GROUNDWATER PROSPECT USING ELECTRICAL RESISTIVITY METHOD IN KOKO AREA, WESTERN NIGER DELTA, NIGERIA

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Abstract

The need for portable groundwater in the area necessitated this prospecting using the electrical resistivity method. Earth resistivity meter was used to acquire the Vertical Electrical Sounding (VES) data using Schlumberger configuration. Acquired data were subjected to manual computation and application of processing software. The results revealed four geoelectric sections of the KH curve. Topsoil, sand, sandy clay and coarse sand were delineated. Topsoil has a resistivity of 69.3 Ohm-m and thickness of 0.7m, the second layer is composed of sand has a resistivity of 196.9 Ohm-m and thickness of 5.9m; being a sedimentary terrain, groundwater can be exploited in this layer, but may not be portable due to its nearness to the surface. The third layer is composed of sandy clay with a resistivity of 66.8 Ohm-m and a thickness of 38.7 m, this layer is an aquiclude and water cannot be transmitted easily. The fourth substratum is composed of coarse sand with a resistivity of 341.7 Ohm-m at a depth of 46 m and beyond. Coarse sand is the confined aquifer where portable groundwater can be exploited in wet and dry seasons. It is recommended that boreholes be drilled to at least 46 m to get portable water.

Keywords: Groundwater; Resistivity; Sand; Stratigraphy.

Introduction

The search for portable water for the well-being of the citizenry cannot be overemphasized. There is much reliance on groundwater for domestic, agricultural and industrial uses. This is because groundwater can be exploited where residential buildings or industrial complexes are situated. The search for portable water is on the increase because most surface water is polluted and more underground water is being contaminated as a result of human activities and environmental reasons (Amadi et al., 2014). In the Niger Delta region where hydrocarbon exploitation and distribution of petroleum products are regular activities, it becomes more problematic to get portable water.

Though the area is in sedimentary terrain where the water level is close to the surface, there is the need to explore the underground water to know the depth at which portable water can be exploited. This can be made possible through the employment of a geophysical method in which electrical resistivity is a desired method for this near-surface exploration.

Exploration of freshwater using the geophysical method of electrical resistivity in the Western Delta region has yielded positive results (Uchegbulam et al., 2022 Alile et al., 2008). These researchers employed the method to report the depths at which portable water can be exploited in some parts of the Western Niger Delta region. Atakpo and Ayolabi (2008) used the electrical resistivity method to assess the vulnerability of groundwater in oil-producing areas of the Western Niger Delta and reported that some areas are prone to pollution due to their low protection capacity. These were revealed through the application of longitudinal conductance calculations.

Electrical resistivity investigations delineate subsurface resistivity distribution by making measurements on the ground surface. The true resistivity of the subsurface can be estimated from the apparent resistivity measurements. Resistivity is associated with different geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock (Benard, 2003). These can be used to characterize subsurface formations and environmental studies like groundwater exploration, pollution investigation, search for buried objects, etc. Shallow boreholes are always contaminated because they are prone to environmental contaminants. The city hosts a seaport, and some petroleum products marketing companies operate tank farms in the area. There is therefore the need to know the depth at which portable water can be exploited before sinking boreholes in such a residential area. So electrical resistivity method will be employed to characterize the lithostratigraphy and delineate the depth where portable water can be exploited in the study area.

The Study Area

Koko is in Warri North local Government area of Delta State, Western Niger Delta (Figure 1). It lies in the range of latitude 60 00″ – 60 10 ″ N and longitude 50 26′ 30″ - 50 28′ 30″ E in geographic coordinates (Figure 3). A Map of Delta State showing the study area is shown in Figure 1.

