The effect of geological structures on groundwater in sedimentary formation of Abuja. Nigeria.

BY

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ABSTRACT

Abuja sedimentary formation is located within the southern part of the federal capital territory which house Abaji and Kwali area councils. This area was investigated for ground water potential using the effect of the rock structures to determine the hydrology components of the studied area. Geophysical method and geological method of exploration involving the vertical electrical sounding was employed to prospect for groundwater in the Abuja sedimentary Formations. Vertical electrical sounding using the Schlumberger electrode array configuration were deployed along traverses within the area. The soundings were conducted at seven locations .The qualitative analysis of the resistivity data identified relatively high conductive regions indicating possible aquifer zones. The quantitative interpretation of the modelled sounding curves delineated between five and seven subsurface layers at different location within the Formation. These layers were inferred to be the top soil, sandy-clay/clayey-sand, laterite and coarse sandstone. The modelled VES curves characterized the topsoil/weathered basement with resistivity range of 4 to 10Ωm with an estimated depth to basement ranging from 45 m to 120m. The results of the study confirm that the VES methods are very suitable for development of groundwater in these communities within Abuja sedimentary formation. Geophysical method combined with geological logging should hence, form an integral part of groundwater exploration programmes in solving problems associated with groundwater prospecting to locate potential aquifers for the supply of potable water to communities within this Formation.

INTRODUCTION

Water resources development and management is as old as mankind. In Exodus 17:1-6, God provided the children of Isreal with water in a miraculous way on their journey through the Sinai desert to the Promised Land. In 2 kings, chapter 2:19-22, Elisha, the prophet of God cleaned the well of Jericho, which had become contaminated. And when a remnant of repentant Isrealites returned from Babylon to their homeland, God led them to "water in the wilderness- Isaiah 43:14, 19-22. Globally, regionally and locally, different scholars and experts have carried out research into exploration of groundwater using different concepts and geophysical arrays. Efforts at all tiers of government in Nigeria (federal, state and local governments) in the provision of adequate water to meet demand have been evidence in many water planning projects since 1917. This ranges from setting up of Nigerian Geological Survey (NGS), the Federal Ministry of Water Resources (FMWR), River Basin Development Agencies and state water boards to manage and oversee water projects in Nigeria (FMWR, 2000). Groundwater containing by far the largest volume of unfrozen fresh water on Earth and is a hugely important natural resource. However, what the general public and most decision-makers know and understand about groundwater is usually very little (UNESCO, 2012). Today, knowledge of groundwater around the world, its functions and its use is increasing rapidly and views about the many ways in which groundwater systems are linked with other systems are changing accordingly.

The responsible factors for under-utilisation of groundwater resources development of sedimentary formations has been attributed to poor hydrogeological survey to accurately infer and identify viable groundwater potential areas (Ibrahim *et al*, 2012) and this is the gap identified in my study area which require adequate study. In order to maximize the optimal exploration of groundwater for the purpose of solving the problem of water resource crisis, there is need for detailed hydrogeophysical. investigation coupled with application of geospatial technology for maximizing the potential of groundwater resources both at the local and regional scale analyses.

THE STUDY AREA

Abuja is located in the centre of Nigeria as the Federal Capital Territory (FCT). Abuja officially became Nigeria's capital on 12 December 1991, which replaced the previous capital Lagos. As of the 2006 census, the Federal Capital Territory has a population of 778,567(Jatau,2013).Abuja's geography is defined by Aso Rock, a 400-metre monolith left by water erosion (Abam,2012) "Aso" means "victorious" in the language of the (now displaced indigenous people) Asokoro ("the people of victory").

Abuja is located between longitude 6^{o} $50^{"}$ and 8^{o} $55^{"}$ East of the Greenwich Meridian and latitude 8^{o} 45" and 9^{o} $44^{"}$ North of the Equator, within the Savannah region that is blessed with moderate climatic conditions (Abam *et al*, 2013. Avci, 1983). Abuja sedimentary formations is found around the boundaries of Kwali and mostly in Abaji area.

