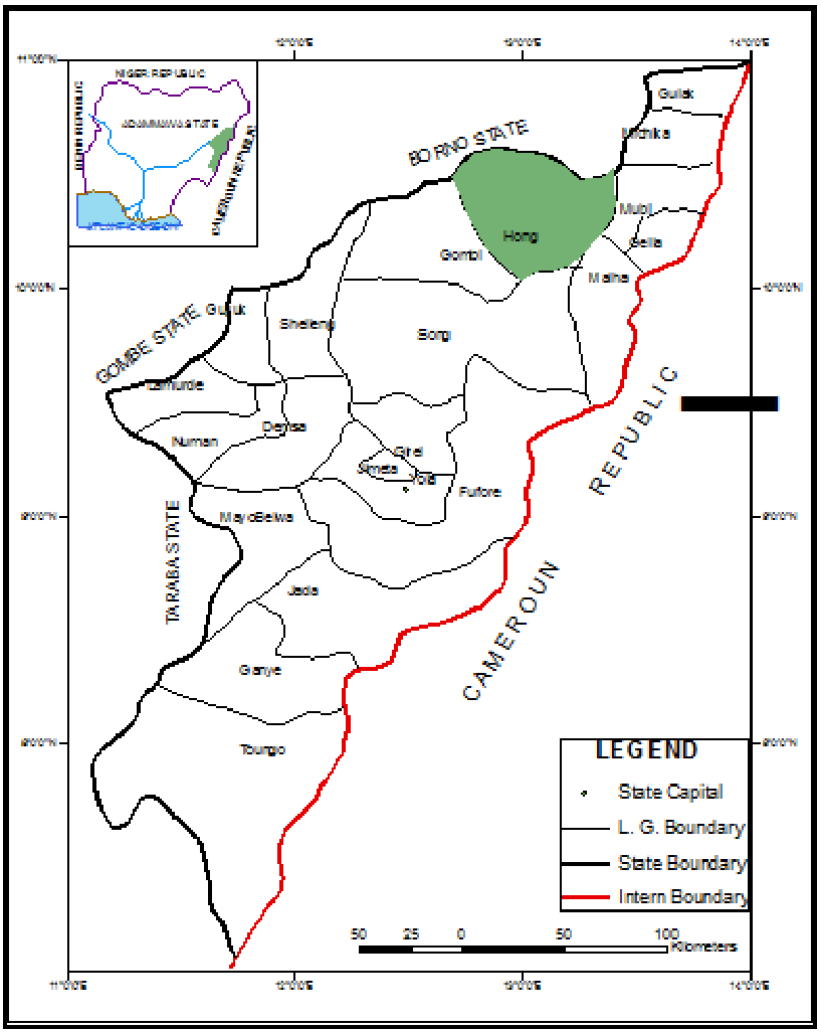


Figure I: Map of Nigeria showing Adamawa State and the study area (Kefas, 2016)

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Materials and Method

At the beginning of the Vertical Electrical Sounding (VES), four steel electrodes were positioned and pinned collinearly into the ground using the Schlumberger array, as seen in Figure 2.

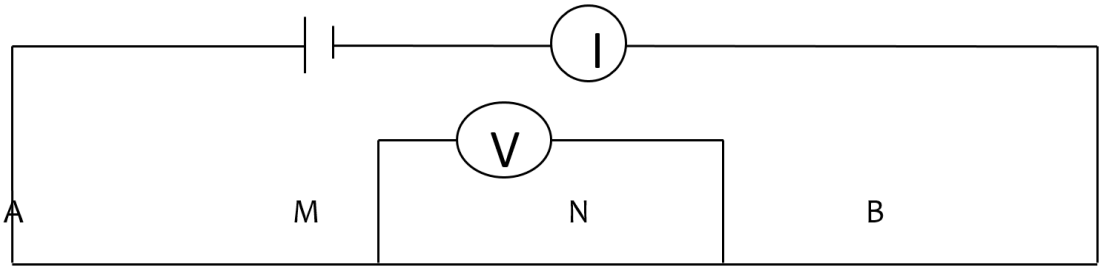


Figure 2: Schlumberger Configuration.

