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Full Length Research Paper

Geoelectric investigation of groundwater resources and aquifer characteristics in Utagba-Ogbe kingdom Ndokwa land area of Delta State, Nigeria

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Vertical electrical sounding data were acquired from 10 locations evenly distributed within Utagba-Ogbe Kingdom. The apparent resistivity values obtained in the field were plotted against half current electrode spacing. Interpretation of data were done both quantitatively and qualitatively and bringing in to bare the knowledge of the local geology of Utagba-Ogbe and her environs. Based on the geoelectric section, which shows the relationship between the drillers log and the resistivity measurements at a common depth of penetration, 4 prominent geoelectric layers of near surface aquifer that are not confined were identified in Utagba-Ogbe Kingdom. The study revealed Utagba-Ogbe Kingdom as an extensive sandy unit. The best layer of the aquifer in Utagba-Ogbe kingdom for groundwater development is at a depth between 35.00 - 45.00 m within the second layer. This layer consist medium-grained sand to coarse-grained sand formations, which is the best formation to obtain an appreciable quantity of water for sustainable groundwater development. The results when correlated with lithologic log from a producing borehole in second Owessei Street Umusadege were found to be consistent.

Key words: Vertical electrical sounding, groundwater potential, aquifer, Umusadege, Umuseti, Umusedeli, Umusam, Owessei, drillers log and geoelectric section.

INTRODUCTION

When rain falls to the ground, the water does not stop moving. Some of it flows along the surface in streams or lakes, plants use some while some evaporates and return to the atmosphere, others sink into the ground. Imagine putting a glass of water onto a pile of sand. Where does the water go? The water moves into the spaces between the particles of sand.

Groundwater is the water that is found in cracks and spaces within the soil, sand and rocks. The area where water fills the space is called the saturated zone. The top of this zone is the water table. Assume the top of water to be a table. The water may be only a foot below the ground surface or it may be hundreds of feet down.

Groundwater can be found almost everywhere. The water table may be deep or shallow and may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise or an extended period of dry weather may cause the water table to fall.

Groundwater is stored in, and moves slowly through layers of soil, sand and rocks called aquifers. The size of the spaces in the soil or rock and how well the spaces are connected determine the speed at which groundwater flows.

Aquifers typically consist of gravel, sand, sandstone, or fractured rock, like limestone. These materials are permeable because they have large connected spaces that allow water to flow through. Aquifers are also known as underground reservoirs otherwise called underground flood and the water that reached this chamber is usually much cleaner than the water or reservoirs at the earth surface. Aquifer could be confined or unconfined.

Unconfined aquifers lie very near the water table, with little or no overlying rock or sediment and their water is usually at atmospheric pressure.

Most local groundwater comes from unconfined aquifers made of loose slope materials, sands, gravels, and floodplain deposits left by stream and rivers.

Confined aquifers are sandwiched between rock layers that are either effectively impermeable or have very low permeability. However, a combination of the two can occur and that aquifer is called Leaky or a semi-confined aquifer. The local occurrence of groundwater is the consequence of a finite combination of climatic, hydrologic geologic, topographic, and ecological and soil forming factors.

Resistivity of a material therefore is defined as the opposition to the flow of current in Ohms between opposite faces of a unit cube of the material.

Electrical method utilizes direct current or low frequency alternating current to investigate the electrical properties of the subsurface. It is a technique used to study the shallow layer of the earth by sending direct electric current through a pair of electrodes and studying the potential distribution it produces.

From Ohms law, we can then deduce the resistance and hence the resistivity. Apart from current electrodes, the region we are probing sets a limit on the applicability since we need long lengths of cables and strong power source.

Electrical resistivity of earth materials varies over a wide range. Hence it is possible to determine resistivity measurement.

The method is particularly useful for soil testing, engineering purposes or hydrological checks. Generally, the electrical resistivity method involves the use of artificially sourced current, which is introduced into the ground through a pair of electrodes (current electrodes) while the resulting potential difference is measured by another pair of electrodes called potential electrodes which may or may not be located within the current electrodes (Kearey and Brooks, 1991). Potable water is not only commonly found and its provision limits the setting up of villages and towns to places where there is an existence of supply (Shanker, 1994).

