



Geo-electric Investigation for Groundwater Potential Zones at Permanent Site of Federal University Birnin Kebbi (Clinic Site)

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ABSTRACT

Geophysical investigation was carried out using vertical electrical sounding (VES) with the aim of determining the subsurface layers' parameters (resistivity, and thickness) across various layers with varying depth penetrated and use same to characterize the Aquiferous zones of the study area. A modified Half Schlumberger array method was used for data acquisitions across nine (09) vertical electrical soundings. The half-current electrode ($AB/2$) used range from 1 to 60 m. The depth sounding interpretation results were used to generate geo-electrical sections/ layers from which the aquifer zones were characterizes. The results were interpreted using geological software IPI2WIN 12.0 version which gave an automatic interpretation of the apparent resistivity data. Sounding curve obtained from the study area revealed that two-three-four geo-electric layers could be delineated which are the brown clay/ironstone (132-6700 Ωm , with a thickness of 1.027-16.7 m), coarse sand (289 to 6341 Ωm with corresponding thickness from 0.603 to 38.8 m) and sandstone (125 to 8864 Ωm with thickness value from 6.6 to 31.6 m), this characteristic indicates that there is overlapping layers and thickness formation within the depth surveyed, while the fourth layer has a resistivity values ranges 129.4 to 1246 Ωm and thickness runs to infinity. The results revealed that the groundwater bearing zones (Aquifer), lies within the intermediates fracture layers (sandstone). The results of the resistivity sounding were correlated with the lithological formation of nearby boreholes log around the study area. However, in light of this present investigations its recommended that the suitable zone for groundwater potentials can be found across VES points in the following order of its suitability/productivity as VES 3, 1, 2, 9, 6 and 8 respectively.

Keywords: Depth, Groundwater, Investigation, Vertical electrical sounding & Thickness.

INTRODUCTION

Due to ever increasing population growth and continuous evacuations of students and staffs from temporary to permanent site, it is an undeniable fact that there are corresponding needs of potable water supply. Groundwater research in Kebbi State does not seem to be growing at the same rate with its high demand as a result of population explosion which to a large extent is a major challenge for future development of groundwater in the state. Due to the population rise, urbanization, industrialization and extreme agricultural activities in Kebbi State in particular and Nigeria in general, the requirement for groundwater has increased immensely in recent years (Yahaya, 2018). Groundwater is the water held in the subsurface within the zone of saturation under hydrostatic pressure below water table. It is characterized by a certain number of parameters which geophysical methods are trying to determine from surface measurements, mostly indirectly, but sometimes directly. The most usual parameters are the porosity, the permeability, the transmissivity and the conductivity. Practically all groundwater that is used by human beings originates from the atmosphere or has a "meteoric" origin, and the principal source of natural recharge is precipitation that falls directly on the Earth's surface (Telford *et al.*, 1990).

In Nigeria, the ratio of people with access to safe water declined from 49% in 1990 to 48% in 2004 due to population increase, etc. The ratio is especially low in rural areas at 31% compared to 68% in the cities in 2004 (JICA, 2011). There is an urgent need to secure safe water supply because many people drink surface water and puddle water with risk of water-borne diseases. Worldwide, over 1.1 billion people do not have access to

safe water (WHO/UNICEF, 2000). The scarcity of water is more intense in the developing countries where statistics show that 67% of the rural population have no access to safe water supply (Rosen and Vincent, 1999). This is so because people in the rural areas tend to depend mostly on surface water (from lakes, streams, ponds and rivers) for sustenance.

Fadele *et al.* (2013) also used vertical electrical sounding (VES) for groundwater exploration around Nigerian College of Aviation Technology, Zaria Kaduna State, Nigeria. Their study used Schlumberger arrangement in fifteen (15) VES stations and the resultant data was analyzed using computer software (IPI2win) which gives an automatic interpretation of the apparent resistivity. Similarly, Abdullahi (2009) carried out an integrated geophysical technique in the investigation of groundwater contamination at two waste disposal sites in Kaduna Metropolis. The result of the research indicated three to four layers in the area and the resistivity imaging had delineated the leachate plume in the area as low resistivity zones (6- 33 Ωm).

