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Delineation of Lithology and Depth to Groundwater Using Geo-Electrical Resistivity Survey in Ndele Community, Rivers State, Nigeria

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Abstract: Geo-electrical resistivity survey was carried out in the study area to determine the depths to potable water and the subsurface lithologic distribution in the study area. Vertical electrical sounding method with Schlumberger array using ABEM SAS 1000 Terrameter was employed to delineate the variation in the lithologic distribution and depths to groundwater in the three locations studied. The VES raw data obtained was improved with the use of IP2WIN computer software by converting the apparent resistivity values obtained from electrode spacing to real time resistivity values as a function of the depth of each layer delineated. The data obtained from VES1 revealed that the area is underlain by six (6) lithologic layers of HKHK curve with topsoil to a depth of 0.74m, 2nd layer; clay with strata thickness of 0.67m, 3rd layer; sandy clay with thickness of 1.83 m, 4th layer; clayey sand with thickness of 9.27m, 5th layer; coarse sand with thickness of 34.4m and 6th layer; clayey sand to an infinite depth, possiblegroundwater is observed at the 5th layer with resistivity of 173Ωm at depth of 47.3m. VES2 revealed that the location 2 is underlain by five (5) lithologic layers of AAK curve types with topsoil to a depth of 1.76m, 2nd layer; clayey sand with thickness of 2.1m, 3rd layer; medium sand with thickness of 9.6m, 4th layer; coarse sand with thickness of 39.6m, 5th layer; clayey sand to an infinite depth, possible groundwater is observed at the 4th layer with a resistivity of 209?m at depth of 53.1m. VES3 revealed that location 3 is underlain by five (5) lithologic layers of KAA curve types with topsoil to a depth of 1.6m, 2nd layer; sandy clay with thickness of 2.6m, 3rd layer; clayey sand 12.2m, 4th layer; coarse sand 29.5m, 5th layer; clayey sand to infinity depth, possible groundwater is observed at the 4th layer with resistivity of 163Ωm at depth 46.3m. A recommendation of an average depth of 50m is to be drilled for all boreholes in the study area to yield potable water in the area.

Key words: Geoelectric layer · Resistivity survey · Lithology · Groundwater · Borehole

INTRODUCTION

Adequate supply of quality water is generally becoming more severe effect due to ever increasing of population, irrigation and industrialization [1]. Due to this situation, surface water cannot be dependable throughout the year; hence other alternative is needed in order to supplement for surface water.

Groundwater is the water that lies beneath the ground surface in pore space of sedimentary terrains and in faults, fractures or weathered zones of rocks in a basement terrain called aquifer [2]. The confined and unconfined aquifers are the two sources of groundwater; an important difference in the both sources is their susceptibility to contamination from either the surface of the earth or nearby contaminated groundwater [3]. The unconfined aquifer is highly vulnerable to contamination while the confined aquifer has a lower susceptibility to contamination and therefore the major source of water for human consumption.

Geo-scientists are utilizing available advancements of geophysical tools and also creating new technologies to better understand the earth which helps in the exploration of hydrocarbons, groundwater, solid minerals, environmental studies etc [4]. Among the geoelectrical methods, vertical electrical sounding technique has been frequently used in hydro-geophysical studies for groundwater in both porous and fissured media [5, 6, 4].

