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Determination of groundwater potential in obiaruku and environs using surface geoelectric sounding

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Abstract The interpretation of ten resistivity curves in Obiaruku and environs indicates that the area has a great groundwater potential. Correlation of the curves with the lithologic log from a nearby borehole in Ghana quarters, reveals the lithologic succession as an extensive sandy unit between the range of 20 m and 136 m. The medium grained sand unit, which is the aquiferous zone, has a resistivity range of between 300 Ωm and 600 Ωm. The result of the interpreted data and the lithologic log from the borehole indicates three to five geoelectric layers except at Adonishaka, which has a confined aquifer in the third layer and Umukwata that has a confined aquifer in the second layer, the study area generally has an unconfined aquifer, which is in the second layer. In the event of pollution, the groundwater may be contaminated. Sinking of water borehole is not recommended in these areas. Boreholes for potable water are therefore recommended at locations within Adonishaka and Umukwata areas. The present study acts as a guide for future groundwater exploration and exploitation.

Keywords Vertical electrical sounding · Groundwater potential · Aquifer thickness and depth · Obiaruku · Obinomba · Ebedei · Umutu · Umuaja

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Introduction

Groundwater is water that occurs beneath the surface of the earth within saturated zones where the hydrostatic pressure is equal to or greater than atmospheric pressure. It is among the natural resources of prime importance to man. From earliest time and in many parts of the world, the development of civilization has been dependent upon it. Despite our familiarity with water, its occurrence is still a subject of misconceptions. For example, it is commonly believed that groundwater occurs in large lakes or pools beneath the land. The truth is that it occurs in pore spaces and fractures in rocks (Tyson, 1993). Nearly all the water in the ground comes from precipitation that has infiltrated into the earth. Observations have shown that a good deal of surplus rainfall runs-off over the surface of the ground while the other part of it infiltrates underground and becomes the groundwater responsible for the springs, lakes and wells (Oseji et al., 2005)

The town Obiaruku was recently made the Headquarter of Ukwuani Local Government Area in Delta State resulting in Government investments. Secondly, over 40% of the workers in Delta State University, Abraka live in Obiaruku. These factors led to a huge increase in population and consequently a high demand for potable water.

To obtain a potable water supply, surface geoelectric soundings were necessary in the study area. Hence the study was carried out to establish baseline geophysical data and hydrological characteristics using the Vertical

Electrical Sounding (VES) method and lithologic log from nearby borehole in Ghana quarters Obiaruku.

The VES was chosen for this study because the instrumentation is simple; field logistics are easy and straightforward and the analysis of data is economical and less tedious than other methods. Zhody et al. (1974), Ekine and Osobonye (1996), Van Overneeren (1989), Etu-Efeotor and Akpokodje (1990) and Ako and Olorunfemi (1989).

The resistivity technique has been used successfully in investigating groundwater potential in different geological settings. Emenike (2000) used this method to explore for groundwater in a sedimentary environment. Ako and Osundu (1985) used the method to delineate aquifer units and established the thickness and depth of water bearing formation. Okwueze (1996) used the method to determine the groundwater potential of Obudu basement area.

Resistivity of water may vary from 0.2 to over 100 Ohm-m depending on its ionic concentration and the amount of dissolved solids (Ali et al., 1999). Resistivity of natural water and sediments without clay vary from 1 to 1000 ohm-m, while the resistivity of clay alone may vary from 1 to 120 Ohm-m (Zhody and Martin, 1993). The type of curve (Selemo et al., 1995) and the modified table of resistivity of water and sediments by Oyedele (2001) were used as guides in the interpretation of resistivity data in terms of probable aquifer in this work.

In a sedimentary environment, high resistivity may broadly be associated with the presence of fresh groundwater in porous medium (aquifer), but low resistivity may result from the presence of clays and /or brackish water (Emenike, 2000).

