

Assessment of groundwater potential using vertical electric sounding technique at Faculty of Medicine and Engineering, Federal University Dutsin-ma Katsina State, Nigeria

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Received 31st August, 2021; Accepted 28th September, 2021

ABSTRACT: Geophysical exploration is used to locate boundaries between different elements of the subsoil as these procedures depend on variations in the gravitational, magnetic, electrical, radioactive or elastic properties of the subsurface. Electrical resistivity method was employed to investigate the groundwater potential of the Faculty of Medicine and Engineering at permanent site of Federal University Dutsin-ma, Katsina State. The study was carried out using ABEM SAS 300 Terrameter, Schlumberger electrodes configurations were used to acquire 9 Vertical Electrical Soundings (VES) soundings. The VES data obtained were interpreted using Winresist computer software which reveal five (5) geoelectric layers, namely; the topsoil, laterite, weathered basement, fractured basement and fresh basement. The weathered and fractured layers constitute the aquiferous zone in all the stations. The results of the interpreted VES data showed that the resistivity of the topsoil varies from 17.1 to 109.8 Ω m with an average value of 137.7 Ω m. The thickness of the weathered basement varied from 1.7 to 7.9 m with an average value of 4.67 m, while depth to this layer varies from 4.6 to 13.8 m with an average value of 10.6 m. The thickness of the fractured basement varied from 3.0 to 15.6 m with an average value of 8.01 m, while depth to this layer varies from 6.3 to 33.7 m with an average value of 18.85 m. The depth to aquifer ranges from 17 to 69 m, the resistivity of the aquifer unit ranges between 35 and 830 Ω m. Based on the results, the potential VES points for groundwater exploitation in the study area includes VES 02, 03 and 05 which indicates low to moderate resistivity at greater depth and are therefore recommended for borehole establishment.

Keywords: Aquifer, electrical resistivity, Katsina State, Nigeria, Schlumberger array.

INTRODUCTION

The problem of obtaining adequate supply of quality water is generally becoming problematic due to ever increasing population and industrialization. In terms of quality, surface water cannot be dependable throughout the year, hence, the need to look for other alternatives to supplement surface water (Alisiobi and Ako, 2012). According to Alabi et al. (2010), about 53% of all population relies on groundwater as a source of drinking water. Groundwater is water located beneath the ground surface in soil pore spaces and in fractures of lithologic formations. To realize the potential of water availability, geophysical field measurements is carried out targeting the assessment of

the groundwater availability within the study area and identifying best boreholes locations for ground water extraction (Helaly, 2017). Most of water underground comes from precipitation that has infiltrated into the earth. Observations have shown that a good deal of surplus rainfall runs-off over the surface of the ground while the other part of it infiltrates underground and becomes groundwater responsible for springs, lakes and wells (Oseji et al., 2006). A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water (Alabi et al., 2010). Geo-electrical methods are particularly suitable for groundwater studies

because the hydro geological properties; such as porosity and permeability; can be correlated to electrical resistivity values. Geo-electrical techniques are essentially concerned with the measurement of electrical resistivities of subsurface materials, which preferentially provides information on the different geological layers, structures and the associated occurrence of groundwater (Stewart 1982, Danielsen et al., 2007; Nowroozi et al., 1999; Meju, 2005). Vertical Electrical Sounding (VES) technique can provide information on the vertical variation in the resistivity of the ground with depth and the Constant Separation Traversing (CST) provides a means of determining interval variation in the resistivity of the ground (USEPA, 2000; Ariyo, 2005; OEPA, 2008).

The use of geophysical methods for both groundwater resources mapping and water quality evaluation has increased dramatically over the last decades due to rapid advances in electronic technology and the development of numerical modeling solutions (Olayinka, 1992, Metwaly et al., 2009; Ndlovu et al., 2010) although various hydro-geophysical techniques are available, electrical resistivity is a popular method because of its low cost, simple operation and efficiency in areas with high contrasting resistivity, such as between the weathered overburden and the bedrock (Telford et al., 1990).