Hence the need for Environmental Geophysical Surveys cannot be overemphasized in getting background information on the distribution, formation and type of the near surface aquifer.

The electrical resistivity method is based on the variable resistance in subsurface materials to the conductance of electrical current, depending on variations in fluid content, density and chemical composition of the material (Parasnis, 1986).

This work was carried out to establish a baseline geophysical data and hydrological characteristics using the Schlumberger arrangement (a Vertical Electrical Sounding) and drillers log from the study area. The vertical electrical method was chosen for this study because the instrumentation is simple; field logistics are easy and straightforward and the analysis of data is less tedious and economical (Ekine and Osobonye, 1996; Ako and Olorunfemi, 1989; Etu-Efeotor and Akpokodje, 1987 and 1979; Okolie et al., 2005). The resistivity method has been used successfully in investigating groundwater potential. (Oseji et al 2005) used the method to investigate the aquifer characteristics and groundwater potential in Kwale, Delta State, Nigeria. (Oseji et al., 2006) also used the method to determine the groundwater potential in Obiaruku and environs. (Emenike, 2000) used the same method to explore for groundwater in a sedimentary environment. (Ako and Osunde, 1982) 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 at Obudu basement area. (Oseji and Ujuanbi, 2009) used the method to investigate the groundwater potential in Emu Kingdom.

Table 1. Observed (Field) and computed (Theoretical) data for Umusedeli (VES1).

AB/2 Values (m)	Observed Values (ohm-m)	Computed Values (ohm-m)
1.00	392.20	407.52
1.47	454.70	466.46
2.15	580.00	547.73
3.16	625.10	634.82
4.64	703.00	701.59
6.81	732.20	727.45
10.00	675.10	716.26
14.70	711.70	714.26
21.50	784.40	785.21
31.60	1030.30	957.98
46.40	1285.60	1202.87
68.10	1559.50	1468.55
100.00	1697.10	1710.72
147.00	1901.60	1897.24
215.00	2033.90	2010.43
316.00	2102.20	2059.75

FIELD PROCEDURES

Ten Vertical Electrical Sounding data were acquired from 5 locations evenly distributed within Utagba-Ogbe Kingdom. The data acquired from VES (1 - 5) were similar to those acquired from VES (6 - 10) hence only five of the data were displayed (Tables 1 - 5). Interpretation of data were done quantitatively and qualitatively and bringing in to bare the knowledge of the local geology of the area. The apparent resistivity values were plotted against half the current electrode spacing on a log-log graph. The curves of best fit were then traced and the data obtained from the smooth curve (Smoothed values) were noted. Qualitative and quantitative interpretations of the field curves were carried out by inspection to obtain the type of curves and by partial curve matching respectively.

The resistivity and thickness obtained from the partial curve matching were improved upon by employing an iterative computer program following the main ideas of (Zohdy, 1974; Zohdy et al., 1974) to obtain the layers parameter (resistivity, thickness and depth) (Tables 6 - 10).

Here, the number of geoelectric layers and their corresponding specific resistivities were first taken to be equal to the number of measurable points and difference of adjacent current electrode spacing respectively. Layer parameters were consequently modidified in iterative manner until subsequent iteration yields no improvement on the root mean square (rms) error values in percentage.

The numerous layers that were generated by the computer were grouped into relevant geologic depth intervals called geoelectric sections and the resulting layer parameters were then given geologic interpretation. The type of curves, the resistivity of the

Table 2. Observed (Field) and computed (Theoretical) data for Umuseti (VES 2).

AB/2	Observed	Computed
Values (m)	Values (ohm-m)	Values (ohm-m)
1.00	351.20	369.29
1.47	324.80	333.23
2.15	292.00	288.15
3.16	285.00	258.88
4.64	279.40	274.16
6.81	350.00	345.99
10.00	450.10	469.94
14.70	614.40	635.27
21.50	813.40	824.97
31.60	999.00	1017.82
46.40	1195.40	1159.39
68.10	1190.30	1180.06
100.00	1005.70	1041.75
147.00	747.10	799.58
215.00	580.80	578.05
316.00	470.60	446.09

Table 3. Observed (Field) and computed (Theoretical) data for Umusam (VES 3).