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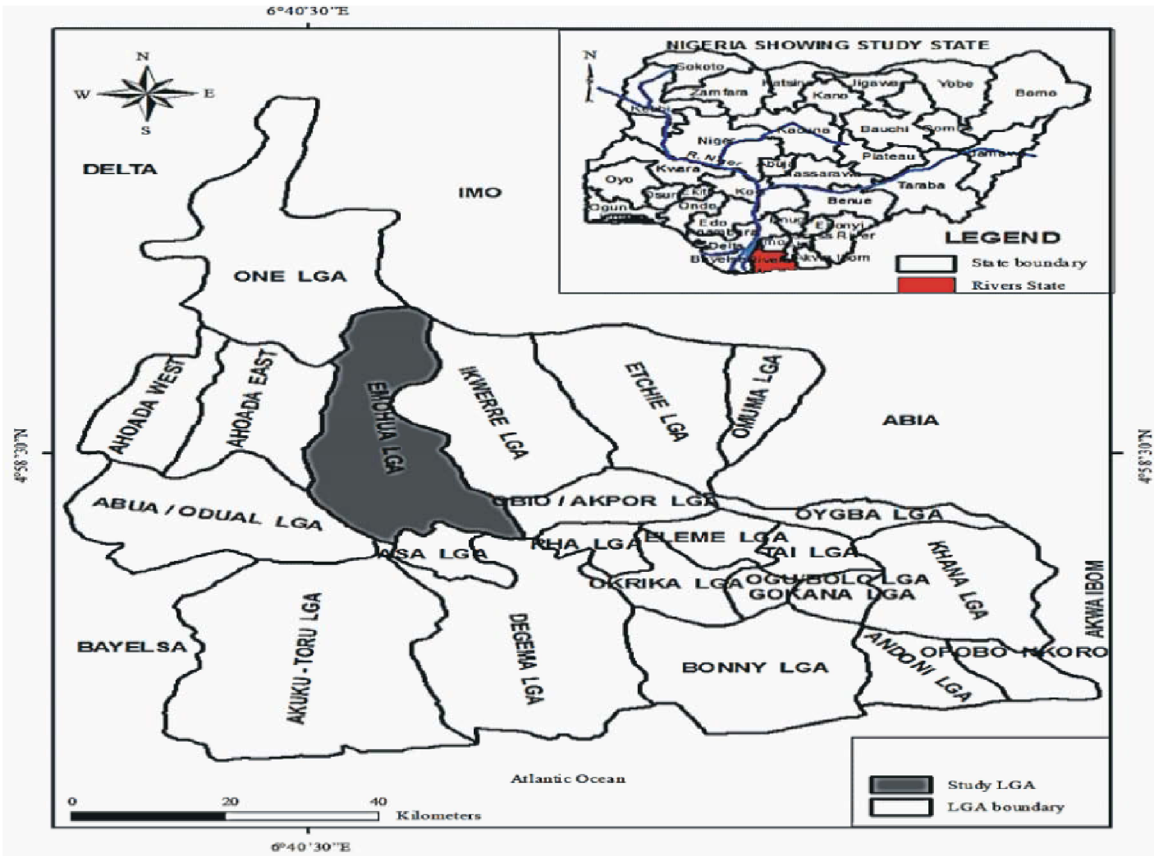


Fig. 1: Map of Rivers State Showing the Local Government Area of Study (Emohua)

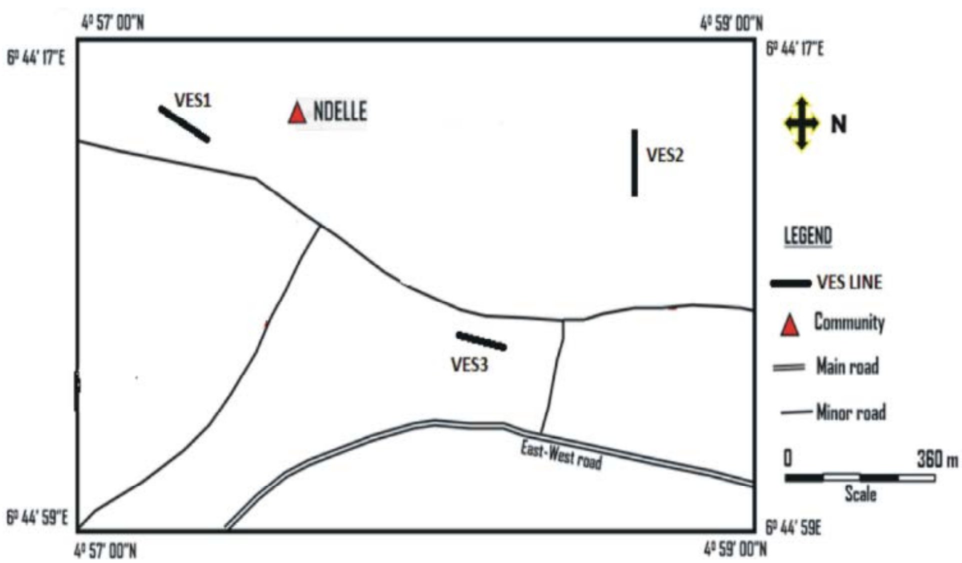


Fig. 2: Base map of study Area showing VES lines

The use of geophysical techniques for groundwater exploration and water quality evaluations has increased recently due to rapid advances in computer software and other numerical modelling techniques [1]. The use of Vertical Electrical Sounding (VES) has also become very popular with groundwater prospecting due to simplicity of the technique. The purpose of electrical geophysical survey method is mainly to detect the surface effects produced by the flow of electric current inside the earth. These techniques have been used in a wide range of geophysical investigations such as mineral exploration, archaeological investigations, engineering studies, geothermal exploration, permafrost mapping and geological mapping. It also has wide applications in groundwater investigations [7, 8].