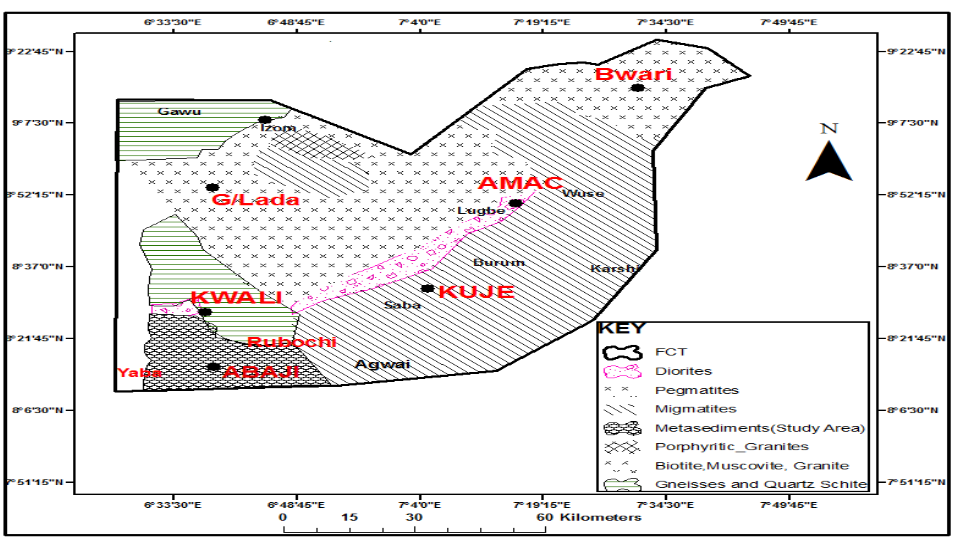

Figure 1.2. Geology of Abuja showing various lithologies.(Desmond,2017)

The FCT is almost predominantly underlain by high grade metamorphic and igneous rocks of precambrian age (Mamman and Oyebanji (2000). Generally the North North East (NNE) South South west (SSW) of the FCT consist of gneiss, migmatites and granites .The belt broadens southwards and attains a maximum development to the southeastern sector of the area where the topography is rugged and the relief is high. In general, the rocks are highly sheared (Kogbe, 1978). The lowest elevation in the Federal Capital territory is found in the extreme southwest where the flood plain of the river Gurara is at an elevation of about 70m above sea level. From there, the land rises irregularly eastwards, northwards and northwestwards. The most prominent of these include the Gawa range in the northeast, the Gurfata range southwest of Suleja, the Bwari Aso range in the northeast, the Ido Kasa range north west of Kuje and the Wuna range north of Gwagwalada. Elsewhere in the territory, there are many rather roundish isolated hills usually called inselbergs.

The FCT has two main seasons, rainy (April to October) and dry (November to March). The high altitude and undulating terrain of the territory act to provide a regulating influence on its weather. The soils of the territory are generally shallow and sandy in nature, especially on the major plains such as lku Gurara, Roboes and Rubochi. The high sand content particularly makes the soils to be highly erodible. The shallow depths are a reflection of the presence of stony lower horizons. The FCT falls within the guinea savannah vegetation zone of Nigeria (Anondonkaa, 2012). Patches of rain forest, constituting about 7.4 per cent of the total mass of vegetation, however, occur in the Gwagwa plains, especially in the gullied terrain to the south and rugged southeastern parts of the territory.

METHODOLOGY AND FIELD PROCEDURE

All resistivity methods employ an artificial source of current which is introduced into the ground through point electrodes or long line contacts. The procedure is to measure potentials at other electrodes in the neighborhood of the current flow. Electrical methods of geophysical investigations are based on the resistivity or its inverse conductivity of materials. The electrical resistance, R of a material is related to its physical dimension, cross sectional area, A, length, L, through the resistivity ρ or its inverse, conductivity, σ is given by

$$\rho = 1/\sigma = RA/L$$

The methodology consisted of a desk study and field investigations. The investigation to determine groundwater potentials were carried out in four stages; (a) desktop study of physical and geological maps of the study area. (b) Field reconnaissance survey; (c) Vertical Electrical Soundings; (d) Processing, Analysis and Interpretation of Data. The desk study involved compiling and assessing the following data sets: Topographic and geological maps, Existing borehole information and Previous hydrogeological work undertaken in the study area. The reconnaissance survey is meant to locate and target areas for geophysical investigations .The point that were selected from the map will now be identified on the ground through with the aid of GPS.

