



Geoelectrical Evaluation of Groundwater Potentials of Shongom and Environs, Upper Benue Trough, Nigeria

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ABSTRACT

The lack of pipe-bone water and ephemeral nature of the streams in the study area necessitates the utilization of groundwater for domestic use. To efficiently harness groundwater resources, the presence and depths of aquifers needs to be determined before drilling, this is best achieved by resistivity method of geophysical exploration. Previous work in the study area have shown that the water in the study area is safe for drinking and other domestic activities but the distribution and depths to groundwater aquifers have not been reported. This study is aimed at determining the presence and depths of groundwater aquifers at different locations in the study area. Vertical electrical sounding (VES) technique using schlumberger array was used to acquire the data at twenty six (26) different locations (VES station/point). The acquired data were processed using WinResist 2 software which gives a sounding curve, the number of geoelectric layers, thickness of the layers and their depths from the surface. The results shows that most parts of the study area are underlain by three to four geoelectric layers: high (> 90 Ωm) and fairly-high resistivity (40.9 – 74.4 Ωm) layers which are mostly encountered either close to the surface or deep down, medium resistivity (11.5 – 39.9 Ωm) layers and low resistivity (0.6 – 10.6 Ωm) layers which are suspected to be aquifers. The thickness of these geoelectric layers range from 0.6 m to 27.1 m. The fairly-high resistivity layers mostly consists the overburden while the high resistivity layers are suspected to be either crystalline rocks or highly indurated sedimentary rocks. Most parts of the study area are rich in groundwater and the aquifers are found within the porous and permeable sandstones of the Bima Group in the sedimentary areas, while overburden and fractured crystalline aquifers are found in areas underlain by the crystalline rocks at a depth range of 20 – 40 m.

Keywords: Shongom, Groundwater, Resistivity, Schlumberger, Vertical Electrical Sounding

INTRODUCTION

Water is an essential commodity to mankind, and the largest available source of fresh water lies in the earth’s subsurface. Increased demands for water due to increasing population and urbanization among others have stimulated the development of groundwater supplies and the last few decades have witnessed a tremendous increase in the application of geophysical techniques in search for groundwater. Lovelyn *et al.*, (2016) studied the pH, temperature, Ec and TDS of waters in part of the study area and reported the water to be fresh water and within the WHO and NIS standard and utilizable for drinking and other domestic purposes. The communities in the study area (Figure 1) rely on groundwater supply for domestic use due to lack of pipe-bone water and the few streams in the area are mostly ephemeral and unhygienic. Thus, groundwater exploration of the deep weathered and fractured aquifers within the study area become imperative. This research employed the use of electrical resistivity

method using vertical electrical sounding (VES) techniques to explore the groundwater potential of the study area for human sustainability and development. The study will provide information on depth to which groundwater can be exploited and reveal the geoelectrical layers one may encounter in the subsurface, which may coincide with geological layers.

The study area (Shongom) is part of sheet 173, Kaltungo Southwest. It is underlain by both Precambrian basement rocks and sedimentary rocks, and forms part of the Gongola Sub-basin (or Arm) of the Upper Benue Trough, Northeastern Nigeria. Rock types encountered during field work include porphyritic biotite granite, hornblende biotite granite, sandstone of the Bima Formation and Basalt. Structures encountered include veins, dykes, fractures joints and bedding planes. Figure 1 shows the geology of the study area. A summary (Table 1) of water storage capacity of the various lithologies found within the Gongola Sub-basin is given by Lovelyn *et al.*, (2016).

Table 1: Lithology and storage of formations (After: Lovelyn *et al.*, 2016)

S/No.	Formation	Lithology	Storage
1.	Kerri- Kerri	Mainly silt sandy clay and sandstone	Deep layer aquifer
2.	Gombe	Sandstone, siltstone, clay and ironstone	Aquifer-Aquicludes
3.	Pindiga	Shale with limestone	
4.	Yolde	Shelly clay, sandstone	Aquifer
5.	Bima	Feldsparthic sandstone, medium to coarse grained	Aquifer
6.	Basement	Granite, Gneiss	Weathered, fractured zone

systematically, the change in the apparent resistivity will be a function of electrode spacing. Subsurface resistivity is measured by applying an electric current through two current electrodes and measuring the resulting voltage

$$U_1 - U_2 = \Delta U = \frac{I\rho}{2\pi} \left\{ \left(\frac{1}{r_1} - \frac{1}{r_2} \right) - \left(\frac{1}{r_3} - \frac{1}{r_4} \right) \right\} \dots\dots\dots (1)$$

$$\Delta U = \frac{I\rho}{2\pi} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right) \dots\dots\dots (2)$$

$$\rho = \frac{\Delta U}{I} \frac{2\pi}{\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right)} \dots\dots\dots (3)$$

