Geophysical Investigation of the Groundwater Potentials in parts of Obowo Area, Imo State, Southern Nigeria

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ABSTRACT

Geoelectric investigation of the groundwater potentials in parts of Obowo area of Imo State, Nigeria was done by carrying out 20 vertical electrical soundings (VES) using ABEM SAS 4000 Terrameter with current electrode spacing varying from 1 – 300m and potential electrode varying from 0.25 to 20m. Seven (7) geoelectric layers were delineated and the results show that 5th and 6th layers are where the aquifers are located. The depth to the aquiferous units ranges from 7.78m to about 54.0m; and the aquifer resistivity ranges from 8.15 Ωm to 3,086 Ωm. The depth at which groundwater can be tapped in various locations was highlighted, and the best location for sustainable groundwater exploitation was recommended.

(Keywords: geoelectric layers, saturated layers, Benin Formation, vertical electrical soundings)

INTRODUCTION

Water occurring beneath the ground surface under the water table in pore spaces and in the fractures of rock formations is usually referred to as groundwater. Groundwater is a natural resource with its characteristics being greatly determined by the geologic properties of the host rock.

A porous substratum that is able to hold and yield (transmit) an appreciable quantity of groundwater upon penetration by a well is called an aquifer. Thus, groundwater exploration and exploitation reliably depend on the empirical knowledge of the geology of the area and the aquifer depth (Amos-Uhegbu, *et al.,* 2019).

Location / Overview of the Physiography and Geology of the Study Area

The study area (Amuzi in Obowo local government area of Imo state, Nigeria) lies within latitudes 5°34' 151'' and 5°34'710'' N and longitudes 7°18'152' 'and 7° 18' 462'' E (Figure 1). It has characteristic mean temperature of above 20˚C. The area falls within the sub-equatorial belt with relative humidity values over 70%; while the rainy season in this area falls between April and October with annual rainfall varying from 1500-2200mm with rainfall peaks in July and September and a short break in August. The study area is drained southward by tributaries of Imo River.

Geologically, the study area belongs to the Coastal Plain Sands (CPS) otherwise called the Benin Formation (Figure 2). It forms the major hydro-geologic units in the study area. It comprises poorly sorted continental (fine-medium-coarse) sands and gravels that alternate with lignite streaks, thin clay horizon and lenses at some locations.

The thin clay/shale horizons truncate the vertical and lateral extents of the sandy aquifers thereby building up multi-aquifer systems in the area. The Benin Formation spans from Oligocene to Recent. It is the youngest of Niger Delta sediments. Its thickness is about 6,000 ft and comprises the top part of the Niger Delta clastic wedge, from the Benin-Onitsha area in the north to beyond the present coastline in the south.

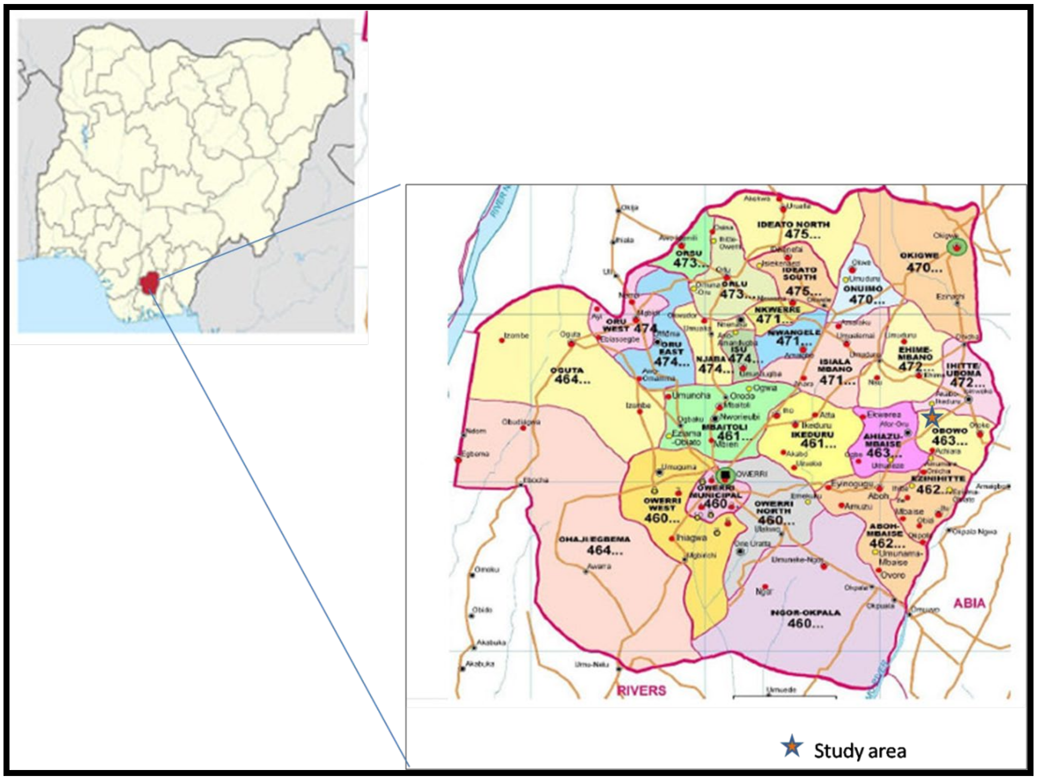


Figure 1: Insert Map of Nigeria showing Imo State and Obowo, the Study Area.

