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GEOELECTRIC SURVEY FOR GROUNDWATER EXPLORATION AT BIRNIN-KEBBI, KEBBI STATE, NIGERIA.

Usman, Z. M.

Department of Physics Kebbi State University of Science and Technology Aliero.

Author's E-mail: uzayyanu@yahoo.com

ABSTRACT

A geophysical investigation was carried out at Birnin Kebbi, Nigeria to determine the groundwater potential and the geological structure of the area. The method employed in this study was the Vertical Electrical Sounding (VES) using the Schlumberger configuration. The data obtained were interpreted by computer iteration process and results when compared with lithologic log from existing borehole indicate a Three to Five layered formation. The first aquifer identified in VES 4 is located along the third layer with resistivity value above 100Ωm and depth starting from 8.28m below the subsurface. Analysis of this layer shows that this aquifer is unconfined and prone to pollution since it underlay's a loose and clayey sand formation that is very thin with few meters below the subsurface. The second aquifer is a viable potable water formation with resistivity value less than 100Ωm and a thickness range of 10.0 to 35 m with varying degree of different VES stations especially VES 4 and VES 7. The depth of the confined aquifer starting from 15m at some point of the areas. Boreholes for potable groundwater are therefore recommended within the forth layer because of its quality and viability.

Keywords: Electrical resistivity sounding, Aquifer, Groundwater, Potable

INTRODUCTION

The advent of technology has made the quest for water for all purpose in life to drift from ordinary search for water to prospecting for steady and reliable subsurface or ground water from bore holes. In Nigeria, currently, bore holes has rescued the citizens from acute shortage of water. The geoelectric method has been found to be very reliable for ground water studies over the years. Asokhia *et al.* (2000), propose a simple computer iteration technique for interpretation of Vertical Electrical Sounding (VES) Pulawski and Kurht (1997). The electrical method is one of the most relevant geographical methods applied in ground water investigation in the basement terrain (Olorunfemi, *etal.*1995). Other geophysical methods such as the seismic refraction, electromagnetic, gravity and direct boring methods are also used in grounds and water prospecting depending on their physiographic, geological disposition and complexities of the area of investigation. The present study involves the use of the electrical resistivity method for the delineation of the different aquifer types and primary parameters (resistivity depth and thickness) that are characteristic of the basement complex terrain and which have good prospect for ground water exploration subsequent assessment of the ground water of the study area. Geophysical survey incorporates the vertical electrical sounding (VES) and Horizontal profiling (HP) activities. The vertical Electrical Sounding (VES) is currently being very popular in ground water investigations due to its simplicity. This geophysical survey method is the detection of the surface effect produce by the flow of electric current inside the earth. It provides depth and thickness of various subsurface layers and their relative water yielding capacities (Shishaye and Abdi 2016).

Generally, borehole water is considered to have better microbial quality than that of hand dug well water because borehole water is from deep aquifer while hand dug well water is from shallow aquifers which makes it more susceptible to microbial pollution, in Nigeria, shallow groundwater is said to be equal with shallow dug-wells and boreholes while deep groundwater is related with deep boreholes, (Linsley and others, 1979; Chilton, 1996). For this study, shallow wells/boreholes will refer to water wells not more than 60m deep, while deep boreholes will refer to those deeper than 60m, which must be completed with steel casings and screens. Private individuals and households own most shallow water wells in Birnin Kebbi. The cost of construction of the handmade shallow boreholes is cheap, in terms of both labour and material. The drilling can be carried out manually by as few as three drilling personnel; and the well can be completed with PVC screen and casing pipes. On the other hand, mostly corporate companies and the government own deeper boreholes, because of the high cost of constructing such water wells.

The study area is fast developing community in terms of population and business activities. This has impacted on the growing demand for portable water. Certainly some areas has no public water supply and depends on personal efforts in getting water for domestic use specifically Bayan Yer yara, Kola and Gonar Sarki. The goals of this study include: (i) to initiate a proper groundwater exploration program with view to locate the target aquifer as well as to avert a recurrence of boreholes abandonment that may encountered at shallow depth and (ii) To have a more detailed understanding of the hydrogeology of this area and delineate zones which are more favorable for groundwater exploration. The realization of such a program requires data from geophysical survey which this study is out to report.

GEOLOGY / HYDROGEOLOGY

The sedimentary rocks of the basin range in age from Cretaceous to Tertiary and are composed mostly of interbedded sand, clay, and some limestone; the beds dip gently toward the northwest. Alluvium of Quatermtry age underlies the lowlands of the River Sokoto (now Sokoto) and its principal tributaries. These rocks contain three important artesian aquifers, in addition to regional unconfined ground-water bodies in all the principal outcrop areas, and a perched water body in the outcrop of the Kalambaina Formation. (Henry R. A *and* William O, 1973). Artesian aquifers occur at depth in the Gundumi Formation, the Rima Group, and the Gwandu Formation and are separated from one another by clay beds in the lower part of the Rima Group and the Dange Formation. In outcrop, clay in the Dange Formation also supports the perched water of the Kalambaina Formation.

