Western Delta University Journal of Natural and Applied Sciences (WDUJNAS).
Vol. 2 (1) September 2022. ISSN 2971-6012

ASSESSMENT OF GROUNDWATER POTENTIAL USING GEOELECTRIC METHOD IN WESTERN DELTA UNIVERSITY PREMISES, NIGER DELTA, NIGERIA

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ABSTRACT

Groundwater potential was investigated using Vertical Electrical Sounding (VES) and Electrical Resistivity Tomography (ERT) methods at the temporary site of Western Delta University, Oghara. The data were acquired through the use of Earth Resistivity Meter and processed with the application of WinResist and Dipro software. The geoelectric section reveal a HA curve with three layers. The topsoil has a resistivity of 300 Ohm-m with thickness of 0.6m. The second layer, which is clayey sand, has resistivity value of 127 Ohm-m with thickness of about 2.25m, while the third layer has resistivity of 480 Ohm-m, which is fine sand, with thickness of 3m. Groundwater can be exploited in medium grained sand from 12m beneath the surface where the resistivity is > 600 Ohm-m, with thickness exceeding 8m. The ERT reveal similar result with resistivity > 600 Ohm-m at the depth of 10m and beyond, which is sand where groundwater can be exploited. Less than 12m beneath the surface, the aquifer is considered shallow. However, confined aquifer where clean water can be exploited is found between 24 – 33m. It could be recommended that borehole should be at least 24m deep within the study area. The two methods show similar results, indicating the correctness of the methods and the usefulness of electrical resistivity method in groundwater exploration.

Keywords: *Groundwater; Resistivity; Sand; Subsurface; Traverse*

INTRODUCTION

Water is an essential substance that made our planet to have life and be habitable. Water covers about 70% of the earth surface, but great proportion of this value is not potable. Most surface water are contaminated due to increasing industrialization and human activities, these are common occurrences in the Niger Delta region. Contaminant load of soil and water is becoming greater each year in parallel with increasing industrialization and energy demand (Wang *et al.*, 1999).There is therefore much reliance on groundwater for domestic, agricultural and industrial uses. Groundwater, through different dissolved salts it contains, by means of ions is conductive and enables electric currents to flow into the ground. As a result, measuring the ground resistivity gives the possibility to recognize the presence of water in a surveyed site.

Talebmorad and Ostad-Ali-Askari (2022) employed a hydro geo-sphere integrated hydrologic model to simulate large scale basin. The study was useful because of the rising demand for water as a result of continued increase in population and human activities. Alile et al. (2008) successfully employed electrical resistivity method in a sedimentary environment of Edo State to explore for groundwater. In Eastern Niger Delta city of Umuahia, Mbonu et al, (1991) utilized electrical resistivity method to carry out aquifer characterization.

Electrical resistivity uses direct current or low frequency alternating current for subsurface investigation (Brooke and Kearey, 1984). Shallow subsurface geology of the area can also be delineated through electrical resistivity method of geophysical investigation (Tearpock and Bischke, 1991).

Atakpo and Ayolabi (2008) used electrical resistivity method to evaluate the aquifer vulnerability and the protective capacity in some oil producing communities of Western Niger Delta. The longitudinal conductance calculations showed that some soils have high protective capacity, which will prevent contaminants from infiltrating into the fresh water aquifer, while some areas have low protective capacity and are prone to pollution. Hence, electrical resistivity method is a preferred and effective method to explore for groundwater in a sedimentary terrain of the study area. Portable water is increasingly under threat as a result of hazardous substances in solid and liquid forms which has negative impact on the environment and the people as reported by Ostad-Ali-Askari (2022), hence the need to exploit underground water which has not been contaminated.

Many inhabitants of Oghara uses hand dug wells, which are shallow; the possibility of getting potable water from these shallow wells is rare. Hence, the study will seek to find the depth at which fresh water can be exploited using the Western Delta University premises as a pilot study.