Where ρ is the resistivity, I is the current and $r_1, r_2, r_3,$ and $r_4,$ are the inter-electrode distances as shown in Figure (4).

$$\rho_a = K_f \left(\frac{\Delta U}{I} \right) \dots\dots\dots (4)$$

Where K_f is the geometric factor and it depends on electrode configuration used in the field measurement. By measuring ΔU and I and knowing the electrode configuration, the resistivity can be calculated. Over uniform earth or homogeneous isotropic medium this calculated resistivity is constant for different electrode separation and any current. However, if the ground is inhomogeneous, the calculated resistivity varies as the electrode spacing is varied or the array is moved about. This calculated resistivity is called “apparent resistivity ρ_a ”, which is diagnostic of the real resistivities of the subsurface in the vicinity of the electrode array. The apparent

difference between potential electrodes. For the general four electrode spread, the potential difference ΔU between the potential electrodes is given below:

resistivity may be smaller or larger than the real resistivities or in rare cases identical with one of the real resistivity values. The apparent resistivity is the same as the real resistivity in a homogeneous subsurface, but normally a combination of contributing strata of an inhomogeneous subsurface. The value of the apparent resistivity obtained with small electrode spacing is called the surface resistivity. In any electrode layout, the potential and current electrodes can be interchanged and from the principle of reciprocity, the apparent resistivity should be the same (unchanged) in either case.

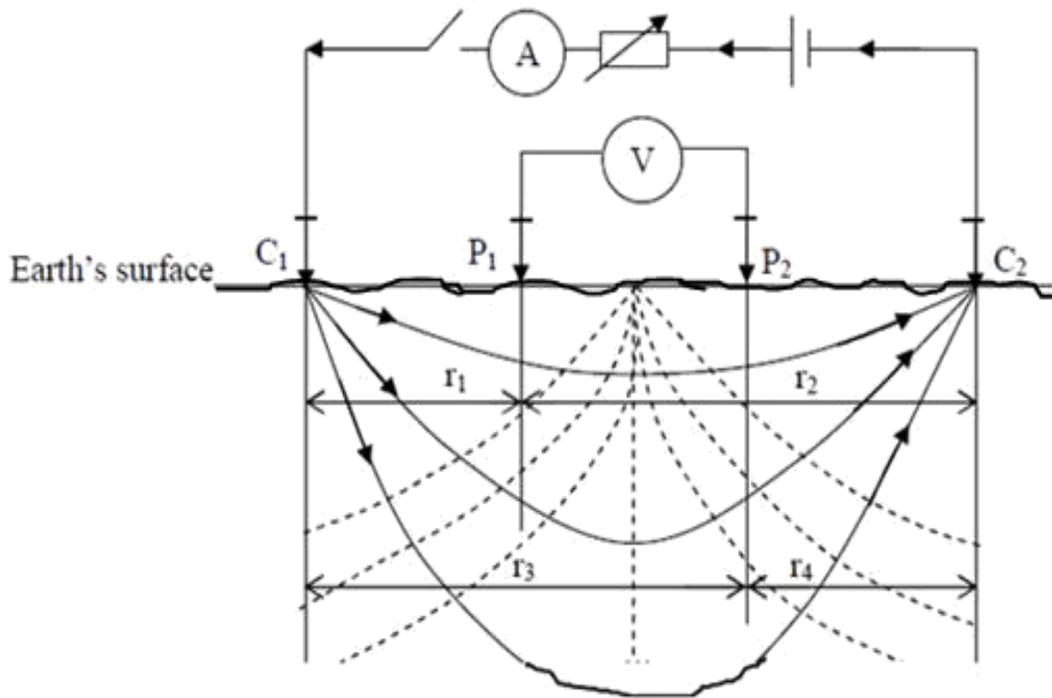


Figure 4: General-four electrode arrangement.