Geophysical investigation of the earth involves taking measurement at or near the earth's surface that are influenced by the internal distribution of physical properties. Geophysics is also considered to be the subsurface site characterization of geology, geological structure, groundwater, contamination, and human artifacts beneath the Earth's surface, based on the lateral and vertical mapping of physical properties variations that are remotely sensed using non-invasive technologies (Afuwai, 2013).

Geology of the study area

The geology of Dutsin-Ma and its environs is underlain by two formations; they are the Illo-Gundumi formation of the Sokoto basin which covers 20% of the total geology of Katsina and the chad basin. The remaining 80% is underlain by basement complex area (older-granite and migmatite-gneiss). Dutsin-Ma is surrounded by rocks (older-granite) that are more than 600 million years old (pre-protozoic). Federal University Dutsin-Ma is underlain by Meta-Sediment which is subjected to transformation from one form to another; from shale, slate pyrite, Gneiss, and migmatite. Figure 2 is the map showing the geology of Katsina state, the area marked pink is the basement complex area and it covers 80% of the geology of the state.

MATERIALS AND METHODS

The study was carried out in Federal University Dutsin-Ma, Dutsin-Ma Local Government area of Katsina State,

Nigeria (Figure 1). The survey area is located within the Federal University permanent site. It lies between latitude 12.2953°N and 12.2957°N and longitude 007.4603°E and 007.4615°E. It is bounded by Kurfi and Charanchi LGAs to the north, Kankia LGA to the east, Safana and Dan-Musa LGAs to the west, and Matazu LGA to the southeast. Dutsin-Ma LGA has a land size of about 552.323 km² (Akor et al., 2017).

The materials employed for this research work include: ABEM TERRAMETER SAS 300 and its accessories hammer for driving the electrodes into the ground for proper electrical contact, measuring tape and a Global positioning system (GPS) for taking the coordinate (longitude, latitude and altitude).

Vertical Electrical Sounding (VES) Schlumberger array configuration was employed in this research work. Four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes are displaced outwards while the potential electrodes in general are left at the same position. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes must also be displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy. Measurements of current and potential electrode positions are marked such that $AB/2 \gg MN/2$. Where $AB/2$ = Current electrode spacing and $MN/2$ = Potential electrode spacing.

The sounding data presented as sounding curves were obtained by plotting apparent resistivity against $AB/2$. The WINRESIST software was then used to obtain the n-layer model curve for the Schlumberger sounding curves. This software automatically interprets the Schlumberger sounding curves. The plotted curves reveal the number of layers, thickness, depth and the average resistivity for each layer at different VES points automatically. The SURFER 2012 software was then used to produce iso-resistivity contour maps from the obtained data. The VES plots along the various profiles generate the geoelectric sections from where the resistivity variation with depth and thickness was obtained. The apparent resistivity ρ_a is given as follows:

$$\rho_a = \pi \left\{ \frac{(\frac{AB}{2})^2 - (\frac{MN}{2})^2}{MN} \right\} R \quad (1)$$

But $V = IR$ from Ohm's law

Therefore, $R = \frac{V}{I}$; Equation (1) becomes

$$\rho_a = \pi \left\{ \frac{(\frac{AB}{2})^2 - (\frac{MN}{2})^2}{MN} \right\} \frac{V}{I} \quad (2)$$

The geometric factor K is expressed as:

