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Estimating Aquifer Transmissivity by the Application of Electrical Resistivity Data and Dar Zarrouk Parameters in Owhelogbo, Isoko North LGA, of Delta State, Nigeria

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ABSTRACT---- ***Thirteen Vertical Electrical Soundings using Schlumberger configuration with a maximum current electrode separation of 500m was carried out in Owhelogbo to determine the aquifer parameters. The data obtained were analysed first by curve matching before computer iteration to obtain the model parameters in terms of resistivity, thickness and lithology of the various layers. The Dar-Zarrouk parameters were used to obtain the hydraulic conductivity, K from aquifer conductivity σ and longitudinal conductance S. The hydraulic conductivity, Kσ values and the transmissivity of the aquifer layers were obtained for the various locations. VEV 4 and VES 2 have the highest and lowest transmissivity of 330.0m²/day and 140.0m²/day respectively.***

Keywords---- aquifer parameters, Dar-Zarrouk parameters, Owhelogbo, hydraulic conductivity, Resistivity

1. INTRODUCTION

Owhelogbo lies between latitude $5^0\ 35^1$ N and $5^0\ 40^1$ N and longitude $6^0\ 18^1$ E $6^0\ 24^1$ E. It is bounded by Ozoro in the East and Orogun in the West while in the North by Abbi and South Otor Owhe. The area has flat terrain with no mountains or hills. It has good roads. It experiences dry and wet seasons with rainy season starting from April to October while the dry season start from November to April. Rain forest is the vegetation of the area.

Transmissivity of aquifer expresses the degree of the aquifer characteristics to transmit water in a given geologic formation. It could also be known as the rate at which groundwater is transmitted through a unit width of an aquifer under hydraulic gradient (Allaby, 2008). It is the product of the hydraulic conductivity and thickness of the aquifer.

Aquifer are large body of permeable material where ground water is present in the saturated zone in the other words it simply refers to rock or soil mass which not only contains water, but from which can be readily abstracted in significant quantities (Katty et al , 1997). Good aquifers have high permeability such as sand stone and gravel, have high underground storage reservoir which are known for high porosity and permeability (County, 1997).

The estimation of aquifer transmissivity by the application of electrical resistivity and Dar Zarrouk parameters have been carefully reviewed by many geophysicists (Niwas and Singhai, 1981, Mazac et al., 1985; Onuoha and Mbazi, 1988; Huntley, 1986; Mbonu et al, 1991; Ijeh and Onu, 2012, Imali and Dharmgunwardhane, 2013; Udoinyang and Igboekwu, 2012).

The evaluation of aquifer transmissivity using Dar Zarrouk parameters and electrical resistivity data was applied in the sedimentary basin area of Owhelogbo Isoko North Local Government Area of Delta State, Nigeria. The aim of electrical resistivity method is to measure the potential difference due to flow of current in the ground. The calculation aquifer transmissivity is as a result of the knowledge of layer thickness got from the model parameters; interpretation of resistivity sounding data and hydraulic conductivity derived from the geophysical and hydrogeophysical parameters.

2. METHODOLOGY AND DATA ACQUISITION

The Schlumberger configuration was adopted for the research with maximum current electrode separation of 500m. Thirteen vertical electrical soundings were carried out to estimate the nature of aquifer characteristics in the area of the research. The Abem Terrameters SAS 1000 was used for data acquisition in the field. The potential electrode in Schlumberger arrangements are close together.

The apparent resistivity is given by

$$\rho_a = \frac{\pi(L/2)^2 - (b/2)^2}{b} \frac{V}{I}$$

where L = distance between the two current electrodes

b = distance between the two potential electrodes

when apparent resistivity values are plotted against electrode spacing (L/2) for the various VES, a smooth curve could be obtained. The resistivity and thickness values were obtained by partial curve matching. The results of the curve matching were used for computer iteration where the model parameters were obtained. This iteration was achieved using WinResist software (Vander Velpen, 1988).

Electrical current, fluid flow and conduction current are generally governed by the same physical parameters hence the lithological condition, hydraulic and electrical conductivities are equally controlled by the same physical parameters.

The transverse resistance of the layer is equal to the product of the thickness and the resistivity

$R = h\rho$ (1)

where h = thickness of the layer, ρ = resistivity.

The longitudinal conductance S of the layer is given by

$S=h/\rho$ (2)

The longitudinal conductance S of the layer is also given as (conductivity x thickness)

$S= \sigma h$ (3)

The conductivity is synonymous to the layer transmissivity, Tr given by

$Tr = Kh$ (4)

Where k= hydraulic conductivity of the layer of thickness h. Equation 1 and 2 are Dar Zarrouk equations with R and S as the parameters which has been taken to very powerful interpretational aids in ground water surveys (Zohdy et al, 1974). With Daray's law, the fluid discharge Q, is given as

$Q= KIA$ (5)

Where K= hydraulic conductivity , I = hydraulic gradient, A= Cross-sectional area perpendicular to the direction of flow.