Location of the area

The study area Obiaruku and environs is in Ukwuani Local Government Area of Delta State carved out from the former Ndokwa west Local Government Area on December 4, 1996. It is located in the southwestern end of Nigeria called the Niger–Delta basin. The detailed description of the geology of Niger–Delta has been extensively given by Short and Stauble (1967) and Kogbe (1981). It lies within Latitudes $5^{o}\ 51^{1}$N and $5^{o}\ 52^{1}$ N and Longitudes $6^{o}\ 12^{1}$ E and $6^{o}\ 18^{1}$E and is bounded in the North by Obi-obeti, South by Abraka, East by Utagba–uno and Amai communities while it is bounded in the West by River Ethiope (Fig. 1). The area is accessible by a network of roads. The Sapele–Abraka–Agbor Express-way is the major road into the

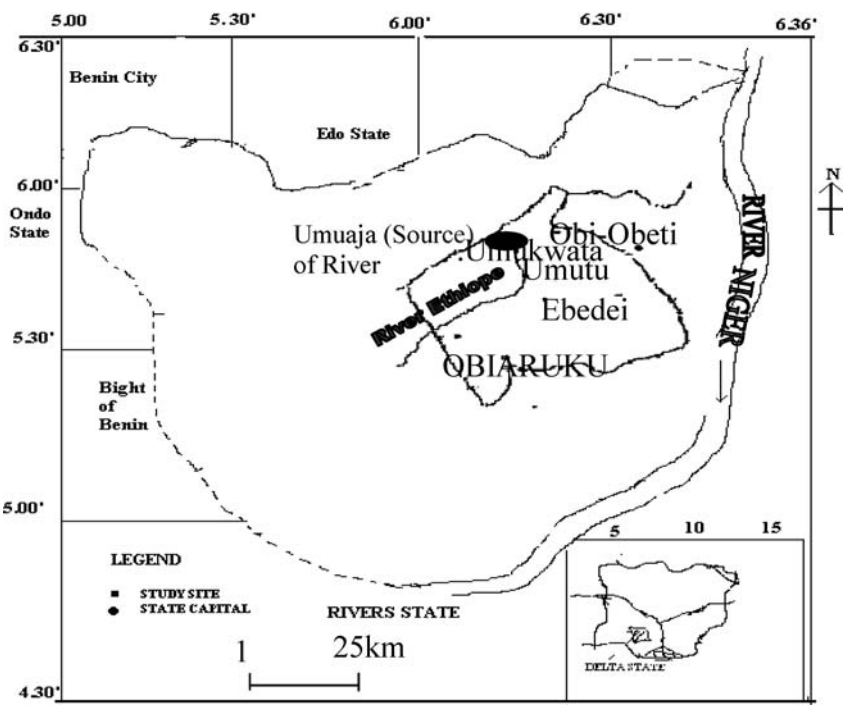

Fig. 1 Base map of study area

area and the streets are linked together by a network of footpaths and roads that are not paved.

Climate, vegetation and drainage

The soil is reddish brown in colour. The study area has a gentle slope, which makes a V-shape towards River Ethiope. The river's source is in the Northern part of the area. There is no visible rock outcrop within the study area. During rainfall, there is a relatively high rate of infiltration into the subsurface through the unconsolidated soil. This reduces surface run-off.

Obiaruku is situated within the humid subequatorial south climatic belt of Nigeria (IIoeje, 1976), which is characterized by a relatively long rain season (wet) that lasts from March to October. This is alternated with a short dry season that lasts from November to February.

The natural vegetation of the study area is that of the rain forest but this has been destroyed by the activities of man such as bush burning, farming, construction and local mining. The area under study is rural with growth potential. The inhabitants of the area are mostly subsistence and peasant farmers. They grow crops such as cassava, melon, maize, yam, pepper, vegetables and native beans (*OLONI)*. However, they also grow perennial crops like palm and rubber trees. In the areas along the river channel, the sharp sand is sold to contractors for delivery to construction sites while some is used to construct houses locally.

Geology of the study area

The study area Obiaruku and environs is within the Niger-Delta Basin. The Niger-Delta in this paper applies to the entire 3-Dimensional bodies of continental, transitional and marine deposits formed by sediments from Rivers Niger and Benue. The continental deposits form the land area otherwise called the sub-aerial regions. The marine deposits are the water filled region otherwise called the sub-aqueous region. The transitional deposits form the swampy (mangrove) regions. (Hospers, 1965; Ejadiavwe, 1981).

The structure of the continental geologic framework directed Rivers Niger and Benue towards the present site of the Delta. Hence the geology of Niger-Delta, like other parts of the earth has undergone different changes right from the tectonic setting through the paleogeographic evolution to the present day. This development of the Delta has been dependent on the balance between the rate of sedimentation and subsidence. The balance and the resulting sedimentary patterns appear to have been influenced by the structural configuration of tectonics of the basement (Evany et al., 1979).