The ground truthing also involves ascertain topography, geology, hydrogeology, structural features and water points. The terrain in the various points was assessed to have a fair idea of the working environment. Terrain evaluation is an inherent part of every groundwater exploration programme. It precedes all geophysical investigations and its main objective is to locate the best site for carrying out geophysical surveys, by identifying surface features, which are characteristic indicators of the presence of subsurface water-bearing formations. involves a very careful observation of the surface physiographic and geologic features in the survey area such as vegetation, outcrops, stream patterns, springs, and the location of any previous boreholes or wells, exposed fractures and the direction of runoffs or the slope of the terrain. The field equipment employed for the resistivity field data measurement is the ABEM SAS 1000C Terrameter. The equipment measures resistivity values digitally as computed from Ohm‘s law. Schlumberger array was employed. Generally the array consists of a pair of potential electrodes (P1P2/2) and a pair of current electrodes (C1C2/2). These are driven into the earth in a straight line to make a good contact with the ground. The Schlumberger VES method involved moving electrodes progressively and symmetrically apart. This was followed by taking and recording of the resistivity data at certain electrodes spacing. Two distinct advantages of taking readings by moving the current electrodes were considered in preference to other methods. These are: (1) there are fewer electrodes to move and (2) the readings are less affected by any lateral variations that may exist (Mussett and Khan, 2000). At some points, the expansions of the current electrodes resulted in a too small potential difference values, which became difficult to precisely measure. This problem was overcome by moving Potential electrodes further apart, while keeping the current electrodes fixed. Further readings were then taken by expanding the current electrodes, using the new potential electrode positions. This also allowed an increase in the depth of the investigation. The current electrode separation C1C2/2 was from 1.5 m to 150m, while the potential electrode separation P1P2/2 was either 0.5 m or 5 m with a view to determining the subsurface layering, overburden thickness and thickness of the aquifer. A total of Thirty (30) Vertical Electrical Sounding points were investigated from the quadrated map of the study area. The The reason for quadrating the map is to choose location within the area randomly. Some of the chosen sites are either at the end of the map or at the middle so that all available area can be cover within this formation. The area that were investigated are Aygana,Yaba,Naharati,Gurdi andTekpesha,Ashara and Pandagi.

The principle governing this method is that the resistivity of a water bearing formation (aquifer) decreases as the amount of water present increases (inverse of conductivity). The development of secondary porosity by jointing and fracturing of rock resulting in a further reduction of the resistivity. A schlumberger vertical electrical sounding configuration was employed in this case. Electric current was introduced into the ground via two current electrodes and potential electrodes. The resistivity value reading of the different layers measured by this machine was multiply by a constant geometric factor (K) from this formula.

$$K = \frac{(AB/2)^2 - (MN/2)^2}{MN} \times 3.141 \qquad \text{Equation 5}$$

Where :

K = Geometric Factor

AB = Current electrodes

MN = Potential electrodes

The value obtained from this multiplication gives the apparent resistivity (Pa) was plotted against electrode spread (AB/2) on the Y and X axes respectively a bilog graph paper.

The data was further processed through curve matching with standard master curve and computer modeling of Zohdy and Bisdorf Schlumberger sounding data processing and interpretation program to determine the thickness of various subsurface layers. Field data was analyzed using the ‗IXID‘software program. The Model outputs include the number of geological layers in the sub-surface, and their corresponding resistivity and thickness.

RESULTS AND DISCUSSION

The success of resistivity survey for groundwater is hinged on a good data presentation which may lead to a correct interpretation to achieve the desired results. The task has always been how to detect groundwater or an aquifer from the resistivity values. To identify the presence of groundwater from resistivity measurements, one can look to the absolute value of the ground resistivity, using the principles of Archie‘s law:

For a practical range of fresh water resistivity of 10 to 100 Ω.m, a usual target for aquifer resistivity can be between 50 and 2000 Ωm. Most of the time it is the relative value of the ground resistivity which is considered for detecting groundwater: In a hard rock (resistant) environment, a low resistivity anomaly will be the target, while in a clayey or salty (conductive) environment, it is a high conductivity anomaly which will most probably correspond to water. In sedimentary layers, the product of the aquifer resistivity by its thickness can be considered as representative of the degree of productive of the aquifer which attract groundwater development (Bernard, 2003). This approach has been adopted in this interpretation.

Results of Agyana VES.

The data obtained was plotted on bilog graph paper and the curve obtained was matched with standard master curve and computer software package to determine the resistivity of different subsurface layer. The geo-electric section on table 4.1, shows six geoelectric layers, but three distinct lithologic layers. The topsoil along the section has resistivity values ranging from 150ohm-m to 1350ohm-m characteristic of topsoil made of clay and silt as from the field during surveying . The third geo-electric layer which is conductive and recognized as the aquifer layer with unit resistivity values between 1486ohm-m to over 5200ohm-m with thickness range of 25-40m is down to the fouth layer with resistivity of 500ohm of 100m thickness down to infinite is the presumed aquifers zone

The survey interpretation reveals a sedimentary setting with formation ranging from sandstone to laterite and also on the figure 4.1, The sudden bend of the graphic line of the VES curve at 80m (spacing) is an indicator of high conductive element (ions) which is contain in a liquid body. This is because lower resistivity value have a high potential for aquifer bearing water according Coker (2012) .Therefore from the survey result on this site, ground water supply can be source at 100m to support human activities which is in line with Stummer (2003) argument .

