Journal of Geology and Mining Research Vol. 3(10), pp. 251-264, October 2011
Available online at http://www.academicjournals.org/JGMR
ISSN 2006-9766 ©2011 Academic Journals

Full Length Research Paper

Determination of aquifer potentials of Abia State University, Uturu (ABSU) and its environs using vertical electrical sounding (VES)

M. U. Igboekwe* and Akpan, C. B.

Department of Physics, Micheal Okpara University of Agriculture, Umudike, P. M.B. 7267 Umuahia, Nigeria.

Accepted 23 October, 2010

Resistivity soundings have been carried out around the Abia State University, Uturu (ABSU) and its environs, using the Schlumberger configuration. The major aim is to delineate potential aquifer zones for regional groundwater harvesting and further development. The geologic formations in the study area consist of a sequence of underlying Lower Coal Measures (Mamu), the Ajali formation and the upper coal measures (Nsukka formation). The Ajali formation, which is the most predominant in the sequence, consists of false-bedded poorly sorted sandstones. Twenty (20) vertical electrical soundings (VES) are taken with AB/2 = 500 m. The geoelectrical data analysis indicates the heterogenous nature of the aquifer with resistivity range between 2291.8 to 100,000 Ωm. Assuming a homogeneous sandy aquifer, the average hydraulic conductivity (k) and transmissivity (Tr) distribution within the study area, are found to be 8.12 m/day and 1154.2 m^2/day respectively. Based on these results, potential aquifer zones have been identified between Ugba junction (Uturu) and 200 m southeastward along Isukwuato-ABSU road.

Key words: Abia State University Uturu (ABSU), aquifer, Schlumberger, VES, resistivity, transmissivity.

INTRODUCTION

Unlike surface water resources, the evaluation of groundwater resources is more difficult, expensive and time consuming. As resistivity is a fundamental electric property of rock materials closely related to their lithology, the determination of the subsurface distribution of resistivity from surface measurement, can yield useful information on the structure or composition of buried formation.

The increasing academic activities in Abia State University Uturu (ABSU) have resulted in an increase in population and demand for potable water. Few wells drilled at few locations on the campus have become abortive because of the high draw-down during dry season, mostly November through February (Igboekwe, 2008). The effect of high draw-down, results in the inadequacy of potable water supply for the teaming population. It therefore becomes necessary to carry out some studies of the ground water potential, in and around the University Campus. Apart from domestic uses, water is equally needed for infrastructural development in the area.

The main objective of the study is therefore to assess the aquifer potentials/parameters of Abia State University Uturu and its environs. In other to achieve this objective, characterization of the geological formations within the area has been done through interpretation of geoelectrical data. Hydrological data analysis for aquifer characteristics has equally been carried out. It is hoped that information from studies like these, will assist in capacity building for regional groundwater development in the study area.

Description of the study area

Figure 1 shows the location map of the study area, Abia State University Uturu. It is located within latitudes

*Corresponding author. E-mail: igboekwemu@yahoo.com.

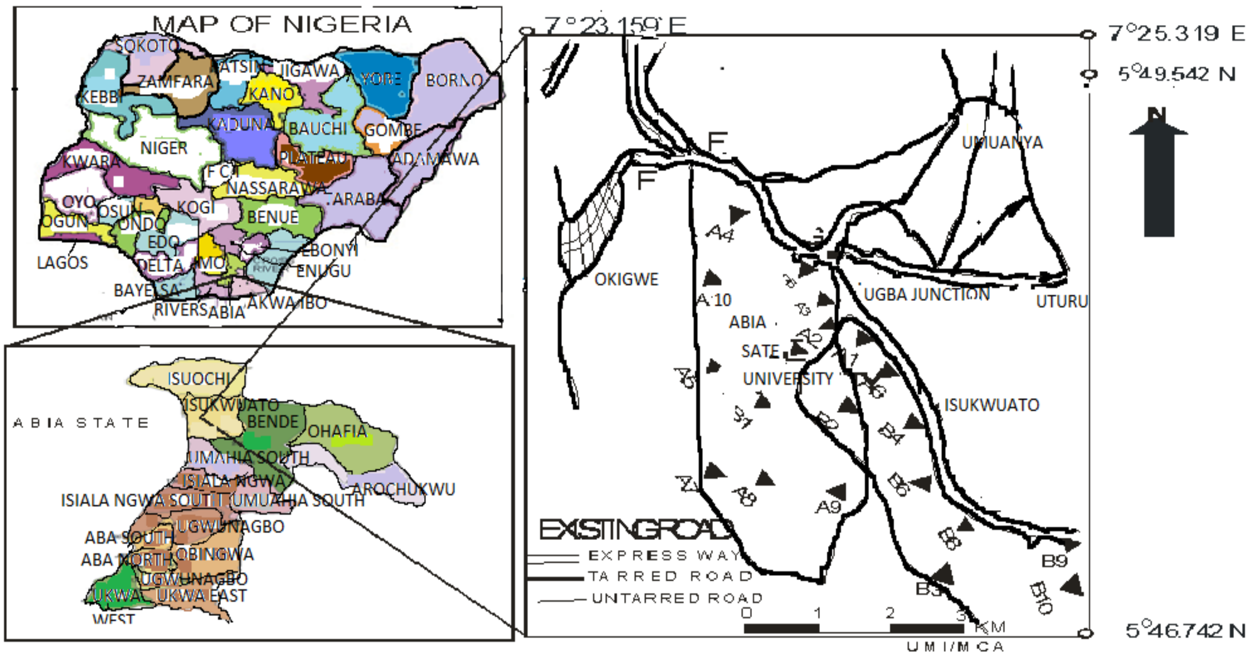


Figure 1. Location map of ABSU showing VES points.

5°46.742′N and 5°49.542′N and longitudes 7°23.159′E and 7°25.319′E within Isuikwuato area of southeastern Nigeria. It is bounded by Ihube and Leru on the North, Umuahia and Bende on the South, Uturu on the east and Okigwe on the West.

The Geology of the area (Figure 2) consists of Ajali Formation (false-bedded sandstones) as well as Lower Coal Measures which Reyment (1965) called “Mamu” Formation. The coal-bearing part of the formations is predominantly mudstone and sandy clay (Simpson, 1955). The formation sediments were deposited during the late Tertiary-Early Cretaceous period. The false-bedded sandstones consist of thick, friable, poorly sorted sandstones typically white in colour, but sometimes iron-stained, often marked by repetitive banding of coarse and fine-grained layers. The sand grains, especially the longer ones are sometimes sub-angular in shape. Because of these characteristics, the formation is highly porous (Igbozurike, 1986). The Lower Coal Measures comprises mainly of coarse-grained, alternating sediment of grey sand, dark, sandy shale and carbonaceous shale, containing thin brand of impure coal in place at various horizons. Estimated thickness is 300 to 350 m (Igbozurike, 1986). These formations give rise to the line of prominent hills along the eastern margins of the escarpment, including those found on the old Okigwe-Enugu road through Ihube.

