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Estimation of Aquifer Protective Capacity Using Geoelectrical Method in Odo Ona Elewe, Ibadan, Nigeria.

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Abstract
The aim of this research is to estimate the aquifer protective capacity in Odo-Ona Elewe, Ibadan, Nigeria using electrical resistivity method. Ten Vertical Electrical Sounding (VES) data were acquired using Schlumberger Electrode Configuration, the VES Data obtained were interpreted using the Win resist software. The results were analyzed using Dar Zarook parameters and Geoelectric section to identify the aquifer zone of groundwater potentiality and to estimate the aquifer protective capacity of the area. The result of the apparent resistivity measurement and interpretation show a four layered resistivity structure made up of top soil, clay/sandy clay, sandy and fresh basement. This study has identified area with good groundwater potential and moderate aquifer protective capacity. The depths of the aquifers from the geosections were within the range 6.5 to 14.0m. Major part of the study area is of moderate protective capacity, but the western side of the study area is vulnerable to pollution because of its weak aquifer protective rating.

Keywords: *Longitudinal Conductance, Transverse Resistance, Tranmisitivity, Aquifer Vulnerability, Vertical Electrical Sounding*

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I. Introduction

An aquifer is an underground layer of water-bearing permeable rock, sediments that tend to make the best aquifers include sandstone, limestone, gravel and, in some cases, fractured volcanic rocks such as columnar basalts make good aquifers while rocks such as granite are poor aquifers because they have low porosity, however, highly fractured rocks are good aquifers. Aquifer protective capacity has been defined as the capacity of the overburden unit to impede and filter percolating ground surface polluting liquid into the aquiferous unit, it is a measure of the ability of an earth medium to retard and filter percolating fluid [1], [2]. The protective capacity of an overburden is directly proportional to its thickness and inversely proportional to its hydraulic conductivity [3]. Permeable materials such as sand and gravels have high permeability, high resistivity, high hydraulic conductivity, and low longitudinal conductance, while impermeable material such as clay and shale have high longitudinal conductance values due to their low resistivity values [4]. The Longitudinal conductance (S) is a secondary geoelectric parameters which can be derive from the two primary geoelectric parameters which are layer thickness and resistivity. The total longitudinal conductance of an overburden can be obtained from equation 1[5].

$$s = \sum_{i}^{n} \frac{h_i}{\rho_i} \qquad 1$$

where h_i is the layer thickness, ρ_i is layer resistivity of the ith layer while the number of layers ranges from the surface top soil downward to the basement from i= 1 to n and n is the number of layers. The total longitudinal unit conductance values can be used to deduce the protective capacity of the aquifer in a geological location because the protective capacity is considered to be proportional to the longitudinal conductance S [1] [6]. Therefore, the higher the overburden longitudinal conductance of an area, the higher its protective capacity[3]. Longitudinal conductance has been used by many researchers to assess the protective capacity of the overburden units [2][3][6][7][8][9] and based on the longitudinal conductance values, overburden units can be classified into excellent, very good, good, moderate, weak and poor aquifer protective capacity[6][10]. Traditional methods for characterizing protective layers include test hole drilling and analysis of log, but the disadvantages of these methods are that they can be labour-intensive, expensive [11] and invasive. The electrical resistivity method is an effective and non-invasive method that can be used to investigate the aquifer protective capacity of an area, the aim of this research is to use electrical resistivity method a geophysical procedure to evaluate or determine the protective capacity of the aquifer at Odo-Ona Elewe, Ibadan, Nigeria.