AB/2	Observed	Computed
Values (m)	Values (ohm-m)	Values (ohm-m)
1.00	259.10	252.87
1.47	284.00	278.29
2.15	320.00	317.14
3.16	375.70	362.00
4.64	414.60	398.41
6.81	429.80	411.99
10.00	408.20	395.66
14.70	373.40	360.16
21.50	338.90	331.50
31.60	345.20	333.73
46.40	365.40	380.85
68.10	485.80	470.27
100.00	597.10	586.27
147.00	698.70	709.15
215.00	798.60	820.15
316.00	909.90	910.46

Table 4. Observed (Field) and computed (Theoretical) data for 2ND Owessei Street Umusadege (VES 4).

AB/2	Observed	Computed
Values (m)	Values (ohm-m)	Values (ohm-m)
1.00	543.96	535.44
1.47	611.19	603.68
2.15	643.61	538.08
3.16	601.06	598.43
4.64	467.09	467.08
6.81	293.38	293.83
10.00	168.23	166.50
14.70	125.48	120.57
21.50	131.35	124.49
31.60	150.87	144.83
46.40	177.28	175.84
68.10	213.11	219.69
100.00	255.28	270.19
147.00	301.40	316.19
215.00	356.07	349.43
316.00	427.22	370.03

Table 5. Observed (Field) and computed (Theoretical) data for Oseji Estate Umusadede (VES 5).

AB/2	Observed	Computed
Values (m)	Values (ohm-m)	Values (ohm-m)
1.00	1256.50	1206.52
1.47	1300.00	1291.13
2.15	1383.00	1372.44
3.16	1437.30	1429.74
4.64	1500.10	1454.63
6.81	1524.80	1462.60
10.00	1529.70	1488.65
14.70	1600.00	1574.56
21.50	1719.00	1735.48
31.60	1882.80	1946.57
46.40	2097.00	2138.23
68.10	2186.20	2224.29
100.00	2011.40	2098.08
147.00	1695.90	1688.24
215.00	1103.50	1108.75
316.00	596.10	602.73

sediments and the lithologic logs from nearby boreholes were used in conjunction with the knowledge of the local geology of the study area as guides in the interpretation and analysis of the geologic section in terms of probable and sustainable water supply.

RESULTS AND DISCUSSION

Utagba-Ogbe is within the Sombriero Warri deltaic plain deposit invaded by mangrove. The curve types are KA for Umusedeli and Umusam, AK for Oseji estate, HK for Umuseti and KH for second Owessei Street Umusadege.

The interpreted sounding curves from the locations at Umusedeli, Umusam and 2nd Owessei Street Umusadege, Umuseti and Oseji estate by Ozoro/ Ogwashi-Uku express road revealed 4 prominent geo-electric layers. However, they appears to be a very thin clay layer between the first and the second geoelectric layers at Umuseti and second Owessei street Umusadege

Table 6. Model parameters VES 1.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1	357.21	0.82	0.82
2	956.00	2.98	3.80
3	513.00	9.95	13.75
4	2907.45	23.53	37.28
5	2096.65	16.10	53.38
6	2238.20	55.01	108.39
7	2043.45	infinity	Infinity
RMS error	1.65%		

Field measurements and data interpretations by: Oseji Julius Otutu.

Table 7. Model parameters VES 2.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1	398.37	0.90	0.90
2	177.00	2.73	3.63
3	2537.83	19.03	22.66
4	889.00	27.06	49.72
5	416.60	58.06	107.78
6	363.00	infinity	Infinity
RMS error	1.76%		

Field measurements and data interpretations by: Oseji Julius Otutu.

Table 8. Model parameters VES 3.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness (m)
1	234.00	0.94	0.94
2	518.03	3.93	4.87
3	265.47	24.63	29.50
4	1285.02	36.35	65.85
5	1071.00	61.12	126.97
6	1055.43	infinity	Infinity
RMS Error	1.20%		

Field measurements and data interpretations by: Oseji Julius Otutu.

thereby given rise to a fifth geoelectric layer. The lithologic information from a producing borehole within the study area in conjunction with the knowledge of the local geology of the area was used in constructing an earth model. The litholog indicates broadly that within the depth penetrated, the succession is lateritic topsoil, thin clay layer, fine grained sand and medium to coarse-grained sands at various depths.

