HYDROGEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS FOR LOCATING OPTIMUM DRILLING POINT(S) FOR DAURA TOWN, NORTHEAST NIGERIA.

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ABSTRACT

Daura town is located south of Damagum in Fune Local Government, Yobe State.It has an approximately 200,000 inhabitants. Daura town is experiencing severe water scarcity, with no source of water within the town and its immediate surroundings. Water for domestic and other uses is transported from far distance via water tankers. Previous boreholes drilled in the town encountered a monotonous shale unit throughout the drilled depth and thus all the wells were abortive. This necessitated the need for a comprehensive geophysical and hydrogeological investigations aimed at locating optimum drilling point(s) as close as possible to the town.

The lithologic logs of boreholes in Daura town, Babrum and Ngelzarma were used to understand the subsurface geology of the study area. The logs show a continuous shaly unit in Daura town, but 4 Km NW of the town at Babrum an aquiferous unit of about 63 m is encountered at a depth of approximately 200 m. These logs also guided the selection of the VES points for geophysical investigation. A total of eight vertical electrical soundings (VES) with AB separation of up to 350 m were carried out using Schlumberger array method. Interpretation of these VES revealed three to five geo-electric layers with the following lithologies: Top soil (silt/sand); shaly sand; shale; saturated sand; and dry sand.

Based on these investigations three optimal drilling points were recommended for the study area. These are ranked based on the suitability as VES 8, VES 3 and VES 7, which are at distances of 4.6 Km, 4.2 Km and 2.1 Km respectively from Daura town. These points are also at approximately 12 m, 20 m and 30 m respectively lower in elevation than Daura town.

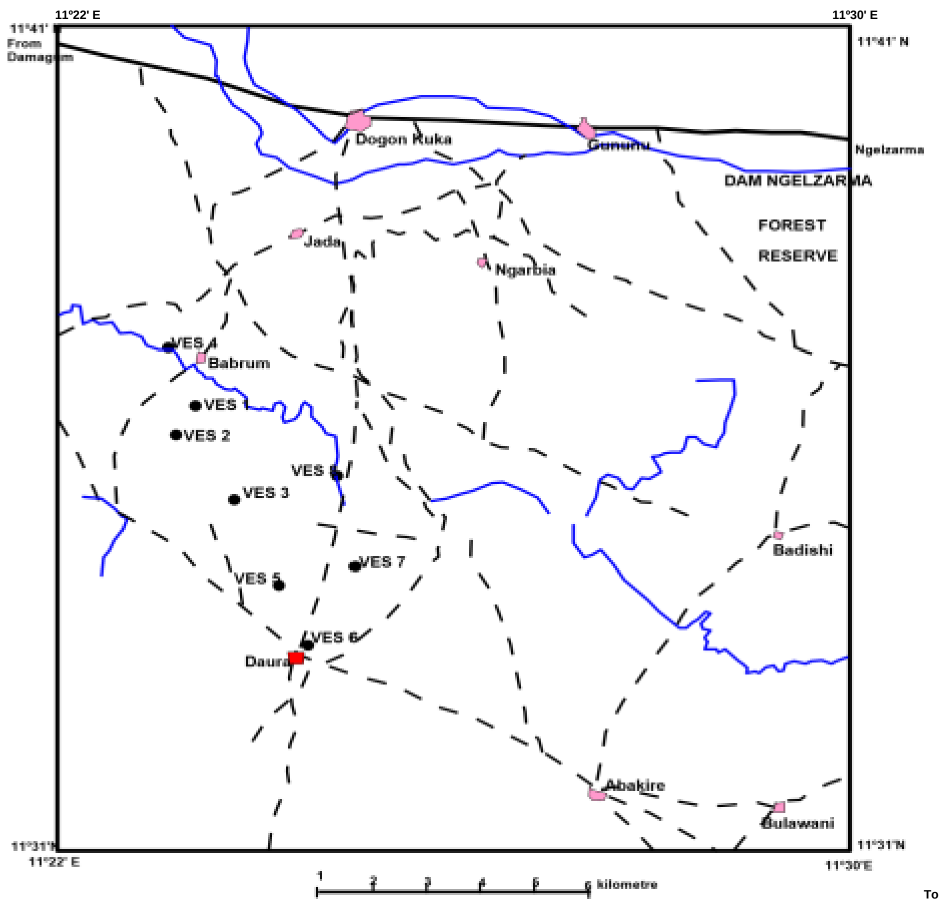
Keywords: *VES, Hydrogeological, Kerri-Kerri Formation, Fika Shale.*

INTRODUCTION

The study area is located on longitude N11^{o}29’ to 11^{o}43’ and latitude E11^{o}17’ to 11^{o}33’, south of Damagum in Fune Local Government Area of Yobe State (Fig. 1). Daura town has a population of approximately 20,000 people. The inhabitants of the Daura town are mostly farmers, engaged in crop cultivation and rearing of animals.Local mining of gypsum and limestone also contribute to the economy of the area.

The climate of Daura town and environ is hot and dry for most period of the year. The highest temperature of 42°C is normally experience in April, while the minimum temperature of about 30°C is recorded in December. Overall mean temperature of the area is about 37°C. Rainfall in the area starts from April/May and ends in September/October with the westward monsoonal wind. Over this period of time, the amount of rain ranges from 700 mm to 1200 mm, with an average of 825 mm.

Daura town is experiencing severe water scarcity, with no water source within the town and its immediate surroundings. Water for domestic and other uses is transported via water tankers. Previous boreholes drilled in the town encountered a monotonous shale unit throughout the drilled depth maximum of (600m) and thus all the wells were abortive. This necessitated the need for a comprehensive geophysical and hydrogeological investigations aimed at locating optimum drilling point(s) and subsequently to develop a suitable water supply scheme that will meet the needs of the community.