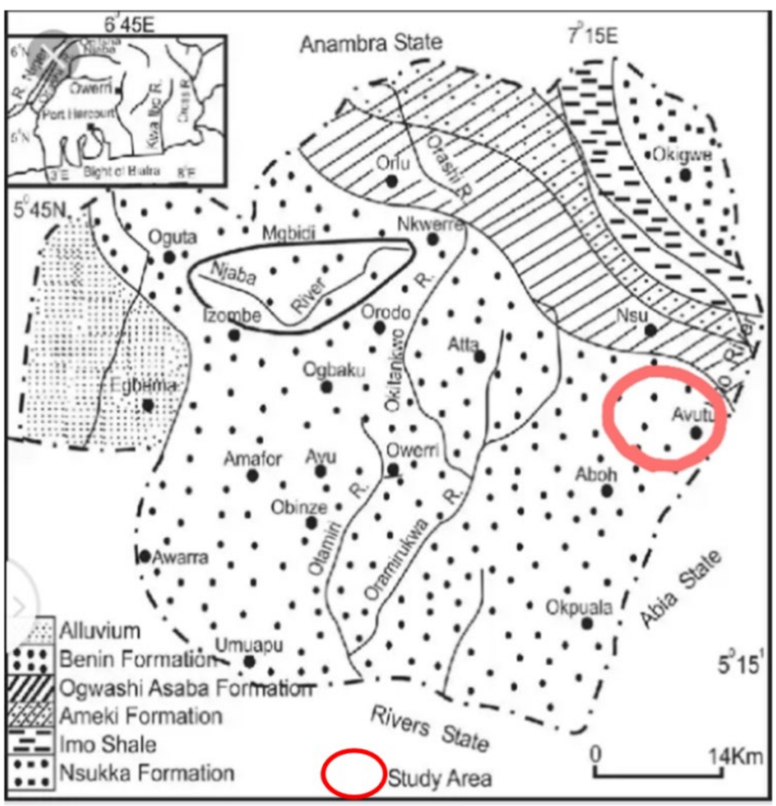


Figure 2: The Geologic Map of Imo State showing Benin Formation in the Study area.

Significance of the Study and Choice of Method

Industrialization and urbanization, together with rising standards of living and increase in population usually add pressure on natural resources. There are reported cases of the failure of water boreholes in the study area; and the greatest contributing factor to this is the lack of a fair knowledge of the subsurface characteristics prior to the drilling.

The preference of groundwater to surface water by the teeming population in the study area has made groundwater the main source of water supply for almost every sector in the area. Since groundwater plays a major role in meeting the ever-increasing demands for various purposes in the area; therefore, an overview of the groundwater potential of the area is essential for effective exploitation and management.

Many approaches and methods have been used in the search for groundwater (Igboekwe, *et al.*, 2008; Achu, *et al.*, 2020; Benjmel, *et al.*, 2020; Aju, *et al.*, 2021; Amos-Uhegbu, *et al*., 2023); but geophysical surveys are the most widely used because of their basic advantage of providing more accurate results than other methods. Many geophysical techniques have been used in groundwater exploration (Afolayan, et al., 2004; Lawrence and Ojo, 2012, Amos-Uhegbu, et al., 2019); but the most widely used is the electrical resistivity method (Ariyo and Adeyemi, 2009; Ochuko, 2013; Amos-Uhegbu and Ndubueze, 2022). This is because less field manpower is required, and the equipment is portable; hence the field operation is easy. It also has greater depth of penetration thus clarifying the subsurface structure together with the delineation of the groundwater.

Resistivity surveys give a picture of the subsurface resistivity distribution. To convert the resistivity picture into a geological picture, some knowledge of typical resistivity values for different types of subsurface materials and the geology of the area surveyed is important. The resistivity of these rocks is greatly dependent on the degree of fracturing, and the percentage of the fractures filled with ground water. Igneous and metamorphic rocks typically have high resistivity values. Sedimentary rocks, which usually are more porous with higher water content, normally have lower resistivity values. Wet soils and fresh ground water have even lower resistivity values. Clayey soil normally has a lower resistivity value than sandy soil. However, note the overlap in the resistivity values of the different classes of rocks and soils. This is because the resistivity of a particular rock or soil sample depends on several factors such as porosity, the degree of water saturation and the concentration of dissolved salts (Figure 3).

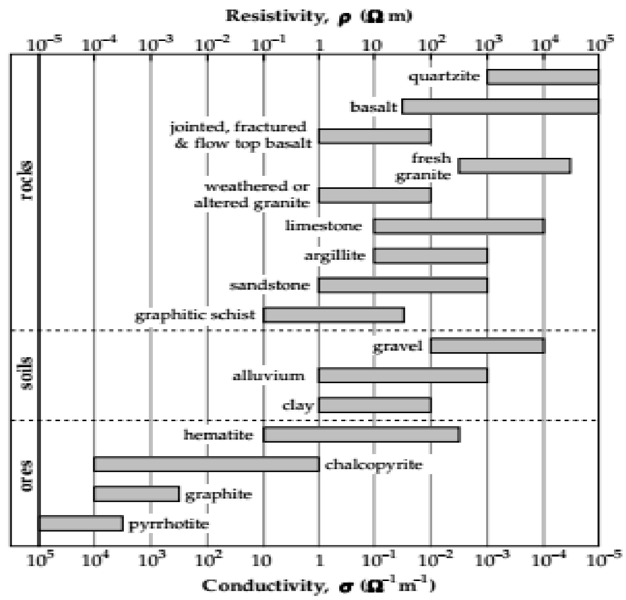


Figure 3: Ranges of Electrical Resistivity for some Common Rocks, Soils and Ores (Adapted from Lowrie, 2007).

Resistivity values have a much larger range compared to other physical quantities mapped by other geophysical methods. The resistivity of rocks and soils in a survey area can vary by several orders of magnitude. In comparison, density values used by gravity surveys usually change by less than a factor of 2, and seismic velocities usually do not change by more than a factor of 10. This makes the resistivity and other electrical or electromagnetic based methods very versatile geophysical techniques.

The Vertical Electrical Soundings (VES) technique of electrical resistivity method gives detailed information of vertical succession of individual thicknesses, resistivities and their different conducting zones; therefore, it was chosen for this study.

A good number of literature materials by renowned scholars shows that VES has proved to be effective in solving groundwater problems (Mbonu, *et al.,* 1991; Igboekwe, *et al*., 2006; Ndubueze, *et al*., 2019). Therefore, this study is aimed at carrying out a geoelectric investigation of the subsurface of the area understudy with the objectives of delineating the geoelectric layers (determining the thickness and resistivity) and subsequently providing a groundwater acquisition guideline in the area.

MATERIALS AND METHODS

Twenty (20) VES were acquired using the Schlumberger electrode configuration with two current electrodes ‘AB/2’ widely spaced out and two potential electrodes ‘MN/2’ closely spaced in between the current electrodes all along the survey line. The current electrode spacing ‘AB/2’ was varied from 1.0 m to a maximum of 300 m; while the potential electrode spacing ‘MN/2’ was varied from 0.25 m to a maximum of 20 m. The Garmin GPS 72 was used in determining the coordinates (longitude, latitude and elevation height above mean sea level) of each sounding point (Figure 4).

