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Assessment of Groundwater Potentials at Ishielu L. G. A. of Ebonyi State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOA designed and supervised the study. Author DEO wrote the first draft of the manuscript, managed the literature and interpret the field data. Author MEA created all graphics, analyzed and interpret field data, proof read/organized manuscript. Author UDA lead the team in carrying out the geophysical surveys in the study area. All authors read and approved the final manuscript.

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ABSTRACT

The overall objective of the survey is to delineate saturation zones in the study area for the purpose to develop an electric-powered underground water scheme in other to improve the living standard of people. Groundwater potentials assessment were carried out at Ishielu local government area of Ebonyi State, Nigeria using Vertical Electrical Sounding (VES) method were applied at three selected locations. The breakdown of the result shows five geological layers: laterite, dry clay, weathered shale formation and weathered mudstone lithologies; the weathered formations serves as an aquifer with resistivity values ranging from 160.2 – 1246.0Ωm, thickness ranging from 16.9 –35.7m . The saturation zone occurs at an average depth of 77.43m.The fractionating zones within this saturation zone are porous to accommodate a pressure pump. The overriding inference is that there is a 70% possibility of success for drilling a borehole on the saturation zones for maximum yield at the selected locations. A downhole drilling method is highly recommended in this area as the subsurface is consolidated and compacted.

Keywords: VES; geoelectric; resistivity; aquifer; saturation zones; groundwater.

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1. INTRODUCTION

Groundwater is the water sourced from underground in cracks, spaces in soil, sand and rock which is stored in and moves slowly through the pores of geologic formation [1]. A large amount of groundwater is distributed throughout the world and good measures of it are still uninvestigated [2]. Groundwater is associated with many goods and services people depend upon, including food and energy production. Over the years, groundwater situations have changed rapidly in many parts of the world due to demand for resources, particularly for irrigation and domestic water supply [3]. According to Zektser and Everett [2] and Japan International Cooperative Agency [4], about 65,000 boreholes and other groundwater sources are present in Nigeria which has a total extraction rate of about 6,340,000 m^3/day). Also with a population of 182.2 million in 2015, the per capita water availability was 1,536 m^3 /year and is expected to drop to 1,175 m^3 in the year 2025 with a projected population of 238.4million people. According to Japan International Cooperative Agency [4], in Table 3, Ebonyi State water demand in Million Litre per Day (MLD) is 182 in 2020, 242 in 2025 and 270 in 2030, hence there is a need for more groundwater exploration. Groundwater is indispensable to human existence and plays a vital role in the development of arid and semiarid regions. Geoelectrical resistivity method, precisely vertical electrical sounding has been employed both in the basement and sedimentary terrain across the world in the assessment of groundwater potentials [5-8]. In their study to delineate groundwater saturation zones and distribution in the complex argillaceous geological unit in Ezza North local government area of Ebonyi State, reveals aquifer parameters distribution in the area and stated that the distribution of these properties reflects the region with high and low groundwater potential. Offiah et al. [9], further observed the area to have a good groundwater potential and if exploited would go a long way in reducing the problem of seasonal water shortage and health problem associated with the consumption of unhygienic surface water in the area.

Prospecting and assessment for groundwater in some parts of Ebonyi State have not been entirely easy as a result of the subsurface comprising mainly of clastic sediments [10]. This has become problematic due to the high surge in population which has led people resorting to other sources of water for consumption thereby causing serious health challenge [9]. This study is aimed at delineating the saturation zones in the study area for the purpose to develop an electric-powered underground water scheme for commercial use in other to improve the living standard of the people.

2. THE STUDY AREA

Ebonyi State falls within the Asu-River geologic group (lower cretaceous), Eze-aku shale formation and Nkporo formation (Table 1). The state is also characterized by tableland topography and hydromorphic soils such as Reddish-brown gravel, pale coloured clay soil etc. The study area is located within Ishielu local government area of Ebonyi State in South Eastern part of Nigeria and lies within the coordinate 6° 22' 64'' N, 8° 5' 13.0812'' E with an elevation of about 72 m above sea level (Fig. 1). The survey area lies within the Asu-River shale group of sediments (Albian) of the Abakaliki anticlinorium's [11].