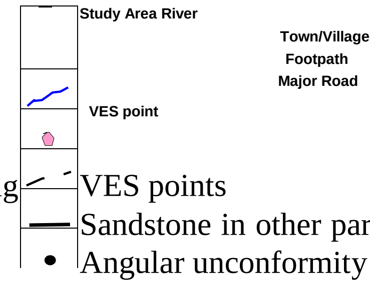


Fig. 1. Location map of study area showing VES points

GEOLOGY AND HYDROGEOLOGY

Daura town and environs are underlain by the Fika Shales and the Kerri-Kerri Formation sequences of the Nigerian sector of the Chad Basin. The characteristics of these formations are described below.

The Fika Shale consists of blue–black shale that are occasionally gypsiferous (Baba, 1995) and which contain thin persistent limestone. The fossils of the Fika Shale are mainly fish remains, chameleon fragments and reptilian remains. These indicate a Senonian-Maestrichtian age (Carter et al., 1963). The Fika Shale appears to have been deposited under a submerged (transgression) environment. It overlies the Gongila Formation conformably.

The Fika Shale is overlain by the Gombe Sandstone in the conventional layering sequence of the Chad Basin. However, in the study area, the Fika Shale is overlain directly by the Kerri-Kerri Formation. The end of the Cretaceous was marked by a period of uplift and erosion. The first deposit in the Nigerian sector of the basin after the Cretaceous period is the loosely cemented coarse to fine-grained sandstone - the KerriKerri Formation. In the Kerri-Kerri Formation, massive claystone and siltstone with bands of ironstone and conglomerate occur locally. The sandstones are often cross bedded and lignite (low grade coal) occurs near the base of the formation. The KerriKerri Formation rests unconformably on the Gombe Sandstone in other parts of the basin. Angular unconformity was thought to exist between the Cretaceous and the Neogene sediments (Carter et al., 1963). The thickness of the Formation increases towards the basin center. The Kerri-Kerri Formation is Paleocene in age and environment of deposition is lacustrine or fluvio-lacustrine.

Hydrogeologically, the Kerri-Kerri Formation is the potential source of groundwater in the area. Fractures in the formation provide groundwater storage and conduit capabilities. There are isolated areas of coarse to fine grained sand that are not well cemented, provide aquifer potential in the formation. This is in addition to secondary permeability created by the fractures in the formation. Depth to groundwater in this formation varies widely from 0 to 20 m below ground surface this is due to these hydrogeological setting. Fika Shale is in general impermeable and thus poor groundwater source. However, some layers of sandy materials exist within the formation that potentially serves as groundwater source. Hydraulic data from existing boreholes tapping the Fika Shale sandy unit show that hydraulic conductivity (K) ranges from 1.1×10^{-9} m/s to 5.2×10^{-4} m/s; transmissivity (T) ranges from 2.9×10^{5} m^2/s to 2.8×10^{-4} m^2/s; and storativity (S) 5.8×10^{-5} to 8.5×10^{-5} (Bukar, et al., 2009).

METHODOLOGY

Hydrogeological and geophysical approaches were used in this investigation. In the hydrogeological realm existing borehole logs close to the study area were collected and used to study the subsurface geology. Logs of three boreholes from Daura,Babrum and Ngelzarma towns that are close to the study area were obtained for lithologic correlation. Electrical resistivity method using Schlumberger configuration was used in this study. Eight vertical electrical sounding (VES) were carried out over the area of investigation

The electrical resistivity surveying involving (VES) is based on measuring the potentials between one electrode pair while transmitting direct current (DC) between another electrodes pair. The depth of penetration is proportional to the separation between the electrodes, in the homogenous ground and varying the electrode separation provides information about the stratification of the ground (Dahlin, 2001).

The electrode spread of AB/2 equal to 350 m was used. The survey was started with a short distance of 1 m for the AB/2 and then increased progressively to a maximum of AB/2 equal to 350 m at various points of investigation. However, in order to fulfill the condition of AB/2 ≥ 5 MN in this survey method, the potential electrodes separation (MN) was increased at appropriate distances of AB/2. Measurements of resistance values of various layers encountered were taken directly from the Terrameter and multiplied by a constant factor (K) to give the apparent resistivity values. These were then plotted on bi-logarithmic papers, with the distance AB/2 against the resistivity values. These results and plots are further processed using interprex 1XD (Interpex, 2002) sounding inversion software.

RESULTS AND INTERPRETATION

Resistivity models are generally not unique, i.e. a large number of earth models can produce the same observed data or sounding curve. In general, resistivity method determines the conductance of a given stratigraphic layer or unit. The conductance is product of the resistivity and the thickness of a unit. Hence, that layer could be thinner and more conductive or thicker and less conductive, and produce essentially the same results. This then calls for qualitative interpretation.

In qualitative interpretation, subsurface information provides controls and confirms the inferences drawn from the geophysical investigation (Abdullaev and Dzhafarov, 1964). Therefore, constraints on the model, from borehole data can greatly enhance the interpretation.

Quantitative treatment and analysis of the data delineate three to five distinct geoelectric layers in the study area and the area is characterized by H-type, HK-type, Q-type, and QK- type curves (Figs.3-10).

