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Delineation of Aquiferous Formation using 2-D Electrical Imaging Technique at Ukwuani, South–South Nigeria.

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Abstract

An aquifer is a body that can hold large volumes of water and also transmit such volumes of water as a result of groundwater potential. To determine groundwater potential, a 2-D Electrical Resistivity Imaging (ERI) technique was carried out within the medium fine-grained formation of the Ukwuani kingdom, South-South, Nigeria. The study is undertaken to determine the thickness, lateral extent and depth of aquiferous formation within the study locations. The Abem Terameter SAS 300C was used for field data acquisition while employing the Wenner-Schlumberger electrode configuration. A 2-D set of apparent resistivity data was generated in different parallel and other orientations with electrode spacing of 5.0m. The four electrodes are positioned at 0m, 5m, 10m and 15, which corresponds to the C1, P1, P2, C2 positions for the current electrodes C1 and C2 and potential electrodes P1 and P2 on the particular profile. In each case, the circuitry is completed by connecting the electrodes to the Abem Terameter SAS 300C via single-core cables. The collected resistivity data was processed and inverted using the RES2DINV software. A probing depth of 17.3m was attained over a profile length of 120m with a unit electrode spacing of 5m. The depth and thickness of investigation suggest that across the traverses and horizons, a viable and sustainable aquifer is best sought for at a depth to formation of about 15m with thicknesses in the range of 4.0m to 7.0m. The study area is a sandy environment with an unconfined aquifer characteristic.

1. Introduction

Geophysical investigation of the subsurface of the earth involves taking measurements on or beneath the earth's subsurface or vertically in a borehole to obtain the internal distribution of physical properties of a subsurface geological structure or material. Various geophysical methods are applied to environmental site investigations. Geophysical methods are employed in the exploration of geological structures and are implemented in a wide range of applications ranging from building and groundwater investigation to the inspection of dams and dikes [1 - 6], aiming towards the exploration of geological structure and the determination of physical parameters of the rock formations/units.

Geoelectrical resistivity method has developed greatly and has become an important instrument in hydrological studies, examining aquiferous formation, mineral prospecting and mining as well as in environmental and engineering applications [7–10]. Groundwater is described as the water found beneath the surface of the earth in underground streams and aquifers [11]. Researchers such as [12 – 19] have all used the electrical resistivity method to explore for groundwater in different locations.

The electrical resistivity method has been the most commonly used geophysical tool for groundwater investigation because of its advantages which include simplicity in field technique and data handling procedure [19]. Electrical resistivity methods are effectively used for groundwater exploration in areas where good electrical resistivity contrast exists between the water-bearing formation and the underlying rocks [13]. Some uses of this method in groundwater are, the determination of depth, thickness and boundary of an aquifer, determination of interface saline water and freshwater porosity of aquifer, hydraulic conductivity of aquifer, transmissivity of aquifer, specific yield of aquifer, and contamination of groundwater [20]. The electrical resistivity method has been adopted in this research work because of the influence of resistivity or conductivity on the electrical nature of groundwater.

The investigation of the aquiferous formation using Electrical Resistivity Imaging was carried out at Ukwuani with over 120.0m profile length of 5.00m unit electrode spacing.

1.1 Site Description/Location

The Study area, Ukwuani in Ukwuani Local Government Area of Delta State Its headquarters are located in Obiaruku. It is in the Southern part of Nigeria known as the Niger Delta and lies within latitudes 5.50^0 to 6.14^{0}N and longitudes 6.14^0 to 6.35^{0}E with an elevation of about 23m (75ft) above sea level as depicted in Figure 1.

Figure 1: Map of Delta State Showing the study Location [21]

Table 1. Ukwuani survey location co-ordinates

POINTS	**CO-ORDINATES**	**LATITUDE**	**LONGITUDE**
POINT 1	Begin coordinate End coordinate	N5.75633^{0} N5.75694^{0}	E006.23797^{0} E006.23708^{0}
POINT 2	Begin coordinate End coordinate	N5.75683^{O} N5.75667^{o}	E006.23806^{O} E006.23770^{O}
POINT 3	Begin coordinate End coordinate	N5.75483^{0} N5.75810^{0}	E006.21589^{O} E006.21592^{O}
POINT 4	Begin coordinate End coordinate	N5.75350^{0} N5.75428^{0}	E006.22653^{O} E006.22553^{O}