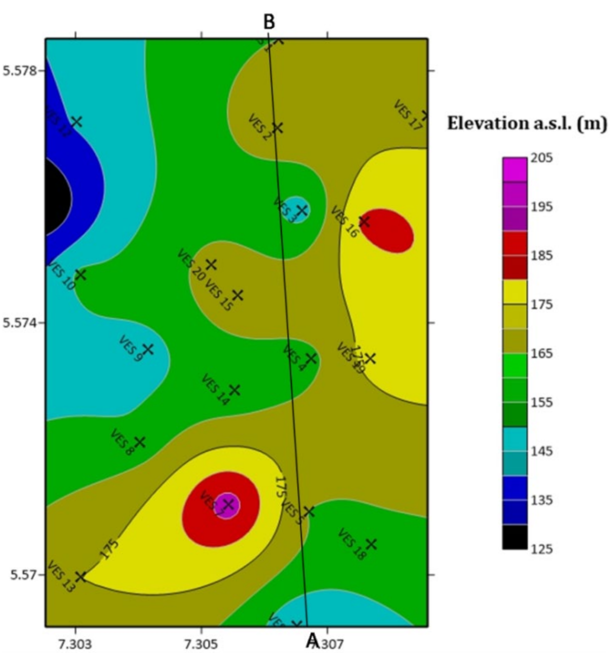


Figure 4: Acquisition/Contour Map of the Study Area.

The ABEM Terrameter SAS 4000 was used in the data acquisition whereby a 12V direct current (DC) from a battery was fed into the Terrameter which was subsequently passed into the ground through the current electrodes ‘AB/2’ linked by insulated cables. The resultant potential difference (voltage) was determined using the potential electrodes ‘MN/2’.

The observed field data is read off directly from the Terrameter, and it is the ratio of the voltage to the current which is a measure of resistance of the subsurface (ground resistance). This measured ground resistance in ohms is used to compute the corresponding apparent resistivity in Ohm-meters by multiplying with the geometric factor.

The value of the geometric factor is a function of electrode spacing, thus giving the required apparent resistivity results as functions of depths of individual layers:

$$\rho a = \pi R\left(\frac{L^2 - l^2}{2l}\right)$$

Where
ρa = Apparent resistivity.
a = ‘AB/2’ = Half current electrode spacing(m).
b = MN/2 = Half potential electrode spacing (m).
R = Resistance in ohms.

$\pi\left(\frac{L^2 - l^2}{2l}\right)$ = Geometric factor (K).

For each sounding point, the subsurface stratigraphy was delineated based on apparent resistivity differences. The apparent resistivity values were plotted against current electrode spacing ‘AB/2’ on a log-log graph paper to obtain sounding curves. Subsequently, initial estimates of the resistivities and thicknesses of the various geoelectric layers were obtained and used for computer iteration using IPI2win software package (Kurniawan, 2003).

Amos-Uhegbu (2014) extensively worked within the study area (Niger Delta basin) and lithologically deduced from drillog and geoelectric data that sediments with resistivity < 100 Ωm are clays:

100 Ωm – 500 Ωm are silts,
500 Ωm – 1500 Ωm are fine-grained sands,
1500 Ωm – 3000 Ωm are medium-grained sands,

3000 Ωm – 5500 Ωm are coarse-grained sands, and >5500 Ωm as sandstone.

This deduction has been used in the characterization of the various geoelectric layers.

RESULTS AND DISCUSSION

Analysis of Sounding Curves

Sounding curve acquired over a horizontally stratified medium is a function of the resistivities and thicknesses of the layers together with the electrode configuration. When the calculated apparent resistivity is plotted against the corresponding half current electrode spacing (AB/2), VES curves are derived, and the letters Q,A,K and H are used singly or in combination to indicate the variation of resistivity with depth (Figure 5).

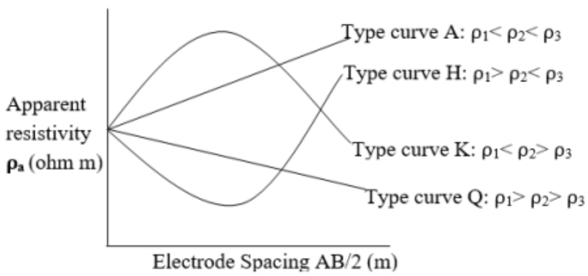
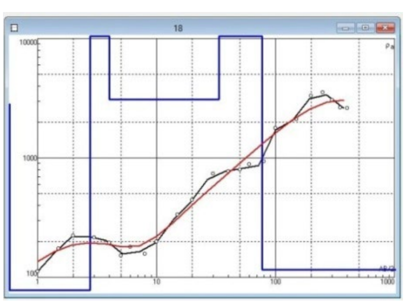


Figure 5: Schematic Diagram of Resistivity Type Curves for Layered Structures.

A display of computer modelled resistivity type curves for some locations in the study area (Figures 6 - 10).



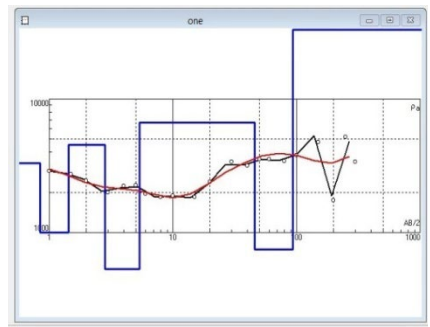
(a)

Error = 15.1%

N	ρ	h	d	Alt
1	72.8	0.433	0.433	-0.4325
2	2824	0.143	0.576	-0.5755
3	55.3	2.19	2.77	-2.77
4	19615	1.25	4.02	-4.016
5	3086	29.6	33.6	-33.6
6	26599	43.3	76.9	-76.87
7	116			

(b)

Figure 6 a & b: Computer Modelled Type Curve for VES 2.



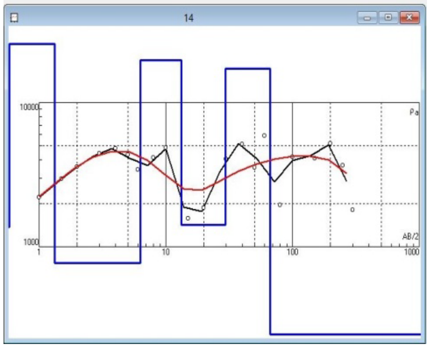
(a)

Error = 18.7%

N	ρ	h	d	Alt
1	3321	0.849	0.849	-0.8486
2	1005	0.594	1.44	-1.443
3	4528	1.37	2.81	-2.81
4	533	2.58	5.39	-5.386
5	6623	40.6	46	-45.96
6	746	47.5	93.5	-93.46
7	2.4E+5			

(b)

Figure 7 a & b: Computer Modelled Type Curve for VES 3.

