Original Research Article

APPLICATION OF INTEGRATED GEOPHYSICAL METHODS IN GROUNDWATER EXPLORATION IN ADAMAWA STATE UNIVERSITY, MUBI.

ABSTRACT

Integrated geophysical methods was used for ground water study in Adamawa state University Mubi. The method employed are powerful tool Audio Magnetic Telluric (ADMT-600 S-X) with powerful software ZondMT 1D and Electrical resistivity with IXD interpex software. In both case electrical proprerty of subsurface are been measured. The magnetotelluric method or magnetotellurics (MT) is an electromagnetic geophysical exploration technique that images the electrical properties (distribution) of the earth at subsurface depths. The energy for the magnetotellurics technique is from natural source of external origin. When this external energy, known as the primary electromagnetic field, reaches the earth's surface, part of it is reflected back and remaining part penetrates into the earth. Earth acts as a good conductor, thus electric currents (known as telluric currents) are induced in turn produce a secondary magnetic field. While the electrical resistivity is an active geophysical method where electric current is injected into the ground through a pair electrodes.Inthis study fourty three profiles were sounded using the magnetotelluric in which only indicates potential for ground water. The nine profiles wre later confirm with electrical resistivity method.the results obtained for drilling optimal Boreholes are as follows: ADMT for the nine profile are:185 m, 210-300 m, 210 m, 210-300 m, 175 m, 195-300 m, 190-270 m, 215-300 m and 185 m and results from RSISTIVITY for VES 1-VES 9 are as follows; 150 m, 200-400 m, 300 m, 210-300 m, 180 m, 180 m, 200 m, and 250 m. the results indicate the reliability and uniqueness of the integrated geophysical survey.

KEY WORDS:

Integrated geophysics, Groundwater, Magneto-telluric, , Borehole, Basement, and Electrical resistivity

1.0. INTRODUCTION

Groundwater development has increased greatly due to high demand. Today groundwater availability is determined by the presence and hydraulic qualities of groundwater bearing units, while portability is determined by hydro geochemical properties [1]. Water is regarded the most important natural resource in the world for survival; hence its significance cannot be overemphasise. It is however disturbing if this all-important resource is becoming more and more scarce or difficult to explore [2].[3].. Water scarcity is acute in Adamawa state University, due to increase in population of students which may lead to lack of access to safe drinking water on campus. Students that would have access to this unsafe drinking water are vulnerable to water borne diseases.

However, groundwater is difficult to locate, a range of geophysical methods are required to offer data on its occurrence and location. Geophysical methods can be used to map groundwater resources as well as assess water quality [4].. Gravity, magnetics, seismic, electrical resistivity, electrical resistivity tomography, and electromagnetic approaches are just a few of the geophysical techniques that have been used to prospect for groundwater [5]..

The electrical and electromagnetic surveys have shown to be very useful in groundwater studies [6]. Many of these geophysical approaches have since been employed to characterize groundwater, but the electrical method has once again proven to be the cheapest and successful [7]. That is why the study seeks to use the Audio Magneto- Telluric (ADMT) and electric resistivity method in the search for groundwater potential zones. In groundwater resource mapping, geophysical technique is used for mapping out subsurface geological structure in which groundwater water occurs [8]..

Mubi and Environs is known to have a lots of failed (aborted) boreholes which are often shallow as a result of the Basement complex terrain. The application of ADMT geophysical technique before drilling of borehole becomes necessary in Adamawa State University Mubi campus since it can image subsurface very deep [6]. and [9]. observed that vertical electrical sounding (VES) approach has been effectively employed in groundwater exploration and the computation of hydraulic properties such as hydraulic conductivity and transmissivity, with very effective and efficient results. [10].

