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Original Article

Geostatistical Analysis of the Geoelectrical Parameters of Oke-Badan Estate, Akobo, South Western, Nigeria

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ABSTRACT

Geostatistical analysis of Oke-Badan was evaluated using Electrical Resistivity Sounding Method. Twenty –one vertical electrical soundings were conducted using the Schlumberger configuration, covering the area. Basic parameters analyzed include resistivity and thickness of topsoil, resistivity and thickness of aquifer layer, resistivity of bedrock, overburden thickness, longitudinal unit conductance, hydraulic conductivity, and transmissivity. The low range of values recorded by the longitudinal unit conductance (0.01 – 0.28), hydraulic conductivity (0.44 x 10^{-5} – 27.92 x 10^{-5}), and transmissivity (2.25 x 10^{-5} – 258 x 10^{-5}) could be attributed to the clay content in the aquifers which affect the porosity of the layer. The resistivity of weathered layer has a low range of values between 25 and 196 ohm-m with an average value of 55 ohm-m and a low standard deviation value of 74 ohm-m. The low range in value of the layer determines to a significant extent the yield of boreholes. Weathered and fractured horizons which underlie VES stations constitute the aquifer zones have been identified in the study area. It is recommended that, the study area where overburden layer is relatively thick and has favorably low resistivity values should be considered for groundwater development.

***Key words**: Basic parameters, fractured horizon, Geostatistical analysis, Schlumberger configuration and Weathered horizon.*

INTRODUCTION

Water, next to air is essential to life on earth, the natural resource that we cannot do without for survival. The distribution and availability of water is intimately associated with the development of human society and it was almost inevitable that some development of water resources preceded a real understanding of their origin and formation [19].

Fortunately, this water has been gifted by nature in bounteous proportion with its quality of transformation through perennial hydrogeological evaporation, condensation and precipitation according to [3]. With the increase for water demanding to meet human domestic use, industrialization and agricultural use this led the people to search for surface water supply. Surface water, which mostly occurs as rivers are subjected to pollution. It is sad to say that most of the rivers in Nigeria are highly polluted, the pollutants being inadvertently introduced by man via industrial and petroleum exploration activities.

As demand for water resources increases and the variety of pollutants becomes more diverse, there is an increasing conflict between the use of rivers for water supply and 'sewers' for disposing of industrial and domestic effluent. Hence, ground water exploration is the only alternative to surface water in order to overcome the variety of pollutants [1]. Although, the quantity and disposition of ground water depends on the geological characteristics of the host rock formation. The search for ground water is faced with lots of uncertainties; to minimize or avoid failures altogether, it is pertinent that the right exploration techniques are utilized in the delineation of subsurface water-bearing formations [7].

Another researcher also noted in their work that the delineation of water occurrence in weathered rocks can be greatly accomplished by the use of suitable techniques [12].

Crystalline basement rocks in Nigeria are located in areas of high relief where runoff is high and infiltration rate is very low [2, 16]. These rocks are devoid of primary porosity and permeability.

In the study of underground structures for the identification of water bearing layers, electrical resistivity method is usually found suitable [10, 5].

The study area is located on latitude 7^{o} 26.034^{1} N and 7^{o} 26.765^{1}N and longitude 3^{o} 57.197^{1} E and 3^{o} 58.486^{1}E in Ibadan, and lies within the South-Western part of the Nigerian Precambrian

basement complex, occupying approximately 50% of the surface area of the country, as part of the Pan African crystalline shield (Figure 1).
The dominant rock types in Ibadan area are quartzite, banded gneiss and granite gneiss. Associated rock suites found in all the major outcrops in the study area include pegmatites and quartz veins. Generally, wells from quartzite areas produce more water than wells from other rock types. This is because their transmissivites and permeability are higher due to the presence of fissures and quartz veins [13].