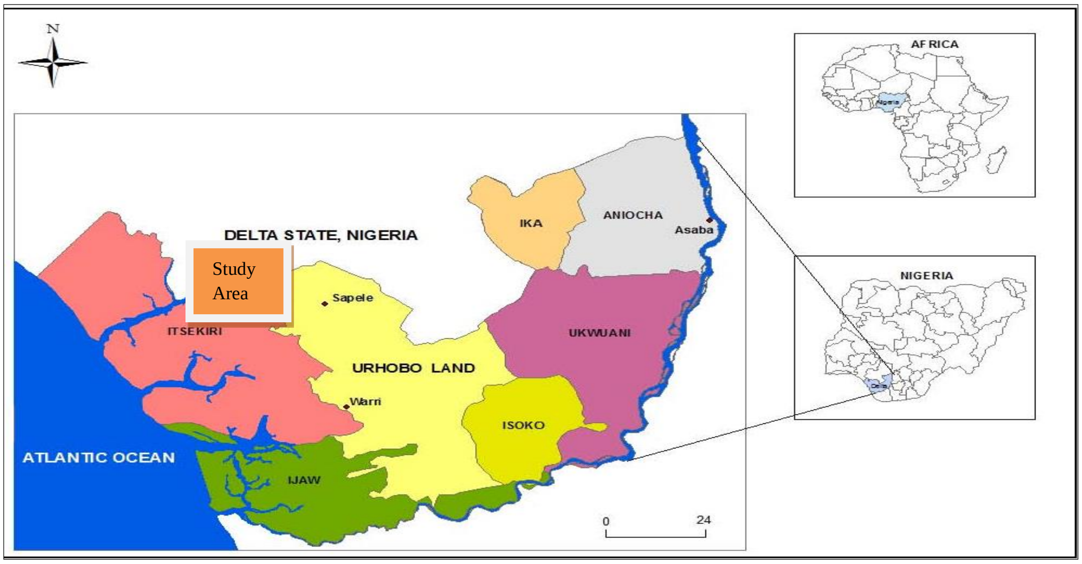

Figure 1: Map of Delta State, Nigeria showing the study area (Adapted after Odemerho, 2008)

Basic Theory

Theory of Current Flow in the Ground

The electrical resistivity measurements are usually made by injecting direct current (DC) into the subsurface through current electrode C1 which is the source and electrode C2 which is the sink and measuring the resulting potential difference at two potential electrodes P1 and P2. Through the values of the measured current (I) and voltage (V), an apparent resistivity (ρa) value can be calculated (Figure 2). The configuration of the electrodes is shown in Figure 2.