II. The Study Area

The city of Ibadan is located approximately on longitude 3^05 east of the Greenwich Meridian and latitude 7^023 north of the Equator. Odo-Ona Elewe is one of the towns located in Challenge, South-East, Ibadan, Nigeria. It lies within the basement complex of southwestern Nigeria. The study area lies between longitude 7^019 0 45.0"N − 7^020 0 15.3"N and latitude 3^051 0 30.3"E − 3^052 0 25.2"E. The area is accessible as a result of availability of major and minor roads and the climate of the study area is tropical savanna climate. There are both dry and wet seasons but the wet season is longer and there is relatively constant temperature. The wet season is from March-October while the dry season is from November-February. The study area has three main landforms which are hills, plains and valleys. The tropical highs include inselbergs of granitic gneisses and steep-sloped northerly trending quartzite ridges. The study area mostly consists of generally undulating plains of elevations of about 150m and mostly underlain by Pegmatite and quartz veins. These form intervening lands between the hills and valleys which largely constitutes the draining network. The major river traverses the district in roughly north-south orientations while the streams form dendritic patterns with easterly and westerly flow directions [12] [13], figures 1 and 2 show the location and accessibility of the study area. The area under study is a flood prone zone and this is due to inadequate drainage systems in the area. The area has one major river, streams and dams which contributes to the flooding, this causes erosion and soil degradation. It has been noted that very few boreholes and hand-dug wells were located in the town and have proven to be slightly inadequate to meet the needs of the inhabitants. The alternative to clean borehole water is a river which has been polluted by human wastes from nearby refuse dump.

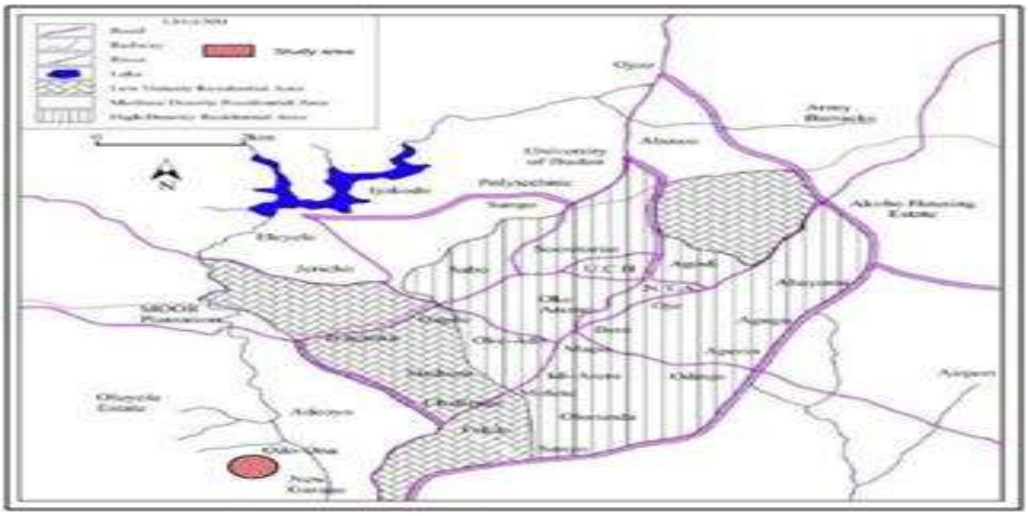

Figure 1: Map of Ibadan showing the study area [14]

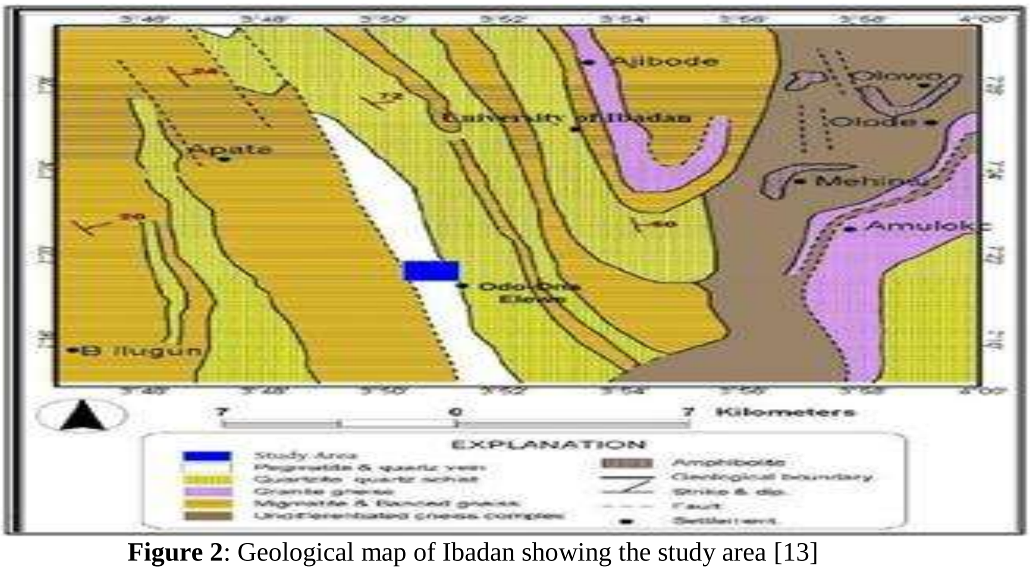

Figure 2: Geological map of Ibadan showing the study area [13]