To recognize the presence of groundwater from resistivity measurements, absolute value of the ground resistivity, through the Archie law can be considered: for a practical range of fresh water resistivity of 10 – 100 Ohm.m, a usual target for aquifer resistivity can be from 50 – 2000 Ohm.m (Benard, 2003).

Location 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 province is in the Gulf of Guinea and extends throughout the Niger Delta as defined by Klett *et al.*, (1997). The Niger Delta province is an oil producing region in Southern Nigeria, West Africa. Oghara is in Western Niger Delta which lies between longitude 5˚E - 5˚45'E and latitude 5˚30'N - 6˚N in geographic coordinate. Oghara situates in latitude 5º56˙˙N and longitude 5º39˙58˙˙E

Oghara is in Sombreiro – Warri deltaic plain, which is part of Benin formation. The aquifer 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 form of pebbles. The thickness is variable but generally exceeds 6000ft (Egbai, 2012). The study area consists of fresh water swamp, coastal plain sands, mangrove swamps, and Sombreiro-Warri plains (Omo – Irabor and Oduyemi, 2006). The water table in the study area is close to the surface, approximately 4 to 5 m beneath the surface and the direction of flow is towards River Ethiope which drains into the Atlantic Ocean through the Benin River (Figure 1). The map of the study area is shown in

Figure 1, while the geologic unit of the Niger Delta is shown in Table 1.

Table 1: Geologic Units of the Niger Delta (Short and Stauble, 1967)

Geologic Unit	Lithology	Age
Alluvium	Gravel,	Quaternary
Freshwater Backswamp	Sand, clay, some silt	
Mangrove and salt	Medium – fine sand,	
Sombreiro – warri deltaic	Sand, clay and some	
Benin Formation	Coarse to medium	Miocene
Agbada	Mixture of	Eocene
Akata	Shale	Paleocene

subsurface can be estimated. The resistivity measurements are normally made by injecting current into the ground through two current electrodes C_1 and C_2 and measuring the resulting voltage difference at two potential electrodes P_1 and P_2 (Figure 2). From the current (I) and voltage (V) values, an apparent resistivity (ρ_a) value is calculated. A conventional four electrode configuration to measure subsurface resistivity is shown in figure 2.

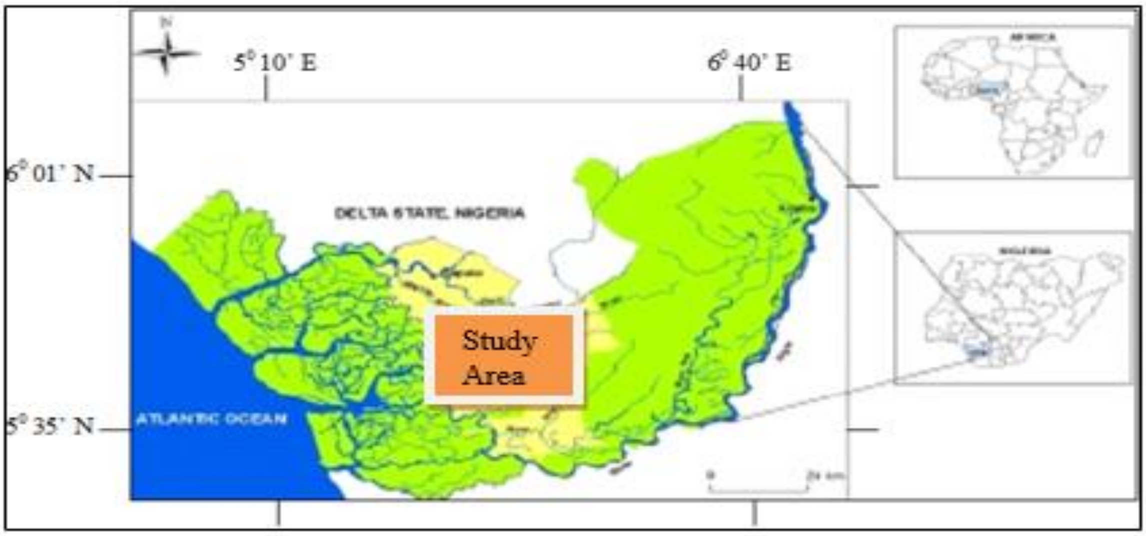

Figure 1: Map of Delta State, Nigeria showing the study Area (After Odemerho, 2007)

