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Exploration of Aquifer Levels in Abraka, Obiaruku and Umutu Communities in Delta State, Nigeria

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ABSTRACT: The Schlumberger vertical electrical sounding method was used to detect aquifer levels in Abraka, Obiaruku and Umutu communities in Delta State respectively. The study recorded the aquifer level in Obiaruku to be between 26m to 34m. In Abraka the aquifer level lied between 20m to about 30m while in Umutu, it was between 50m to 100m. Borehole data showed that portable drinking water lies between 20m to 100m and could easily be assessed in these areas.

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Resistivity survey is generally a very useful and practical method when searching for groundwater and mineral exploration. It can also provide information about underground formations when potential measurements are made on the surface. The resistivity method as a geophysical exploration tool is based on the fact that the underlying rock materials have electrical resistance therefore Ohm's law can be applied to them (Riwayat *et al.*, 2018). If the earth is uniform, the measured resistivity is called the true resistivity, otherwise the term apparent resistivity is used and it is the weighted average of the resistivity of the different forms. The usual practice in resistivity measurement is to introduce a current into the ground using two current electrodes and the potential drop is measured on the second pair of potential electrodes (Sharma, 1976). Electric currents in the earth are influenced by the formation of the subsoil and thus the distribution of potentials. On earth, electrical conduction is carried out by interstitial water present in rocks and containing a certain amount of dissolved salts. Therefore, low resistivity usually indicates the presence of water or clay in strata, so it can be as important as water salinity in establishing the true resistivity of the medium. Hence, the objective of this paper is to employ the Schlumberger vertical electrical sounding method to detect aquifer levels in Abraka, Obiaruku and Umutu communities in Delta State, Nigeria.

MATERIALS AND METHODS

The method applied for this research work is the vertical electrical sounding (VES) method, which is also known as electrical drilling or expanding probe based on a completely homogeneous Iso-tropic earth layer uniform resistivity theory. Deriving from the theory using ABEM SAS – 300 terrameter and deploying Schlumberger electrode configuration, at 75^0 Azimuta for Abraka and Obiaruku locations respectively and 45 Azimuta for Umutu. Now, let us consider a homogeneous layer of length L and resistance R through which a current I, is flowing as

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depicted in equation 1:

$$\Delta V = IR \qquad 1$$

The cross – sectional area A, resistivity L, resistance ℓ and the layer is specified by its length L from resistivity equation, ℓ = RA/L. Therefore, it follows that R = ℓ L/A and equation 1 can be rewritten as

$$\frac{\Delta V}{I} = \frac{\ell L}{A} \qquad 2$$

Or

$$gradV = \ell j \qquad 3$$

Where j is the current density per unit of cross-sectional area and grad V is the potential gradient.

Consider a semi-infinite conducting layer of uniform resistivity bounded by the ground surface and assume a current of strength + 1 entering at point C_1 on the ground surface (Fig 1). This current will flow away radially from the point of entry and at any instant its distribution will be uniform over a hemispherical surface of the underground resistivity. Fig. 2 shows a method of calculating potential distribution due to a current source in a homogeneous medium. The current density j, at a distance r, away from the current source, would be:

$$j = \frac{I}{2\pi r^2} ------a \qquad 4$$
$$-\frac{dv}{dr} = \ell j -----b$$

The potential gradient associated with the Current is given in equation (3). Now let's substitute j in equation 4a. Into equation 4. We then have that

$$\frac{-dv}{dr} = \frac{\ell I}{2\pi r^2} \qquad 5$$

The potential at distance r in Fig. 2 can be obtained by integrating equation (5).