These locations were selected after a reconnaissance visit to the study area. The co-ordinate values of the sites were collected using Geographical Positioning System (GPS) These are shown in figures

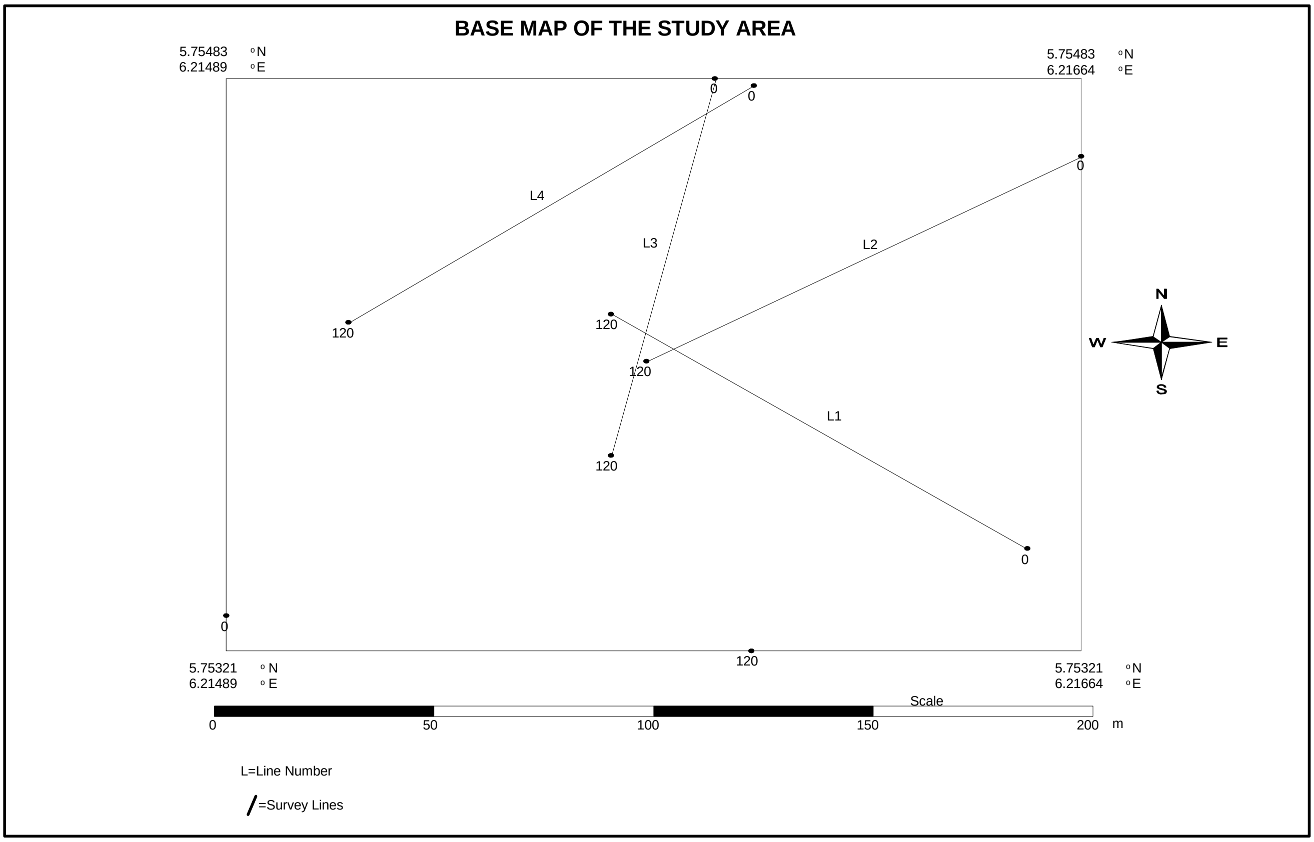

Figure 2: A constructed base map for Ukwuani survey location

1.2 Theory

All resistivity methods employ an artificial source of current which is introduced into the ground through point or long lines of contacts. The procedure is to measure potentials at other electrodes in the neighborhood of the current flow. Electrical methods are based on the resistivity or its inverse; this is the conductivity of the material.

