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Vertical electric drilling for evaluating aquifer levels in Ukwani and ensuring quality drinking water

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Abstract

This study aims to investigate the aquifer levels in the localized area of Ukwani, with a specific focus on the water depths of Obeti, Oliogo, and Ebedei communities. The research utilizes drilling data to determine the water depths and availability of water bodies in these areas. The results revealed that the water depth of Obeti ranges from 6m to 34m, indicating a significant variation in the aquifer level. Similarly, the water depth of Oliogo varies between 10m and 80m, reflecting substantial differences in groundwater availability. Ebedei exhibits a broader range, with water levels varying from 4m to 100 m. The drilling data confirms the presence of water bodies at depths of 25m and 30m in these areas, highlighting potential reservoirs for groundwater extraction and utilization. This study provides valuable insights into the aquifer levels in Ukwuani, shedding light on the variations in water depths and identifying areas with potential water resources. These findings contribute to informed decision-making for water management and resource planning in the region.

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Introduction

Access to safe and clean drinking water is a global health challenge and ensuring reliable and sustainable water supply is essential for the well-being of humans and livestock (Okoro*et al.*,2016).Access to safe drinking water is a pre-condition for health and success in the fight against poverty, hunger, child death, and gender inequality (Lawal and Basorun, 2015) and to poverty reduction and that access to safe drinking water prevents the spread of water-borne and sanitation-related diseases (Ifabiyi and Ashaolu, 2013). In rural areas, groundwater is often the main source of fresh water, and the construction of wells for obtaining groundwater has been a common practice (Carrard, *et al.*, 2019). However, the quality and quantity of groundwater can vary depending on the characteristics of the aquifer such as *porosity, permeability, specific yield*, specific storage (Akhtar *et al.*, 2021)

Therefore, it is crucial to accurately characterize groundwater resources for effective management and infection control (Nishimura*et al.*, 2022)

In Ukwani, a rural area in Nigeria, where the major source of portable water supply has been from rain water, streams, and hand–dug wells. It is therefore imperative to deploy the use of vertical electric drilling for evaluating aquifer levels there to ensure quality drinking water.

Generally speaking, geophysical surveys provides capacity to unearth the internal structure of the earth, beyond the limited depths reached by boreholes or mines, (Aristedemouand Thomas-Betts, 2000). IVertical Electrical Sounding (VES) is a geophysical method that uses the variation of the electrical resistivity of the subsurface formation to gain information about the groundwater exploration (AdiSuryadi *et al.,* 2023, de Almeida, *et al.*, 2021).

The VES method is suitable for identifying the thickness of each layer, the water table, and the quality of the aquifer. The use of VES in Ukwani has revealed the possibility of shallow and deep aquifers in the area, thereby providing valuable information for optimal location of boreholes for access to safe drinking water.

In Ukwani, the need for reliable access to clean water arose after an outbreak of cholera and typhoid in the area. Studies have shown that poor sanitation and hygiene practices, coupled with limited access to clean water have significantly contributed to the prevalence of these diseases (Hutton and Chase, 2017, He*et al.*, 2018). Therefore, there has been an urgent need to ensure quality drinking water and proper sanitation facilities in the area.

The assessment of aquifer levels is essential for understanding the availability and accessibility of portable drinking water in a specific area. In an evaluation of the groundwater quality in Ukwani areas, Obasi *et al.* (2019) reported that the majority of the wells tested had high levels of total coliforms and fecal coliforms. These findings reinforced the need for effective management of groundwater resources to guarantee safe drinking water in the area. The study was therefore aimed to determine the depths at which portable water could be found in three communities in Ukwuani, namely, Ebedei, Oliogo, and Obeti respectively through the use of geophysical observations.

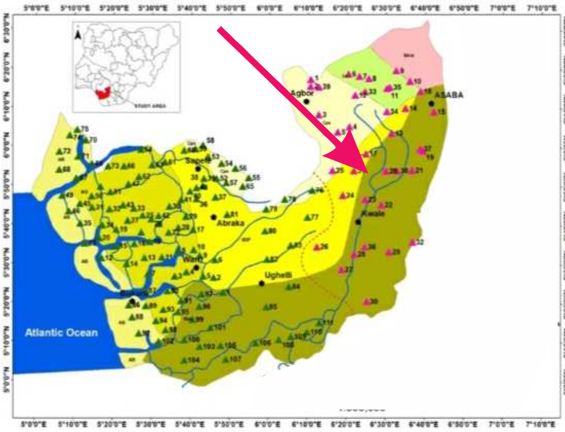
Materials and methods

Research work using vertical electric sound (VES), also known as electric sounding or large was adopted in this study. The method involves the use of a deep electronic technique to collect data from the depth of a particular location on site in line with Chiemeke (2005). It was used to detect changes in soil resistance at different points below the surface. The principle of VES is that wider electrode spacing results in deeper current penetration.

