THE INTERNATIONAL JOURNAL OF
SCIENCE & TECHNOLEDGE

Geoelectric Investigation of Groundwater Potential within Mubiand Environs, Adamawa State, Northeastern Nigeria

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Abstract:
In this paper, ABEM SAS 4000 Terrameter with Schlumberger configuration was used to determine the groundwater potential within Mubi and its environs. The Schlumberger configuration with maximum current electrodes of 100 meters was adopted and a total of twenty-five Vertical Electrical Sounding (VES) was carried out. The results show that the geologic sequence beneath the study area consists of top soil, partly weathered/fractured basement, highly weathered/fractured basement, aquifer with fresh water and presumably fresh basement. The weathered/fractured and aquifer with fresh water horizons constitute the water bearing zones referred to as aquifer with a thickness value of 10.06m to 77.32m and resistivity value of 16.19Ωm to 150.40Ωm. In addition, six distinctive curve types namely H, KH, HK, K, HA and KQ were identified. The results reveal that H curve type dominates the study area with 48%, HK and K curve type have 12% and HA and KQ curve type have 4%. Furthermore, the result shows that out of twenty-five (25) locations considered within Mubi town and Environs, nineteen (19) of them have potentials for ground water.

Keywords; *Geo-electric, Vertical Electrical Sounding (VES), Schlumberger Configuration, Aquifer, Resistivity data Interpretation, Longitudinal unit conductance, transverse resistance, Groundwater potential*

1. Introduction

Of all the resources that the earth possesses, water is the most indispensable. Water is the most precious and commonly used natural resource and is essential for the survival of life. In arid and semi-arid regions, ground water plays a significant role in maintaining sustainability of water resources (Chand *et al*., 2004). Groundwater occurs within a geological stratum (Kumar *et al.,* 2010). The largest available source of fresh water lies underground. Increase demand for water has stimulated development of underground water resources. The increase in infiltration is as a result of topographic depression and high relief while steep slope enhances the runoff in a particular environment of interest (Murugesan*et al*., 2012).

Groundwater is described as the water formed beneath the surface of the earth in underground streams and aquifers (Anomohanram, 2011). It is the largest available reservoir of fresh water. Observation shows that groundwater comes from rain, snow, sheet and hail that soak into the ground and becomes the groundwater responsible for the springs, wells and bore holes (Oseji et al., 2005). Normally, the water required for domestic consumption should possess a high degree of purity and it should be free from suspended and dissolved impurities, bacteria, etc. Both dug wells and boreholes waters are expected to be less contaminated. However, there are possibilities of introduction of contaminants, depending upon management and the temperature gradient of the water environment (Frederick, 1990).

Groundwater is often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. The reason why groundwater has become more popular as a source of potable water in Nigeria is due to its quality when compared to other water sources. It is known to be free most times from pollutants and hence requires little or no decontamination before use. Lawrence and Ojo (2012) noted that groundwater is most generally free from odor, colour and has very low dissolved solid. It is also not usually affected by natural factors such as drought.

The objective of the geophysical survey is to locate subsurface geological characteristics and identify the possible causes of the shortage of groundwater in Mubi and its environs. Moreover, time, money and energy can be saved if geophysical investigation is carried out before embarking on drilling of bore holes for groundwater more especially in basement areas. In this work, nineteen (19) out of twenty-five (25) VES stations have prospective aquifer potentials for ground water. Thus, abortive boreholes and shortage of groundwater in the study area are attributed to poor drilling techniques.

2. Location and Geology of the Study Area

The study area is located within Mubi and its Environs in the Northeastern part of Adamawa State, Nigeria. Moreover, the study area is located between latitudes 10° 11 '30’ and 10° 22' 30’N of the equator and between longitudes 13° 13' 00’’ and 13° 30’ 00’ 'E of Greenwich Meridian. Figure. 1 represents the administrative map of Adamawa state and showing the study area.