The geology and geomorphology of the Niger delta have been described in detail by various authors (Allen, 1965; Akpokodje, 1979, 1987; Assez, 1970, 1976; Avbovbo, 1970; Oomkens, 1974; Burke, 1972; Rement, 1965; Short and Stauble, 1967).

The formation of the present day Niger delta started during early Palaeocene and it resulted mainly from the build-up of fine-grained sediments eroded and transported by River Niger and its tributaries (Efeotor and Akpokodje, 1990). The sub-surface geology of the Niger Delta consists of three lithostratigraphic units (Akata, Agbada and Benin formations), which are in turn overlain by various types of Quaternary deposits.

The soil type section and locality observed in Ghana Quarter, Obiaruku is as follows:

Soil type	Layers depth
Topsoil	1.0 m
Laterite	3.0 m
Siltstone	6.0 m
Fine-sand	12.0 m
Medium-sand	21.0 m
Coarse-sand	36.0 m

Here all other units are similar in properties to those of Oliogo except the depth of occurrence. The additional unit observed, as siltstone, is the vertical variation from laterite to fine sand. The siltstone layers consist of fine-grain particles with mud as the cementing material. Its colour is predominantly pink and it occurs at the depth of 6.0 m–9.0 m.

Rivers Ethiope and Okumeshi are the surface water sources that drain the study area. There are no hand—dug wells in Obiaruku. Rivers Ethiope and Okumeshi supply the domestic water need for the inhabitants of the study area. The river is being polluted by the activities of the farm produce (melon) and fermentation of cassava, washing of clothes and other household effects

Table 1 Qualitative analysis of curve types where ρ represents resistivity of the layer

VES	Curve type	Curve characteristics	No of Geo-electric layers
1	H	$\rho_1 < \rho_2 < \rho_3$	3
2	KH	$\rho_1 < \rho_2 < \rho_3 < \rho_4$	4
3	H	$\rho_1 < \rho_2 < \rho_3$	3
4	AK	$\rho_1 < \rho_2 < \rho_3 < \rho_4$	4
5	KH	$\rho_1 < \rho_2 < \rho_3 < \rho_4$	4
6	K	$\rho_1 < \rho_2 < \rho_3$	3
7	A	$\rho_1 < \rho_2 < \rho_3$	3
8	HKQ	$\rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5$	5
9	A	$\rho_1 < \rho_2 < \rho_3$	3
10	H	$\rho_1 < \rho_2 < \rho_3$	3

into the river and worst still toileting. These activities make the water from these rivers unhygienic and unsafe for domestic use and drinking.

Materials and methods

Electrical prospecting makes use of a variety of principles, each based on some electrical properties or characteristics of the materials in the earth (Chukwurah, 1992).

A total of ten VES were carried out in the study area. Three stations each were established and surveyed in Obiaruku and Ebedei while two stations each were surveyed in Obinomba, and Umutu respectively.

The resistances of the layers were measured using the ABEM SAS 300B Terrameter. The Schlumberger electrode configuration was used for the measurements. The maximum current electrode separation is 215 m for each of the ten VES stations of 170 sounding points.

The apparent resistivity values obtained from the measurement were plotted against half the current electrode spacing on a log-log graph in order to determine the resistivities and thicknesses of the layers. The early method of interpreting sounding curves used curve-matching techniques. This method has the disadvantage that only experienced personnel can usefully handle it, particularly where the layering exceeds two.

In this paper, the vertical electrical sounding field curves were initially interpreted using partial curve matching (Zohdy et al., 1974). The results were improved upon by employing an iterative computer programme. The lithologic log from a nearby borehole was used to correlate the resistivity of the layers to the local geology and strategraphy (Osemeikhian and Asokhia, 1994).

Results and discussion

The sounding curves were analyzed both qualitatively by partial curve matching method and the results were used in the quantitative interpretation through computer iteration to obtain the layer resistivities and their corresponding thickness (Table 2).