Birnin Kebbi (Fig 1), the study area is dominated by two formations; Precambrian Basement Complex in the southern and south east young sedimentary rocks in the north. The Basement Complex region is composed of very old volcanic and metamorphic rocks such as granites schist's, gneisses, quaetzites and migmatites. In addition there are met sediments such as phyllites and met Conglomerates. The sedimentary region consists of the Gwandu, Illo and Rima groups whose ages range from the cretaceous to the Ecocene. The Gwandu group consist of massive clay grits inter bedded with sand stone while the Illo and Rima groups consist of pebby grits, sand stone and clays mudstone and siltstone respectively. The Rima Group contains an extensive artesian aquifer which is economically important in the Sokoto and Birnin Kebbi areas. The aquifer generally provides moderate quantities of water to boreholes (average yield of 5,400 gph among 30 boreholes), but the depth to the water may be as much as 173 feet below land surface. In the Sokoto area the sand of the Rima aquifer is fine to medium; nevertheless, boreholes readily yield as much as 7,000 gph. Moreover, with drawdowns in boreholes of 10 to 65 feet, several aquifer tests have indicated transmissivities averaging about 45,000 gpd per ft. In western Sokoto Province (now part of North Western State), the Rima aquifer is confined by clay in the Dange Formation so that in the River Sokoto fadama the aquifer yields artesian flow to boreholes. At Birnin Kebbi, for example, where fine to coarse sand of the aquifer extends from a depth of 360 to more than 1,000 feet, single boreholes flow as much as 7,000 gph and yield by airlift as much as 18,000 gph. The Illo Group, which is in part contemporaneous with the Gundumi Formation, includes interbedded varicolored clay and grit in the southern part of the Sokoto Basin. The upper part of the Illo is known to be water-bearing; however, except for the test borehole at Mungadi, little is known of its subsurface extent and water-yielding potential. (Henry R. A *and* William O, 1973).

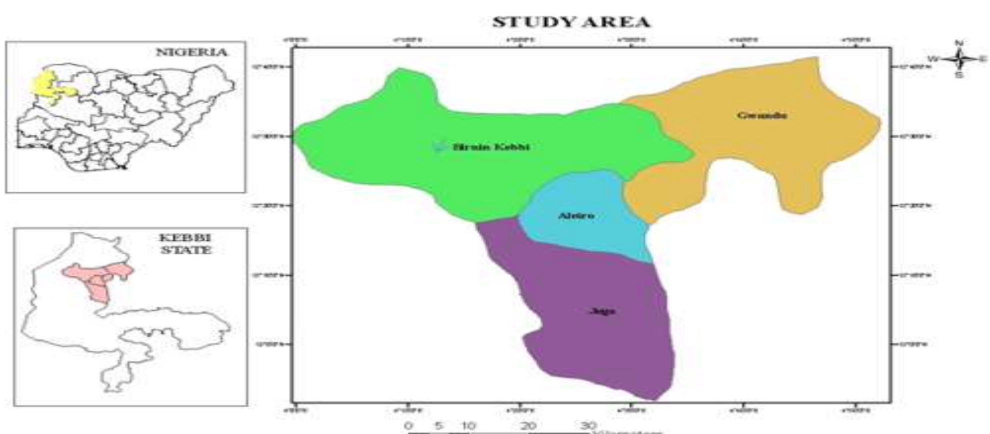


Fig .1: Description of study area (After Kogbe, 1976).

MATERIALS AND METHODS

Vertical Electrical Sounding (VES) using the Schlumberger electrode configuration (Fig 2) was carried out at Ten (10) selected points within the study areas. In all, Ten (10) VES points were located and fully occupied within the study area. The VES data obtained were subjected to partial curve matching using two-layer master curves and auxiliary curves as an initial stage of data interpretation (Orellana and Mooney, 1966; 1972). The layered earth model thus obtained served as the input model for the inversion algorithm as a final stage in the quantitative data interpretation (Zohdy, 1973; 1975 and 1989). The final interpreted results were used for the preparation of geo-electric sections and maps.

Theory

In the Principle of electrical resistivity survey, electric current is usually sent to the ground through the current electrodes. The variation in the potential difference (p.d) between the two electrodes is usually measured, electric current I in an infinite homogenous and isotropic medium of Resistivity ρ is given by

$$V = IR \qquad (1)$$

DV = IV,

Where

DV = Potential difference,

I = Current,

R = Resistance,

Therefore,

$$R = \frac{DV}{I}$$

The inverse of R, is the conductance (S) or (Ω^{-1}) calculate micros/cm or Siemens. Resistance varies for the some material depending on the dimension on the equation. The relationship between resistance (R), length (L) and cross section area (A) is giving a

$$R = \frac{L}{A} \qquad (2)$$

$$R = \frac{1}{\rho} \qquad (3)$$

Where ρ = proportionality constant called resistivity, indicates the ability of a material to oppose the flow of charge. Hence from equation (3)

$$RA = \rho \qquad (4)$$

$$\rho = \frac{RA}{L} \qquad (5)$$

This is the resistance of a material, it defined as the resistance in Ohms between the opposite face of a unit cube of the material. The unit is (Ωm). The inverse of the resistivity is the conductivity of the material, the S. I. unit as Siemens per meter i.e.

$$\sigma = \frac{1}{\rho} \qquad (6)$$

The current from battery was sent into the ground through the outer electrodes. The potential difference generated by this current was measured using a voltmeter. The apparent resistivity value for each electrode spacing was calculated by multiplying the resistance obtained at the point with the geometric factor. In the case of vertical electrical soundings, the maximum spread of the current electrodes was four hundred metres to give room for maximum penetration into the basement rock (Sharma 1997).

