Geophysical Investigation of Groundwater Level Using Vertical Electrical Sounding (A Case Study of Ewu in Edo State Nigeria)

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***Abstract*- In this research work, four Vertical Electrical Soundings (VES) were carried out in Ewu Town at various locations: Eguare-Ewu, Idunwele-Ewu, Flour Mill Road-Ewu and Eko-Ewu using the ABEM terrameter, by employing the Schlumberger electrode configuration system to determine the level of groundwater. From the analysis of field data and results of computer iteration, a maximum of four geoelectric layers were obtained. The first layer of geoelectric section was the lateritic top soil with thickness of 1.21m and 11.1m, for VES 1 and VES 2, with apparent resistivity of 438Ωm and 183Ωm. The possible aquiferous zone for sustaining groundwater are within the second and third layers for VES 1 and the fourth layer for VES 2, at a depth of 2.67m – 47m and infinity respectively. The apparent resistivity of the aquiferous layers of VES 1 and VES 2 are 797Ωm and 362Ωm respectively, which is fine sand layer. The apparent resistivity of the aquiferous layers of VES 3 and VES 4 are 5511Ωm and 129Ωm respectively with infinity thickness.**

Key words: **Geoelectric layer, aquiferous layers, groundwater**

I. INTRODUCTION

One major source of obtaining portable water which is one of the most consumed minerals at homes, in the industries and factories today is through boreholes and drilled wells. Ever since man began to live in communities, the problem of suitable and adequate water supply especially for domestic and farm use has always agitated the mind. However, in most developing countries such as Nigeria, clean water is not continuously available or may not be available at all [1].

Groundwater is considered as a very important natural resource [2, 3, 4, 5]. In arid, semi arid, and dry regions, this may be the only source of water supply. Even in humid areas, groundwater is considered a better resource for many economic and hygienic reasons. The role of groundwater in sustaining the life of man on this planet can hardly be overemphasized. Presently, all the developed and developing countries are giving top priorities to short and long term schemes envisaging exploration and exploitation of groundwater reserves in their respective regions.

Already, millions of gallons of groundwater are being pumped out every day in the world to meet industrial, agricultural and domestic needs of man. In most parts of Ewu, Esan Central Local Government Area, Edo State, not all wells yield appreciable quantity of portable water since they are prone to variation in groundwater characteristics because of the disparity in lithological, structural formation and sedimentation parameters. The existence of failed boreholes and dry wells has posed a great concern. This is however, traceable to sitting and drilling of boreholes without geophysical studies. Therefore, it is essential that a reliable geophysical study should be carried out before drilling of boreholes.

II. LOCATION AND GEOLOGY OF STUDY AREA

Ewu, is situated within the northern part of Edo State in Esan Central Local Government Area. The people that inhabit the area are the Esan people of Edo State and their main occupation is farming. The four areas we worked on are Eguare Ewu, Idunwele Ewu Flour Mill, Ewu and Eko Ewu.

The study area is 36.5 square kilometers. The main area we worked in is Ameki formation. Geographically Eguare Ewu lies within latitude $06^0$48.316'N and longitude $006^0$14.596'E with elevation of 316m. The second study area Idunwele Ewu lies within latitude 0647.745'N and longitude $006^0$14.464'N with elevation of 353m. The third study area Flour Mill Ewu lies within latitude $06^0$46'N 12.5"N and longitude 006^0 13' 29.6"E with elevation of 417m and the last study area Eko Ewu lies within latitude 06^0 40' 43.7"N and longitude 006^0 14" 20.1"E with elevation of 417m. The area is accessible through the Benin-Abuja express way, which has linkage to the areas we worked on.

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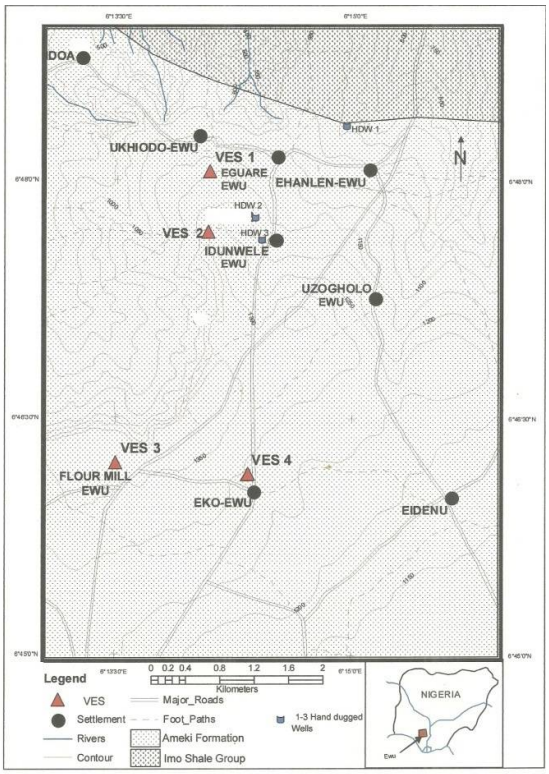