Ten VES curves whose layers vary generally from 3 to 5 were analyzed. The curves are prominently of H, KH, AK, A, K and HKQ type curves (Table 1)

Locations 1, 3, and 10 from Secretariat Road Obiaruku, Ghana quarters Obiaruku and Michelin road Umutu towards Utagba—uno are three-layered "H" type curves. The aquifer in these sites is at about 30 m in the third layer and is unconfined. Therefore in the event of a spill of other pollution activities, the groundwater may be contaminated. Sinking of water borehole is therefore, not recommended in these areas. The type section and locality observed indicates

Table 2

Site/Location	Curve Type	$\mathbf{e}_{1(\Omega m)}$	$\mathbf{e}_{2(\Omega m)}$	$\mathbf{e}_{3(\Omega m)}$	$\mathbf{e}_{4(\Omega m)}$	$\mathbf{e}_{5(\Omega m)}$	$\mathbf{h}_{1(m)}$	$\mathbf{h}_{2\ (m)}$	$\mathbf{h}_{3\ (m)}$	$\mathbf{h}_{4\ (m)}$	$h_{5\ (m)}$	RMS (%)
Obiaruku (Ghana Quarter)	H	700	500	1100	1400		1.2	4.8	29	α		1.96
Obiaruku (Wire Road)	KH	110	300	400	250	800	0.5	2.5	6.5	23.5	α	2.23
Obinomba	AK	110	250	250	700	1000	0.5	7.5	32	40.0		1.60
Umukwata Rd	K	700	1150	900	800		7.0	15	35	α		2.23
Ebedei	HKQ	1000	400	700	800	800	1.2	8.8	18.8	28.8	α	1.40
Umutu	A	110	120	130	600		0.8	4.0	10.0	α		2.25

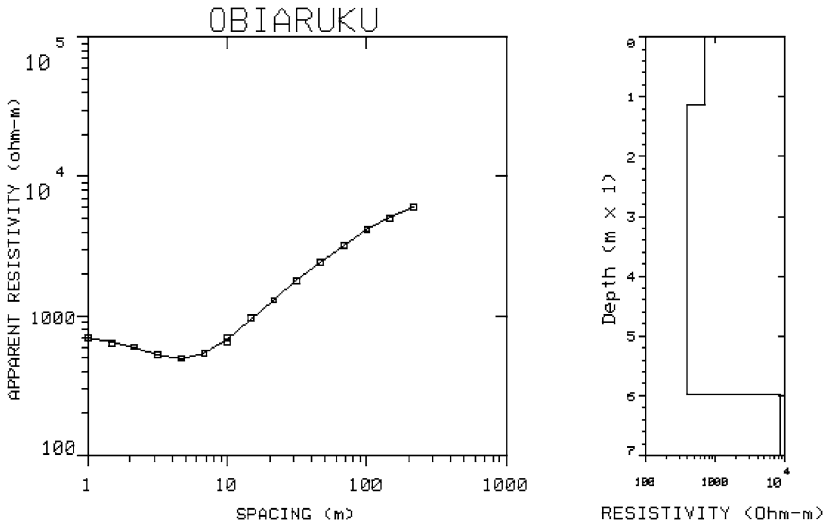

Fig. 2 Apparent resistivity versus half current electrode spacing curve for the secretariat road off Amai road, Obiaruku Ukwuanit L G A, delta state. Model parameters: $\mathbf{e}_1 < \mathbf{e}_2 < \mathbf{e}_3$ (H type curve)

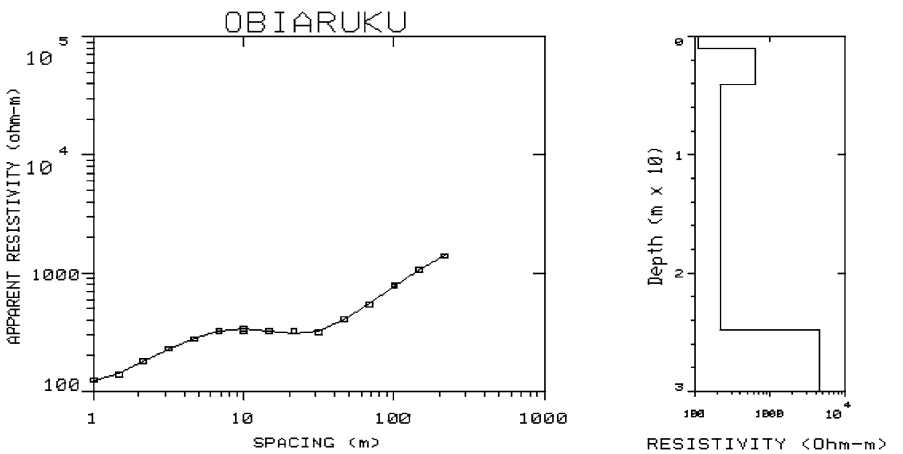

Fig. 3 Apparent resistivity versus half current-electrode spacing curve for wire road, Obiaruku, Ukwuani LGA, delta state. Model parameters: $\mathbf{e}_1 < \mathbf{e}_2 < \mathbf{e}_3 < \mathbf{e}_4$ (kH type curve)

broadly that within the depth penetrated, the lithologic succession is an extensive sandy formation (Figs. 2 and 3).