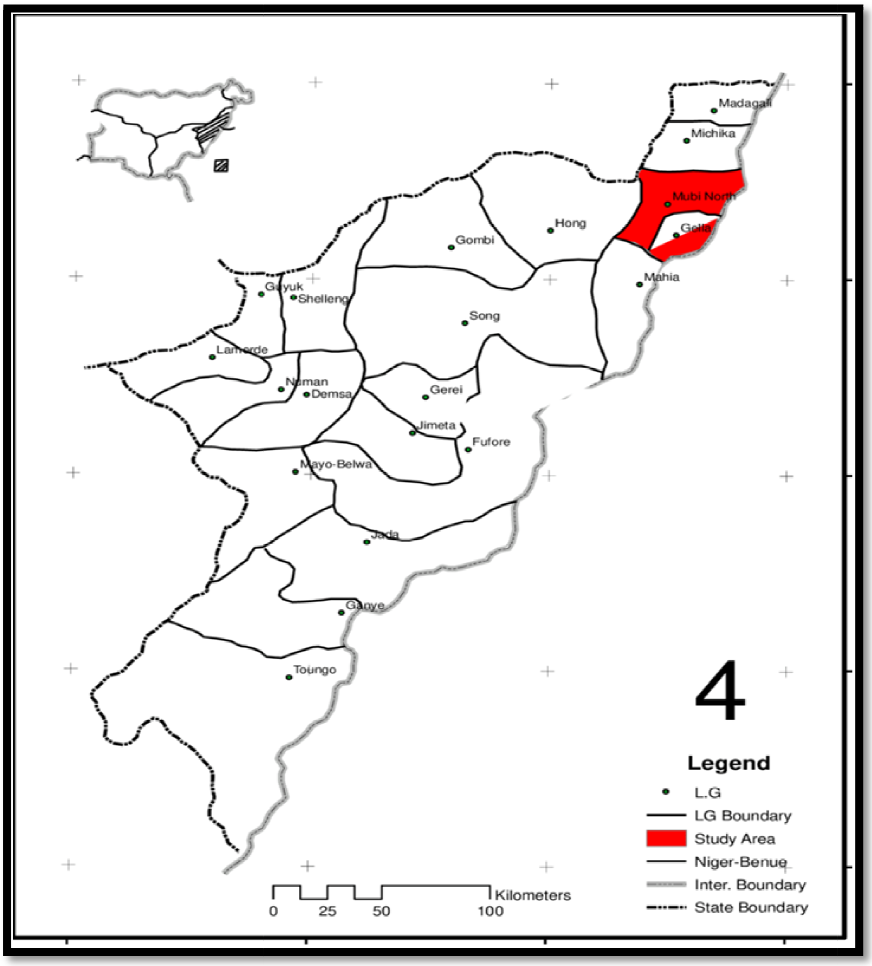

Figure 1: Administrative Map of Adamawa State showing the Study Area

The Geology of the study area (Mubi region) is situated in the north-eastern part of Nigeria and in the northern part of old Sardauna Province which now forms Adamawa northern senatorial district as defined by CIA 2013. It has a land area of 4728.77 km^2. Martins *et al.* (2015) cited Max Lock Group (1973-1976), that Mubilies in the Mandara hills, close to the Camerouns border. The area is bounded to the east by Republic of Cameroon, to the North by Michika local government area of Adamawa State, to the west by AskiraUba local government area of Borno State and to the South by Hong local government area. The area is hilly in the eastern, northern and southern parts and relatively flat in the west but despite the hilly nature of some parts of the area, there are good road networks, foot-paths and tracks. The area is drain by River Yedzeram, one of the major rivers that drain into the Lake Chad. It has a total length of about 330 kilometers (Uba Topographic sheet 156, Edition 1, 1974). It takes its source from the Hudu hills south-east of Mubi town and flows northward into Lake Chad (Adebayo and Dayya, 2004). The study area covers an area of 35.1 km^2 and falls within the Mubi (North and South) political boundary. However, it falls within the section of the middle course of River Yedzeram which covers a length of 30 km from Va’atita in Mubi south to Mayo Bani in Mubi North Local government area. The Yedzeram valley soil is mostly hydromophic in nature and fall within the 213-mapping unit made up of Entisol and Inseptisols. Based on USDA soil order (Nwaka, 2004). They are recently formed or embryonic soils derived from Granite or Gneisse, saprolite and alluviums of the basement complex. Their formation could be attributed to processes such as mass movement and erosion, communization, saturation with water and water logging. The area is characterized by two climatic seasonal patterns; the wet season is between the months of May-October, while the dry season is between the months of November-April. The average annual rainfall is about 935 mm. Generally, in the months of September, August and July the heaviest and also the largest number of raining days are usually observed. During the raining season, the relative humidity of the study area is high, but with the onset of the dry season and tropical continental air mass with dry dust laden north-east trade wind, with the relative humidity falling to about 15% or less are experienced (Daral, 1991). The rains last from April to October with a mean annual rainfall ranging from 700mm to 1,050mm (Adebayo and Dayya, 2004).

Mubi region is located within the North East Basement complex of Nigeria. The rocks are pre pan African orogenic rocks (gneiss migmatite rocks) or pan African granitoids (older granites). They geological structures predominant in the area are dykes, quartz, veins, folds, sheer zones (Cobbing and Davies, 2008). The gneisses and migmatites occupy mainly the lowlands as small outcrops. They are bended, foliated with felsic. This mineral differentiation imparts the foliation to the rocks. The granitoids which are younger are intrusive to the gneissic and magmatic rocks (Cobbing and Davies, 2008). The digitized topographic map of the study area is shown in Figureure 2.