The potential electrode, MN/2 (M), was located 0.2 meters from the center electrode, whereas the current electrode, AB/2 (M), was located 1 meter away. The electrodes were pounded to establish good contact with the earth and suitably linked via cables to their corresponding terminals on the Terameter. During the sounding, a digital ABEM SAS 1000 Terameter was used to send direct current through two steel current electrodes into the earth's subsurface. The Terameter then used the steel potential electrodes to measure the established subsurface potential difference across the subsurface under investigation. By utilizing the theory of the measured potential difference, the Terameter calculates and shows a mean digital value of the apparent resistivity of the subsurface being studied for every sounding. The sounding at 8.0 and 10.0 was repeated as a result of a change at AB/2 (M) and MN/2 (M) when the ratio of current electrode to potential electrode increased. A maximum of 100 meters separated the electrodes. Typically, two current electrodes (C1 and C2) are used to inject current into the ground, and the voltage difference at two potential electrodes (P1 and P2) is measured to determine the resistivity. A value of apparent resistivity (pa) was computed using the current (I) and voltage (V) data (Lazarus *et al.*, 2020).

Data Acquisition

Variations of resistivity in the subsurface geology were identified using the geo-electrical resistivity method. For data collection, the ABEM SAS 1000 Terameter was used for Vertical Electrical Soundings (VES). The Terameter's role is to measure the subsurface's resistive property when current (particularly in DC) is injected into the ground. With a maximum electrode separation of 100 meters, ten VES points were used in the study region. All of the VES points were Schlumberger electrode arrays. An electrical resistivity

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geophysical investigation of the subject area was conducted using the Schlumberger array method. For the electrical soundings, an ABEM SAS 1000 Terameter was utilized, with a maximum electrode spread of 100 m. The collected data was documented for every VES. Using the equation, apparent resistivity was determined (Usifo, 2013).

$$\rho_a = \frac{KV}{I} = KR \qquad (1.0)$$

Where

$$K = \frac{\frac{\Pi}{2}\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{\left(\frac{MN}{2}\right)} \qquad (2)$$

and

ρ_a is apparent Resistivity

K is Geometric Factor

V is Volt, I is Current, R is Resistance and AB is the Current Electrode Separation.

Interpretation process

VES point data that was gathered and processed by computer software. Utilizing 1XD resistivity software Data on apparent resistivity was entered using this software in a common geo-soft format. By using a filtering technique that includes vertical curve segment shift and single point correction, it also improves the field curve. This package can transform the apparent resistivity values as a function of electrode spacing that were obtained as field data into true resistivity values as a function of layer depth so that the true state of the ground may be interpreted. Nonetheless, the qualitative interpretation of the VES curves necessitates the assumption that the ground is made up of horizontal strata known as geo-electric formations, each of which has a distinct resistivity.

Vertical Electrical Sounding (VES) Result and Interpretation

The two primary methods for interpreting resistivity data are qualitative and quantitative. In this study, the qualitative approach was used to determine the number of layers, their thickness, and their corresponding resistivity. Generally, low results imply high conductivities of the subsurface, which may represent layers that contain water. Conversely, the study area with high apparent resistivity values suggests that there is no

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water present and that fresh basement rocks may be present. In other words, areas with low resistivity values are typically found in worn, fractured basements and are frequently linked to thick water-bearing overburden.