Geo-electrical resistivity survey method is based on the response of the earth to the flow of regulated input current source. It is an efficient and cost effective method. Vertical electrical sounding (VES) provides a 1-D electrical impedance of the ground based on surface measurements, from which water saturation and lithological information are obtained [9].

This study utilizes vertical electrical sounding; employing schlumberger array method to delineate the variation in the lithologic distribution and depths to potable groundwater in the Ndele, Emuoha L.G.A. of Rivers State, Nigeria.

Location and Accessibility of the Study Area: Ndele is a town located in emohua L.G.A of Rivers state. Ndele is located approximately between latitude 04°58’05’’ – 04° 58’08’’ N and longitude 006°44' 44''– 006° 45'05''E (Fig. 1) in the South South region of Nigeria. Ndele is bounded to the north by Elele alimini and Omagwa and then to the south by Rumuekpe.

Relief and Drainage: The study area lies within the coastal flat plains of the Niger Delta which is a depositional environment basically and of almost featureless land sloping gently above mean sea level at the coastal fringe, though relatively low elevation occur around the shore lines, waterfronts and stream [10]. The area is affected by tide with a maximum range of tide fluctuating between 1.8m below mean sea level and 2.2 m above mean sea level [11]. The study area which is in Rivers State is drained by numerous rivers and creeks sourced from River Niger. The study area, Ndele is drained by the new Calabar River.

Geology and Hydrology of the Study Area: The study area, Ndele in Emuoha Local Government Area of Rivers state is located within the Niger Delta region of Nigeria, situated in the gulf of Guinea and therefore has same geology of the Niger Delta. The Niger Delta is composed of marine shale at the base of its stratification, an overlying formation of intercalation of sandstone and clays of marginally marine origin, but eventually grading upward into a huge sandstone deposit. The groundwater formation is a multi-aquifer system because of the presence of certain clayey strata in formations of various thicknesses that acts as confining layer between two rock strata [12, 13]. The present day Niger Delta was formed during the tertiary period as a result of the interplay between subsidence and deposition arising from a succession of transgression and regression of the three main tertiary subsurface litho-stratigraphic units of Akata, Agbada and Benin Formations [14]. Further studies and evidence from deep wells in the Niger Delta has also proven that the Niger Delta has a three litho-stratigraphic depositional succession (Akata, Agbada and Benin Formations) with an approximate thickness of over 5000m of sediment body.

Although the Agbada Formation has a sandy unit with aquifer qualities and confirmed water saturation, its depth has made it an unsuitable source for groundwater in the region. Aquifers of the Benin Formation bear the ground water needs of the region. The poorly sorted Benin coastal sands become increasingly sandy and unconsolidated towards the surface. These parameters increase the porosity and permeability and thus, the increase in storage coefficient of the aquifer. The region is composed of multiple aquifer system due to the presence of thin clayey or silty layers acting as confining layer and boundary between distinct aquifer formations [13]. The groundwater in the area is recharged either by a nearby water body such as surface water or a more prolific aquifer and extensive percolation from rainfall. This has resulted to a prolific hydrologic unit with depth to water table ranging between 0.3m - 15m [15].

Methods of Study: Vertical Electrical Sounding (VES) technique was employed using the Schlumberger electrode configuration for the ground water investigation. Sounding was carried out in three traverses, VES1 for location 1, VES2 and VES3 location 2 and 3 respectively, areas cutting across three communities in Ndele, Emuoha L.G.A of Rivers State.

The survey equipment used was Abem Terrameter SAS 1000C. During sounding, the four (4) electrodes were arranged along a straight line. The potential electrodes were placed between the current electrodes and all four were on a straight line, disposed with respect to the centre of the configuration at each spreading. The current electrode spacing was constant on either side by AB/2 (horizontal distance between the two electrodes).