The geological setting and depth to the prolific aquiferous formation of the continental zone of southeastern Nigeria varies from place to place (Edet et al., 1997; Okereke et al., 1998). There has been a notable variation in the rock formation. The alluvial deposit consists of clay, silt, sand, gravel, shale, pebble and unconsolidated sediment whose thickness ranges between 10 m to 15 m towards Isuikwuato. The youngest cretaceous rocks of the escarpment constitute an important aquifer, effectively underlying some 17% of the study area, Ebillah (1993)

MATERIALS AND METHODS

Variations of electrical conductivity from which different subsurface strata are inferred are investigated with the help of electrical resistivity soundings (Zohdy et al., 1974). Twenty Schlumberger Vertical Electrical Sounding (VES) are acquired in the entire area to understand the aquifer correctly, using a maximum current electrode separation AB/2 = 500 m. A digital averaging instrument, ABEM SAS 4000 Terrametter was used.

Data was collected and the apparent resistivity values were plotted against half the current electrode spacing on a double logarithmic graph, for manual interpretation. These later served as input, for a fast computer assisted interpretation. The computer programme of Resist (designed and used at National Geophysical Research Institute (NGRI) India was employed in the modeling of the VES data (NGRI, 1977). The result of this computer VES curves are presented partly in Figures 3 and 4 and fully in Tables 1 and 2.

Most of the sounding curves in Abia State University Uturu (ABSU) reflect the presence of four or five geoelectric layers with resistivity increasing ($\rho1 < \rho2 < \rho3 < \rho4 < \rho5$) or decreasing ($\rho1 >$

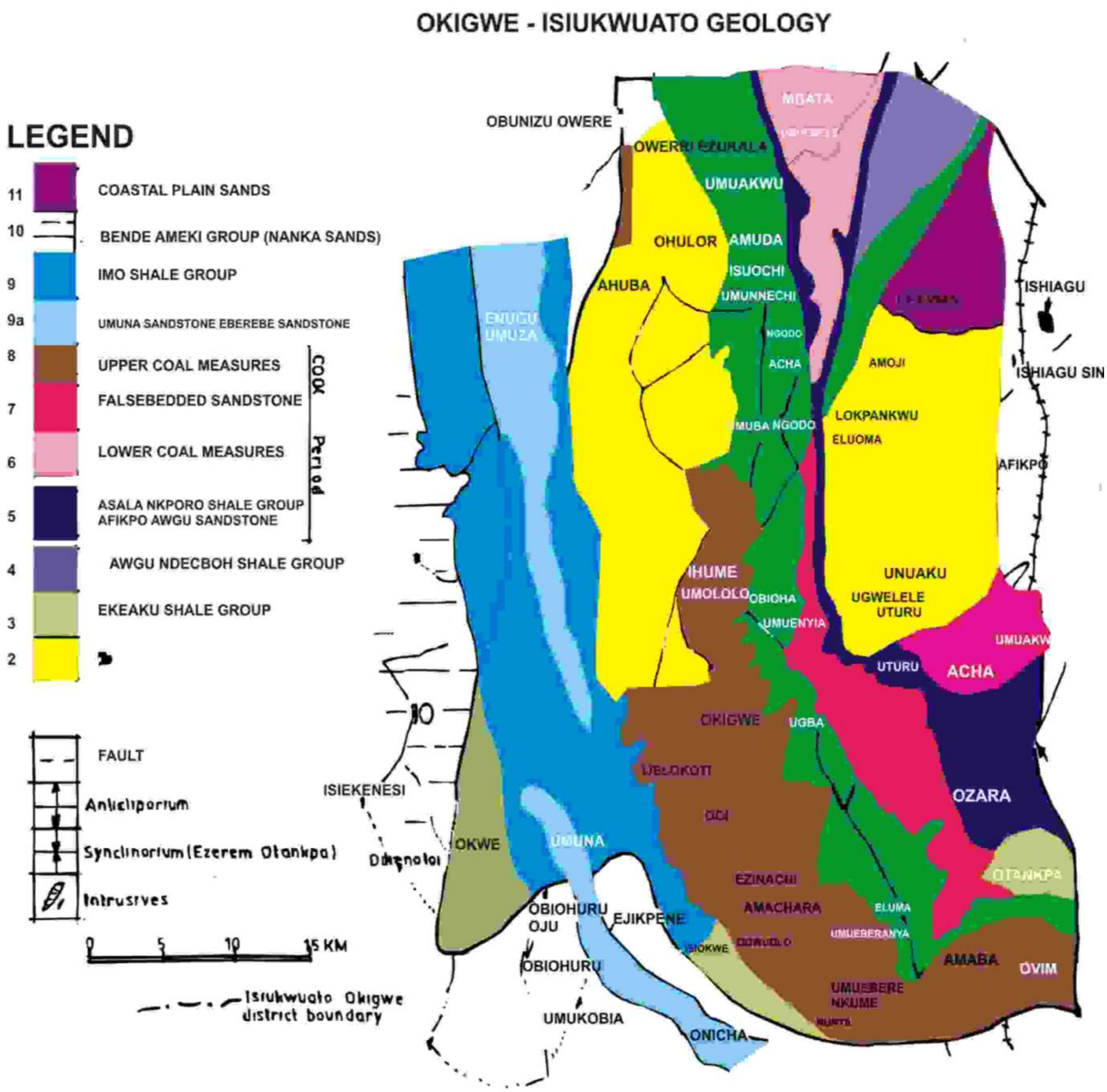


Figure 2. Okigwe-Isiukwuato geologic map.

$\rho 2 > \rho 3 > \rho 4$) with depth (Mbonu et al., 1991). An example of the latter is the QQ-type curve shown in Figure 4. However, a few other sounding curves reflect the presence of eight geoelectric layers with the result of most of them being the HAAAKQ-type curves.

