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Full Length Research Paper

Determination of groundwater potential in Asaba, Nigeria using surface geoelectric sounding

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Providing potable water has been a major concern to the people of Asaba the capital city of Delta State, Nigeria. This study which is aimed at identifying formations that present fresh and healthy aquifer water for the people employed the use of the geoelectric sounding to probe the subsurface. Data collected were interpreted in terms of the true resistivity and thickness of subsurface layers and result correlated with record from existing borehole. Results indicate that there are four to five distinct formations in the study area. Analyses of the data suggest that water bearing formation exist in the third formation having resistivity range of 318 to 567 Ωm. The thickness of the aquifer ranges from 20.4 to 33.9 m, while the depth range is from 43.5 to 52.8 m. The study therefore indicates the presence of thick and highly prolific aquifer zone which is an indication of adequate water resource in the area. It is recommended that boreholes for good drinking water and water scheme be drilled to the third layer of the various locations investigated.

Key words: Schlumberger array, groundwater, geoelectric sounding, electrical resistivity, aquifer, electrode separation.

INTRODUCTION

Groundwater is described as water which exists below the earth surface within saturated layers of sand, gravel and pore spaces in sedimentary as well as crystalline rocks (Oseji and Ofomola, 2010). Todd (2004) explains groundwater to mean the water occupying all the empty spaces within a geologic stratum. It is among the natural resources of prime importance to man throughout the world. Oseji et al. (2005) noted that groundwater occurs in many types of geologic formations. Those known as aquifer are the most important and are defined as formations containing sufficient saturated permeable material to yield significant quantities of water to wells and spring (Abiola et al., 2009). Groundwater can be explored using many methods which include the electrical resistivity method (Alile et al., 2008a). According to Iserhien-Emekeme et al. (2004), electrical resistivity of rock is a property which depends on lithology and fluid content. For instance, the resistivity of coarse-grained and well-consolidated sandstone saturated with fresh water is higher than that of unconsolidated silt of the same porosity and saturated with the same amount of water.

The electrical resistivity of a rock formation limits the amount of current passing through the formation when an electric potential is applied. Todd (2004) stated that the resistivity of a rock material whose resistance is R and having a cross sectional area A and length L is expressed as:

$$\rho = \frac{RA}{L} \qquad 1$$

In the Schlumberger array, as shown in Figure 1, A and B are current electrodes, while M and N are potential electrodes. The current entering the ground at A and returning at B as shown in Figure 1 is 'I'. Assuming the medium below the surface of the earth is homogeneous and isotropic with resistivity ρ, the potentials V_M and V_N as measured at M and N, respectively are given by:

$$V_M = \frac{\rho I}{2\pi}\left(\frac{2}{L-a}\right) \qquad 2$$

and

$$V_N = \frac{\rho I}{2\pi}\left(\frac{2}{L+a}\right) \qquad 3$$

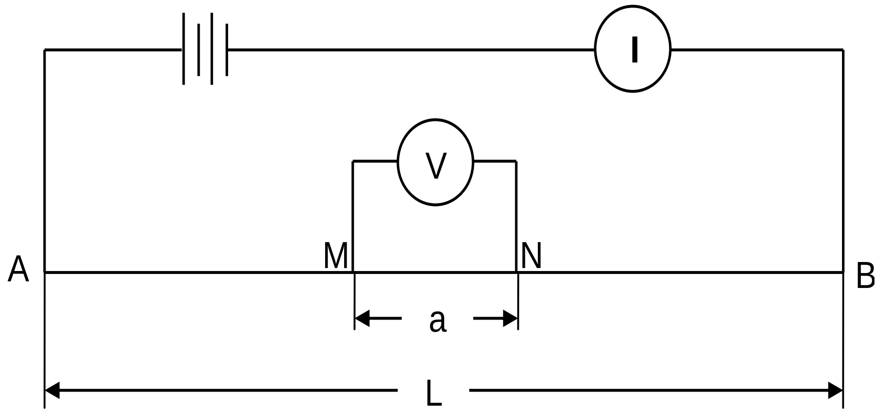

Figure 1. The Schlumberger array configuration.