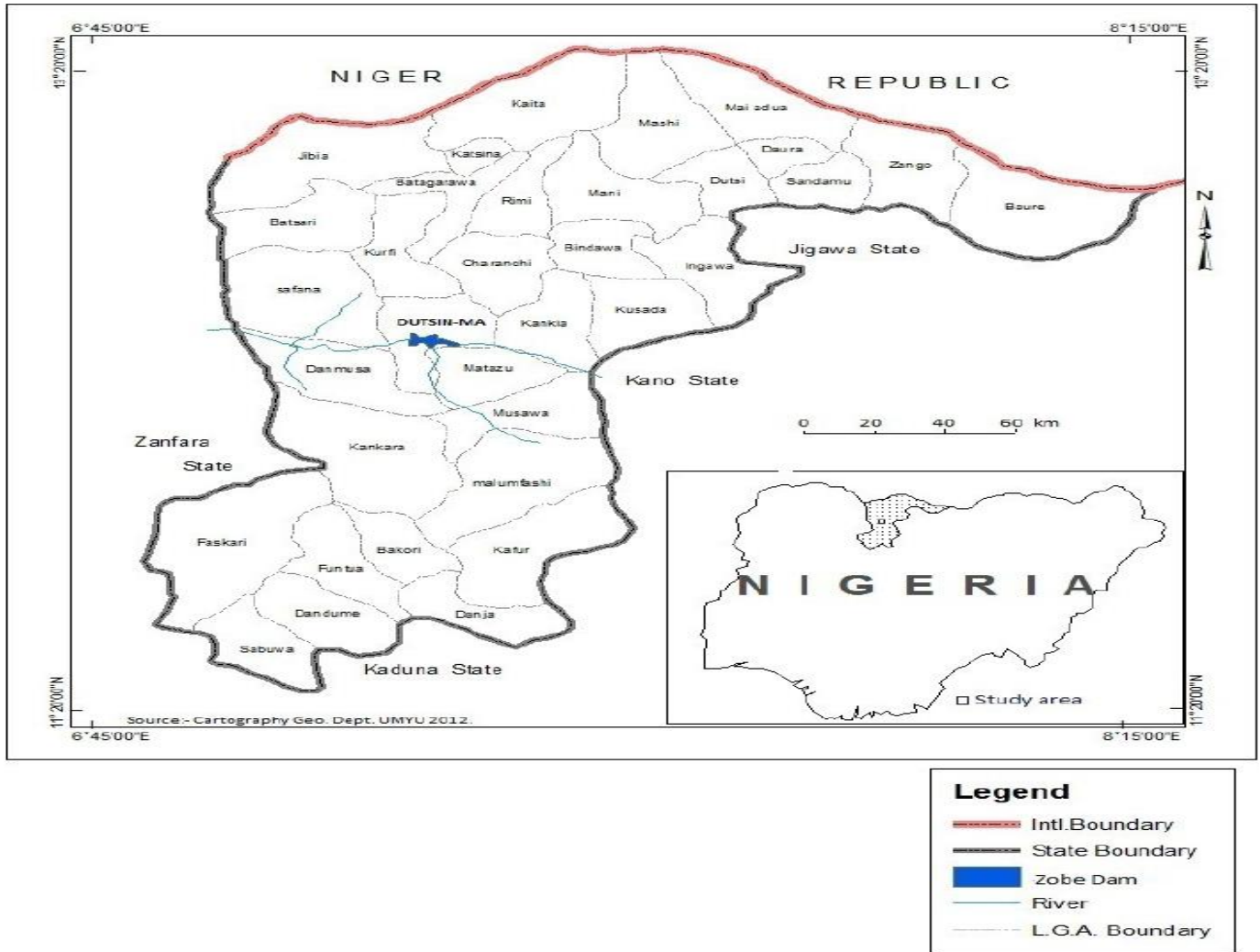


Figure 1. Map of Katsina State showing the study location (Source: Gnes/spot image).

$$K = \pi \left\{ \frac{(AB)^2 - (MN)^2}{MN} \right\} \tag{3}$$

Therefore, $\rho_a = KR$ (4)

Where: ρ_a = Apparent resistivity, K = geometric factor, R = measured resistance, AB = current electrode spacing in meter, MN = potential electrode spacing in meter, V = potential difference in volts and I = electric current in Amperes

RESULTS AND DISCUSSION

VES data curves and geo-electric parameters

The study area revealed a five geoelectric layer curve which include the AH, QA, AA, HK curve types. The AH and AA curve-type been predominant in the study area

with a percentage distribution of 33.33% followed by QA type curve (22.22%) while HK (11.11%).