Niwas and Singhai, 1981 established a relationship governing aquifer transmissivity and longitudinal conductance as

$$Tr = K\sigma R = \frac{KS}{\sigma}$$

Where Tr= transmissivity, k= hydraulic conductivity, σ= electrical conductivity (reciprocal of resistivity), R= transverse resistivity, and S = longitudinal conductance. An average hydraulic conductivity of 10/m/day MWT, 1974 is assumed for calculating the transmissivity of the aquifer in Owhelogbo community. Table 1 shows the Model parameters from the iterated values.

Table 1: Geoelectric Parameters and Lithology of the study Area (OWHELOGBO)

VES	Layer	Resistivity Ωm	Thickness m	Depth m	Lithology	Rms % error	Curve Type
	1	317.0	1.1	1.1	Lateritic top soil		$\rho_1<\rho_2>\rho_3>\rho_4<\rho_5$
	2	577.9	10.4	11.5	Coarse grained sand		KQH
1	3	546.8	13.0	24.5	Medium grained sand	2.4	
	4	352.0	18.8	43.3	Sandy clay		
	5	784.7			Coarse sand		
	1	656.2	1.0	1.0	Lateritic top soil		$\rho_1>\rho_2<\rho_3<\rho_4<\rho_5$
	2	452.5	10.0	11.0	Medium grained sand		HAA
	3	620.2	14.9	25.9	Coarse grained sand	2.3	
2	4	821.4	14.0	39.9	Coarse sand		
	5	1111.2			Gravelly sand		
	1	545.9	1.9	1.9	Lateritic top soil		$\rho_1>\rho_2<\rho_3<\rho_4$
	2	259.9	17.0	18.9	Clay		HA
3	3	524.7	22.5	41.4	Clayey sand	2.5	
	4	978.3			Gravelly sand		
	1	348.6	1.8	1.8	Lateritic top soil		
	2	130.6	5.4	7.2	Clayey sand		$\rho_1>\rho_2<\rho_3<\rho_4<\rho_5$
4	3	705.1	13.8	21.0	Coarse grained sand	2.6	HKH
	4	102.9	33.0	54.0	Clay sand		
	5	1017.3			Gravelly sand		
	1	865.0	1.1	1.1	Lateritic top soil		
	2	533.0	10.3	11.4	Fine grained sand	2.0	$\rho_1>\rho_2<\rho_3<\rho_4$
5	3	899.0	25.0	36.4	Coarse sand		HA
	4	1284.5			Gravelly sand		
	1	137.7	1.8	1.8	Lateritic top soil		
	2	632.3	5.5	7.3	Coarse sand		$\rho_1<\rho_2>\rho_3<\rho_4<\rho_5$
	3	65.3	15.9	23.2	Clay	3.8	KHA
6	4	519.3	15.3	38.5	Coarse grained sand		
	5	1145.2			Gravelly sand		
	1	286.6	1.1	1.1	Lateritic top soil		$\rho_1>\rho_2<\rho_3<\rho_4$
	2	169.2	9.1	10.2	Clayey sand	2.3	HA
7	3	493.2	25.8	36.0	Fine grained sand		
	4	649.0			Coarse sand		
	1	134.4	1.2	1.2	Top lateritic sand		$\rho_1<\rho_2<\rho_3>\rho_4<\rho_5$
	2	423.6	7.6	8.8	Clayey sand	2.3	AHA
8	3	456.9	11.7	20.5	Fine grained sand		
	4	220.4	18.3	38.8	Coarse grained sand		
	5	516.3			Coarse sand		
	1	204.4	1.3	1.3	lateritic top sand		$\rho_1<\rho_2>\rho_3>\rho_4<\rho_5$
	2	552.2	8.4	9.7	Coarse sand		KQH
9	3	542.0	11.4	21.1	Coarse grained sand	2.2	
	4	177.5	24.5	45.6	Clayey sand		
	5	659.3			Coarse sand		
	1	701.9	1.1	1.1	lateritic top sand		$\rho_1<\rho_2>\rho_3>\rho_4<\rho_5$
	2	432.6	5.9	7.0	Fine grained sand	2.4	QHA
10	3	306.4	13.3	20.3	Clayey sand		
	4	651.5	16.9	37.2	Coarse sand		
	5	945.0			Gravelly sand		
	1	43.8	1.1	1.1	lateritic top sand		$\rho_1>\rho_2<\rho_3>\rho_4$
11	2	78.0	10.5	11.6	Clayey sand		HK
	3	730.5	26.6	38.2	Coarse sand	2.5	
	4	105.3			clay		
	1	57.1	1.0	1.0	lateritic top sand		$\rho_1>\rho_2<\rho_3<\rho_4$
	2	29.4	5.7	6.7	clay	2.5	HA
12	3	128.9	16.0	22.7	Clayey sand		

	4	154.0			Coarse grained sand		
13	1	576.9	1.0	1.0	lateritic top sand	1.9	$\rho_1>\rho_2<\rho_3<\rho_4>\rho_5$ HAK
	2	392.3	10.7	11.7	fine grained sand		
	3	772.1	23.8	35.5	Coarse grained sand		
	4	887.4	19.2	54.7s	Coarse sand		
	5	725.3			Coarse grained sand		

Table 2: Aquifer Parameters and Resistivity for the 13 VES (Locations).