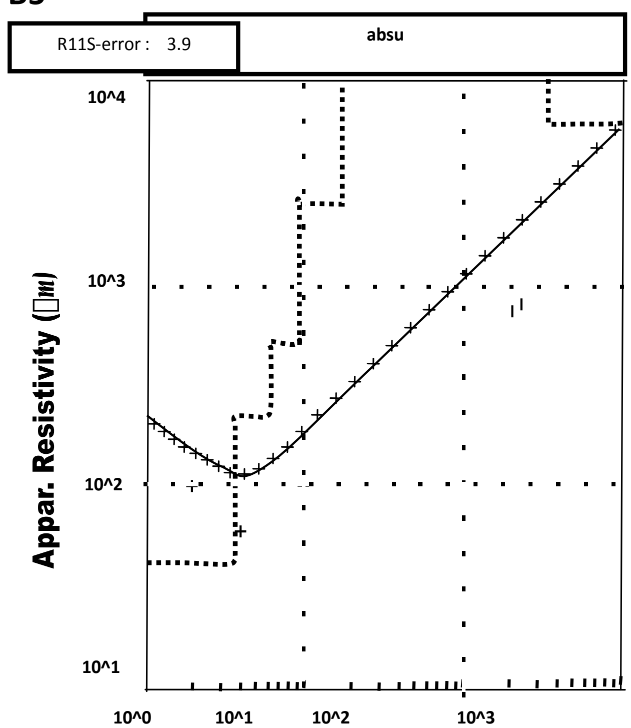
Geoelectrical sections

Twenty (20) interpreted electrical resistivity soundings carried out at ABSU and its environs are presented in Tables 1 and 2. The aquiferous zone is seen to consist mainly of sandstones (SST). Three geoelectrical sections have been prepared from the interpreted results of the vertical electrical soundings within the area, as shown in Figures 5, 6 and 7.

Section AA'

The results of some soundings are shown in Figure 5. It spans through Ugba Junction- Uturu (B5), Via ABSU gate to Isuikwuato

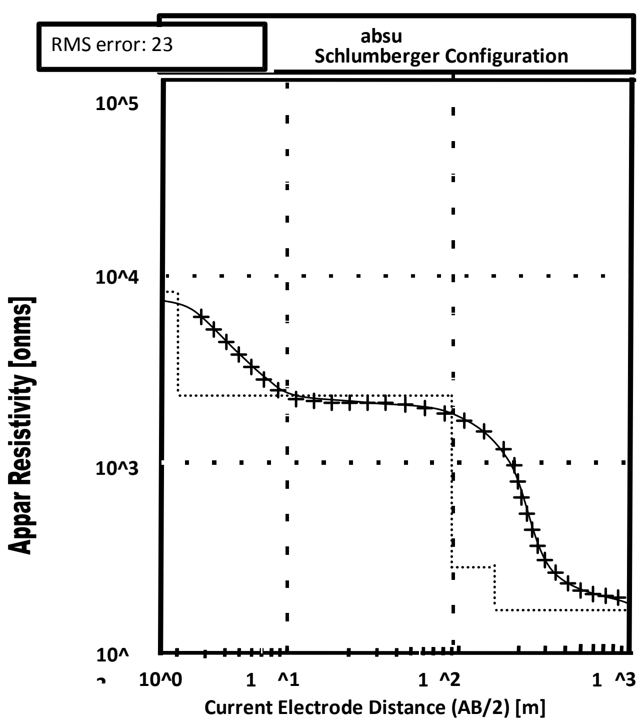
B5



No	Res	Thick	Depth
1	156.7	1.0	1.0
2	40.7	2.8	3.7
3	221.6	2.5	6.2
4	497.4	3.0	9.2
5	2465.9	8.1	17.3
6	23285.0	106.1	123.4
7	10624.0	109.6	333.0
8	5999.5	- . -	-.-

Figure 3. Computer modelled curve of VBS B5.

VERS



No	Res	Thick	Depth
1	7835.6	1.3	1.3
2	2340.3	6.0	7.3
3	2314.3	81.5	88.8
4	228.8	126.9	215.7
5	155.2	-.-	-.-

Figure 4. Result of computer modelled curve for VERS A[10].

Table 1. Results of geo-electrical Survey (Group A)

Ves Nos	Locations	Longitude	Latitude	Alt (amsl) ft	No. of Layers		ρ_1h_1	ρ_2h_2	ρ_3h_3	ρ_4h_4	ρ_5h_5	ρ_6h_6	ρ_7h_7	ρ_8h_8	Thickness (m)	Error (%)
Ves A_1	Erosion spot along Isiukwu-ato Rd	07°23.754′E	05°42.892′N	164	8	ρ(Ωm)	605.6	920.9	2611.6	6298.0	10325.7	8864.4	8439.0	8881.5	266.3	2.4
						h(m)	0.5	2.3	5.0	14.8	46.4	78.0	1193	………..		
						Geology	Top soil	Lateritic earth	Lateritic earth	Lateritic earth	Sand stone	Fine sand	Fine sand	Conductive layer		
Ves A_2	Before erosion spot along Isiukwuato Rd	07°24.775′E	05°48.913′N	625	8	ρ(Ωm)	4040.5	2017.1	3142.2	9535.2	35814.6	36635.1	28258.8	28589.0	224.7	2.3
						h(m)	0.5	2.1	3.4	7.6	29.5	64.1	117.5	………		
						Geology	Top soil	Lateritic earth	Lateritic earth	Coarse sand	Sand stone	Fine sand	Fine sand	Conductive layer		
Ves A_3	Near the University along Isiukwuato Rd	07°24.027′E	05°·49.363′N	787	8	ρ(Ωm)	81.4	445.4	2035.3	7209.7	44305.0	100000.0	13445.8	20267.5	363.9	4.8
						h(m)	0.4	0.5	0.7	1.4	5.6	64.5	290.8	…..		
						Geology	Top soil	Top soil	Lateritic earth	Lateritic earth	Coarse sand	Stand stone	Conductive layer			
Ves A_4	Beside ABSU gate (120m) to the gate	07°23.848′E	05°49.56′N	782	6	ρ(Ωm)	1799.1	5900.0	2291.8	13157.1	18348.2	14298.8	………	……	268.7	1.9
						h(m)	0.5	3.9	20.4	66.8	177.1	……	………			
						Geology	Top soil	Lateritic soil	Sand	Coarse sand	Sand stone	Stand stone	Conductive layer			
Ves A_5	Beyond the erosion spot along Isiukwuato Rd	07°23.198′E	05°.48.664′N	876	8	ρ(Ωm)	300.2	1499.5	4900.4	7535.9	13448.7	11805.5	10785.3	10345.4	216.7	2.1
						h(m)	0.5	1.2	2.9	6.7	27.3	58.4	119.7	…...		
						Geology	Top soil	Lateritic earth	Lateritic earth	Coarse sand	Sand stone	Stand stone	Conductive layer			

Table 1. Contd.