The vertical electrical sounding (VES) technique was proven to be useful in achieving good lateral coverage for mapping aquifer units and drilling productive boreholes, according to the submission[11]. the electrical resistivity approach is a useful tool for identifying locations with good groundwater and development potential. [12]. and [13]. vertical electrical sounding (VES) is a geophysical technique for determining subsurface geology. It's alsobeen frequently utilized for determining aquifer potential in borehole drilling. [14], [15]. have been successful with the vertical electrical approach and used integrated geophysical approaches to prospect for groundwater in a fractured shaleaquifer. Also,[16]. geo-electrical survey was conducted utilizing the electrical resistivity method to study subsurface layers and determine aquifer features.

This work is aimed at carrying out integrated geophysical survey using Audio Magneto-Telluric (ADMT 600S-X) and Vertical electrical soundingby running some profiles alongside resistivity survey on the profiles to delineate optimal drilling point.

ADMT method is a non-destructive, non-invasive, portable, and environmentally friendly technique with a wide range of applications in engineering, environmental science, and subsurface geology ,[17]. ADMT approach is a more effective and powerful way for studying both shallow and deep subsurface electrical structures in a variety of situations. ,[18], [19], ,[20]., ,[21], [22]groundwater exploration and prospecting, engineering geophysics, and environmental site evaluations have all made substantial use of Audio Magneto- Telluric (ADMT)

The Geology of thestudy area forms part of the northeast basement complex and comprises of metamorphic gneisses, (migmatitic, amphibolite, mylonites) and igneous (intrusive granitoids and volcanics) rocks. The drainage pattern in the area is typically dendritic and characteristic of igneousmetamorphic terrains with streams emanating from areas of high relief and draining into low relief areas. The presence of major road (Mubi to Cameroon through Tsahuda, Madanya to Cameroon through Moduguva) and foot paths makes the area quite accessible. [23]. differentiated the undifferentiated north eastern Nigerian basement rocks into major and minor types based on study of aerial photographs, field and laboratory studies, while[24]mapped and divided the north-eastern Nigerian basement complex into four; the Mandara Mountain, the Alantika Mountain, the Shebshi Mountain and the Adamawa Massif. ,[25]. investigated the geochemical characters of the main petrographical and structural units of northern Cameroun and assessed its implication for Pan African evolution.

The occurrence, field relationships and petrography of different rock types have been described on a regional scale by some workers ,[26]. and ,[27]. The study of the rocks of Mandara Hills have been made by ,[28], ,[29]and [30]where they documented the petrogenesis and geochemistry of rocks from Gwozaand Madagali areas (located at the northern tip of the study area). Also, ,[31]. studied the occurrences of some ore minerals such as cassiterite, wolframite, galena, chalcopyrite, barite and gem minerals in the ObanObudu-Mandara-Gwoza area in the eastern part of the Nigerian Basement complex. The Mubi area like most basement terrains in Nigeria have experienced extensive tectonism and metamorphism leaving behind imprints, structures and the emplacement of large volumes of granitoid in the Pan-African (600 ±150 Ma) but because of lack of enough geologic data in the area these events were not adequately documented(Fig.1)..