Table 4.1 is the summary of the interpretation of the data obtained through curve matching of the field curves with standard master curve of various resistivity and thickness of various lithologies. Table 4.2 show the reading of various stratigraphic sequence of the earth.Intepretation of this table give us the value of each lithology as presented in table 4.1. which is compare with the standard resistivity value of lithological formation of Moris and Johnson in 1967.

Results of Ashara Modelled VES.

The survey interpretation which is presents in table 4.3 reveals a sedimentary setting with formation ranging from topsoil to sandstone. The topsoil which is relatively thin is characterized by resistivity values ranging from 760 ohm-m to 6840ohm-meter with a thickness that varies from 0.7m to 4m, is composed of predominantly laterite, and clay.The second layer has resistivity values that vary from 6840-2414ohm-m The next layer with resistivity range of 184-128 ohm-m and a thickness between 30m- ∞m is presumed to be coarse to fine sandstone. It is predominantly wet. The fouth layer which is probably conductive and reflects the layer identified as the aquifer unit characterized by resistivity values between 184 ohm-m and 128 ohm which is in agreement with Ajayi and Hassan (1990), Oyedele and Adeyemo (2001) who are of the view that the decomposed layers with resistivity of 20-1000ohm-m and thickness of 14-28m forms the aquifer which are subject to groundwater development .and The sandstone ranges from fine to coarse grain which constitutes the main aquifer in this location.. Below is the summary of the interpretation of the data obtained through curve matching of the field curves with standard master curve as interpreted by the IXID software which is presented in figure 4.2? The sandstone formation in most part of the area is consolidated and well sorted which is responsible for availability of good underground water. Therefore if groundwater is development at 50m depths within Ashara area, there will be availability of water to support human activities for sustainable development.

Results of Gurdi VES Modelled .

The survey interpretation of Gurdi area as presented in table 4.5.The cross section shows seven to eight geo-electric layers. The topsoil has resistivity value ranging from 1000ohm-m to 1500ohm-m with thickness varying from 0.8m-2.5m characteristic of lsandstones. The sixth layer which is recognized as the aquifer layer has resistivity range of 1615ohm-m – 1200 ohm-m with thickness of 40m- ifinite metre . The sediment within 9m to 30 are dry sand because of their high resistivity at according coker (2012). The sandstone ranges from fine to coarse grain that constitutes the main aquifer in this location. The shallow aquifer is from 35-80m which is as a result of presence of highly permeable rocks which allow free movement of water within the ground of. The sandstone is well sorted and highly consolidated; therefore availability of groundwater for sustainable development can be drilled at 70-80m depth. From this results, ground water can be made a major source of water supply because the aquifers are close to the surface which according Bernard (2003) where ground water is close to surface, groundwater become the major source of water for agricultures and other humans activities because water can be source at cheapest cost to support life. Below is the summary of the interpretation of the data obtained through curve matching of the field curves with standard master curve.

Table 4.1 Lithologic sequence of Agyana

VESTATION	RESISTIVITY (ohm-m)	THICKNESS (m)	LITHOLOGY OF FORMATION
VES 1	150	0.6	Top soil (Silt and clay
	1350	8	Sandstone
	1486	25	Medium grained sandstone
	5200	40	Lateritic sand
	500	100	Medium grained sandstone
	5500	∞	Coarse grained sandstone