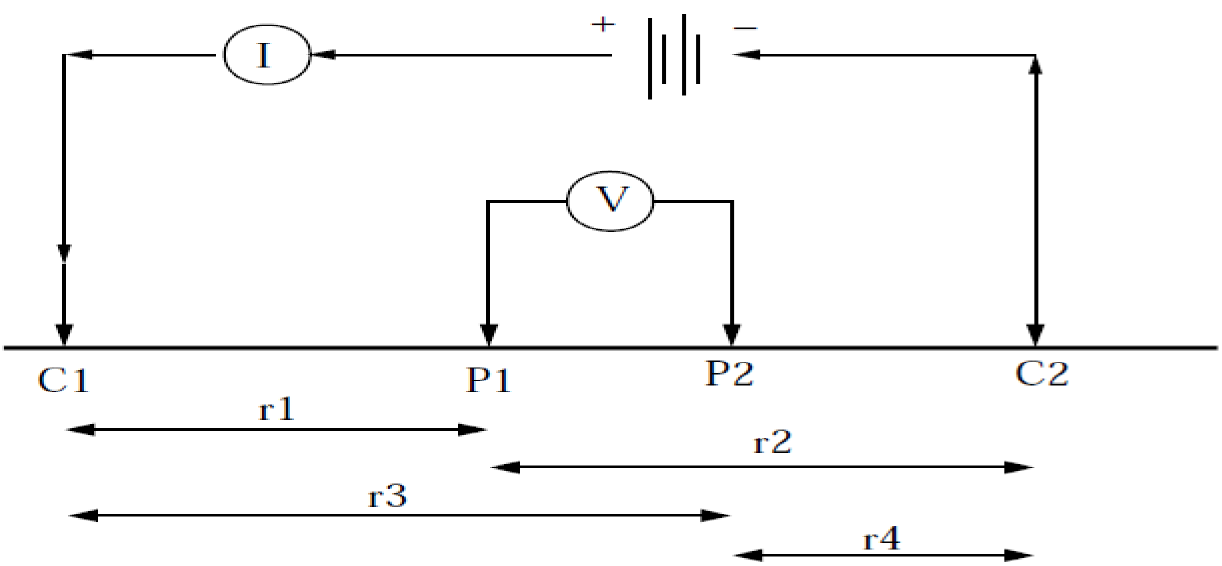

Figure 2: General four-electrode configuration for resistivity measurement, consisting of pair of current electrodes (C_1, C_2) and a pair of potential electrodes (P_1, P_2).

Starting with Ohm's law;

$$V = IR \qquad 1$$

And defining the resistance R in terms of the resistivity of the *equipotential* surface, the potential difference V, across the surface is;

$$dV = (iR)I\left(\rho\frac{L}{A}\right) = I\left(\rho\frac{dr}{2\pi r^2}\right) \qquad 2$$

Integrating equation 2 and setting the potential at infinity to zero, the electric potential V at a distance r from the source is given by;

$$V = \left(\frac{\rho I}{2\pi R}\right) \qquad 3$$

Resistivity surveys measure the potential difference between two points P_1 and P_2 due to the current from two current electrodes C_1 and C_2.

$$VP_1 = \frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2} \qquad 4$$

$$VP_2 = \frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4} \qquad 5$$

Therefore, the potential difference becomes

$$\Delta V = VP_1 - VP_2$$

$$\Delta V = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right) \qquad 6$$

Equation 6 is used to determine subsurface resistivity in resistivity survey.

$$\rho = 2\pi\frac{\Delta V}{I}\frac{1}{G} \qquad 7$$

where $\frac{2\pi}{G}$ denotes the geometric factor of an electrode configuration and is generally designated by the letter K. Thus equation 7 can be rewritten as

$$\rho = K\frac{\Delta V}{I} \qquad 8$$

Resistance values is what is normally given by Earth resistance meters

$$R = \frac{V}{I} \qquad 9$$

(Sharma, 2002)

Geology and Hydrogeology of the Study Area

The Niger Delta region is a geologic area in West Africa also known as the Niger Delta basin. The Niger Delta province is in Southern Nigeria, and exploitation of hydrocarbon has led to the pollution of surface and groundwater in the region (Tamunu and Felix, 2006). A delta is a deposit of sediments formed at the mouth of a river where it enters a lake or the sea. It is normally built up only where there is no tidal or current action capable of removing the sediment as fast as it is deposited, and hence the delta builds forward from the coastline. The stratigraphic columns of the Niger Delta from top to bottom are Benin, Agbada and Akata formations. Benin Formation is the main aquifer unit. The aquifer in the Benin formation is largely phreatic, these formations are overlain by various types of quaternary deposits made up of topsoil, red laterite, clay, fine sand, medium sand and coarse sand in the form of pebbles. The stratigraphic geologic unit of the Niger Delta is shown in Table 1

Table 1: Geologic Units of the Niger Delta (Doust and Omatsola, 1990)

Geologic Unit	Lithology	Age
Alluvium (General) Freshwater Backswamp and meander belt Mangrove and salt water / backswamps Sombreiro – warri deltaic plain	Gravel, sand, clay, silt Sand, clay, some silt and gravel Medium – fine sand, clay and some silt Sand, clay and some silt	Quaternary
Benin Formation (coastal plain sand)	Coarse to medium sand with subordinate silt and clay lenses	Miocene
Agbada Formation	Mixture of sand, clay and silt	Eocene
Akata Formation	Shale	Paleocene

Materials and Method

Earth Resistivity Meter (Petrozenith PZ-02 Terrameter) was used to acquire the Vertical Electrical Sounding (VES) data. Schlumberger array was utilized for the VES data acquisition due to its good vertical resolution. The configuration was used for a distance of 500m. A VES station was located in front of the proposed water borehole site, and 250m (L/2) was covered.