Electrical resistivity has been proved successfully in delineating a suitable fracture in identifying zones of relatively low resistivity which might be a good signatory of a saturated points for groundwater explorations zone and their directions of flows. It became very important prior to any drilling Geophysical investigation should be done which could mitigate/ address the failure of most drilled boreholes or hand dug well (Oyedele and Olayinka, 2012). Similarly, in a sedimentary terrain, permeable and porous zone such as sandstone and loose sand serve as good indicator of aquifer productive zone, and these are often characterized by relatively low resistivity value

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(Odunaike, 2013). Therefore, measuring the good resistivity from the surface of the earth could provide information concerning the occurrence, location and direction of groundwater flow beneath the earth's subsurface. The reliability of VES method over other geophysical methods used for groundwater exploration was stated by Olasehinde *et al.* (2015), Oladimeji *et al.* (2013), Oyedele and Olayinka (2012) and Alile *et al.* (2011). The aim of this research work is to use vertical electrical sounding technique to determine groundwater potential zones at permanent site of Federal University Birnin Kebbi.

GEOLOGY OF THE STUDY AREA

The study area is generally underlain by Sedimentary Complex Terrain of the Gwandu Formation. It contains a number of prominent ridges and group of flat-topped steep-sided hills capped by ironstone. The sediments consist of massive white clays interbedded with coarse and medium-grained red stones and mud-stones with occasional peat bands. beneath the lateritic capping is a hard-ferruginous sandstone layer which is easily eroded into a network of gullies. These are underlain by red sandy clays and white massive mudstones, which are invariably

stained pale brown or pink (Reyment, 1965). The mudstone with sandstone intercalations extends monotonously throughout the sections. Similar, section of Gwandu formations occurs on the slopes of the Gwandu outliers within the Kalambaina formation. The sand at the surface are quite red in colour, often showing colour banding and poor stratification, the mudstones often show a nodular structure with nodules suggestive of local turbulence in the depositional environment. The study area does not have any major river that passes through it. However, there exists a seasonal river and swamp/depression that can be found around the vicinity of the institution. This swamp functions only during the rainy season where it drains and collects all the excess runoff water from the surrounding scarps and hills. The swamp serves as a major source of water supply for irrigation activity for the neighbouring communities during the dry season (Ariyo, 2009). The principal water-bearing beds in the Sokoto sediments are the surface laterites, sandstones and grits in the Gwandu Formation, limestone beds in the Kalambaina Formation, sandstones in the Wurno and Taloka Formations as well as grits and sandstones in the Gundumi Formation/Illo Formations (Oluyide *et al.*, 1998; Du Preez., 1952).

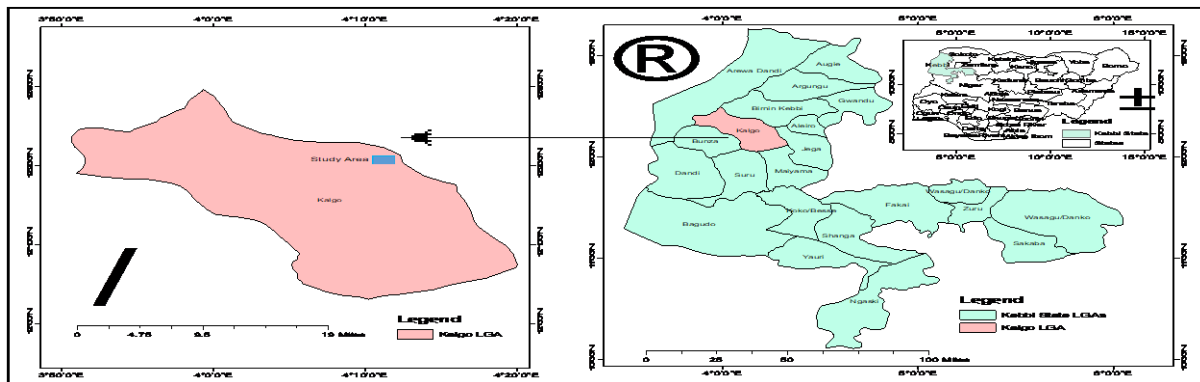


Fig. 1: Geologic map of the study area.

