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Delineation of Groundwater Potential Zones in Tanke Area of Ilorin, Southwestern Nigeria

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ABSTRACT

Results of 24 Vertical Electrical Soundings, using the Schlumberger configuration were used to explore for groundwater potential of in Tanke area of Ilorin, Southwestern Nigeria. Field data were processed using the partial curve matching and iterative resistivity sounding interpretation software, WinResist Version 1.0 of 2004.The results show three to five geoelectric layers, namely: the top soil, lateritic clay, weathered basement and Fresh/Fractured basement rock. The topsoil had resistivities ranging from 60.2 - 889.7Ωm to a depth of 0.9-6.6m. The regolith layer had resisitivities ranging from 21.7-479.0Ωm to a depth of 1.9m-14.1m. The weathered aquifer unit had resistivities ranging from 45.7 -188.8Ωm to a depth of 9.0-38.5m. The fractured basement where encountered, had a resistivities ranging from 116.6-374.7Ωm to depth rangebetween 15.8-41.2m while the unfractured bedrock had resistivity value greater than 3747.7Ωm. From the two dominant geoelectric sounding curve types identified, H and HA, it is can be interpreted thatlocalized fractured basement rocks of the study area constitute and control the major aquifers system in the area. This is reflected in the hydro-resistivity mapwhich was used to categorise the area into Low, Medium and Highpotential for groundwater exploration with the southwestern region having the highest potential.

KEYWORDS: Delineation, Potential, Exploratory, Groundwater, Tanke

Introduction

Groundwater is a very important natural resource for socio-economic development of an area or even a nation at large. It is the only viable source of portable water in many rural areas where development ofsurface water is not economically viable. Tanke community is underlain by the Precambrian rocks which are generally regarded as impermeable and have no appreciable water storage capacity (Offodile, 2002).The availability of groundwater in theserocks is largely due to the development of secondary porosity and permeability resulting from weathering and fracturing. The productivity of any aquifer however is a function of the permeability, porosity, geometry of the reservoir rock, mineralogy and degree of weathering (Olasehinde and Taiwo, 2000; Omorinbola, 1979 and Omosuyi, 2007).

The integration of electromagnetic method (EM) and geoelectric sounding techniques of electric resistivity methodhas been successfully and extensively used for groundwater exploration in the basement terrains of Nigeria because of their accuracy in defining geoelectric contrast and operational convenience (Olorunfemi *et al.*, 1991;Ariyo *et al.*, (2009).The geoelectric sounding using the Schlumberger array has proved useful especially for delineation of weathered and fractured zones which are the major aquifers in the basement rocks.

According to Ademilua *et al.*, 2012; Olayinka, 2000; Olayinka *et al*., 2004, the geoelectric succession in the basement terrains of Nigeria usually consists of a thin (0 - 2 m) resistive topsoil (between 40.0-1000 ohm-m), a highly resistive lateritic layer (with resistivities between 1000-3000), conductive clay/weathered basement (with resistivity between 20-200 ohm-m and thickness less than 35m), a fractured/slightly weathered material (with resistivity between 300-750 ohm-m and thickness exceed 100.0 meter) and a highly resistive crystalline basement whose resistivity exceeds 3000 ohm-m. Any basement rock resistivity exceeding 3000 ohm-m can be thought of as representing fresh basement containing little or no water (Oloruniwo *et al.,* 1987).

The present study aims at determining the geoelectric parameters (layer resistivity, layer thickness) coefficient of an isotropy of the subsurface layer in order to delineate the aquiferous zones.

Materials and Methods

The study area (Tanke Community) is located in the Ilorin South Local Government Area of Kwara State, southwestern Nigeria. It lies within latitudes 04°.20’N to 5°.55’N and longitudes 8°.2E to 8°.4’E (Fig. 1). It covers an area of about 2.3sq Km. Thearea is tropical and falls within the dry lowland rainforest which is typical of the sub-equatorial beltof southwestern Nigeria The mean annual rainfall in the area is between 1000-1500mm with mean annual temperature in the range of 25-27.50C . It is also characterized by two Seasons, namely: the dry season which lasts from November-March and the rainy season that lasts from April-October.