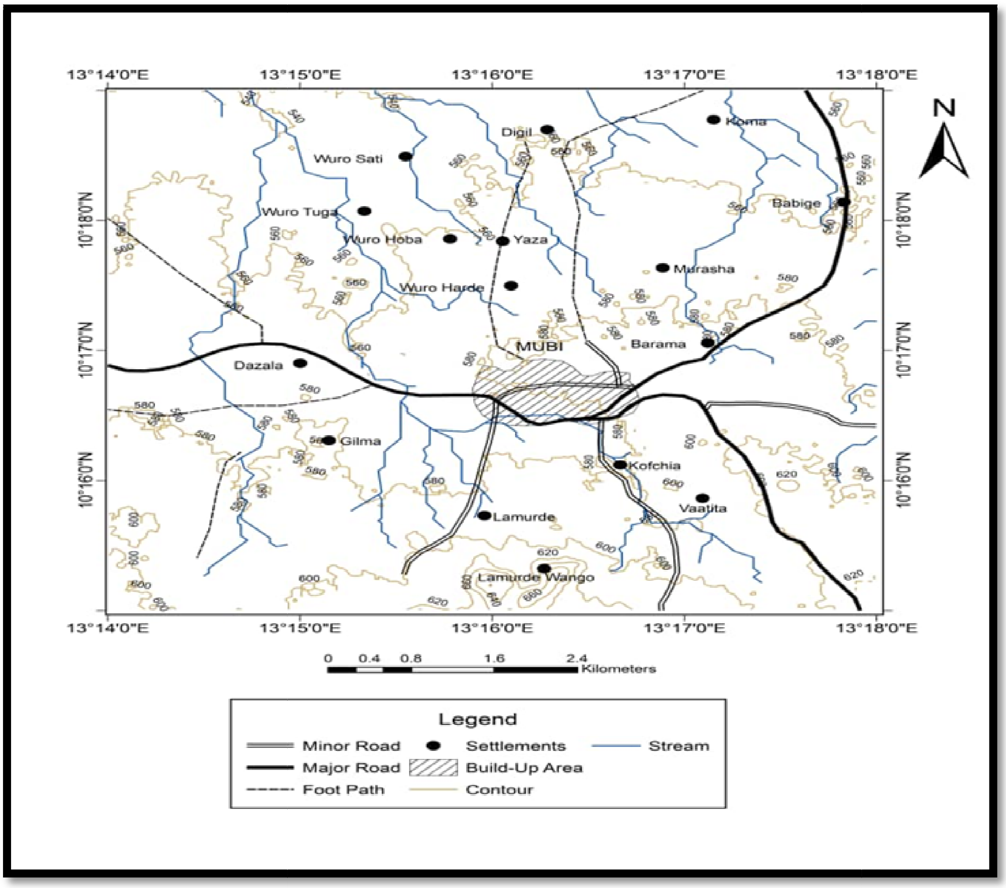

Figure 2: Topographic Map of the Study Area

3. The Description and Working Principle of the ABEM SAS 4000 Terrameter with Schlumberger Configure ration

The field work accessories of ABEM SAS 4000 Terrameter include current electrodes, potential electrodes, sounding cables, GPS, sledge hammers, technical personnel, computer, calculator, and recording systems. In this case, the ABEM SAS Terrameter to be in the form of Schlumberger array with maximum current electrodes of 100 meters is considered. The schlumberger configuation is usually chosen because it generally produces better resolution, greater probing depth, and less time-consuming field deployment than the Wenner array. Furthermore, only the current electrodes need to be shifted to new position for most readings while potential electrodes are kept constant. In this con Figure ration, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes are displaced outwards while the potential electrodes in general, are left at the same position. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the current electrodes must also be displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy (Koefoed, 1979). For this example, let the measurement of current and potential electrode positions be marked such that $\frac{AB}{2} > \frac{MN}{2}$ where $AB/2$ = 100 m (Current electrode spacing) and $MN/2$ = Potential electrode spacing. During the field work, taking a sounding, the ABEM Terrameter (Self-Averaging System) performs automatic recording of both voltage and current, stacks the results, computes the resistance in real time and digitally displays it (Dobrin and King, 1976). The Terrameter works on the principle that any subsurface variation in resistivity/conductivity alters the current flow, which in turn affects the distribution of electric potential at the surface; thereafter the terrameter is switched OFF. The exploration field work involves vertical electric sounding within the area. During field procedure, midpoint of the array is fixed while the distance between the current electrodes is progressively increased. This causes current lines to penetrate to even greater depths depending on the vertical distribution of conductivity. This effect yields a rapidly decreasing potential difference across (MN), which ultimately exceeds the measuring capabilities of the instrument. At this point a new value for potential distance is chosen, typically five times greater than the preceding value and the survey process continues (Keller and Frischnecht, 1966; Osemeikhian and Asokhia, 1994). The systematic movement of the current and potential electrodes is to continue until the area under survey is covered completely (Mooney, 1980).

4. Experiment

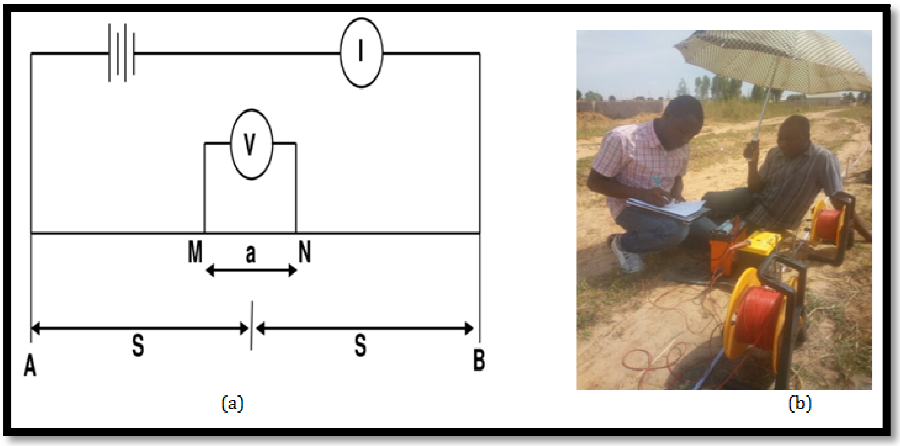

Figure 3: (a) Geometric Schlumberger array (b) Typical Terrameter Field Display

Figure 3 (a) is the schematic geometrical experimental set up and Figure. 3 (b) is the typical experimental field set up adopted in this work. With geometric Schlumberger circuit (Figure. 3a) in place,a fixed point or VES station was marked and its position coordinates were recorded by means of GPS.The two current electrodes A and B at equal distances on the opposite sides of the VES station were driven into the ground with the aid of a sledge hammer for proper contact with the ground.Similarly, the two potential electrodes M and Nat equal distances from the current electrodes on either side of the VES station were also driven into the ground with the aid of a sledge hammer for proper contact with the ground. The current and potential electrodes aligned in a straight line were connected to the Terrameter through points (AB) and (MN) respectively (Figure. 3a). The terrameter was switched ON and current introduced artificially into the earth through the pair of electrodes (AB) and the resulting potential difference between the potential electrodes (MN) was measured by ammeter and voltmeter respectively. Next the current electrodes were moved equally away on the opposite sides of the VES station according to the design acquisition parameter AB, MN and the ammeter and voltmeter readings were recorded at the new position. The field procedure of expanding the distance between current electrodes (AB) while holding potential electrode distance (MN) fixed was repeated until the spacing between A and B was reached. This process yields a rapidly decreasing potential difference across (MN), which ultimately exceeds the measuring capabilities of the instrument (voltmeter) when the ratio AB/2 > MN/2. At this point a new value for the potential electrode spacing was chosen, typically five times greater than the preceding value and the survey continued. The systematic movement of the current and potential electrodes continued until the study area was covered completed.