Regular readings were taken to capture changes in the ground as the water flows deeper. In this study, three sound points were selected and the Schlumberger sequence method was used. The electrode spacing ranged from 1 meter to approximately 464 meters which allowed visualization of the various layers below the surface.

Drilling data were collected following a survey method to determine the total water flow in these areas as depicted in picture 3 of Bates *et al.* (1991).

0 indicates the Schlumberger array method.



Map of Delta State showing sampled location

Fig. 1. Map of Delta State Showing Sampled location.

Results

Field Results (Ebedei)

Electrode Configuration: Schlumberger

Site Location Ebedei

Instrument AbemSas – 300 Terrameter (Abem, 2006)

Bearing 400 Azimuth

Date 10th March, 2012

Table 1. Field results (EBEDEI).

MN/2	AB/2	Resistance R(M)	Geometric Factor	Apparent Resistivity (M)
0.2	1.000	7	7.540	51.37
0.2	1.470	3.8	16.660	60.08
0.2	2.150	2.5	35.990	82.88
0.2	3.160	1.9	78.110	132.89
0.2	4.640	1.1	168.780	152
1.0	6.810	3.72	71.280	251.2
1.0	10.000	2.14	155.510	301.79
1.0	14.700	0.95	337.860	253.49
3.0	21.500	0.927	237.320	172.63
3.0	31.600	0.75	518.130	285.07
8.0	46.400	1.84	410.170	672.78
8.0	68.100	0.344	898.030	129.42
16.0	100.000	0.344	956.610	137.85
16.0	147.000	0.303	2096.320	216.02
30.0	215.000	0.548	2373.210	825.98
50.0	316.000	0.44	3058.530	734.15
50.0	464.000	0.295	6685.180	635.19

The MN/2 and AB/2 values in the table vary between 0.2 and 50.0 and between 1,000 and 464,000, respectively.

The resistance (R) values show the range of 0.295 to 7.540 without any correlation with the MN/2 and AB/2 values. Geometry values range from 51.37 to 825. 98. It has been observed that larger MN/2 and AB/2 values tend to result in larger geometry factors. Found resistance values from 60.08 to 672.78. It is clear that similar to the geometry conditions, the resistance generally increases with the increase of MN/2 and AB/2. However, there are some exceptions where the lower of MN/2 and AB/2 makes this more obvious. Therefore, the data show that the geometry factor and apparent resistivity are affected by changes in MN/2 and AB/2. Higher MN/2 and AB/2 values generally result in higher geometry factors and lower visibility.

Field Result (Oliogo)

Electrode Configuration: Schlumberger

Site Location: Oliogo

Instrument: Abem Sas-300 Terrameter

Bearing: 75^{o} Azimuth

Date: 10th March, 2012

Table 2. Field result (Oliogo).

MN/2	AB/2	Resistance R(M)	Geometric Factor	Apparent Resistivity (M)
0.2	1.000	16.75	7.54	124.89
0.2	1.470	4.77	16.66	76.24
0.2	2.150	3.13	35.99	105.55
0.2	3.160	1.76	78.11	121.95
0.2	4.640	1.00	168.78	135.12
1.0	6.810	2.65	71.28	174.74
1.0	10.000	0.61	155.51	63.86
1.0	14.700	1.031	337.86	280.93
3.0	21.500	1.401	237.32	285.12
3.0	31.600	0.802	518.13	312.04
8.0	46.400	1.103	410.17	370.48
8.0	68.100	0.794	898.03	533.53
16.0	100.000	0.571	956.61	355.04
16.0	147.000	0.266	2096.32	138.46
30.0	215.000	0.342	2373.21	337.1
50.0	316.000	0.274	3058.53	226.43
50.0	464.000	0.239	6685.18	260.82

MN/2 and AB/2 values in the tables are given at different intervals. The resistance (R) values vary significantly between 0.239 and 7.540 and do not correlate with the MN/2 and AB/2 values. The maximum value of the geometry factor is 0. 571 to 956.61. It can be seen that higher MN/2 and AB/2 values tend to result in higher geometry factors. For example, at MN/2 = 16.0 and AB/2 = 100. At 0, the geometry index reaches a maximum of 956.61. The apparent resistivity values in the table vary between 63.86 and 6685.18.

It is clear that similar to the geometry conditions, the resistance generally increases with larger values of MN/2 and AB/2. However, there are exceptions, such as MN/2 = 1.0 and AB/2 = 10.0 where the lower ratio of MN/2 and AB/2 leads to a more pronounced resistance, the apparent resistivity is 63.86. From these data, it is seen that geometric factors and visual resistance are affected by the changes in MN/2 and AB/2. Higher MN/2 and AB/2 values usually result in higher geometry factors and lower sharpness, indicating the relationship between these variables.