The above equation 6 can be said to be the basic equation, which enables the calculation of the potential distribution in a homogeneous conducting semi-infinite medium (Olayinka and Olorunfemi 1992). It is also easy to see from equation (6) that the potential difference between points P_1 and P_2 (Fig 2) coursed by current + 1 at the "source" entry point C_1) is given as equation 7.

$$-\int \frac{dv}{dr} = \int \frac{\ell I}{2\pi r^2}$$
$$-\int \frac{dv}{dr} = \frac{\ell I}{2\pi}\int r^2$$
$$-\int dv = \frac{\ell I}{2\pi}\int r^{-2} dr \qquad 6$$
$$-v = -\frac{\ell I}{2\pi} r^{-1}$$
$$\therefore v = \frac{\ell I}{2\pi r}$$

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1}\right] - \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_2}\right] ......7$$

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2}\right]$$

In the same manner, the potential difference between P_1 and P_2 is

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_2P_1} - \frac{1}{C_2P_2}\right] \qquad 8$$

The total potential difference between P_1 and P_2 is therefore, given by the sum of the right hand sides of equation (7) and (8) as given by Lisowski, (2016):

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2}\right] - \frac{I\ell}{2\pi}\left[\frac{1}{C_2P_1} - \frac{1}{C_2P_2}\right]$$

$$v = \frac{I\ell}{2\pi C_1P_1} - \frac{I\ell}{2\pi C_1P_2} - \frac{I\ell}{2\pi C_2P_1} + \frac{I\ell}{2\pi C_2P_2}$$

Collecting like terms to give equations 9 and 10

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C1P_2} - \frac{1}{C_2P_1} + \frac{1}{C_2P_2}\right] ---9$$
$$or$$
$$\ell = 2\pi G\frac{\Delta v}{I}(Sharma, P.V.1976) ------10$$

Where:

$$\frac{1}{G} = \frac{1}{C_1P_1} - \frac{1}{C1P_2} - \frac{1}{C_2P_1} + \frac{1}{C_2P_2}$$
$$and$$
$$G = C_1P_1 - C_1P_2 - C_2P_1 + C_2P_2$$

G denotes the geometric factor of an electrode configuration.

Here, the value of ℓ for a homogeneous conducting medium is independent of the positions of electrodes and is not affected when the positions of the current and potential electrodes are interchanged (Nelson 2018). It is the use of electrical methods with depth control in which electrode spacing is increased to obtain information from greater depths at a given surface location (Morka and Molua 2022). It is used for detecting changes in the resistivity of the earth with depth beneath the given location. The principles of VES was based on the fact that the wider the current electrode separation the deeper the current penetration (Ogwu *et al.*,2022) As the current reached greater depths subsequent readings are progressively taken. For this research work three sounding points were occupied using the schlumberger array – method with electrode spacing varying from 1m to about 464m and it helped in showing the multi-layered subsurface. Borehole data was sampled after the sounding in order to determine the general aquifer levels in these areas.

RESULTS AND DISCUSSION

The computed values from the survey are presented Tables 1, 2 and 3 respectively. Calculations on Ves I (Umutu) from fig. 1a shows that $k_1 = 19$, $K_2 = 19$, $k_3 = 3$, $k_4 = 7/13$ $\ell_1 = 38\Omega m$, $\ell_{2r} = 80\ \Omega m$, $\ell_{3r} = 380\Omega m$, $\ell_{4r} = 94\Omega m$; $H_1 = 0.84$ m, $h_{2r} = 2m$, $h_{3r} = 11m$, $h_{4r} = 160m$; $1D_1 = 1.4$, $1D_2 = 4.3$, $1D_3 = 14$. $\ell_1 = 38\ \Omega m$
$\ell 2 = K1 \times \ell 1 = 19 \times 38 = 722\Omega m$; $L3 = K2 \times \ell 2r = 19 \times 80 = 1520\ \Omega m$; $\ell 4 = K3 \times \ell 3r = 3 \times 380 = 1140\Omega m$; $\ell 5 = K4 \times \ell 4r = 7 \times 945 = 508.8\ \Omega m$, H1 = 0.84m; H1 = 1S1 x h1 = Thickness of the layer
H2 = 1D1 x h1 = 1.4 x 0.84 = 1.18m, H3 = 1D, x h2r = 4.3 x 2 = 8.6m; H4 = 1D3 x h3r = 14 x 11 = 154m
H5 = Continuous.