The resistance data acquired from the site at each point of Sounding 'i.e., resistance value' was multiplied by a geometric factor 'K' which is dependent on the nature of the spacing. This geometric factor was generated using spreadsheet application software 'Microsoft Excel' from which the value of the apparent resistivity of the layer was calculated. The resistivity and thickness of each layer were obtained from the graph of apparent resistivity against electrode spacing while the result from the vertical electrical sounding was interpreted qualitatively using computer software. Furthermore, the VES data was analyzed initially with curve matching using various master curve manuals namely master curve and auxiliary curve. The parameters were determined by a model that best fits the observed data. The sounding curves were grouped under various types of curves depending on whether the resistivity of each layer is greater or less than the next layer.

5. Results

In Mubi and its environs, resistivity sounding measurements were carried out at twenty-five VES stations selected at convenience but far away from contaminant source(s). The data were interpreted with the aid of ZondIP2.exe computer software. In this paper, Figures. 4-7 represent four selected samples of such computer interpreted field data that display three-to-four geoelectric and pseudo sections in the form of curves. The shape of the VES curves depends on three factors namely the thickness of each layer, the number of layers in the subsurface and the ratio of the resistivity of the layers. In addition, Figures. 4-7also show the variations in apparent resistivity and thickness with increasing depth. Furthermore, the geo-electric and Pseudo section characteristics give the respective layer resistivity values and thickness. Thus, in this work, Table 1 contains the average layer resistivity, layer depth, layer thickness and curve types for the twenty-five (25) VES stations.

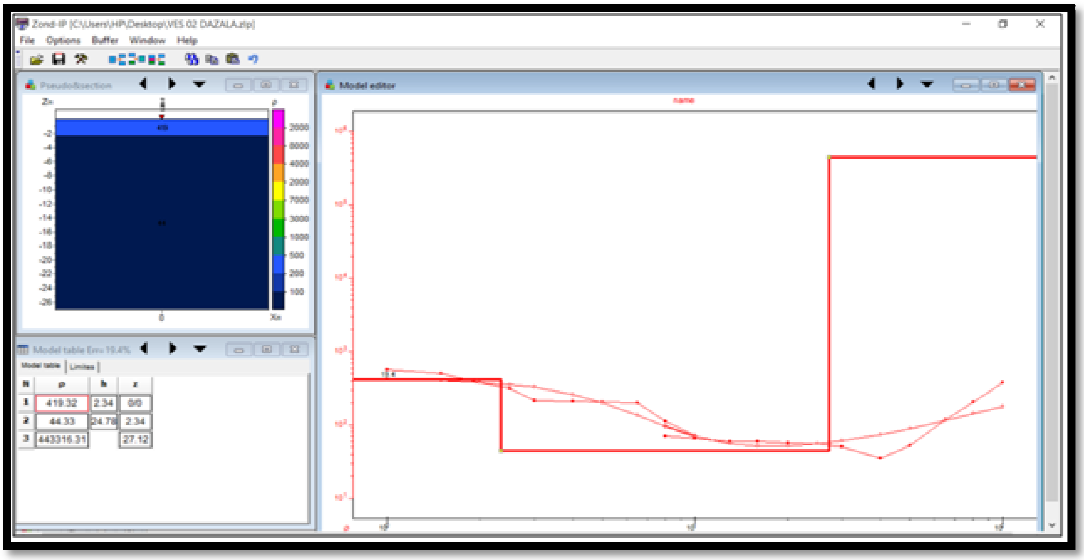

Figure 4 GeoelectricSections (VES Curves and Pseudo-Sections of VES 02)