Table 1

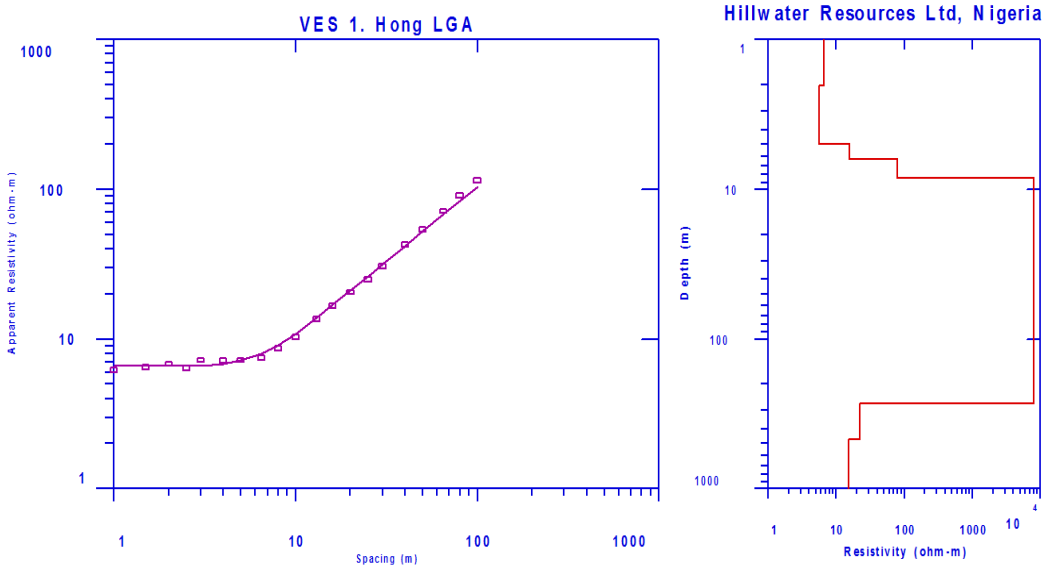
S/N	Numbers of Layers	Resistivity (ρ)	Thickness(m)	Depth (m)	Lithology
VES 01	1	7.0	2.0	-	Top Soil
	2	5.0	3.0	2.0	Clay Soil
	3	18.0	2.0	5.0	Clayey Soil
	4	900	2.0	7.0	Sandy Soil
	5	10,000	291	9.0	Weathered basement
	6	21,000	30.0	300	Fractured Basement
	7	18.00	-	330	Fresh Basement
VES 02	1	6.0	1.1	-	Top Soil
	2	7.0	3.9	1.1	Clay Soil
	3	20.0	1.0	5.0	Clayey Soil
	4	80.0	02	6.0	Sandy Soil
	5	10,000	281	8.0	Weathered Basement
	6	25	120	289	Milled Fracture
	7	10	-	409	Fresh Basement
VES 03	1	11.00	0.5	-	Top Soil
	2	60	5.5	0.5	Clay Soil
	3	17	2.0	6.0	Clay and Mart
	4	70	2.0	8.0	Clayey Soil
	5	>10,000	340	10.00	Weathered Basement
	6	21	190	350	Fractured
	7	17	-	540	Fresh Basement
VES 04	1	10	2	-	Top Soil
	2	18	25	2	Clay
	3	5	2.0	27	Clay and Mart
	4	50	2.0	29	Sandy Clay
	5	>10,000	300	31	Weathered Basement
	6	21	18	331	Fractured
	7	18	-	349	Fresh Basement

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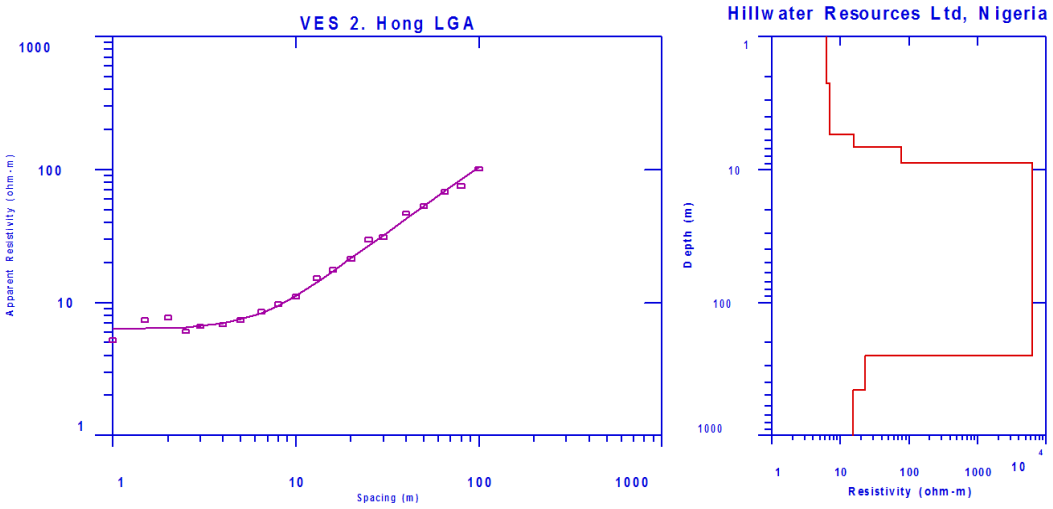
VES 05	1	130	1.0	-	Top Soil
	2	22	10	1.0	Weathered Basement
	3	1.0	-	11	Fresh Basement
VES 06	1	80	40	-	Top Soil
	2	20	20	40	Clay Soil
	3	2000	-	60	Fresh Basement
VES 07	1	72	4.8	-	Top Soil
	2	10	9.7	4.8	Clay Soil
	3	3000	-	14.5	Fresh Basement