III. Material and Method

Resistivity surveying meter and its accessories such as self rechargeable battery, measuring tape, crocodile clips, hammer, cables and four electrodes were used for the field survey. The vertical electrical sounding using Schlumberger array was used for the data acquisition, the data consist of ten VES spread across the study area as shown in the base map in Figure 3.The data obtained from the field was process using partial curve matching technique and computer iteration software computer model Win resist. Geoelectric sections and the Dar Zarrouk Parameters such as longitudinal conductance, transverse resistance (T) and transmissivity were obtained from the iteration result. The Transverse resistance (T) is a Dar Zarrouk parameter used for detection of quality ground- water potentiality. It has a direct relationship with transmissivity which implies that the highest Tranverse values would most likely be the highest transmissivity values of the aquifers or aquiferous zones. Transmissivity is the rate at which groundwater can flow through an aquifer section of unit width under a unit hydraulic gradient, it describes the ability of the aquifer to transmit groundwater throughout its entire saturated thickness A geological formation with relatively high transverse resistance values depicts high resistivity or thickness which shows favorable aquifer conditions. Transverse resistance of any geological formation is given by the product of resistivity and thickness,

$$T = \rho h \ (\Omega m^2) \qquad 2$$

The Longitudinal conductance (S) is a parameter used to define target areas of groundwater potential. The total longitudinal unit conductance values determined from equation 1 were used in deducing the aquifer protective capacity of the study area.

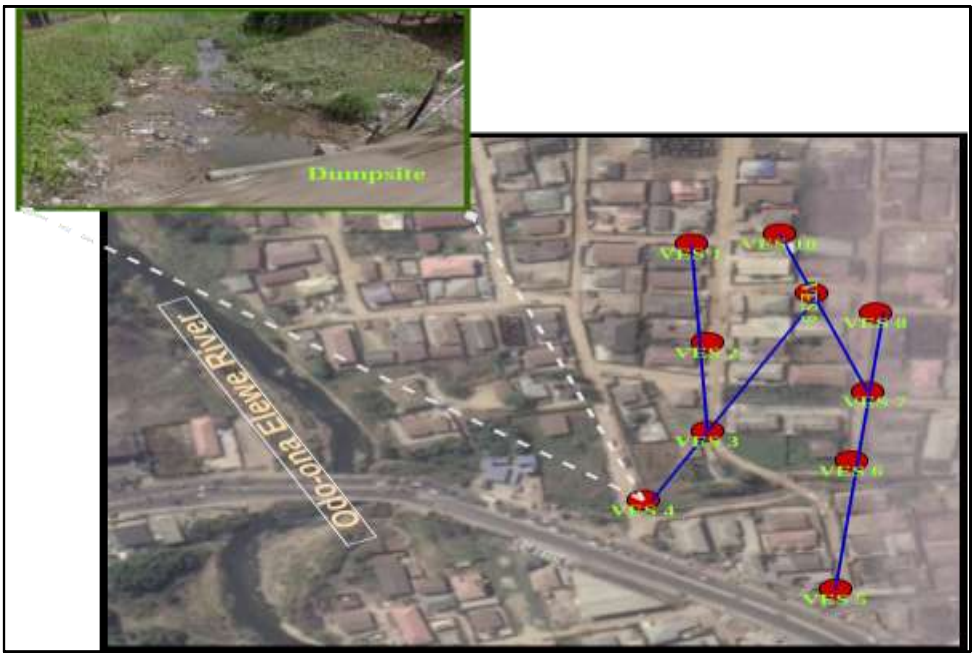

Figure3: Map of the study area showing the VES points

IV. Results and Discussion

The apparent resistivity curves revealed that curve type HA is the curve type over the entire area i.e. $\rho_1 > \rho_2 < \rho_3 < \rho_4$ having four layers. The top layer has resistivity value ranging from 13.8 to 193.9Ωm showing that it consists of clay, sandy, clay and clayey sand with layer thickness ranging from 0.4 to 1.0 m. The resistivity of the second layer ranges from 7.6 to 49.7Ωm while the thickness varies between 1.1 to 6.2 m which consists of majorly clay then sandy clay. The third layer is the weathered zone, which has resistivities from 106.9 to 1245.3Ωm while this layer thickness varies between 1.0m to 11.1 m which is most likely a good layer for groundwater exploration.