Table 1: Stratigraphic Sequence of the Tertiary Niger Delta [14]

Age	Surface Formation		Subsurface	Environment
Pliocene to Recent	Coastal Plain Sands		Benin Formation	Continental
Miocene to Recent	OgwashiAsaba formation	Ijebu Formation		
Eocene to Recent	Ameki Formation	Ilaro Formation Oshobu Formation	Agabada Formation	Paralic
Paleocene	Imo Formation		Akata Formation	Marine

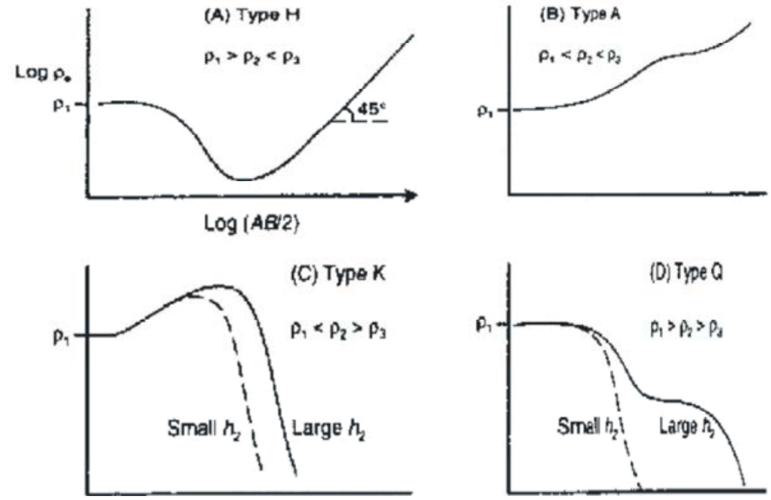


Fig. 3: Graphical representations of VES curve types [16]

The electrical current (I) was applied to A and B electrodes and potential was measured between M and N electrodes. The geometric factor (K) can be obtained for four electrode array of AMNB configuration as:

$K = [(AB/2)^2 - (MN/2)^2/MN]\pi$ (1) (geometric factor)

where AB/2= half current electrode spacing
MN/2= half potential electrode spacing

The VES array consists of the series of the electrode combinations AMNB with gradually increasing distances among the electrodes for consequent combinations.

The depth of sounding increases with distance between A and B electrodes. The K factor for the combinations is calculated with Equation 1 above. From this field work, Four (3) VES were done on the field. The plots obtained from the resistivity data were examined and their character noted in terms of the pattern of resistivity with depths of VES or laterally in profile data. The areas of high resistivity were noted, described and attributed to the presence or absence of conducting bodies below the surface at the point or area of the observation of the anomalies.

For VES, the types of curve obtained were noted in terms of:

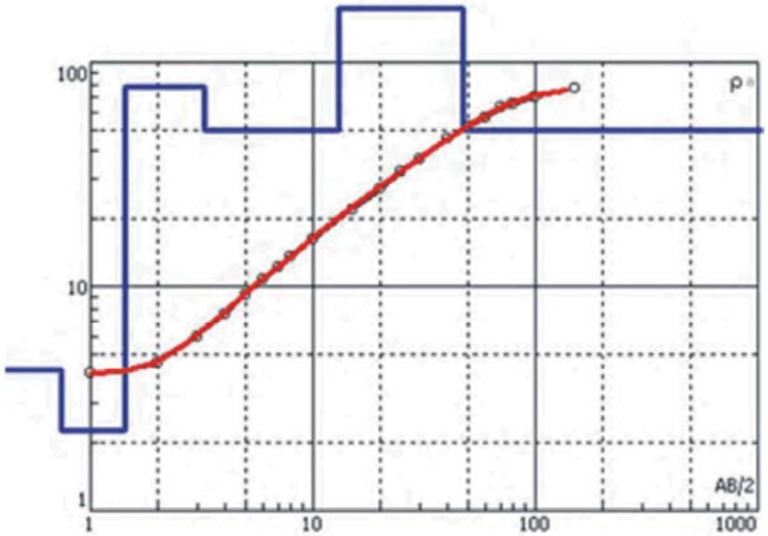
A - Type: Continuous increase of resistivity with depth i.e. p1<p2<p3

Q - Type: Continuous decrease of resistivity with depth i.e. p1>p2>p3

H - Type: 3 layer in which $\rho1>\rho2<\rho3$
K - Type: 3 layer in which $\rho1<\rho2>\rho3$