VES	Aquifer Resistivity Ωm	Aquifer Thickness (h) m	Aquifer Conductivity $\sigma(\Omega m)^{-1}$	Longitudinal Conductance S (Ω^{-1}) $(\sigma \times h)$	Transverse Resistance R he Ωm2	Kσ	Transmissivity m^2/day Tr
1	352.0	18.8	2.84×10^{-3}	0.053	6617.6	0.028	188.0
2	821.4	14.0	1.22×10^{-3}	0.017	11499.6	0.012	140.0
3	524.7	22.5	1.91×10^{-3}	0.043	11805.8	0.019	225.0
4	102.9	33.0	9.72×10^{-3}	0.321	3395.7	0.097	330.0
5	899.0	25.0	1.11×10^{-3}	0.028	22475.0	0.0111	250.0
6	519.3	15.3	1.93×10^{-3}	0.029	7945.3	0.019	153.0
7	493.8	25.8	2.02×10^{-3}	0.052	1274.0	0.020	258.0
8	220.4	18.3	4.54×10^{-3}	0.083	4033.3	0.045	183.0
9	177.5	24.5	5.63×10^{-3}	0.138	4348.8	0.056	245.0
10	651.5	16.9	1.53×10^{-3}	0.026	11010.4	0.015	169.0
11	730.5	26.6	1.37×10^{-3}	0.036	19431.3	0.014	266.0
12	128.9	16.0	7.76×10^{-3}	0.124	2062.4	0.078	160.0
13	887.4	19.2	1.13×10^{-3}	0.022	17038.1	0.0113	192.0

3. RESULT AND DISCUSSION

The study shows 8 VES locations having 5 layer earth and 5 VES (locations) with four layers earth. These are VES 1, 2, 4, 6, 8, 9, 10 and 13 with five layers while VES 3, 5, 7, 11 and 12 have 4 layers respectively. These are shown in Table 1.

The VES with five layers have the aquiferous layer in the fourth layer while VES with four layers have the 3rd layer as the aquiferous layer.

The Dar –Zarrouk parameter were used for the assessment of the various hydraulic characteristics of the aquifer systems in the area of the study. The transverse resistance R, and the longitudinal conductance make up the Dar- Zarrouk parameters.

Table 2 shows the aquifer characteristics for Owhelogbo, Isoko North Local Government Area. The aquifer resistivity for the 13 VES is within the range of 102.9Ωm for VES 4 to 899.0Ωm for VES 5 while the thickness varies from 14.0m to 33.0m. The minimum aquifer electrical conductivity σ_{min} = $0.0011\Omega^{-1}$ (VES 5) and maximum σ_{max} = $0.0097\Omega^{-1}$ (VES 4) and average σ_{ave} and = 0.0054 Ω^{-1}. The aquifer transmissivity for these locations are locations $250m^2$/day and $330m^2$/day respectively.

The minimum longitudinal conductance ranges from S_{min} =$0.17\Omega^{-1}$ (VES 2) to S_{max} = $0.321\Omega^{-1}$ (VES 4) and S_{ave} = $0.169\Omega^{-1}$. The minimum transverse resistivity, R_{min} =2064.2 Ωm^{-2} (VES 12), R_{max} = 22475.0 Ωm^{-2} (VES 5) with R_{ave} 12268.7 $\Omega m^{-2.}$

The minimum values of $K\sigma_{min}$ = 0.0111 $(\Omega day)^{-1}$ (VES 5), $k\sigma_{max}$ = $0.097(\Omega m)^{-1}$ (VES 4) with $K\sigma_{ave}$ = 0.17 $(\Omega day)^{-1}$. The transmissivity ranges from Tr_{min} = $140.0m^2$/day (VES 2), to Tr_{max}= $330.0m^2$/day (VES 4) with average transmissivity of $235.m^2$/day. This transmissivity is good for sedimentary location of Owhelogbo.

VES 4 has the best aquifer transmissivity of $330.0m^2$/day followed by VES 11 with $266.0m^2$/day while the lowest is VES 2 with transmissivity $140.0m^2$/day followed by VES 6 with transmissivity of $153.0m^2$/day.

The result shows that the best site for borehole location and construction is VES 4 (location 4) followed by VES 11 (location 11). These areas have been demarcated as having the best groundwater potential for borehole construction. These layers for the 13 locations are made up of lateritic top soil, fine grained sand, coarse sand, coarse grained sand, medium grained sand and gravelly sand.