The Google image of the study area showing the VES point is shown in Figure 3.

Field data were subjected to manual computation and computer processing techniques, with the application of WinResist software. Results of the data processed by the software were integrated to get a realistic delineation of the strata and depth of the subsurface.

The apparent resistivity ρa was calculated using the relation:

Relation used: $$\frac{\pi}{4}\frac{V}{I}\frac{L^2}{a} = \frac{\pi L^2 R}{4a} = kR$$

$$k = \frac{\pi L^2}{2a}$$

AB/2 = Current Electrode,

MN/2 = Potential Electrode

where L is the current electrode and a is the potential electrode. Table 2 is VES data.

Table 2: VES Data

AB/2 (m) (L)	MN/2 (m) (a)	Resistance, R (Ω)	k (m)	Resistivity,ρ (Ωm)
1	0.5	32.9700	2.3562	77.684
2	0.5	7.7400	11.781	91.185
7	0.5	1.0500	153.15	160.81
10	1	1.0100	155.51	157.07
14	1	0.8740	306.31	267.72
17	1	0.2734	452.39	123.7
21	1	0.1414	691.15	97.708
32	5	0.0707	313.85	22.18
47	5	0.4243	686.12	29.112
70	5	0.0623	1532	95.398
100	5	0.0482	3134	150.96
150	10	0.5538	3519	1949
200	10	0.0576	6267	361.36
250	10	0.0463	9802	454.32

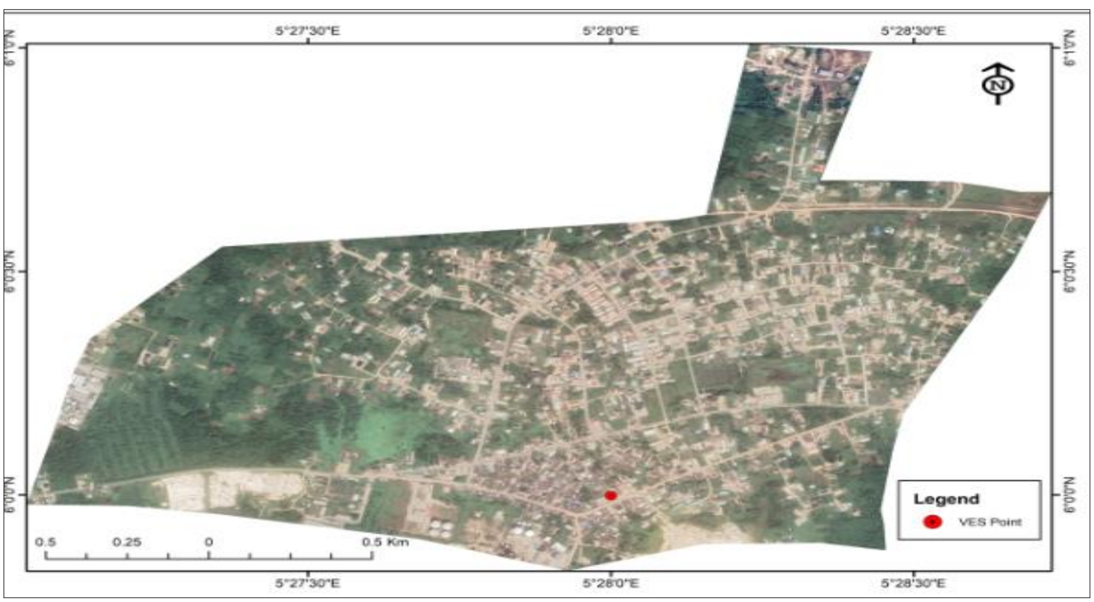

Figure 3: Google image of the study area in Koko showing the VES point

Results and Discussion

The results are presented as graph, table and logs. The apparent resistivity curve is shown in Figure 4; the geoelectric section is shown in Figure 5, while the lithostratigraphy of Koko for boreholes 1 and 2 (BH 1 and BH 2) is shown in Figure 6. The borehole data is used as an aid in interpreting the results. Table 3 is the geoelectric data for VES.