Table 1: Survey values for Umutu

MN/2	AB/2	Resistance R(Ω)	Geometric factor	Apparent resistivity (Ωm)
0.2	1.000	6.800	7.540	51.270
0.2	1.470	3.600	16.660	59.980
0.2	2.150	2.300	35.990	82.780
0.2	3.160	1.700	78.110	132.790
0.2	4.640	0.900	168.780	151.900
1.0	6.810	3.520	71.280	251.100
1.0	10.000	1.940	155.510	301.690
1.0	14.700	0.750	337.860	253.390
3.0	21.500	0.727	237.320	172.530
3.0	31.600	0.550	518.130	284.970
8.0	46.400	1.640	410.170	672.680
8.0	68.100	0.144	898.030	129.320
16.0	100.000	0.144	956.610	137.750
16.0	147.000	0.103	2096.320	215.920
30.0	215.000	0.348	2373.210	825.880
50.0	316.000	0.240	3058.530	734.050
50.0	464.000	0.095	6685.180	635.090

Calculations on Ves 2 (Abraka). From the curve in fig 1b, it shows that: K1 = 5, K2 = 17/3, K3 = 3/7; H1 = 0.79m, h2r = 5.8m, h3r = 92.5m; ID1 = 5.8, ID2 = 16
$\ell 1 = 56\Omega m$, $\ell 2r = 162\Omega m$, $\ell 3t = 550\Omega m$ $\ell 1 = 56\Omega m$
$\ell 2 = K1 \times \ell 2r = 17 \times 162 = 918\Omega m$ $\ell 4 = K3 \times \ell 3r = 3 \times 550 = 235.7\Omega m$; H1 = 0.79m; H2 = ID1 x h1 = 0.79 x 8 = 6.32m; H3 = 1D2 x h2r = 16 x 5.8 = 99.91m; H4 = Continuous.

Table 2: Survey values for Abraka

MN/2	AB/2	Resistance R (Ω)	Geometric Factor	Apparent resistivity (Ωm)
0.2	1.000	16.550	7.54	124.79
0.2	1.470	4.570	16.66	76.14
0.2	2.150	2.930	35.99	105.45
0.2	3.160	1.560	78.11	121.85
0.2	4.640	0.800	168.78	135.02
1.0	6.810	2.450	71.28	174.64
1.0	10.000	0.410	155.51	63.76
1.0	14.700	0.831	337.86	280.83
3.0	21.500	1.201	237.32	285.02
3.0	31.600	0.602	518.13	311.94
8.0	46.400	0.903	410.17	370.38
8.0	68.100	0.594	898.03	533.43
16.0	100.000	0.371	956.61	354.94
16.0	147.000	0.066	2096.32	138.36
30.0	215.000	0.142	2373.21	337.00
50.0	316.000	0.074	3058.53	226.33
50.0	464.000	0.039	6685.18	260.72

Table 3: Survey values for Obiaruku

MN/2	AB/2	Resistance R (M)	Geometric factor	Apparent resistivity (M)
0.2	1.00	9.160	7.54	69.06
0.2	1.47	2.330	16.66	38.82
0.2	2.15	0.920	35.99	33.12
0.2	3.16	0.376	78.11	29.36
0.2	4.64	0.170	168.78	28.76
1.0	6.81	0.305	71.28	21.74
1.0	10.00	0.240	155.51	37.32
1.0	14.70	0.168	337.86	56.76
3.0	21.50	0.349	137.32	82.82
3.0	31.60	0.220	518.13	113.99
8.0	46.40	0.226	410.17	92.70
8.0	68.10	0.143	898.03	128.42
16.0	100.00	0.149	956.61	142.53
16.0	147.00	0.107	2096.32	224.31
30.0	215.00	0.039	2373.21	92.59
50.0	316.00	0.128	3058.53	392.00
50.0	464.00	0.028	6685.18	187.00

From the curve in Fig 2c it was shown that: K1 = 7/13, K2 = 99, K3 = 13/7, K4 = 7/13; $\ell 1 = 46\Omega m$, $\ell 2r = 26\Omega m$, $\ell 3r = 165\Omega m$, $\ell 4r = 240\Omega m$;
H1 = 0.77m, h2r = 5.8m, h3r = 38, h4r = 180m
ID1 = 5.8, ID2 = 5.0, ID3 = 4.5. $\ell 1 = 46\Omega m$ $\ell 2 = K1 \times \ell 1 = 7/13 \times 46 = 24.8\Omega m$; $\ell 3 = K2 \times \ell 2r = 99 \times 26 = 2574\Omega m$ $\ell 4 = K3 \times \ell 3r = 13/7 \times 165 = 306.4\Omega m$ $\ell 5 = K4 \times \ell 4r = 7/13 \times 240 = 129.2\Omega m$; H1 = 0.77m; H2 = h1 x ID1 = 5.8 x 0 77 = 4.466m; H3 = h2r x 1D2

= 5.0 x 5.8 = 29m; H4 = h3r x 1D3 = 4.5 x 38m = 171m H5 = Continuous.