The geo-electric parameters of the various VES points across the area is shown in Table 1. Five (5) lithological sections were inferred which includes the topsoil, laterite, weathered basement, fractured basement, fresh basement. The thickness of these geo-electric layers varied from 0.9 to 2.2 m for topsoil, 0.9 to 8.1 m for laterite, 1.7 to 7.9 m for weathered basement, 3.0 to 15.6 m for fractured basement and 4.2 to 50.7 m for fresh basement. Their resistivity value ranges from 10.9 to 376.6 Ω m for topsoil, 17.1 to 109.8 Ω m for laterite, 30.2 to 235.9 Ω m for weathered basement, 19.9 to 830.3 Ω m for fractured basement, 1106.1 to 6285 Ω m for fresh basement. The weathered/fractured basement is believed to constitute the water bearing layer of the study area. It has thickness ranging from 1.7 to 7.9 m for the weathered basement and 3.0 to 15.6 m for fractured basement. In order to arrive at the resistivity values used for the interpretation in this work,

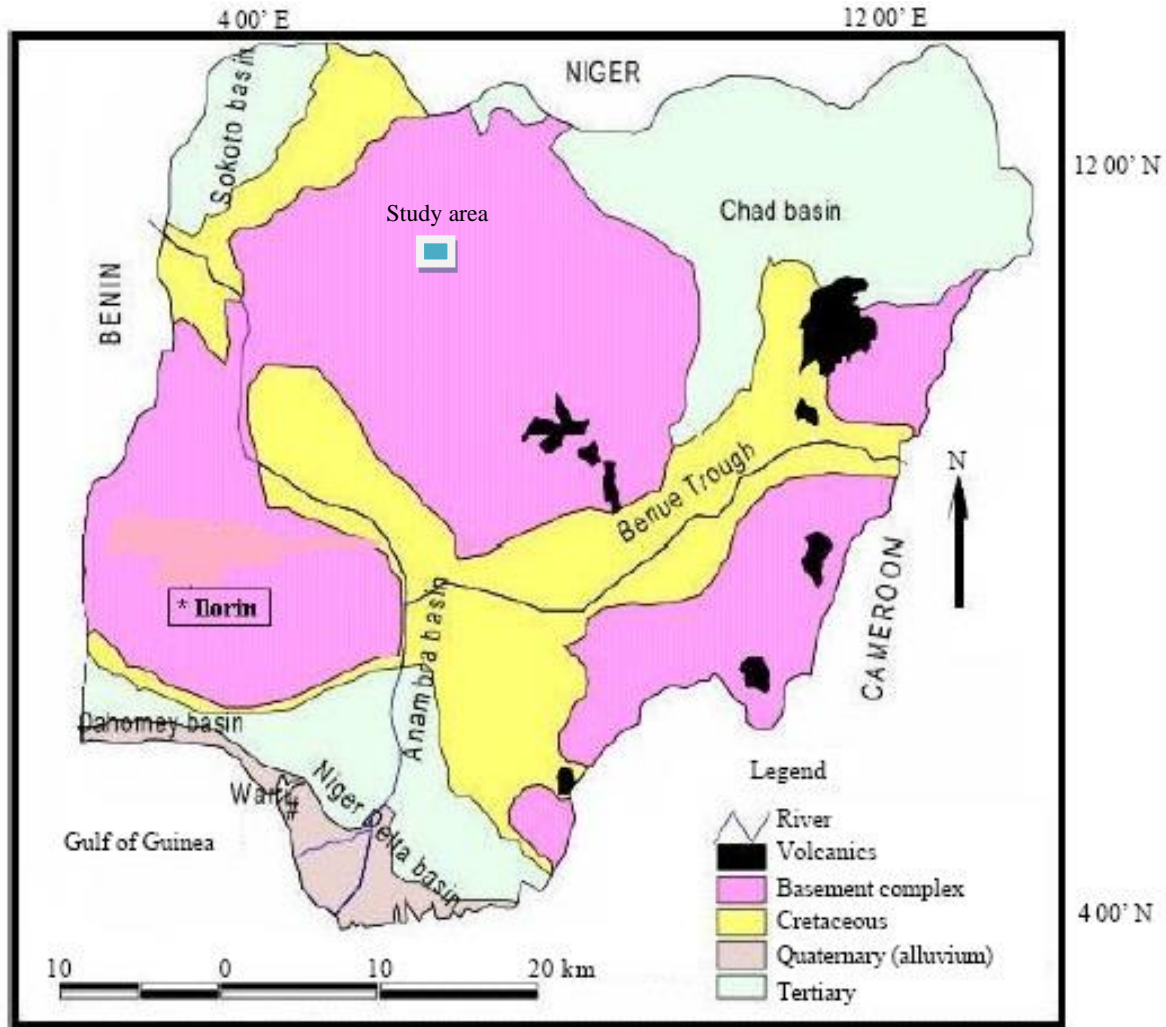


Figure 2. The geologic map of Nigeria (from: Geological Survey of Nigeria, 1974, modified).

Table 1. Quantitative interpretation of VES results.

VES point	Curve type	Number of layers	Resistivity	Thickness	Depth	Lithology
VES 1	AH	1	30	1.4	1.4	Top soil
		2	24.5	8.1	9.4	Laterite
		3	84.7	3.9	13.4	Weathered basement
		4	376.1	6.3	19.7	Fractured basement
		5	6285.4			Fresh basement
VES 2	AH	1	11.2	2.2	2.2	Top soil
		2	109.8	1.0	3.2	Laterite
		3	2937.5	20.1	23.3	Fresh basement
		4	760.1	10.4	33.7	Fractured basement
		5	2410			Fresh basement
VES 3	AH	1	373.4	1.5	1.5	Top soil
		2	44.3	7.3	8.8	Laterite
		3	235.9	4.9	13.7	Weathered basement
		4	810.7	7.8	21.5	Fractured basement
		5	5516.8			Fresh basement

Table 1. Contd.

VES 4	QA	1	169.3	2.1	2.1	Top soil
		2	46.7	3.9	6.0	Laterite
		3	30.2	7.9	13.8	Weathered basement
		4	149.6	7.7	21.8	Fractured basement