From the surface potential we have,

$$U(r) = \frac{I\rho}{2\pi r} \quad (1)$$

Where

I = current
ρ= resistivity
r = distance between electrodes

A single-point current source can be achieved in theory by placing a corresponding current source at infinity. Determination of subsurface resistivities requires knowledge of the potential distribution in addition to the input current. Given two current electrodes A and B in Figure 3. when we apply equation 1, the potential at arbitrary point M is

$$U_m = \frac{I\rho}{2\pi}\left[\frac{1}{r1} - \frac{1}{r2}\right] \quad (2)$$

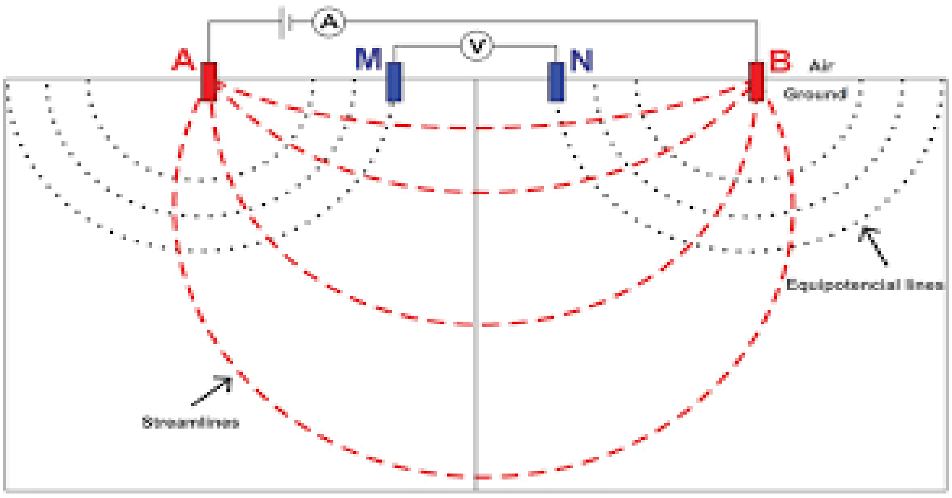

Figure 3: Distribution of current and potential lines for two current electrodes at the surface of a homogenous half-space source**.**

To measure potential difference, two electrodes are needed. Theoretically, the injecting electrodes A and B could be used to measure the response signal. A dedicated pair of electrodes for measuring voltage difference completes a four-electrode array commonly used in DC resistivity surveying. Subtracting the potential at point M gives the potential difference ΔU between M and N:

$$\Delta U = \frac{I\rho}{2\pi}\left[\frac{1}{r1} - \frac{1}{r2} - \frac{1}{r3} + \frac{1}{r4}\right] = \frac{I\rho}{K} \quad (3)$$

Where r_3 is the distance between M and A, r_4 is the distance between N and B. Since K only contains the distance between electrodes, it is called the geometric Factor which depends on the relative distribution of electrodes. On rearranging equation 2, we obtain

$$\rho = K \frac{\Delta U}{I} \quad (4)$$

For an inhomogeneous earth, this equation will produce values that vary according to the geometrical arrangements of electrodes on the surface. Values obtained from equation 4 or an inhomogeneous underground are referred to as apparent resistivities, ρ_a.

2. Methodology

The electrical resistivity method using the Wenner – Schlumberger electrode configuration was adopted for this geophysical survey. All resistivity methods employ an artificial source of current which is introduced into the ground through point electrodes. In practice, it involves passing an electric current into the ground and measuring the resulting voltage difference between a pair of potential electrodes placed between the current electrodes on the surface
Before carrying out any field measurement, the reading of the prepared imaging survey base map for the survey area was used alongside the compass to locate the traverse on the ground.

2.1 Data Acquisition

The ERI survey data was acquired using the Abem Terameter SAS 300C earth resistivity meter while employing the Wenner-Schlumberger electrode array. A 2-D set of apparent resistivity data was generated in different parallel and other orientations with electrode spacing of 5.0m. For the first measurement, n=1, a=5, K=3.142 which stands for serial number 1. The four electrodes are positioned at 0m, 5m, 10m and 15m, which corresponds to the C_1, P_1, P_2, C_2 positions for the current electrodes C_1 and C2 and potential electrodes P_1 and P_2 on the particular profile. The next serial number 2, is a forward shift of electrode positions by 5m each. The electrodes assumed the new positions 5m, 10m, 15m and 20m. However, the P_1 and P_2 difference of 5m is maintained throughout the measurements. 120m profile length is observed for twenty-six (26) electrodes. The circuitry is completed by connecting the electrodes to the ABEM TERAMETER SAS 300C - Earth Resistivity meter via single-core cables before taking the reading. The resistance of the formation was measured which was then transformed to apparent resistivity through the transformation equation.