Where: Hn = height or thickness of each layer
Hur = apparent thickness of each layer; N = 1, 2, 3, ID = hn+1 = index value; Ln = resistivity of each layer Lnr = apparent resistivity.

Qualitative Interpretation reveals that there are different types of curves namely; A-type, Q-type, K-type, H-type and KH-type curves. Characteristics of each of the curve are as shown in Figure 1 and 2.

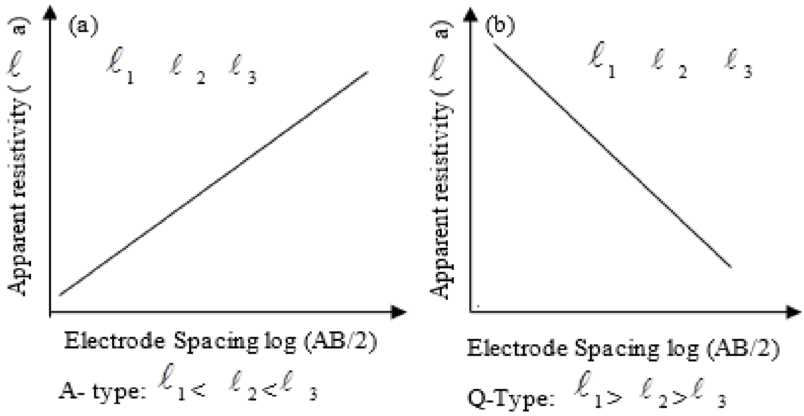

Fig 1. Apparent resistivity against electrode spacing using a log scale

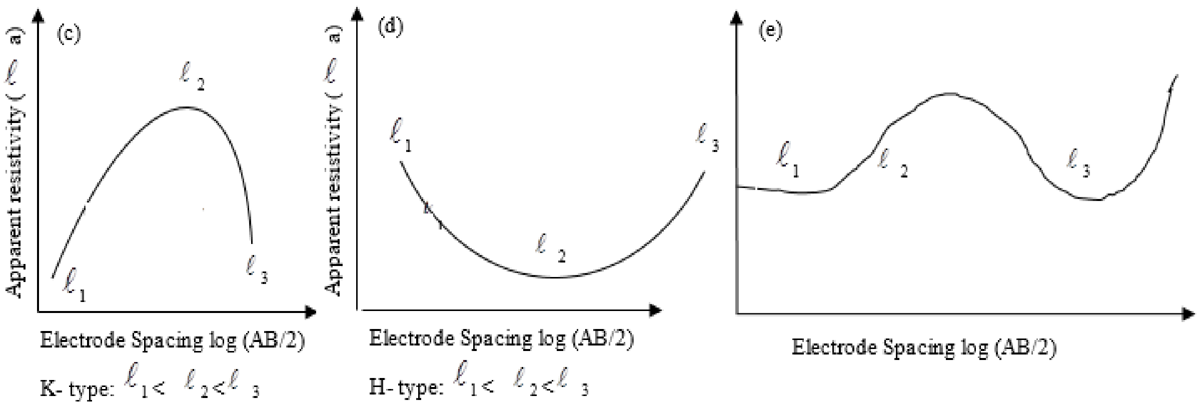

Fig. 2: apparent resistivity against electrode spacing using a log scale

Figure 2 shows the apparent resistivity against electrode spacing using a log scale. From VES 1 calculations (Umutu), it shows ℓ1 = 38 ℓm, ℓ2 = 722 ℓm, ℓ3 = 1520Ωm, ℓ4 = 1140Ωm and ℓ5 = 508Ωm. This implies that ℓ1 < ℓ2 < ℓ3 > ℓ4 > ℓ5 and it has the characteristics of K type curve. It shows that the curve has five layers. From VES 2 calculation (Abraka), it shows that G = 56 m, ℓ2 = 280Ωm, = 918 Ωm, ℓ4 = 235.7Ωm. This implies that ℓ1 < ℓ2 < ℓ3 > ℓ4. It has the characteristics of both A-type and K-type curves. Therefore, it is Ak-type curve. And it has four layers. From VES 3 calculation (Obiaruku), it shows that ℓ1 = 46Ωm, ℓ2 = 24.8ΩmΩm, ℓ3 = 2574Ωm, ℓ4 = 306.4Ωm, ℓ5 = 129.23Ωm. This implies that ℓ1 > ℓ2 < ℓ3 > ℓ4 > ℓ5. It has the characteristics of both Q-type and H-type curves. It is said to be QH-Type curve. It has five layers. The easiest method of interpreting the curve is by applying the curve matching technique. Although computers can now be used in interpretation, it was not used for the purpose of this research work. In applying the curve matching technique, the study placed the field curve over a 2 layer master curve and on AH and KQ – Curves, which was used to find out the curves that best fit from where we deduced the apparent resistivity and thickness of each layer in agreement with Amey and Hambuger (2018). The purpose of using these master curves was to detect the thickness and resistivities of the different layers after carrying out all the necessary calculations. From VES I calculation (Umutu), it was shown that the first layer has a resistivity of 38 Ωm and a thickness of 0.84m. The second layer has a resistivity of 733Ωm and a thickness of 1.176m. The third layer has a resistivity of 1520Ωm and a thickness of 8.6m. While the fourth layer has a resistivity of 1140 Ωm and a thickness of 154m. And the fifth layer has a resistivity of 508.8Ωm and its thickness is continuous from VES 2 calculation (Abraka), it shows that the first layer has a thickness of 0.79m and resistivity of 56Ωm. The third layer has a thickness of 99.91, and resistivity of 