		5	1176.8			Fresh basement
VES 5	AA	1	20.1	1.1	1.1	Top soil
		2	27.3	3.9	5.1	Laterite
		3	40.2	6.2	11.3	Weathered basement
		4	67.3	5.3	16.6	Fractured basement
		5	2944.1			Fresh basement
VES 6	QA	1	379.6	1.8	1.8	Top soil
		2	50.9	4.1	5.9	Laterite
		3	35.9	4.9	10.8	Weathered basement
		4	324.8	8.0	18.8	Fractured basement
		5	1460.6			Fresh basement
VES 7	HK	1	228.2	0.9	0.9	Top soil
		2	50.9	2.7	3.6	Laterite
		3	193.6	3.2	6.8	Weathered basement
		4	559.5	15.6	22.4	Fractured basement
		5	19.9			Fractured basement
VES 8	AA	1	16.6	0.9	0.9	Top soil
		2	17.1	2.1	3.0	Laterite
		3	204.3	1.7	4.6	Weathered basement
		4	1106.1	4.2	8.8	Fresh basement
		5	6891.1			Fresh basement
VSES 9	AA	1	10.9	2.3	2.3	Top soil
		2	93.9	0.9	3.2	Laterite
		3	830.3	3.0	6.3	Fractured basement
		4	5248.9	50.7	57.0	Fresh basement
		5	1552.7			Fresh basement

different geophysical works carried out in various places were considered such as the work of Olugbenga (2009), Okubenga (2009) and Ahmed et al. (2020) and was further compared with the resistivity values given by Telford (1990). The variation in resistivity could be as a result of the rate of accumulation/availability of minerals (specifically water) at these stations. The lower the resistivity of a station, the higher the conductivity and as such the higher the water content of that station may be. The observed results in this study are in conformity and close agreement with the observation of Ahmed et al. (2020) and Salahudeen and Sadeeq (2018). The electrical conductivity of a geological strata depends on the conductivity of the rock formation (sand, clay, etc.), its porosity, the water contained in its pore spaces, the salinity of the water, etc. Therefore, in a resistivity survey, the determination of the resistivity structure of the substratum might reveal not only the geological structure but also the water bearing layers (Afuwai, 2013).