The study area is underlain by Pre-Cambrian crystalline rocks of the Basement Complex. Rahaman, (1989) classified the Basement Complex rocks of Nigeria into five (5) groups namely:

(i) Migmatite-Gneiss-Quarzite Complex which comprises of migmatite, gneisses, quartzite and quartz schist and small lenses of calsilicate rocks.
(ii) Slightly migmatised to unmigmatised paraschist and meta-igneous rocks.
(iii) Charnockitic rocks.
(iv) Older Granites which comprises of rock varying in composition from granodiorite to granite and potassicsyenite.
(v) Unmetamorphosed doleritic dykes.

The area is underlain by the Migmatite-Gneiss-Quarzite Complex rocks and the main rock type is the Granitic gneiss (Fig. 1). In places where these rocks are not exposed, the fresh basement rock is overlain by the weathered basement rock (saprolite) which comprises clayey/sandy materials derived from in-situ chemical weathering of the parent rocks. The studyarea can be divided into two hydro-geological units namely: the aquiferous zone within the weathered overburden overlying the major basement rock and the aquiferous zone within the intense fracture and joint systems in the partially weathered basement.

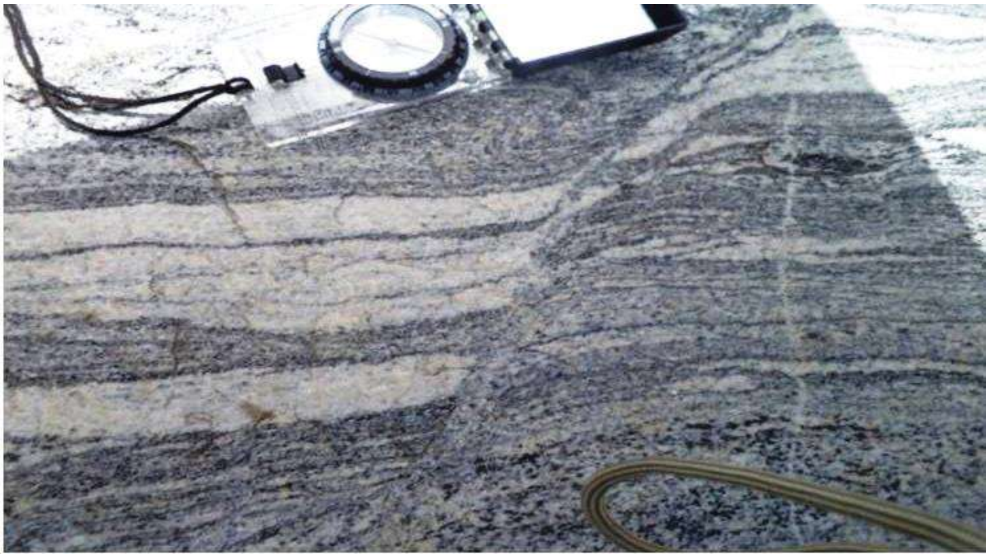


Figure 1: Granitic Gneiss as the major rock type in the study area (around Minaret School).