918Ωm.The thickness of the fourth layer is continuous but its resistivity is 235.7 Ωm. And from VES 3 calculation (Obiaruku) it shows that the resistivity of the first layer is 46Ωm and its thickness is 0.77m. The second layer has a resistivity of 24.8Ωm and its thickness is 4.466m. While the third layer has a resistivity of 2574Ωm and its thickness is 29m. Also, it shows that the fourth layer has a resistivity of 306.4Ωm and its thickness is 171m. And the fifth layer has a resistivity of 129.2Ωm and its thickness is continuous. Geoelectric Sectional Interpretation varied among the locations sampled. From VES I (Umutu), it was noted that the top soil which is the first layer was clayish in nature because of its low resistivity. The second layer had fine to silty sand, while the third and fourth layers were both medium to coarse grained. The fifth layer also had fine to silty sand. For VES 2 (Abraka), the top soil was also clayish in nature and was the first layer. The second layer has fine to silty sand. The third layer is medium to coarse grained. The fourth layer also recorded fine to silty sand. Furthermore, VES 3 (Obiaruku), presented first and second layers consisting of clay. The third layer was medium to coarse grained while the fourth layer presented fine to silty sand with a fifth layer of sandy clay. The layers that portable drinking water could be found were layers that contained medium to coarse grain which were areas that showed high resistivity. This is as a result of the low conductivity of fresh water. But salt water has high conductivity which will result in low resistivity. All the areas sampled for the study showed prospects for portable drinking water. With respect to the geoelectric section, it was deduced that from a depth of 20m to 100m portable drinking water could be found in all the locations investigated. Since the study areas have fresh water due to little or no content of salt, conductivity is ascribed to be very low. This accounts for the high resistivity value because resistivity is reciprocal to conductivity. The nearness of water to the earth surface and the source of river ethiope also explains why there are hand dug wells in Obiaruku and Umutu and Abraka.

Conclusion: The results of the pre-drilling geophysical investigations using vertical electrical sounding [VES] techniques carried out in Umutu, Abraka and Obiaruku communities was presented in this report. The three communities had potentials for portable water which could be reached at minimum depth of twenty meters. The results in this study will provide cost effective prospects for borehole engineers within these communities.

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