Table 1. Stratigraphic sequence of South Eastern part of Nigeria axis of the lower Benue trough [11]

Era	Age	Stratigraphic sequence	Structural evolution
Paleocene	Danian	Nsukka Formation	
			Enugu Escarpment
	Maastrichtian	Ajali Sandstone	(Anambra Basin)
		Mamu Formation	
		Nkporo group	
Upper Cretaceous	Campanian		
	Santonian	**Tectonic period**	
	Coniacian	Awgu Formation	
	Turonian	Ezeaku Group	Abakiliki Anticliorial axis,
	Cenomanian	Hiatus (Erosion)	Afikpo syncline and
Lower Cretaceous	Albian	Asu River Group	Awgumasif
Precambrian		Crystalline Basement Complex	

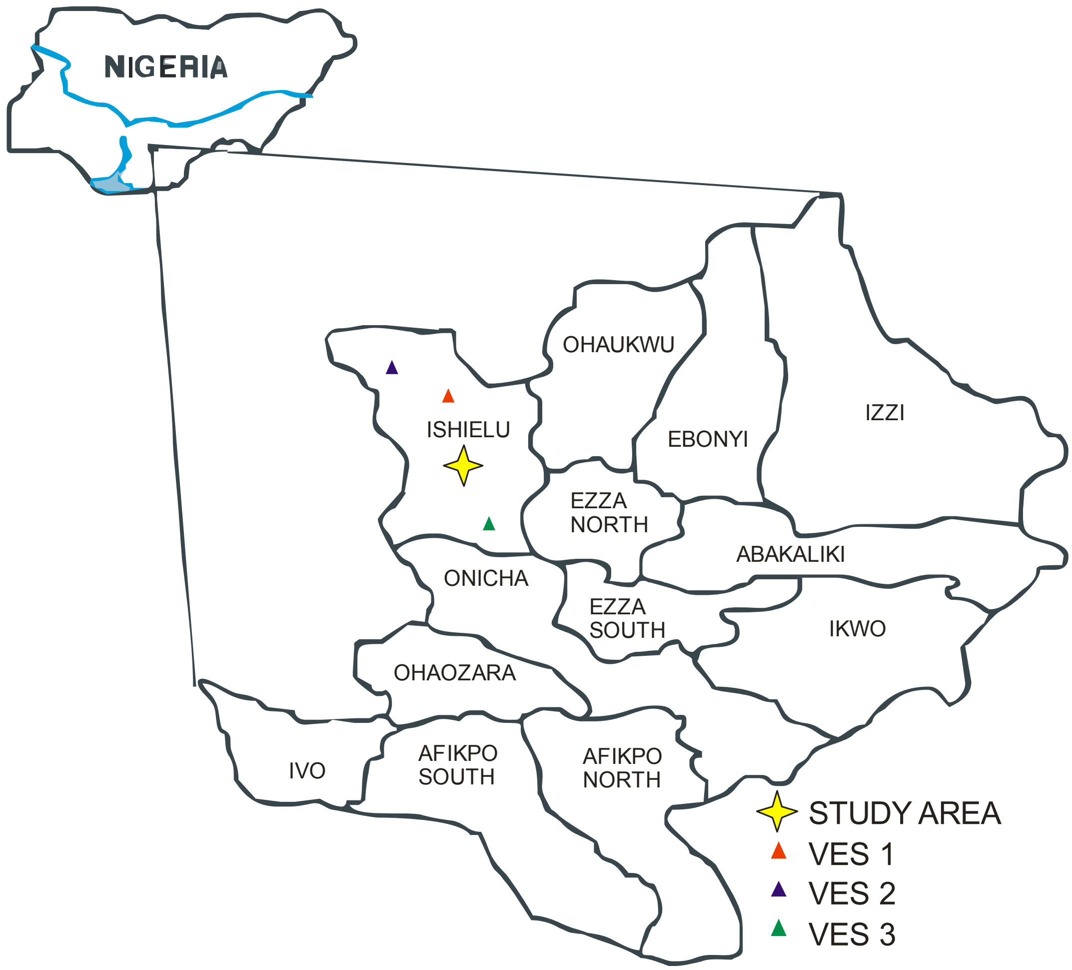


Fig. 1. Map of the Study Area

The oldest sediment in the area is the lower cretaceous Asu-River group. Incidentally, it is the dominant member of this group. The Asu-River shale is researched to have been deposited in the Albian stage. This geological group is characterized by shale's of granite, ranging from dark gray to blue-black shale's siltstone, mudstone, clay and occasional intercalation of granite [12]. Because the Asu-Rivers sediments are dominated by shale, they are practically a bad aquifer except in the area where they are fractured or weathered. The formation in this area is associated with hydrothermal Pb-Zinc ores [13,14]. Hydrogeologically, the possible aquifer(s) in this area can be located at weathered rock and fractured zones, however, weathered segments and fractured rocks may form pickets of groundwater reservoirs thereby making regional groundwater flow in the area almost impracticable. The various streams existing in this study area are seasonal.