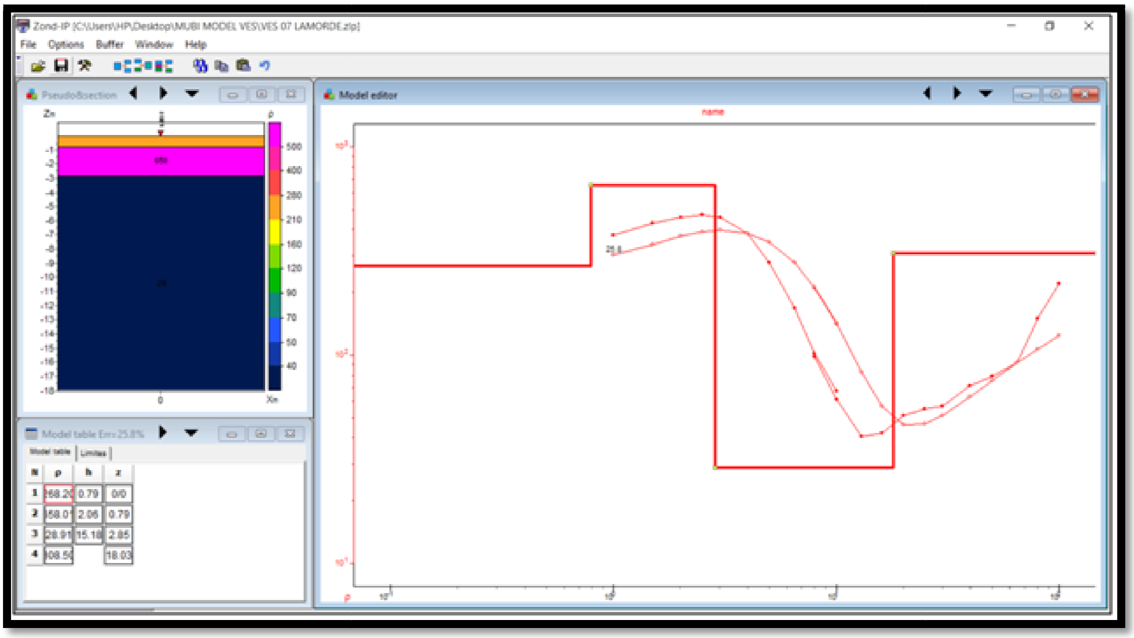

Figure 5:GeoelectricSections (VES Curves and Pseudo-Sections of VES 07)

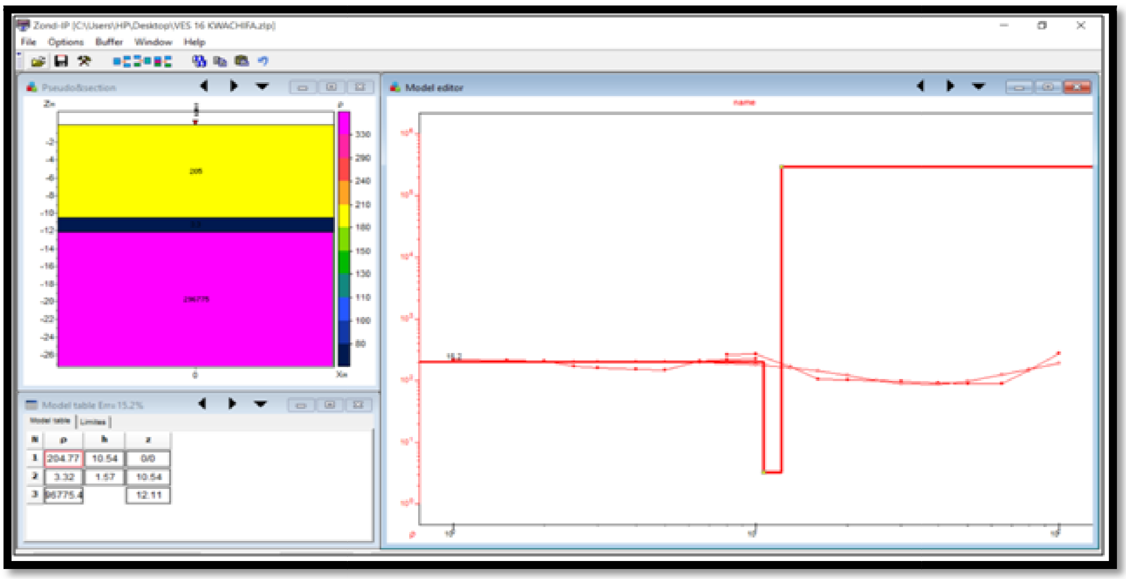

Figure 6:GeoelectricSections (VES Curves and Pseudo-Sections of VES 16)

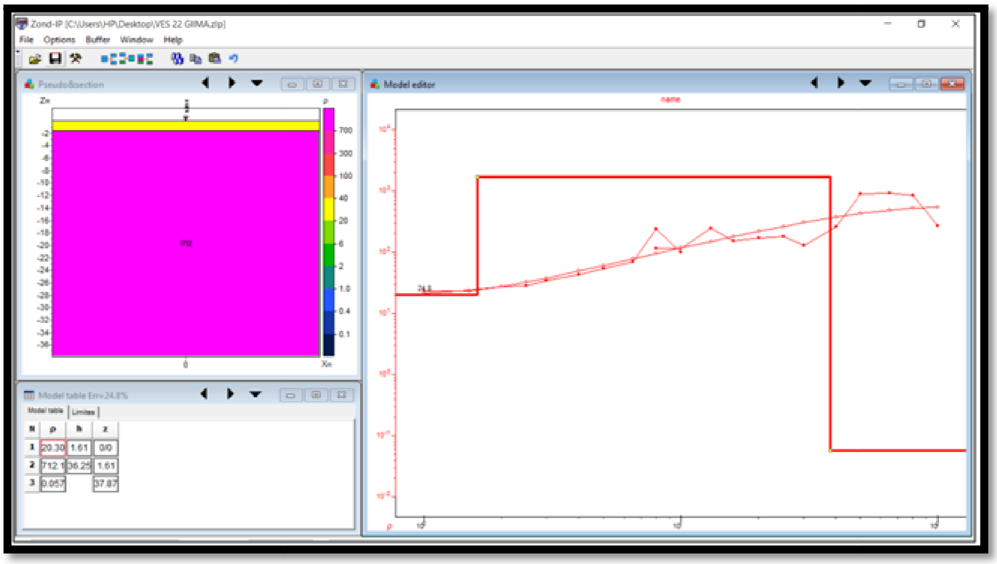

Figure 7:GeoelectricSections (VES Curves andPseudo-Sections ofVES 22)