Fig 1. Map of Ewu Showing the Geology and VES locations

III. MATERIALS AND METHOD

The electrical resistivity method was used in this survey because of its flexibility and qualitative interpretation which is straight forward [6]. The electrode configuration used is the schlumberger array using the ABEM SAS 300B Terrameter with a maximum current electrode separation of 500 metres, which were spread out along a straight transverse This instrument has a basic advantage of being able to give an average of four readings to sixteen readings or thirty two readings and is also capable of operating at two different modes, the resistivity surveying mode and the voltage measuring mode.

The resistivity mode was used in this survey. In this work, the Schlumberger vertical electrical sounding was used, since it was considered to have numerous advantages over the other array system. This array is less sensitive to the influence of near-surface lateral heterogeneity. Smoothing and interpretation techniques are much more developed in the Schlumberger than other array. This array is often used as it would provide subsurface information considering the depth of penetration which ranges between 1/3 and ¼ of the total electrode separation [7,8,9].

In the Schlumberger electrode array configuration employed in this work, the depth range of measurement was customarily increased by an outward displacement of the current electrodes; the potential electrode being kept generally fixed at their original position. Usually, at the beginning of a sounding, the ratio of the potential electrodes spacing and current electrodes spacing was maintained at ratio 1:5. When this ratio has become too small the potential differences also become very small so that the observed internal resistance becomes too small to be measured with sufficient accuracy.

At this point, the potential electrodes spacing was therefore increased and a repeated measurement carried out at the two values $P_1P_2/2$ for the same position of the current electrode to establish the change on measurement. Qualitative interpretation data was done using the computer iteration method using the computer software, IPI2WIN which automatically plot the field curve and the model curve

IV. RESULTS AND DISCUSSION

The results collated during the field work are displayed in table 1.0, 2.0, 3.0 and 4.0. Computer iteration method of interpretation was used to interpret the field data. The apparent resistivity values were input into the computer software, IP12WIN which automatically plot the field curve and the model curve .The field data were adjusted as necessary to have an error tolerance within 0 ---- 10% .

Resistivities and layer thickness as well as depths to the layers probed were displayed. The Geological interpretation of the layers electrical resistivities was carried out based on the knowledge of geology of the survey area and electrical resistivities of various earth materials.

Graphic display (Geoelectric log) of the lithologies interpreted from the layer resistivities at each VES location was constructed using, software, Strater3 and these are shown in fig 1-4

Fig 1. Geological Interpretation of Eguare-Ewu Schlumberger Vertical Electrical Sounding Data for Aquifers

VES	LAYER	RESISTIVITY (Ω m)	LITHOLOGY	THICKNESS (m)	DEPTH(m)	Curve type	REMARKS
1	1	438	Laterite	1.21	1.21	HA	
	2	165	Clayey Sand	1.46	2.67		Water bearing
	3	797	Fine Sand	44.3	47		Water bearing
	4	1911	Coarse Sand /Gravel				Water bearing(more productive)

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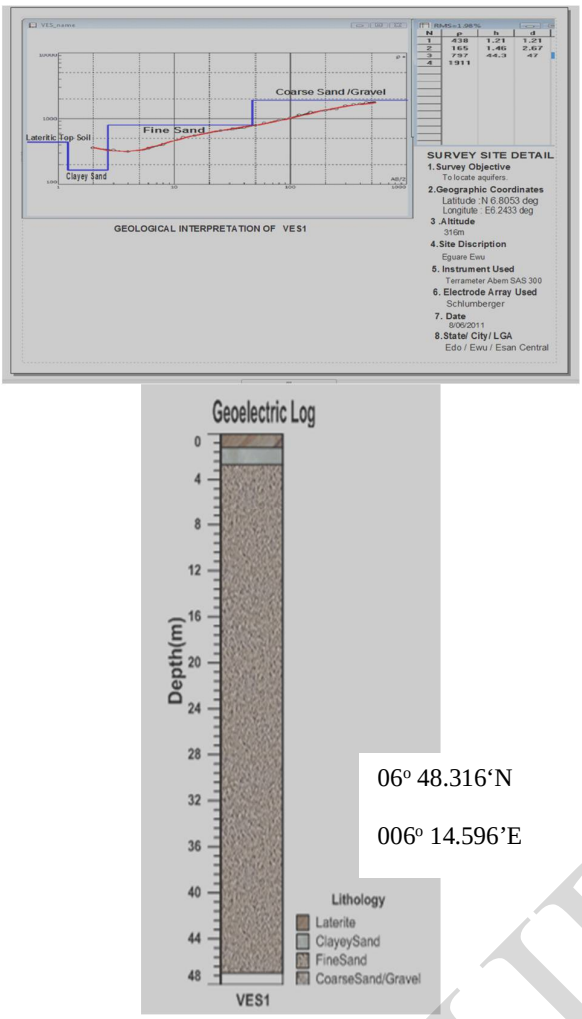