RESULTS AND DISCUSSION

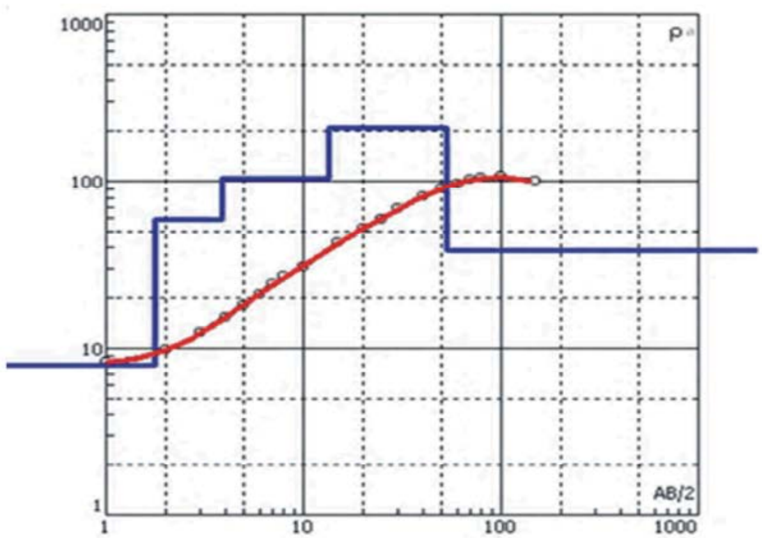
Interpretation of Resistivity Data: The data obtained from the VES1 carried out in location 1 of the study area was plotted using a computer software; IP2WIN software (Fig. 4). The resistivity curve obtained from the computer interpretation revealed a 6 layer HKHK Type curve with resistivity $\rho1>\rho2<\rho3>\rho4<\rho5>\rho6$. It is made up of four distinct curve types with the resistivity of the 1st layer greater than that of the 2nd layer and that of the 2nd layer less than the 3rd layer, the resistivity of the 4th layer was less than that of the 5th layer and that of the 5th layer greater than the 6th layer. The lithologic distribution of the study location shows that the area is underlain by 6 soil layers, with the first layer made up of unconsolidated topsoil to a depth of 0.7m followed by a layer of clay to a depth of 1.4m. The 3rd and 4th layers are made of a mixture of clay and sand from a depth of 1.4m to 13m. The aquiferous zone is the 5th layer at the depth of 47.3m with resistivity of 173Ωm. The 6th layer was made of a mixture of clay and sand which brought about a lower resistivity of 50.3 m to an infinity depth.



RMS=1.58%

N	1	2	3	4	5	6	
ρ	4.24	2.29	77.9	49.7	173	50.3	
h	0.743	0.674	1.83	9.72	34.4		
d	0.743	1.42	3.25	13	47.3		
Alt	-0.7428	-1.417	-3.248	-12.97	-47.34		

Fig. 4: Graphical interpretation of VES data for location 1 (IP2WIN SOFTWARE)



RMS=0.982%

N	1	2	3	4	5		
ρ	8	58.8	104	209	38.7		
h	1.76	2.1	9.61	39.6			
d	1.76	3.87	13.5	53.1			
Alt	-1.763	-3.865	-13.48	-53.06			

Fig. 5: Graphical interpretation of VES data for location 2 (IP2WIN SOFTWARE)