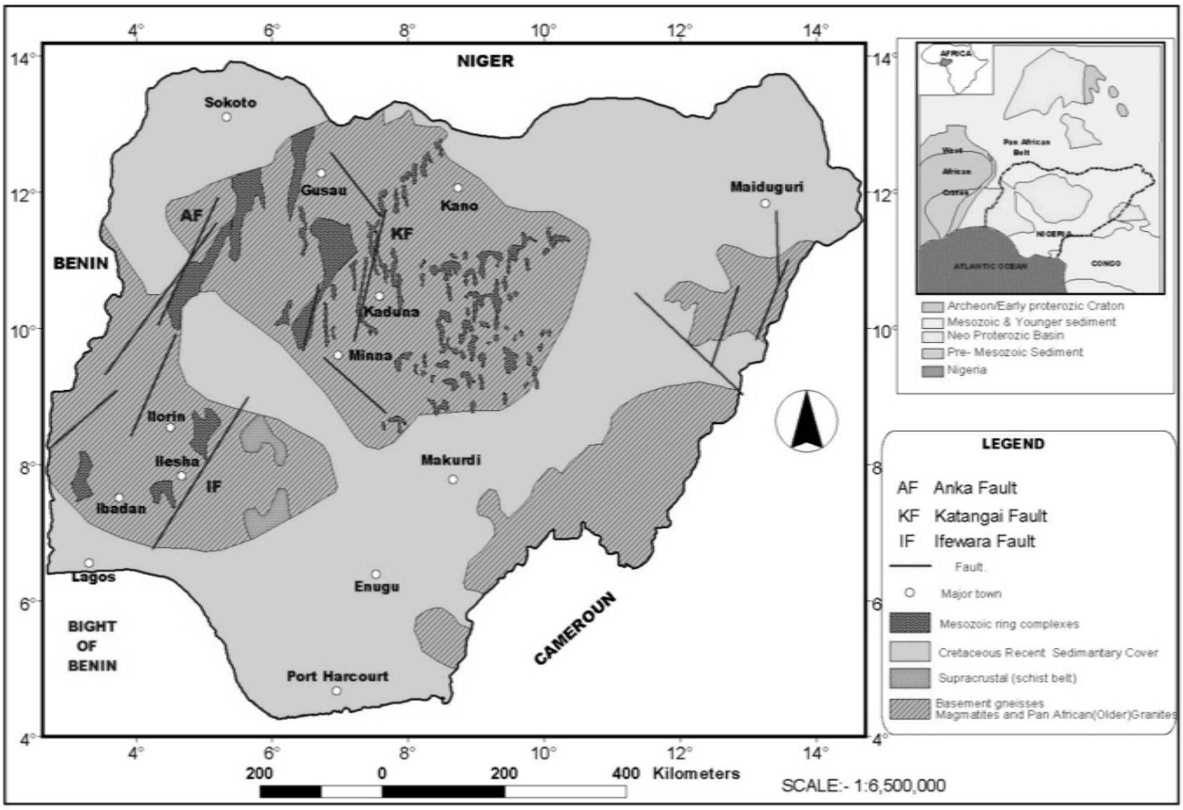

Fig. 1: Regional Geology of the Pan-African Shield of Nigeria, Inset Geological Map of Africa (Modified after 1994 edition of the Geological Survey of Nigeria Map).

METHODOLOGY

Several geophysical tools find application in locating and defining subsurface water resources in harder rock terrains [4]. They provide useful information on the subsurface geology of a region without the large cost of an extensive drilling progamme.
According to [23], the electrical resistivity method, of all the surface geophysical methods, has been most widely applied in groundwater exploration studies; this is so because it can clarify the subsurface structure, capable of delineating subsurface geology for engineering construction, delineate groundwater zone and is in expensive [9,18,24,17,21].
The electrical resistivity method can be best employed to estimate the thickness of overburden and also the thickness of weathered/fractured zones with reasonable accuracy [26, 15].
So, for this work, the electrical resistivity methods were considered because the field operation is easy, less field personnel is required, has greater depth of penetration in comparism with other methods employed in groundwater investigation. Twenty-one [21] stations were probed in the study area (Fig.2) using Vertical Electrical Sounding (VES) with Schlumberger electrode configuration (Fig.3).