Locations 2, 4 and 5 from wire road Obiaruku and Obinomba respectively are 4-layered "KH" curves. The aquifer in these sites is within the fourth layer. The second layer is only a thin confining bed. In the event of pollution, the groundwater may be contaminated (Fig. 3).

Locations 7 and 9 from Ebedei and Umutu consist of three layered "A" type curves. The layers become more resistive with depth. This is not an encouraging trend for viable groundwater prospects. Though one of the resistive layers contains sand, it will not be a reliable aquifer because it is not confined and, as such, is prone to contamination (Fig. 5).

Location 6 from Umukwata is a three-layer "HK" curve type. It is the most desirable field curve in the area. It consists of clay formation close to the surface. At about 6 m, where the resisitivity value of 900 Ωm, there is evidence of groundwater accumulation. Further analysis indicates that potable groundwater exists in form of confined aquifer at about 20 m depth in Umukwata (Fig. 6).

Location 8 from Adonishaka in Ebedei is a 5-layer "HKQ" type curve. It has two aquifers. The first aquifer within the second layer at a depth of about 9 m with resisitivity value of 338 Ωm is not confined while the second aquifer in the fourth layer at a depth of 136 m and resistivity value of 18.22 Ωm is confined (Fig. 7). Boreholes within such field curve contain mineralized water (Selemo et al., 1995).

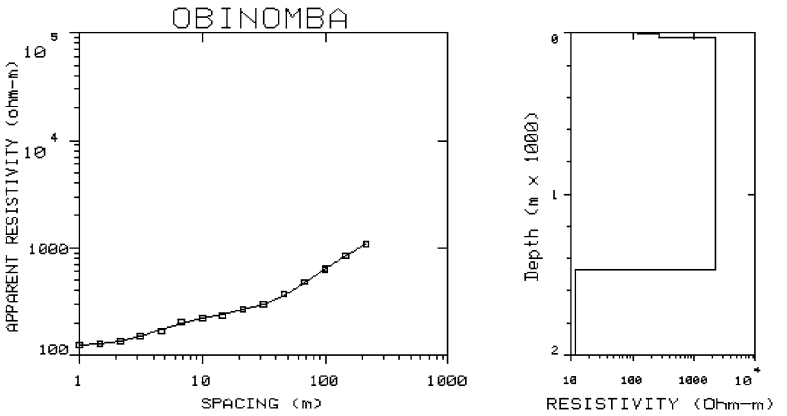

Fig. 4 Apparent resistivity versus half current-electrode spacing curve Obinomba. Ukwuani LGA, delta state. Model parameters: $\mathbf{e}_1 < \mathbf{e}_2 < \mathbf{e}_3 < \mathbf{e}_4$ (AK type curve)

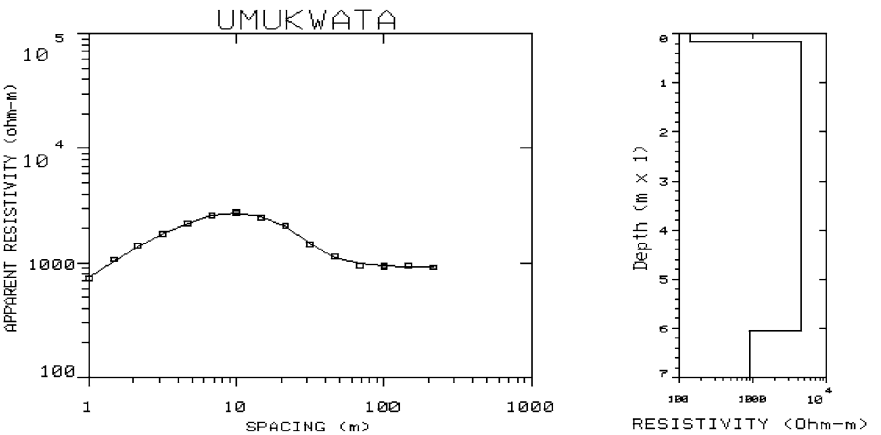

Fig. 5 Apparent resistivity versus half current-electrode spacing curve for Umukwata road, Ukwuani LGA, delta state. Model parameters: $\mathbf{e}_1 < \mathbf{e}_2 < \mathbf{e}_3$ (K type curve)

