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Geo-Electric Study for Groundwater Development in Ikunri Estate, Kogi West, Southwestern Nigeria.

Ologe[1], O., Bankole[1], S. A. and Adeoye[2], T. O.

[1]Department of Chemical and Geological Sciences, Al-Hikmah University, Ilorin, Nigeria.

[2]Department of Geology and Mineral Sciences, University of Ilorin, Ilorin, Nigeria

Abstract

A total of fifteen (15) vertical electrical soundings (VES) were conducted at Ikunri estate with the aim of having an idea about the overburden thickness, determining the geoelectric layers and locating depths that are of hydrologic significance. The vertical electrical soundings (VES) were performed using Schlumberger array with half current electrode separation (AB/2) varying from 1m to 65m. The geo-electric parameters obtained from the sounding curves revealed 3-layer, 4-layer and 5-layer earth models. The 3-layer model constitutes 80% of the coverage area while the 4- layer and 5-layer models constitute 6.67% and 13.33% respectively. All the models showed that the subsurface are distinguishable into the topsoil, clay /sandy-clay, weathered/fractured basement rock, and the fresh basement rock. The thickness of the weathered and/or the fractured basement ranges from 1.5m to 9.5m and these are the aquifers in the area. The resistivity values of the weathered/the fractured basement ranged from 21.2-494.9 Ωm. Based on the isopach and basement relief maps, the study area was zoned into high, intermediate and low groundwater potential. The study revealed that basement depressions mostly constitute high groundwater potential zones. It will serve as a guide on the groundwater potential of the area and expected to assist in future development of groundwater resources in the area.

Keywords: Fresh basement, vertical electrical sounding, isopach map and aquifer

1. Introduction

During the last decade, electrical resistivity method has become increasingly successful in the search for groundwater in the basement complex terrains (Olayinka and Olorunfemi, 1992; Omosuyi, 2000) and in the sedimentary basins (De Beer and Blume, 1985; Shemang, 1993) due to its effectiveness in locating subsurface water bearing zones.

Corresponding Author: Bankole, S. A.
Email: bayus4sure2@yahoo.com

Industrialization recently witnessed by the Aiyetoro metropolis in Kogi State, Nigeria has resulted in

population increase and has resulted in urbanization of satellite villages and settlements of which the ancient Ikunri settlement is one. Ikunri Estate is underlain by Basement Complex rocks of the southwestern Nigeria. In a basement terrain thorough geophysical investigation is required to locate water bearing zones which are restricted to the weathered and/or fractured portion of the basement rocks or alluvial deposits within flood plains (Wright, 1992; Olorunfemi and Fasuyi, 1993). Ikunri Estate depends solely on surface water from streams and hand dug wells for domestic use. However, these sources of water are highly vulnerable to pollution thereby making the people to be vulnerable to water borne diseases. Furthermore, rapid population growth of Ikunri occasioned by the influx of people from nearly congested city has also made these sources of water indequate for Ikunri dwellers, and the need for quality and readily available portable groundwater in this area forms the basis for this research.

Description of the study area

Ikunri Estate is located southwest of Ayetoro in Kogi State and lies within latitude 07° 18' 6" N to 07° 18' 40" N, and longitude 05° 04' 26" E to 005° 04' 58" E (Fig. 1). The topography is relatively undulating terrain with surface elevations ranging from 295.4m to 332.8m above sea level. The geologic setting of the area is typical of migmatite gneiss complex rocks of the Precambrian Basement Complex of southwestern Nigeria (Rahaman, 1976). It comprises undifferentiated granite, charnokite, medium to coarse grained granite and migmatite gneiss rocks (Fig. 2). Only Migmatite gneiss was mapped in Ikunri. The migmatite gneiss rocks around the study area are weathered and fractured. The aquifer units in the area and other similar Basement complex environment are believed to be derived essentially from the weathered rocks (Bala and Onugba, 2001; Olayinka and Olayiwola, 2001). The weathered profile developed above the crystalline basement rocks in low latitude regions where the study area lies. It has been documented by Olayinka and Olayiwola (2001) that such terrain comprises from top to bottom, the soil layer, the saprolite (i.e., the product of the in situ chemical weathering of the bedrock), fractured bedrock and fresh bedrock. The vegetation in the study area is of rainforest type, characterized by short dry season and a long wet season, with high annual rainfall of about 1,300mm. Annual mean temperature is between 18°C and 33°C with relatively high humidity (NIMET, 2007).

2. Materials and Methods

Fifteen (15) vertical electrical soundings were carried out following standard procedures of Schlumberberger array with half electrode spacing (AB/2) varying from 1 to 65m. The equipment used for the field data measurement is the PASI-E2 DIGIT Resistivity Meter.

VES curves were generated with the aid of computer aided iteration curve matching techniques using WinResist software (Vander Velpen, 2004). The VES curves generated gave the thickness and the resistivities of the different geoelectric layers. The established depths to the bedrock beneath all the VES locations occupied were plotted and contoured as isopach map of the overburden. Basement relief map which is a contoured map of the elevation of bedrock beneath all the established sounding station was generated.