The potential at A is

$V_A = V_M – V_N$

$$V_A = \frac{\rho I}{2\pi}\left(\frac{2}{L-a} - \frac{2}{L+a}\right) \qquad 4$$

and

$V_B = V_N – V_M$

$$V_B = \frac{\rho I}{2\pi}\left(\frac{2}{L+a} - \frac{2}{L-a}\right) \qquad 5$$

Thus, the potential difference measured by the voltmeter connected between A and B becomes:

$V = V_A - V_B$

$$V = \frac{4\rho I}{\pi}\left[\frac{a}{L^2-a^2}\right] \qquad 6$$

The apparent resistivity is therefore given by the relation:

$$\rho_a = \frac{\pi V\left(L^2-a^2\right)}{4I} \qquad 7$$

where L and a are the current and potential electrode spacing, respectively.

When apparent resistivity is plotted against half electrode spacing (L/2) in the Schlumberger configuration for various spacing, a smooth curve can be drawn through the points (Alile et al., 2008b).

Various studies using the vertical electric sounding (VES) method have been used successfully in the determination of groundwater potential in many areas of Nigeria as it remains the cheapest method of subsurface exploration for water (Ezeh and Ugwu, 2010). The works of several researchers, such as Tammaneni et al. (2006), Batayneh (2009), Batayneh et al. (2010), Atakpo et al. (2008), Okolie et al. (2008), Okolie (2010), Oseji and Ujuanbi (2009), Nwankwo (2011) and Anomohanran (2011) are also supportive of this fact. Some investigators have also used this method to determine the structure and fault line of the earth (Kumar et al., 2007; Al-Saigh, 2010).

The present water hardship experienced by the inhabitants of Asaba results from the increase in population and industrial development within the area. These have put high demand on water assessment and management. In a bid to ameliorate this present condition, it has become imperative to carry out a geophysical survey. This survey will provide information to the people on the water bearing formations and groundwater potential of the area. It is therefore expected that the results obtained from this work would produce detailed groundwater condition and recommend areas where wells could be located.

MATERIALS AND METHODS

The study area is Asaba the capital city of Delta State, Nigeria located within latitude 6°10' to 6°20'N and longitude 6°35' to 6°45'E (Figure 2). The study area is typical of the Benin formation which consists of thick friable sands with minor intercalation of clay beds, silts and lenses and pods of fine grained sandstones (Okwueze and Offong, 1992).

Vertical electrical sounding was carried out using Schlumberger electrode configuration. The ABEM SAS 300 Terrameter was used for the investigation in five locations with electrode spacing of about 350 m. An electrode made of stainless steel was driven into the soil at each end of the spread A and B (Figure 1). Both electrodes were then connected to the current sender of the Terrameter. The electrodes M and N were also driven into the soil and connected to the voltage receiver. At each position of A and B, the current was sent, and the potential difference between A and B was measured. Also, the distances AB and MN were measured. From the field data, the apparent resistivity was determined and plotted against half electrode separation (AB/2).