Transverse resistance (T)

The transverse resistance of the study area ranges from 390Ωm^2 to 4249.35Ωm^2. High transverse resistance value implies an aquifer that may likely have high transmissivity with quantifiable groundwater potentials. VES 2, 3, 5, and 9 with relatively high transmittivity will have good groundwater potentials, VES 1,6,7 and 8 have moderate potential while VES 4 and 10 indicate poor groundwater potentials.

Table1: Summary of the computer iteration

VES	N	ρ	t	Depth (m)	Curve type	S	T
1	1	53.5	0.8	0.8	HA		
	2	16.9	2.9	3.8			
	3	156.1	11.1	14.9		0.258	1732.71
	4	7910.9					
2	1	63.9	0.6	0.6	HA		
	2	13.1	3	3.6			
	3	260.1	9.9	13.5		0.276	2574.99
	4	10378.7					
3	1	62.7	0.4	0.4	HA		
	2	13.1	2.8	3.2			
	3	598.5	7.1	10.3		0.339	4249.35
	4	5433.2					
4	1	20.1	0.6	0.6	HA		
	2	7.6	1.3	1.8			
	3	134.7	2.9	4.7		0.222	390.63
	4	259.4					
5	1	13.8	0.5	0.5	HA		
	2	7.8	2	2.4			
	3	769.8	3.4	5.8		0.296	2617.32
	4	74935.4					
6	1	51.6	0.8	0.8	HA		
	2	13.9	2.5	3.3			
	3	318.4	5.3	8.6			
	4	34268.4				0.212	1687.52
7	1	152.1	0.7	0.7	HA		
	2	38	1.1	1.8			
	3	106.9	9.7	11.5		0.125	1036.93
	4	4640.7					
8	1	193.9	0.6	0.6	HA		
	2	49.7	6.2	6.7			
	3	1245.3	1	7.7		0.129	1245.3
	4	6656.6					
9	1	182.6	0.6	0.6	HA		
	2	18.9	4.1	4.8			
	3	445.7	5.5	10.4		0.232	2451.35
	4	15122.4					
10	1	60.3	1	1	HA		
	2	8	1.3	2.3			
	3	108.1	4.2	6.5		0.219	454.02
	4	2312					

Geoelectric sections

The Geoelectrical section 1 revealed that the profile is made up of four layers, the first layer is the topsoil which is made up of loose sand. The resistivity of this layer ranges from 60 to 186Ωm and its thickness ranges from 0.6 to 1.0 m. The second layer has resistivity of 8 to 38Ωm which is made up of clay. The aquifer is found in the third layer with resistivity ranging from 106.9 to 524.4Ωm, it is composed of fine sand formation with thickness range of 4.2 to 9.7 m the depth ranges from 6.5m to 11.5m. The last layer is the fresh basement which has resistivity range of 4219.9Ωm to 15122.4Ωm.

The Geoelectrical section 2 along profile 2 revealed that the profile is made up of four layers. The first layer is the topsoil. The resistivity of this layer ranges from 53.5 to 63.9Ωm and the thickness ranges from 0.6 to 0.8m. The second layer is clay with resistivity ranging from 13.1 to 16.9Ωm and thickness range of 2.5 to 3.8 m. The aquifer is in the third layer having resistivity range of 156.1 to 598.5Ωm and the depth ranges from 10.3 m to 14. 9m the fourth layer is the fresh basement which has resistivity range of 365.5 to 5126.4Ωm.