The data obtained from the field revealed high resistivity values in areas along Umusedeli. This was attributed to both the dried nature of the soil and the

Table 9. Model parameters VES 4.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1	401.00	0.48	0.48
2	1056.30	0.67	1.15
3	655.00	1.46	2.61
4	66.60	3.82	6.43
5	132.30	21.33	27.76
6	726.92	29.90	57.66
7	347.10	61.12	118.78
8	395.31	infinity	Infinity
RMS error	2.01%		

Field measurements and data interpretations by: Oseji Julius Otutu.

Table 10. Model parameters VES 5.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness (m)
1	1088.41	0.56	0.56
2	1548.50	2.04	2.60
3	1360.40	2.99	5.59
4	1502.66	6.42	12.01
5	2800.60	56.77	68.78
6	1050.00	41.93	110.71
7	342.00	36.14	146.85
8	236.55	infinity	Infinity
RMS error	1.05%		

Field measurements and data interpretations by: Oseji Julius Otutu.

effects of buried petrol tanks at Agip Petrol Station that exists below the sounding point and along the spread line of the VES.

The various layers obtained from the iterated results were reduced to 4 relevant geoelectric depth intervals called geoelectric sections as shown in Figure 1.

The first geoelectric layer corresponds to the topsoil with resistivity values ranging from 200.00 - 400.00 Ωm reflecting the various compositions and moisture content of the weathered lateritic layers. The thickness of this layer varies from 0.40 - 1.00 m.

The second geoelectric layer at locations 7 and 9 in Umuseti and second Owessei Street Umusadege has resistivity values of between 66.00 and 170.00 Ωm. This is diagnostics of clay formation, which may act as a confining bed. However, because of the thickness, the area may be susceptible to contamination in the event of pollution.

The second geoelectric layer at Umusedeli, Umusam and Oseji estate is composed of medium/coarse sand formation with resistivity ranging from 100.00 - 500.00 Ωm and thickness of between 5.00 - 10.00 m. This layer is shallow but constitutes the first aquifer at a