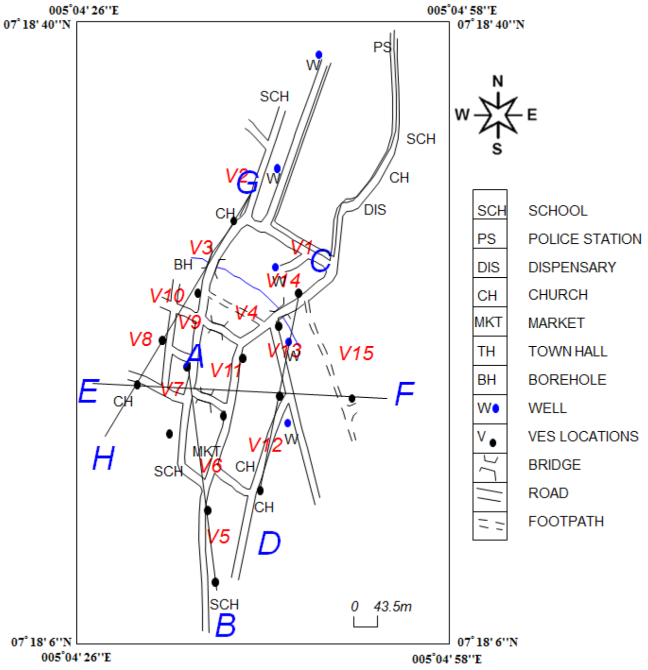


Figure 1: Layout Map of the Study Area Showing the VES Locations

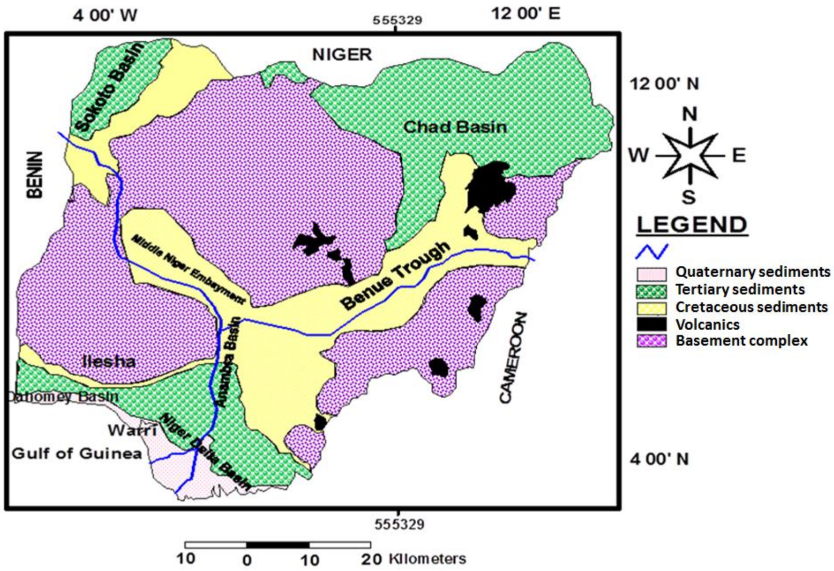
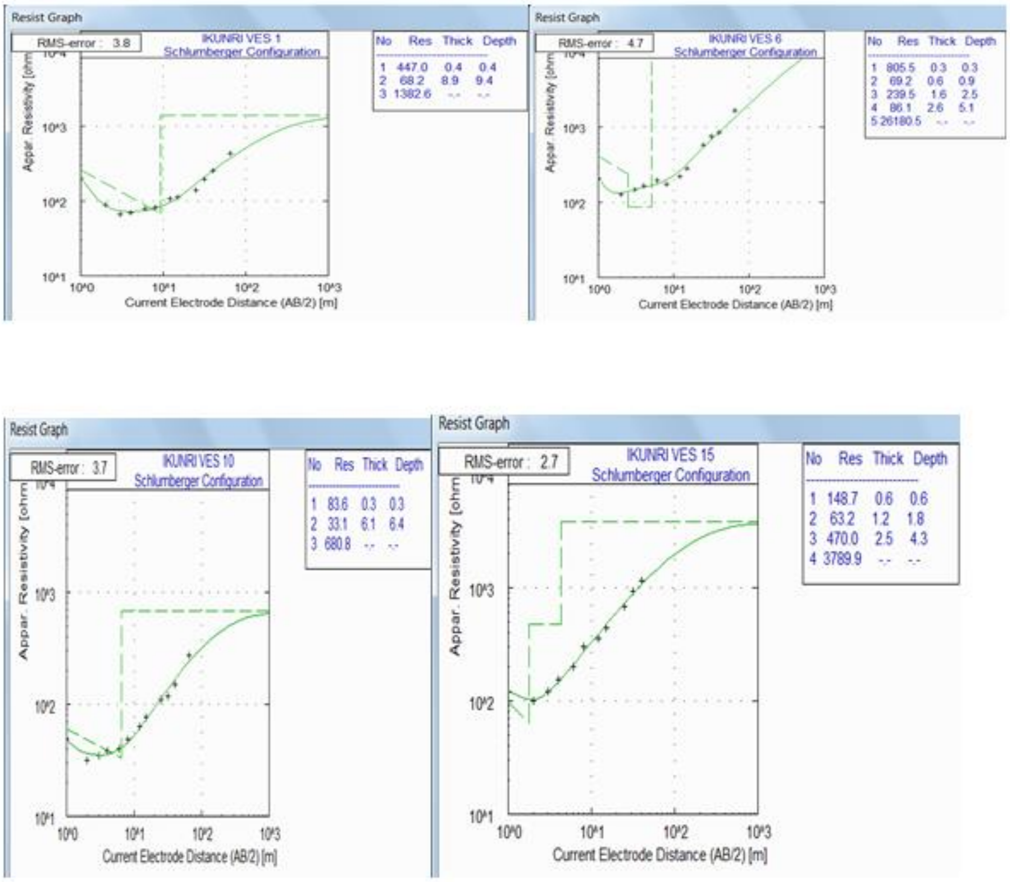