VES Point	Resistivity of Layers (Ωm)				Thickness of Layers (m)			Depth (m)			Curve Type
	ρ1	ρ2	ρ3	ρ4	h1	h2	h3	d1	d2	d3	
VES 1	461.18	37.52	3437.87	195.63	2.67	13.90	18.25	2.67	16.59	34.84	HK
VES 2	419.32	44.33	443316.31	-	2.34	24.78	-	2.34	27.12	-	H
VES 3	429.05	136.54	4065774.00	29227.00	3.31	63.98	14.30	3.31	67.29	-	H
VES 4	565.96	114.94	4641.14	1870.81	2.24	17.76	24.72	2.24	20.00	44.72	HK
VES 5	327.42	34.29	420.90	-	2.74	24.65	-	2.74	27.37	-	H
VES 6	19.61	614.30	3.32	10000.00	0.11	0.23	0.55	0.11	0.34	0.89	KH
VES 7	268.20	658.01	28.91	308.51	0.79	2.06	15.18	0.79	2.29	18.03	KH
VES 8	311.20	1139.98	99.89	296.95	0.71	2.83	21.46	0.71	3.54	25.00	KH

VES Point	Resistivity of Layers (Ωm)				Thickness of Layers (m)			Depth (m)			Curve Type
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	d_1	d_2	d_3	
VES 9	517.18	56.04	809316.41	-	2.16	24.15	-	2.16	26.32	-	H
VES 10	282.00	17477.20	48.34	135645.20	0.69	0.05	27.63	0.69	0.74	28.37	KH
VES 11	305.62	848.11	16.19	180.21	0.61	1.60	15.82	0.61	2.31	18.03	K
VES 12	256.49	97.17	303.87	136.00	1.12	10.06	5.96	1.12	11.18	-	H
VES 13	367.33	49.35	150.40	295.36	1.41	6.33	19.64	1.41	7.75	27.39	HA
VES 14	265.00	129.69	84205.4	-	4.40	77.32	-	4.40	81.72	-	H
VES 15	196.22	57.51	296.58	-	2.74	24.65	-	2.74	27.39	-	H
VES 16	204.79	3.32	96775.4	-	10.54	1.57	-	10.54	12.11	-	H
VES 17	826.53	67.72	471.79	-	2.74	24.65	-	2.74	27.49	-	H
VES 18	16.70	357.69	155.44	-	4.03	36.28	-	4.03	40.31	-	K

VES Point	Resistivity of Layers (Ωm)				Thickness of Layers (m)			Depth (m)			Curve Type
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	d_1	d_2	d_3	
VES 19	373.46	47.08	471.59	-	0.71	6.36	-	0.71	7.07	-	H
VES 20	217.06	733.03	64.01	298.42	0.79	4.21	26.62	0.79	5.00	31.62	KH
VES 21	41.53	2945.99	43.76	1.46	6.89	16.19	7.53	6.89	23.08	30.61	KQ
VES 22	20.30	712.10	0.057	-	1.61	36.25	-	1.61	37.87	-	K
VES 23	97.27	56.14	18967	-	1.03	32.05	-	1.03	33.08	-	H
VES 24	343.12	50.28	195790.5	-	1.02	21.44	-	1.02	22.46	-	H
VES 25	232.77	78.60	4215.84	118.15	2.34	2.56	0.78	2.34	4.89	5.67	HK
Mean	294.612	1035.47	229160.60	13564.61	2.39	19.04	16.20	2.39	21.86	24.12	-

Table 1: Layer Resistivity, Thickness, Depth and Curve Types of VES Points

From Table 1, the expected aquifer layer is determined based on the values of its resistivity, thickness and depth. That is, the layer with the lowest resistivity and having both values of the thickness and depth less than 10 m is considered aquifer layer. Using this criterion, 19 out of the 25 VES stations are aquifer zones or layers (Table 2). Thus, low resistivity, large thickness and depth greater than 10 m are good indices for identifying aquifer layer. The low value of resistivity Value indicates the presence of water while aquifer thickness is proportional to the

S/N	VES Point	Number of layers	Layer resistivity (Ωm)	Layer thickness (m)	Layer depth(m)	Curve types
1	VES 1	4	37.52	13.90	16.59	HK
2	VES 2	3	44.33	24.78	27.12	H
3	VES 3	3	136.54	63.98	67.29	H
4	VES 4	4	114.94	17.76	20.00	HK
5	VES 5	3	34.29	24.65	27.37	H
6	VES 7	4	28.91	15.18	18.03	KH
7	VES 8	4	99.89	21.46	25.00	KH
8	VES 9	3	56.04	24.15	26.32	H
9	VES 10	4	48.34	27.63	28.37	KH
10	VES 11	3	16.19	15.82	18.03	K
11	VES 12	3	97.17	10.06	11.18	H
12	VES 14	3	129.69	77.32	81.72	H
13	VES 15	3	57.51	24.65	27.39	H
14	VES 16	3	3.32	1.57	12.11	H
15	VES 17	3	67.72	24.65	27.49	H
16	VES 20	4	64.01	26.62	31.62	KH
17	VES 21	4	43.76	7.53	30.61	KQ
18	VES 23	3	56.14	1.61	33.08	H
19	VES 24	3	50.28	32.05	22.46	H

Table 2: Properties of 19 Aquifer Zones

Quantity of water available and depth of aquifer determines the purity of the water in the aquifer zone. In Table 1, VES 14 aquifer layer of thickness 77.32 m and depth 81.32 m is expected to have the largest volume and best quality water while VES 12 aquifer layer with smallest thickness 10.06 m and depth 11.18 m should have the smallest quantity and worst quality of water among the 19 VES aquifer zones identified (Table 2).