$$\rho_a = KR \quad (5)$$

Where $K = \pi\, an\,(n + 1)$ (6)

ρ_a is apparent resistivity, R is resistance, K is the Geometrical factor

2.2 Inversion of 2-D Apparent Resistivity Data

The collected resistivity data was processed and inverted using the RES2DINV software. The programme automatically creates a 2D model by dividing the subsurface into rectangular blocks [18] and the resistivity of the blocks was iteratively adjusted to reduce the difference between the measured and the calculated apparent resistivity values. The apparent resistivity values were calculated by the finite–difference method. The programme calculates the apparent resistivity values and compares these to the measured data. During iteration, the modeled resistivity values will be adjusted until the calculated apparent resistivity values of the model agree with the actual measurements. The iteration is stopped when the inversion process converges.

3. Results and Discussion

3.1 Results

Field data obtained from the instrument readings at each survey lines were recorded in a data sheet. The geometrical factor "K" for each sequence of measurement "n" was computed using equation (5). This was then used to multiply the resistance values read from the instrument to obtain the apparent resistivity.

For clarity, organization and data analysis, the results of the inverted ERT1 images of the various profiles of the survey area are presented in figures.

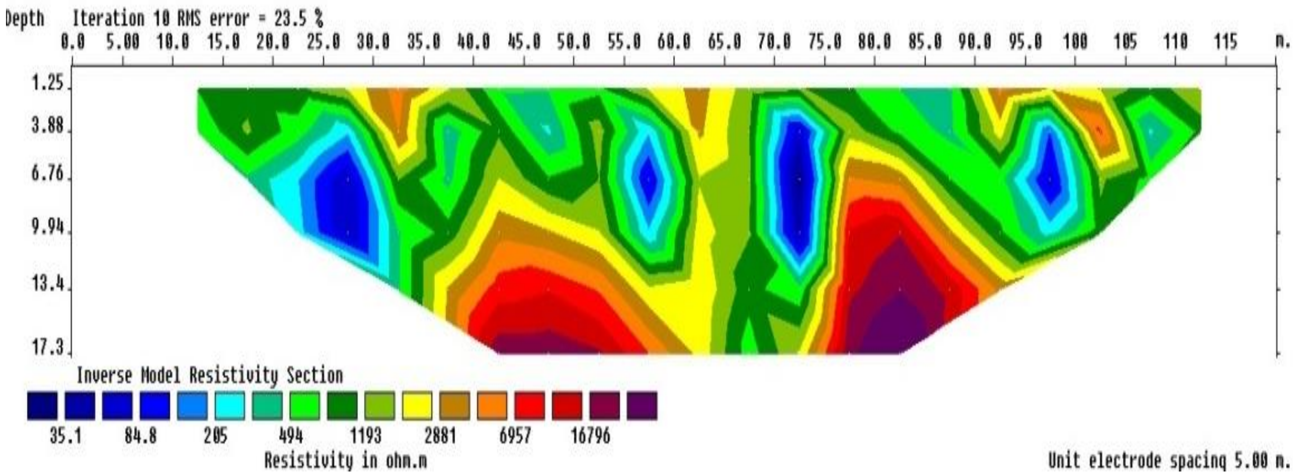

Figure 4: Inverse model resistivity section of traverse 1 of the Ukwuani survey location.