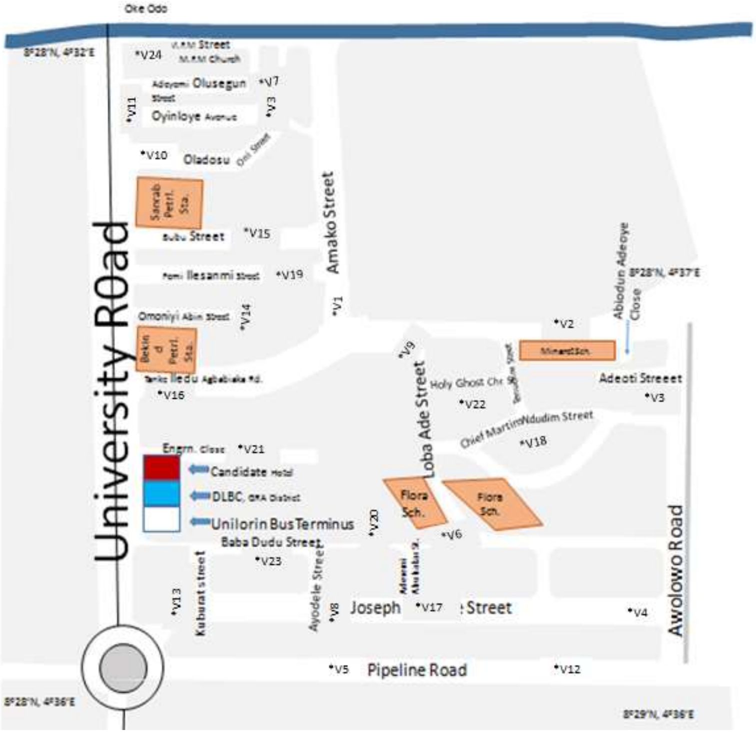


Figure 2: A sketch of the layout of study area.

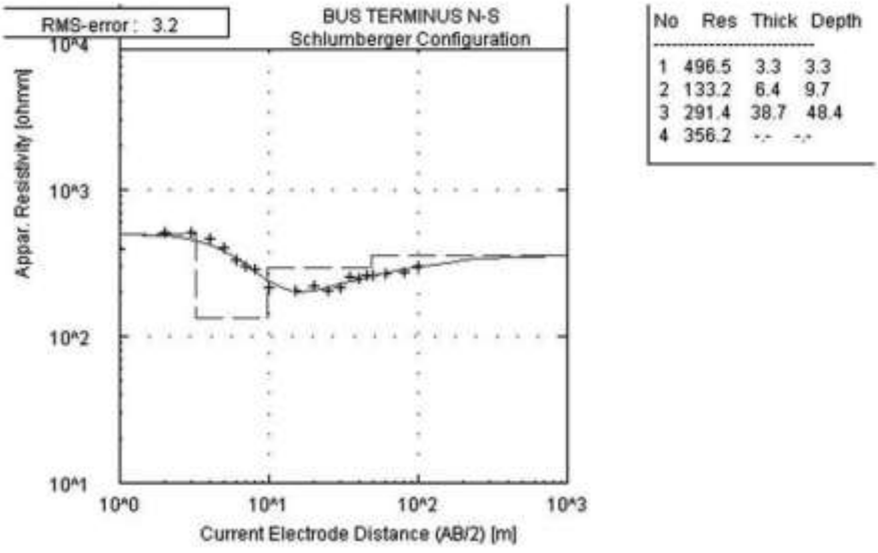
Geoelectric sounding (VES) surveys in the area were conducted using ABEM SAS 300Cterrameter with its accessories. Twenty Four (24) geoelectric soundings were carried out in the studyarea (Fig.2). The Schlumberger electrode array was employed with the maximum electrode spacing (AB/2) of 100m. The axes of all the geoelectric soundings were aligned parallelto the geological strike in order to reduce the effects of lateral variations where possible. The field data obtainedwas first interpreted using partial curve matching approach (Orellana and Mooney, 1966) whereas the layer thicknesses and resistivities thus obtained served as the input for iterative resistivity sounding interpretation software, WinResist Version 1.0. The Golden SURFER 8.2 was used to produce the relevant hydro-resistivity map of the study area.

Results and Discussion

Geoelectrical Characteristics

Interpretation of the geoelectric sounding data acquired in the area shows three to five geoelectric layers (Table 1.0), namely: the topsoil (60.2 to 889.7 ohm-m), Clay/ lateritic layer (21.7 to 479.0 ohm-m), weathered layer (116.6 to 374.7 ohm-m), Slightly weathered basement rock (1588 to 2588.9 ohm-m), fractured fresh basement rock (2419 to3605 ohm-m). The weathered basement (saprolite) and fractured basement rocks constitute the major aquifers zones in the area. Geoelectric sounding curve types identified are H, HA, HK, QH, KH, A and AA which represent typical Basement complex area.