Field Results Ves 3 (Obeti)

Electrode Configuration: 5 Chlumberger

Site Location: Obeti

Instrument: Abem Sas-300 Terrameter

Bearing: 75° Azimuth

Date: 10th March, 2012

Table 3. Field results ves 3 (Obeti).

MN/2	AB/2	Resistance R(M)	Geometric Factor	Apparent Resistivity (M)
0.2	1.00	9.36	7.54	69.16
0.2	1.47	2.53	16.66	38.92
0.2	2.15	1.12	35.99	33.22
0.2	3.16	0.576	78.11	29.46
0.2	4.64	0.37	168.78	28.86
1.0	6.81	0.505	71.28	21.84
1.0	10.00	0.44	155.51	37.42
1.0	14.70	0.368	337.86	56.86
3.0	21.50	0.549	137.32	82.92
3.0	31.60	0.42	518.13	114.09
8.0	46.40	0.426	410.17	92.8
8.0	68.10	0.343	898.03	128.52
16.0	100.00	0.349	956.61	142.63
16.0	147.00	0.307	2096.32	224.41
30.0	215.00	0.239	2373.21	92.69
50.0	316.00	0.328	3058.53	392.1
50.0	464.00	0.028	6685.18	187.1

The resistance value observed in the table varies between 0.028 and 69.16. The apparent resistance of decreases with increasing MN/2 and AB/2, which show a good relationship.

The minimum value is 0. 028 is found at MN/2 = 50.0 and AB/2 = 464.00, while the maximum value of 69.16 corresponds to MN/2 = 0.2 and AB/2 = 1.00. Geometry factors range from 0.028 to 168.78.

Higher MN/2 and AB/2 values usually result in higher geometry factors indicating a positive relationship. For MN/2=0.2 and AB/2=4.64, the largest geometry is recorded as 168.78, while the lowest value 0.028 is equal to MN/2=50. 0 AB/2 = 464.00. The resistance is 0.239 ~ 2373.21, it has nothing to do with MN/2 and AB/2.

Qualitative Description

There are many types of curves; Type A, Type Q, Type K, Type H, Type KH. The properties of each curve are as follows:

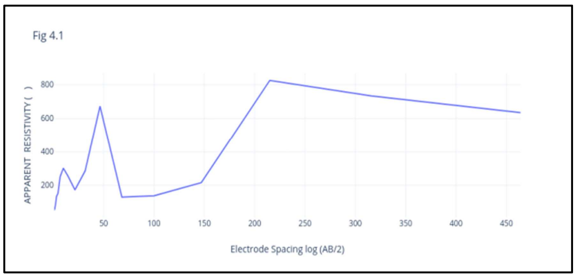


Fig. 4.1. Graphical representation of Ebedei.

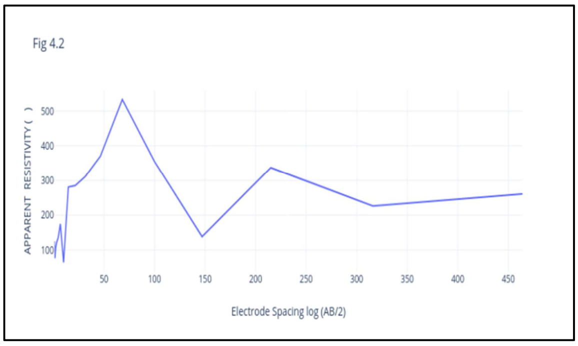


Fig. 4.2. Graphical representation of Oliogo.

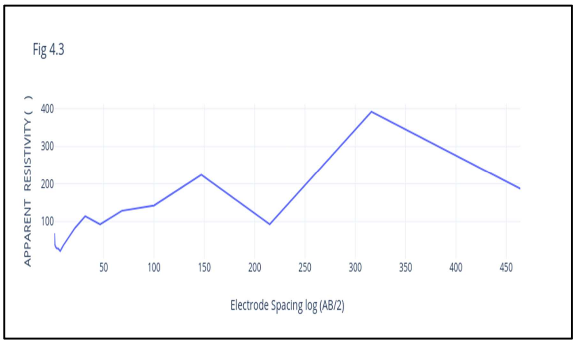


Fig. 4.3. Graphical representation of Obeti.

Quantitative Comment

This work interprets the curve using the competitive curve without using a computer. The area curves are superimposed on the 2 standard curves, the AH curve and the KQ curve, to determine the best-fit curve. From this analysis, the apparent resistivity and thickness of each layer are determined. After making the necessary calculations, use the master curve to determine the thicknesses and resistivities of the different layers Jegede (2009).