Figure 2: Geological Map of Nigeria showing Basement Complex and Sedimentary terrain.

3. Results and Discussions

The typical sounding curves shown in Fig. 3 were used to generate the geoelectric parameters presented in Table 1. Geoelectric sections were constructed based on the 2D geoelectric parameters and were divided into four geoelectric sections namely; A-B, C-D, E-F and G-H. The A-B geolectric section was derived from VES 9, 6 and 5 which was drawn in northwest to southeast direction (Fig. 4). In this section, the top soil is thin with thickness ranges between 0.2m and 2m and the resistivity values between 177 Ωm and 702 Ωm. The top soil extends southeasternly of VES 6 and VES 5. The top soil is underlain by a clay/sandy clay layer. This layer has a resistivity values between 26 Ωm and 373 Ωm and with thickness between 0.6 m and 7.2 m. The next geoelectric layer was the fresh basement rock which has resistivity values between 1348 Ωm and 5189 Ωm. In this section, there was no potential aquifer and this made the zones unproductive. The C-D geolectric section falls along VES 1, 13 and 12. In this section, four geoelctric layered were interpreted namely; topsoil, clay/sandy clay, weathered/fractured basement and fresh bedrock (Fig. 5). The topsoil has resistivity values ranging from 62 Ωm to 362 Ωm and thickness between 1.5 to 7.7m. The resistivity value for the weathered/fractured basement stands at 937 Ωm while that of the fresh bedrock ranges between 6438 Ωm and 8323 Ωm. The possible water bearing zone was located around the VES 1 where a thick overburden overlying the weathered zone made up of basement depression (Fig. 5). Interestingly, the thick overburden materials are clay which can serve as a natural filter for the underground water. In the VES 13 and 12, no potential aquifer was identified as the moderately thick overburden material unconformably overlies the fresh basement ridge. The third geoelectric section (E-F) runs through VES 8, 13 and 15. The geoelectric layers interpreted within this section are; topsoil, clay/sandy clay, weathered/fractured and fresh bedrock. In this section only VES 15 is slightly prolific to groundwater at its fractured portion (Fig. 6). In the fourth geolectric section which passes through VES 2,3,10 and 8 (Figs. 1 and 7). The section is differentiated into topsoil, clay/sandy clay, fractured basement and fresh basement. The topsoil has resistivity between 38 Ωm and 395 Ωm with thickness between 0.4 to 0.9 m. The resistivity of the clay/sandy clay was between 19 Ωm and 134 Ωm. Groundwater potential area in this section was located around VES 10 which is underlain by fractured basement and has moderate overburden thickness. Other VES stations along the profile (VES 2, 3, and 8) were underlain by fresh basement aquifer which rendered them unproductive zones.



No	Res	Thick	Depth
1	447.0	0.4	0.4
2	68.2	8.9	9.4
3	1382.6	-.-	-.-

No	Res	Thick	Depth
1	805.5	0.3	0.3
2	69.2	0.6	0.9
3	239.5	1.6	2.5
4	86.1	2.6	5.1
5	26180.5	-.-	-.-

No	Res	Thick	Depth
1	83.6	0.3	0.3
2	33.1	6.1	6.4
3	680.8	-.-	-.-

No	Res	Thick	Depth
1	148.7	0.6	0.6
2	63.2	1.2	1.8
3	470.0	2.5	4.3
4	3789.9	-.-	-.-

Figure 3: Typical VES Curves for the Study Area.

Table 1: Summary of the geoelectric parameters in the study area.