4. CONCLUSION

The evaluation of aquifer transmissivity by the application of electrical resistivity and Dar-Zarrouk parameters were carried out in Owhelogbo, Isoko North Local Government Area of Delta State. Thirteen VES (location 13) were carried out using Schlumberger configuration. The method is to measure the potential difference due to flow of current in the ground which enables us to obtain the apparent were resistivity.

The Dar-Zarrouk parameters were used to evaluate the aquifer hydraulic characteristics of the 13 VES. The values of $k\sigma_{min}$ = 0.0111 (Ωday) and $k\sigma_{max}$ = 0.097 $(\Omega day)^{-1}$ and $k\sigma_{ave}$ = 0.17 (Ωday). The transmissivity of aquifer is good for the sedimentary area of Owhelogbo with highest transmissivity of 330.m^2/day and the lowest of 140.0m^2/day.

5. ACKNOWLEDGEMENT

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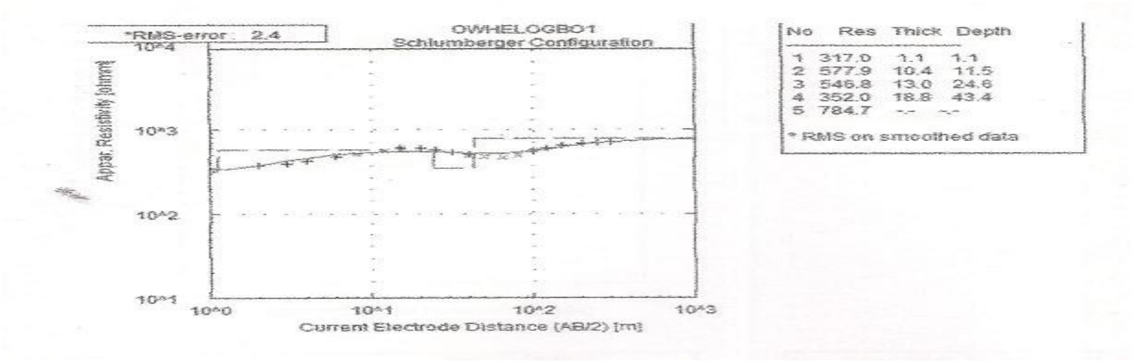