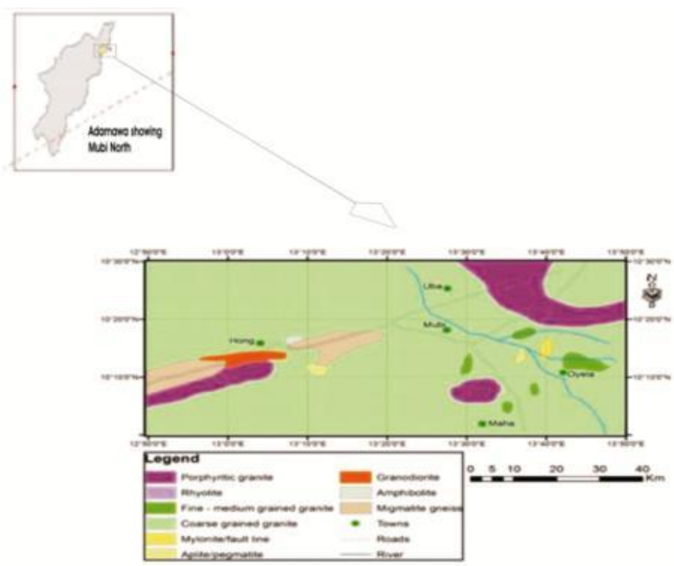


Figure.1. Geological Map of Mubi Area

1.1. LOCATION OF THE STUDY AREA

The study area lies between longitude 13^o 16^I 28.11^{II} and 13^o 17I 15.91^{II} E and Latitude 10^O 16^I 40^{II} to 10^I 17^I 28.11^{II} N (Fig.2.). Adamawa state University is located in Mubi town, Adamawa north senatorial district. The town is situated at the foot of Mandara shield, bordered to the East with republic of Cameroon to the North and West with Borno state. (Fig.2)

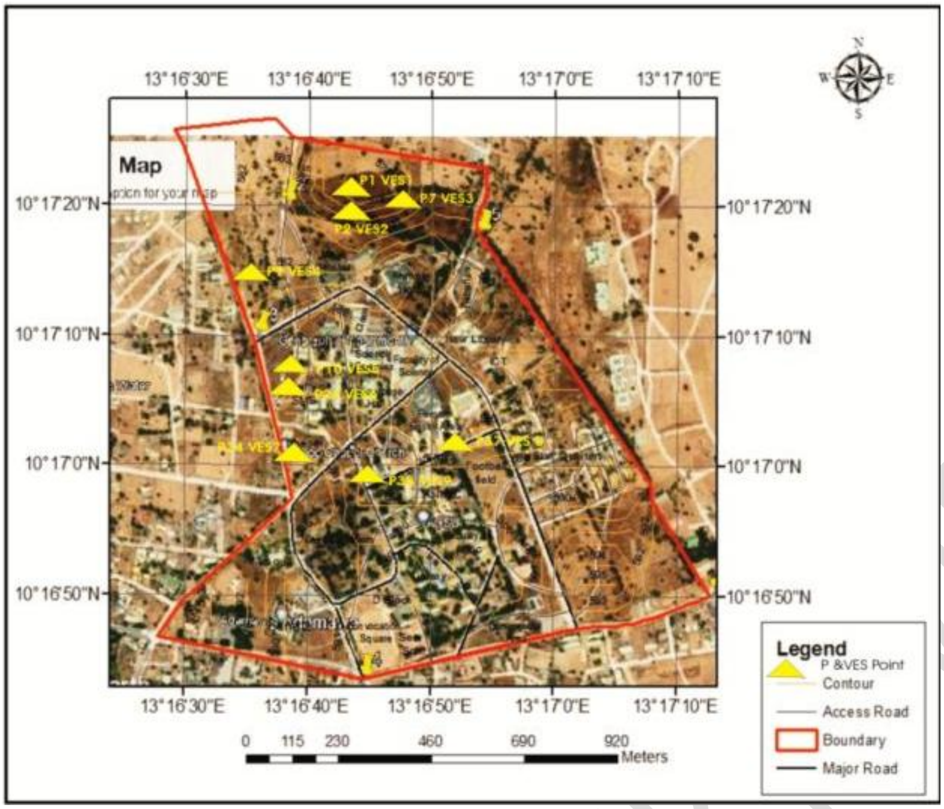


Figure.2. Location Map of the study area

2.1 MATERIALS AND METHODS

2.1.1 Magneto telluric

The magnetomagnetotellurics (MT) is an electromagnetic geophysical exploration technique that images the electrical properties (distribution) of the earth at subsurface depths. The energy for the magnetotellurics technique is from natural source of external origin. When this external energy, known as the primary electromagnetic field, reaches the earth's surface, part of it is reflected back and remaining part penetrates into the earth. Earth acts as a good conductor, thus electric currents (known as telluric currents) are induced in turn produce a secondary magnetic field.