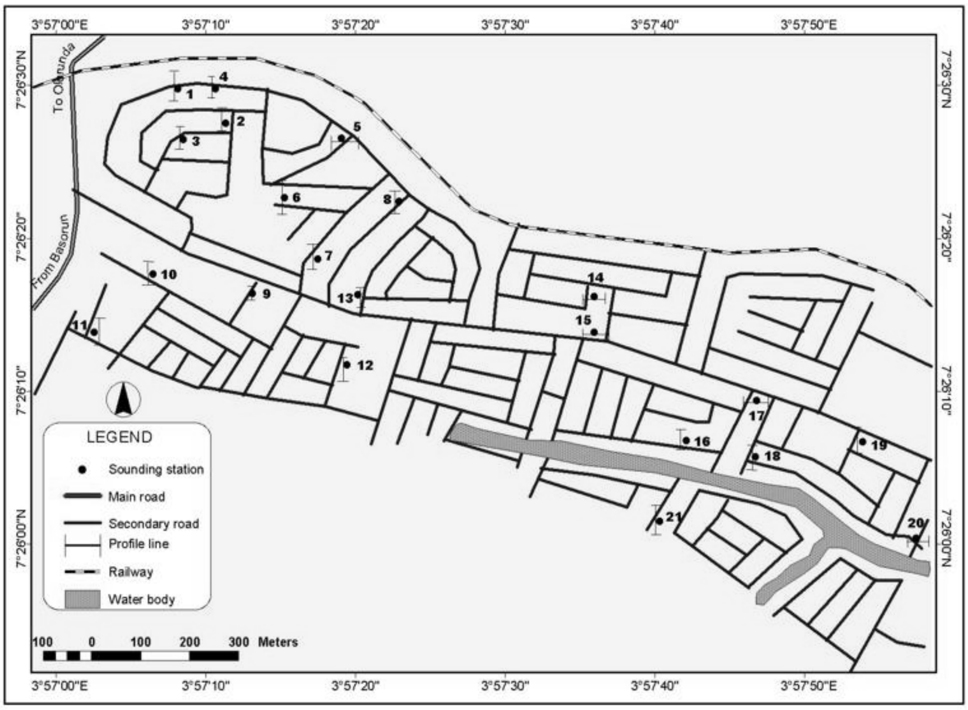

Fig. 2: Location Map of OKE-BADAN Estate,Akobo, Showing the Sounding Points.

Schlumberger Electrode Configuration

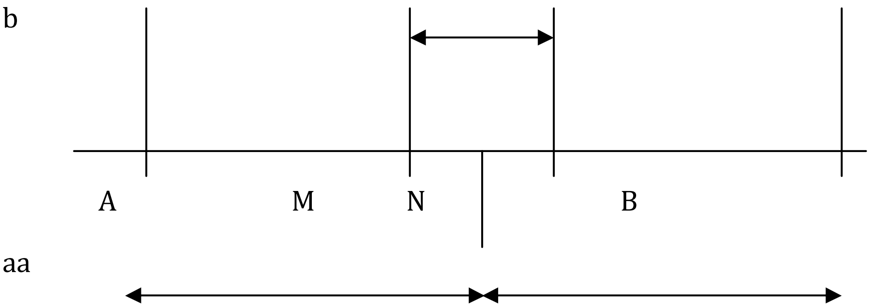

Fig. 3: Schlumberger Electrode Configuration

This involves spacing of four electrodes with two current electrodes widely spaced outside and two potential electrodes closely spaced within them along the survey profile (Fig. 3). In this array potential electrodes MN can be fixed while current electrodes A and B are changed. It is normally assume that MN < AB/5.