Source; Field Data, 2016

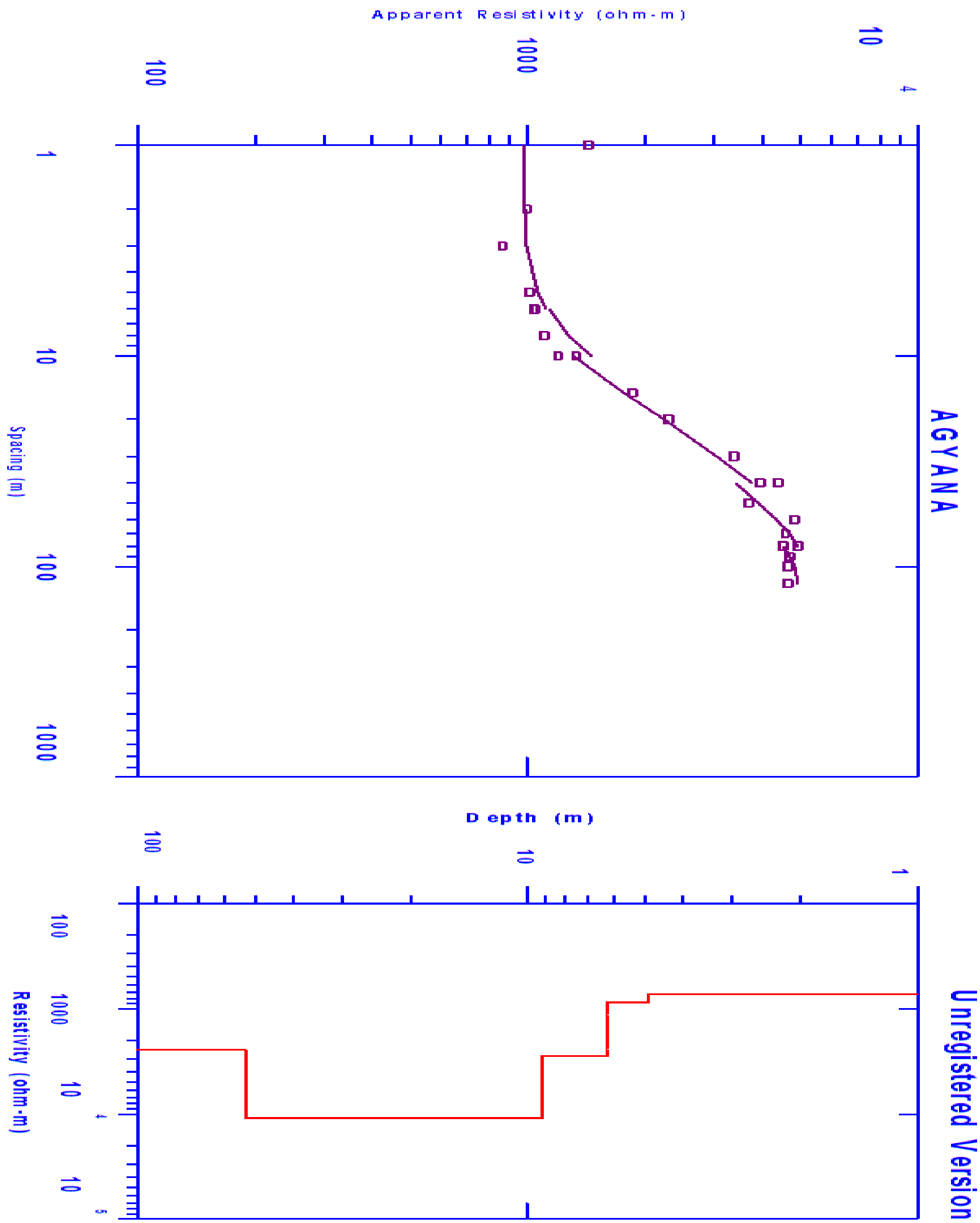

Figure 4.1. VES curve modeled of Agyana (Source; Field data, 2016)

Table 4.2.Resistivity of Agyana VES schlumberger Array (Source; Field data 2016)

Spacing	Data	Synthetic

No	(Meters)		Resistivity	Resistivity	Difference
	AB/2	MN			
1.	1.00	0.500	1426.4	977.1	31.50
2.	2.00	0.500	996.5	983.2	1.33
3.	3.00	0.500	862.5	998.8	-1581
4.	5.00	0.500	1014.3	1068.8	-5.37
5.	6.00.	0.500	1035.4	1124.4	-8.59
6.	6.00	1.00	1046.0	1139.5	-8.59
7.	8.00	1.00	1106.0	1284.1	-16.05
8.	10.00	1.00	1330.5	1467.3	-10.27
9.	10.00	2.50	1195.6	1318.7	-10.27
10.	15.00	2.50	2859.2	1788.0	3.83
11.	20.00	2.50	2505.3	2259.6	1.98
12.	30.00	2.50	3372.0	3105.0	7.91
13.	40.00	2.50	4379.3	3807.9	13.04
14.	40.00	7.50	3947.7	3432.6	13.04
15.	50.00	7.50	3681.1	3948.6	-7.26
16.	60.00	7.50	4839.1	4359.6	9.90
17.	70.00	7.50	4573.3	4678.0	-2.15
18.	80.00	7.50	4911.5	4916.1	-0.0937
19.	80.00	15.00	4500.8	4505.0	-0.0937
20.	90.00	15.00	4691.1	4660.0	0.662
21.	100.0	15.00	4641.1	4761.8	-2.60
22.	120.0	15.00	4637.5	4839.7	-4.36

Table 4.3. lithologic Sequence of Ashara.