Magnetotellurics is based on the simultaneous measurement of total electromagnetic field, i.e. time variation of both magnetic field B(t) and induced electric field E(t). The electrical properties (e.g. electrical conductivity) of the underlying material can be determined from the relationship between the components of the measured electric (E) and magnetic field (B) variations, or transfer functions: The horizontal electric (Ex and Ey) and horizontal (Bx and By) and vertical (Bz) magnetic field components. According to the property of electromagnetic waves in the conductors, the penetration of electromagnetic wave depends on the oscillation frequency. The frequency of the electromagnetic fields development of the theory determines the depth of penetration. In half a century since its inception, important developments in formulation, instrumentation and interpretation techniques have yielded MT as a competitive geophysical method, suitable to image broad range of geological targets.

Magneto telluric method allows the determination of an electric conductivity earth model from the measurements of natural variation of the surface electric (E) and magnetic field (H) over wide frequency range ,[32]. Magneto telluric field that moves through the earth is dependent on the resistivity of the geologic materials and frequency of the equipment ,[33]. Detailed explanation on magneto telluric technique is found in ,[32], ,[16].,[34], ,[35]. The inversion was done using ,[36].) with the inversion generated and represented as continues resistivity progression versus depth. The instrument used is ADMT 600 – SX, it is considered cheap but it has proved useful and effective in delineating natural magneto telluric field within the earth for mineral and groundwater study. ADMT 600 – SX geophysical instrument comprises of two electrodes, connecting cable and main frame with touch screen. Ground electromagnetic waves in the earth and soil follows the Maxwell equation as presented in equations 1 - 8. Assuming that most of the sub-surface geologic formation are non-magnetic and uniformly conductive macroscopically, therefore, no charge accumulation, then, the Maxwell equation can be simplified as:

$$\nabla^2 H + k^2 H = 0 \qquad (1)$$

$$\nabla^2 E + k^2 E = 0 \qquad (2)$$

Where k is called the wave number (or propagation coefficient)

$$K = [\omega^2 \mu\varepsilon - i\omega\mu\sigma]^{1/2} \qquad (3)$$

Considering that the propagation coefficient k, is a complex number, let k = b + a

Where: ‘a’ is called the phase coefficient and b is called the absorption coefficient.

In the electromagnetic frequency range measured by the ADMT series of natural electric field geophysical instruments (0.1Hz to 5 kHz), the displacement current can usually be ignored, and k is further simplified as:

$$K = -i\omega\mu\sigma \qquad (4)$$

Wave group resistance and resistivity

A magnetic field with a change in the Helmholtz equation induces a changing electric field, and the magneto electric relationship is:

$$\frac{E}{H} = -\frac{i\omega\rho}{k} \qquad (5)$$

The surface impedance Z is defined as the ratio of the surface electric field and the horizontal component of the magnetic field. In the case of uniform earth, this impedance is independent of the polarization of the incident field and is related to the earth resistivity and the frequency of the electromagnetic field:

$$Z = \frac{E}{H} = \sqrt{i\omega\mu\rho}^{i\pi/4} \qquad (6)$$

Equation (5) can be used to determine the resistivity of the earth:

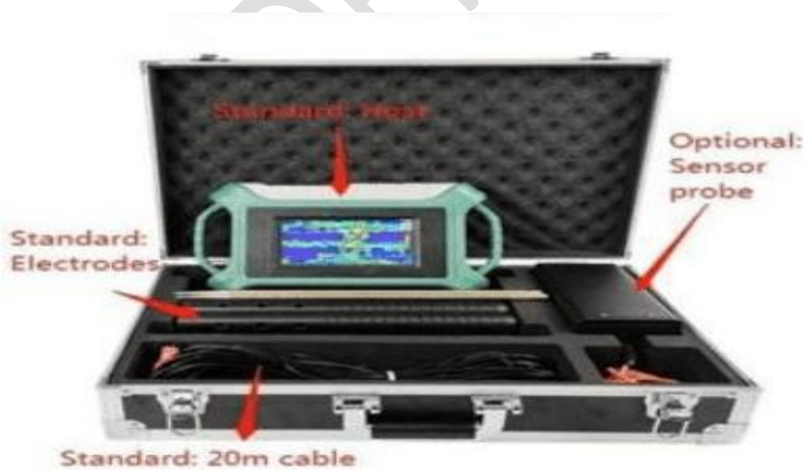
$$\rho = \frac{1}{5f}\left|\frac{E}{H}\right|^2 \qquad (7)$$