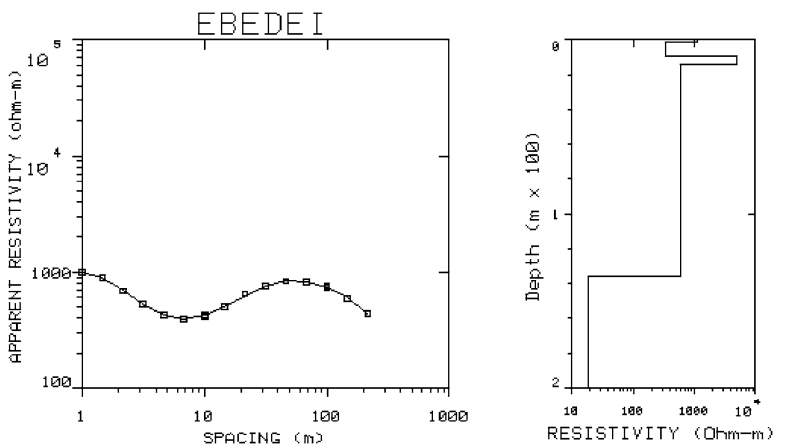

Fig. 6 Apparent resistivity versus half current-electrode spacing curve for Asonishaka, Ebedei. Ukwuani LGA, delta state. Model parameters: $\mathbf{e}_1 > \mathbf{e}_2 < \mathbf{e}_3 > \mathbf{e}_4 > \mathbf{e}_5$ (HKQ type curve)

Conclusion

The study area reveals Obiaruku and environs as an extensive sandy unit. The interpretation indicates that the water-bearing formation (sandstone unit) is between the range of 30 m and 136 m deep. The presence of water in the borehole recently drilled very close to Location 1 is in agreement with the result of the research work.

The results of the interpreted data and the lithologic log from the borehole indicate 3 to 5 geoelectric layers. Apart from Adonishaka in Ebedei and Umukwata that

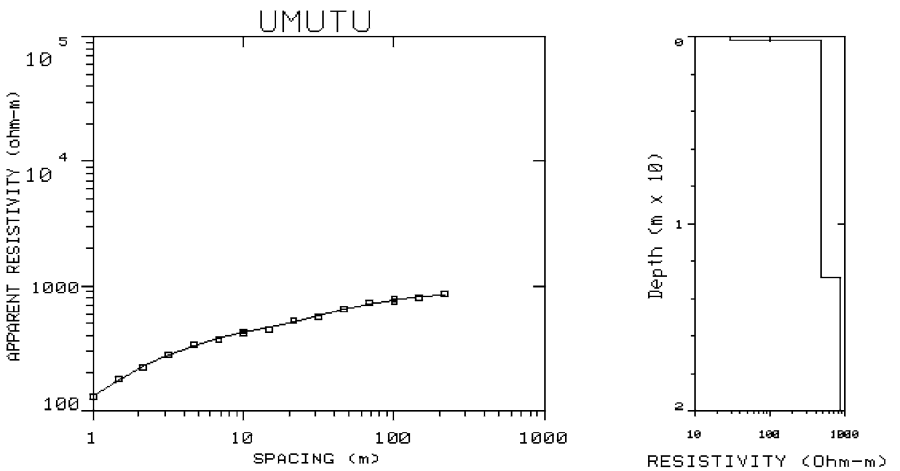

Fig. 7 Apparent resistivity versus half current-electrode spacing curve for Umutu Ukwuani LGA, delta state. Model parameters: $\mathbf{e}_1 < \mathbf{e}_2 < \mathbf{e}_3$ (A type curve)

have confined aquifers in the third and second layers respectively the study area consists generally of unconfined aquifers. This could be the reason for delay in recharging of boreholes in parts of Obiaruku during the dry season.

Viable boreholes for potable water are therefore recommended at locations within Adonishaka and Umukwata. The present study acts as a guide for future exploration and exploitation of groundwater.

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