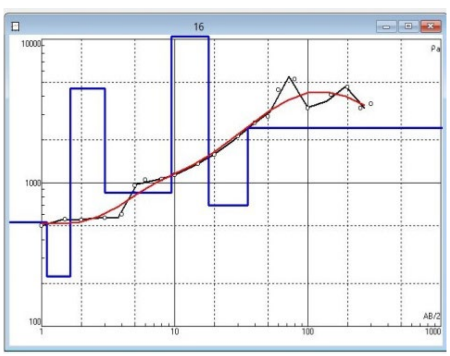


(a)

N	ρ	h	d	Alt
1	1370	0.561	0.561	-0.5611
2	25503	0.758	1.32	-1.319
3	772	4.95	6.27	-6.27
4	19792	6.99	13.3	-13.26
5	1419	16.4	29.6	-29.64
6	17166	36.7	66.3	-66.34
7	36.4			

Error = 21.4% (b)

Figure 8 a & b: Computer Modelled Type Curve for VES 6.

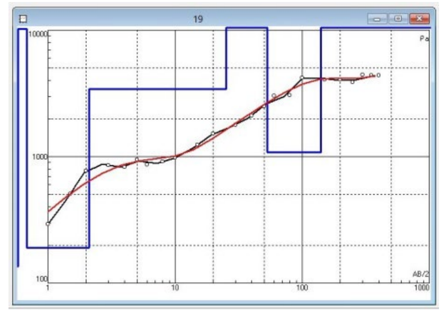


(a)

N	ρ	h	d	Alt
1	531	1.09	1.09	-1.094
2	223	0.544	1.64	-1.637
3	4522	1.35	2.99	-2.987
4	854	6.46	9.44	-9.445
5	51311	8.61	18.1	-18.06
6	699	17.2	35.2	-35.23
7	2424			

Error = 13.2% (b)

Figure 9 a & b: Computer Modelled Type Curve for VES 15.



(a)

N	ρ	h	d	Alt
1	135	0.337	0.337	-0.3369
2	10241	0.345	0.682	-0.6817
3	190	1.43	2.11	-2.109
4	3419	23.1	25.2	-25.22
5	16019	28.2	53.4	-53.44
6	1088	87.6	141	-141
7	66107			

Error = 9.04% (b)

Figure 10 a & b: Computer Modelled Type Curve for VES 16.

A display of the VES interpretation for the sounding stations in the study area is shown in Table 1.

Seven geoelectric layers were delineated for all the sounding stations. Six curve types KHAKH, KHKHK, KHKQH, KHKHA, KQHKH and QQHKH were identified within the study area, with KHKHK layered type curves predominant with a total number of 8, followed by KHAKH with 5, KHKQH with 3, and KHKHA with 2. While KGHKH and QQHKH are only one each (Table 1).

Finally, interpreted results were used for the preparation of geoelectric sections, resistivity maps and interpretation of groundwater potentials.

Geoelectric Sections of the Study Area

Subsurface resistivity is related to the physical property of interest such as lithology, porosity, water content, etc., therefore electrical resistivity measurements determine subsurface resistivity distributions thereby differentiating layers based on resistivity values.

Table 1: A Display of Interpreted VES Data and their Groundwater Potentials.

VES Station	GPS reading	Resistivity of layers (Ωm)	Inferred Lithology of layers	Thickness of layers (m)	Maximum depth of layers (m)	Type Curves	Inferred saturated layers
1	5°34.710'N , 7°18.373'E, H541ft	ρ1 =104 ρ2 = 34778 ρ3 = 208 ρ4 = 1050 ρ5 = 9304 ρ6 = 174 ρ7 = 17795	Clayey-Silt Topsoil Sand Stone Silt Fine-Grained Sand Sand Stone Silt Sand Stone	t1 = 0.334 t2 =0.375 t3 = 1.94 t4 = 1.32 t_5 = 23.4 t_6 = 36.6 t7 =?	h1 = 0.334 h2 = 0.709 h3 = 2.65 h4 = 3.97 h5 = 27.3 h6 = 63.9 h7 =?	KHAKH	1st layer 2nd layer 3rd layer 4th layer 5th layer **Aquifer** 7th layer
2	5°34.626'N , 7°18.372'E, H568ft	ρ1 = 72.8 ρ2 = 2824 ρ3 = 55.3 ρ4 =19615 ρ5 = 3086 ρ6 =26599 ρ7 = 116	Clay Topsoil Medium-grained Sand Clay Sand Stone Medium-Grained Sand Sand Stone Silt	t1 =0.433 t2 =0.143 t3 = 2.19 t4 = 1.25 t_5 = 29.6 t_6 = 43.3 t7 =?	h1 = 0.433 h2 = 0.576 h3 = 2.77 h4 = 4.02 h5 = 33.6 h6 = 76.9 h7 =?	KHKHK	1st layer 2nd layer 3rd layer 4th layer **Aquifer** 6th layer 7th layer
3	5°34.547'N , 7°18.396'E, H492ft	ρ1 =3321 ρ2 =1005 ρ3 =4528 ρ4 = 533 ρ5 = 6623 ρ6 = 746 ρ7=2.4E+5	Sandy Topsoil Fine-Grained Sand Coarse-Grained Sand Fine-Grained Sand Sand Stone Fine-Grained Sand Sand Stone	t1 = 0.849 t2 = 0.594 t3 = 1.37 t4 = 2.58 t_5 = 40.6 t_6 = 47.5 t7 =?	h1 = 0.849 h2 = 1.44 h3 = 2.81 h4 = 5.39 h5 = 46 h6 = 93.5 h7 =?	HKHKH	1st layer 2nd layer 3rd layer **Water table** 5th layer **Aquifer** 7th layer
4	5°34.406'N , 7°18.405'E, H533ft	ρ1 =132 ρ2 = 2280 ρ3 = 182 ρ4 =12015 ρ5 = 723 ρ6 = 71.1 ρ7 =58755	Silty Topsoil Medium-Grained Sand Silt Sand Stone Medium-Grained Sand Clay Sand Stone	t1 =0.305 t2 = 1.91 t3 = 1.41 t4 = 26.4 t_5 = 19.9 t_6 = 25.9 t7 =?	h1 = 0.305 h2 = 2.21 h3 = 3.62 h4 = 30 h5 = 49.9 h6 = 75.8 h7 =?	KHKQH	1st layer 2nd layer 3rd layer 4th layer **1st Aquifer** **2nd Aquifer** 7th layer
5	5°34.260'N , 7°18.403'E, H539ft	ρ1 = 2097 ρ2 = 8841 ρ3 = 36.7 ρ4 = 331 ρ5 = 289 ρ6 = 29.9 ρ7 = 8203	Sandy Topsoil Sand Stone Clay Silt Silt Clay Sand Stone	t1 = 0.861 t2 = 0.582 t3 = 1.78 t4 = 48.5 t_5 = 2.8 t_6 = 58 t7 =?	h1 = 0.861 h2 = 1.44 h3 = 3.22 h4 = 51.8 h5 = 54.6 h6 = 113 h7 =?	KHKQH	1st layer 2nd layer 3rd layer 4th layer **1st Aquifer** **2nd Aquifer** 7th layer
6	5°34.151'N , 7°18.391'E, H480ft	ρ1 = 1370 ρ2 =25503 ρ3 = 772 ρ4=19792 ρ5 = 1419 ρ6 =17166 ρ7 = 36.4	Sandy Topsoil Sand Stone Fine-Grained Sand Sand Stone Fine-Grained Sand Sand Stone Clay	t1 = 0.561 t2 = 0.758 t3 = 4.95 t4 = 6.99 t5 = 16.4 t6 = 36.7 t7 =?	h1 = 0.561 h2 = 1.32 h3 = 6.27 h4 = 13.3 h5 = 29.7 h6 = 66.3 h7 =?	KHKHK	1st layer 2nd layer **Water table** 4th layer **1st Aquifer** 6th layer 7th layer
7	5°34.267'N , 7°18.326'E, H659ft	ρ1 = 376 ρ2 = 2483 ρ3 = 108 ρ4 = 819 ρ5 = 32.2 ρ6 = 1225 ρ7 =22545	Silty Topsoil Medium-Grained Sand Clay Silt Medium-Grained Sand Clay Medium-Grained Sand Sand Stone	t1 = 0.354 t2 = 0.589 t3 = 2.96 t4 = 1.06 t_5 = 11.4 t_6 = 1.22 t7 =?	h1 = 0.354 h2 = 0.943 h3 = 3.9 h4 = 4.96 h5 = 16.4 h6 = 17.6 h7 =?	KHKHA	1st layer 2nd layer **Water table** 4th layer **Perched aquifer** 6th layer 7th layer