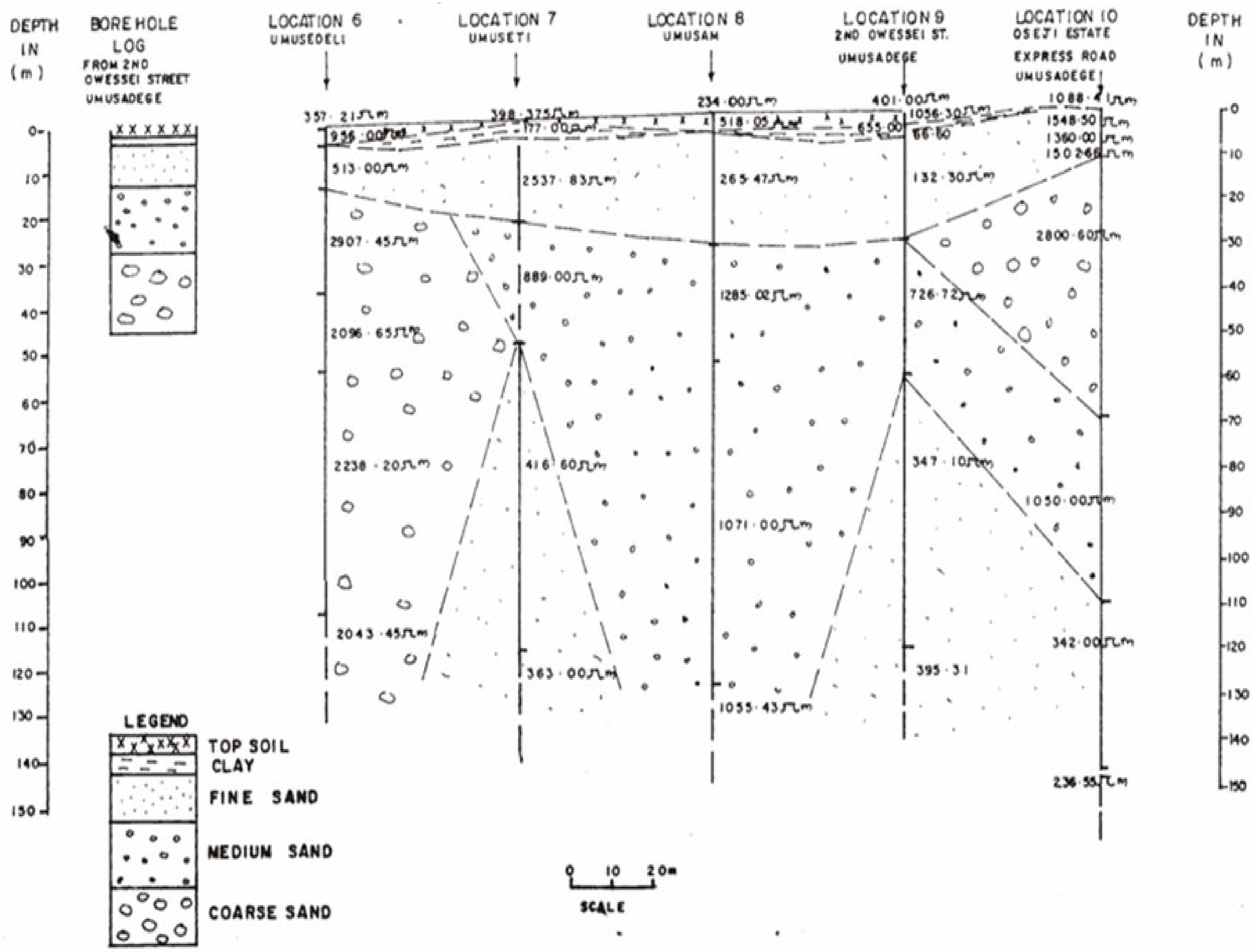


Figure 1. Geoelectric section of Utagba-Ogbe kingdom.

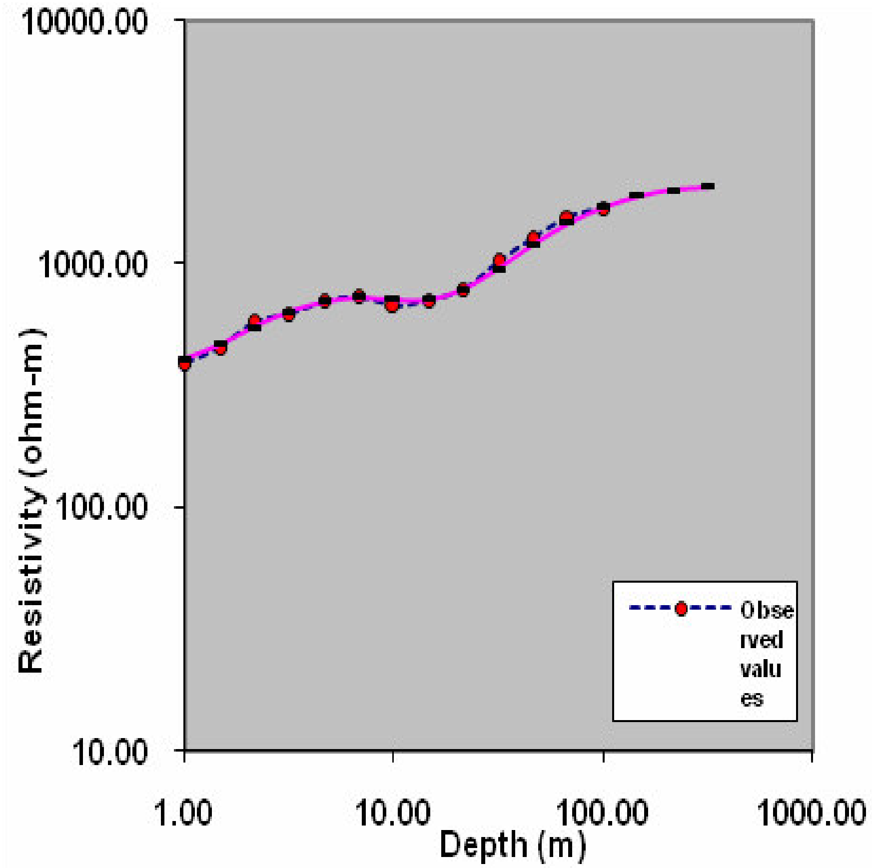
depth of between 10.00 - 15.00 m.