Subsurface geologic information of the study area is obtained directly from existing lithologic logs of boreholes around the study area (fig 2). The logs from borehole drilled at Daura town showed a continuous shale unit from about 6 m depth to the total drilled depth of 600 m. Babrum is a village about 8 km to the NW of Daura town, where drilled borehole showed a shale unit from 3 m to 198 m and a sandy unit from 198 to 263 m. Ngelzarma town is about 28 km NE of Daura town and borehole drilled at the centre of the town to depth of 500 m gave the following lithology. 0 to 30 m clay layer; 30 to 500 m shale layer; but between 250 to 400 m there are intercalations of sands of various thickness ranging from 10 to 15 m. It is clear from these boreholes that 2-4 distinct lithologic units can be identified.

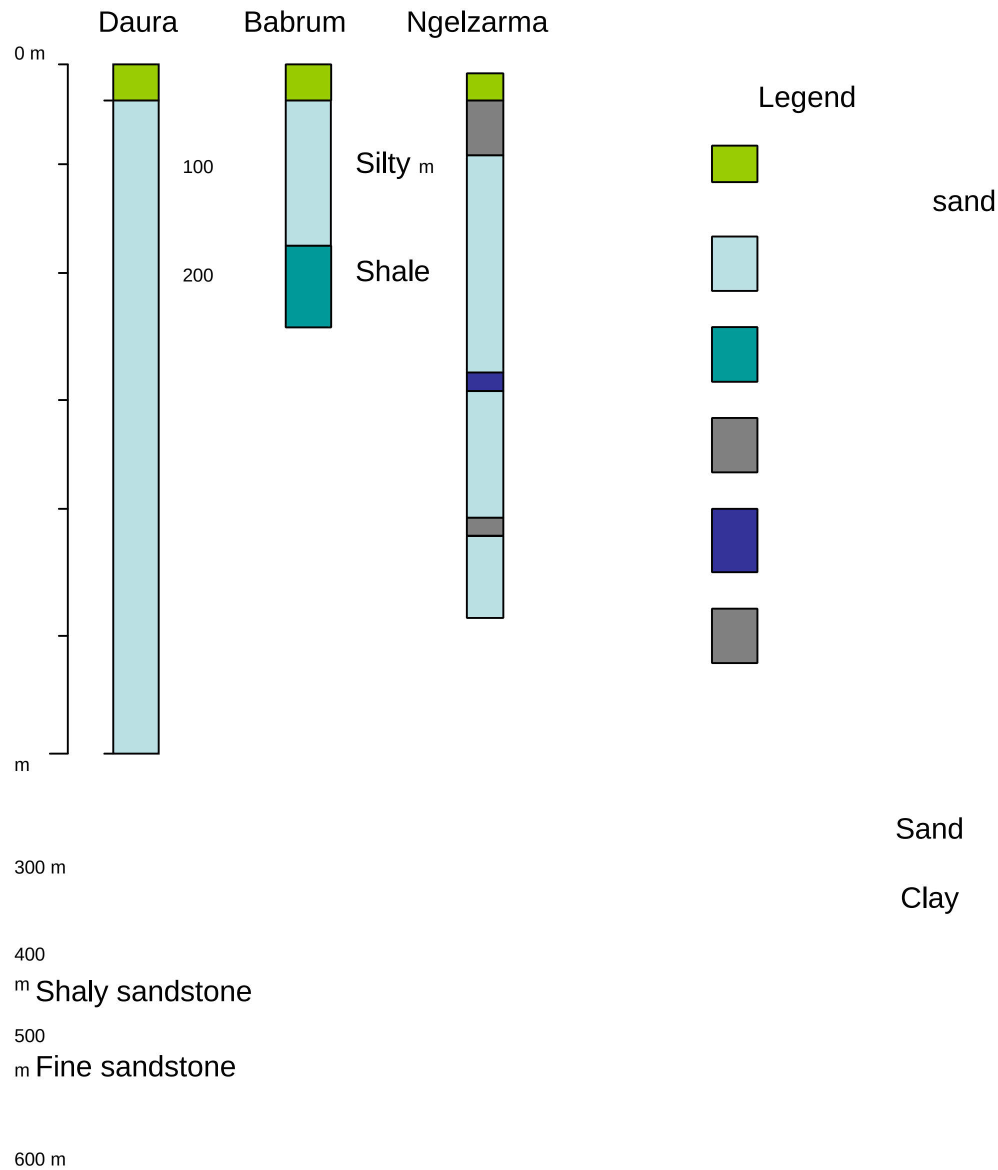


Fig. 2. Lithologic logs of boreholes on the Fika Shale

GEOPHYSICAL INTERPRETATION.

Table 1. VES 1 is 0.5 km away from Babrum towards Daura town. (11^0 36' 45.5", E 11^0 23' 22.3". Elevation 422 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	214	8	Top soil (silt/sand)
2	101	34	Shaly sand
3	21	72	Shale
4	117	31	Sand (Saturated)

VES 1 revealed QH type of curve (fig 3.) with four geo-electric layers, indicating layer with relatively low resistance in third layer, which is typical of shale formation while the fourth layer is interpreted as a layer of sand that is saturated with groundwater.