8	5°34.326'N , 7°18.241'E, H517ft	ρ1 = 36.6 ρ2 = 8163 ρ3 = 92.8 ρ4 = 1521 ρ5 = 32.1 ρ6 = 89.8 ρ7 =31669	Clay Topsoil Sand Stone Clay Medium-Gained Sand Clay Clay Sand Stone	t1 =0.355 t2 =0.388 t3 = 1.64 t4 = 11.9 t_5 = 18.9 t_6 = 11.5 t7 =?	h1 = 0.355 h2 = 0.743 h3 = 2.39 h4 = 14.3 h5 = 33.2 h6 = 44.6 h7 =?	KHKHA	1st layer 2nd layer 3rd layer 4th layer **Aquifer** 6th layer 7th layer
9	5°34.415'N , 7°18.249'E, H497ft	ρ1 = 767 ρ2 =48734 ρ3 = 346 ρ4 = 5987 ρ5 = 1716 ρ6 =23152 ρ7 = 2381	Sandy Topsoil Sand Stone Silt Sand Stone Medium-Grained Sand Sand Stone Medium-Grained Sand	t1 =0.324 t2 =0.588 t3 = 1.5 t4 = 6.15 t_5 = 17.1 t_6 = 29.1 t7 =?	h1 = 0.324 h2 = 0.912 h3 = 2.41 h4 = 8.57 h5 = 25.7 h6 = 54.8 h7 =?	KHKHK	1st layer 2nd layer 3rd layer 4th layer **Aquifer** 6th layer 7th layer
10	5°34.486'N , 7°18.185'E, H516ft	ρ1 =113 ρ2 = 3225 ρ3 = 1067 ρ4 = 56.5 ρ5 = 508 ρ6 = 25.6 ρ7 = 4503	Silty Topsoil Coarse-Grained Sand Fine-Grained Sand Clay Silt Clay Coarse-Grained Sand	t1 = 0.469 t2 = 2.46 t3 = 2.91 t4 = 6.33 t_5 = 17.8 t_6 = 33.5 t7 =?	h1 = 0.469 h2 = 2.93 h3 = 5.84 h4 = 12.2 h5 = 30 h6 = 63.4 h7 =?	KQHKH	1st layer 2nd layer 3rd layer **Water table** 5th layer **Aquifer** 7th layer
11	5°34.549'N , 7°18.152'E, H408ft	ρ1 = 1261 ρ2 = 1338 ρ3 = 49.7 ρ4 = 947 ρ5 = 19.5 ρ6 = 1340 ρ7 = 17.4	Sandy Topsoil Fine-Grained Sand Clay Fine-Grained Sand Clay Fine-Grained Sand Clay	t1 = 1.39 t2 = 0.13 t3 = 2.3 t4 = 5.98 t_5 = 15.8 t_6 = 41 t7=?	h1 = 1.39 h2 = 1.52 h3 = 3.82 h4 = 9.81 h5 = 25.6 h6 = 66.6 h7 =?	KHKHK	1st layer 2nd layer 3rd layer 4th layer **Aquifer** 6th layer 7th layer
12	5°34.631'N , 7°18.181'E, H480ft	ρ1 = 2395 ρ2 = 16606 ρ3 = 14.2 ρ4= 7127 ρ5 = 2019 ρ6 = 119 ρ7=1.3E+5	Sandy Topsoil Sand Stone Clay Sand Stone Medium-Grained Sand Silt Sand Stone	t1 = 0.919 t2 = 0.136 t3 = 1.27 t4 = 2.43 t5 = 3.08 t6 = 7.77 t7 =?	h1 = 0.919 h2 = 1.05 h3 = 2.32 h4 = 4.75 h5 = 7.83 h6 = 15.6 h7 =?	KHKQH	1st layer 2nd layer 3rd layer 4th layer **Water table** **Perched Aquifer** 7th layer
13	5°34.198'N , 7°18.185'E, H574ft	ρ1 = 40.5 ρ2 = 5888 ρ3 = 187 ρ4 = 8001 ρ5 = 939 ρ6 =15037 ρ7 = 691	Clay Topsoil Sand Stone Silt Sand Stone Fine-Grained Sand Sand Stone Fine-Grained Sand	t1 = 0.463 t2 = 0.165 t3 = 1.88 t4 = 1.62 t_5 = 8.51 t_6 = 17.6 t7 =?	h1 = 0.463 h2 = 0.627 h3 = 2.51 h4 = 4.13 h5 = 12.6 h6 = 30.3 h7 =?	KHKHK	1st layer 2nd layer 3rd layer 4th layer **Perched Aquifer** 6th layer 7th layer
14	5°34.376'N , 7°18.332'E, H519ft	ρ1 = 1118 ρ2 =15017 ρ3 = 560 ρ4 = 3435 ρ5 = 7954 ρ6 = 42.6 ρ7 =10532	Sandy Topsoil Sand Stone Silty Sand Coarse-Grained Sand Sand Stone Clay Sand Stone	t1 =0.343 t2 = 0.53 t3 =0.906 t4 = 13.8 t_5 = 14.9 t_6 = 28.5 t7 =?	h1 = 0.343 h2 = 0.874 h3 = 1.78 h4 = 15.5 h5 = 30.4 h6 = 58.9 h7 =?	KHAKH	1st layer 2nd layer 3rd layer 4th layer 5th layer **Aquifer** 7th layer