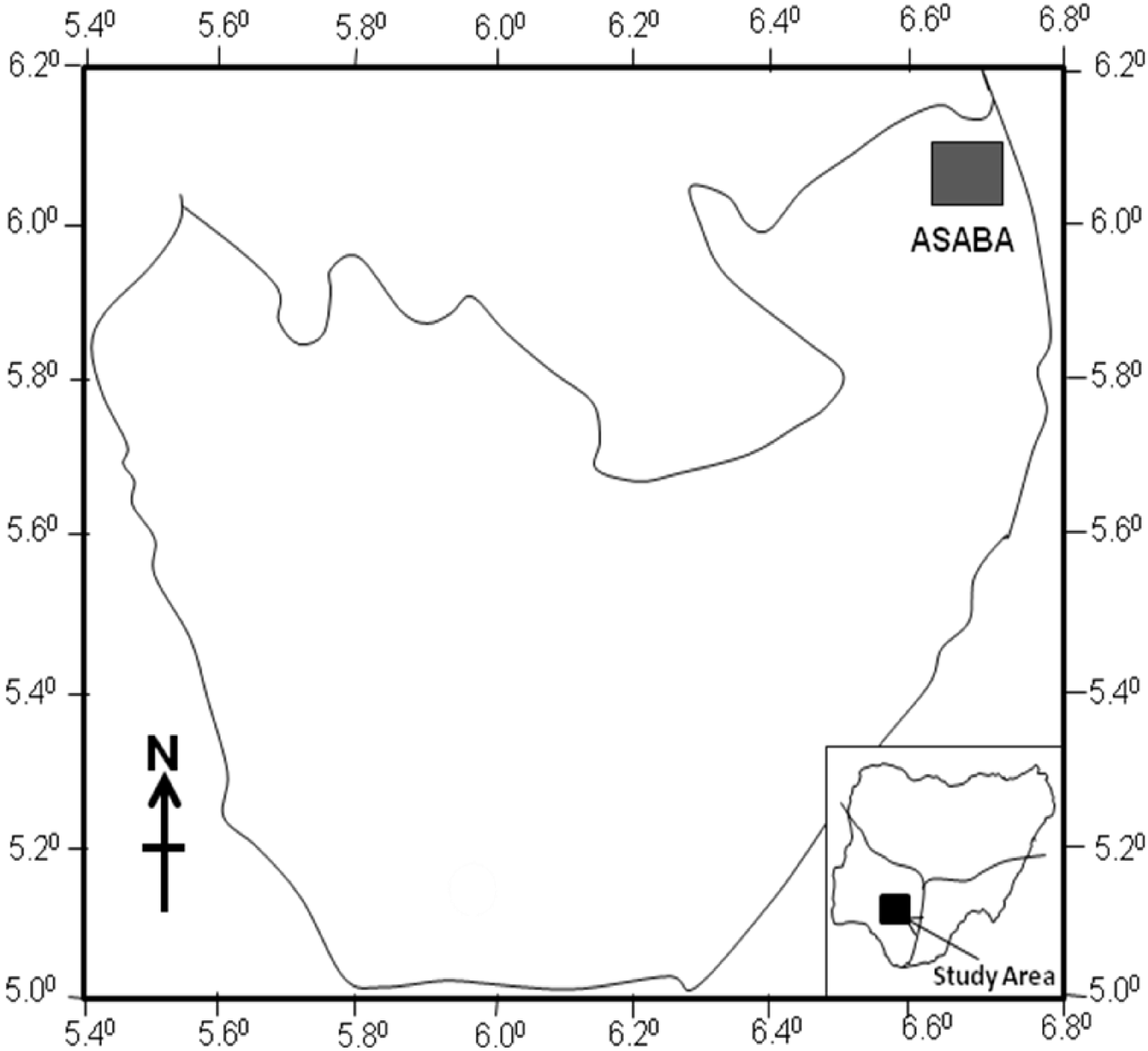

Figure 2. Location map of the study area.

RESULTS

The data obtained from this study were initially interpreted using conventional partial curve matching techniques. Based on this, estimates of layer resistivities and thickness were obtained, which serve as a starting point for computer assisted interpretation. The electrical resistivity curves obtained from the analysis of the field data are as shown in Figure 3 while the true resistivity and thickness of the layers delineated in this study are as shown in Table 1. The curve types for the various locations are prominently AK and KHK as shown in Table 2.

DISCUSSION

The interpretation of the resistivity data indicates that there are four to five layers in the area under study (Figure 4). The top layer shows diversity of resistivity values ranging from 18 to 66 Ωm and can be classified as loose soil. The thickness of this layer differs from one location to the other ranging from 0.4 to 6.4 m. The resistivity of the second layer ranges from 70 to 95.9 Ωm and is interpreted as clayey sand to sandy clay. The thickness of this layer varies from 15.8 to 20.2 m. The third layer has a resistivity range of 317 to 567 Ωm and is an indication of alluvial deposits (fine sand, coarse grain