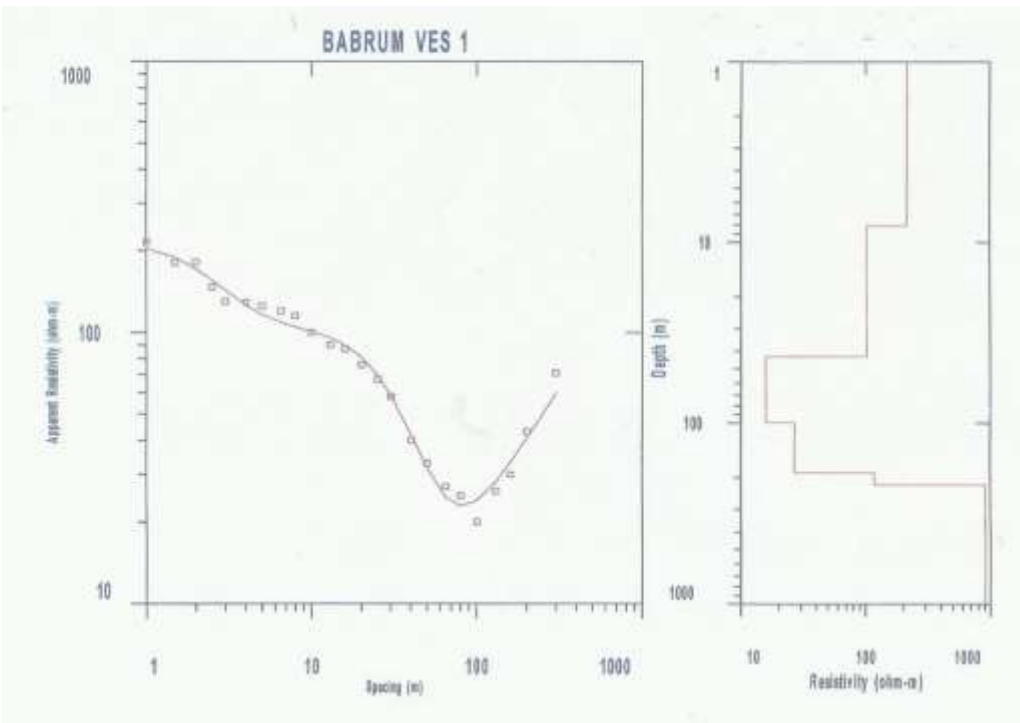


Fig.3. Field curve and model for VES 1.

Table 2. VES 2 is 6.5 km from Daura town towards Babrum (N 110 36’15.8”, E11^{0} 23’41.2”. Elevation 433 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	754	2	Top soil (silt/sand)
2	161	28	Shaly sand
3	63	48	Shale
4	102	75	Shaly sand
5	441	84	Sand (Saturated)

VES 2 shows H type of curve (fig.4) with five geo-electric layers having relatively higher resistivity values that indicate the presence of shaly sand. The fifth layer is interpreted as sand with resistivity of 441 Ωm and a thickness of 84 m.

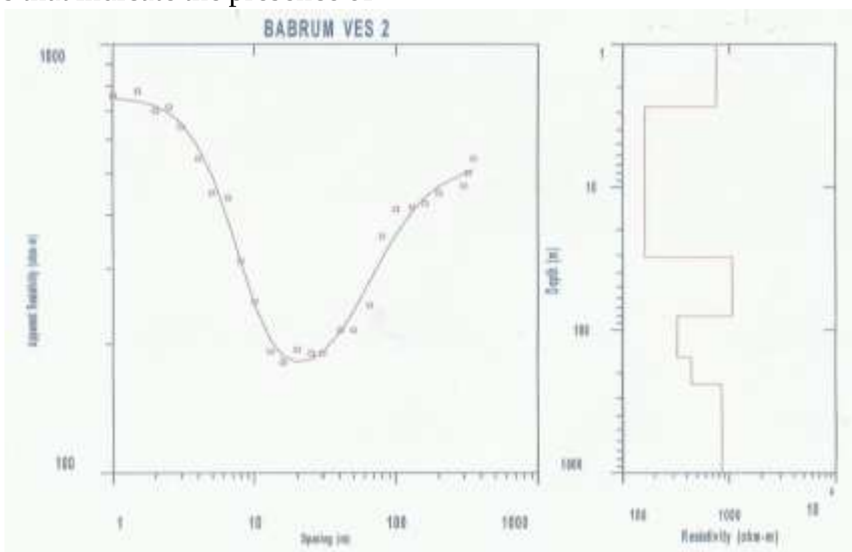


Fig. 4. Field curve and model for VES 2.

Table 3. VES 3 is 4 km from Daura town towards Babrum (N 11^0 35’ 32.3”, E11^0 23’ 57.5”. Elevation 448 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	1205	1	Top soil (silt/sand)
2	125	20	Shaly sand
3	45	65	Shale
4	108	75	Sand (Saturated)

VES 3 revealed HK type of curve (fig.5) shale. The resistivity value of the forth layer with four different geo-electric layers which is 108 Ωm indicating a porous and saturated are interpreted as layers of shaly sand and layer of sand.