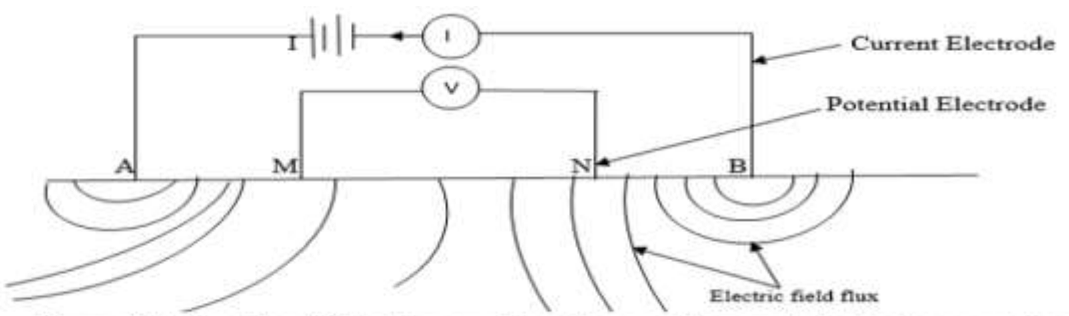


Figure 2: Principle of electric sounding. For small current electrode separation. The Current is virtually confined to the surface layer (resistivity) and the measurement of P.d. between and gives information about. As the separation AB increases a greater fraction of the current penetrates deeper into the substratum (resistivity) and the measurements give more information about (Afte Usman, 2016).

RESULTS AND DISCUSSION

Field Curves

For the multilayer sounding curves obtained after curve matching and computer iteration, various types of curves were determined by the relationship existing between the layer resistivity values ρ_1, ρ_2, ρ_3 ... ρ_n. It was discovered that the curves are mostly Q-type (3 VES stations), and HKH-type (3 VES stations), while 2 VES stations showed KH-type, 1 VES station showed H-type and 1 VES station showed H-type. Samples of the curves are presented in Fig 3. The result shows a three to five layered formation. The first layer is mainly top soil. The resistivity of this layer ranges from 216 to 4630 Ωm. The thickness of this layer ranges from 0.5 to 5.83 m. The areas which show high resistivity in this layer are observed to be waterless. The second layer is mainly clayey sand and loose sand. The resistivity of this layer ranges from 18.8 to 40896 Ωm. The thickness of this layer ranges from 0.7 to 5.4 m. This is a very thin unconfined bed and will therefore be prone to contamination. The first aquifer is found in the third layer with resistivity ranging from 5.5 to 15285 Ωm. It is composed of Fine sand to Sandy clay formation with thickness range of 3.43 to 64.7 m. Consequently, this aquifer is reliable and will yield potable water for the residents of the area especially in VES 4 and VES 7 as shown in Pseudo cross-section at starting point of 10m fig 4. The forth layer is made up of clay with resistivity ranging from 11.2 to 2380 Ωm while the thickness ranges from 3.43 to 64.7 m. The last layer is composed of medium grain sand with resistivity of 0.5319 to 10.1 Ωm.