Interpretation of the contour maps

Interpretations of vertical electrical sounding (VES) were

used to generate longitudinal contour maps. True aquifer contour map was prepared and interpreted in terms of resistivity using SURFER 2012 computer software. Similarly, depth to aquifer map was also prepared.

True aquifer resistivity contour map

The true aquifer resistivity map (Figure 4) shows the variation in resistivity within the aquifer unit of the study area, the resistivity of the aquifer unit ranges between 35 and 830 Ωm . According to White (1992), VES points with resistivity value less than 35 Ωm is clayey and possess limited aquifer potential. In the study area VES 2, 3, 9, with resistivity value between 235 and 830 Ωm are zones with optimum weathering and good ground water potentials, VES 4, 7, 8, whose resistivities ranges within 147 and 204 Ωm possess medium aquifer potential, while the low aquifer potential is observed in VES 1, 5, 6, with resistivity ranging 35 to 85 Ωm .

Depth to aquifer map

Figure 5 shows the spatial map for the depth to the aquifer

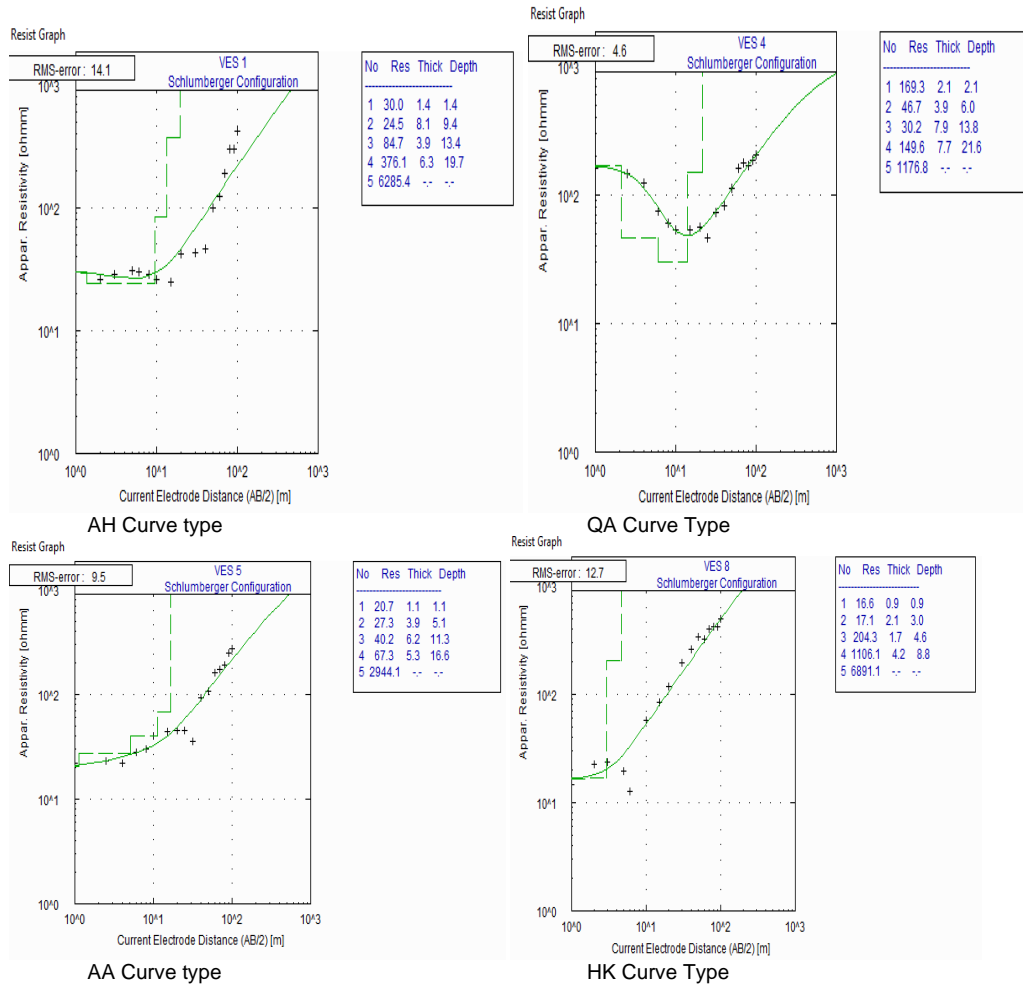


Figure 3. Typical curve types in the study area.