Principles of Electrical Resistivity Survey

The purpose of electrical survey is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the

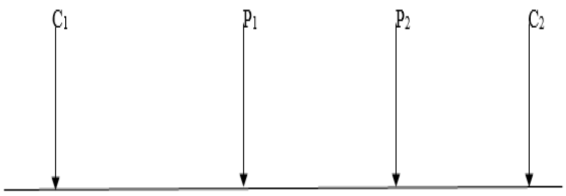

Figure 2: A conventional four electrode array to measure the subsurface resistivity

A uniform layer of length, L and resistance, R, through which a current I, is flowing, the potential difference, ΔV, across the ends of the resistance is given by Ohm's law:

$$\Delta V = RI \qquad (1)$$

using the relationship between R and ρ that is,

$$\rho = \frac{RA}{L} \qquad (2)$$

$$\frac{\Delta V}{L} = \frac{\rho I}{A} \qquad (3)$$

$$-gradV = \rho I \qquad (4)$$

$$E = \rho J \qquad (5)$$

The generalized equation for resistivity survey is

$$\rho = 2\pi \frac{\Delta V}{I}\frac{1}{G} \qquad (6)$$

$$\rho_a = k\frac{\Delta V}{I} \qquad (7)$$

where k is the geometric factor which depends on the arrangement of the four electrodes.

Resistivity meters normally give resistance value,

$$R = \frac{V}{I} \qquad (8)$$

In practice the apparent resistivity value is calculated by

$$\rho_a = kR \qquad (9)$$

(Sharma, 2002)

The resistivity of rock depends on water content (porosity), the resistivity of the water, the clay content and the content in metallic mineral (Benard, 2003).

Archie's law is given by

$$\text{Rock Resistivity} = \frac{a[waterresistvity]}{porosity^n} \qquad (10)$$

where a and n are constants which depends on the nature of the rock.

MATERIALS AND METHOD

Vertical Electrical Sounding (VES) and 2-dimensional electrical resistivity methods were employed to assess groundwater potential in the study area.

Data Acquisition

Wenner array, because of its lateral resolution was used for the 2-D data acquisition, while Schlumberger array was utilized for VES data acquisition due its good vertical resolution. Two vertical electrical sounding stations were acquired because the space available was small. A distance of about 100m meters were occupied in each case.

VES data sets

Midpoint of VES $N5^0 56' 42"$ $E5^0 40' 13"$ Elevation = 12.2m

Formula Adopted:

$$\frac{\pi}{4}\frac{V}{I}\frac{L^2}{a} = \frac{\pi L^2 R}{4a} = kR \quad k = \frac{\pi L}{2l} \qquad (11)$$

AB/2 = Current Electrode,

MN/2 = Potential Electrode

where L is the current electrode and a is the potential electrode. Table 2 is VES 1 data.

Table 2: WDU Premises (VES 1) data

AB/2=L (m)	MN/2 = a=l (m)	Resistance, R (Ω)	k (m)	Resistivity,ρ (Ωm)
1	0.25	34.8	6.280	219
2	0.25	6.6	25.136	166
3	0.25	3.3	56.560	187
4	0.25	2.1	100.540	211
4	0.5	4.7	50.272	236
6	0.5	2.5	113.112	283
8	0.5	1.7	211.088	342
10	0.5	1.3	314.200	409
12	0.5	0.952	452.448	431
12	1.0	1.80	226.224	407
15	1.0	1.30	353.475	460
20	1.0	0.868	628.400	546
25	1.0	0.559	981.875	549
32	1.0	0.367	1608.704	590
40	1.0	0.254	2513.600	639
40	2.5	0.693	1005.440	697
50	2.5	0.488	1571.000	767

Data Processing

Curve matching was applied for the VES data. Two curves (H and A) were established. The results of the VES curves obtained from the partial curve matching were then used to constrain the data. The transformation of the VES data was achieved with the use of WinResist Software. The combined processing resulted in obtaining the resistivity, thickness and depth of the model.