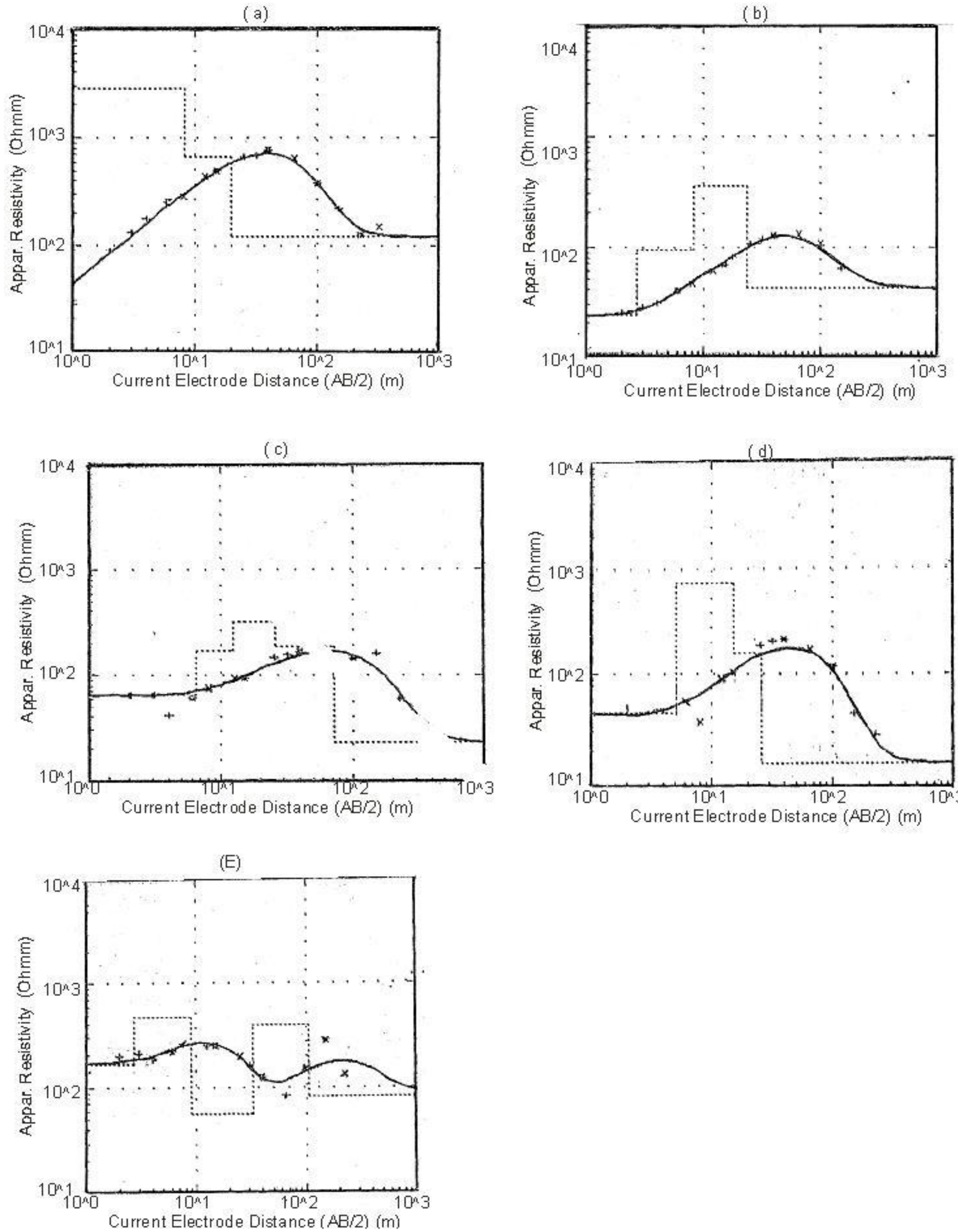

Figure 3. Resistivity plots of some VES stations: (a) VES 1, (b) VES 2, (c) VES 3, (d) VES 4 and (e) VES 5.

and gravel). There is evidence of groundwater accumulation in this layer. Further comparison with close borehole indicates that groundwater exist at a depth of 43.5 m downward. The thickness of this aquifer ranges

Table 1. Summary of results obtained from computer iteration.

Location	Number of layers	Resistivity (Ωm)	Thickness (m)	Depth (m)
Stadium area	1	18.70	0.40	0.40
	2	85.00	17.80	18.20
	3	565.80	26.50	44.70
	4	122.70	-	-
Hospital area	1	23.40	2.70	2.70
	2	95.90	15.50	18.20
	3	524.00	25.30	43.50
	4	118.60	-	-
old secretariat area	1	48.10	5.10	5.10
	2	70.30	20.20	25.20
	3	567.20	20.40	45.60
	4	157.10	-	-
Government house area	1	44.00	6.40	6.40
	2	72.90	15.80	22.20
	3	317.80	23.60	45.80
	4	292.17	9.50	55.30
	5	230.70	-	-
Anwai road	1	66.00	2.70	2.70
	2	86.00	16.20	18.90
	3	558.00	33.90	52.80
	4	95.30	15.40	68.20
	5	128.70	-	-

Table 2. Qualitative analysis of curve types (ρ represent the resistivity of the layers).