The third geoelectric layer at Umusedeli, Umusam and Oseji estate consists of medium to coarse-grained sand. This layer constitutes an aquifer of very good quantity of groundwater. The average depth to this aquifer is between 35.00 - 45.00 m with an undefined thickness since it is the last layer. However, in Umuseti, second Owessei Street and Oseji estate, there exists a fourth geoelectric layer whose resistivity ranges from 200.00 - 400.00 Ω m and consist fine grain sand. This is the third layer, whose thickness is not defined, since it is the last layer. It occurs at an average depth of between 60.00 - 100.00 m. Based on the resistivity measurements, it is clear that three near surface layers, which are not confined, have been identified in Utagba-Ogbe and environs. In the event of pollution, groundwater may be contaminated.

The first aquifer is at an average depth of between 5.00 - 15.00 m and has a thickness of 10.00 - 20.00 m. This is a very shallow aquifer and it is not an encouraging prospect for groundwater development.

The second layer consist medium to coarse grained sand formation. This layer has good potential for groundwater development and occurs at an average depth between 35.00 - 45.00 m.

The third layer in Utagba-Ogbe is at a depth of between 60.00 - 100.00 m with an undefined thickness. It consists of fine-grained sand formation which is not an encouraging formation for groundwater development.



Site 1. Umusedeli-Ogbe by Agip petrol station, Kwale. VES No : 1.

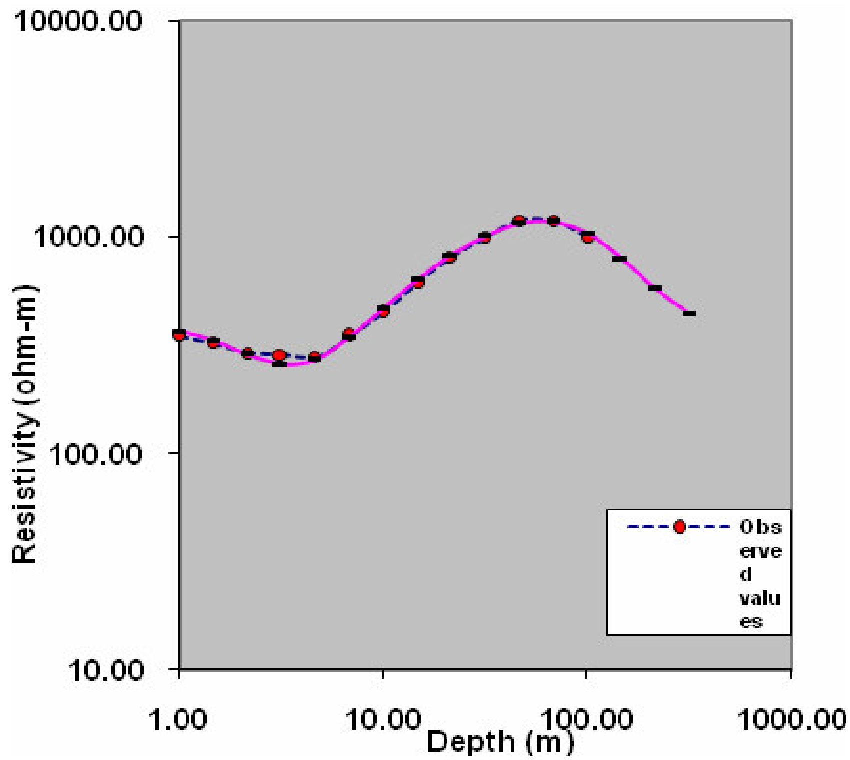
The best layer in Utagba-Ogbe and environs for groundwater development is at a depth of between 35.00 - 45.00 m within the second layer and in the medium to coarse grained sand formation. Generally, materials that lack pore spaces will show high resistivity. Materials whose pore spaces lack water will show high resistivity such as dry sand or gravel. Materials whose water content is clean will show high resistivity such as clean gravel or sand even if water is saturated. Weathered rocks and clay will show medium to low resistivity. Frozen ground will show much higher resistivity than unfrozen ground.