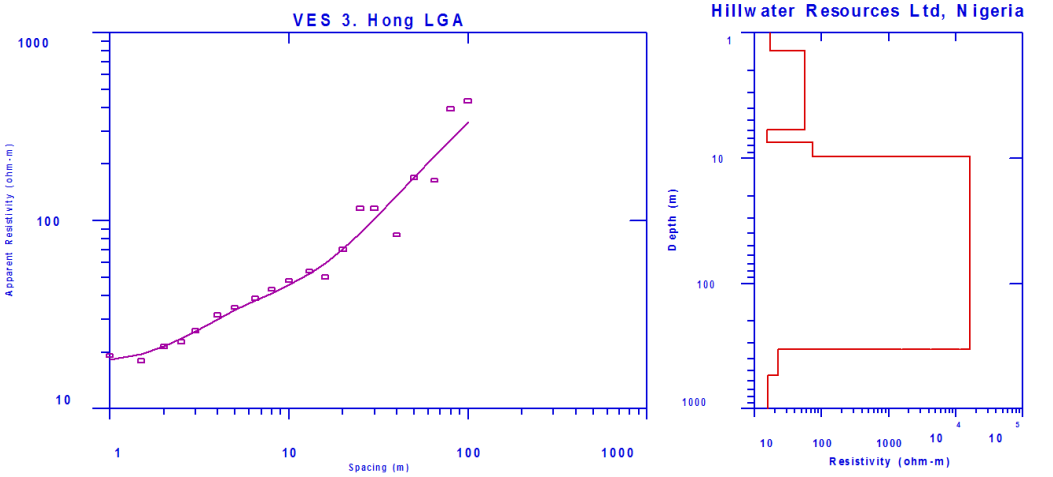
Table 1

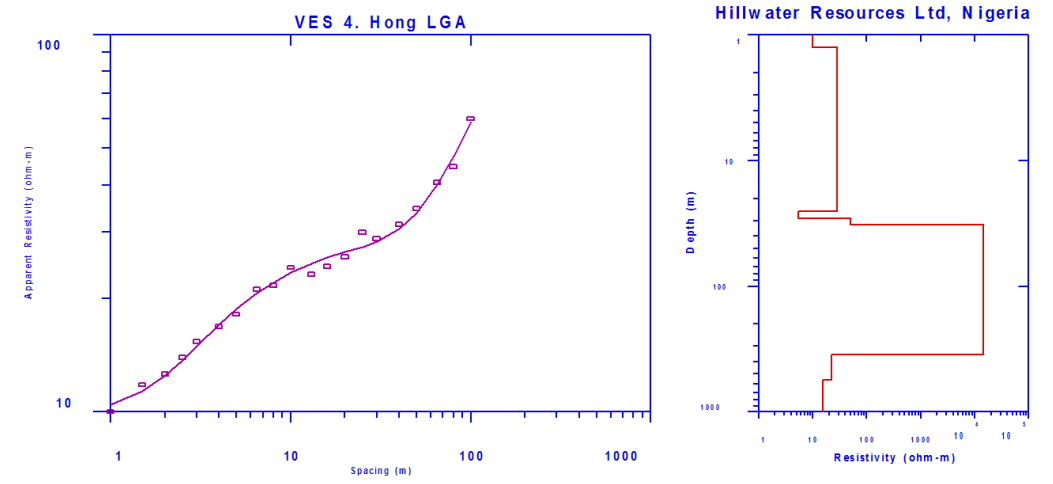
S/N	Numbers of Layers	Resistivity (ρ)	Thickness(m)	Depth (m)	Lithology
VES 08	1	500	0.5	-	Top Soil
	2	15	4.7	0.5	Clay Soil
	3	8000	-	5.2	Fresh Basement
VES 09	1	500	0.9	-	Top Soil
	2	1.0	16.1	0.9	Clay Soil
	3	>10,000	-	17.0	Fresh Basement
VES 10	1	110	0.59	-	Top Soil
	2	18	5.40	0.59	Clay Soil
	3	280	-	5.99	Fresh Basement