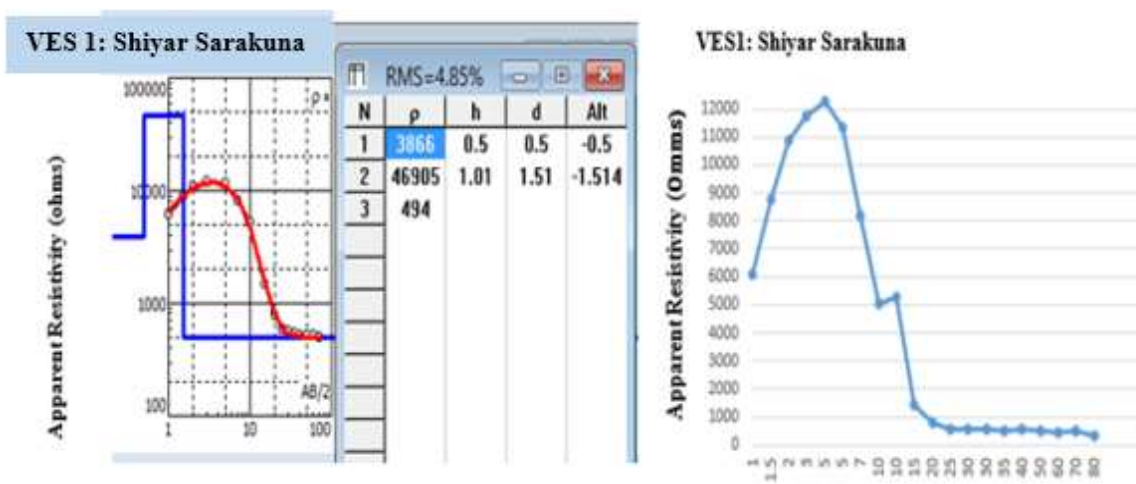
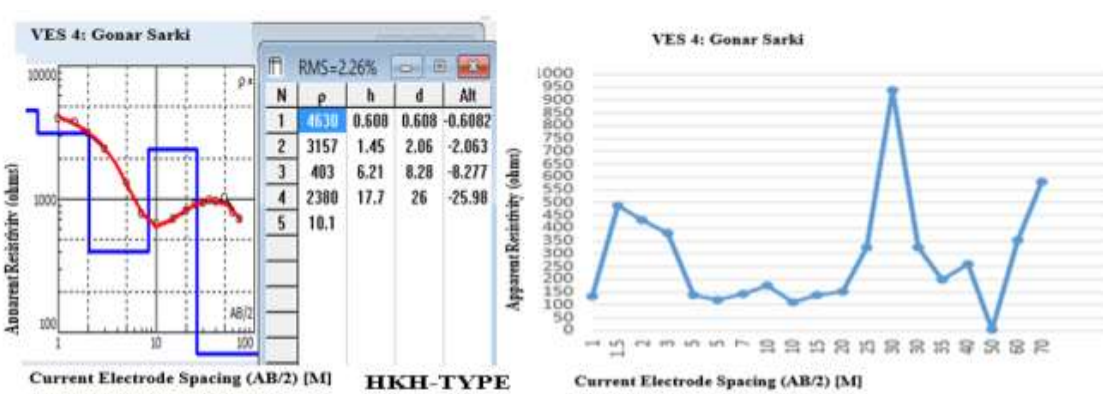


Fig. 3. Apparent resistivity versus half current electrode spacing curve for VES 1 to 10.



Investigation indicates that potable groundwater exist in the form of confined aquifer with depth range of 10m to 30m at Gonar Sarki area of VES 4, as well as Gesse Phase 3 of VES 7, The thickness of this aquifer is from 13.4 up to 19.2 m, the lowest resistivity values of the investigated areas indicate ground water occurrence, other VES points that indicate high resistivity's are dry areas , which implies that those areas will face difficulties in finding ground water, The analysis of the results indicate that those areas will go beyond certain depth of the two (VES 4,7) point in other to access ground water. Quality and Viable boreholes for potable water are therefore recommended to be sank to the third layer with a depth range of 10 down wards up to 51.4m with variant degree of depth in different areas. Fig. 5a shows the top soil resistivity histogram, the resistivity values vary with respect to different point. The low resistivity end (<250 ohm-m) is diagnostic of clay-sandy clay and clayey sand, while the high resistivity end (>250 ohm-m) typifies compact sand. Table 1, shows approximate resistivity range values for rocks and minerals and water.

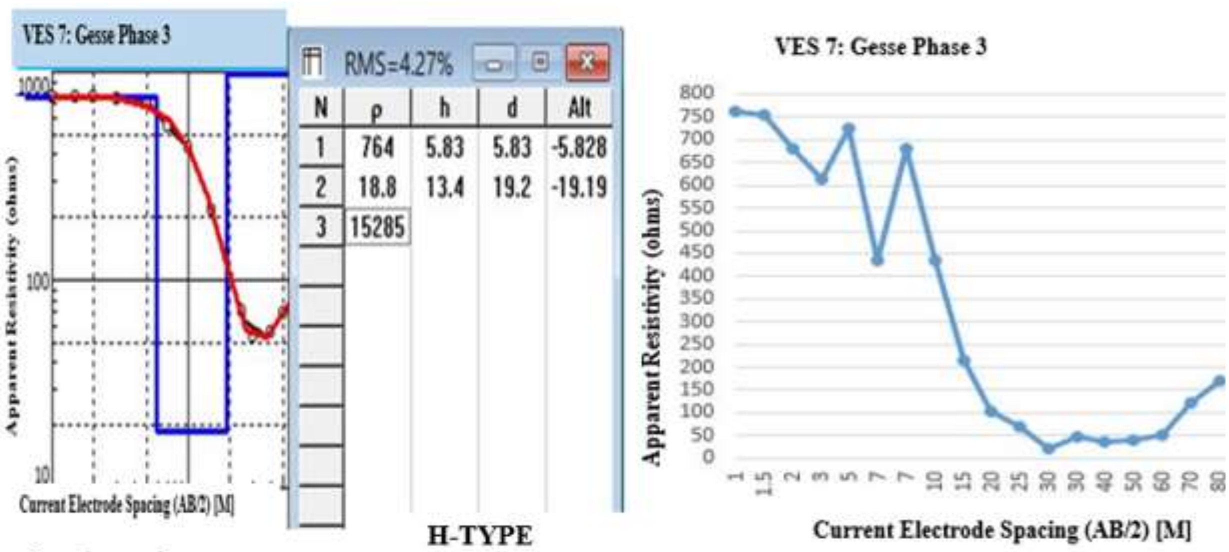


Table 1: Approximate Resistivity Ranges for Various Rocks, Water (After Telford et al. 1976)