15	5°34.466'N , 7°18.335'E, H570ft	ρ1 = 531 ρ2 = 223 ρ3 = 4522 ρ4 = 854 ρ5 =51311 ρ6 = 699 ρ7 = 2424	Sandy Topsoil Silt Coarse-Grained Sand Fine-Grained Sand Sand Stone Fine-Grained Sand Medium-Grained Sand	t1 = 1.09 t2 =0.544 t3 = 1.35 t4 = 6.46 t_5 = 8.61 t_6 = 17.2 t7 =?	h1 = 1.09 h2 = 1.64 h3 = 2.99 h4 = 9.44 h5 = 18.1 h6 = 35.2 h7 =?	HKHKH	1st layer 2nd layer 3rd layer **Water table** 5th layer **Aquifer** 7th layer
16	5°34.536'N , 7°18.455'E, H617ft	ρ1 = 135 ρ2 =10241 ρ3 = 190 ρ4 = 3419 ρ5 =16019 ρ6 = 1088 ρ7 =66107	Silty Topsoil Sand Stone Silt Coarse-Grained Sand Sand Stone Fine-Grained Sand Sand Stone	t1=0.337 t2 =0.345 t3 = 1.43 t4 = 23.1 t_5 = 28.2 t_6 = 87.6 t7 =?	h1 = 0.337 h2 = 0.682 h3 = 2.11 h4 = 25.2 h5 = 53.4 h6 = 141 h7 =?	KHAKH	1st layer 2nd layer 3rd layer 4th layer 5th layer **Aquifer** 7th layer
17	5°34.548'N , 7°18.395'E, H558ft	ρ1 = 108 ρ2 = 6445 ρ3 = 283 ρ4 = 1110 ρ5 = 19862 ρ6 =361 ρ7 = 77755	Silty Topsoil Sand Stone Silt Fine-Graine Sand Sand Stone Silt Sand Stone	t1 =0.348 t2 = 0.314 t3 = 0.82 t4 = 10.6 t_5 = 13.6 t_6 = 33.8 t7 =?	h1 =0.348 h2 = 0.661 h3 = 1.48 h4 = 12.1 h5 = 25.6 h6 = 59.4 h7 =?	KHAKH	1st layer 2nd layer 3rd layer 4th layer 5th layer **Aquifer** 7th layer
18	5°34.229'N , 7°18.462'E, H532ft	ρ1 = 315 ρ2 = 123 ρ3 = 1660 ρ4 = 83.4 ρ5 = 478 ρ6 = 44 ρ7 = 2175	Silty Topsoil Silt Medium-Grained Sand Clay Silt Clay Medium-Grained Sand	t1 =0.803 t2 =0.615 t3 = 1.36 t4 = 3.41 t_5 = 4.83 t_6 = 18.7 t7=?	h1 = 0.803 h2 = 1.42 h3 = 2.77 h4 = 6.18 h5 = 11 h6 = 29.8 h7 =?	HKHKH	1st layer 2nd layer 3rd layer **Water table** 5th layer **Aquifer** 7th layer
19	5°34.406'N , 7°18.461'E, H585ft	ρ1 = 829 ρ2 =68179 ρ3 = 1754 ρ4 = 5820 ρ5 =13711 ρ6 = 469 ρ7 =90453	Sandy Topsoil Sand Stone Medium-Grained Sand Sand Stone Sand Stone Silt Sand Stone	t1 = 0.6 t2 = 0.72 t3 = 1.59 t4 = 3.49 t_5 = 7.68 t_6 = 54.1 t7 =?	h1 = 0.6 h2 = 1.32 h3 = 2.91 h4 = 6.39 h5 = 14.1 h6 = 68.2 h7 =?	KHAKH	1st layer 2nd layer 3rd layer 4th layer 5th layer **Aquifer** 7th layer
20	5°34.495'N , 7°18.309'E, H552ft	ρ1 = 1123 ρ2 = 657 ρ3 = 283 ρ4 = 15.9 ρ5 = 1675 ρ6 = 8.15 ρ7 = 4243	Sandy Topsoil Fine-Grained Sand Silt Clay Medium-Grained Sand Clay Coarse-Grained Sand	t1 =0.466 t2 = 1.37 t3 =0.136 t4 = 2.67 t_5 = 13.9 t_6 = 43.6 t7 =?	h1 = 0.466 h2 = 1.84 h3 = 1.97 h4 = 4.64 h5 = 18.5 h6 = 62.1 h7 =?	QQHKH	1st layer 2nd layer 3rd layer **Water table** 5th layer **Aquifer** 7th layer