METHODOLOGY

A modified half-Schlumberger array was employed for data acquisition. Nine (9) Vertical Electrical Sounding points were surveyed. ABEM Terrameter (SAS 300c) were used for the collection of data due to the deeper penetration and its ability to provide information about resistivity variation with depth. A maximum half current electrode spacing used for data collection was 60 m. The depth penetrated by the current lines increases by increasing the separation of the half current electrodes. The measurements were repeated and recorded with MN/2 fixed at its initial distance and AB/2 was symmetrically increased. Whenever the resistance measured becomes too small then MN/2 was also increased symmetrically. Global Positioning System (GPS) which gives accurate geographical navigation of the study area and VES sounding points were used, connecting cables, four electrodes (steel rods), measuring tapes and hammers were used during the data collection. The data obtained were analysed using geological software IPI2WIN, which generates two-three-four geo-electric layers. Similarly, Lithologic (borehole log data), were obtained at Sokoto Agricultural and Rural Development Agency (SARDA, 1988). The VES field data were interpreted through partial curves matching technique with preliminary interpretation

from the result of nine (09) sounding points investigated helps to characterize and identify weak resistivity zone which serve as the aquifer productive zone. At each measurement the resistance measured were multiplied with corresponding values of geometrical factors in order to get the apparent resistivity value.

Let assumes, the ground surface to be homogeneous and a current I is passes through the earth and a potential drop – δV can occur between the ends of the element.

From Ohm's law $\rho \delta R = \delta L / \delta A$.

Since, $V = IR$ (1.0)

It follows that,

$$\frac{\delta V}{\delta L} = - \frac{\rho I}{\delta A} \dots\dots\dots(1.1)$$

Where V = potential difference, L = current electrode separation, A = cross sectional area, I = current and ρ = resistivity. However, the current density in any direction within a material is generally given by the negative partial derivative of the potential in that direction divided by the resistivity. Hence, current density can be derived with respect to surface area:

$$i = \frac{l}{2\pi r^3} \dots\dots\dots(1.2)$$

From equation (3) the potential gradient associated with current density is given as:

$$\frac{\delta V}{\delta r} = \rho I = - \dots \dots \dots (1.3)$$

Then the potential with respect to distance r is given

$$Vr = \int \delta V = \int \frac{\rho I \delta r}{2\pi r^3} = \frac{\rho I}{2\pi r^2} \dots \dots \dots (1.4)$$

Equation (1.4) can be said to allow any calculation of potential at any point on or below the surface of homogeneous half space. Furthermore, we can consider a case where the sink is at a finite distance from source (Fig. 1).