In the sedimentary environment, high resistivity may broadly be associated with the presence of fresh groundwater in porous medium aquifer while low resistivity may be due to the presence of clay and/or brackish water (Emenike, 2000). The type of curve (Selemo et al., 1995), the modified water and sediments resistivity table by Oyedele (2001) and Zohdy and Martins (1993) as well as the knowledge of the local geology of Utagba-Ogbe Kingdom were used as guides in the interpretation of the VES data in terms of probable aquifer in this work. The results were correlated with lithologic log from a producing borehole in second Owessei Street Umusadege between VES 4 and 9, and they were found to be consistent.

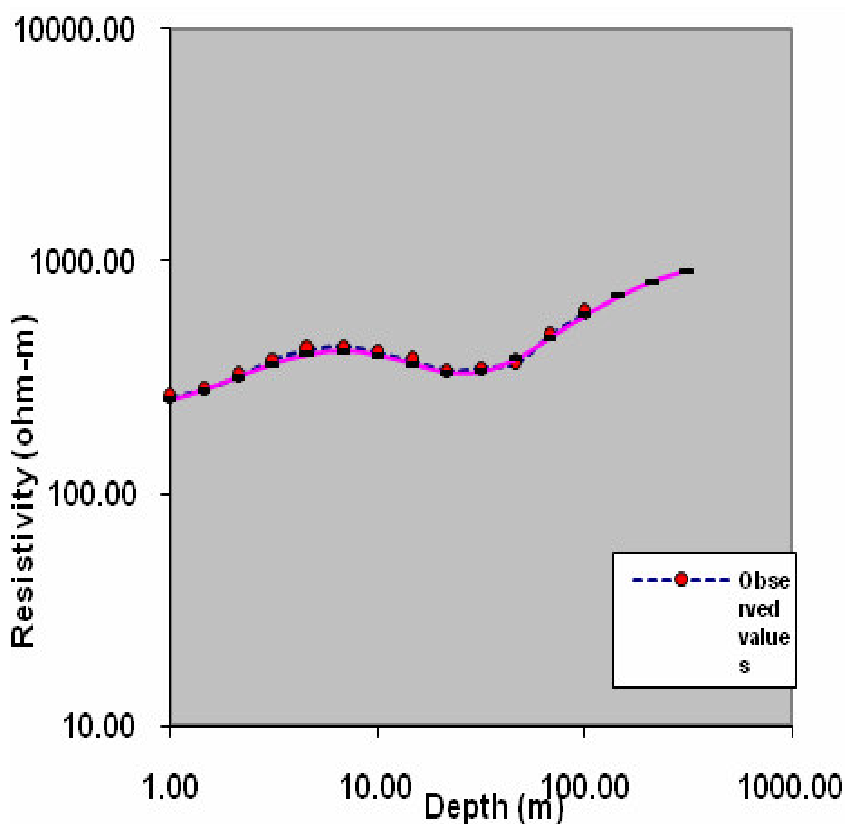
Conclusion and Recommendation

The study revealed Utagba-Ogbe Kingdom as an extensive sandy unit. The best layer of the aquifer in Utagba-Ogbe kingdom for groundwater development is at a depth between 35.00 - 45.00 m within the second layer. This layer consist medium-grained sand to coarse grained sand formations, which is the best formation to obtain an appreciable quantity of water for sustainable groundwater development since it has high porosity.