$AM = \frac{a-b}{2}$, $BM = \frac{a+b}{2}$, $AN = \frac{a+b}{2}$ and $BN = \frac{a-b}{2}$.

Using the above equation (6) where $G = \frac{2\pi}{\{(\frac{1}{AM})-(\frac{1}{BM})-(\frac{1}{AN})+(\frac{1}{BN})\}}$.

In Schlumberger array, $AM = \frac{a-b}{2}$, $BM = \frac{a+b}{2}$, $AN = \frac{a+b}{2}$ and $BN = \frac{a-b}{2}$.

i.e. $G = \frac{2\pi}{\{(\frac{1}{a})-(\frac{b}{2})-(\frac{1}{a})+(\frac{b}{2})-(\frac{1}{a})+(\frac{b}{2})-(\frac{1}{a})+(\frac{b}{2})+(\frac{1}{a})-(\frac{b}{2})\}}$

$= \pi\,(a^2/b - b/4)$

From. $\rho_a = GR = \pi R(a^2/b - b/4)$ where a is half array length and b is the minimum spacing between the potential electrodes. In this work the Schlumberger array was employed because it requires less man- power and it is less sensitive to the effects of near surface lateral inhomogeneities than the Wenner arrangement (20, 8). These advantages bring about a realistic quantitative interpretation of field data obtained.

RESULTS AND DISCUSSION

Simple statistical analysis of the geoelectrical parameters has been carried out on the twenty-one Schlumberger VES data obtained from the study locations (Table 1). Basic parameters analyzed include resisitivity and thickness of topsoil, resistivity and thickness of aquifer layer, resistivity of bedrock, overburden thickness (Resist and WinGLinkprogrammes), longitudinal unit conductance, hydraulic conductivity, and transmissivity.

Table 1: Geoelectric Parameters Analysed

VES No	Top Res (Ωm)	Top Thick (m)	Wea Res (Ωm)	Bedrk Res (Ωm)	Aquifer Thick (m)	Overbu. Thick(m) (Resist)	Overbu. Thick(m) (WinGLink)	Longi. Conduc (s)	Hydrau Conduc $X10^{-5}$ (m/s)	Trans-misivi $X10^{-5}$ (m^2/s)	Longitudinal Conductance
1	795	0.8	113	1093	8.4	15.9	15.3	0.02	6.14	51.3	51.3
2	396	0.7	25	1338	5.1	6.0	5.8	0.1	0.45	2.25	2.25
3	805	0.3	104.1	1319	12.8	14.8	13.1	0.1	0.44	2.82	2.82
4	2186	0.4	43	853	6	6.4	6.4	0.07	0.85	5.09	5.09
5	1698	0.3	117.5	5490	10.3	11.0	10.6	0.05	1.29	9.04	9.04
6	2713	0.8	161.8	1533	13.7	14.6	14.6	0.02	12.54	73.88	73.88
7	1488	0.4	126	5237	8.4	12.3	12.1	0.01	26.87	225.75	225.75
8	1015	0.3	189	715	9.4	11.9	11.7	0.01	11.48	108.29	108.29
9	1860	0.3	140	1264	11.4	15.9	14.5	0.03	18.01	204.49	204.49
10	185	1.7	98	870	19.8	25.4	25	0.04	5.33	105.63	105.63
11	635	8.0	174.3	553	10.4	14.6	13.6	0.06	8.54	19.5	19.5
12	261	0.9	196	1187	20.2	33.4	32.9	0.03	27.92	258	258
13	185	1.8	30	3072	5.1	9.1	8.7	0.06	0.56	2.8	2.8
14	237	1.8	86	1084	25.1	25.0	26.8	0.15	1.94	48.6	48.6
15	290	0.5	63	792	22.1	28.3	27.7	0.03	6.71	147.54	147.54
16	4209	0.2	48.9	1983	26.3	27.3	26.5	0.23	0.52	8.74	8.74
17	356	0.8	60	910	22.9	29.8	28.9	0.14	1.27	29.01	29.01
18	201	1.1	71	580	16.5	19.3	17.6	0.11	1.81	29.82	29.82
19	702	0.7	33	819	21.9	29.2	28.1	0.24	0.61	13.42	13.42
20	225	0.9	26	1114	12.3	13.8	13.2	0.24	0.47	5.81	5.81
21	242	1.0	25	1249	13.1	14.8	14.2	0.28	0.44	5.75	5.75