3. MATERIALS AND METHODS

A general reconnaissance survey was first carried out to ascertain the facial appearance of the geology of the area. A three (3) vertical electrical sounding (VES) using Schlumberger configuration was carried out in the study area and the data was acquired using a resistivity meter (Terrameter SAS 300) which displays the subsurface data on the digital screen. The procedure involves sending a current signal into the ground using a pair of current electrodes (C_1C_2) and measuring the corresponding potential difference using another pair of potential electrodes (P_1P_2) [15,16]. Schlumberger configuration was adopted to acquire deeper current penetration. The coordinate of every sounding point was recorded using a geographical position system (GPS). The current electrode was extended progressively from 1 to 300m (AB/2 = 150m). The computation of apparent resistivity from the measured resistance was done using the equation below.

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

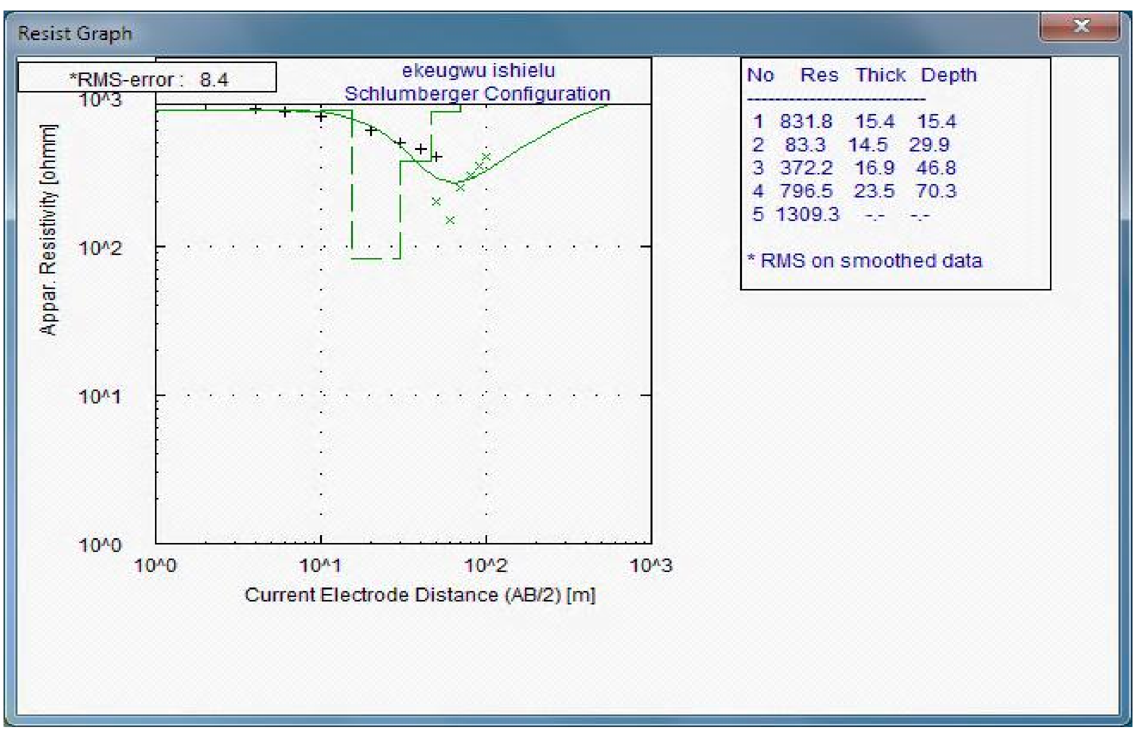
$\pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right]$ is the geometric factor (K)

Where: ρ_a = apparent resistivity (Ohm-m), R = resistance (Ohm), AB = distance between current electrodes, MN = distance between potential electrodes.