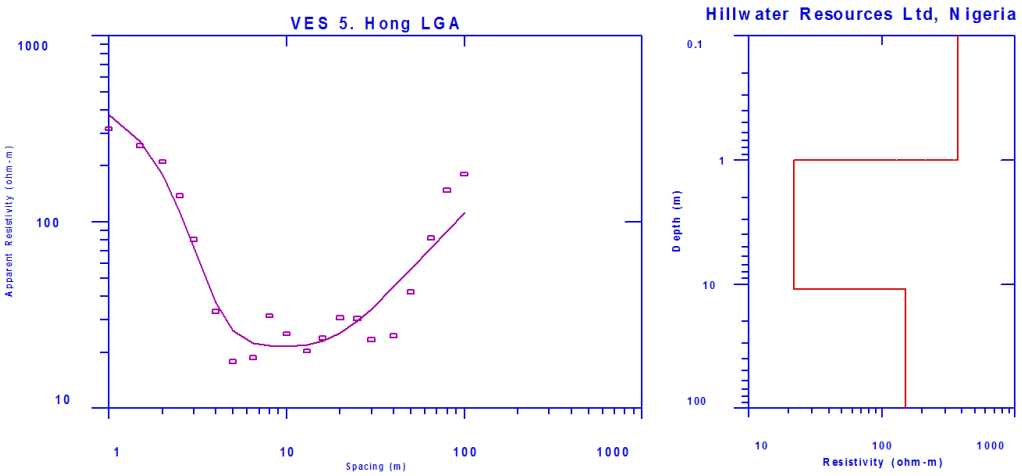


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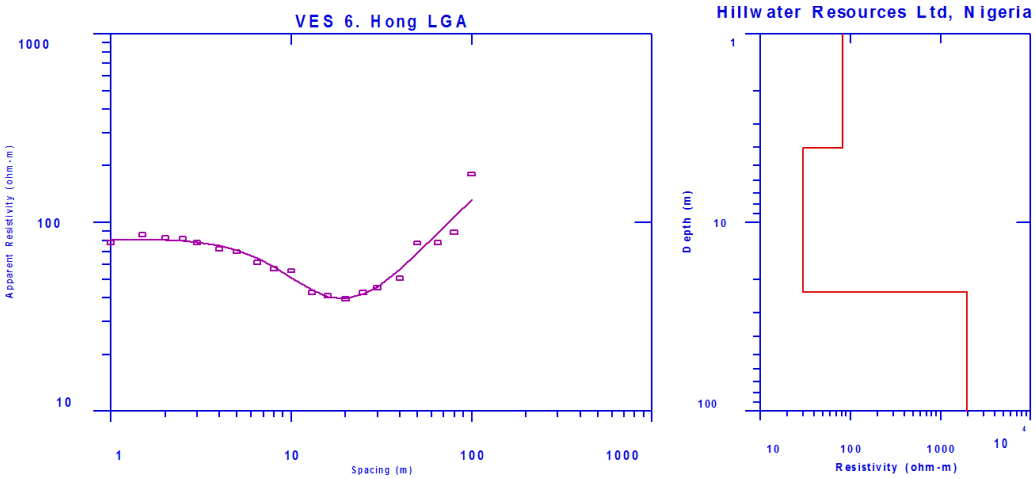

VES 2. Hong LGA
Apparent Resistivity (ohm-m)
Spacing (m)
Hillwater Resources Ltd, Nigeria
Depth (m)
Resistivity (ohm-m)

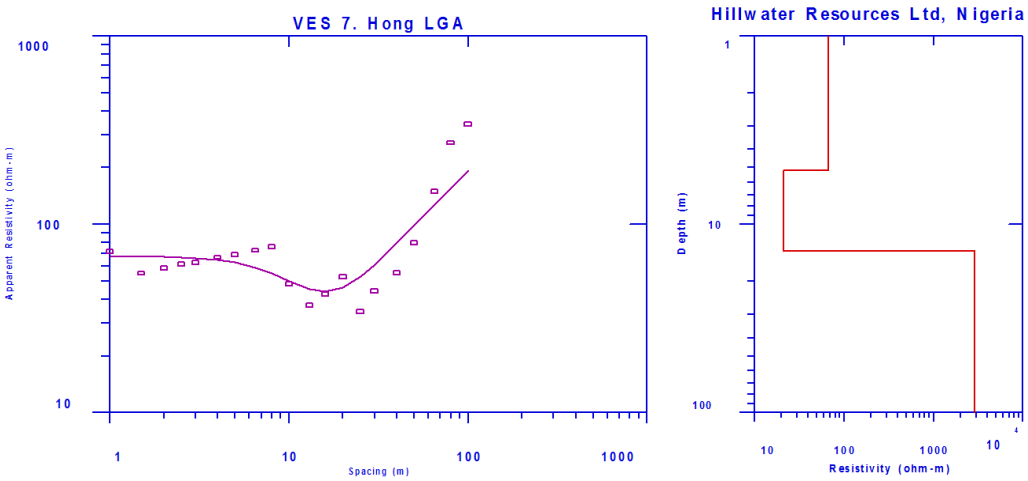

VES 3. Hong LGA
Apparent Resistivity (ohm-m)
Spacing (m)
Hillwater Resources Ltd, Nigeria
Depth (m)
Resistivity (ohm-m)


VES 4. Hong LGA
Apparent Resistivity (ohm-m)
Spacing (m)
Hillwater Resources Ltd, Nigeria
Depth (m)
Resistivity (ohm-m)