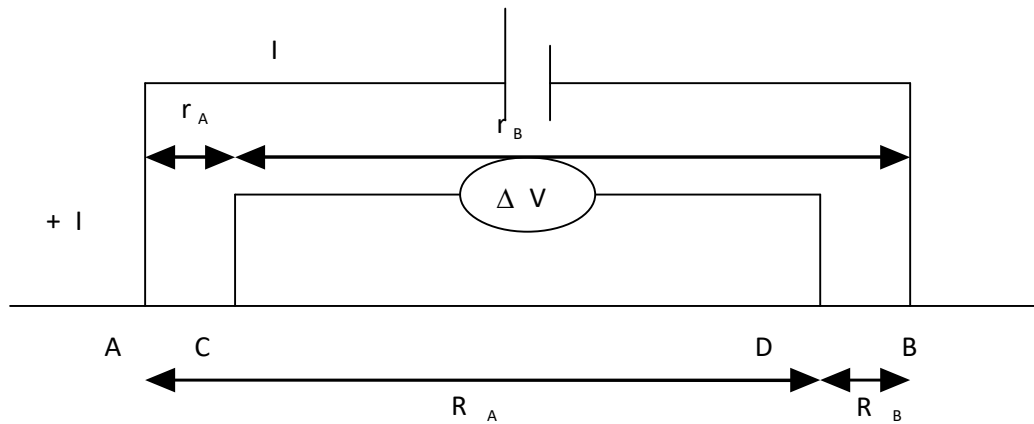


Fig. 1: Schlumberger Electrode arrangements.

From Figure (1.1) the potential V_C at an electrode C is the sum of the potential contributions V_A and V_B from current source at A and the sink at B.

$$V_C = V_A - V_B \dots \dots \dots (1.5)$$

From equation (1.5), $V_C = \frac{\rho I}{2\pi} \left(\frac{1}{r_A} - \frac{1}{r_B} \right) \dots \dots \dots (1.6)$

$$V_D = \frac{\rho I}{2\pi} \left(\frac{1}{r_A} - \frac{1}{r_B} \right) \dots \dots \dots (1.7)$$

Hence the potential difference ΔV between electrode C and D is given as

$$\Delta V = V_C - V_D = \frac{\rho I}{2\pi} \left\{ \left(\frac{1}{r_A} - \frac{1}{r_B} \right) - \left(\frac{1}{r_A} - \frac{1}{r_B} \right) \right\} \dots \dots (1.8)$$

$$\rho = \frac{2\pi \Delta V}{I \left\{ \left(\frac{1}{r_A} - \frac{1}{r_B} \right) - \left(\frac{1}{r_A} - \frac{1}{r_B} \right) \right\}} \dots \dots \dots (1.9)$$

Equation (1.9) is viable when the ground is uniform, giving a constant resistivity which is independent of both electrode spacing and surface location. In the case of subsurface inhomogeneities the resistivity obtained is the apparent resistivity which is a function of the inhomogeneity. The current and potential electrodes are maintained at the same relative spacing and is progressively expanded about a central fixed point. Therefore, the depth of current penetration increases with increase in current electrode separation in homogeneous layers (Telford *et al.*, 1990), the Schlumberger configuration can be represented by:

$$\rho_a = \frac{\pi \Delta V L^2}{2I} \dots \dots \dots (1.10)$$

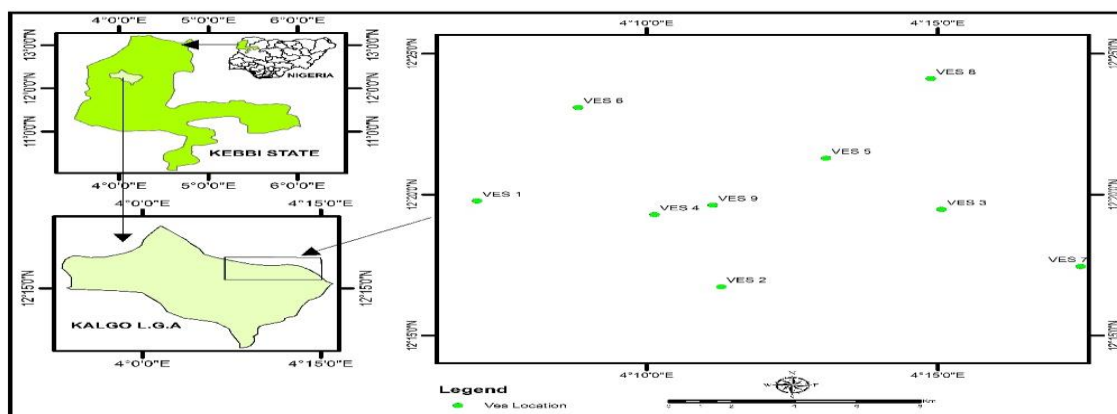


Fig. 2: Location map showing the geometric VES points arrangement.