Geoeletric earth layer model type	Curve Type	VES Number	Resistivity (Ohm-m)	Thickness (m)	Number of Occurrence	Percentage of Occurrence (%)	Layer	Resistivity Range (Ohm-m)	Thickness Range (m)	Characteristic Lithology
3-layers	A	5	250.6,373,5189.3	2.0, 7.2	2	13.33	1	55.7-250.6	0.8-7.2	Topsoil
		14	55.7,132.5,1355.1	0.8,7.0			2	132.5-373		Clay
							3	1355.1-5189.1		Fresh basement
	H	1	362.1,64.2,936.7	0.5,7.7	10	66.67	1	33.0-362.1	0.2-8.5	Topsoil
		3	37.6,19.4,3983.9	0.9,1.9			2	19.4-110.3		Clay
		4	135.9,37.0,3376.8	0.4,5.4			3	680.6-3983.9		Fresh basement
		7	163.4,33.4,3445.7	0.5,5.8						
		8	216.1,43.8,2345.3	0.4,4.9						
		9	175.5,25.6,1347.7	0.2,6.2						
		10	33.0,72.4,680.6	0.4,6.1						
		11	85.4,30.4,1385.5	0.5,8.5						
		12	291.4,56.9,8323.1	0.8,1.5						
		13	61.5,110.3,6437.6	1.1,3.2						
4-layers	HA	15	145.8,62.3,494.9,3563.	0.6,1.2,2.2	1	6.67	1	0-145.8	0.6-2.2	Topsoil
							2	145-62.3		Clay
							3	62.3-494.9		Fractured basement
							4	494.9-3563		Fresh basement
5-layers	HKH	2	394.9,43.5,133.9,21.2,1751.5	0.6,2.5,2.8,3.2	2	13.33	1	394.9-706.2	0.3-6.1	Topsoil
		6	706.2,69.2,219.3,88.3,1903.9	0.3,0.6,1.7,2.6			2	43.5-69.2		Clay/sandy clay
							3	19.3-133.9		Sandy clay
							4	21.2-88.3		Fractured basement
							5	1751.5-1903.9		Fresh basement

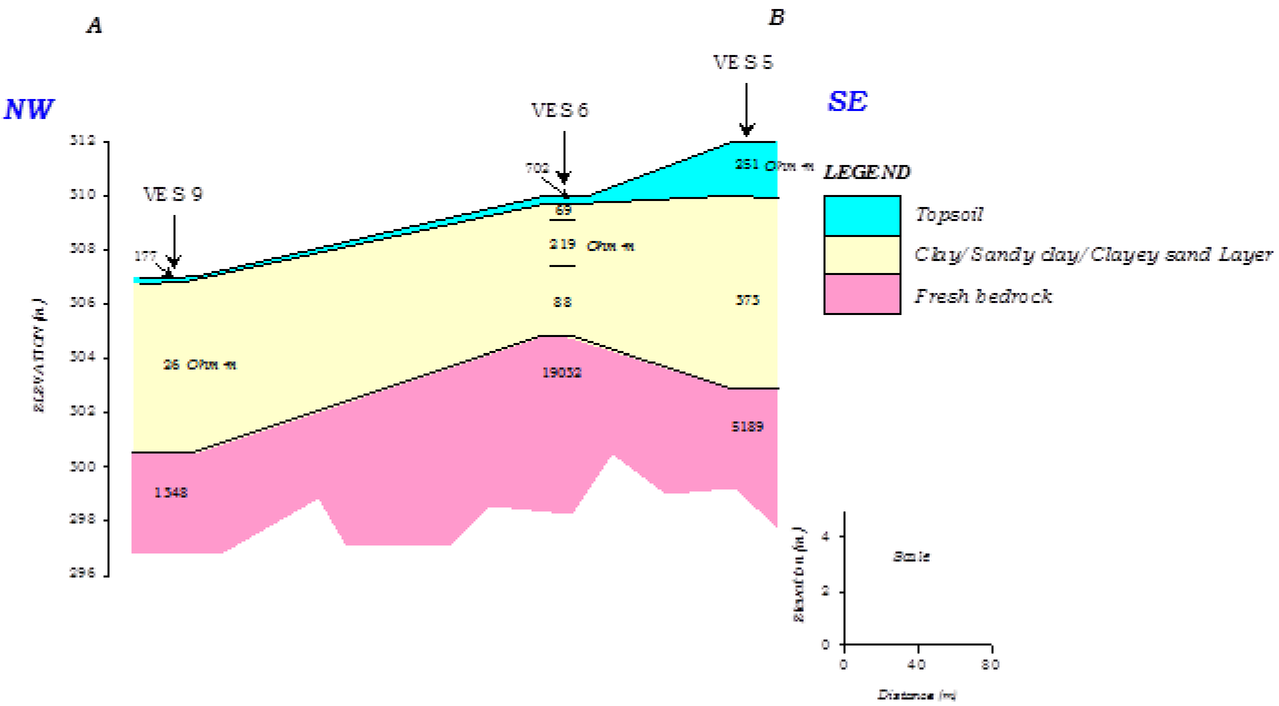


Figure 4: Geoelectric section A-B in NW – SE direction.