MATERIALS AND METHODS

Data Acquisition

The Vertical Electrical Sounding (VES) data was acquired using terrameter, steel electrodes, wire cables, tapes and hammer. A global positioning system (GPS) receiver was used to take the geographic coordinates of the sounding stations or VES points. Schlumberger array was used in acquiring the VES data with 80 m long profiles. The profiles were laid with different orientations that depend on the topography of the area. Profile orientation with least topographic undulation were chosen to minimize the effect of topography which distorts equipotential surfaces and leads to false resistivity anomalies or masks the real resistivity anomalies (Telford et al., 1990).

Data Processing

The resistivity data were processed using WinResist software. WinResist software generates resistivity curves from the modeled data and presents the result as resistivity curve, number of geoelectric layers (geoelectric layers can be the same with geologic sections if there is marked change in texture), layer thickness and depth. WinResist is a forward and inverse modeling program for interpreting resistivity sounding data build for the various resistivity sounding methods or configurations such as the Schlumberger configuration. The assumption during the interpretation is that the underlying formation is horizontal and parallel to the earth's surface.

RESULTS AND DISCUSSION

The result in Table 2 shows the processed VES data including VES location, the number of geoelectric layers and apparent resistivity for each layer, and resistivity curve type that best describes the modeled data. The dominant type of resistivity curve obtained from the data is the H-type, which is characterized by a low (minimum) resistivity geoelectric layer overlain and underlain by higher resistivity geoelectric layers. This is the type of resistivity curve that is commonly associated with areas that have groundwater and the region of the aquifer is where the lowest resistivity values are obtained.

The geoelectric layers obtained from the processed data can be grouped into:

High resistivity ($> 90 \Omega\text{m}$) layers: These layers are interpreted to be the unweathered crystalline rocks of the study area, while in the sedimentary portion of the study area, the high resistivity values were observed to be associated with highly consolidated sandstones of the Bima Group. The crystalline rocks and highly compacted sedimentary rocks normally have low porosity and permeability, except where they are faulted, fractured or jointed. Thus, they are devoid of groundwater which influences the resistivity. Non-fractured crystalline rocks have a porosity of $<3\%$ (Offodile, 1976). Fairly-high resistivity ($40.9 - 74.4 \Omega\text{m}$) layers: These layers are interpreted to represent the slightly weathered and fractured zone, and the slightly porous and permeable rocks underlying the weathered material. The extent of weathering and fracturing is generally limited in crystalline rocks (Offodile, 1976). As a result, groundwater may occur only in small pocket or basins depending on the extent of weathering.

Medium resistivity ($11.5 - 39.9 \Omega\text{m}$) layers: medium resistivity values were observed to be associated with topsoil, weathered zones and some low permeability sedimentary layers.

Low resistivity ($0.6 - 10.6 \Omega\text{m}$) layers: This unit is characterized by low resistivity values relative to the medium and high resistivity units. These units were interpreted as the highly weathered and highly porous and permeable sandstones composed of sands, clays or clayey sands depending on the local variation of the mineralogy of the basement and sedimentary rocks. These units may contain groundwater, large enough to produce a successful borehole where thickly developed.

Conclusion

Most of the sounding points have shown good prospects for groundwater which can be best exploited through drilling of boreholes. The aquifers are mostly shallow with depths range of 20 – 40 m.