Rock type	Resistivity (Ωm)
Clay and marl	1–67
Top soil	67–100
Clayey soil	100–133
Sandy soil	670–1,330
Limestone	67–1,000
Lignite	9–200
Sandstone	33–6,700
Sand and gravel	100–180
Schist	10–1,000
Granite	25–1,500
Basalt	10^3–10^6
Quartzite	10^2–2×10^8
Surface water (in igneous rock)	30–500
Sea water	0.20
Saline water 3 %	0.15
Saline water 20 %	0.05
Groundwater (in igneous rock)	30–150

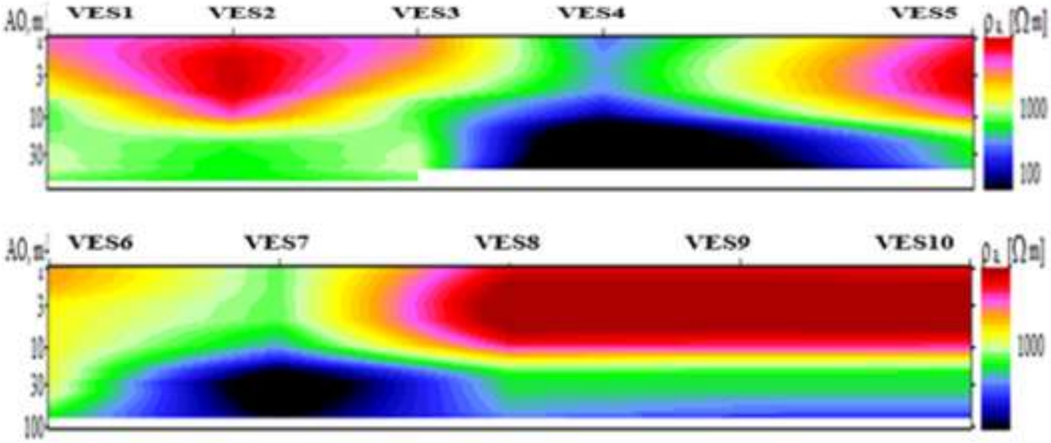


Fig 4: Pseudo-Section Equivalent to Geo-election Formation

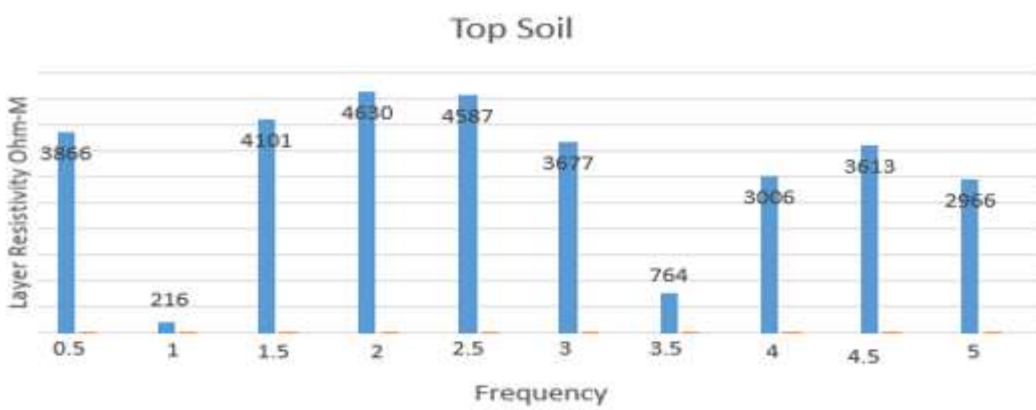


Fig 5: Histogram of the layer resistivity

Table 2: layer resistivity and their corresponding thickness

VES	Curve types	ρ_1 (Ωm)	ρ_2 (Ωm)	ρ_3 (Ωm)	ρ_4 (Ωm)	ρ_5 (Ωm)	h_1 (m)	h_2 (m)	h_3 (m)	h4 (m)	RMS (%)
1	KH	3866	46905	494			0.5	1.01			4.85
2	HKH	216	1501	5.5	42.7	0.0319	0.924	0.727	3.43	7	3.97
3	Q	4101	443	3592	11.2		1.66	7.83	12.4		4.73
4	HKH	4630	3157	403	2380	10.1	0.608	1.45	6.21	17.7	2.26
5	K	4587	3532	430	1245		0.5	1.39	5.28		2.26
6	KH	3677	41168	497	20.9		0.5	1.09	64.7		4.23
7	H	764	18.8	15285			5.83	13.4			4.27
8	Q	3006	1349	7.22			0.743	37.6			3.65
9	HKH	3613	40896	131	1646	8.64	0.5	1.11	3.59	11.6	3.88
10	Q	2966	1325	29.1			0.737	51.4			2.36