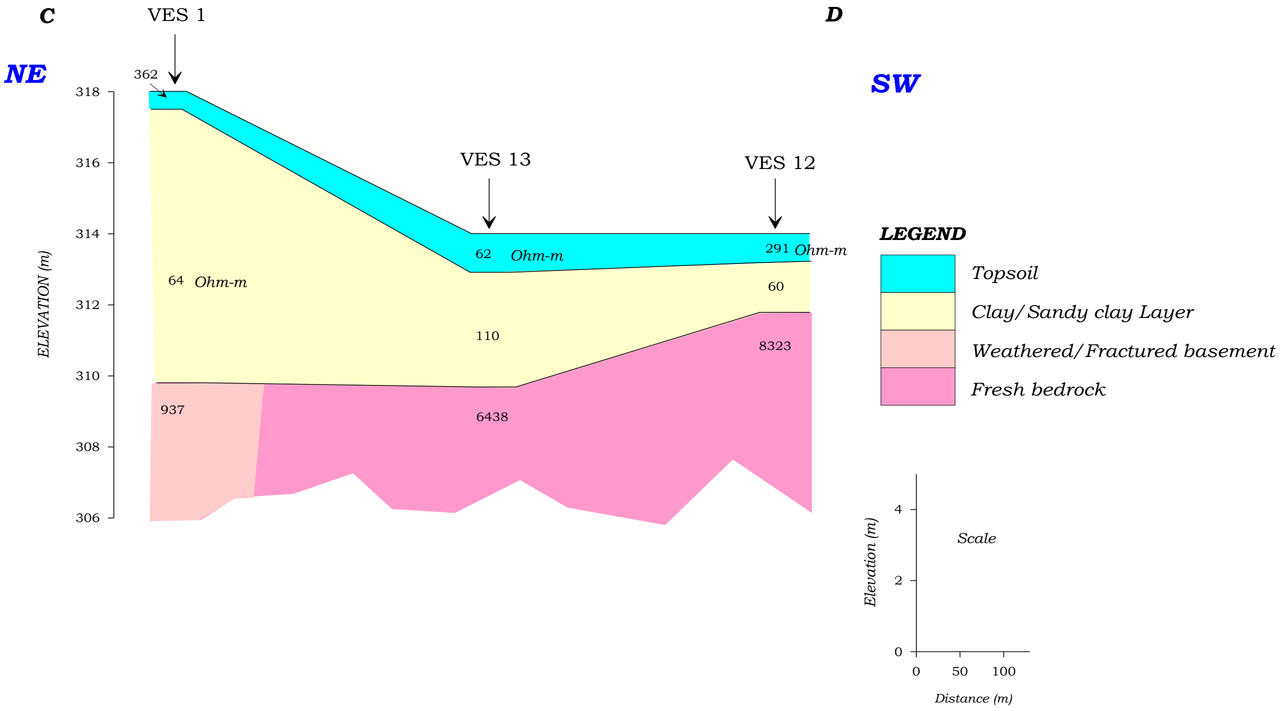


Figure 5: Geoelectric section C-D in NE – SW direction.