The DIPRO software was used for the inversion of the 2D resistivity data. The Google Earth Image of WDU Premises showing VES Points, traverse and borehole is shown in Figure 2.

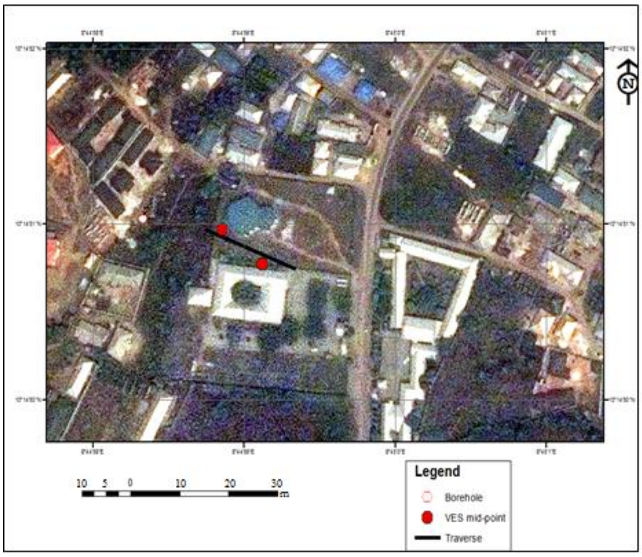

Figure 2: Google Earth Image of WDU Premises showing VES Points, traverse and borehole

RESULTS AND DISCUSSION

The results are presented as tables, maps and curves. The resistivity curve for VES 1 is shown in Figure 3, while Figure 4 shows the Geoelectric section. The stratigraphy column of the lithology of Oghara used in comparing the results is shown in Figure 5.

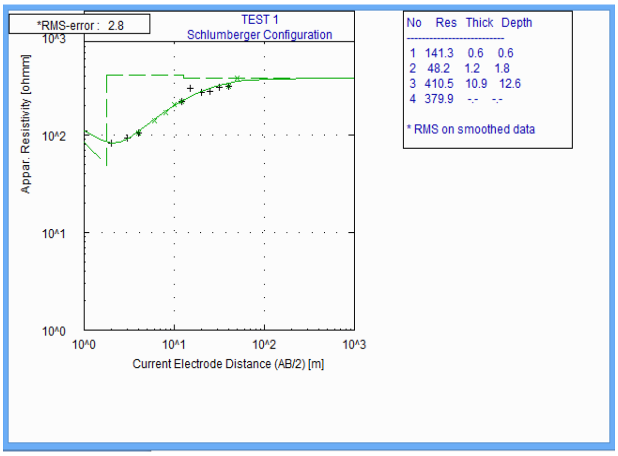

Figure 3: Resistivity Curve of VES 1 (HA

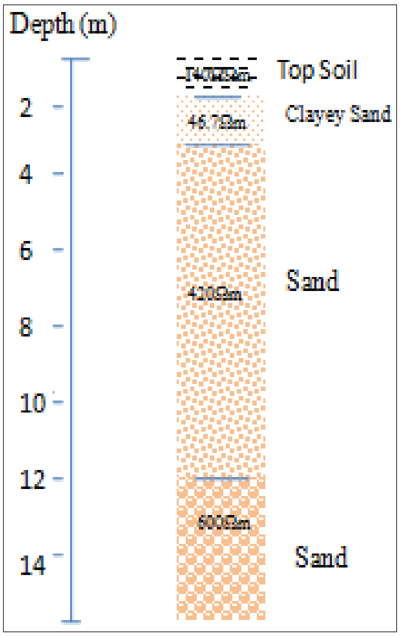

Figure 4: VES 1 Geoelectric Section.