Skin depth

In non-magnetic media, the skin depth formula is:

$$\delta \approx 503\sqrt{\frac{\rho}{f}} \qquad (8)$$

It can be seen from the above equation that the penetration depth of electromagnetic waves is related to frequency and resistivity. The frequency is certain, the higher the resistivity, the greater the penetration depth, the higher the resistivity, and the lower the frequency, the greater the penetration depth. Through multi-channel simultaneous input measurement, large data with high-density measurement can be obtained, which breaks through the depth's limitation of traditional high density electrical method and enables the maximum exploration depth. Two methods are involved in carrying out the measurement of the subsurface using this equipment below:



Method 1: Electrode measurement

The measuring points is at the midpoint of the MN electrode as explained in Fig. 4

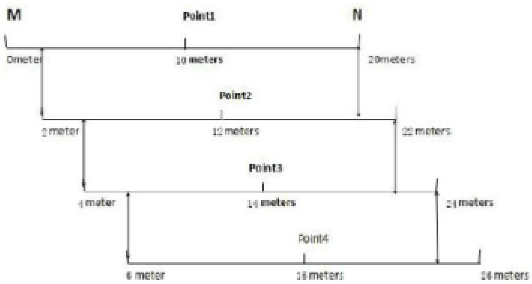


Figure. 3: Electrode measurement, [37].

Method 2: Wireless probe measurement

The measurement point of the wireless probe is at the midpoint of the wireless probe when the probe is continuously moved at 2m intervals as presented in Fig. 4

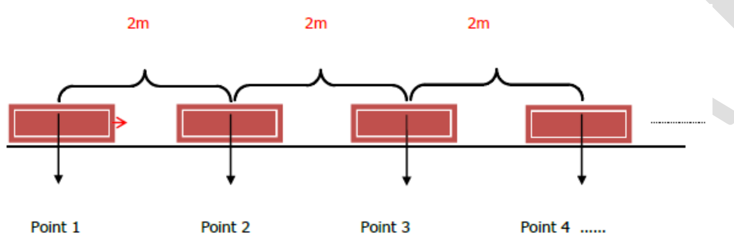


Figure. 4: Wireless probe measurement [37].

In this research a total of fourty profiles were sounded and the best nine profiles was used for this paper, this nine profiles were further confirmed using Electrical resistivity method. The measured data transformed from the frequency domain and each corresponding potential difference into depths with each corresponding potential difference to can be interpreted and confirmed.

2.1.2 Electrical resistivity

The following instruments were used for the dataacquisitionABEMSAS1000digitalTerrameter,Personalcomputer,GlobalPositioningSystem(GPS),Hammers,Measuringtape,UPSBatteryandCharger,pegs,ABEMSASexternalBatteryAdapter (EBA), Electrodes, Reels of Cables andJumpers. The VES stations that were used for thestudyare indicatedin Fig.5.