Fig 2. Geoelectric Interpretation Curves and Geoelectric Log for VES1

A. *Discussion Of Ves* 1

The curve type for VES 1 is HA ($\rho_1 > \rho_2 < \rho_3 < \rho_4$).

- Layer 1 with a resistivity of 438ohm-m and a thickness of 1.21m is designated as the lateritic top soil.
- The second layer in the subsurface succession, having an apparent resistivity of 165ohm-m and a thickness of 1.46m is described as the clayey sand.
- Layer 3 with a resistivity of 797ohm-m and a thickness of 44.3m is the fine sand.
- The fourth layer with a resistivity of 1911Ωm and an unknown thickness is designated as the coarse sand/gravel.

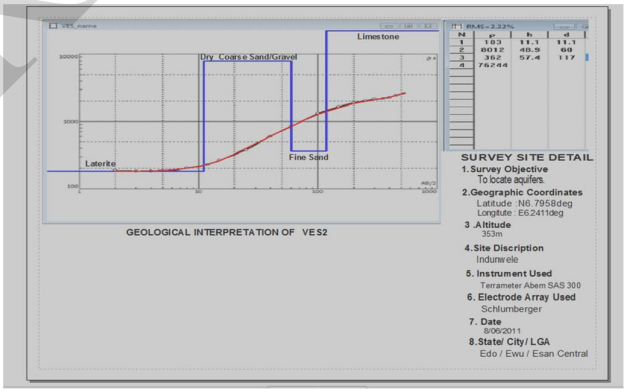
It was observed that among the four geoelectric layers underneath VES 1, there are two distinct saturated sandy horizons. These two horizons (layer 3 and layer 4) can be designated as aquifers. The depth to the top of layer 3 is 2.67m and its thickness being 1.46m, while the depth of the top of layer 4 is 47m. A deep hand-dug well of about 60m from the VES point was sighted during the field work. The observed static-water level was about 40m. Although, its total drilled depth could not be clearly ascertained, it was obvious that the well tapped from the first aquifer (layer 3). The second aquifer is obviously beyond the penetration of a manual hand-dug well device.

The aquifers underlying VES 1 can be described as confined aquifers. While the upper (shallow) aquifer (layer 2) is confined above and below by geoelectric layers 1 and 3, it is only the upper confining layer for the deep aquifer that is known.

Resistivity Sounding Interpretation Site: Idunwele-Ewu

Fig 3. Geological Interpretation of Idunwele-Ewu Schlumberger Vertical Electrical Sounding Data for Aquifers

VES	LAYER	RESISTIVITY (Ωm)	LITHOLOGY	THICKNESS (m)	DEPTH (m)	Curve type	REMARKS
2	1	183	Laterite	11.1	11.1	KH	
	2	8012	Coarse Sand/Gravel	48.9	60		Dry
	3	362	Fine Sand	57.4	117		Water bearing
	4	76244	Limestone				Massively bed rock



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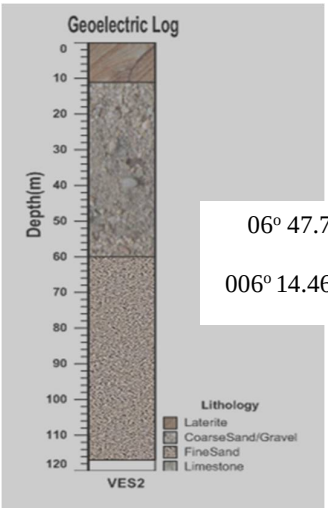