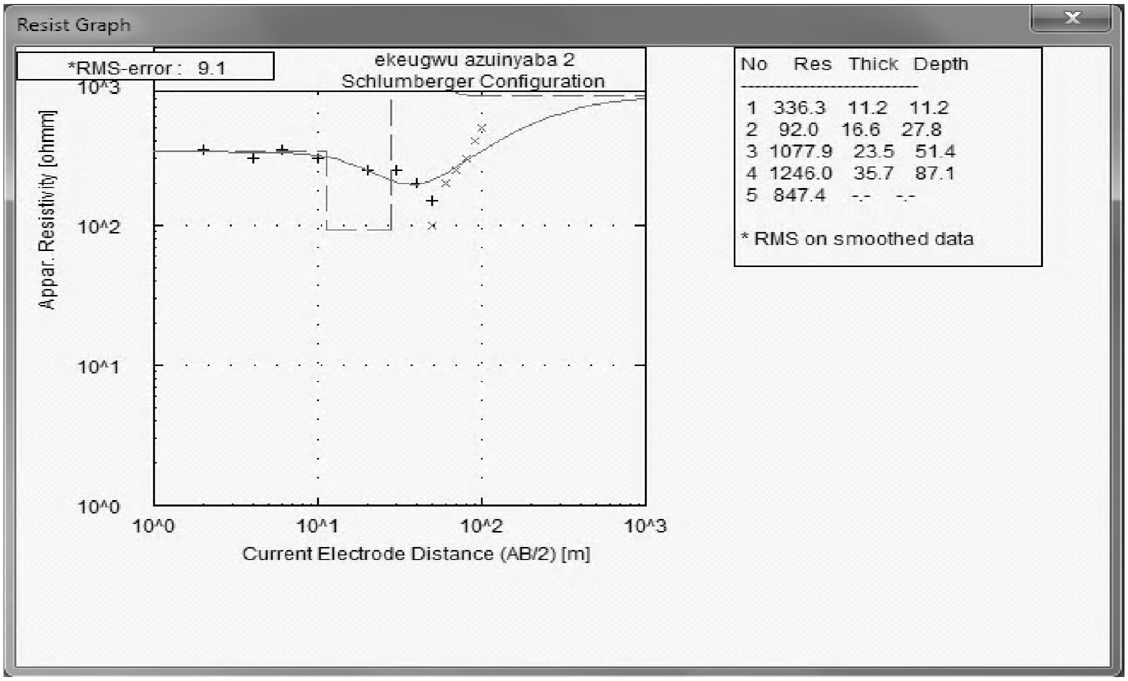
All raw field data was analyzed using a FORTRAN Resistivity 2D Inverse Computer program. The VES data are then presented as sounding curves (Fig. 2) which are obtained by plotting apparent resistivity (ρ_a) versus half-current electrode spacing (AB/2) on double logarithmic graph sheets.