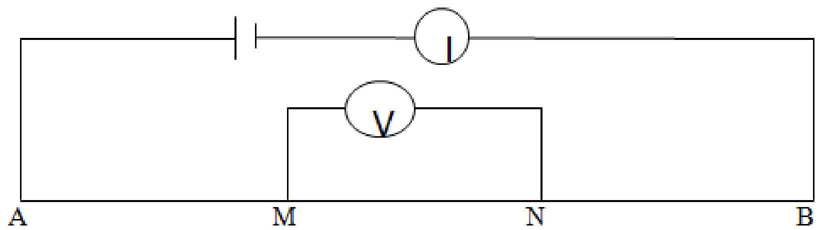


Figure.5:SchlumbergerArray

Electrical resistivity method using Schlumbergerarraywasusedforthisstudy,itinvolvestheplacingoffour(4)electrodescollinearly.TheVES stations were carefully selected andthe electrical cables were laid along the profile,they were then linked to the ground using theelectrodes through the sets of cable jumpers. Thecontact between the electrode cables, electrodetake-outsandcablejumperswerecheckedforproperconnections.Theelectrodetestwasperformedtoensurethat currentwasflowingthroughalltheelectrodes.Theinnerelectrodesarethe potential electrodes and the outer electrodesarethecurrentelectrodes (Fig 5).Nine (9)verticalelectricalresistivitysoundingswerecarriedoutinthe study area corresponding with nine profiles of ADMT to confirm the potentials areas established from ADMT profiles with the aimof delineating thedepth to the groundwater, aquifer thickness andlithologyofthestudyarea.TheTerrametermeasures the resistance, voltage and current. Theapparentresistivityvalueswereobtained. Duringsoundings, apparent resistivities of the subsurface material weremeasuredasafunctionofdepth.Theprogressive increase in the distance between thecurrentelectrodescausesthecurrentlinestopenetrate to greater depths. The acquired verticalelectricalsounding(VES)datawasprocessedusingIXD interpex software. In this research Schlumberger configuration was adopted. Where apparent resistivity was measured using the formula;

$$\rho_a = \frac{KV}{I} = KR \qquad (9)$$

$$K = \frac{\frac{\Pi}{2}\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{\left(\frac{MN}{2}\right)} \qquad (10)$$

and ρ_a is apparent Resistivity K is Geometric Factor, V is Volt, I is Current R is Resistance, and AB is the Current Electrode Separation.

3.0 RESULTS AND DISCUSSION

The results acquired from ADMT survey are presented as images(Fig.6) of the subsurface from which depths, thickness and geoelectric sections was obtained are as follows;

Figure.6. ADMT Profiles of the study area (Nine Profiles)

Table 1.Interpretation of Audio Magnetic Telluric Data(ADMT-600 S-X) results

PROFILES	ZONES	THICKNESS (M)	DEPTH(M)	Pdf(mV)	LITHOLOGIC SECTIONS
***Profile 1*:**	A	0 - 60	60	0.16 - 0.25Wet topsoil/Overburden	
	B	61 - 160160	0.4 - 0.57Fresh Basement		
	C	161 -185	185	0.24-0.36Weathered Basement	
	D	186 - 260	260	0.44-0.57Fresh Basement	
	E	261 - 300	300	0.36-0.44Fractured Basement	
Profile 2:	A	0 - 60	60	0.19-0.27	Wet topsoil/overburden
	B	61 - 180	180	0.43-0.61Fresh Basement	
	C	18 - 210210	0.19-0.35	Weathered Basement	
	D	211 - 270	260	0.43-0.61	Fresh Basement
	E	271 - 300	300	0.19-0.35	Weathered/Fractured
Profile 7:	A	0-60	60	1.4-2.4	Dry topsoil/fresh Basement
	B	61-210	210	0.2-1.2	Fractured Basement
	C	211-240	240	1.4-2.4	Fresh Basement
	D	241 - 300300	0.2-1.6	FracturedBasement	
Profile 9:	A	0 - 55	55	0.37-0.58Wet Clay topsoil	
	B	56 -- 120	120	0.13-0.41	Fractured Basement
	C	121-180	180	0.41-0.58	Partially Fractured
	D	181-210	210	0.13-0.25	Weathered Basement
	E	211-240	240	0.37-0.58	Partially Fractured
	F	241 – 300	300	0.13-0.29	Weathered Basement
Profile 10:	A	0-30	30	0.54-1.19	Dry topsoil/overburden
	B	31-175	175	0.24-0.44	Weathered Basement
C	176-300	300	0.54-119Partially Fractured		
Profile 24:	A	0-135	135	0.65-0.83	Dry topsoil
	B	361-195	195	0.23-0.53	Weathered Basement
	C	196 -220	220	0.41-0.47	Fresh Basement
	D	221 - 300	300	0.23-0.53Weathered Basement	
Profile34:	A	0-30 30	0.11-0,21Wet Clay topsoil		
B	31-105	105	0.41-0.61	Partially Fractured	
	C	106-190	190	0.11-0.31	Weathered Basement