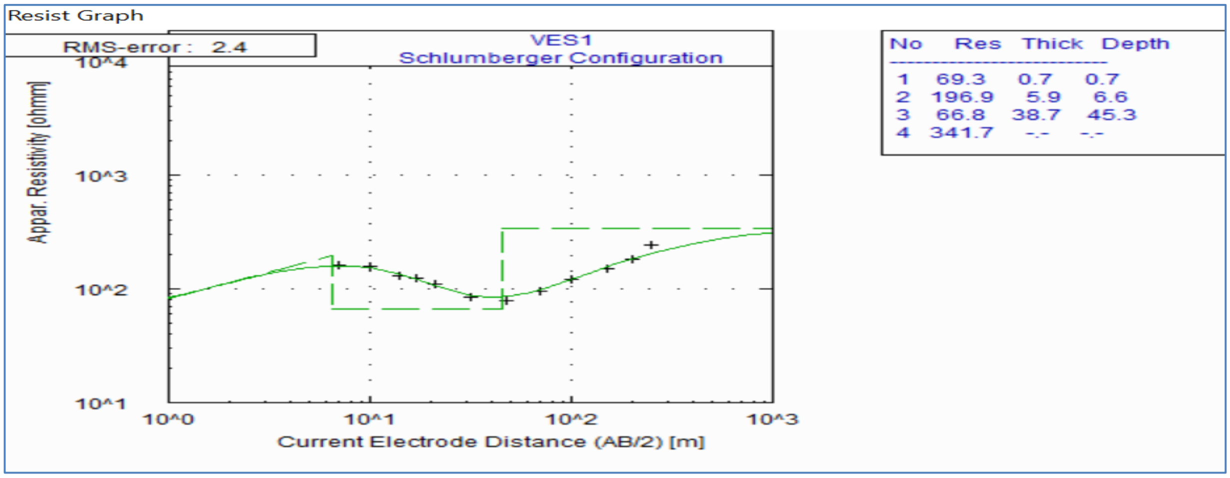

Figure 4: Apparent Resistivity graph of VES 1

Table 3: Geoelectric table of VES

VES No	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	CURVE TYPE KH	LITHOLOGY
1	1	69.3	0.7	0.7	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	Topsoil
	2	196.9	5.9	6.6		Sand
	3	66.8	38.7	45.3		Sandy clay
	4	341.7	---	---		Coarse sand