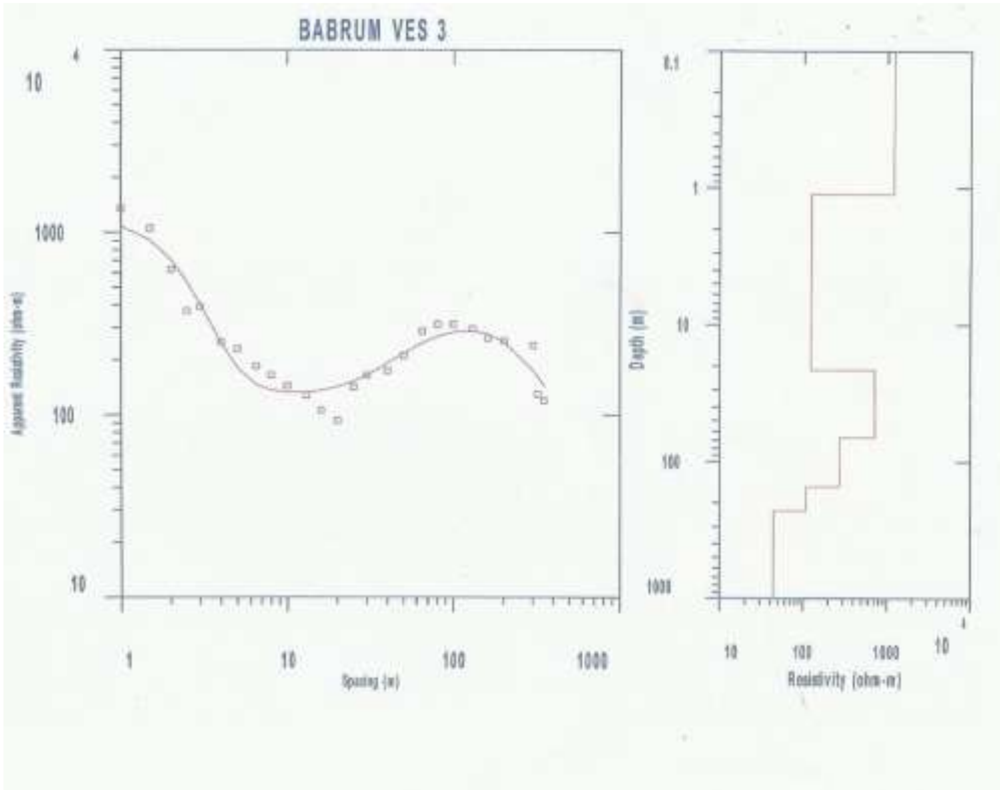


Fig.5. Field curve and model for VES 3.

Table 4. VES 4 is adjacent to an uncompleted Borehole at Babrum.(N 11^0 37’ 00.7”, E11^0 23’ 13.0”. Elevation 433 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	1021	0.9	Top soil (silt/sand)
2	512	24	Sand
3	125	67	Shaly sand
4	105	81	Shale
5	604	34	Sand

VES 4 revealed H type curve with five different geoelectric layers as shown in figure 6.

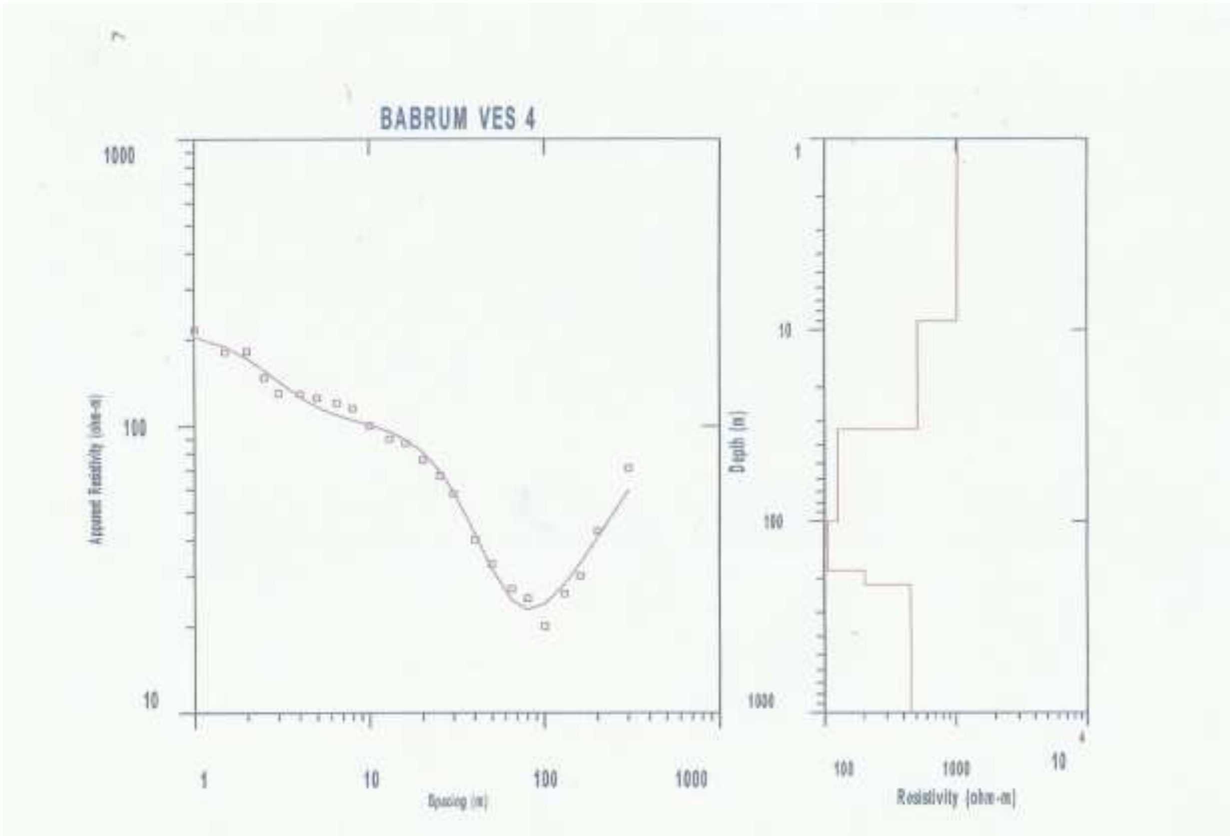


Fig. 6. Field curve and model for VES 4.