Over fifty percent (50%) of all the sounding curves are HA and H curve types (table 1). Therefore, the HA and H curve types are the dominant sounding curves in the study area which suggest that the major aquifer is in the weathered basement and fractured basement aquifer (Fig. 2).



No	Res	Thick	Depth
1	496.5	3.3	3.3
2	133.2	6.4	9.7
3	291.4	38.7	48.4
4	356.2	-.-	-.-

Figure 2: A typical Geoelectric sounding curve from the study area.

Table 1: Summary of the Geoelectric Parameter and Model Theoretical Resistivity Curve Types of the Study Area.

NO.	STREET NAME	LAYER THICKNESS	LAYER RESISTIVITY	CURVE TYPE	OVER BURDEN THICKNESS (M)	LITHOLOGY
1	AMAKO STR	2.4/4.8/25.1/-	657.5/127.1/141.8/474.7	HA	7.0	Topsoil/ Clay lateritic/Weathered/ Fractured rock.
2	MINARET SCHOOL	1.4/5.3/37.6/-	887.7/224.9/1543.0/2898.9	HA	6.7	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
3	ADEOTI STR	2.2/5.6/23.0/-	87.1/25.8/182.3/395.9	HA	7.8	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
4	AWOLOWO ROAD	1.3/4.3/32.3/-	99.1/50.6/328.5/356.6	HA	5.6	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
5	PIPELINE RD	5.0/7.1/17.3/-	666.4/203.3/715.2/3112.3	HA	12.1	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
6	FLORA SCHOOL	2.6/7.0/19.4/28.7/-	832.5/199.8/251.5/308.4/801.9	QQH	9.6	Top soil/ Lateritic clay/ Weathered rock/ Slightly weathered rock/ Fractured rock
7	ADEYEMI	1.4/13.3/-	181.5/74.6/765.3	H	14.7	Clay/lateritic/ weathered/ Fractured rock
8	AYODELE	1.6/10.7/19.9/-	195.9/56.1/582.8/1335.7	HA	12.3	Top soil/ Clay/lateritic/

						Slightly weathered/ Fractured rock
9	LOBALADE	5.6/4.5/10.8/17.7/-	78.8/52.8/36.3/166.7/502.0	QHH	20.9	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
10	OLADOSU	2.4/4.0/19.7/41.7/-	179.4/89.3/1720.4/663.4/1217.4	QQH	6.4	Top soil/ Lateritic clay/ Weathered rock/ Slightly weathered rock/ Fractured rock
11	OYINLOYE	1.8/8.1/10.9/24.8	275.2/479.0/586.9/2125.1/2812.2	AA	9.9	Top soi/ Lateritic clay/ Weathered rock/ Slightly weathered rock/ Fractured rock
12	PIPELINE	1.0/1.9/18.4/42.2/-	130.3/21.7/800.4/201.8/501.0	QQH	21.3	Top soil/ Lateritic clay/ Weathered rock/ Slightly weathered rock/ Fractured rock
13	KUBURAT DRIVE	4.7/5.9/9.6/27.2/-	300.3/51.7/280.5/481.2/377.6	HAH	10.6	Top soil/ Lateritic clay/ Weathered rock/ Slightly weathered rock/ Fractured rock
14	OMONIYI	2.1/6.0/33.4/-	533.4/86.4/144.8/410.2	HA	8.1	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
15	BUBU	2.5/7.2/38.5/-	73.7/325.1/125.0/449.0	KH	9.7	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
16	TANKE-	1.3/3.9/12.9/37.2/-	107.8/37.2/196.9/116.5/376.5	HKH	5.2	Top soil/ Clay/lateritic/