Saturated units displayed in bold in the table

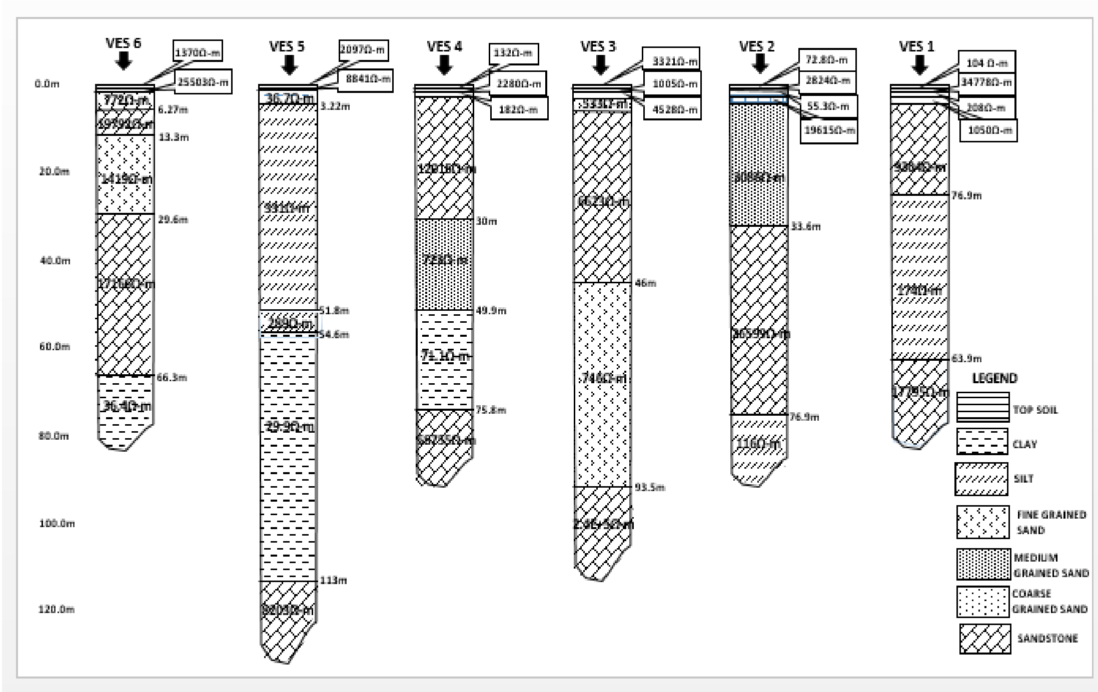


Figure 11: A Geoelectric Section along Profile AB.

Sounding curves obtained over a horizontally stratified medium could be presented as a descriptive profile displaying variation of apparent resistivity with depth. The profile is a scale drawing of the successive layer resistivities and thicknesses; so, a geoelectric section is a profile displaying variation of apparent resistivity with depth (Figure 11).

A display of the interpreted data which is within the limit of the probe has revealed the existence of seven geoelectric layers in the study area for each of the 20 VES locations (Table 1). The layers consist of topsoil, sandstone, fine-grained sand, medium-grained sand, coarse-grained sand, silt, clayey-silt, and clay layer deposits with resistivity values ranging from 14.2 Ωm (the 3rd layer of VES 12) to 240,000 Ωm (the 7th layer of VES 3).

The topsoil which is the first geoelectric layer has the resistivity varying from 36.6 Ωm to 3321.0 Ωm and the thickness varies from 0.31 m to 1.39 m.

The resistivity of the 2nd layer ranges from 123 Ωm to 34,778 Ωm, while the thickness varies from 0.13 m to 2.46 m.

The 3rd layer resistivity ranges from 14.2 Ωm at VES 12 to 4,552 Ωm at VES 15, while the thickness varies from 0.14 m at VES 20 to 4.95 m at VES 6.

The resistivity of the 4th layer ranges from 15.9 Ωm at VES 20 to 19,792 Ωm at VES 6, while the thickness varies from 1.06 m at VES 7 to 48.5 m at VES 5.

For the 5th layer, the resistivity ranges from 19.5 Ωm at VES 11 to 51,311 Ωm at VES 15, while the thickness varies from 2.8 m at VES 5 to 29.5 m at VES 2.

The 6th layer resistivity ranges from 14.2 Ωm at VES 12 to 4,552 Ωm at VES 15, while the thickness varies from 1.22 m at VES 7 to 87.6 m at VES 16.

For the 7th layer, the resistivity ranges from 17.4 Ωm at VES 11 to 90,453 Ωm at VES 19, the thickness could not be determined because current terminated at this layer.

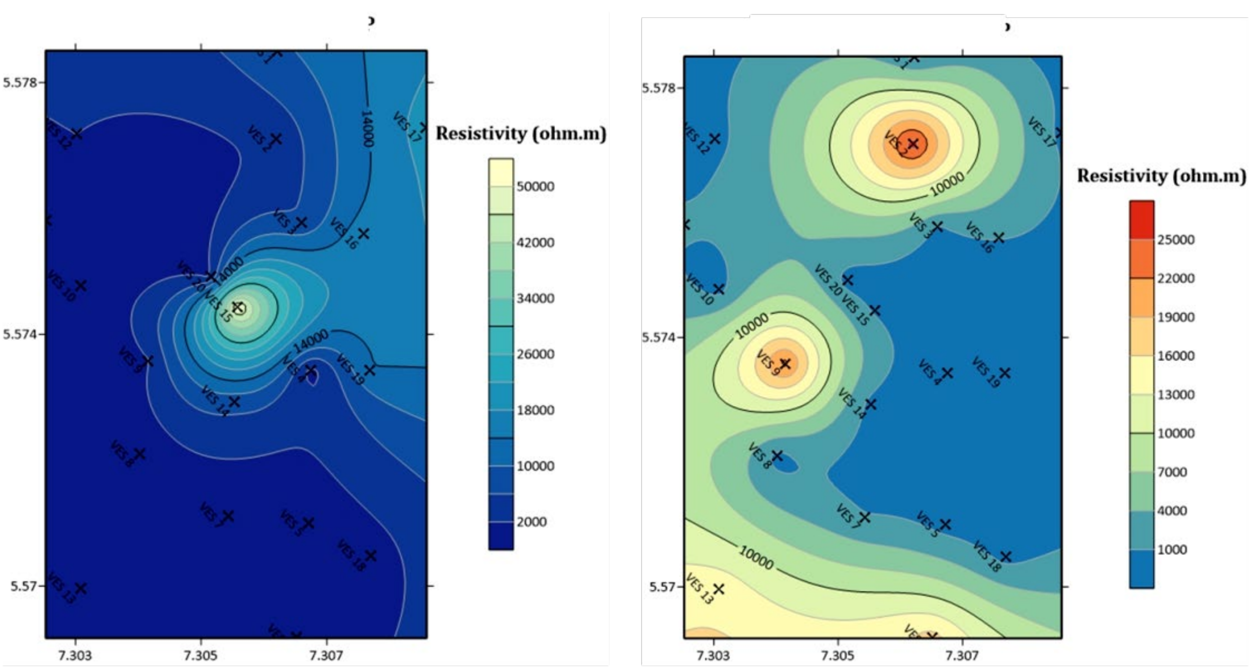
Parameters of Saturated Units in the Study Area