RESULTS AND DISCUSSIONS

The apparent resistivity (ohm-meter) was plotted against the current electrode spacing AB/2. The results of the nine (09) VES soundings points interpreted revealed that there are multi-layered geo-electric sections typical of Gwandu sedimentary formation. It is the primary aim of collecting

geophysical data to interpret it in terms of a geologically identifiable condition. It is evident that in some cases, the interpreted situation may differ slightly from the actual geologic situation. Nevertheless, it is the best that approximates the true geological situation.

Table 1: Result of the interpreted VES sounding curves.

VES station (s)	Coordinates (Latitude & Longitude)	Number of layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Thickness and Depth of water bearing zone (m)	
						Thicknesses (m)	Depth (m)
VES 1	12°19'47"N 04° 07'5"E	1	961	8.32	8.32		
		2	2643	36.6	44.9	36.6	44.9
		3	125	∞	∞		
VES 2	12°19'35"N 04°11'12"E	1	132	16.7	16.7		
		2	289	26.9	43.6	26.9	43.6
		3	134	∞	∞		
VES 3	12°19'29"N 04°15'04"E	1	6700	9.8	9.8		
		2	4228	38.8	48.6	38.8	48.6
		3	1222	∞	∞		
VES 4	12°19'18"N 04°01'08"E	1	6290	1.027	1.725		11.68
		2	6341	2.498	5.165	8.159	
		3	8864	8.159	11.68		
		4	129.4	∞	∞		
VES 5	12°19'47"N 04°13'12"E	1	157.6	12.24	12.24		12.24
		2	951.2	∞	∞	12.24	
VES 6	12°19'38"N 04°9'7"E	1	4561	1.98	1.98		35.3
		2	1128	2.7	4.67	30.6	
		3	7462	30.6	35.3		
		4	1150	∞	∞		
VES 7	12°19'29"N 04°17'5"E	1	4031	1.153	1.15		8.36
		2	602	0.603	1.76	6.6	
		3	7100	6.6	8.36		
		4	130	∞	∞		
VES 8	12°19'41"N 04°15'11"E	1	4962	3.82	3.82		23.7
		2	1617	19.8	23.7	19.8	
		3	389	∞	∞		
VES 9	12°19'38"N 04°11'8"E	1	4400	4.55	4.55		41.0
		2	7864	4.86	9.41	31.6	
		3	2833	31.6	41.0		
		4	1246	∞	∞		

interpreted results of the nine VES sounding points surveyed with their corresponding thicknesses and depth to weak resistivity unit estimated to be groundwater bearing zones. From the results obtained geo-electric sections reveals that there are two-four layers across the sounding points investigated (Figure 3). The resistivity variations across all the VES points penetrated shows the existence of two-four lithologic formations with the first layer has a resistivity values ranging from 132-6700 Ωm , this layer has a thickness of 1.027-16.7 m which is typified as superficial layer (top soil). Similarly, the resistivity value of the second layer ranges from 289 to 6341 Ωm with corresponding thickness from 0.603 to 38.8 m with lithologic formation as sandstone gravelly sand formation. The results obtained helps in locating some subsurface

structural trends in the study area and also its reveal the lithological sequence of the geological formation beneath the earth, specialized maps were produced from the interpreted resistivity value and thickness data obtained. However, the third layer has a resistivity ranges from 125 to 8864 Ωm with thickness value from 6.6 to 31.6 m, with lithologic formation as coarse sand or sandstone and gravelly-sand. The fourth layer which occurs at VES 4, 5, 6, & 9 has a resistivity ranges between 129.4 to 1246 Ωm and thickness runs to infinite this layer has a lithologic formation as gravelly-sand, sand, limestone. The corresponding decrease in resistivity values that occur in the third and fourth layers in some VES points within the study area was attributed due to the presence of saturated zones or probably groundwater bearing formations.