Ves A_6	**Beyond the Erosion spot along Isiukwuato Rd**	**07°25.319/E**	**05°48.451/ N**	**868**	**8**	**ρ(Ωm)**	**378.9**	**971.0**	**5019.8**	**13267.4**	**30236.9**	**40378.9**	**29320.9**	**17435.1**	**134.4**	**2.1**
						h(m)	**0.5**	**0.9**	**1.7**	**4.0**	**11.6**	**31.3**	**84.4**	**............**		
						Geology	**Top soil**	**Lateritic earth**	**Lateritic earth**	**Lateritic earth**	**Coarse Sand**	**Coarse sand**	**Fine sand**	**Conductive layer**		
Ves A_7	Inside ABSU Opposite Dept of Foreign Languages	07°23.666/E	05°49.386/ N	707	5	ρ(Ωm)	3478.0	4239.0	4141.3	14431.4	14735.4	1157.0	……	……	117.4	2.1
						h(m)	0.5	2.5	26.0	88.4	….	……	………	……		
						Geology	Top soil	Lateritic earth	sand	sandstone	Sand stone	Stand stone ```````````` `	Stand stone			
Ves A_8	Along Hostel Lane	07⁰23.550/E	05°49.168/ N	573	7	ρ(Ωm)	209.8	770.2	246.2	724.8	4741.4	9853.0	11572.4	…….	128.9	2.5
						h(m)	0.6	3.2	8.3	10.3	29.3	77.2	………	……		
						Geology	Top soil	Lateritic earth	Shale	Clay	Fine sand	Fine sand	Conductive layer			
Ves A_9	Opposite Dept of Comm. Rd	07⁰23.814/E	05°49.168/ N	620	6	ρ(Ωm)	4566.5	152.4	1489.1	2748.7	8010.7	1661.4	37090.9	100000.0	94.4	2.5
						h(m)	0.6	1.7	3.3	6.8	13.5	20.8	47.7			
						Geology	Top soil	Lateritic earth	Sand	Sand	Sand stone	Fine sand	Conductive layer			
Ves A_{10}	At ABSU's Pavillion	07°23.770/E	05°49.542/ N	651	5	ρ(Ωm)	7885.6	2340.3	2314.3	228.8	155.2	……	………	……	215.7	2.3
						h(m)	1.3	6.0	81.5	126.9	….	……	………	……		
						Geology	Top soil	Coarse SAND	Coarse sand	Fine Sand	Cond layer					

Table 2. Results of Geo-electrical Survey (Group B).

Ves Nos	Locations	Longitude	Latitude	No of Layers		$\rho_1 h_1$	$\rho_2 h_2$	$\rho_3 h_3$	$\rho_4 h_4$	$\rho_5 h_5$	$\rho_6 h_6$	$\rho_7 h_7$	$\rho_8 h_8$	$\rho_9 h_9$	Total Thickness (m)	Fitting Error%
Ves B_1	Along Isiukwu-ato Rd	7°23.5450′ E	$05^{0}49.422^{/}$N	8	ρ(Ωm)	3356.5	2993.0	11033.0	7666.6	6930.5	13301.2	13968.4	13775.7	…	176.7	2.4
					h(m)	0.4	1.1	5.0	3.8	9.8	19.5	46.1	96.0			
					Geology	Top soil	Lateritic earth	Lateritic earth	Coarse sand	Coarse sand	Coarse sand	Fine sand	Conductive layer	…..		
Ves B_2	Inside ABSU Pavillion	7°23.4173′ E	$05^{0}49.243^{/}$N	9	ρ(Ωm)	1243.2	1649.3	3164.9	1872.5	2247.0	258.0	5078.4	1118.1	2762.0	357.8	**224.** 3.6
					h(m)	0.5	1.8	5.2	9.7	16.8	57.9	176.6	89.3	……		
					Geology	Top soil	Lateritic earth	Sand	Sand	Coarse sand	Fine sand	Fine sand	Fine sand	Conductive layer		
Ves B_3	Near the Ugba Junction	7°.23 .558′ E	$05^{0}49.436^{/}$N	7	ρ(Ωm)	2069.3	3239.0	2091.3	8405.8	17470.4	2919.7	1490.6	**………**	…	**1213** 121.3	2.9
					h(m)	0.6	4.6	8.7	10.4	35.7	61.3	………	**………..**	**…….**		
					Geology	Top soil	Lateritic earth	Lateritic earth	Lateritic earth	Lateritic earth	Fine sand	Conductive layer	**………**			**363.9**
Ves B_4	Along Isiukwuato Rd before the Gully Spot	7°23.5379′ E.	$05^{0}49.528^{/}$N	8	ρ(Ωm)	242.5	246.3	1557.8	2749.9	14791.7	21999.2	10658.6	7688.9	…	343.4	2.9
					h(m)	0.5	1.3	3.2	14.2	33.5	91.8	199.1	……..	…		
					Geology	Top soil	Lateritic earth	Lateritic earth	Sand	Coarse sand	Coarse sand	Fine sand	Conductive layer	…		
Ves B_5	Along Isiukwuato Rd at Ugba Junction	7°23.8925′ E	$05^{0}49.7185^{/}$N	8	ρ(Ωm)	156.7	40.7	221.6	497.4	2465.9	23285.0	10624.0	5998.5	…	333.0	3.9
					h(m)	0.5	2.8	2.5	3.0	8.1	106.1	209.6	………	…		
					Geology	Top soil	Lateritic soil	Lateritic soil	Lateritic earth	Coarse sand	Fine sand	Fine sand	Conductive layer	…		

Table 2 Contd.

Ves B_6	Beyond the erosion spot along Isiukwuato Rd	7°23.5355′ E	05°49.4129′N	8	ρ(Ωm)	2218.5	4588.2	97471.0	14212.0	26810.9	7295.0	1333.3	….	……	427.8	2.4
					h(m)	0.5	4.9	12.8	34.1	116.6	252.5	……	………	…		
					Geology	Top soil	Lateritic earth	Coarse sand	Coarse sand	Fine sand	Fine sand	Con layer	…….	…	…..	
Ves B_7	Inside ABSU	7°23.5564′	05°49.3824′N	8	ρ(Ωm)	1299.8	1614.8	3351.1	1456.1	3198.0	1411.5	141.4	3527.5	…	118.7	4.7
					h(m)	0.5	1.8	4.6	9.6	18.0	5.8	78.4	………	…….		
					Geology	Top soil	Lateritic earth	Lateritic earth	Fine sand	Fine sand	Fine sand	Conductive lsolayer	……	…	…..	
Ves B_8	Along Isiukwuato Rd after the erosion spot	7°23.5323′ E	05°49.4097′N	7	ρ(Ωm)	2667.9	856.9	4225.2	13756.7	31440.4	100000.0	100000.0	……	…	160.2	3.7
					h(m)	0.5	3.0	3.2	8.5	25.1	119.9	……	……	…		
					Geology	Top soil	Lateritic earth	Lateritic earth	Coarse sand	Fine sand	Fine sand	Conductive layer				
Ves B_9	Along Isiukwuato Rd near the L.G.H/Q	7°23.1506′ E	05°48.767′N	8	ρ(Ωm)	772.8	2989.4	802	2743.8	54635.8	6043.3	764.2	2357.0		386.0	4.5
					h(m)	0.6	1.8	3.9	3.2	23.7	29.4	323.4	……			
					Geology	Top soil	Lateritic earth	Lateritic earth	Lateritic earth	Coarse sand	Fine sand	Fine sand	Conductive layer			
Ves B_{10}	At the Isiukwuato L.G.H/Q	7°23.153′ E	05°46.7709′N	8	ρ(Ωm)	7885.6	99.3	405.2	172.1	212.9	29.5	26.7	16.3	312.8	151.2	2.5
					h(m)	0.5	1.3	2.0	6.5	11.1	17.6	39.9	73.7	…		
					Geology	Top soil	Lateritic earth	Lateritic earth	Shale	Shale	Fine sand	Fine sand	Conductive layers			