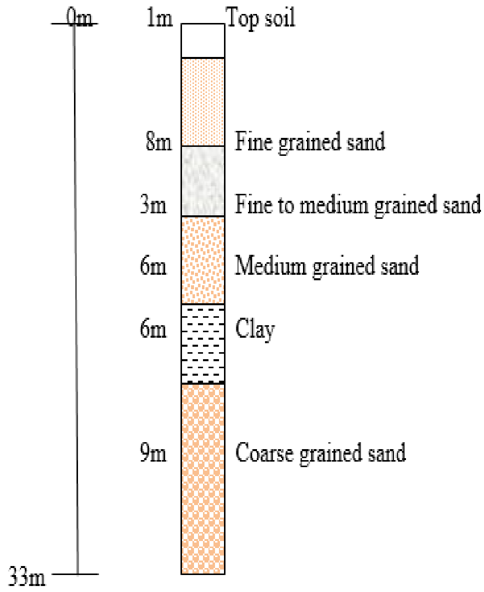

Figure 5: Stratigraphic column of Lithology in Oghara

The 2D resistivity map is shown in Figure 6.

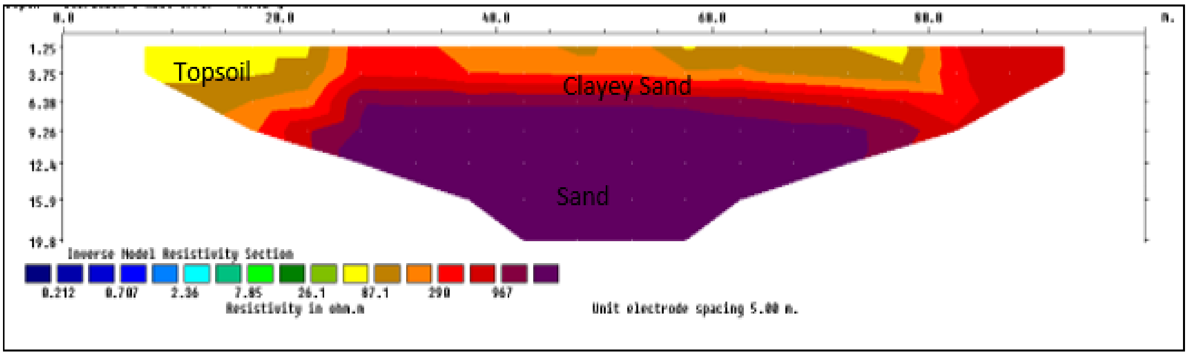

Figure 6: 2D Electrical image using Wenner array

The geoelectric section (Figure 4) reveals a HA curve with three layers. The topsoil has a resistivity of 300 Ohm-m with thickness of 0.6m. The second layer, which may be clayey sand has resistivity value of 127 Ohm-m with thickness of about 2.25m, while the third layer has resistivity of 480 Ohm-m, which is fine to medium grained sand, with thickness of 3m. Groundwater can be exploited from 12m beneath the surface, where the lithology is medium grained sand. The geoelectric section in Figure 4 is in agreement with the litho-stratigraphy of the area and electrical resistivity tomography shown in Figures 5 and 6 respectively. The resistivity structure shows that the resistivity ranges from 87-967 Ωm indicative of varying lithology. The resistivity structure shows that from the lateral distance of 10-100m, at the depth of 1-9m, the resistivity range is 87-290 Ωm indicating that the soil is composed of clayey sand to sandy clay, while from the lateral distance of 25-80m at the depth of 6-19m, the resistivity is in the range ≥ 967 Ωm which indicate fine to medium grained sand. Groundwater can be exploited from 12m beneath the surface.

This is in agreement with the geoelectric section of the electrical sounding result.

However, from the litho-stratigraphy of the area, there is coarse grained sand at the depth of 24m after clay formation, with thickness of about 9m. The clay filters the groundwater before getting to the confined aquifer at the depth of 24m and beyond. Water may be exploited from the depth of 24m beneath the surface.

CONCLUSION

Groundwater can be exploited at the depth of 12m beneath the surface. However, abundant fresh water may be exploited at the depth of 24m and beyond. It is recommended that drilled borehole in the study area get to the depth of 24m as there is possibility of getting fresh water at that depth in wet and dry seasons.

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