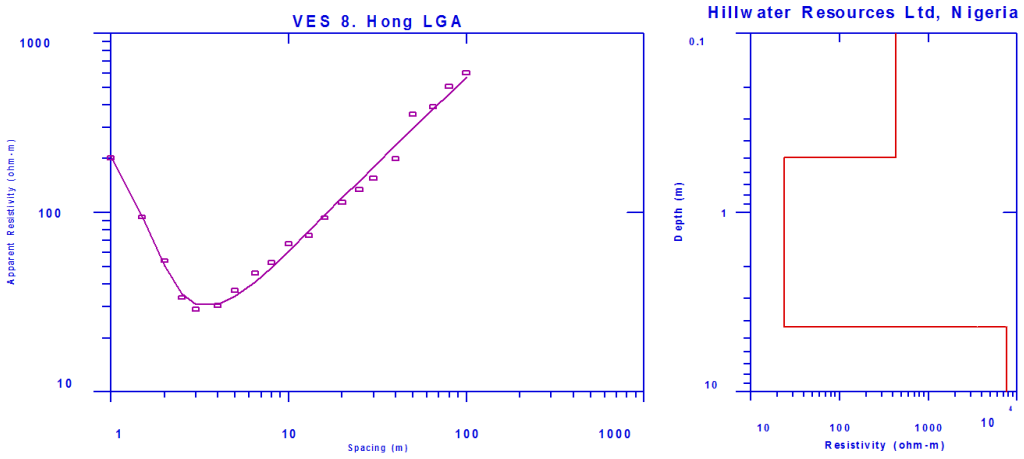
DEPTH 50M ± 5 m MOTORIZED BOREHOLE



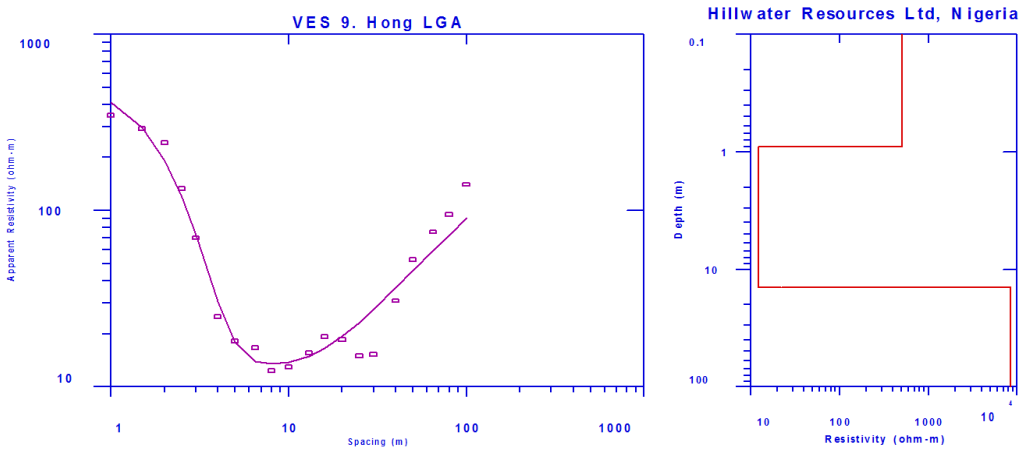


45M± 5 m HAND PUMP BOREHOLE

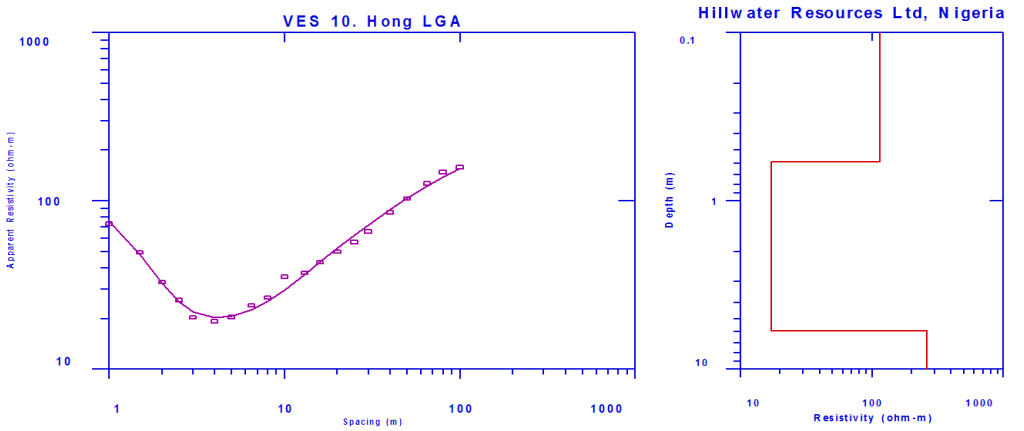
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DEPTH =10 M± 5 m