Local Government headquarters, (B10). Geologic layers namely the top soil is underlain by brown-reddish lateritic earth. Other layers lying immediately below the lateritic earth are the medium-coarse grained sandstones. Following these immediately, are the aquiferous zone and the conducting layer. It is observed that fresh aquifer with good quality water, consists of white fine-medium-coarse grained sandstones whose resistivity range between 2291.8 to 100,000 Ωm. The aquiferous zone expressed a thick layer whose thickness ranges between 102.6 m to 328.2 m. The VES points suitable for boreholes with high yield and good for groundwater development, lie between VES B5 to A2. The aquiferous zone is shallowest at B9. The resistivity range of this zone is between 6298 Ωm to 100000 Ωm.

Section BB'

The geoelectric Section BB' (Figure 6) consists of five VES points namely: B5, A10, B7, B2 and A9. The section starts from Ugba Junction (B5) and cuts across the ABSU campus diagonally. The section shows the same structure as AA' namely, a thin top soil underlain by undifferentiated laterite, followed by aquifereous sandstones (SST) and a conducting zone which is most probably clay. This last layer is not clearly defined because of the lack of drilling information at such depth. The aquifer is observed to be most prolific at VES B5 and VES A10 points .The resistivity values ranged between 221.6. Ωm to 23,285.0 Ωm. The aquifer thickness is between 54.0 m to 325.0 m. The shallow aquifer is observed most at VES A9.

Section CC'

The geoelectric section CC,' (Figure 7) lies across the

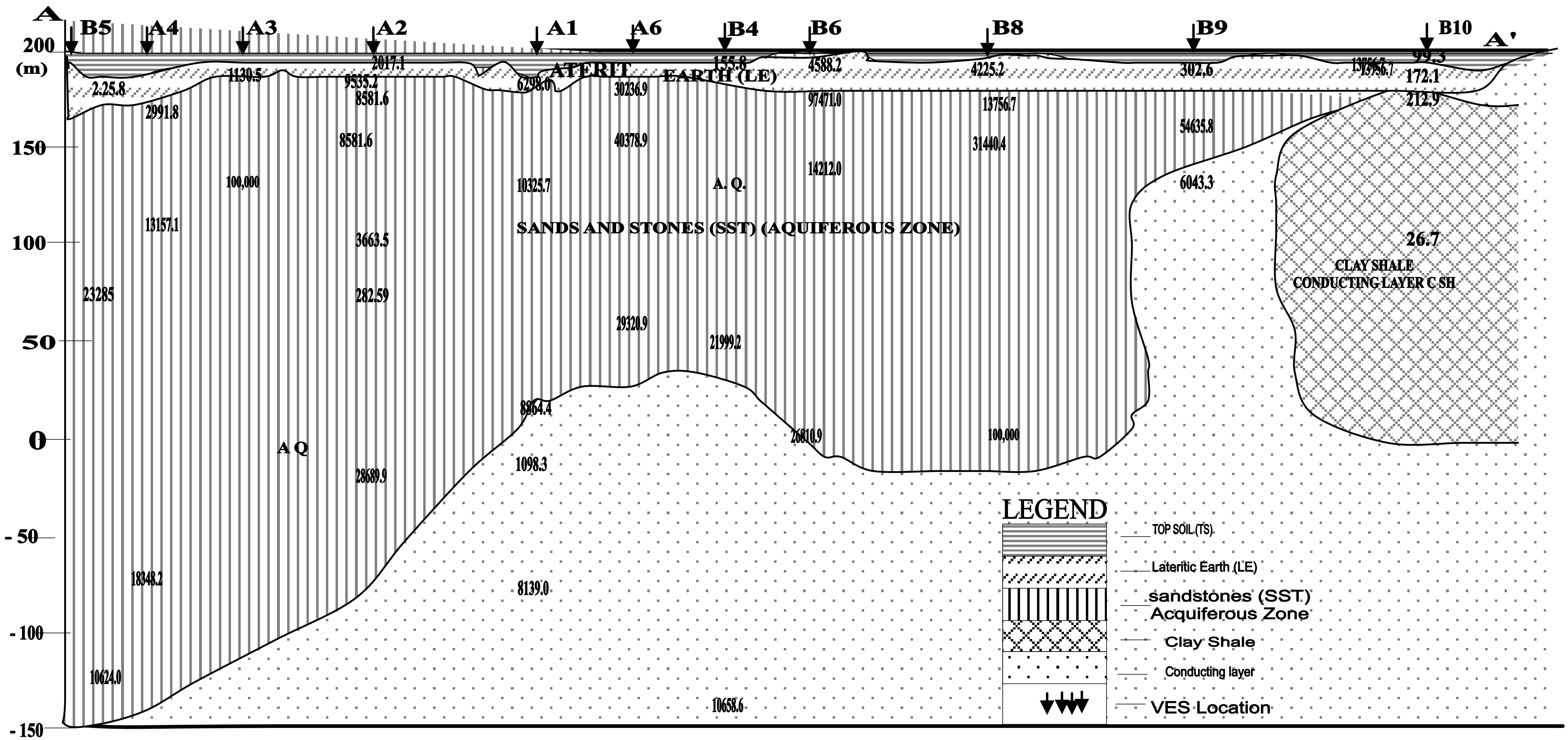


Figure 5. Geoelectrical section along AA$^{/}$.