	ILEDU					Slightly weathered/ Fractured rock
17	JOSEPH	0.9/8.4/24.8/-	183.8/38.9/163.9/324.0	HA	9.3	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
18	CHIEF MARTHINS NDUDIM	2.9/5.2/19.2/41.2/-	190.2/58.1/555.5/318.2/689.9/514.5	QQH	8.1	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
19	FEMI ILESANMI	6.6/6.0/18.0/-	514.5/267.3/318.4/2123.0	HA	12.6	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
20	BUS TERMINUS	3.3/6.4/38.7/-	496.5/133.2/291.4/356.2	HA	9.7	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
21	ENGINEERING CLOSE	1.5/10.0/15.9/17.0/-	253.8/341.3/1861.8/1551.2/2521.3	AH	11.5	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
22	HOLYGHOST CHURCH	2.3/7.6/13.0/-	569.6/216.3/272.2/3747.7	HA	9.9	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock
23	BABADUDU	1.8/3.3/10.5/15.6/-	60.2/149.1/48.4/226.0/378.9	KHH	15.6	Top soil/ Lateritic clay/ Weathered rock/ Slightly weathered rock/ Fractured rock
24	MFM CHURCH	5.0/5.8/12.4/-	343.6/98.0/306.3/1055.3	HA	10.8	Top soil/ Clay/lateritic/ Slightly weathered/ Fractured rock

Coefficient of Anisotropy (λ)

The coefficient of anisotropy (λ) is a measure of the degree of in homogeneity of a medium. From the vertical electrical sounding (VES) quantitative interpretation, the geoelectric parameters for each sounding station were determined. Using the relevant equations (Keller and Frischknecht, 1966 and Zohdy *et al.,* 1974), the layer resistivity and thickness can be converted into coefficient of anisotropy (λ) values.

$$\lambda = \sqrt{\frac{\rho_t}{\rho_i}} = \sqrt{\frac{\sum_{i=1}^{n-1} hi\rho i \sum_{i=1}^{n-1} \frac{hi}{\rho}}{(\sum_{i=1}^{n-1} hi)^2}}$$

where

ρ_t is the traverse resistivity

ρ_i is the longitudinal resistivity

i the summation limits vary from 1 to n-1 where the nth layer represents the infinitely resistive bedrock.

The anisotropic value for each of the VES stations is contoured and presented as map (Fig. 3).

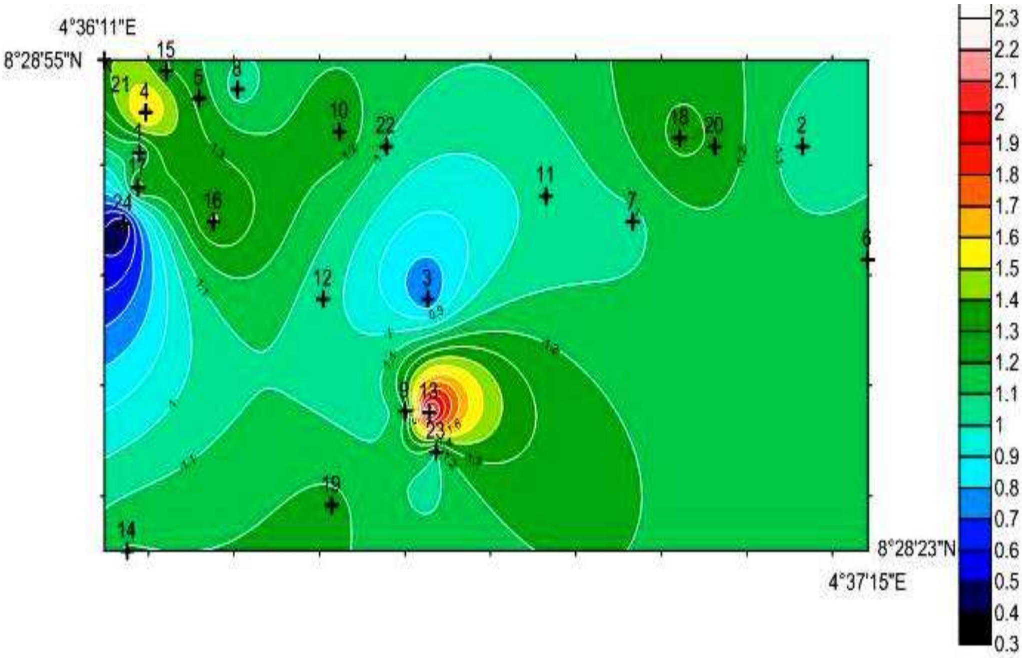


Figure 3: Coefficient of anisotropy map of the area.