Depth to Groundwater= 50 M ± 5 m



VES 10. Depth to Groundwater = 30 m ± 5 m

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Response Curve and Model Interpretation of VES 1 to VES 10 of the Study Area

Result and Discussion

The geo-electric section of VES 01 indicates seven geoelectric layers and its apparent resistivity curve is the A type with $\rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5 > \rho_6 > \rho_7$. The first layer has resistivity value of 7.0 Ωm with thickness of 2.0 m on the top soil. The second layer has resistivity of 6.0 Ωm with thickness of 3.0 m at the depth of 2.0 m in clay. The third layer has resistivity value of 18.0 Ωm with thickness of 2.0 m at the depth of 5.0m in clayey soil. The fourth layer has a resistivity value of 900 Ωm with thickness of 9.0 m and depth of 7.0 m at sandy soil. The fifth layer has resistivity value of 10,000 Ωm with thickness of 291m and depth of 9.0 m at weathered basement. The sixth layer has resistivity value of 21.00 Ωm with the thickness of 30.00 m at 300 m depth in the fractured basement and finally the seventh layer has resistivity value of 18.00 Ωm it is suspected to be at fresh basement.

The geo-electric section of VES 02 indicates seven geo-electric layers, and its apparent resistivity curve is A-type with $\rho1 > \rho2 < \rho3 < \rho4 < \rho5 > \rho6 < \rho7$. The first layer has a resistivity value of 6.0 Ωm with a thickness of 1.1 m at the topsoil. The second layer has a resistivity value of 7.0 Ωm with a thickness of 3.9 m at 1.1 m in clay soil. The third layer has a resistivity of 20.00 Ωm with a thickness of 1.0 m at 5.0 m in clayey soil. The fourth layer has a resistivity value of 80.00 Ωm at 2.0 m thickness at the depth of 60 m in sandy soil. The fifth layer has a resistivity value of 10,000 Ωm with a thickness of 281 m at 8.0 m depth in the weathered basement. The sixth layer has a resistivity of 25 Ωm with a thickness of 120 m at 289 m depth in mildly fractured rock, and the seventh layer has a resistivity value of 10 Ωm; it is suspected to be at the fresh basement.

The geo-electric section of VES 03 indicate seven geo-electric layers and it apparent resistivity curve is A type with $\rho1 < \rho2 > \rho3 < \rho4 < \rho5 > \rho6 < \rho7$. The first layer has a resistivity value of 11.00 m with thickness of 0.5 m at top soil. The second layer has resistivity value of 60 Ωm with thickness of 5.5 m at 0.5 m depth in clay soil. The third layer has a resistivity value of 17 Ωm with thickness of 2.0 m at 6.0 m depth in clayey and mart. The fourth layer has a resistivity value of 70 Ωm with 2.0 m thickness at 8.0 m depth in clayey soil. The fifth layer has resistivity value of >10,000 Ωm with 340 m thickness at 10.00 m depth in weathered basement. The sixth layer has a resistivity value of 21 Ωm with thickness of 190 m at 350 m depth in fracture basement. The seventh layer has a resistivity of 17 Ωm. It is suspected to be at fresh basement.

The geo-electric section of VES 04 indicate seven geo-electric layers and it apparent resistivity curve is A type with $\rho1 > \rho2 < \rho3 < \rho4 < \rho5 > \rho6 < \rho7$. The first layer has resistivity value of 10 Ωm with thickness of 2m atop soil. The second layer has apparent resistivity value of 18 Ωm with thickness of 25 m at 2m depth in clay soil. The third layer has resistivity

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value of 5Ωm with 2.0m thickness at 27 m depth in clay and mart. The fourth layer has resistivity value of 50 Ωm with 2m thickness at 29 m depth in sandy clay. The fifth layer has resistivity value of >10,000 Ωm with 300 m thickness at 31m depth in weathered basement .The sixth layer has a resistivity value of 21 Ωm with thickness of 18 m at 331 m depth in fractured basement. The seventh layer resistivity is 18 Ωm and is suspected to beat fresh basement.