VESTATION	RESISTIVITY (ohm-m)	THICKNESS (m)	LITHOLOGY OF FORMATION
VES 1	760	0.7	Top soil
	6840	4	Laterite
	2414	10	Laterite
	184	30	Medium to coarse sandstone
	128	∞	Medium to fine sandstone

Source; Field data, 2016

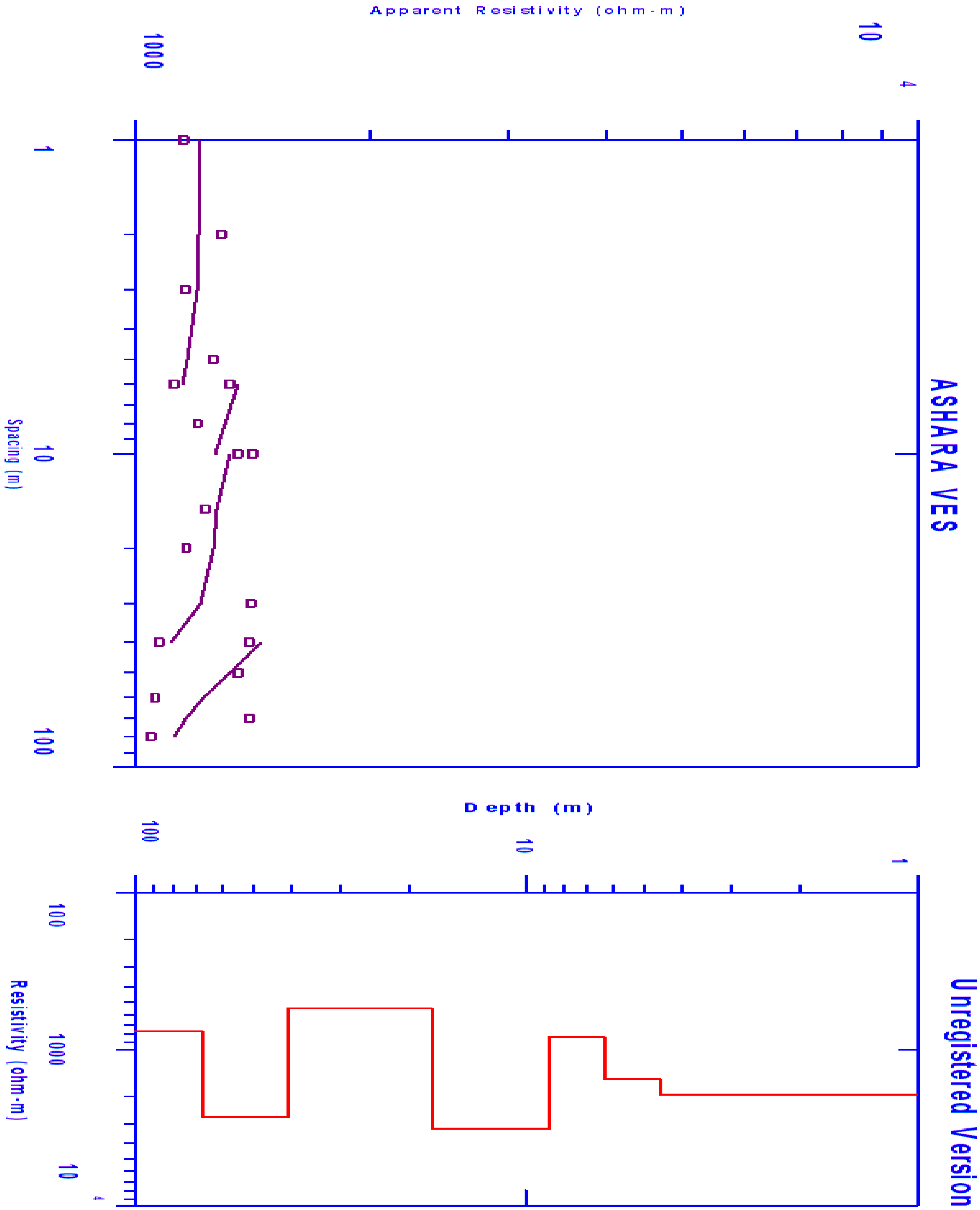

Figure 4.2 VES curve modelled of Ashara. (Source; Field data, 2016)