Table 5. VES 5 is 2 km away from Daura town to the NW (N 11^0 34’ 20.3”, E 11^0 24’ 14.8”. Elevation 456 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	1253	0.8	Top soil (silt/sand)
2	290	56	Sand
3	1129	74	Sand (Unsaturated)

VES 5 shows H type of curve (fig.7) with interpreted as layers of sand but dry. The three different geo-electric layers that have data in VES five is noisy and therefore not relatively higher resistivity values which are very reliable.

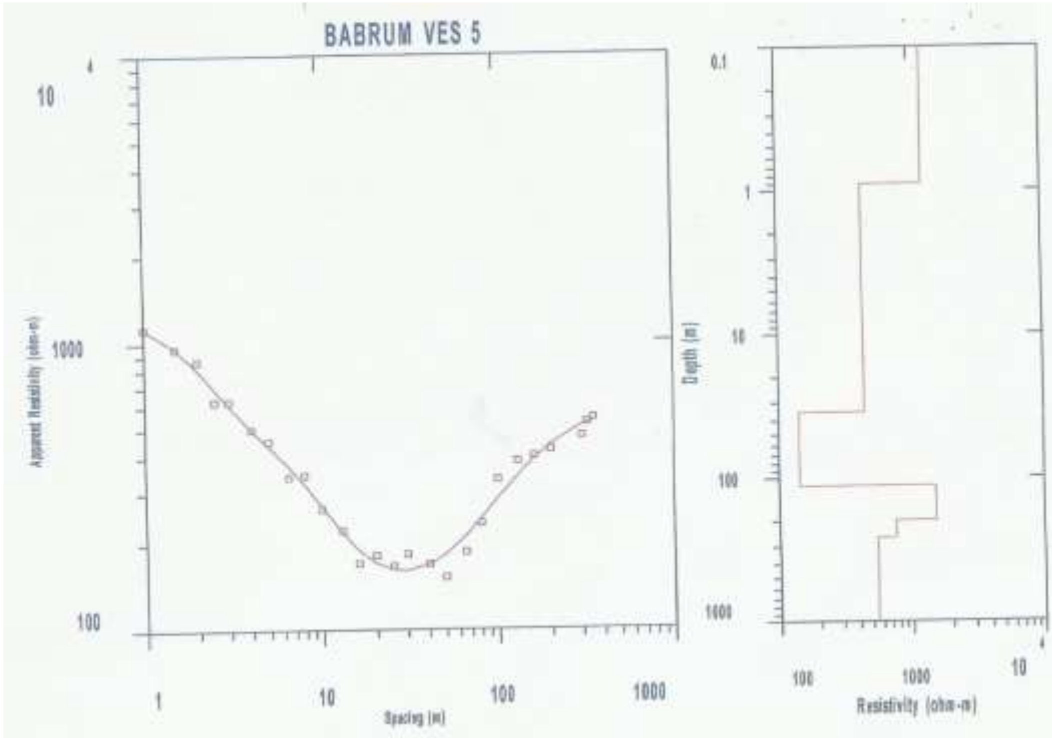


Fig.7. Field curve and model for VES 5.

Table 6. VES 6 is in Daura Town.(N 11^0 33' 32.1", E 11^0 24' 34.6" Elevation 460 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	755	12	Top soil (silt/sand)
2	219	48	Sand (Dry)
3	42	85	Shale

VES 6 indicates Q type of curve (fig.8) with is typical of an area that is highly conductive three different geo-electric layers. The curve indicating layers of shale without indication of a layer of sand at a depth of about 200 m.