According to VES I (Ebedei) calculations, the first layer was found to have a resistance of 38 Ωm and a thickness of 0.84 m. The thickness of the second layer is 1.166m and its resistivity is 734Ωm. The third layer has a resistivity of 1520Ωm and a thickness of 8Ω. 6m The fourth layer has a resistivity of 1140Ωm and a thickness of 154m.

The resistivity of the fifth layer is 508.8Ωm and its thickness was calculated with VES 2 (Oliogo). In Oliogo the thickness of the first layer is 0. 79m, resistance is 56Ωm. The thickness of the third layer is 99.91m and its resistivity is 918Ωm. The fourth layer maintains its thickness while having a resistance of 234.3Ωm.

In VES 3 calculations (Obeti), the resistivity of the first layer is 46Ωm and the thickness is 0.77m. The resistivity of the two layers is 24.8Ωm and the thickness is 4.466m.

The resistance of the third layer is 257.4Ωm and the thickness is 29m. The fourth layer has a resistivity of 306.4Ωm and a thickness of 171m. The resistivity of the fifth layer is 129. 2Ωm, continuous thickness.

Geoelectric Section Interpretation

According to the results of VES I (Ebedei), the topsoil (first layer) is clay due to its weakness. The second layer is fine to ground, and the third and fourth layers are medium to coarse. The fifth layer contains fine silty sand. In VES 2 (Oliogo), the topsoil is clay (first layer), followed by a thin layer of silt (second) and a medium to coarse-grained material layer (third). The fourth layer is suitable for sand.

In VES 3 (Obeti), the first and second layers are clay, the third layer is medium to coarse grain, the fourth layer is fine to silt, and the fifth layer is sandy clay. Layers with medium to coarse material have been shown to have potable water potential as they are more resistant and have lower resistance to fresh water. The presence of high-conductivity brine leads to low resistivity values. Since the fresh water in the study area has very little salinity, the expected conductivity is very low, which gives positive results.

Borehole Data

According to the drilling data, water can be found at depths between 25 meters and about 3.0 meters. Most of the holes drilled at Oliogo, Obeti, and Ebedeiwereless than 40 meters deep. All drilling data collected from these three sites range from 25m to about 3.0m.

Discussion of results

The geoelectrical profile interpretation revealed valuable information about the aquifer levels in the study area.

1. *Ebedei:* In the area of Ebedei, portable drinking water can be found at depths ranging from approximately 4 meters to 150 meters. The abundance of water in this location may be attributed to its proximity to the source of the Ethiope River. This indicates that a reliable source of portable water exists within a relatively shallow depth, making it accessible for potential use.

2. *Oliogo:* In Oliogo, the water depth varies between approximately 10 meters and 80 meters. This suggests that portable water can be obtained at these depths, although it may require slightly deeper drilling compared to the Ebedei area. The presence of a water source within this range signifies the potential for accessing portable drinking water in Oliogo.

3. *Obeti:* Similarly, portable drinking water can be found in Obeti at depths ranging from approximately 6 meters to 34 meters. The shallower water near this site explains the existence of hand wells in Obeti and Ebedei, providing a readily available water source.

The aquifer in Obeti extends to the third layer, indicating the possibility of accessing water from deeper layers.

Overall, the results of the vertical electric drilling assessment highlight the presence of portable drinking water at various depths in the localized areas of Ukwani. The proximity to the Ethiope River and the existence of aquifers in multiple layers suggest a reliable and potentially sustainable water supply for the community. The result obtained in this study is in agreement with the reports of Omosanya *et al.* (2021) who documented that the evaluation of groundwater productivity using VES and borehole yield was effective in identifying potential aquifers and borehole locations and that boreholes drilled based on the VES method had a higher yield compared to boreholes located based on traditional methods. Generally, the quality of the water from these boreholes was proven to be within acceptable standards for drinking.

Conclusion

The assessment of aquifer levels using vertical electric drilling in the localized area of Ukwani yielded valuable information regarding the availability of portable drinking water. The results indicated that Ebedei, Oliogo, and Obeti possess accessible water sources at varying depths. These findings could serve as foundation for future water resource management and development plans in the area, ensuring a sustainable supply of portable water for the community. Further analysis is needed to determine the potential impact on prevention. The study shows the apparent resistance and geometry factors affected by changes in MN/2 and AB/2. In general, with the increase of MN/2 and AB/2, the visual resistance decreases, and the geometric coefficient increases. The use of vertical electric drilling for evaluating aquifer levels, providing valuable information for optimal location of boreholes for access to safe drinking water in Ukwani, Nigeria has been effective in this study. It is apt that a collaborative effort between the Ukwani Local Government and the National Integrated Water Resources Management Commission of Nigeria could assist in the implementation of several water projects to address these issues and ensure safe, portable drinking water for the people.

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