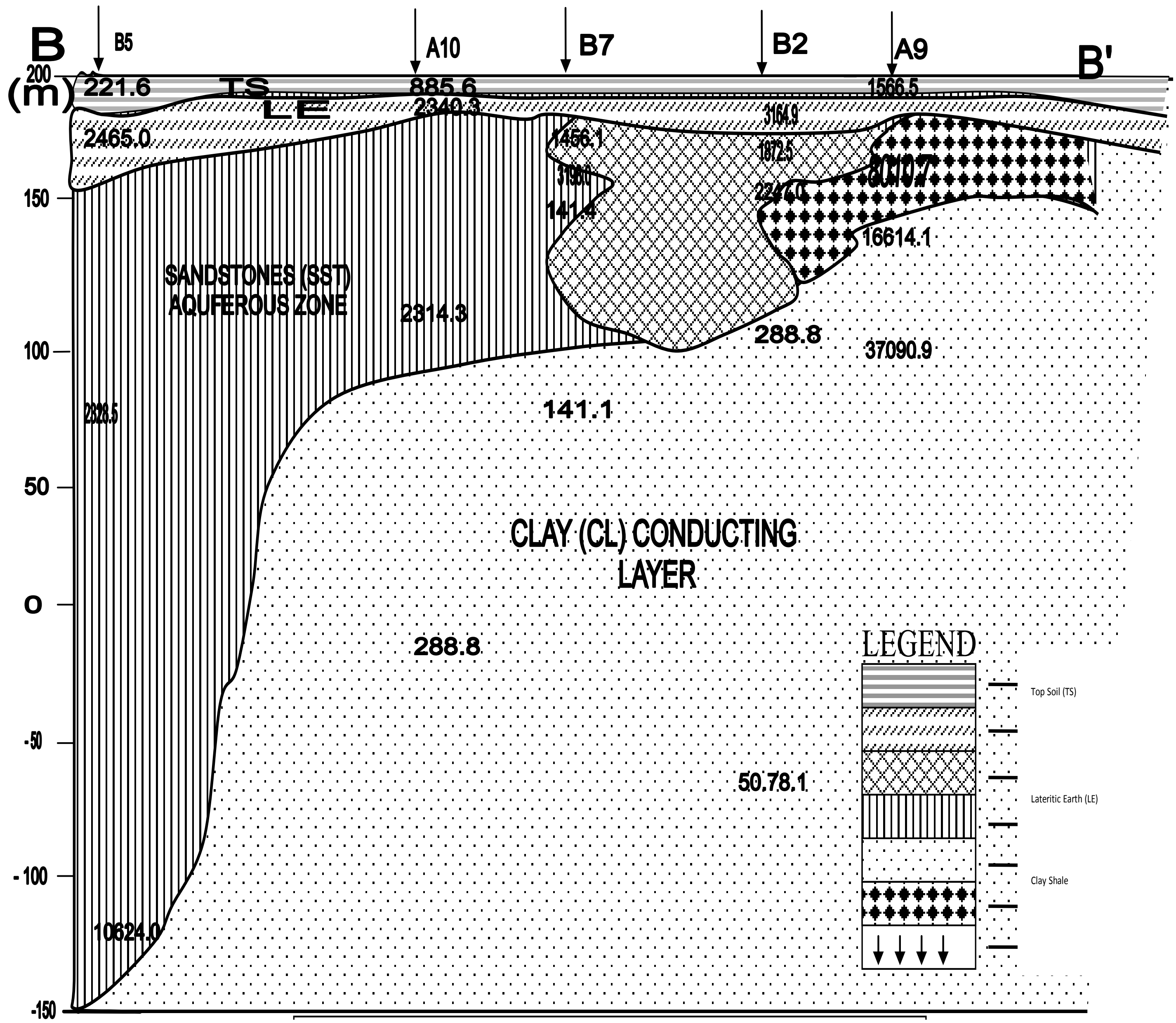


Figure 6. Geoelectrical section along BB/.

northeast to southwest (NE to SW) of the study area, starting from VES B10 to VES A8. The VES points are B10, B9, A9, B2 and A8. Prolific aquifer is thickest at VES A8 and A9, with thickness between 203.2 m to 227.8 m. The corresponding resistivity ranged between 209.8 Ωm to 100,000 Ωm. The thinnest aquifer is indicated at VES B2. The VES A10 indicates clay / shale conducting zone whose resistivity range between 29.5 Ωm to 312.8 Ωm

Iso-resistivity curve and its interpretation

An iso-resistivity map seeks to portray variations of resistivity of the earth at various locations and at a particular depth. To draw such a map, a depth of AB/2 = 80 m is chosen across the entire study area to show two distinct zones, namely high and low resistive zones.

Resistivity values of each VES location at the depth chosen are noted. Intervals for the spread of contour lines e.g. 50, 100 and 1000 m are chosen within the range of the resistivity values.

Contour lines are drawn at the intervals so chosen across the entire study area, bearing in mind their resistivity values. The basis for the choice of the depth, AB/2 = 80 m, is to show the clear distinction between the northern and southern resistive zones.

Figure 8 shows the variation of resistivities at various VES points, at 80 m across the study area. Here the northern part of the study area has higher concentration of contour lines than the southern part. The VES points showing the concentration at this depth