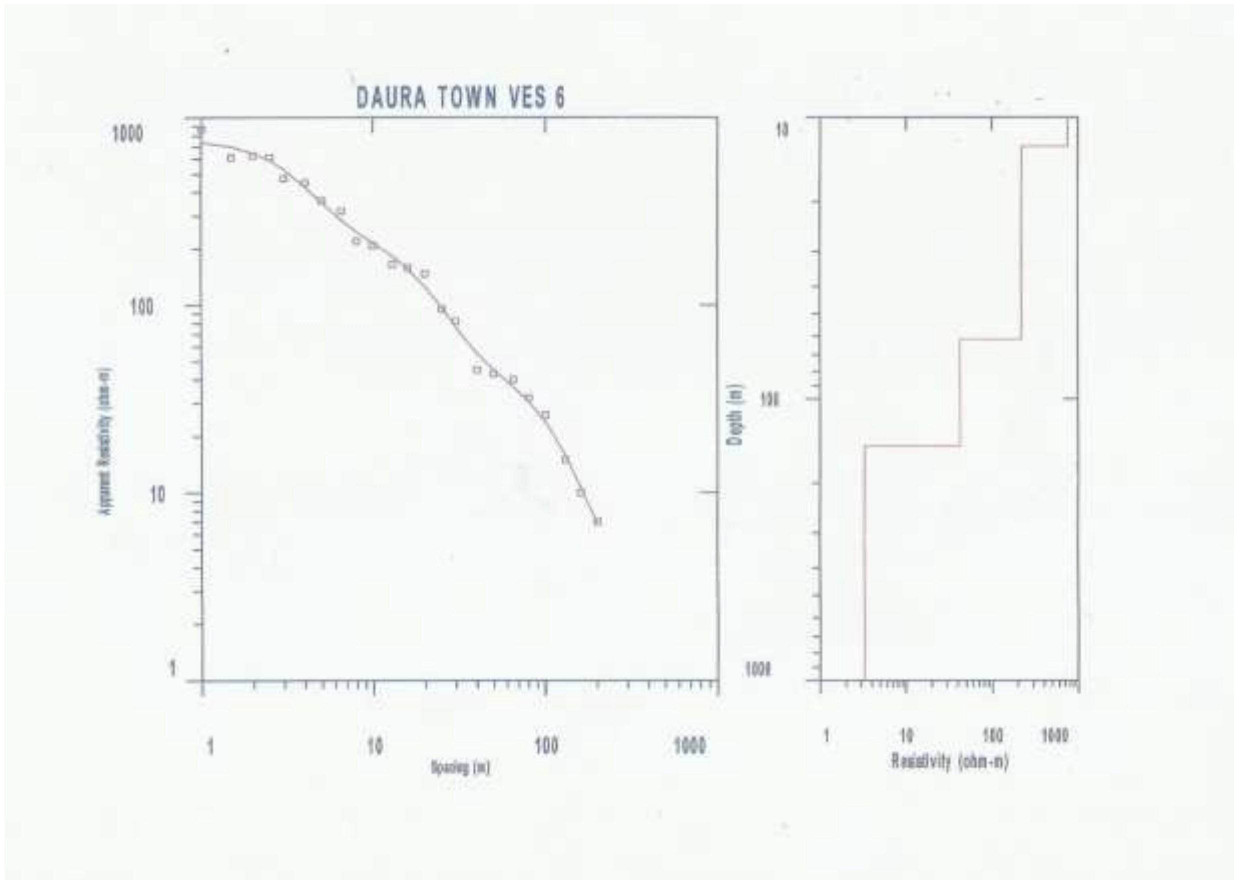


Fig. 8. Field curve and model for VES 6.

Table 7. VES 7 is 2 km NE of Daura town toward Dogon Kuka.(N 11^{0} 34’ 26.9”, E11^{0} 25’ 00.4”. Elevation 438 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	252	1	Top soil (silt/sand)
2	24	3	Shale
3	366	49	Shaly sand
4	276	100	Sand (Saturated)

VES 7 indicates H type of curve (fig.9) with thickness of 100 m and resistivity value of four different geo-electric layers. The forth 276 Ωm. layer is interpreted as a layer of sand with

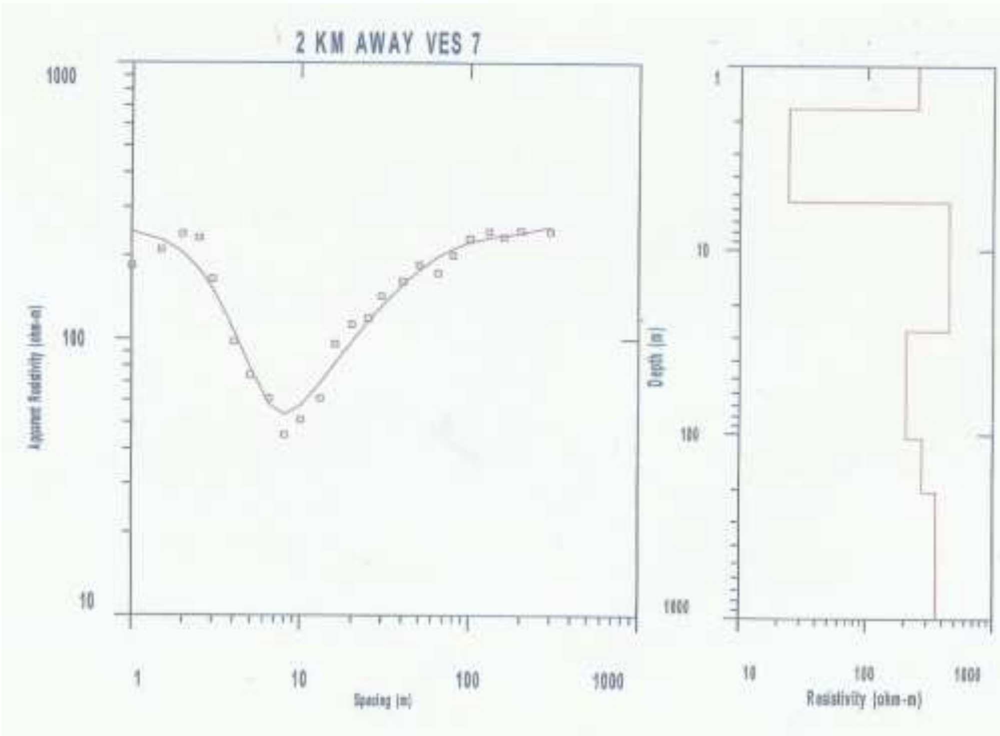


Fig.9. Field curve and model for VES 7.

Table 8. VES 8 is 4.5 km away from Daura town along Dogon Kuka road.(N 11^0 35' 45.1", E 11^0 24' 52.9". Elevation 430 m)

S/NO.	RESISTIVITY (Ωm)	THICKNESS (M)	GEO-ELECTRIC LAYER (LITHOLOGY)
1	1320	0.9	Top soil (silt/sand)
2	44	23	Shale
3	2117	61	Sand
4	154	34	Shale
5	236	43	Sand (Saturated)

VES 8 revealed HK type of curve (fig.10) with five different geo-electric layers. The fifth layer is interpreted as a layer of sand with resistivity of 236 Ωm and 43 m thick and is saturated.

The surface unit which has resistivity range of 214 Ωm-1320 Ωm is found in all the VES locations with varying thickness of 1 to 12m. This unit is dry sand. Underlying the surface unit is a layer with resistivity range of 24 - 512 Ωm and the thickness of 3 - 56 m. This unit consists of shale, shaly sand and dry sand.

The third unit is also similar to the second unit which consists of shaly sand and shale. The fourth and fifth units in the study area are the saturated geologic layers.