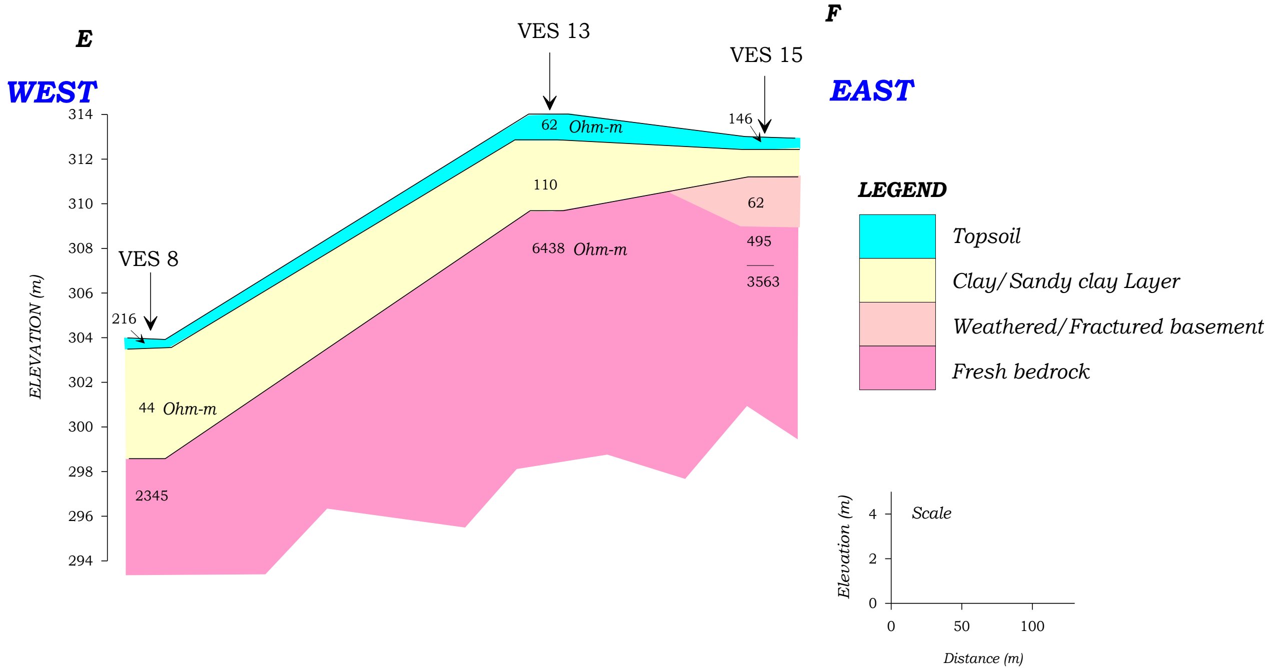


Figure 6: Geoelectric Section E-F in West – East direction.

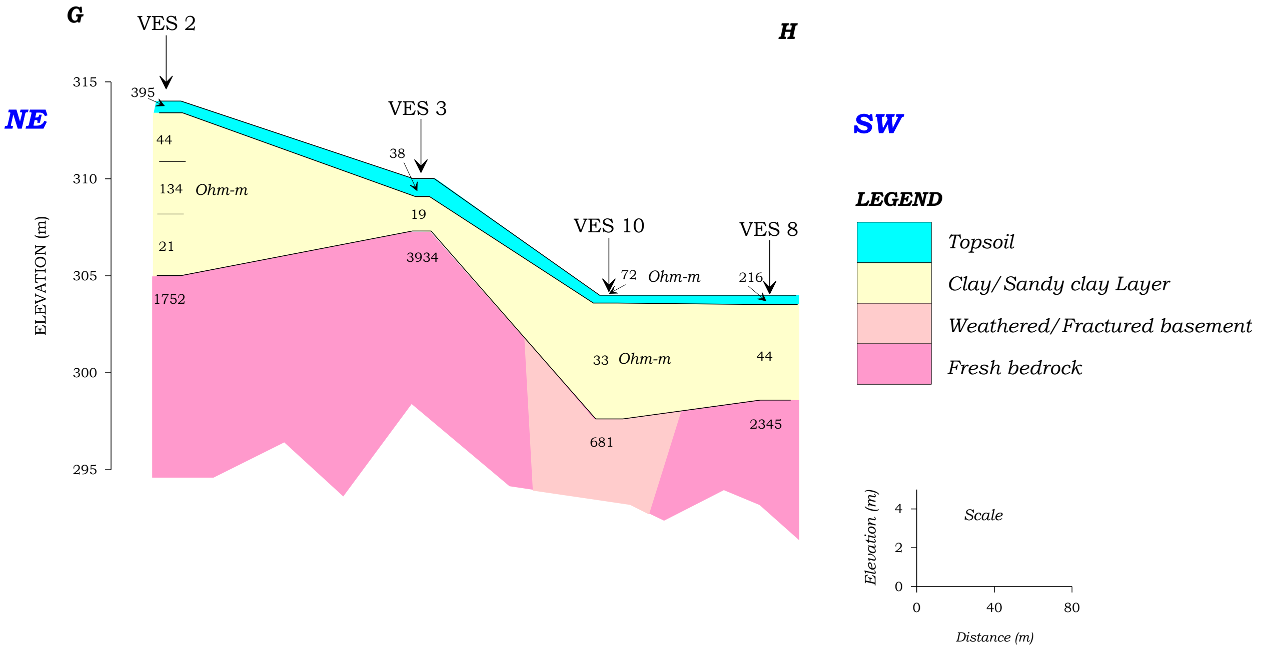


Figure 7: Geoelectric Section G-H in NE – SW direction.

Isopach Map of the Overburden

The overburden thickness in the study varies from 1.5 to 10m. The result agrees with Okhue and Olorunfemi (1991) who predicted a depth to bedrock ranging from 4 to 79.2m as a maximum depth to bedrock in basement complex area of Ile-Ife. The isopach map of the overburden (Fig. 8) showed area with thick overburden (>6.0 m) marked E and C, while area with relatively thin overburden (<6.0 m) was marked A, B and D. (Okhue and Olorunfemi 1991) have identified areas with thick overburden cover as high groundwater potential zones. Consequently zones designated E and C are considered as priority areas for groundwater development. The VES stations that fall within the area of thick overburden (>6.0 m) are VES 1, 2, 3, 10, 14 and 4. Only VES stations 1 and 10 along the profile have potential for groundwater accumulation. The VES stations that fall in the area of thin overburden (<6.0 m) are VES 5, 6, 15, 12, 13, 11, 8, 7 and 9. Among the VES stations that fall within the thin overburden (<6.0 m), only VES 15 has aquifer where groundwater could be exploited.