1. Those areas with peak values are the most promising locations for groundwater prospecting (Olorunfemi and Okhue, 1992). Groundwater yield increase linearly in the basement complex of Nigeria with increase in coefficient of anisotropy (Olorunfemi and Olorunniwo, 1985; Olorunfemi *et al.*, 1991). Thus, Hydro-resistivity map generated from geoelectric parameters and the Coefficient of anisotropy map were used to delineate areas of groundwater potential (Fig. 4).
2.

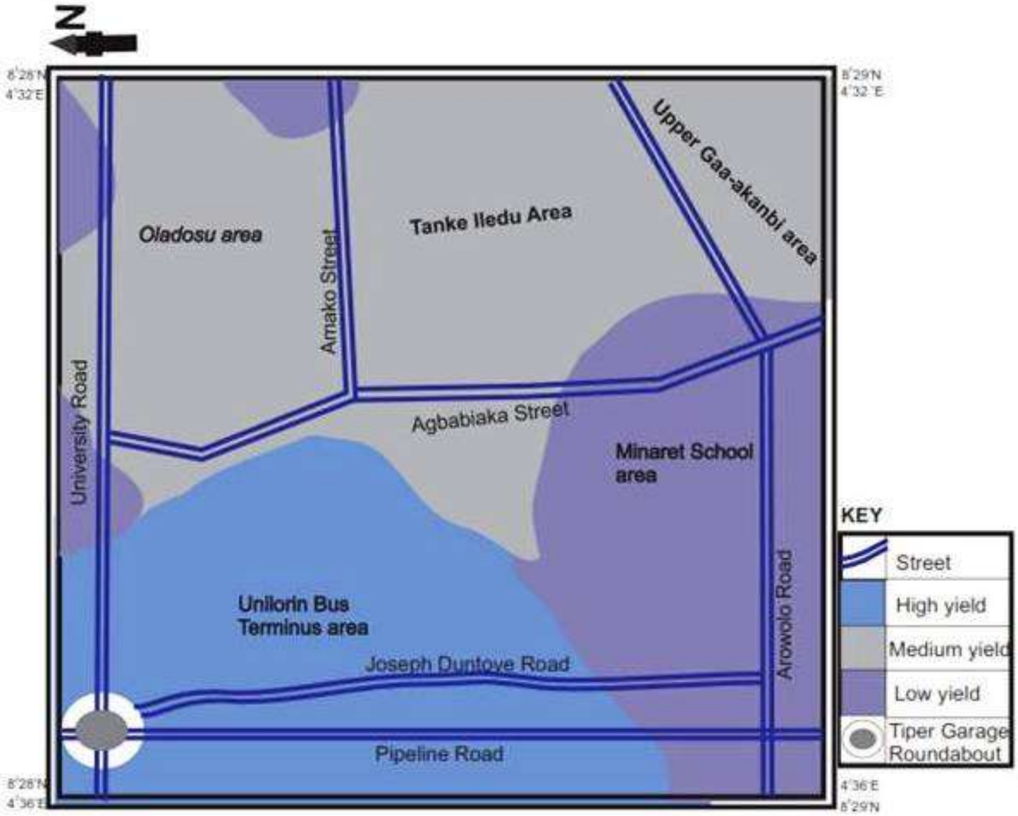


Figure 4: Groundwater Potential Map of the study area

Conclusion

The investigation of the study area for groundwater potential provides the following conclusion.

3. Three to five geoelectric layers were encountered, namely: the topsoil (60.2 to 889.7ohmm), Clay/Lateritic layer (21.7 to 479.0 ohmm), weathered/slightly weathered basement rock (116.6 to 374.7 ohm-m), fractured basement rock (1588 to 2605 ohm-m) and fresh basement rock (>3419 ohm-m).
4. The weathered layer and fractured basement rocksare the major factors controlling groundwater availability.

5. Two dominant geoelectric sounding curve types identified are H and HA which is an indication of a typical basement complex area.
6. About one-third of the study, limited to the southwestern region has high groundwater potential

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