DISCUSSION

Based on the lithologic logs of boreholes in the study area, it is clear that groundwater potential in Daura town is very low, because of the impermeable shale unit underlying the town (Fig. 2). The Babrum borehole log showed good potential for groundwater extraction, with over 60 m of sandy unit. In Ngelzarma too, the potential for groundwater extraction appears good with the sandy layers intercalating within the shale (Fig.2). These logs were used to guide the selection of VES point in the geophysical survey carried out. The target was to trace the sandy units observed in Babrum towards Daura town.

From the vertical electrical sounding results, the most suitable site for groundwater extraction via borehole drilling are in VES 3, 7 and 8 (fig.1). These are at 4.2 km, 2.1km and 4.6 km respectively from Daura town. They are also about 12 m, 20 m and 30 m respectively lower in elevation relative to Daura town. This means that at any selected point for drilling borehole there will be both vertical and horizontal distance to be overcome for supply to reach Daura town.

The most promising point is VES 8, followed by VES 3 and then VES 7. The VES 8 site (table 8) indicates a layer of shale at a very shallow depth followed by a layer of sand, which is a very good indication for

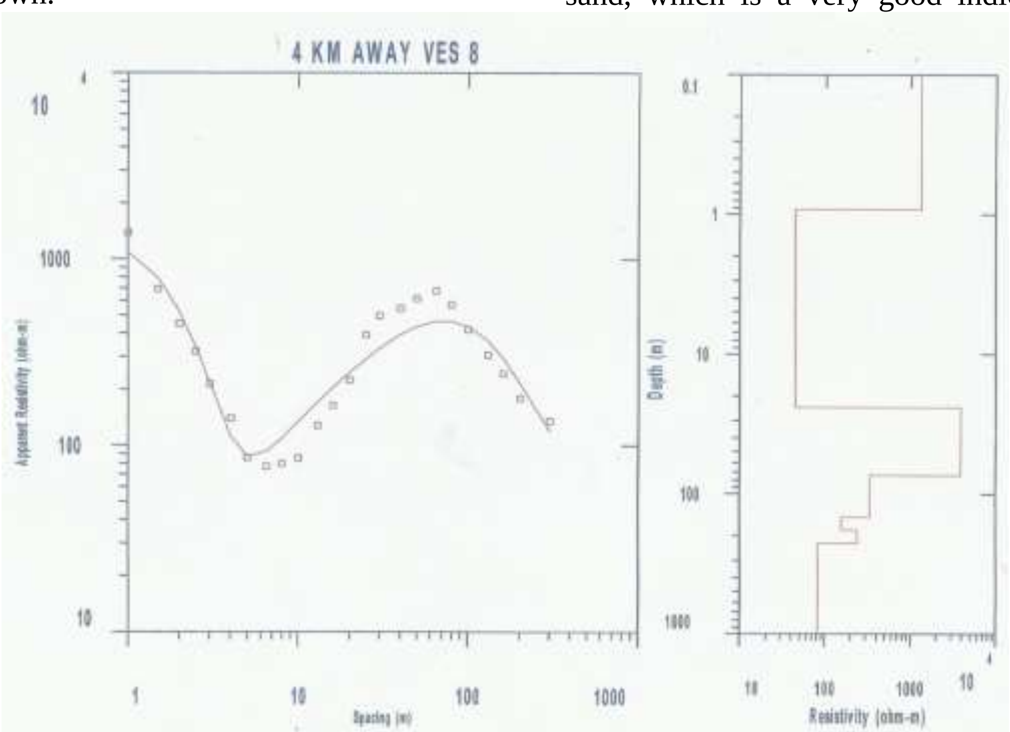


Fig.10. Field curve and model for VES 8.

groundwater potential, considering the complex geology of the area. VES 8 also revealed that groundwater at that point will be encountered at relatively shallow depth compared to VES 3 and VES 7. The expected depth to be drilled in this location is 180 m +/- 40 m. VES 3 showed a result that is similar to VES 8; the only difference being in the expected drilling depth, which is put at 226 m +/- 40 m. VES 7 is less suitable compared to both VES 3 and VES 8 as the data show lower resistivity values – an indication of more shale layers within the sand. Although, the expected depth of drilling at this point is 202 m +/- 40 m, the shale layers have made it less promising as borehole drilling point.

From the foregone, all the potential drilling points have both horizontal and vertical differences with the Daura town, which have to be factored in for water supply to reach Daura town. These must be considered before final decision on which of these points are selected for drilling a water supply borehole. Thus, there will be need to carry out ground surface elevation survey in order to have best possible path to convey water from selected points to Daura town.

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CONCLUSION

Hydrogeological and geophysical investigations were carried out to locate optimum drilling point(s) in Daura town south of Damagum, Yobe State. The lithologic logs of boreholes in Daura town, Babrum and Ngelzarma were used to study the subsurface geology, which indicates some sandy beds within the Fika Shale in some of the wells. In the geophysical investigation, a total of eight vertical electrical soundings (VES) with AB separation of 350 m were carried out. Interpretation results of the VES points revealed three to five geo-electric layers of top soil (silt/sand), shaly sand, shale, saturated sand and dry sand.

From these results three drilling points were recommended. These are ranked based on the most optimum as VES 8, VES 3 and VES 7. These points are at 4.6 km, 4.2 km and 2.1 km respectively away from Daura town. They are also at approximately 30 m, 12 m and 20 m respectively lower in elevation relative to the town. Therefore, drilling for water supply to Daura town at any of these recommended VES points will require horizontal and vertical distances to be overcome.

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