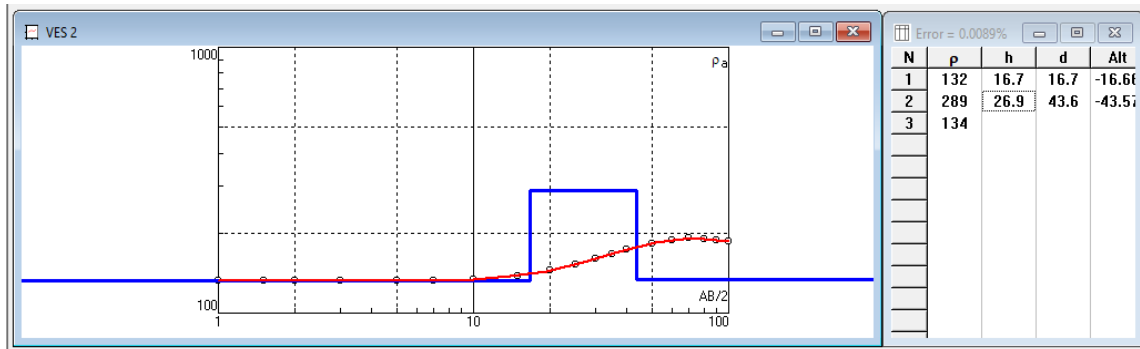


Fig. 3: Typical resistivity curve in the study area.

The electrical resistivity contrasts between lithological sequences in the subsurface are usually adequate to enable the delineation of aquiferous or non-aquiferous layers. The data analyses across the nine sounding points reveal that the subsurface formations of the study area show the existences of two-four subsurface geo-electric sections with different curves types penetrated across (09) sounding points. Table 1 give the interpreted layer parameters (layer thickness and electrical resistivity patterns) of (09) VES points. The maximum depth of

penetration was obtained at around VES 3, 1, 2, 9, 6 & 8 (Fig. 6) respectively and these values area well correlated with the borehole lithology drilled near the study area (Fig. 4). The lithological formations across (09) sounding points reveal that the study area was underlain by sand, sandstone, clay/silt, coarse-sand, gravelly- sand and limestone. The geo-electric parameters of the lithologic units were delineated from the interpreted sounding curves. The log shows an overburden and layers overlapping dominated by three-four geologic layers.

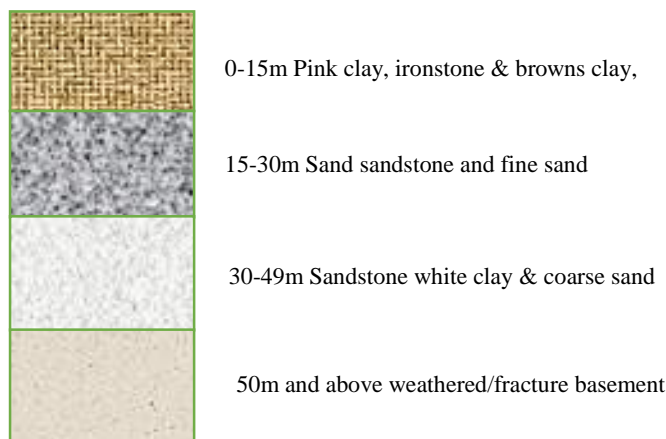


Fig. 4: Borehole log data drilled near the study area (SARDA, 1988).