CONCLUSION

The hydro-geophysical investigation of Birnin Kebbi L.G.A of Kebbi State, Nigeria for groundwater exploration has revealed Three to five major geoelectric units. These include: the top soil, the clayey sand/loos sand, the fine sand / sandy clay and the clay unit. The clay constitutes the main aquifer unit in the study area. The Pseudo cross section has revealed the groundwater potential with highest aquifer thickness of about 5m, and depths to the fresh basement vary from 1.51 to 66.3 m. The geoelectric interpretation of the electrical resistivity data obtained in the area has elicited a lobe of low resistivity (Fig.4 VES 4, VES 7) which constitutes the prospective zone for water exploration. The study area has been delineated into prospective high and low groundwater potential zones based on geoelectric characteristics. The output of this work will definitely benefit the people of the areas as it will aid them in the sinking of boreholes to depth which will provide clean and healthy water that is free from contamination. This investigation confirmed the fact that the vertical electrical sounding (VES) is a reliable tool for underground water exploration in a sedimentary basin.

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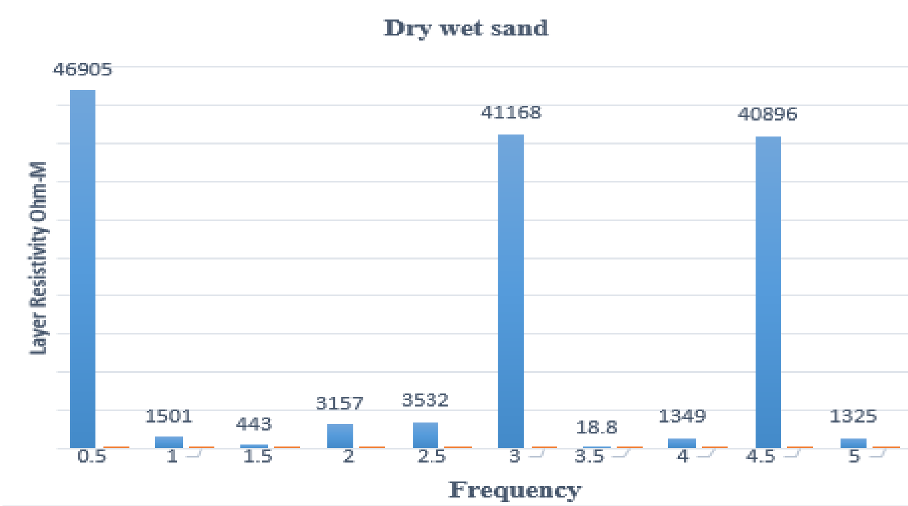
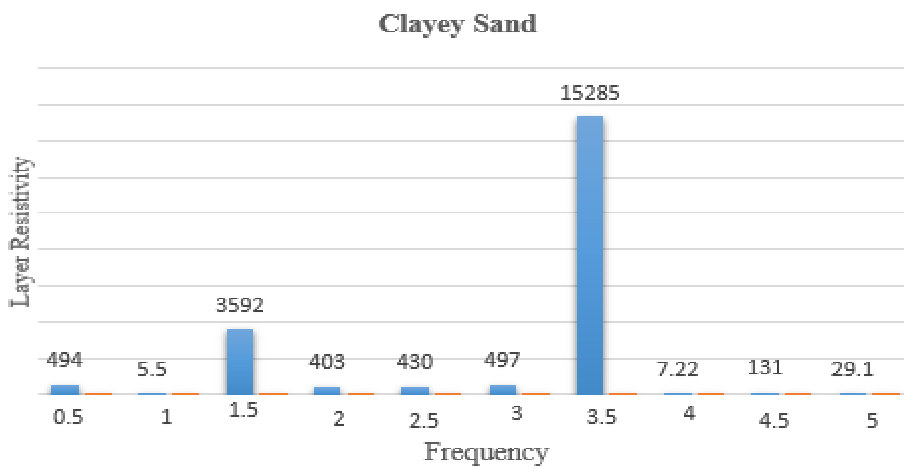
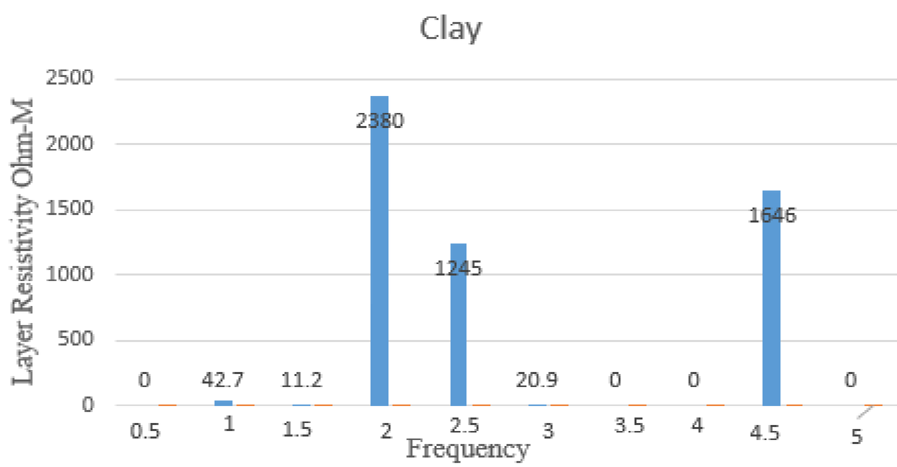
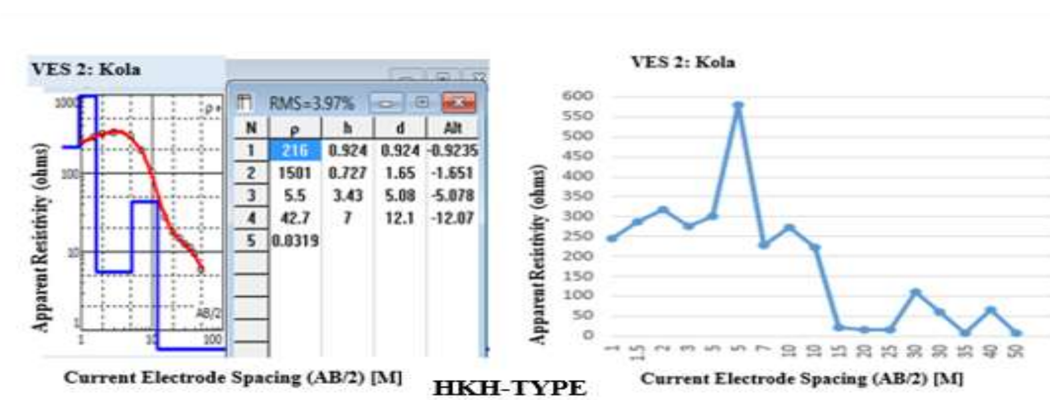
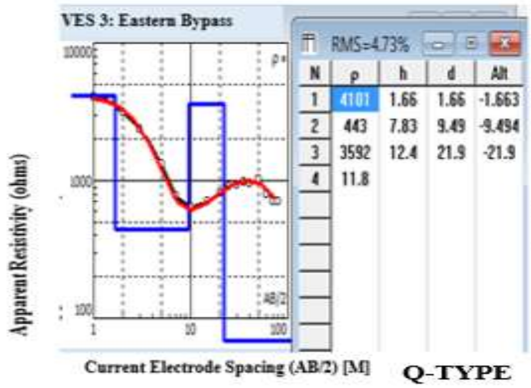