Figure 1: VES 1 for Owhelogbo

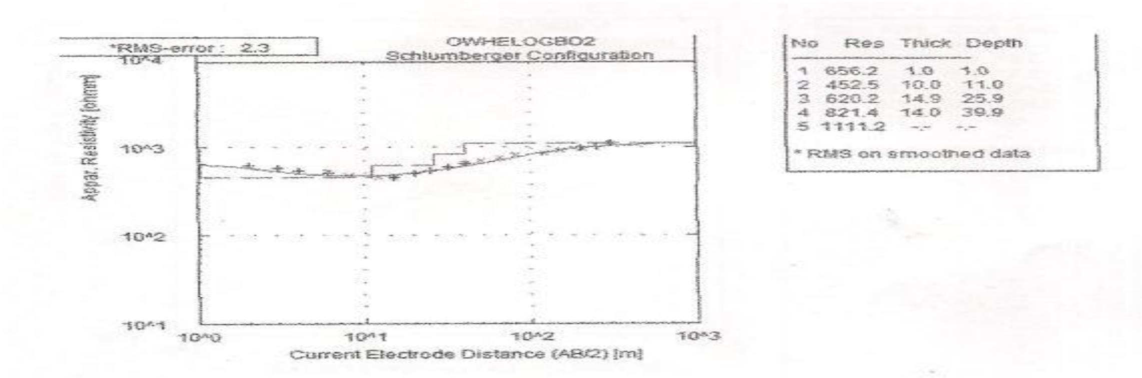

Figure 2: VES 2 for Owhelogbo

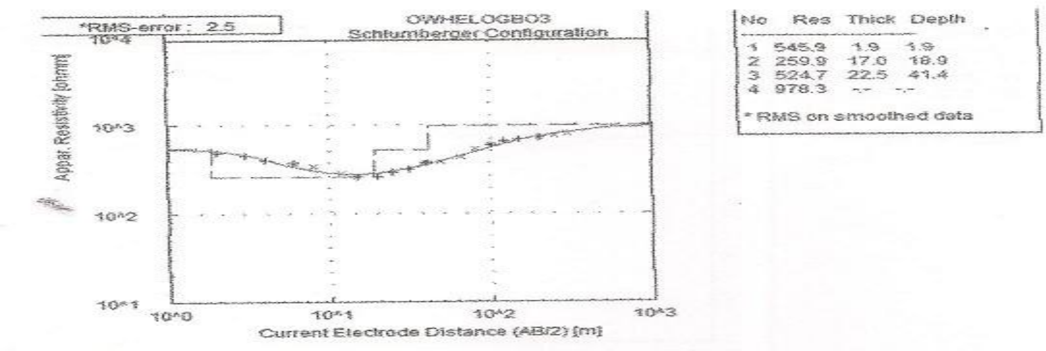

Figure 3: VES 3 for Owhelogbo

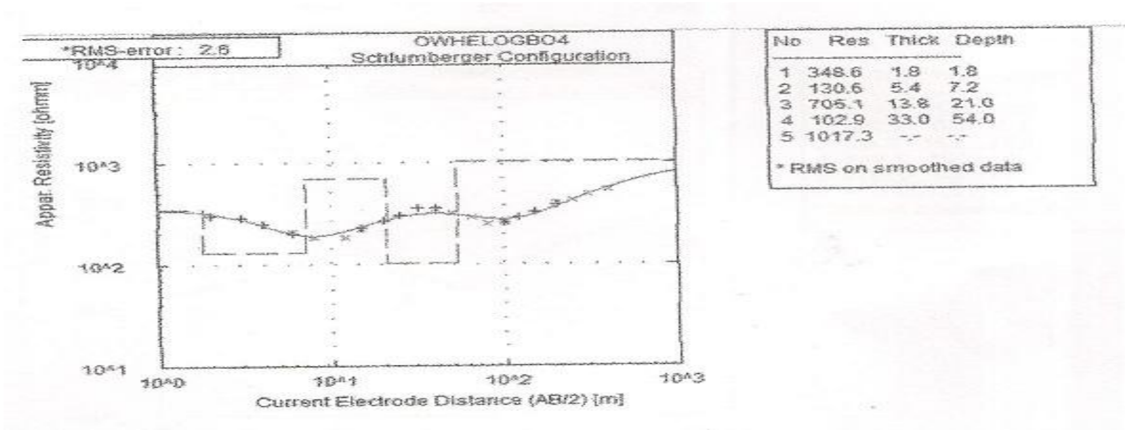