The results of geostatistical analysed are hereby presented in table 2 using Statistical Packages for Social Sciences (SPSS).

Table 2: Results of Geostatistical Analysis

Geoelectric Parameters	Range	Mean	Median	Mode	S.D.	Variance	Skewness
Topsoil Resistivity (Ωm)	185-4209	975.4	635	185	1055	113025	+0.97
Topsoil Thickness (m)	0.15-1.78	0.90	0.80	0.33	0.72	0.5184	+0.42
Weathered Resistivity (Ωm)	25-196	55	80.00	25.00	74	59049	+0.49
Bedrock Resistivity (Ωm)	553-5490	1454.6	1187	1185	1460.37	2131600	+0.54
Aquifer Thickness (m)	5.1-26.3	12.7	11.40	6.00	7.09	50.268	+0.55
Overburden Thickness(Resist)	5.95-33.36	18.0	14.78	14.26	8.21	67.4041	+1.17
Overburden Thick(Wingk)	5.80-32.90	17.5	14.48	14.20	8.20	67.24	+1.10
Longitudinal Conductance	0.01-0.28	0.095	0.06	0.05	0.08	$6.4x10^{-3}$	+0.44
Hydraulic Conductivity	0.44-27.92	6.4	1.29	0.45	8.53	72.7609	+0.59
Transmissivity	2.25-258.00	64.6	29.01	5.81	80.39	6448.09	+0.44

Resistivity and thickness of Topsoil

The value of topsoil resistivity ranges between 185 and 4209 ohm-m. The range of resistivity values suggests dissimilarities in the composition of materials constituting the topsoil in the study area. The mean value of topsoil thickness is 0.90m. The thin in thickness value is as a result of high resistivity mean value recorded in the first layer which is 975ohm-m.

Resistivity and thickness of Weathered Layer

The resistivity of weathered layer has a low range of values between 25 and 196 ohm-m with an average value of 55 ohm-m and a low standard deviation value of 74 ohm-m. The low range in value of the layer determines to a significant extent the yield of boreholes (6)

The resistivity suggests lithology in the suite of sandy clay, clayey sand and shale/clay to be widespread .Hydrogeologically, the weathered layer is relevant in groundwater prospecting when it is thick enough, above minimum thickness of 10m suggested by (25), the layer could support hand dug well (14).In this study area, the average value is 12.7m with a variance value of 50m which is relatively low and measures the degree of clustering of the data around the mean.

Resistivity of the Bedrock

It has a high mean value of 1454 ohm-m. According to (11), the resistivity values that exceeded 1000 ohm-m are of fresh bedrock and if less, the bedrock is fractured and saturated with fresh water.

From table 1, it was shown that few location give low resistivity value less than 1000 ohm-m which suggests lithology in the suite of clayey sand (VES 4,11,18 &19), sandy clay (VES 17),and fractured(VES 8,10&15) . This gives 38% of the total study area. Therefore, it could be stated that, areas with low bedrock resistivities are the areas of prospects in term of groundwater abstraction.

Longitudinal Unit Conductance (S)

Using the equation $S_i = h_i/p_i$ where h_i and p_i are the $_i$th layer thickness and resistivity respectively. The conductance is related to clay content which increases the porosity of a layer but decreases its permeability according to [22].