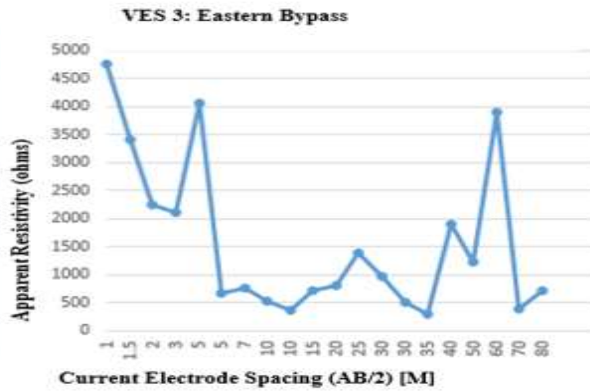

Clayey Sand
Layer Resistivity
494
5.5
3592
403
430
497
15285
7.22
131
29.1
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Frequency

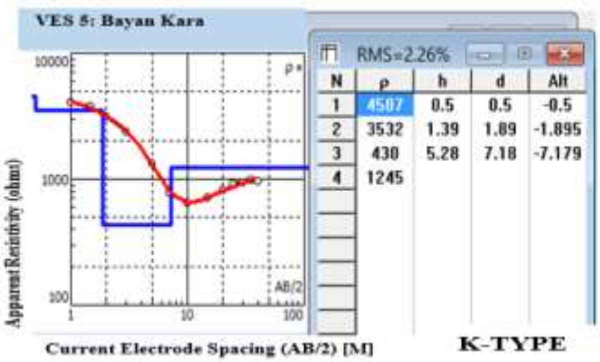

Clay
Layer Resistivity Ohm-M
2500
2000
1500
1000
500
0
42.7
11.2
2380
1245
20.9
1646
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Frequency


VES 2: Kola
Apparent Resistivity (ohms)
RMS=3.97%
N ρ h d Alt
1 216 0.924 0.924 -0.9235
2 1501 0.727 1.65 -1.651
3 5.5 3.43 5.08 -5.078
4 42.7 7 12.1 -12.07
5 0.0319
Current Electrode Spacing (AB/2) [M]
HKH-TYPE
VES 2: Kola
Apparent Resistivity (ohms)
Current Electrode Spacing (AB/2) [M]