VES number	VES coordinates		Aquifer layer	Aquifer layer Lithology
	Latitude	Longitude		
1	10.1599650	13.1963683	Layer 3	Fractured basement
2	10.27099170	13.2367567	Layer 2	Aquifer with fresh water
3	10.2863333	13.2633767	Layer 2	Weathered basement
4	10.3186000	13.2677267	Layer 2	Fractured basement
5	10.2713717	13.2718000	Layer 2	Aquifer with fresh water
7	10.2635367	13.2652583	Layer 3	Aquifer with fresh water
8	10.1811800	13.2238183	Layer 3	Fractured basement
9	10.2923331	13.3079810	Layer 2	Weathered basement
10	10.2672400	13.2505567	Layer 3	Aquifer with fresh water
11	10.2632167	13.2943450	Layer 3	Brackish water
12	10.2786050	13.2808867	Layer 2	Weathered basement
14	10.2701750	13.2705483	Layer 2	Fractured basement
15	10.2653674	13.2877583	Layer 2	Aquifer with fresh water
16	10.2761083	13.2528600	Layer 2	Clay soil
17	10.2639300	13.2770567	Layer 2	Aquifer with fresh water
20	10.2542200	13.2859417	Layer 3	Aquifer with fresh water
21	10.2677600	13.2407767	Layer 3	Aquifer with fresh water
23	10.2674350	13.2409533	Layer 2	Weathered basement
24	10.2779000	13.2508100	Layer 2	Weathered

Table 3: VES Station Coordinates Aquifer Layer and Lithology

Table 3 contains the VES number, VES coordinates, aquifer layers and the lithology of the 19 layers identified. The results show that aquifers are mostly located in the second and third layers of the geologic sections. Thus, there are 12 aquifers located in layer 2 and 7 aquifers are located in layer 3 with varying lithology. Figure. 8 shows the distribution of the VES station coordinates with (♦) and without (■) aquifer zones. The VES station coordinates lies in the latitude range 10.1599650^{o}-10.3186000^{o} with span 0.1586500^{0} and longitude range 13.1963683^{o}-13.3079810^{0}.

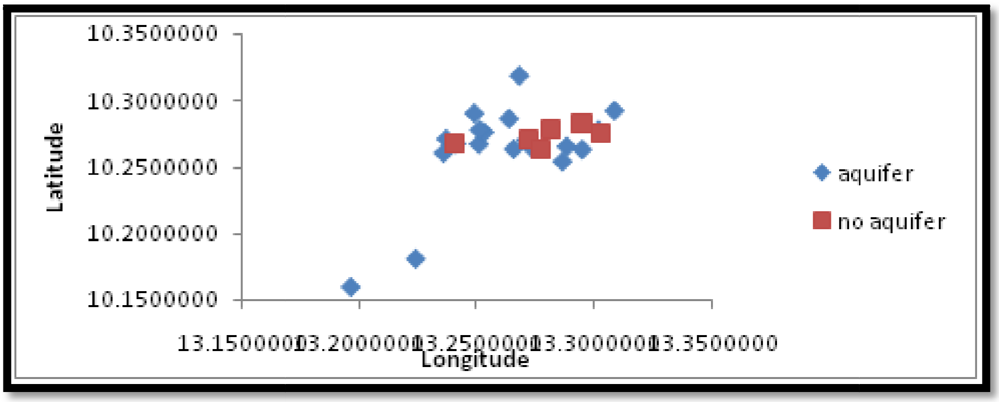

Figure 8: Distribution of VES Station Coordinates with and without Aquifer

S/N	VES number	Curve Type	Number of layers	Curve distribution (%}
1	2, 3, 5, 9, 12, 14, 15, 16, 17, 19, 23, 24	H	3	48
2	6, 7, 8, 10 and 20	KH	4	20
3	1, 4 and 25	HK	4	12
4	11, 18 and 22	K	3	12
5	13	HA	4	4
6	21	KQ	4	4

Table 4: Curve Types and % Abundance

Table 4 shows that the number of curve types identified is six namely H, KH, HK, K, HA, and KQ. In addition, Table 4 shows that the sections identified have at least four or three geologic subsurface layers.

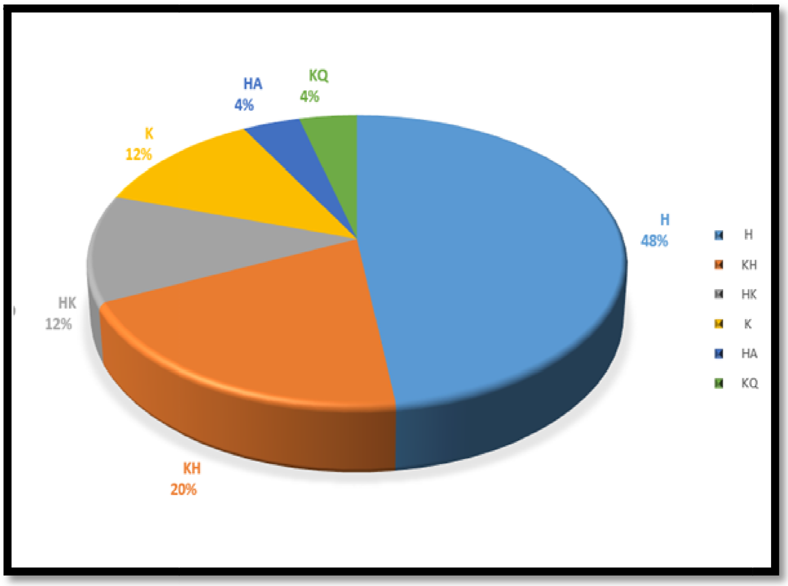

Figure 9: Chart showing the Curve Type Distribution

The pie chart distribution of the curves types is shown in Figure 9. The distribution shows that the H-Type is the dominant curve with 48%, KH curve type 20%, HK and K curvetypes12% each and HA and KQ curve types 4% each.