Fig 4. Geoelectric Interpretation Curves and Geoelectric Log for VES 2

B.Discussion Of VES2

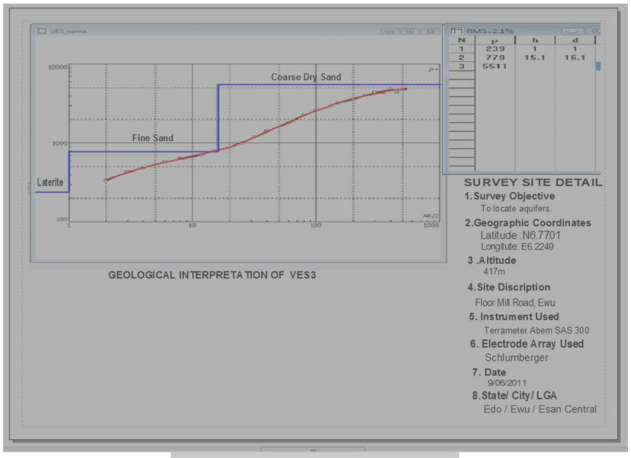
- The Curve Type For VES 2 Is KH ($\rho_1 < \rho_2 > \rho_3 < \rho_4$).
- Layer 1 With A Resistivity Of 183ΩM And A Thickness Of 11.1m, Is The Lateritic Top Soil.
- The Second Layer, Having A Thickness Of 48.9m And Resistivity Of 8012ΩM Is The Coarse Sand/Gravel.
- With A Resistivity Value Of 362ΩM And A Thickness Of 57.4m, Layer 3 Is Designated As Fine Sand.
- Layer 4 Of Unknown Thickness And A Resistivity Value Of 76244ΩM, Is Described As Limestone.

The only fine sand layer delineated underneath VES 2 is layer 3. Furthermore, the aquifer underlying VES 2 (i.e. layer 3) can be rightly described as a confined aquifer. This saturated layer is entrapped between two dry / resistive layers 3 and 4.

Project: Resistivity Sounding Interpretation Site: Flour Mill Road, Ewu.

Fig 5. Geological Interpretation of Flour Mill Road- Ewu Schlumberger Vertical Electrical Sounding Data for Aquifers

VES	LAYER	RESISTIVITY (Ωm)	LITHOLOGY	THICKNESS (m)	DEPTH (m)	Curve type	REMARKS
3	1	239	Laterite	1	1	A	
	2	779	Fine sand	15.1	16.1		Water bearing
	3	5511	Coarse Sand				Dry



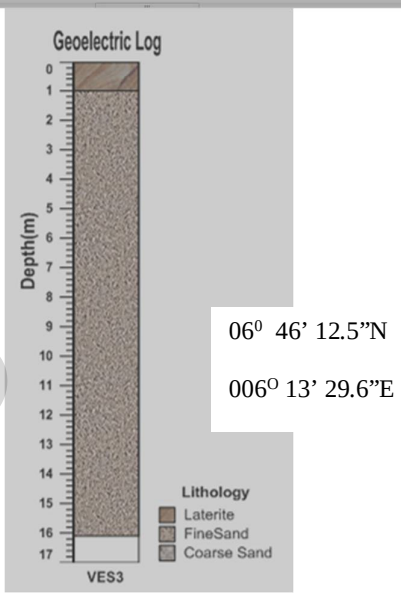


Fig 6. Geoelectric Interpretation Curves and Geoelectric Log for VES3.

C. Discussion Of VES 3

- The curve type for VES 3 is A ($\rho_1 < \rho_2 < \rho_3$).
- Layer 1 stands for lateritic top soil with a thickness of 1.00m and resistivity of 239Ωm.
- The second layer is the fine sand, having a thickness of 15.1m and apparent resistivity of 779Ωm.
- Layer 3 which has unknown thickness and a resistivity of 5511Ωm is designated as coarse sand.

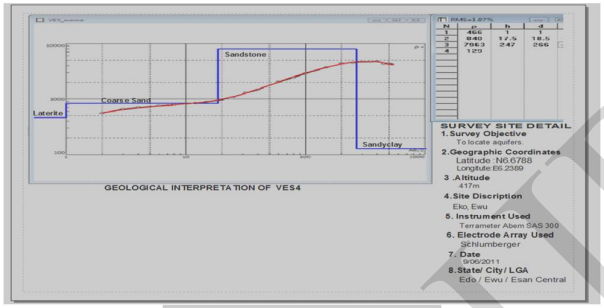
A closer look at the geoelectric layers beneath VES 3 shows only one deep-seated aquifer (layer 3). The scenery here is significantly different from VES 1 and 2, where there are relatively shallow aquifers being tapped by hand-dug wells. No hand-dug well or borehole was sighted within the immediate vicinity of the VES point. The depth to the top of the aquifer (layer 3) is 16.1m. Similarly, as observed in VES 1 and 2, the deep-seated aquifer underlying VES 3 is also confined.