	D	196-225	260	0.41-0.56.	Partially Fractured
	E	226-270	270	0.11-0.26	Weathered Basement
	F	271-300	300	0.46-0.61	Fresh Basement
Profile37:	A	0-15050		0.56-1.12	Dry top/Sandy overburden
	B	151-180	180	0.38-0.92	Partially Fractured
	C	181-215	215	0.29-0.56	Weathered Basement
	D	216-260	260	0.65—1.01	Partially Fractured
	E	261-300	300	0.29-0.47	Weathered Basement
Profile 38:	A	0-30	30	0.0.6-1.6	Wet topsoil
	B	31-70	70	3.1-5.3	Fresh Basement
	C	71-185	185	0.6-1.6	Weathered Basement
	D	186-300	300	0.36-5.3	Fresh Basement

Figure 6, represents the cross-sections of the nine profiles which describe the potential difference contoured sections. The potential difference is directly proportional to the electric resistivity distribution through the area under the profiles where (the highest potential difference equivalent to the highest electric resistivity and Vis versa) so we can identify the properties and the types of the geological formations, geological structures features and groundwater aquifers extensions and properties.

From the interpreted profiles there are several geologic strata differentiated according to the change in their electric properties such as resistivity and potential difference. The nine profiles can be divided into three to six zones each based on their differences in the electric resistivity as shown in Fig.7 and the description of the of the lithological sections and thickness are displayed in table 1 above just as described for profile one below.

For profile 1: first zone (A) has Medium potential difference about (0.16 – 0.25 mV) with thickness of about 50-60 meter and extended into depth of about 0 – 60 meter from the ground surface which composed of a surficial deposits (Wet topsoil/Overburden).

Zone (B) has high potential difference about (0.4 – 0.57 mV) with thickness of about 60 meter and extended into depth of about 61-160 meter which composed offresh Basement.

Zone (C) has low to medium potential difference about (0.24 – 0.36 mV) with thickness of about 161-185 which composed of weathered Basement.

Zone (D) has very high potential difference about (0.44 – 0.57 mV) with thickness of about 186 - 260 meter and extended into depth about 290 – 300 meter which composed of shale and mudstone.

Zone (E) has very high potential difference about (0.36 – 0.44 mV) with thickness of about 261 - 300 meter composed of fractured Basement.

The areas observe to have low/medium potential difference due to weathering and fracturing of Basement rocks are considered potential zone for Borehole drilling. While zone of high potential difference are considered not favouring zone for groundwater utilization. For the area surveyed, the nine profiles are potential areas for borehole drilling as confirmed by electrical resistivity method. Based on the above ADMT results, borehole can be drilled on those nine profiles at the depth of 185 m, 210-300 m, 210 m, 210-300 m, 175 m, 195-300 m, 190-270 m, 215-300 m and 185 m respectively.

To confirm the interpretation of the potential difference cross sections across the ADMT profile, we used Electrical resistivity method from which the apparent resistivity values was interpretedwith IXD interpex software to get the true resistivity values and locate the accurate depth to overburden, weathered and fractured basement aquifer, and locate the accurate location for drilling a new wells to increase the water supply on campus. From the electrical resistivity sounding carried out the following results were obtained and interpreted Fig. 7 and table 2.