4. RESULTS AND DISCUSSION

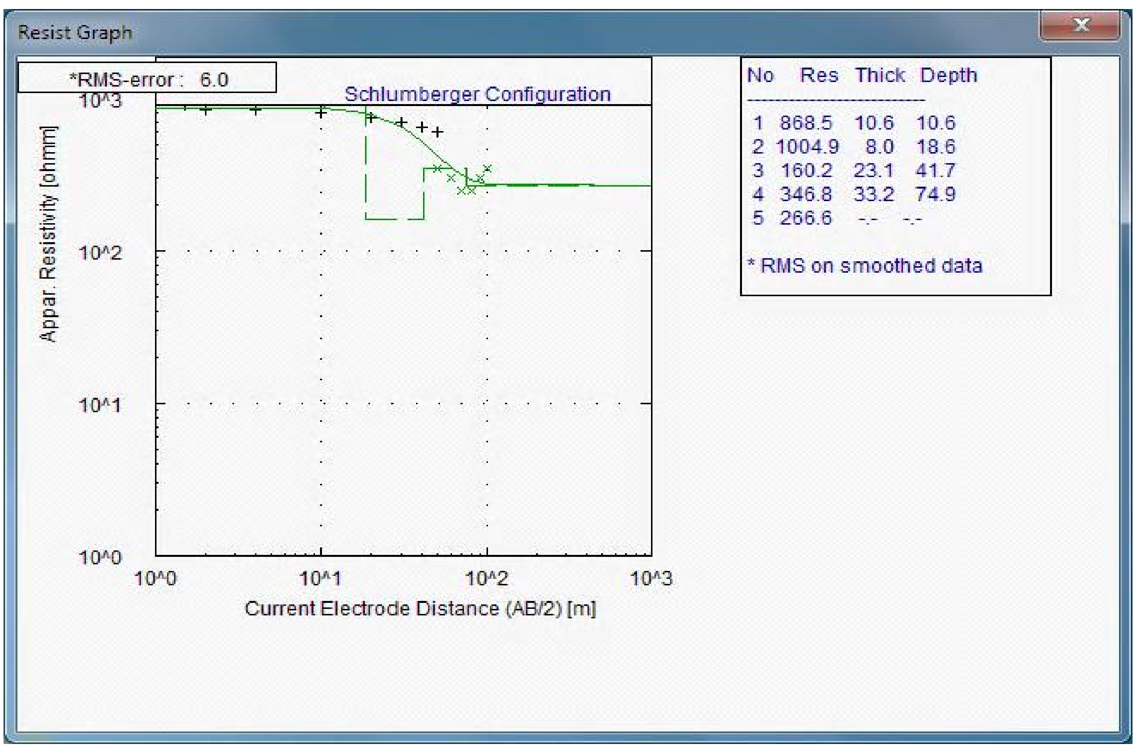
The summarized results of the interpreted vertical electrical sounding (VES) data and the geologic section across the area are shown in Figs. 2 and 3 and Table 2. The subsurface shows the uniform number of layers, curve types (HAK, HAA and KHK) and similar geologic characteristics. A total of five (5) layers were depicted in all the VES stations with different formations consisting of laterite, dry clay, weathered shale formation and weathered mudstone. The first layer has resistivity ranging from 336.3 – 868.5Ωm with its thickness ranging from 10.6-15.4m at a maximum depth of 15.4m. The high apparent resistivity values which characterize the top layer is clearly an indication of a laterite formation zone. The second layer has resistivity values ranging from 83.3 – 1004.9Ωm, and is deduced to be a dry clay formation. The third layer has resistivity ranging from 160.2 – 1077.9Ωm with its thickness ranging from 16.9 – 23.5m at a maximum depth of 51.4m which is inferred as weathered shale formation. The fourth layer has resistivity ranging from 346.8 – 1246.0Ωm with its thickness ranging from 23.5 – 35.7m at a maximum depth of 87.1m which is inferred as weathered mudstone. The last layer with resistivity ranging from 266.6 – 1309.3Ωm, whose thickness and depth are undefined probably, indicates weathered mudstone. From Fig. 3, VES 1 is more prolific aquifer than the others due to its high depth and thickness at the weathered shale formation region.



(a)



(b)



(c)

Fig. 2. VES curves obtained at the study area: a, b and c

Table 2. Summary of VES result

VES	Geographic Location	Layer Resistivity ρ_1/ρ_2/---/ρ_n (Ωm)	Thickness h_1/h_2/---/h_n (m)	Depth D_1/D_2/---/D_n (m)	Layer	Curve type
1	6°19' 2.4456" N 8°71' 30.5364" E	336.3/92.0/1077.9/1246.0/847.4	11.2/16.6/23.5/35.7/∞	11.2/27.8/51.4/87.1/∞	5	HAK
2	6°19' 22.1016"N 8°8' 18.7692"E	831.8/83.3/372.2/796.5/1309.3	15.4/14.5/16.9/23.5/∞	15.4/29.9/46.8/70.3/∞	5	HAA
3	6°19' 14.1168"N 8°6' 26.0748"E	868.5/1004.9/160.2/346.8/266.6	10.6/8.0/23.1/33.2/∞	10.6/18.6/41.7/74.9/∞	5	KHK