Basement Relief Map

The basement relief map (Fig. 9a and 9b) showed the subsurface topography of the bedrock across the study area. The hydrogeologic significance of bedrock relief has been recognised by Dan-Hassan and Olorunfemi (1999), Olorunfemi *et. al* (1999). Topographic depressions (D1 and D2) and ridges (R1 and R2) were identified in the bedrock relief map. Depressions were characterized by thick overburden while ridges were noted for thin overburden cover. In addition to being characterized by relatively thick overburden, basement depressions also constitute groundwater-collecting troughs. The VES stations that fall in the area of basement depression D1 and D2 are VES 8, 10, 3, 2, 7, 9, 4, 6 and 5. Among these VES points, only VES 10 has aquifer where groundwater could be exploited.

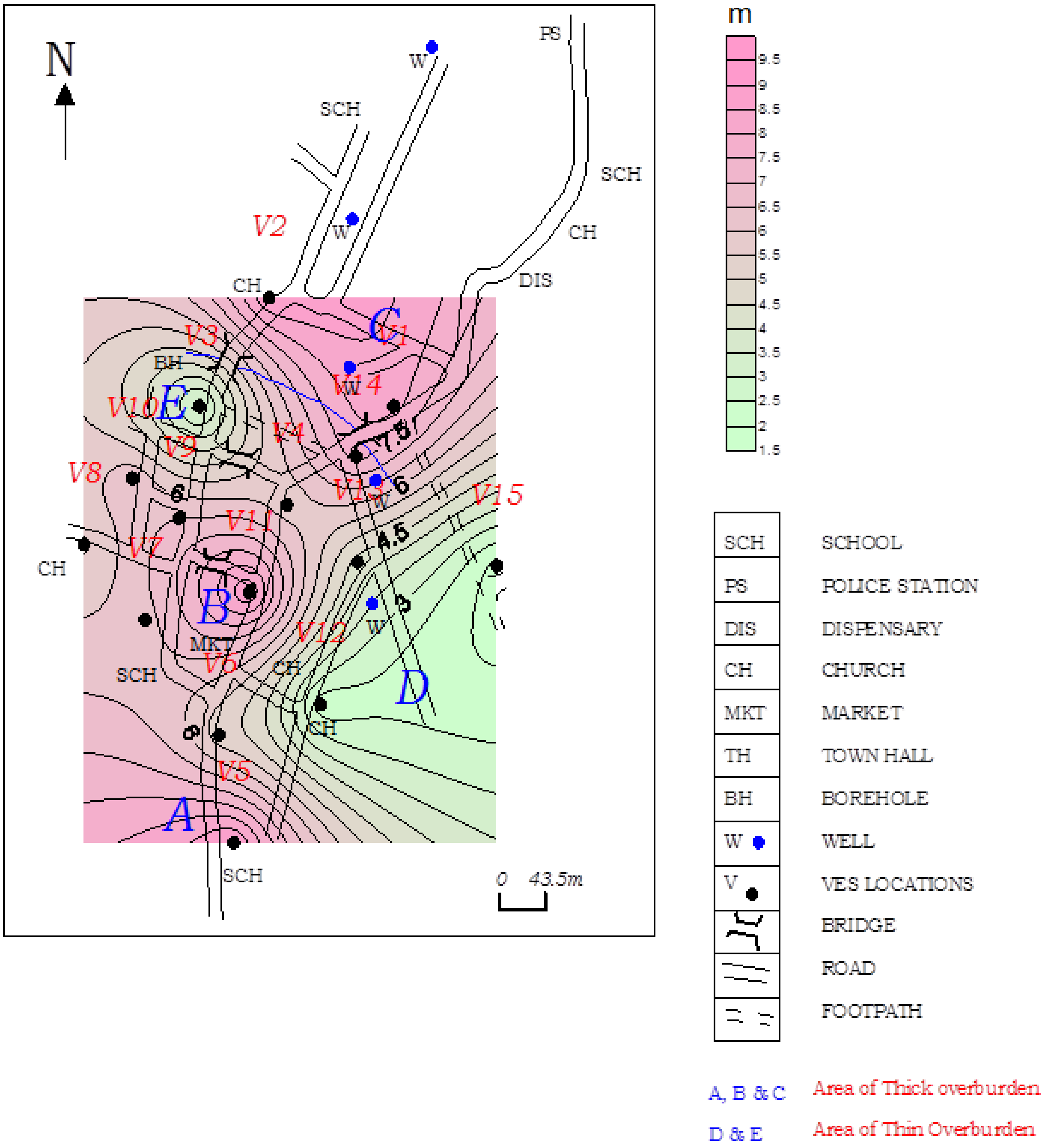


Figure 8: Isopach Map of the Study Area.