Location	Curve characteristics	Curve type	Number of geoelectric layers
Stadium area	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	AK	4
Hospital area	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	AK	4
Old secretariat area	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	AK	4
Government house area	$\rho_1 < \rho_2 < \rho_3 < \rho_4 > \rho_5$	KHK	5
Anwai road	$\rho_1 < \rho_2 < \rho_3 > \rho_4 < \rho_5$	KHK	5

from 20.4 to 33.9 m. This is an indication of the presence of thick and highly prolific aquifer zone. The fourth layer resistivity ranges between 95 and 292 Ωm which is typical of sandy clay to sandy formation. The fifth layer occurs in locations along Anwai road and Government House area. The resistivity range is from 128.7 to 230.7 Ωm and is typical of sandy clay and sand.

Conclusion

The application of vertical electric sounding technique has provided detailed information on the thickness and hydroelectrical characteristics of the aquifer in the study area. Analysis of the data indicate that water bearing formation exist in the third layer within the area under study with thickness ranging from 20.4 to 33.9 m. Boreholes for good drinking water and water scheme are recommended to be drilled to the third layer of the different locations. The presence of thick and highly prolific aquiferous zone assures the area of adequate water resource. This study will no doubt guide the bore-hole program of the state capital and provide additional

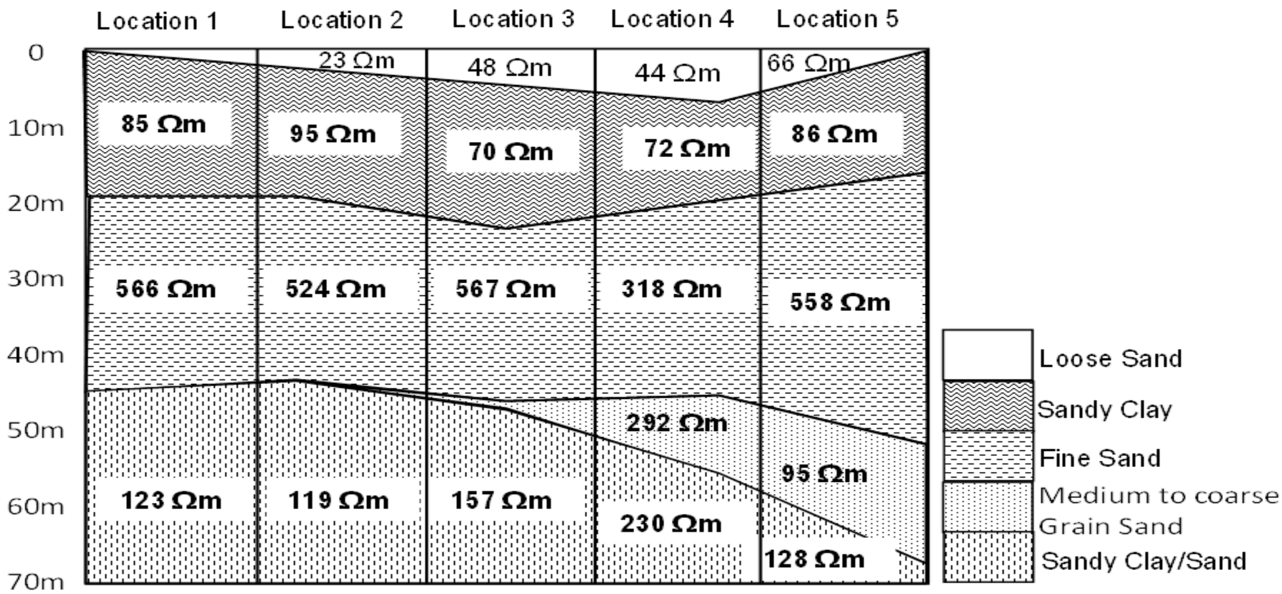

Figure 4. Geoelectric section of the study area.

database for groundwater development and utilization in the area.

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