Aquifer resistivity ranges from 8.15 Ωm at VES 20 to 15,037 Ωm at VES 13 (Table 1, Figure 12). The aquifer thickness ranged from 11.4 m at VES 7 to 87.6 m at VES 16, and their depth ranged from 16.4m at the same VES 7 to 141m at the same VES 16 (Figure 13).

Undoubtedly, the area has huge groundwater potential. Hand dug wells could be gotten between 3m and 5.4m within the vicinity of VES 3, it could also be gotten between 6.4m and 12m at the vicinity of VES 10. At the location of VES 12, hand dug wells could also be gotten between the depth of 3.1m and 7.8m, while likely a perched aquifer underlies it at a depth of about 7.9m to 15.6m.

Generally, aquiferous units exist in the 5th and 6th layers in the study area. Nine (9) VES locations (2, 4, 5, 6, 7, 8, 9, 11, and 13) have their saturated layers (aquifer) in the 5th layer, while thirteen (13) VES locations (1, 3, 4, 6, 10, 12, 14, 15, 16, 17, 18, 19, and 20) have their saturated layers (aquifer) in the 6th layer; and two (2) VES locations (4 and 6) have their saturated layers (aquifer) in the 5th and 6th layers (Table 1).

About five (5) shallow saturated units (water table) suitable for hand dugs wells can be found in the 4th layer of VES 3, 10, 15, 18 and 20, while two (2) shallow saturated units (water table) can be found in the 3rd layer of VES 6 and 7; and one (1) in the 5th layer of VES 12 (Table 1).



5th Layer 6th Layer

Figure 12: The Resistivity Map of Layer 5 and Layer 6, Respectively.

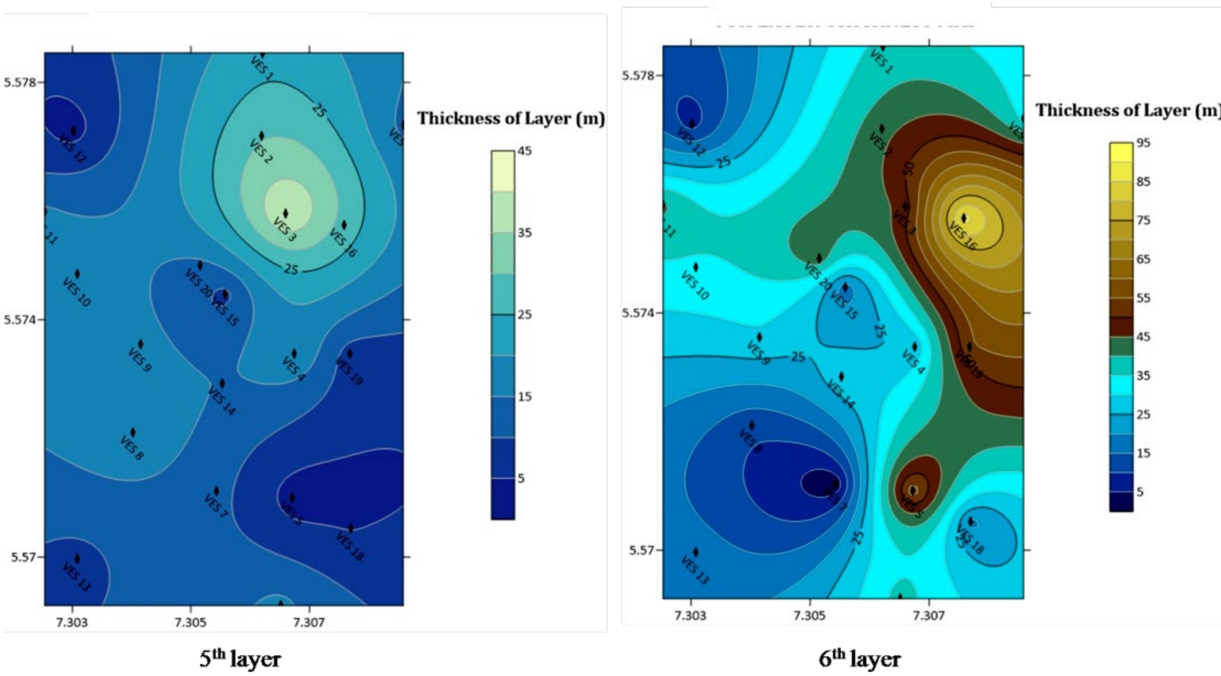


Figure 13: The Thickness Map of Layer 5 and Layer 6, Respectively.

CONCLUSION AND RECOMMENDATION

The geoelectric investigation of the groundwater potentials in parts of Obowo area of Imo State, Nigeria involved the use of the Vertical Electrical Sounding technique of electrical resistivity method. The study reveals that the subsurface is made up of seven geoelectric layers consisting of topsoil, sandstone, fine-grained sand, medium-grained sand, coarse-grained sand, silt, clayey-silt, and clay layer deposits with range of resistivity of 14.2 Ωm (the 3rd layer of VES 12) to 240,000 Ωm (the 7th layer of VES 3).

The aquifer units are found within the 5th and 6th geoelectric layers, though predominantly in the 6th layers, and are having resistivity which ranges from 8.15 - 3086.00 Ωm; while the depth to the aquifer units (perched, confined or semi-confined) for most of the area is between 9.80 m and 89.80m.

Within the limit and depth of investigation, the vicinity of VES locations 7 and 12 are possibly the least in groundwater potential and are likely perched aquifer, while the vicinity of VES location 16 has the best groundwater potential with an aquifer thickness greater than 87m and is therefore, the best location recommended for sustainable groundwater acquisition in the study area. Finally, the study has indicated that the entire area has good groundwater potential.

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