Table 2: Geo-Electrical parameters from VES inlocation 1

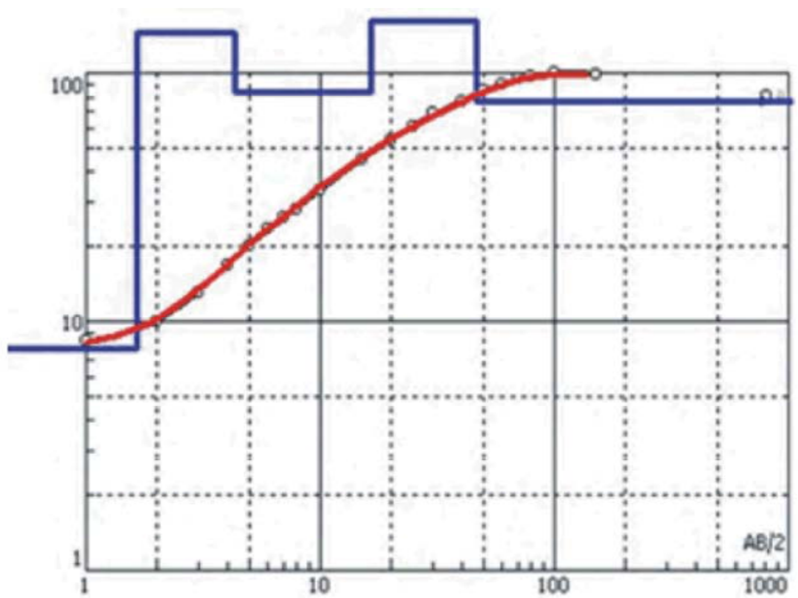
Lithologic Description	Geoelectric Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
Topsoil	1	4.24	0.743	0.74
Clay	2	2.29	0.674	1.42
Sandy Clay	3	77.9	1.83	3.25
Layey Sand	4	49.7	9.72	13
Sand	5	173	34.4	47.3
Clayey Sand	6	50.3	Infinity	Infinity

Table 3: Geo-Electrical parameters from VES in location 2

Lithology Description	Geoelectric Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
Topsoil	1	8	1.76	1.76
Clayey Sand	2	58.8	2.1	3.87
Sand	3	104	9.61	13.5
Sand	4	209	39.6	53.1
Clayey Sand	5	38.7	Infinity	Infinity

Table 4: Geo-Electrical parameters from VES in location 3

Lithologic Description	Geoelectric Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
Topsoil	1	7.86	1.66	1.66
Sand	2	145	2.64	4.29
Clayey Sand	3	83.7	12.2	16.5
Sand	4	163	29.5	46
Clayey Sand	5	76	Infinity	Infinity



RMS=1.78%

N	1	2	3	4	5		
ρ	7.86	145	83.7	163	76.4		
h	1.66	2.64	12.2	29.5			
d	1.66	4.29	16.5	46			
Alt	-1.656	-4.295	-16.5	-46.02			

Fig 6: Graphical interpretation of VES data for location 3 (IP2WIN SOFTWARE)

For VES2, location 2 point, the resistivity curve (Fig. 5) showed 5 layers, three curve types of AAK with resistivity $\rho 1<\rho 2<\rho 3<\rho 4>\rho 5$ i.e. the resistivity of the 1st layer is less than that of the 2nd layer and that of the 2nd layer is also less than the 3rd layer, that of the 3rd layer is less than the 4th layer and the 4th layer is greater than the 5th layer. The lithologic distribution of the study location shows that the area is underlain by 5 soil layers, with the first layer made up of unconsolidated topsoil to a depth of 1.8m followed by a mixture of sand and clay to the depth of 3.9m. The third layer consists of medium sand to the depth of 13.5m and resistivity of 104Ωm. The aquiferous zone started from the 4rd layer at the depth of 53.1m with resistivity of 209Ωm. The 5th layer had an intercalation of clay and thereby dropping its resistivity down to 38.7Ωm.

The third location VES3 showed a resistivity curve (Fig.6) with 5 layers, three curve typesof KAA with resistivity $\rho 1<\rho 2>\rho 3<\rho 4<\rho 5$ i.e. the resistivity of the 1st layer is less than that of the 2nd layer and that of the 2nd layer is greater than the 3rd layer, the 3rd layer is less than the 4th layer and the 4th layer is also less than the 5th layer. The lithologic distribution of the study area shows that the area is underlain by 5 soil layers, with the first layer made up of unconsolidated topsoil followed by a layer of sand with a higher resistivity of 145Ωm. The 3rd layer is a mixture of clay and sand with a resistivity of 83.7Ωm to the depth of 16.5m. The aquiferous zone is the 4th layer at the depth of 46m with resistivity of 163Ωm which can yield potable water. The 5th layer has a low resistivity because of its intercalation of clay.

CONCLUSION

The Geo-Electrical Resistivity surveys carried out in the study area revealed that the subsurface lithology consist of formations that clearly defines the Benin Formation of the Niger Delta. The lithology ranges from clay to medim and coarse sand. The depths to potable water in the three VES locations showed that depths exceeding 50m in the area will yield potable water in the area. This implies that all boreholes drilled in the study area must exceed 50m to sustainably yield potable water.

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