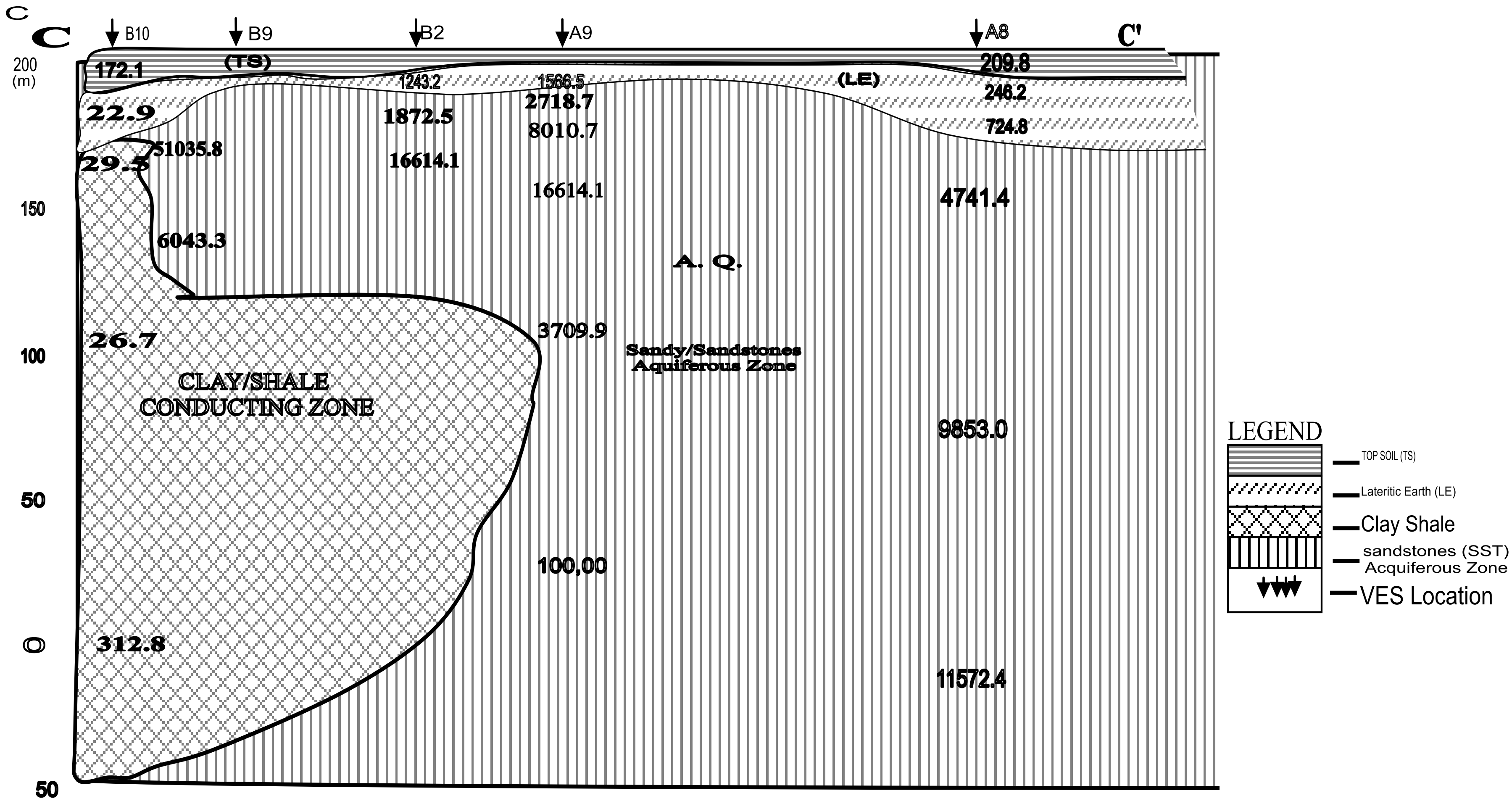


Figure 7. Geoelectric section along CC'.

include VES A4,A2, B6, A8 and B10. This shows that the northern part of the study area is likely to have a thick aquifeous zone. The converse is also true of the southern part of the study area where the contour lines are sparsely distributed and the resistivity values are generally low. Examples here include the VES points labeled A10 and A9.

Aquifer parameters

Aquifer parameters such as hydraulic conductivity (permeability) and transmissivity are determined. A horizontal homogenous and isotropic medium is assumed. The constant layer conductivity is first calculated by applying the mathematical method of variation into the Dar Zarrouk parameters (Niwas and Singhal, 1981; Mbaonu et al., 1991) for any two known VES points.

$$\rho = \frac{T_1 - T_2}{h_1 - h_2}$$

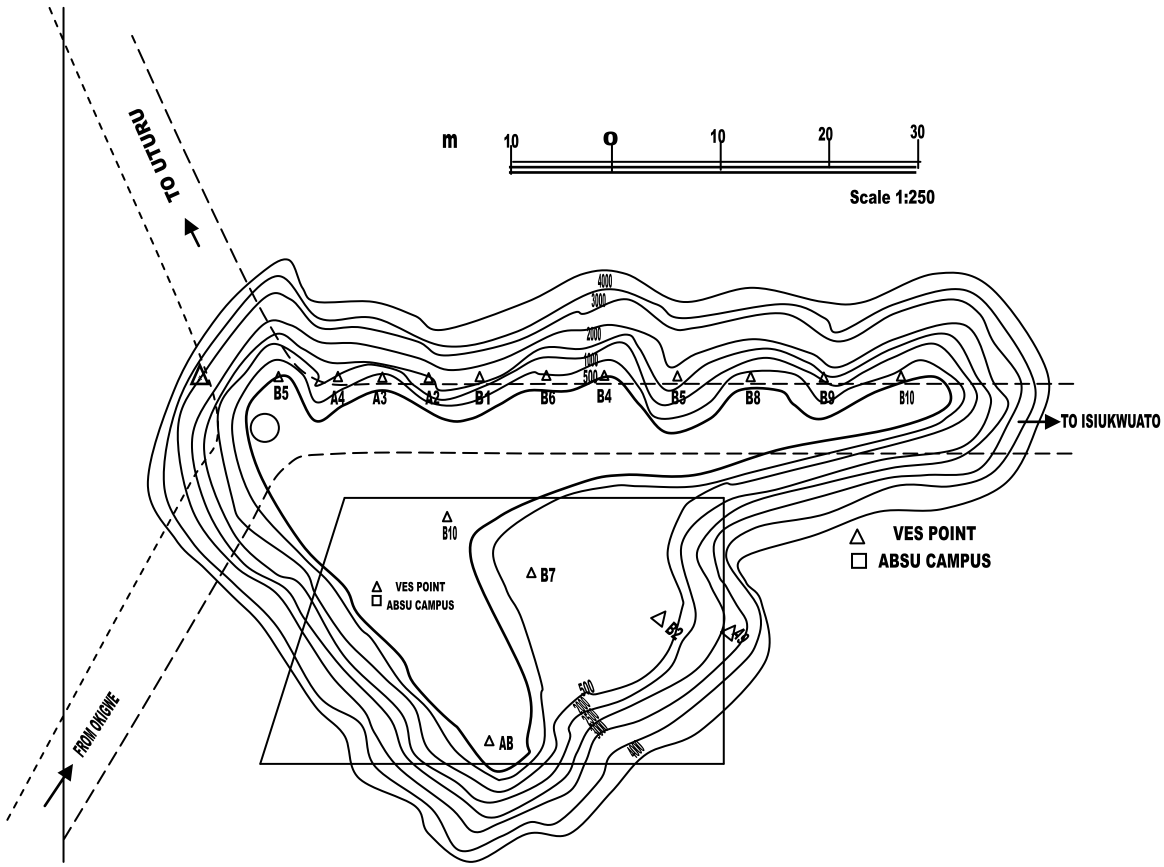


Figure 8. Iso-resistivity map of study area.

Where T is the transverse resistance and h is the thickness of the aquiferous layer.

Aquifer transmissivity has been found to be a very powerful means of confirming potential zones of prolific aquifers. It isdefined as the product of hydraulic conductivity (or permeability) and thickness. That is,

$$Tr = kh \qquad \ldots 2$$

Aquifer transmissivity is measured in square meters per day. With an average hydraulic conductivity of 8.12 m/day obtained from pumping tests around the area (see Igboekwe, 2006), the aquifer transmisivity of the zone is calculated as shown in Tables 3,4 and 5.