Table 4.4. Resistivity of Ashara VES.(Source, field data,2016)

No	Spacing (Meters) AB/2	Data Resistivity MN	Synthetic Resistivity	Synthetic Resistivity	Difference
1.	1.00	0.500	1153.1	1210.6	4.98
2.	2.00	0.500	1289.5	1207.4	6.36
3.	3.00	0.500	1159.7	1199.7	.3.44
4.	5.00	0.500	1256.7	1170.1	6.89
5.	6.00.	0.500	1120.0	1150.4	2.71
6.	6.00	1.00	1320.0	1355.8	2.71
7.	8.00	1.00	1202.1	1307.5	.8.76
8.	10.00	1.00	1352.0	1266.7	6..30
9.	10.00	2.50	1413.5	1324.4	6..30
10.	15.00	2.50	1228.2	1272.9	.3.63
11.	20.00	2.50	1162.3	1262.6	8.62
12.	30.00	2.50	1072.5	1213,3	13.64
13.	40.00	2.50	1399.6	1112.6	3.74
14.	40.00	7.50	1355.2	1452.0	3.74
15.	50.00	7.50	1355.2	1320.8	2.53
16.	60.00	7.50	1060.0	122.7	.15.35
17.	70.00	7.50	1398.6	1160.5	17.02
18.	80.00	7.50	10.49	1126.	1 7.33

Table 4.5. Lithologic Sequence of Gurdi

VESTATION	RESISTIVITY (ohm-m)	THICKNESS (m)	LITHOLOGY OF FORMATION
VES 1	1000	0.8	Top soil
	1500	2.5	Sandstone
	2229	9	Medium grained sandstone
	1077	15	Medium grained sandstone
	6400	30	Medium to coarse grained sandstone
	1615	40	Medium grained sandstone
	4643	70	Medium to coarse grained sandstone
	12000	∞	Coarse grained sandstone