Figure 4: VES 4 for Owhelogbo

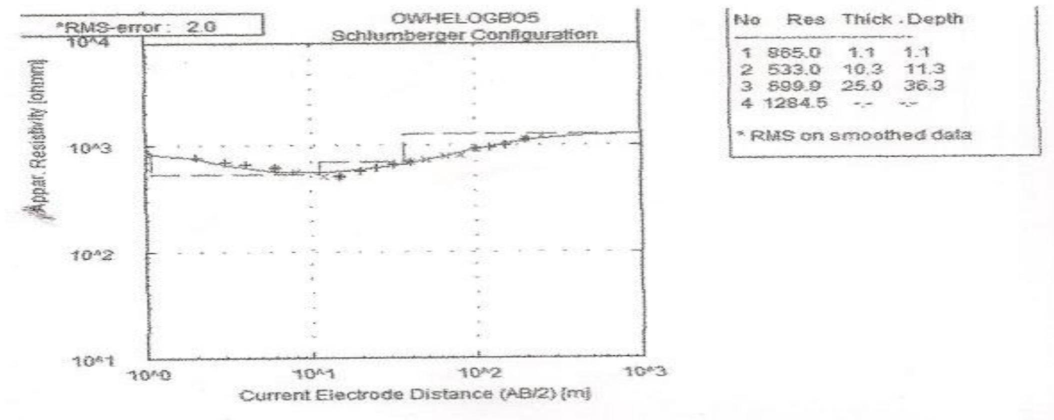

Figure 5: VES 5 for Owhelogbo

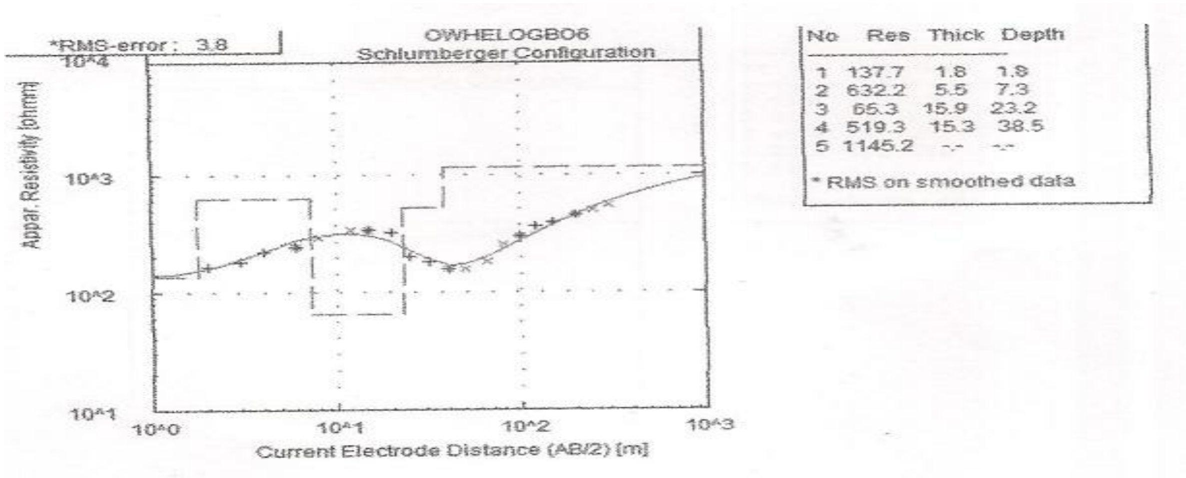

Figure 6: VES 6 for Owhelogbo

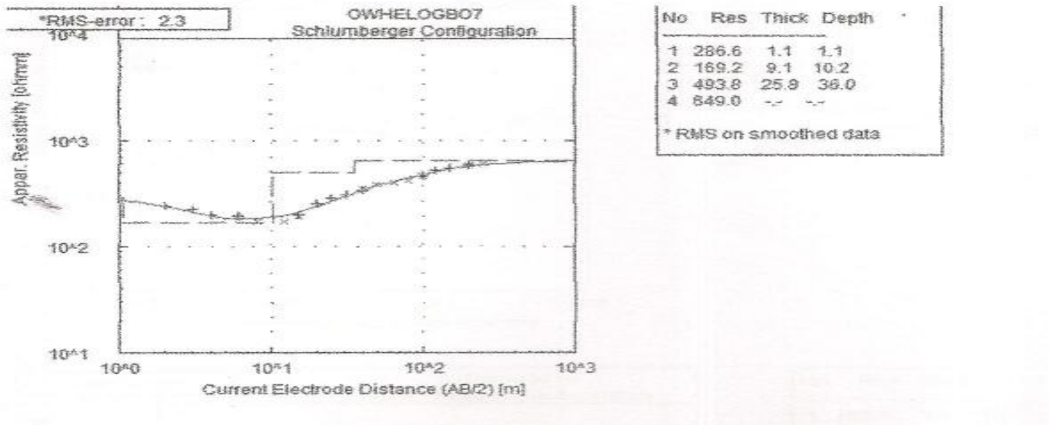

Figure 7: VES 7 for Owhelogbo