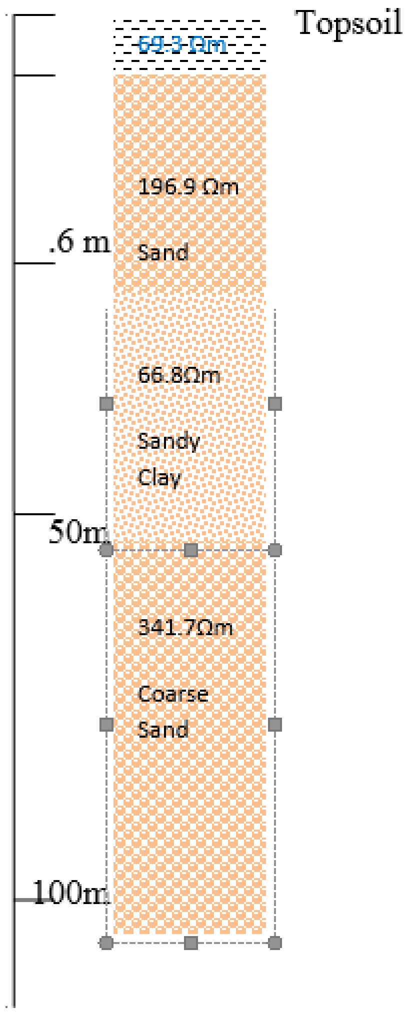

Figure 5: Geoelectric section of VES 1

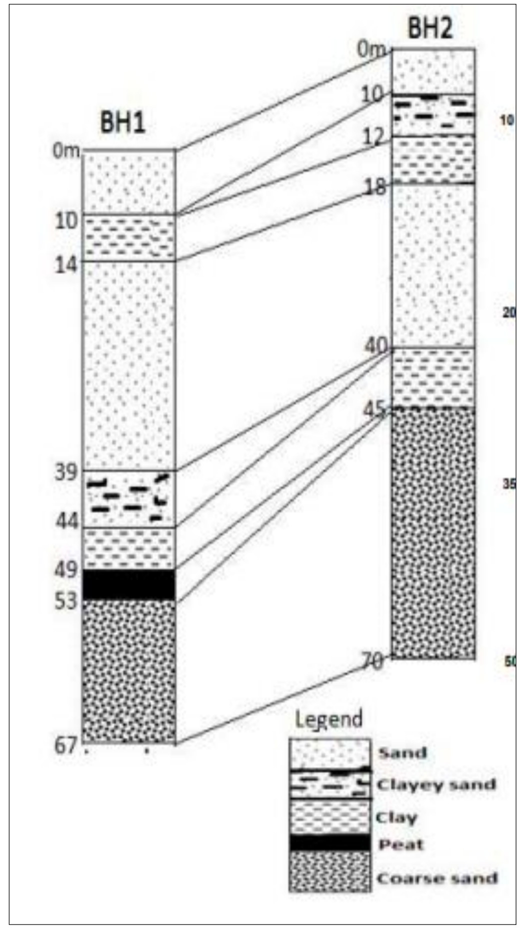

Figure 6: Lithostratigraphy of Koko for BH 1 and BH 2 (After Asuma et al., 2019)

The geoelectric section (Figure 3) reveals four (4) subsurface layers namely topsoil, sand, sandy clay and coarse sand. The topsoil is characterized by a resistivity value of 69.3 Ohm-m and a layer thickness of 0.7 m. The soil in this section is highly weathered due to nearness to the surface and long exposure to weather changes. The second identified layer denotes sand with a resistivity of 196.9 Ohm-m and a thickness value of 5.9 m, being a sedimentary terrain, groundwater can be exploited here, though may not be portable due to closeness to the surface and the thickness is small. This is the depth at which shallowest boreholes are situated and there is the possibility of wells being dry during the dry season. This environment of sand is in agreement with the lithological stratigraphy information of boreholes 1 and 2 of the area study. The third layer connotes sandy clay with a resistivity of 66.8 Ohm-m and thickness of 38.7m, this is an aquiclude and water here cannot be transmitted easily because of the size of the pores as it is a sandy clay environment. The amount of clay mixed with sand tends to be high. The fourth substratum is composed of coarse sand having a resistivity value of 341.7 Ohm-m but the layer thickness could not be determined because the current terminated within this horizon. The coarse sand in this zone represents a confined aquifer unit where groundwater could be tapped with the assurance of getting water in wet and dry seasons because of the thickness of the layer. Groundwater exploration carried out near the study area by Uchegbulam et al., (2022) reported that about 46m beneath the surface is where fresh water can be tapped. The geoelectric section revealing different layers is in agreement with the lithological stratigraphy information of borehole 2 of the study area.

Conclusion

The geophysical investigation using the electrical resistivity method delineated a depth of 46m and beyond where portable water can be exploited in the study area. However, at a depth of 5 – 7m beneath the surface, shallow boreholes can be dug but the water may not be portable due to its nearness to the surface.

Recommendation

It is recommended that dug boreholes should get to a depth of at least 46m to get portable water and physicochemical testing of the groundwater from this area should be carried out to know if there are chemical pollutants in the water.

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