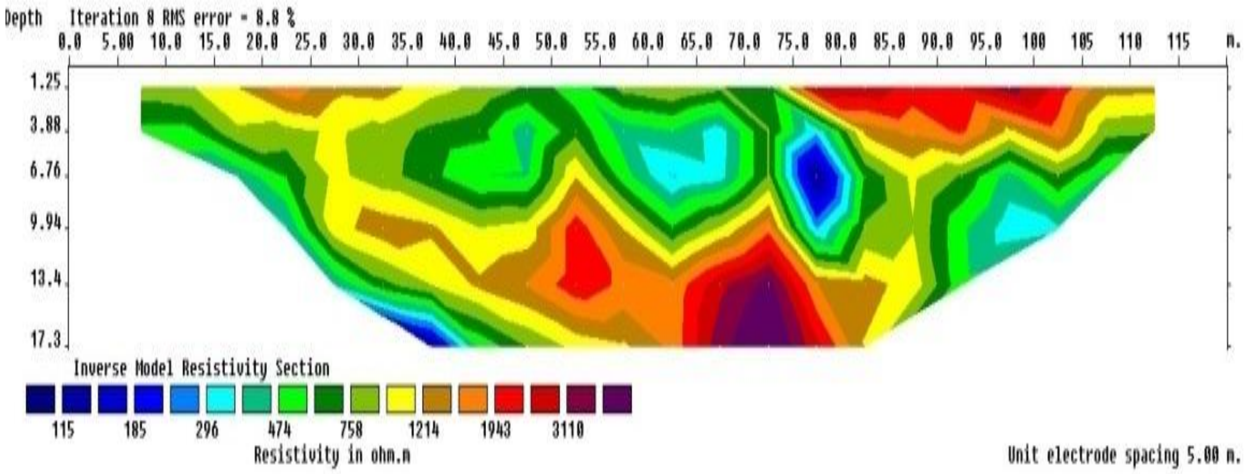

Figure 5: Inverse model resistivity section of traverse 2 of the Ukwuani survey location.

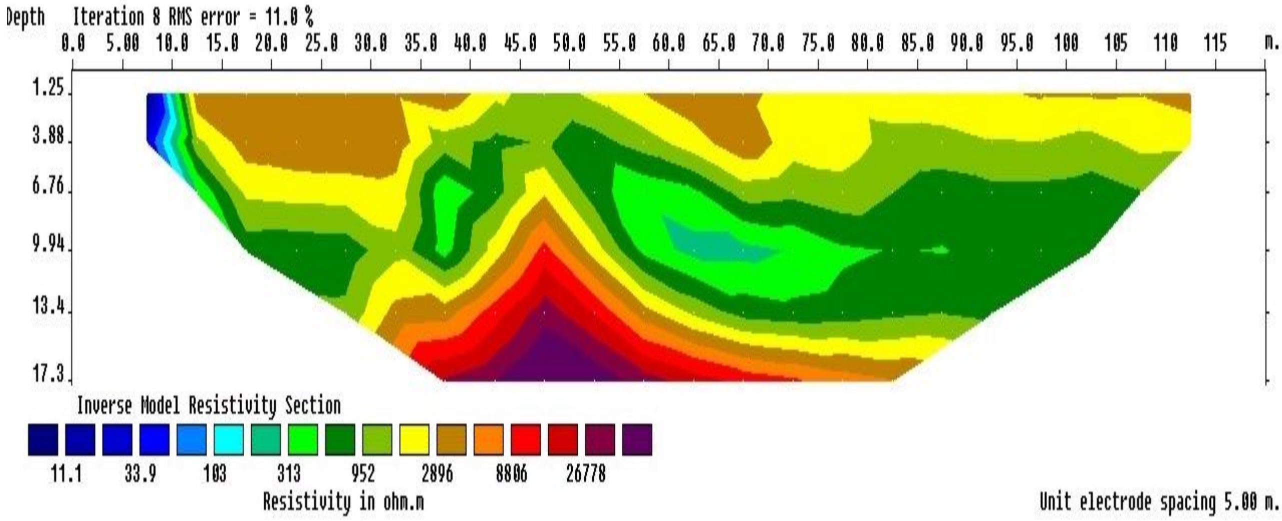

Figure 6: Inverse model resistivity section of traverse 3 of the survey location.