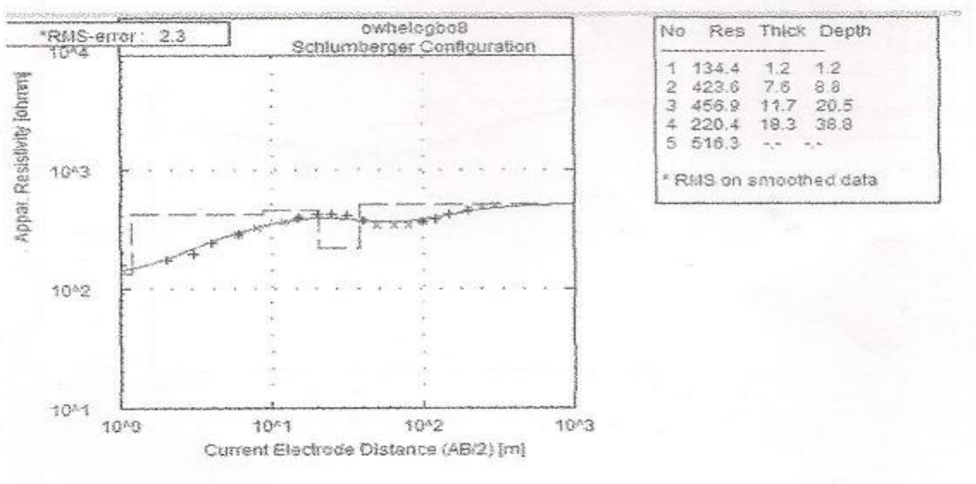

Figure 8: VES 8 for Owhelogbo

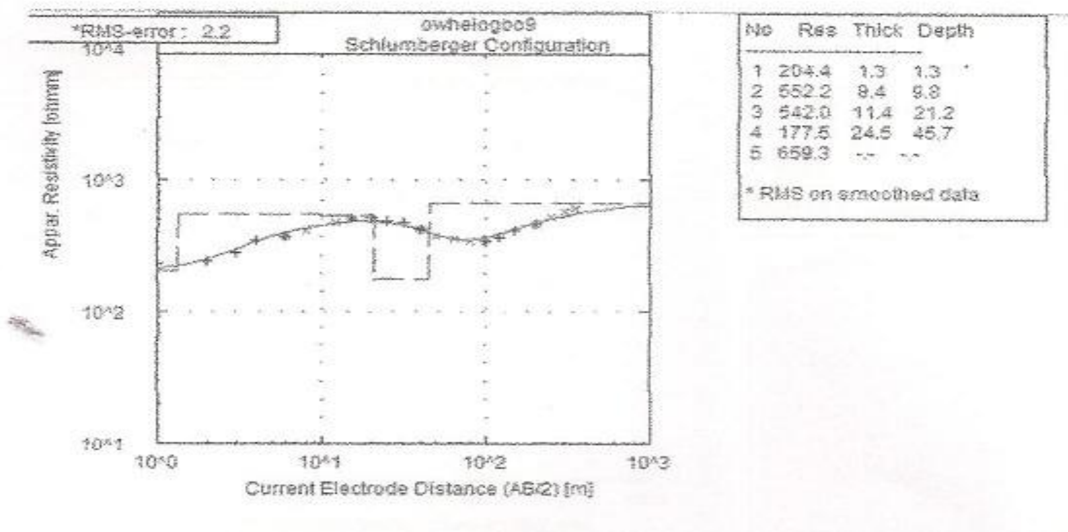

Figure 9: VES 9 for Owhelogbo

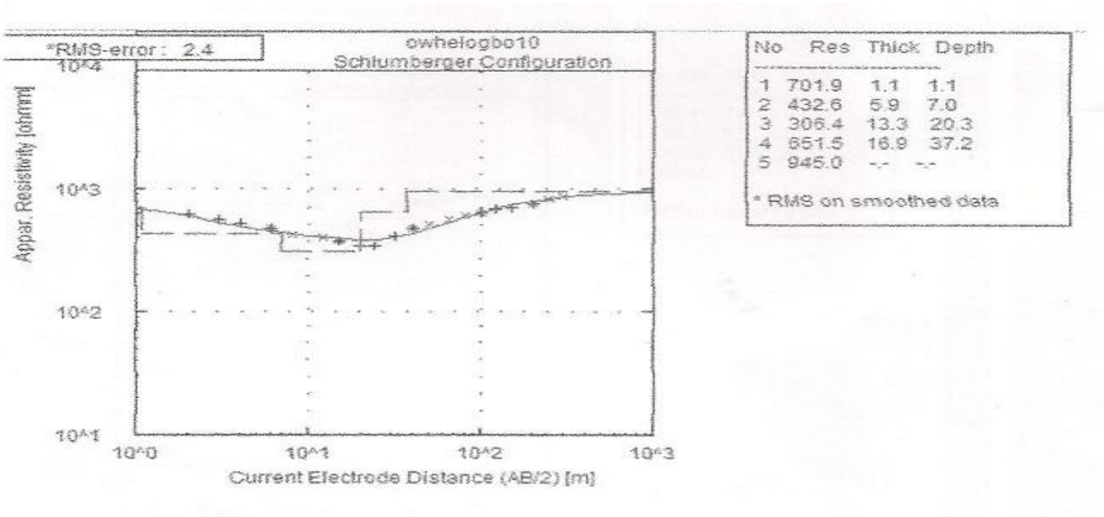

Figure 10: VES 10 for Owhelogbo