VES Position	Layer No.	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Northing	Easting
Lapandintai VES 01	1	123.8	0.7	0.7	Q	9°36'12.20"	11°11'39.50"
	2	9.7	4.8	5.5			
	3	8.9	--	--			
Lapandintai VES 02	1	899.5	2.1	2.1	H	9°35'23.22"	11°11'06.06"
	2	150.2	14.3	16.3			
	3	204.2	7.9	24.2			
	4	1443.4	--	--			
Yebilo	1	31.6	0.6	0.6	K	9°36'40.90"	11°09'49.00"
	2	4597.4	5.8	6.4			
	3	489.0	14.9	21.3			
	4	200.4	--	--			
Lakalgam	1	846.3	1.4	1.4	H	9°35'29.40"	11°11'09.30"
	2	7.8	6.7	8.1			
	3	24.2	--	--			
KammoDran	1	210.4	1.0	1.0	H	9°37'01.10"	11°09'50.50"
	2	38.5	6.9	7.9			
	3	152.6	8.2	16.1			
	4	843.5	--	--			
Gomle	1	595.4	1.1	1.1	Q	9°36'11.90"	11°12'20.70"
	2	69.0	15.0	16.1			
	3	19.4	--	--			
Kauri	1	62.0	2.9	2.9	A	9°45'58.90"	11°13'34.61"
	2	1967.1	3.7	6.6			
	3	5547.9	14.6	21.2			
	4	2611.7	--	--			
Kushi	1	11.5	4.6	4.6	H	9°37'11.66"	11°16'30.49"
	2	3.7	11.4	16.0			
	3	14.2	--	--			
Dejam- latidi- burak	1	388.7	0.9	0.9	H	9°47'10.90"	11°14'44.52"
	2	10.6	15.6	16.4			
	3	26.7	--	--			
Labeke	1	115.0	1.1	1.1	H	9°35'35.90"	11°02'30.80"
	2	33.2	1.6	2.7			
	3	17.1	5.4	8.1			
	4	40.9	--	--			
Kane	1	307.4	1.1	1.1	H	9°35'57.50"	11°11'20.02"
	2	43.3	15.8	16.8			
	3	95.7	--	--			
Yeburo	1	20.9	2.1	2.1	A	9°34'23.61"	11°05'37.48"
	2	81.4	3.9	6.0			
	3	115.5	4.6	10.6			
	4	313.9	--	--			
Shagaram	1	940.1	1.3	1.3	A	9°36'04.72"	11°00'59.31"
	2	564.5	1.7	3.0			
	3	79.4	2.8	5.8			
	4	544.2	2.3	8.1			
	5	10394.1	--	--			
Gwandum Primary School	1	109.8	0.6	0.6	H	9°39'16.73"	11°17'31.13"
	2	9.8	14.5	15.1			
	3	95.5	--	--			
KasuwanDwaja	1	29.9	0.6	0.6	H	9°38'03.70"	11°20'22.48"
	2	5.5	19.9	20.5			
	3	22.5	--	--			
Labayo	1	157.1	3.1	3.1	Q	9°37'57.26"	11°18'44.72"
	2	39.9	4.6	7.7			
	3	15.2	--	--			
FadaBagunji	1	114.1	0.6	0.6	H	9°53'38.00"	11°15'09.10"
	2	14.3	16.6	17.2			
	3	40.1	--	--			
BilwalaBangunji	1	74.4	0.6	0.6	H	9°34'57.81"	11°06'01.78"
	2	9.9	9.7	10.3			
	3	187.6	--	--			
Lakai	1	100.2	1.0	1.0	H	9°33'52.85"	11°10'15.00"
	2	11.0	8.5	9.5			
	3	233.4	--	--			
BakinKasuwa	1	757.3	0.9	0.9	Q	9°35'23.30"	11°04'14.90"
	2	98.3	6.6	7.4			
	3	49.4	9.5	17.0			
	4	22.7	--	--			
Lakal Gam	1	839.5	1.3	1.3	Q	9°48'17.79"	11°16'10.90"
	2	132.6	0.6	1.9			
	3	4.0	3.4	5.3			
	4	33.6	11.2	16.6			
	5	16.4	--	--			
Yelwayepilo	1	36.5	0.8	0.8	K	9°42'06.37"	11°09'25.15"
	2	277.5	4.2	5.0			
	3	7138.3	7.7	14.7			
	4	840.3	12.4	25.1			
	5	478	--	--			
LababaleFiliya	1	175.8	1.2	1.2	Q	9°39'53.29"	11°17'18.15"
	2	27.0	0.8	2.0			
	3	5.3	5.6	7.7			
	4	9.4	--	--			
Lasaklak	1	136.3	0.8	0.8	H	9°41'07.54"	11°06'41.77"
	2	14.8	0.8	1.7			
	3	16.6	6.5	8.1			
	4	16.3	9.4	17.6			
	5	33.3	17.9	35.5			
	6	47.1	--	--			
LawishiKolok	1	819.9	1.6	1.6	Q	9°36'14.34"	11°09'50.62"
	2	310.5	1.5	3.1			
	3	80.5	3.5	6.6			
	4	63.0	5.2	11.8			
	5	12.5	18.6	30.4			
	6	32.7	--	--			
KalishinKulishiu wu	1	210.8	1.0	1.0	H	9°42'24.77"	11°08'36.91"
	2	38.4	7.0	8.0			
	3	126.4	5.4	13.4			
	4	771.6	27.1	40.5			
	5	258.9	10.3	50.8			
	6	493.2	--	--			

Table 2: Results of Vertical Electrical Sounding

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