The geo-electric section of VES 05 indicates three geo-electric layers, and its apparent resistivity curve is H-type with $\rho1 > \rho2 < \rho3$. The first layer has a resistivity value of 130 Ωm with a thickness of 1.1 m at the topsoil. The second layer has a resistivity value of 22 Ωm with a thickness of 10 m at 1.0 m in clay soil. The third layer has a resistivity value of 1.0 Ωm, and it is suspected to be at the fresh basement.

Geo-electrical section of VES 06 indicates three geo-electric layers, and its apparent resistivity curve is H-type with $\rho1 < \rho2 < \rho3$. The first layer has a resistivity value of 80 Ωm with a thickness of 40 m in topsoil. The second layer has a resistivity value of 20 Ωm with a thickness of 20 m at a 40 m depth in clay. The third layer has a resistivity value of 2000 Ωm, and it's suspected to be at the fresh basement.

The geo-electric section of VES 07 indicates three layers, and its apparent resistivity curve is H-type with $\rho1 > \rho2 < \rho3$. The first layer has a resistivity value of 72 Ωm with a thickness of 4.8 m at the topsoil. The second layer has a resistivity value of 10 Ωm with 9.7 m thickness at 4.8 in clay. The third layer has a resistivity value of 3000 Ωm, and it's suspected to be at the fresh basement.

The geo-electric section of VES 8 indicates three geo-electric layers, and its apparent resistivity curve is H-type with $\rho1 > \rho2 < \rho3$. The first layer has a resistivity value of 500 Ωm with a thickness of 0.5 m at the topsoil. The second layer has a resistivity value of 15 Ωm at 4.7 m with a depth of 0.5 m in clay. The third layer has a resistivity of 8000 Ωm, and it's suspected to be at the fresh basement.

The geo-electric section of VES 9 indicates three geo-electric layers, and the apparent resistivity curve is H-type with $\rho1 > \rho2 < \rho3$. The first layer has a resistivity value of 500 Ωm with a thickness of 0.9 m at the topsoil. The second layer has a resistivity value of 1.0 Ωm with a thickness of 16.1 m at the depth of 0.9 m in clay soil. The third layer has a resistivity value of >10,000 Ωm, and it's suspected to be at the fresh basement.

The geo-electric section of VES 10 indicates three geo-electric layers and its apparent resistivity curve of H type with $\rho1 > \rho2 > \rho3$. The first layer has a resistivity value of 110 Ωm at 0.59 m at the topsoil. The second layer has a resistivity value of 18 Ωm with 5.40 m thickness and 0.59 m depth in clay, and the third layer has a resistivity value of 280 Ωm and is suspected to be at the fresh basement.

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The purpose of this research was to assess groundwater potential zones. The fieldwork conducted was instrumental in identifying potential sites for drilling boreholes for groundwater exploration. Ten vertical electrical soundings were carried out on the field, and they were interpreted with 1XD Interpex software. Out of ten (10) vertical electrical soundings, six (6) vertical electrical sounding points were not good for borehole drilling. The Schlumberger method has been found so effective in recent times that Olatunji *et al.* (2017) used Schlumberger techniques to carry out research on the electrical resistivity investigation of groundwater potential in part of Kwara State Polytechnic, Ilorin, Nigeria. Fifteen (15) VES points were carried out in the study area. From the analysis of resistivity and conductivity of the subsurface and lithology, it was observed that only nine (9) VES points out of fifteen (15) VES stations show good groundwater potential as revealed by thick overburden and weathered layers with low resistivity values. VES stations 3, 4, and 13 show poor groundwater potentials, while the others are non-aquiferous in nature. Okolie *et al.* (2010) used the electrical resistivity method on the application of linear Schlumberger configuration in the delineation of formation strata and groundwater distribution in Ifon, Ondo State, Nigeria. Ten (10) vertical electrical soundings were carried out on the study area; they were able to locate high water-bearing media (aquifers) within 25m-30m in some of the VES points that were not promising for groundwater exploration.

Conclusion

After assessing groundwater potential zones using the electrical resistivity method in Hong, Hong Local Government Area of Adamawa State, Nigeria, to determine the depth to groundwater and the geo-electric units. Vertical Electrical Soundings (VES) using the Schlumberger array has proved to be effective. Analysis of the interpreted result has shown the nature and the subsurface lithology units. Thus, this includes the topsoil, clay and marl, weathered basement, and fresh basement. Based on the resistivity value of the area, groundwater potential zones have been identified, which include VES 1, 2, 3, and 4, which do not possess groundwater because of high resistivity values, while VES 5, 6, 7, 8, 9, and 10 possess groundwater due to high conductivity and low resistivity.

Reference

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