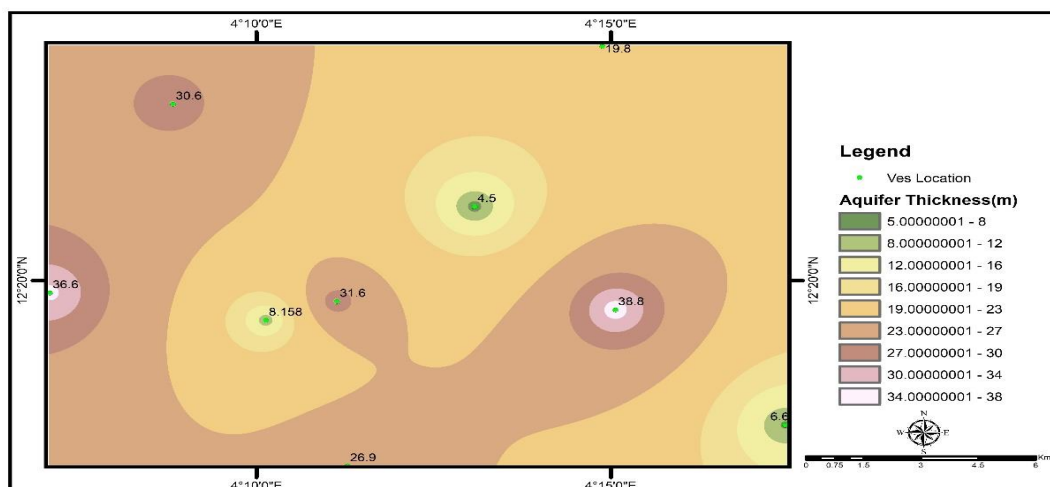


Fig. 5: Aquifer thickness in the study area.

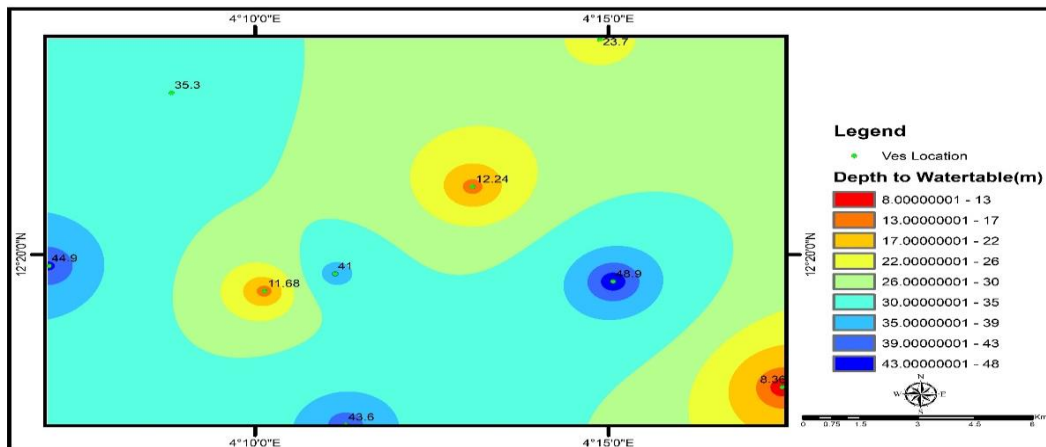


Fig. 6: Depth to water table in the study area.

CONCLUSION

Results from the nine (09) sounding points indicates that, the area under study is underlain by two-three-four geoelectric layers within the depth penetrated, three-four lithologic units could be delineated. The sub-surface geology and lithological formations of the study area shows the patterns of resistivity variation with depth thus revealing its groundwater distribution as well as its potential as a substitute to the surface water resources. The research revealed that, the depth to water table has an aquifer thickness from 4.5 to 38.8 m, while the depth to

water table was obtained at 11.68-48.9 m respectively. The study further reveal that there is layer overlapping across sounding points investigated. There is also variation of groundwater recharge from one VES point to another and can be concluded that the probable water bearing zone across all the surveyed area can be found across six out of nine soundings points investigated arranged in the following order of productivity VES 03, 01, 02, 09, 06 & 08 respectively.

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