In another vein, in Table 5the calculated values of the geoelectric aquifer parameters such as the longitudinal conductance S and transverse resistance T obtained from the resistivity ρ and thickness h of the aquifer using the expressions $S = \frac{h}{\rho}$ and $T = h\rho$. Both S and T are used to define target areas of good groundwater potential. The longitudinal conductance has direct relation with protective capacity of the aquifer while the transverse resistance is proportional to the transmissivity of the aquifer. In other words, as the conductance increases, the resistivity naturally decreases pointing towards groundwater potential aquifers. Table 5 shows that eighteen of the aquifer layers or zones according to Oladapo and Akintorinwa (2007) have moderate protective capacity of the overburden materials because their S values lies in the range $0.2 \leq S < 0.69$ except VES 11 with S range $0.7 \leq S < 4.9$considered good protective capacity overburden materials. On the other hand, Table 5 contains the values of the transverse resistance of 19 aquifers layers in the range 1.826-10028 Ωm^2 with an average value of 1547.6 Ωm^2. Out of the 19 aquifer zones, 7 with VES numbers 3,4, 8, 14, 17 and 23 have high transverse resistance values in the range $1669 < T < 10028$ Ωm^2 are expected to have high yield while the remaining 12 with $T \leq 1669$ Ωm^2 are expected to give low yield.

VES Point	Aquifer Resistivity(ρ) (Ωm)	Aquifer Thickness(h) (m)	Aquifer Conductivity (Ωm)	Longitudinal Conductance (Ω)	Transverse Resistance (Ωm^2)
1	37.52	13.90	0.0266	0.3705	521.53
2	44.33	24.78	0.0226	0.5589	1098.50
3	136.54	63.98	0.0073	0.4686	8735.80
4	114.94	17.76	0.0087	0.1545	2041.30
5	34.29	24.65	0.0292	0.7189	845.25
7	28.91	15.18	0.0346	0.5251	438.85
8	99.89	21.46	0.0100	0.2148	2143.60
9	56.04	24.15	0.0178	0.4309	1353.40
10	48.34	27.63	0.0207	0.5716	1335.60
11	16.19	15.82	0.0618	0.9771	256.13
12	97.17	10.06	0.0103	0.1035	977.53
14	129.69	77.32	0.0077	0.5962	10028.00
15	57.51	24.65	0.0173	0.4286	1417.60
17	67.72	24.65	0.0148	0.3639	1669.20
20	64.01	26.62	0.0156	0.4159	1703.90
21	43.76	7.53	0.0229	0.1721	329.51
22	20.30	1.61	0.0493	0.0793	32.68
23	56.14	32.05	0.0178	0.5709	1799.30
24	50.28	21.44	0.0199	0.4264	1075.00
Avg	56.08	19.87	0.0452	0.3729	1547.60
Min	13.70	0.55	0.0016	0.0793	32.68
Max	136.54	77.32	0.1056	0.9771	10028.00

Table 5: Aquifer Parameters

The aquifer parameters such as longitudinal conductance and Transverse resistance define areas of groundwater potentials. The ratio of different layer in their respective resistivity's is known as longitudinal conductance, the properties of a thin conducting layer can be determined in terms of longitudinal conductance and a resistance layer can be determined by transverse resistance. Table 4 shows the Aquifer parameters in the study area. High longitudinal conductanceis found at VES 2, 5, 7, 10, 11, 14, 16, and 23. Areas with low longitudinal conductance are found at the Southern and Eastern part of the study area. It can be inferred that the zones with low longitudinal conductance values have less or no water potentials. Areas with high conductivity signify water potentials, fracture/weathered and aquifer with fresh water zones at depth. The transverse resistance within the study area ranges from 1.826Ωm^2 to 10028Ωm^2 with an average of 1547.6Ωm^2. The zones with the highest transverse resistance (Tr) values are expected to give the highest well yield (Opara, et al., 2012). Thus, the VES (14, 3, 8, 23, 20, 17, 4) points with the highest transverse resistance of 10028Ωm^2, 8735.8Ωm^2, 2143.6Ωm^2, 1799Ωm^2,1703.9Ωm^2, 1669.2Ωm^2, 2041.3Ωm^2respectively are expected to give the highest yield while the VES (11, 22) points with low transverse resistance values 256.13Ωm^2 and 32.68Ωm^2 expected to give the least yield.

6. Conclusion

In this research, out of eight (25) VES points investigated, 19 locations proved to have ground water potentials while the other six locations prove abortive. The result presented in this work has attempted to define the sub-surface geo-electrical structure underlying some parts of the Mubi area of Adamawa state, Nigeria. The interpreted result revealed that the area is underlain by three and four layers of different geo-electrical units; the aquifer thickness varies from 0.55 to 77.32 m with an average of 19.87 m; the central portion of the northeast-northwest axis (VES 2, 5, 10, 11, 14 and 23) has been found to be the most promising region for the exploitation of groundwater within the study area. Therefore, the portion is recommended for siting of groundwater tube. From the study, it is recommended that boreholes are drilled to 35-70 m to harness potable water within the 2nd and 3rd aquifer.

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