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Project: Resistivity Sounding Interpretation Site: Eko-Ewu.

Fig 7. Geological Interpretation of Eko - Ewu Schlumberger Vertical Electrical Sounding Data for Aquifers

VES	LAYER	RESISTIVITY (Ωm)	LITHOLOGY	THICKNESS (m)	DEPTH (m)	Curve type	REMARKS
4	1	466	Laterite	1	1	AK	
	2	840	Coarse Sand	17.5	18.5		Water bearing
	3	7963	Sandstone	247	266		Water bearing bedrock
	4	129	Sandy clay				Water bearing but not productive



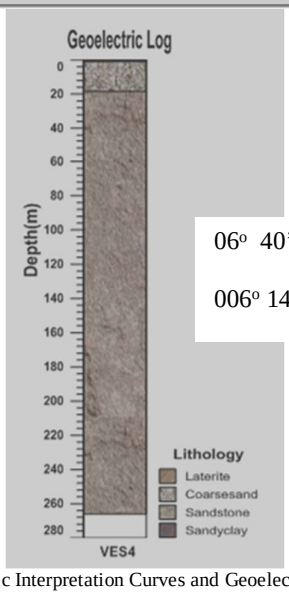


Fig 8. Geoelectric Interpretation Curves and Geoelectric Log for VES4

D. Discussion Of VES 4

- The curve type for VES 4 is AK ($\rho_1 < \rho_2 < \rho_3 > \rho_4$)
- Layers 1 and 2 represent lateritic topsoil and coarse sand with thickness 1.00m and 17.5m respectively. Layer 3 is designated as sandstone horizon.
- The fourth layer of unknown thickness with relative low resistivity value is designated as sandy clay horizon.

Two saturated layers (aquifer) were delineated underneath VES 4. They are: layer 3 is 18.5m, while the depth to the top of layer 4 is 266m.

It is evident from the geoelectric model for VES 4 that two aquifers are confined. Although the first aquifer appears to be relatively shallow, it is within the outer limit of penetration for manual hand-dug well device. This may probably account for the absence of hand-dug well within the vicinity of the VES point.

V. HYDROGEOLOGIC DEDUCTIONS

Generally speaking, the prospect for groundwater abstraction through water well/borehole drilling across the VES points can be described as good to fairly good.

VES 1, located at Eguare-Ewu and VES 2 located at Idunwele-Ewu appear to have good prospect. This is evident in the prevalence of manually constructed hand-dug wells in the two localities. While the yield of the wells may not be on the very high side, it is sufficient to meet the water needs of the people, bearing in mind that the communities are not densely populated.

For VES 3 and 4 located at Flour Mill Road–Ewu and Eko-Ewu respectively, the groundwater prospect here can be described as fairly good. This is due to the fact that the targeted aquifers in these study areas are generally deep-seated. This (noted above) is evident in the absence of hand-dug well (and even boreholes) within the vicinity of the two localities.

Fig 9. STATIC WATER LEVEL

S/N	WATER LEVEL (m)	LATITUDE (E)	LONGITUDE (N)	ELEVATION (m)
Well 1	31.5	006^0 14' 36.7"	06^{0}48' 19.0"	321
Well 2	34.6	006^0 14' 27.2"	06^{0}47' 45.0"	367
Well 3	42.0	006^0 14' 25.6"	06^{0}47' 34.0"	368

The water level appears to be in alignment with the topography of the area as stated in table 5.0

VI. CONCLUSION

Based on the results obtained from this study, the following conclusions were drawn.

The depth to the aquifer varies across the study area. While the depth to the shallow aquifers at Eguare-Ewu and

Idunwele-Ewu is 31.26m and 40.51m respectively, the depth to the aquifers at Flourmill Road Ewu and Eko-Ewu is fairly deep seated.

The aquifers are generally confined. The confining layers being very dry/resistive sandy/sand stone/clayey layer. The static water level for the observed hand-dug wells in the area is also relatively deep varying between 31.5m and 42.0m. The aquifer across the study area is not entirely homogeneous. Though it is sandy, there is a possibility of having variable degree of associated clay admixture. The elevation level for the observed hand-dug wells in the study area also varies between 321m and 368m.

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