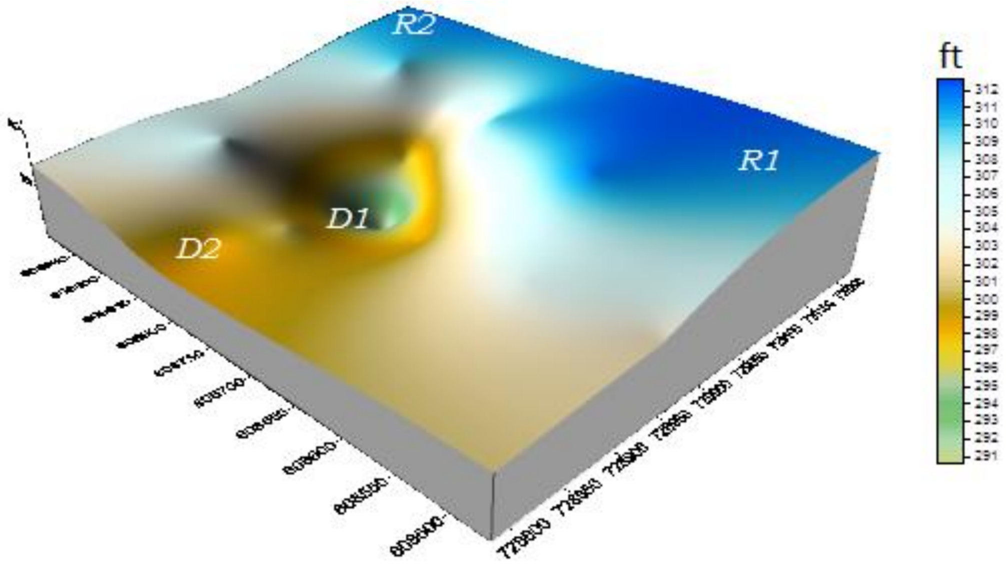


Figure 9a: 2-D Basement Relief Map of the Study Area

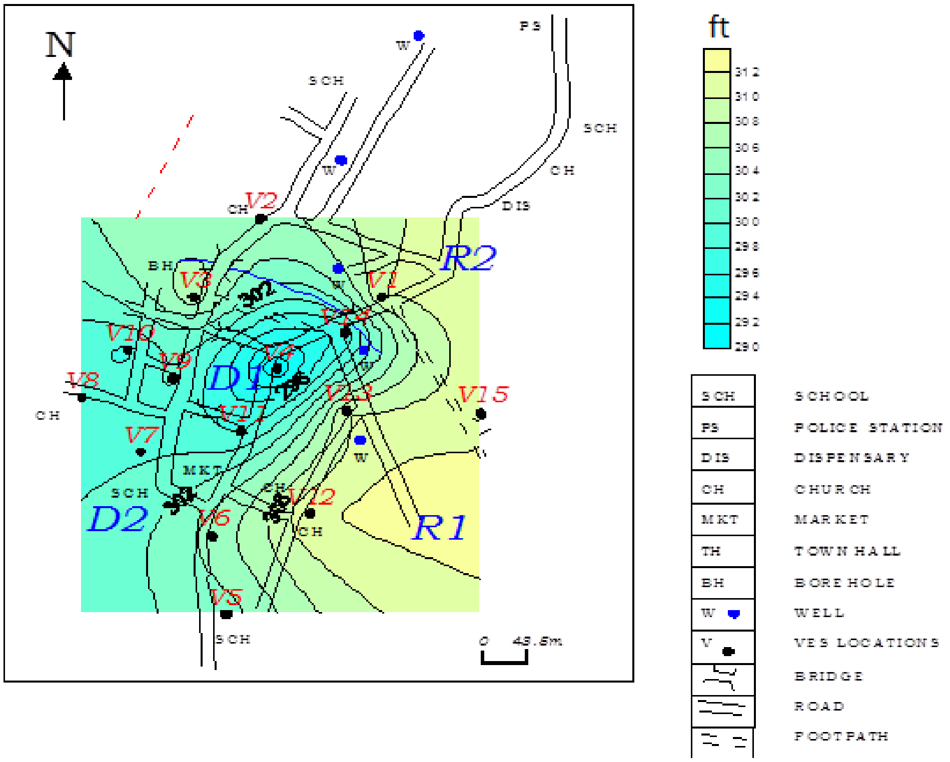


Figure 9b: 3-D Basement Relief Map of the Study Area.

4. Conclusion

Electrical resistivity method was used to evaluate groundwater potential of Ikurin Estate. The geoelectric parameters obtained from the inverted Vertical electrical resistivity sounding data were used to construct cross sections, isopach and basement relief maps which gave insights to the hydro-geologic significance of the area. The maps showed the cross sectional impression of the subsurface lithology and the characterization of the study area into different hydro-geologic targets (high medium and low groundwater potential zones). The results also indicated aquifers that were basically within the weathered bedrock or fractured bedrock. Other geologic feature delineated from the distribution of the subsurface resistivity is the bedrock depression, which is of significant hydro-geologic importance. The study also revealed that depressions overlain by relatively thick overburden mostly constitute the area adjudged high groundwater potential zones, as typical of basement complex terrains.

The findings in this work are envisaged to provide reliable background information for an elaborate groundwater development in the area. Future studies in this respect, could adopt integrated geophysical methods such as very low frequency electromagnetic (VLF-EM) and seismic refraction techniques in order to enhance accurate delineation of groundwater potential zones in the study area.

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