Therefore the average transmissivity, Tr for the entire study area is1154.2 m^2/day

RESULTS AND DISCUSSION

Three geologic Formations can be seen in the study area namely the Lower Coal Measures (Mamu Formation), the Ajali Formation (False- bedded sandstones) and the Upper Coal Measures (Nsukka Formation). The Lower Coal Measures underlie the study area while the Upper Coal measures with the Ajali Formation (False-bedded sandstones) overlie this Formation. The junction between the last two Formations is consequently very distinct with the Ajali Formation predominating. It is within this Formation that the geologic units namely the cross-bedded sandstones and Fine-medium-coarse grained sands are more evident.

Interpretation of VES point B2, shows a shallow thin top soil layer of thickness 2.6 m followed by a reddish-brown lateritic earth of thickness 3.5 m. This is underlain by reddish-brown medium grained sands which are 7.6 m thick. Following this is another layer, the medium-coarse grained sands with thickness 29.5 m. This is followed by coarse sandstones with thickness 64.1 m. Immediately below the coarse-sandstones, is the fine- medium grained sandstones (aquiferous zone) with a thickness of 116.7 m. The possible total drilled depth (TDD) for VES B2 therefore stands at 224.0 m. This kind of interpretation is also applicable to the remaining 19 VES points. The interpreted parameters are true resistivities and thicknesses of the layers. Geologic layers delineated from the electrical resistivity soundings along particular profiles have been presented in the three geoelectrical

Table 3. Transmissivity values from geoelectric section AA/.

VES no.	B5	A4	A3	A2	A1	A6	B4	B6	B8	B9	B10
h(m)	325	300	280	230	150	130	135	180	200	55	120
Tr(m^2/day)	2639	2436	2274	1868	1218	1056	1096	1461	1624	447	974

Table 4. Transmissivity values from geoelectrical section BB/.

VES no.	B5	A10	B7	B2	A9
h(m)	325	100	75	65	25
Tr(m^2/day)	2639	812	609	528	203

Table 5. Transmissivity values from geoelectrical section CC/.

VES no.	B10	B9	B2	A9	A8
h (m)	120	55	65	25	25
Tr(m^2/day)	974	447	528	203	203

sections namely AA', BB' and CC'.

The Vertical Electrical Soundings conducted in this study reveals the subsurface geology of the study area. The resistivities are quite progressively increasing with depth. This could be seen from the layer parameters, obtained from the soundings at different locations. This means that the Formation in question, helps in holding the aquifer. The geology portrays layers of various grades of sands (SD) Sandstones (SST), Shale (SH) and Clay (CL). This confirms that the area falls into Ajali Formation and the Lower and Upper Coal Measures whose age range from the Tertiary to Early cretaceous period.

These Formations consist of a sequence of sedimentary rocks whose lithologic and geologic settings control the occurrence of flow of groundwater. They are characterized by consolidated yellowish-white sandstones. They are also characterized by lenses of gray sandy clay. They contain groundwater. It can be seen that the highly permeable formation, the lateritic overburden and the weathered top soil of this formation, as well as the underlying clay-shale membrane, provide the hydrologic conditions favouring aquifer formation in the area.

Conclusion

From the foregoing, we conclude that the geologic sequence in the study area consists of the lower coal measures (Mamu formation), Ajali formation and the upper coal measures (Nsukka formation). The Mamu formation is overlain by the Ajali formation. The latter is subsequently overlain by the upper coal measures (Nsukka Formation).The Ajali formation, which is the most predominant in the sequence consists of fine-medium-coarse grained sandstones. The soundings precisely identified thick aquifer zones along VES B5-A2, B5-A9 and A9-A8 as favourable zones for regional groundwater harvesting and development. This area begins from Ugba Junction (Uturu) and continues for about 200 m southeastward, along ABSU-Isukwuato road.

The average hydraulic conductivity (k) and transmissivity (Tr) distribution within the study area were found to be 8.12 m/day and 1154.2m^2/day respectively. Decreasing values of resistivity observed at some locations, indicate the presence of conducting layers that serve as the bases that hold the prolific aquifer zones. As one would expect, the low resistivity areas observed at these depths indicate the presence of shale/clay members of the Lower Coal measures (Mamu Formation). The results demonstrate the reliability of geoelectric soundings in the delineation of aquifers.

ACKNOWLEDGEMENT

The authors wish to acknowledge, Prof. E. E. Okwueze (University of Calabar), for his kind advice.

REFERENCES

Ebillah S (1993). Abia State Rural Water Supply Project, Feasibility

Report and Preliminary Engineering Design Report. Ebillah-Salmon and Partners in association with Esokay Ltd, p. 183.
Edet AE, Okereke CS (1997). Assessment of hydrogeological conditions in basement aquifers of Precambrian Oban massif, southeastern Nigeria. J. Appl. Geophys., 36: 195-204
Igboekwe MU, Gurunadha RVVS, Okwueze EE (2008). Groundwater flow modelling of Kwa-Ibo River Watershed, Southeastern Nigeria, Hydrological Processes, 22(10): 1523-1531
Igboekwe MU, Okwueze EE, Okereke CS (2006). Delineation of Potential Aquifer Zones from Geoelectric Soundings in Kwa-Ibo River Watershed, Southeastern Nigeria. J. Eng. Appl. Sci., 1(4): 400-421
Igbozurike UM (1986). Isukwuato-Okiqwe Region Published by School of Environmental Studies, Imo State University, Okigwe Nigeria. pp. 6-16.
Mbonu PDC, Ebeniro JO, Ofoegbu CO, Ekine AS (1991). Geoelectric sounding for the determination of aquifer characteristics in parts of the Umuahia area of Nigeria. Geophysics, 56(2): 284-291.
National Geophysical Research Institute, Hyderbad, India (1977) Workshop Report on Water Pollution Assessment and Management p. 169.
Niwas S, Singhal DC (1981). Estimation of Aquifer transmissivity from Dar Zarrouk parameters in porous media. J. Hydrol., 50: 529-556.
Okereke CS, Esu EO, Edet AE (1998). Determination of potential groundwater sites using geological and geophysical techniques in the Cross River State, southern Nigeria. J. Afri. Earth Sci., 27(1): 149-163.
Reyment RA (1965). Aspect of the geology of Nigeria, University of Ibadan Press p. 102.
Simpson A (1955). 'The Nigeriran Coalfield: The Geology of parts of Owerri and Benue Provinces," Bulletin of the Geological Survey of Nigeria. No. 24, Lagos.
Zohdy AA. Eaton GP, Marbey DR (1974). Application of Surface Geophysics to Groundwater Investigations. In tech. Water Resources Investigations USGS Book 2, pp. 100-116.