Since permeability decreases with an increase in conductance, therefore the overburden might have absorption and retention capacity. In the study area, the conductance has a range of value between 0.01 and 0.28 with an average value of 0.095 Siemen and very low in most of the locations. Many of the locations have low clay content thus, a decreased porosity of the layer but an increase in its permeability. The longitudinal unit conductance is positively skewed.

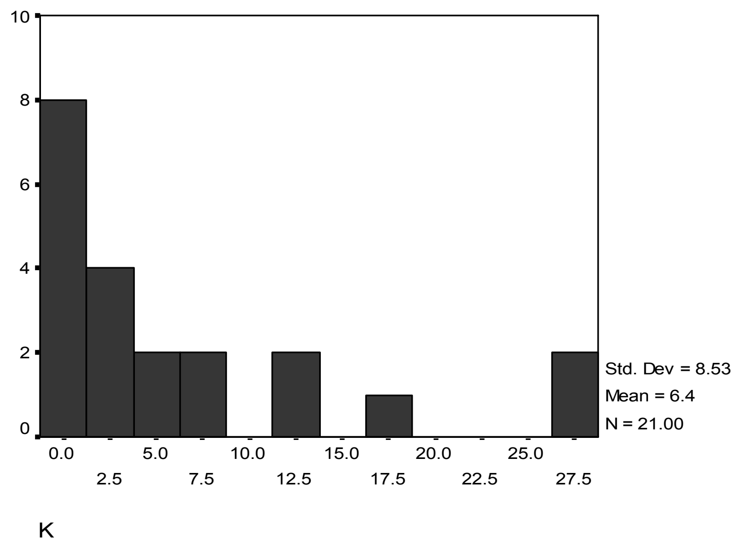

Figure 4: Hydraulic conductivity Histogram

Hydraulic Conductivity (K)

Using the relation $K = 95.5x10^{-9}\ p^{1.195}$ where p is the resistivity of the porous layer in ohm-m [9], the conductivities was found to vary from aquifer to aquifer and range from 0.44 x 10^{-5} m/s to 27.92 x 10^{-5} m/s with a mean value of6.4 x 10^{-5} m/s.

In general, these values are very low except in a few locations which are moderately high (VES 7 and VES 12) as shown in table 1. The low values recorded could be attributed to the clay content in the aquifers and the fact that the degree of hydraulic conductivity between the fractures is low.The mean is low (6.4), and K is positively skewed with value 0.59 as a result of low departure from the symmetry. The scatter is also small with a very low value of standard deviation 8.53 as recorded in hydraulic conductivity histogram (Fig.4).

Transmissivity (T)

It is the rate at which water flows through a vertical strip of the aquifer of unit width and extending to full saturated thickness under hydraulic gradient 1.00. Using T = Kh, where K is the coefficient of conductivity (m/s), h is the aquifer thickness (m), the estimates of T obtained in the study area shows that the value ranges from 2.25×10^{-5} to 258×10^{-5} m^2/s.

In general, it is very low in many of the locations since; the values are expected to be higher than the values recorded. The weathered nature of the basement rock may be responsible for the relatively low transmissivity values. The average value recorded is 64.6×10^{-5} m^2/s with a relatively high standard deviation value of 80.39. It is positively skewed with value 0.44.

CONCLUSION

Based on the electrical resistivity survey conducted in the study area, geostatistical analysis of Oke-Badan has been evaluated. The longitudinal unit conductance value is between 0.01 and 0.28, the hydraulic conductivity value is between $0.44 \times 10^{-5}$and 27.92×10^{-5}, and the transmissivity value is between $2.25 \times 10^{-5}$and 258×10^{-5}.

The low range of values recorded by the longitudinal unit conductance, hydraulic conductivity and transmissivity could be attributed to the clay content in the aquifers which affect the porosity of the layer.

Weathered and fractured horizons which underlie VES stations constitute the aquifer zones have been identified in the study area [7].

It is recommended that, the study area where overburden layer is relatively thick and has favorably low resistivity values should be considered for groundwater development.

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