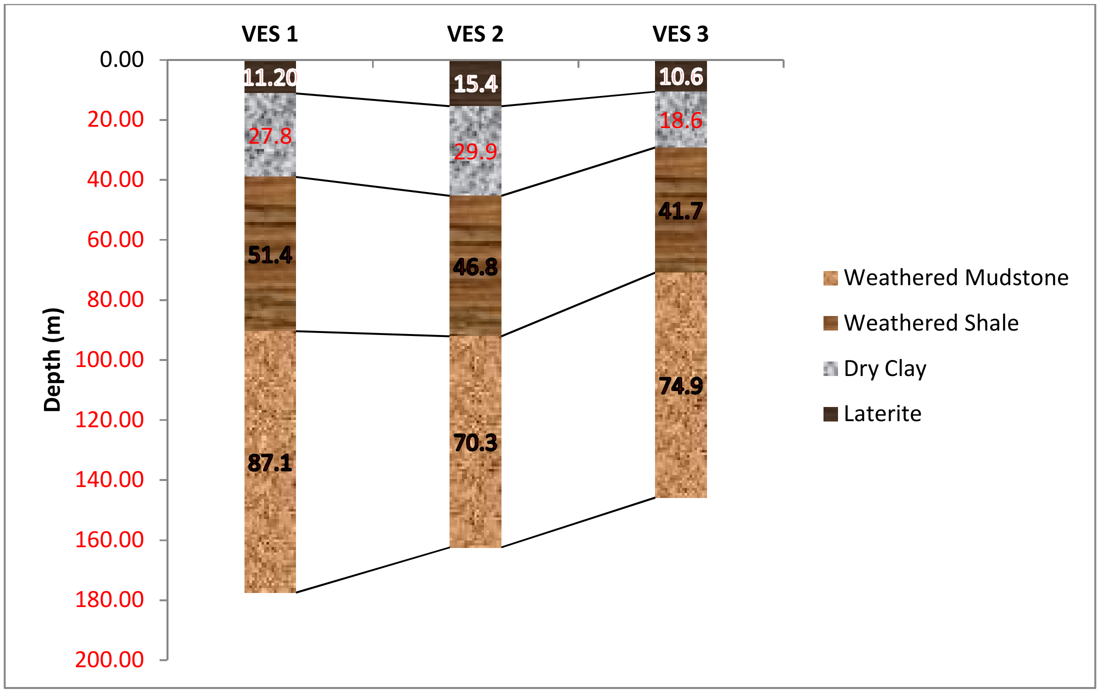


Fig. 3. Geologic section

Table 3. Water demand projection by states (JICA Project team)

National, state or HA		Water demand (Million Litre per Day: MLD)					2030/2010 Ratio
		2010	2015	2020	2025	2030	
National		8,254	11,666	15,890	20,994	23,876	2.9
State-wise							
1	Abia	211	276	355	447	495	2.3
2	Adamawa	60	142	241	360	398	6.6
3	Akwa ibom	225	308	411	534	606	2.7
4	Anambra	157	292	454	646	714	4.5
5	Bauchi	174	274	398	547	617	3.5
6	Bayelsa	9	70	149	245	275	31.0
7	Benue	202	282	378	492	552	2.7
8	Borno	199	293	407	545	613	3.1
9	Cross river	107	173	253	348	386	3.6
10	Delta	189	309	457	635	713	3.8
11	Ebonyi	88	131	182	242	270	3.0
12	Edo	266	328	401	486	541	2.0
13	Ekiti	150	203	267	343	388	2.6
14	Enugu	78	186	319	479	534	6.8
15	Gombe	67	125	198	285	319	4.8
16	Imo	155	260	390	548	618	4.0
17	Jigawa	265	335	419	516	576	2.2
18	Kaduna	394	498	622	767	852	2.2
19	Kano	629	869	1,165	1,521	1,741	2.8
20	Katsina	186	322	489	689	770	4.1
21	Kebbi	114	183	268	370	416	3.7
22	Kogi	111	195	298	422	473	4.3
23	Kwara	151	200	259	327	364	2.4
24	Lagos	1,397	1,716	2,102	2,555	2,934	2.1

National, state or HA		Water demand (Million Litre per Day: MLD)					2030/2010 Ratio
		2010	2015	2020	2025	2030	
25	Nasarawa	87	128	179	237	267	3.1
26	Niger	253	327	417	523	592	2.3
27	Ogun	319	402	502	620	707	2.2
28	Ondo	197	262	341	433	486	2.5
29	Osun	258	319	392	478	541	2.1
30	Oyo	458	566	696	848	959	2.1
31	Plateau	123	194	280	381	422	3.4
32	Rivers	355	500	679	893	1,014	2.9
33	Sokoto	197	268	353	453	506	2.6
34	Taraba	39	99	172	261	291	7.4
35	Yobe	84	138	206	289	327	3.9
36	Zamfara	171	227	294	374	420	2.5
37	FCT Abuja	130	267	496	855	1,182	9.1

5. CONCLUSION AND RECOMMENDATION

In this study, we assessed the groundwater potentials at Ishielu local government area using the vertical electrical sounding (VES) method at three selected locations for the purpose to develop an electric-powered underground water scheme for commercial use. The breakdown of the result shows:

1. Saturation zones occur at an average depth of 77.43m
2. Borehole drilling should be dug at depth within the saturation zones for maximum yield
3. The following layers were delineated: laterite, dry clay, weathered shale formation and weathered mudstone lithologies.
4. The presence of the weathered formations serves as an aquifer

These results are in agreement with existing literature in this domain of study. The fractionating zones within these saturation points are porous to accommodate a pressure pump. The over-riding inference is that there is a 70% possibility of success for drilling a borehole at the site locations selected. A downhole drilling method is highly recommended in this area as the subsurface is consolidated and compact.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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