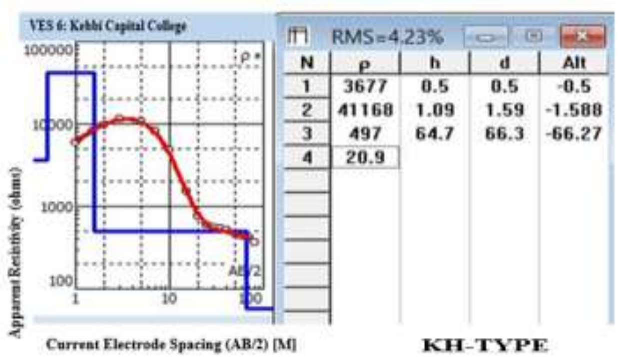


Q-TYPE

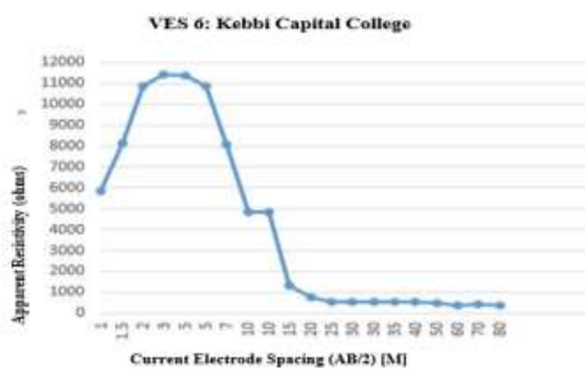


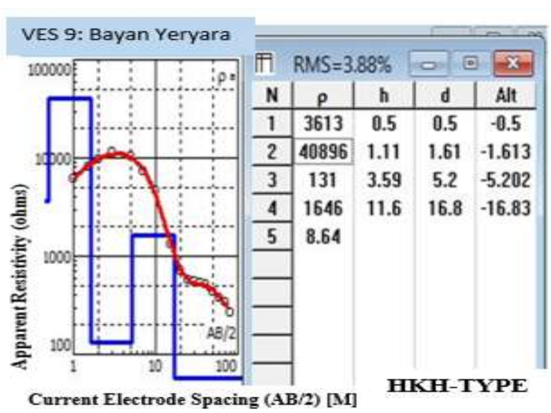


K-TYPE

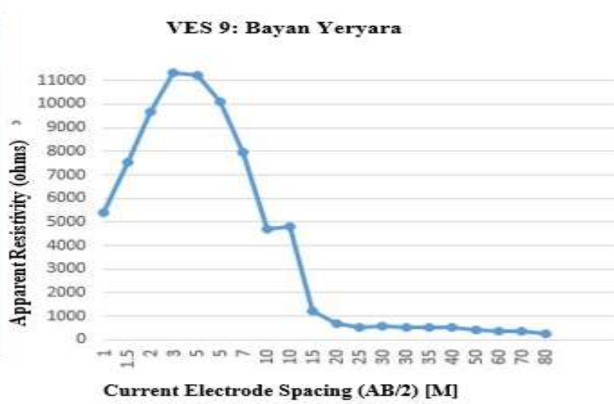


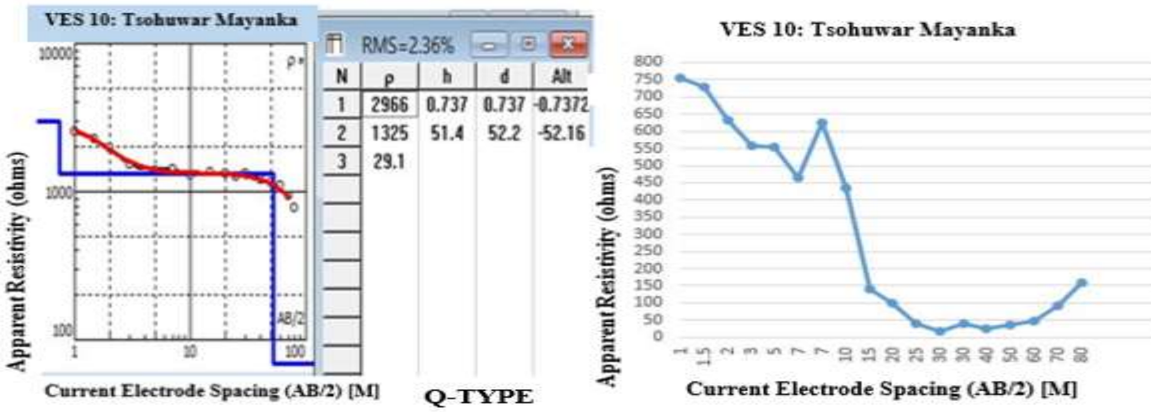
KH-TYPE





HKH-TYPE




VES 10: Tsohuwar Mayanka
Apparent Resistivity (ohms)
Current Electrode Spacing (AB/2) [M]
RMS=2.36%
N ρ h d Alt
1 2966 0.737 0.737 -0.7372
2 1325 51.4 52.2 -52.16
3 29.1
Q-TYPE
VES 10: Tsohuwar Mayanka
Apparent Resistivity (ohms)
Current Electrode Spacing (AB/2) [M]