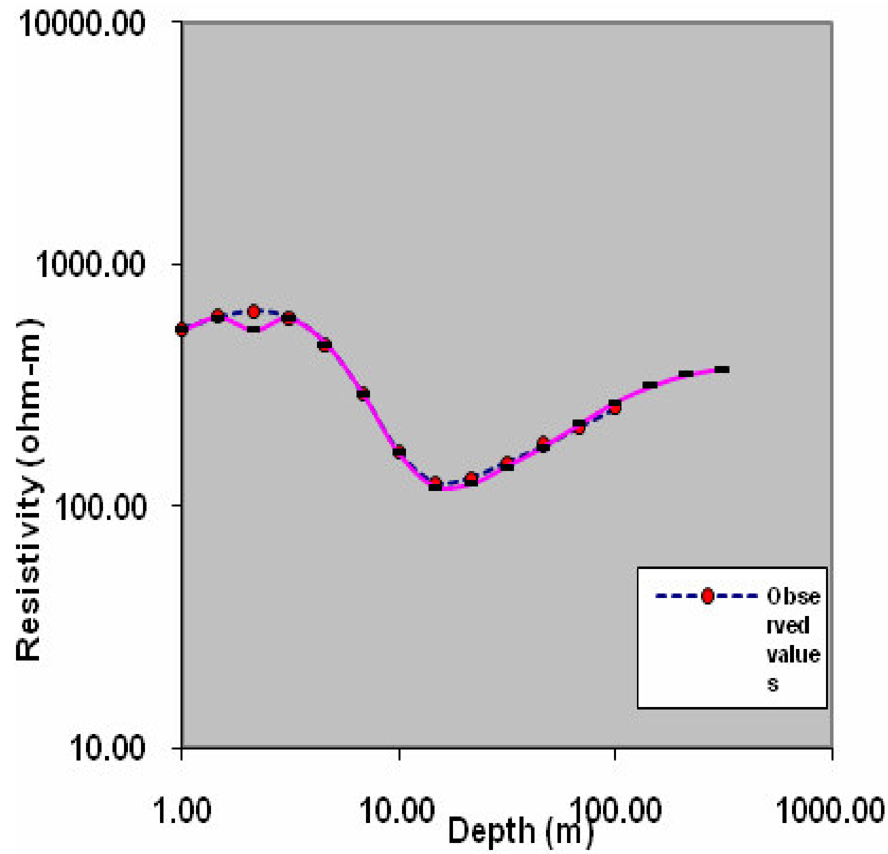
The research did not only pave way for a clear picture of the hydro geological knowledge of Utagba-Ogbe Kingdom in other to create awareness on the productive and prolific aquifer for sustainable groundwater supply but act as guides to both the Government and individuals especially those involved in groundwater development on the type of near surface aquifers, the formation of the aquifer as well as the thickness of the aquifer and the depths boreholes could be drilled for sustainable water supply (Site 1 - 5).



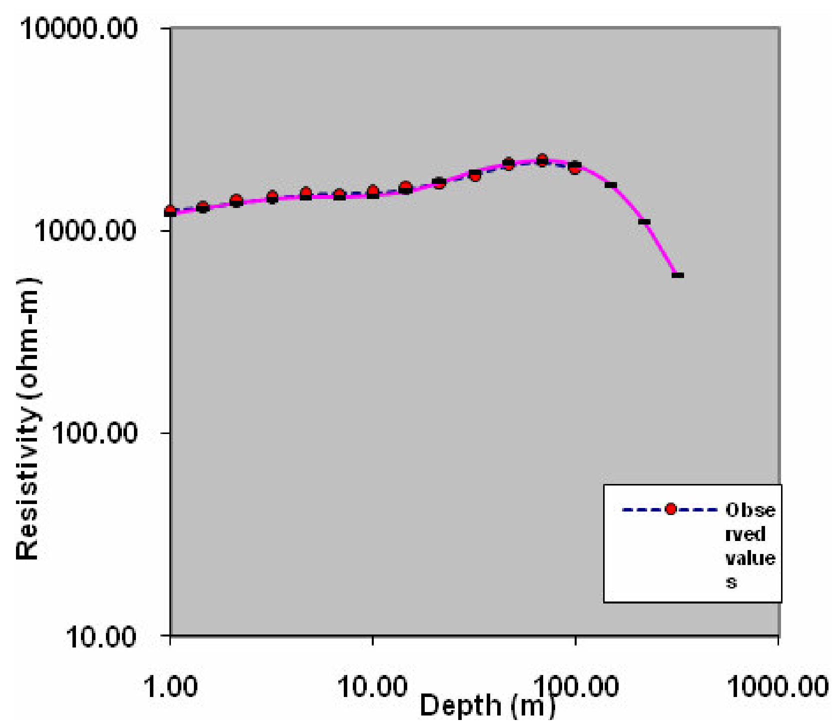
Site 2. Umuseti-Ogbe opposite chief Onefeli's Compound, Kwale. VES No: 2.



Site 3. Umusam-Ogbe by the Obiogwa, Kwale. VES No: 3



Site 4. Umusadege-Ogbe by SECOND Owessei Street, Kwale. VES No: 4.



Site 5. Umusadege-Ogbe (Oseji Estate, Ozoro/Asaba Express Rd.) Kwale. VES No: 5.

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