Figure.7. Resistivity Curves of Nine VES points

Table 2. Interpreted Resistivity data over the Nine Profiles

S/N	Layers	Resistivity(Ωm)	Thickness(m)	Depth(m)	Lithologic Section
VES1	1	55.00	1.0	1.0	Wet Clay topsoil
	2	25.00	9.0	10.0	Alluvium/Overburden
	3	75.00	50.0	60.0	Weathered Basement
	4	150.00	250.	310	Fractured Basement
	5	400.00	---	---	Fresh Basement
VES2	1	150.00	1.0	1.0	Dry Topsoil
	2	90.00	29.0	30.0	Weathered Basement
	3	220.00	170.0	200.0	Partially Weathered
	4	90.0	-	-	Weathered Basement
VES3	1	220.00	1.0	1.0	Dry topsoil
	2	180.00	29.0	30.0	Partially Weathered
	3	60.00	70.0	100.0	Weathered Basement
	4	200.00	200	300.0	Partially Weathered
	5	180.00	----	---	Fractured Basement
VES4	1	90.00	1.0	1.0	Wet topsoil
	2	200.00	9.0	10.0	Fresh Basement
	3	90.00	50.0	60.0	Weathered Basement
	4	200.00	150.0	210	Partially Fractured
	5	80.00	----	----	Weathered Basement
VES5	1	220.00	1.0	1.0	Dry Topsoil
	2	200.00	9.0	10.0	Partially Weathered
	3	70.00	170.0	180.0	Weathered Basement
	4	230.00	-	-	Partially Weathered
VES6	1	500.00	1.0	1.0	Dry Topsoil
	2	450.00	9.0	10.0	Fresh Basement
	3	390.00	70.0	80.0	Fractured Basement
	4	110.00	-	-	Weathered Basement
VES7	1	55.00	1.0	1.0	Wet Topsoil
	2	25.00	29.0	30.0	Alluvium/Over burden
	3	250.00	60.0	90.0	Partially Weathered
	4	180.00	----	----	Weathered Basement
VES8	1	180.00	1.0	1.0	Dry Topsoil
	2	120.00	29.0	30.0	Partially Weathered
	3	230.00	60.0	90.0	Fresh Basement
	4	90.00	-	-	Weathered Basement
	1	15.00	1.0	1.0	Wet Alluvium Topsoil
	2	180.00	34.0	35.0	Partially Weathered

VES9	3	40.00	215.0	250.0	Weathered Basement
	4	170.00	-	-	Partially Weathered

From the resistivity data interpretation, the depths to potential aquifers for drilling new boreholes in Adamawa state University from VES 1-VES 9 are as follows; 150 m, 200-400 m, 300 m, 210-300 m, 180 m, 180 m, 200 m, and 250 m respectively. These shows that the result obtained from electrical resistivity method confirmed what was obtained from ADMT profiles.

4.0. CONCLUSION

Fromtheresultsandfindingsofthestudy, groundwater exploration using integrated geophysical methods gives a better result for groundwater exploration in Basement complex area where groundwater are basically found in over burden, fractures and weathered zones.However,from the survey carried out, fourty nine (43) profile was run in Adamawa state University out of which only nine were potential areas, These nine potential areas were followed up with electrical resistivity method to confirm the result of ADMT 600S-X. The results obtained from these two methods which are to be utilized for Borehole drilling : ADMT for the nine profile are:185 m, 210-300 m, 210 m, 210-300 m, 175 m, 195-300 m, 190-270 m, 215-300 m and 185 m and results from RSISTIVITY for VES 1-VES 9 are as follows; 150 m, 200-400 m, 300 m, 210-300 m, 180 m, 180 m, 200 m, and 250 m. From these result one can conclude that application of integrated geophysical method in groundwater exploration is very important as you can see the results of two methods are in agreement with each other.

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