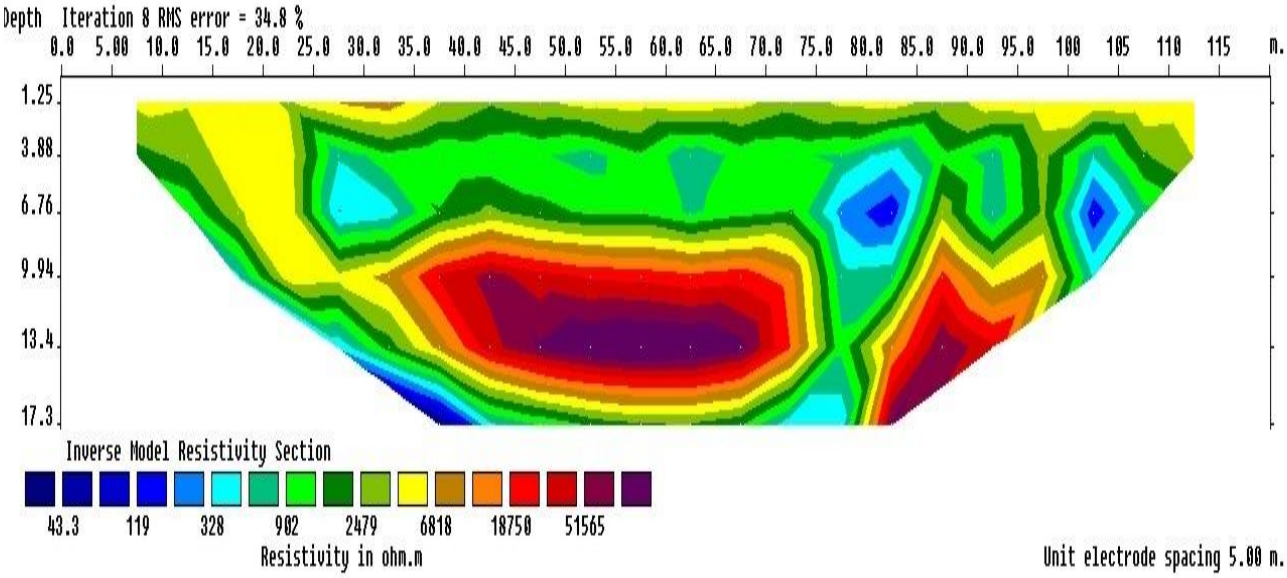

Figure 7: Inverse model resistivity section of traverse 4 of the Ukwuani survey location.

3.2 Discussions

The inverse resistivity model of traverse in Figure 4 shows four low resistivity anomalies at a horizontal distance of 24 – 30m, 57 – 60m, 70 – 75m and 95 – 100m with resistivity values less than 100Ωm. Reference to the resistivity range, these are indication of water bearing formations or an aquiferous formations. These formations generally vary in thickness between the range of 3.80 – 6.94m at depths range of 3.88 – 6.76m and 3.80 – 9.44m. This traverse holds good prospect for water exploitation at about 8.15m. The areas between 40 - 55m and 75 - 85m lateral distance, form a discontinuous basement at a depth of about 13 – 17.3m.

The inverse resistivity model of traverse 3 in Figure 5 depicts a subsurface formation of resistivity less than 100Ωm. This formation is inferred to be a water bearing formation. It has an average thickness of about 5.00m at depth of 8.6m over a lateral extent of 7.00m(ranging from 75.00m – 82.00m) .The Root-mean-square(Rms) value of 8.8% from eight iterations was observed.

From the inverse model resistivity section of transverse 1 in Figure 6, it is observed that the subsurface lithology of resistivity in the range of 10.0 - 90Ωm exists at a lateral distance of about 7.0 – 10.0m from the surface up to 5.0m in depth. This formation is inferred to be shallow unconfined aquifer that could serve the purpose of a hand dug water well. It has an average thickness of 4.99m.

The Root-mean-square(Rms) value of 11.0% from eight iterations was observed.
In Figure 7, an anomalous resistivity range of about 43.3 - 119Ωm is delineated at a horizontal distance of 75 - 85m and 100 - 105m at a depth of 7.0m. This formation is inferred to be groundwater formation in a sandy environment. The basement rock is typical of a very high resistive material that is inferred to be compacted sandstone. This traverse is computed over eight iterations.

4. Conclusion

Aquiferous formation investigation using the 2-D ERT technique was successfully carried out in the sedimentary environment of Ukwuani. A probing depth of 17.3m was attained over a profile length of 120m with a unit electrode spacing of 5.00m. The depth and thickness of investigation suggest that across the traverses and horizons, the viable and sustainable aquifer is best sought for at a depth to the formation of about 8.20m with thicknesses in the range of 4.00m to 7.00m. The study area is a sandy environment with an unconfined aquifer characteristic.

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