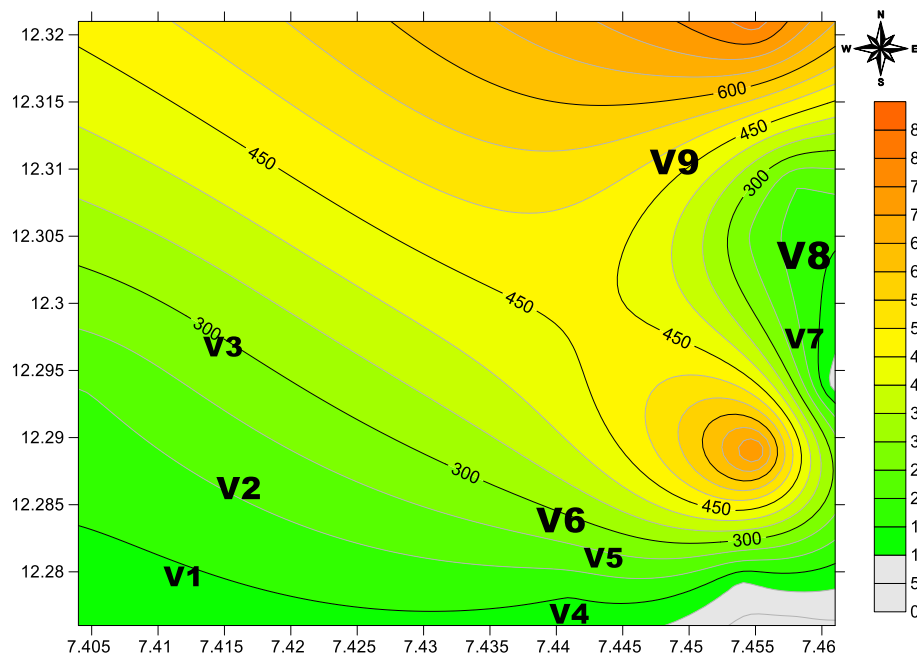


Figure 4. True Aquifer resistivity map of the study area.