Source; Field data, 2016

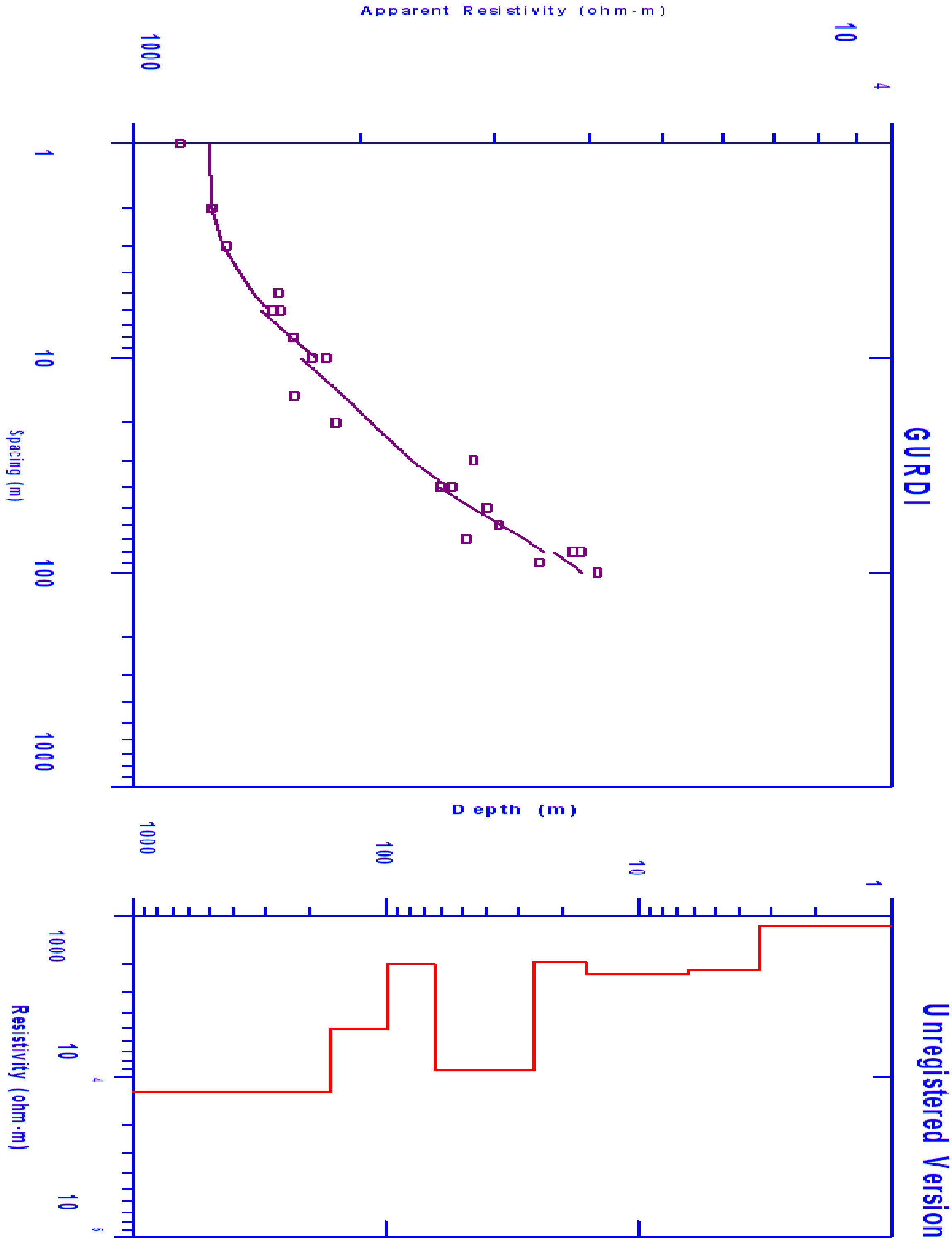

Figure 4.3. VES Curve Modelled of Gurdi (Source; Field data 2016)

Table 4.6. Resistivity of Gurdi (Source; field data, 2016)

No	Spacing (Meters) AB/2	Data Resistivity MN	Synthetic Resistivity	Synthetic Resistivity	Difference
1.	1.00	0.500	11.521 1234.5	.7.16	
2.	2.00	0.500	1268.5	1259.5	0.704
3.	3.00	0.500	139.1	1311.2	1.34
4.	5.00	0.500	1556.0	1461.0	6.10
5.	6.00.	0.500	1578.0	1539.7	1.80
6.	6.00	1.00	1527.7	1500.2	1.80
7.	8.00	1.00	1626.4.	1638.3	.0.731
8.	10.00	1.00	1800.0	1752.1	2.65
9.	10.00	2.50	1721.6	1675.9	2.65
10.	15.00	2.50	1630.9	1878.2	.15.16
11.	20.00	2.50	1852.5	2034.3	.9.81
12.	30.00	2.50	2810.0	2323.4	17.31
13.	40.00	2.50	3634.2	2537.4	0.490
14.	40.00	7.50	3550.0	2821.7 0.490	
15.	50.00	7.50	2925.7	3083.1	3.55
16.	60.00	7.50	3035.4	3311.7	.1.57
17.	70.00	7.50	2755.4	3505.5	20.18
18.	80.00	7.50	3797.1	3595.5	7.67
19.	80.00	15.00	3894.5		7.67
20.	90.00	15.00	3437.5	3761.2	.9.41
21.	100.0	15.00	4095.0	3898.3	4.82

CONCLUSION

In conclusion, the main objective of this study is to determine the potential of groundwater and geological structure of the study area. The study area reveals seven (7) lithostratigraphy of various thicknesses and apparent resistivities values which ranges from 13Ωm to 7342Ωm.This clearly shown that some area is clay formation while others are highly consolidated. In most VES points in the study area, water bearing zones are within the fouth and sixth lithological layer which is as a result of low to moderate resistivity value of 45Ωm to 600Ωm.The Study area is underlined with Patti Formation consisting of thick unconsolidated sand of Nupe Bida sandstone with an intercalation of clay bands. In some areas, the clay units are more prominent which are covered by lateritic sand and often reach a thickness of 8 to 14m. This lithostratigraphy determine the occurrence, type and characteristics of the aquifers. Intercalation of sand and clay constitute a system of aquifer separated by aquitards. The (unconfined water table) aquifer zone exists in all the area from 20m to about 40m.

The minimum drilling depth should be in the range of 50 - 120 m; however, the drilling supervisor is mandated to determine the final drilling depth based on the ground conditions.

Due to reasons beyond my control, the drill logs could not be obtained so as to correlate the geophysics findings with the drill logs. This is because, the drilling of the selected points was not done at the time of writing this research work. It is therefore recommended that future geophysical groundwater interpretations should include the drill logs. Further conductivity and resistivity modelling research should be done in the Abuja Sedimentary Formation to establish the conductivity and resistivity at depth for which groundwater can be obtained.

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