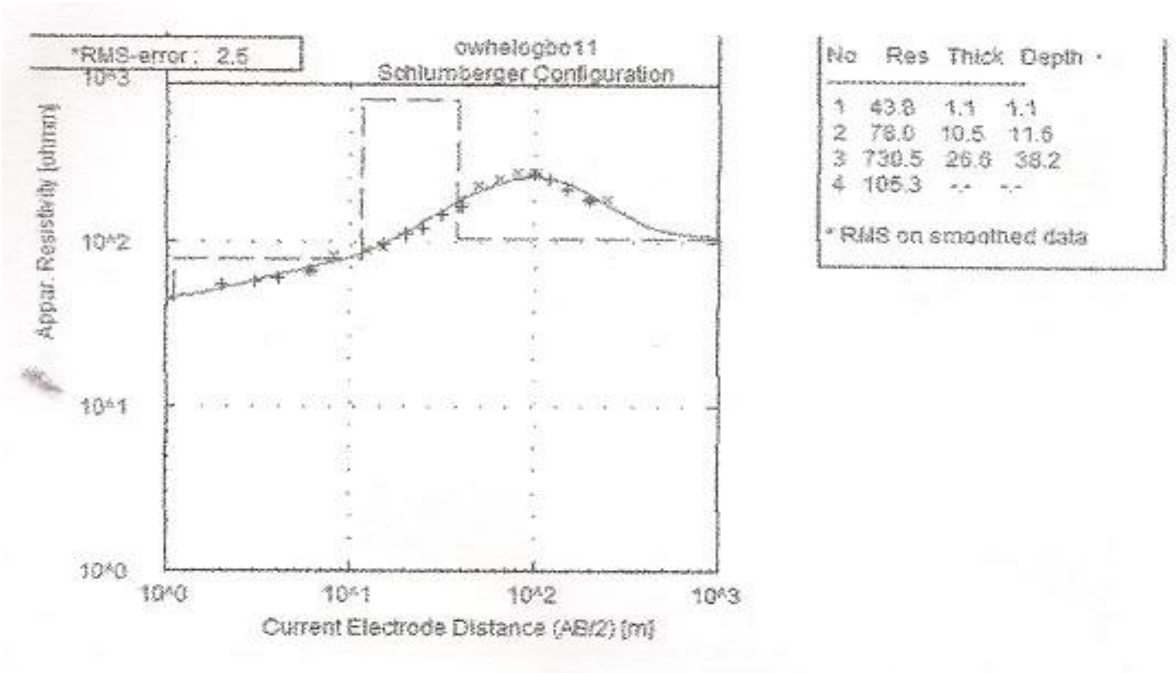

Figure 11: VES 11 for Owhelogbo

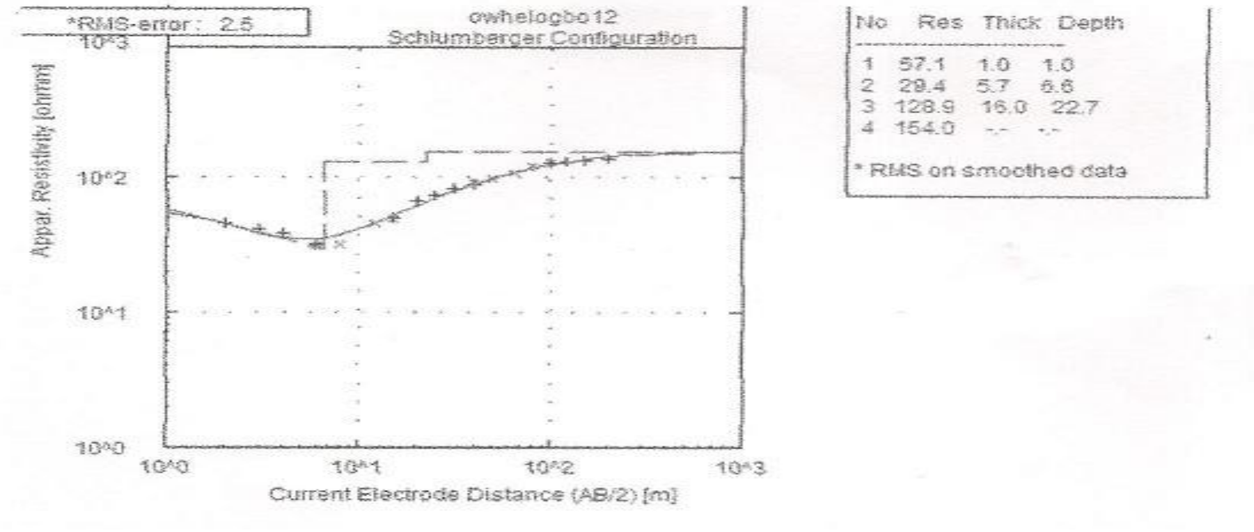

Figure 12: VES 12 for Owhelogbo

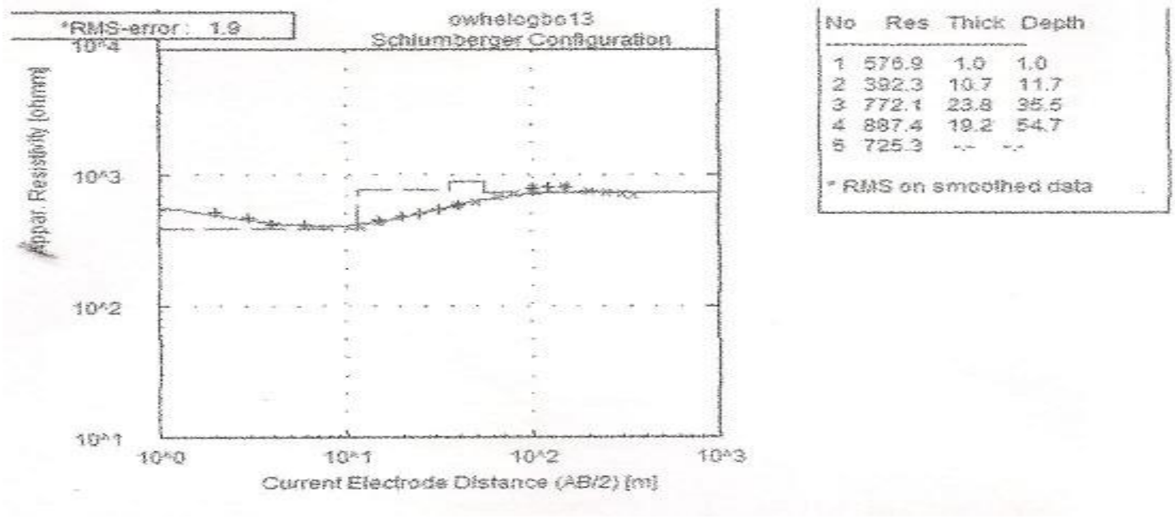

Figure 13: VES 13 for Owhelogbo