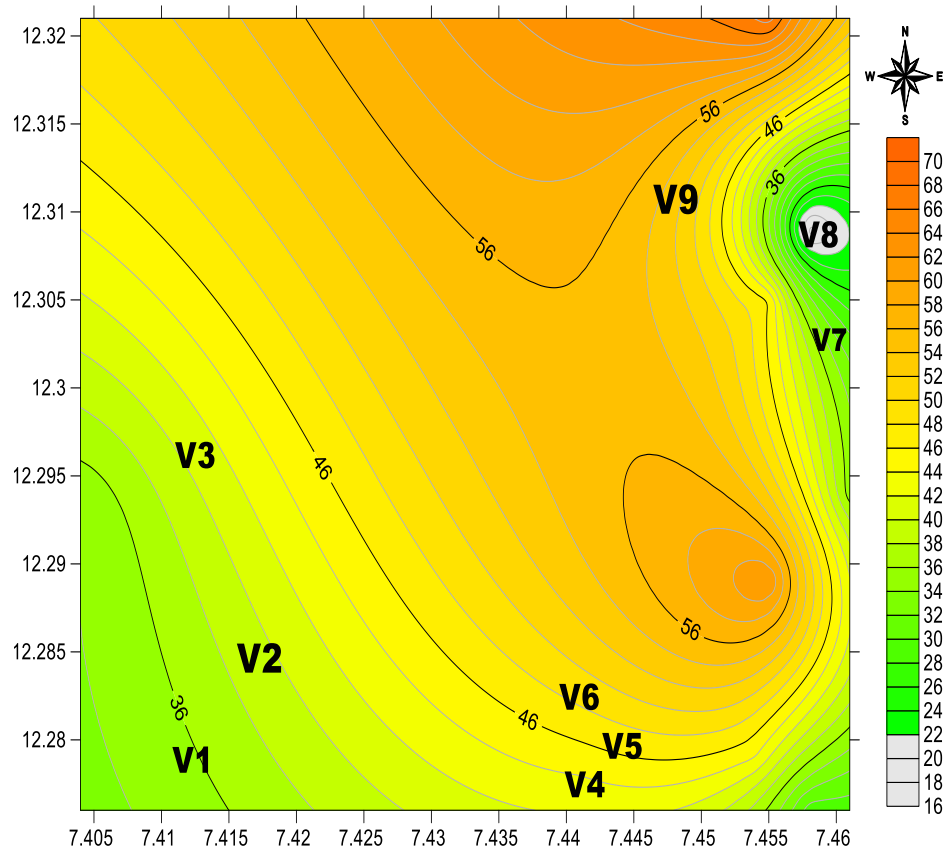


Figure 5. Depth to aquifer.

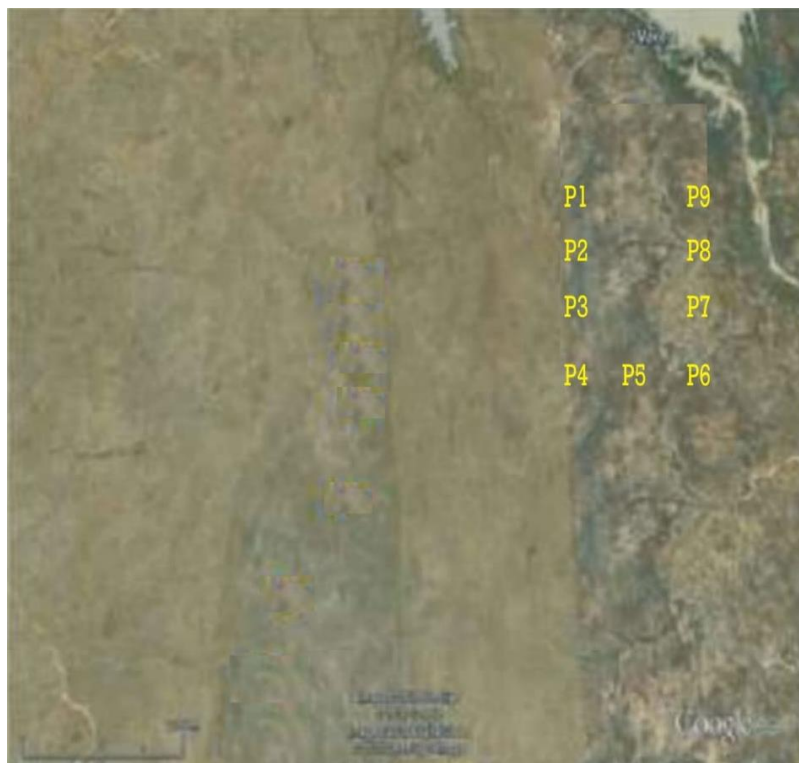


Figure 6. Satellite image map of the survey area.

zone in the study area, the depth to aquifer ranges from 17 to 69 m. The depth is lower at VES 2, 3, 9, which ranges between 6.3 to 33.7 m, VES 1, 4, 5, 7, shows medium depth to aquifer zones varying from 34 to 44 m, whereas, shallow depth in VES 6 and 8 (36 to 62 m). This implies that ground water level at VES 2, 3, 9 closer than at VES 6 and 8.

Conclusion

Based on all the findings made in the interpretation of the VES data, VES stations 2, 3 and 9 have been chosen as the most viable locations for the development of groundwater resources in the study area. The thickness and resistivity of the aquifers at these VES stations indicate very good potential for groundwater. The study will no doubt guide the borehole programs and provide additional database for effective water scheme and utilization in the area.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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