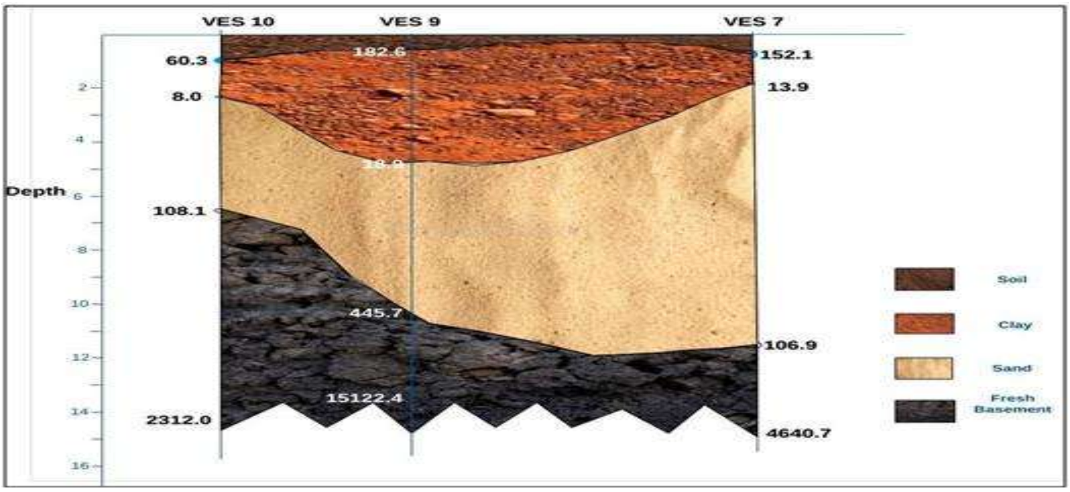

Figure 4: Geoelectric section 1

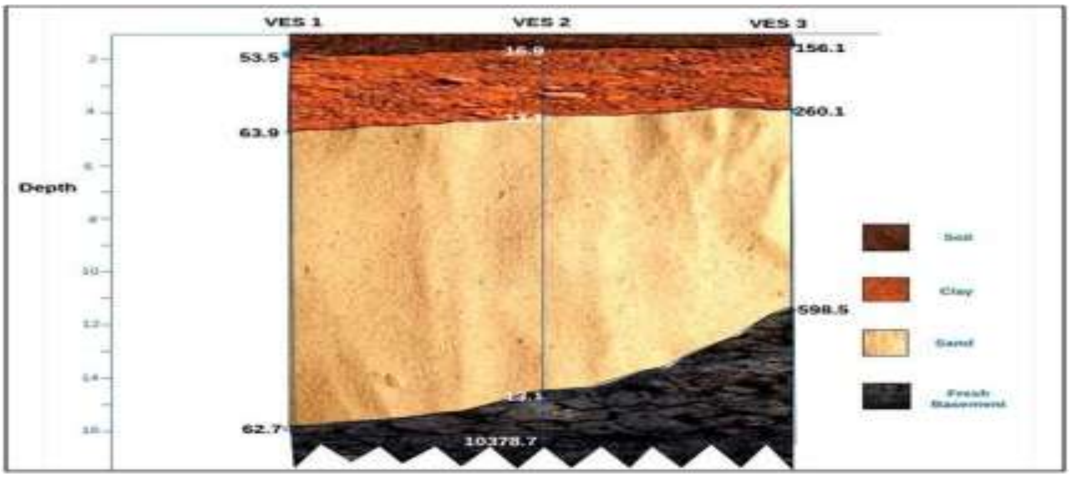

Figure 5: Geoelectric section 2

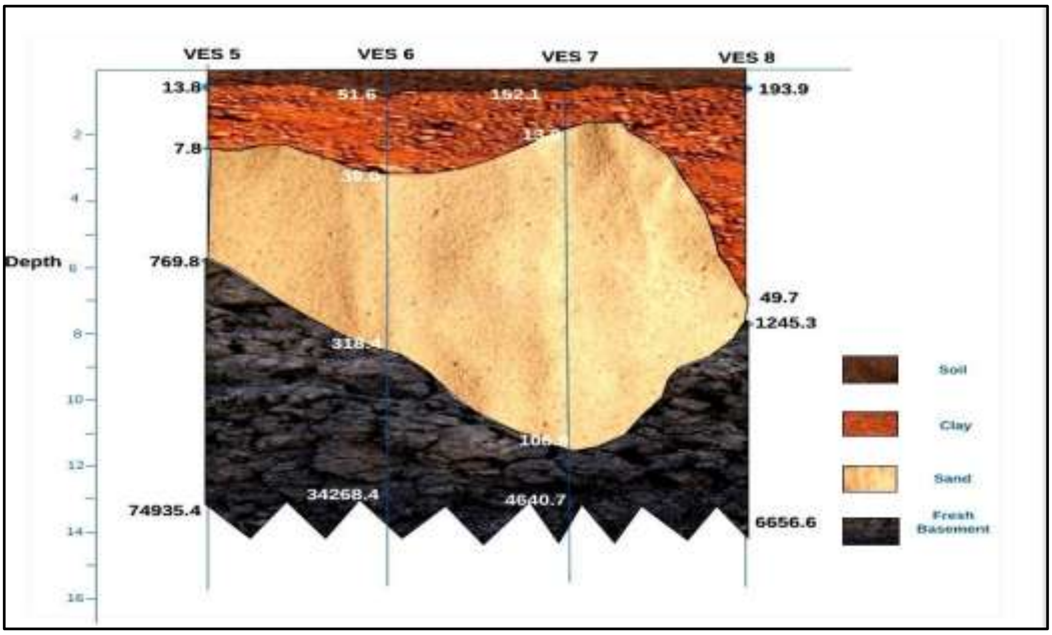

Figure 6: Geoelectric section 3

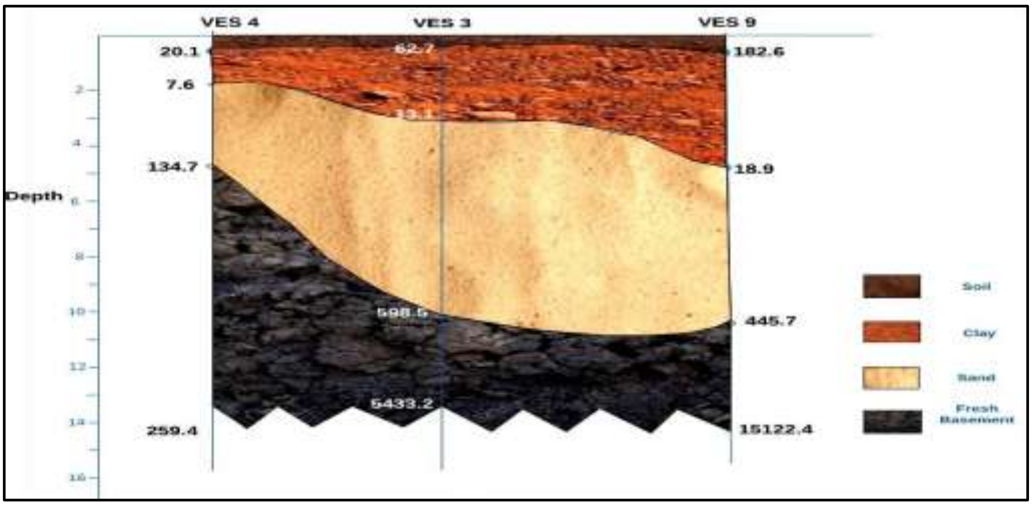

Figure 7: Geoelectric section 4

The Geoelectrical section 3 along profile 3 revealed that the profile is made up of four layers. The first layer is mainly clayey and loose sand, the resistivity of this layer ranges from 13.8 to 193.9 Ω*m* and the thickness ranges from 0.5 to 0.8m. The aquifer is found in the third layer with resistivity ranging from 106.9 to 769.8 Ω*m*, it is composed of fine sand formation with a thickness range of 1.0 to 9.7m. The depth ranges from 5.9m to 11.3m. The fourth layer is the basement having a resistivity range from 4640.7 ohm m to 74935.4 Ω*m*. The Geoelectrical section 4 along profile 4 revealed that the profile is made up of four layers. The first layer is the topsoil with resistivity ranges from 20.1 to 62.7 Ω*m* and the thickness ranges from 0.4 to 0.6m. The second layer is clay ranging from 7.6 to 18.9 Ω*m* with a thickness range of 1.3 to 4.1 m. The thickness of the third ranges from 2.9 to 7.1m with resistivity between 134.7 to 598.5 Ω*m this* layer is composed of sand, this is an aquifer at depth 4.7 to 10.4m. The fourth layer is the fresh basement which has a resistivity range of 259.4 to 15122.4 Ω*m*. From this profile, it was observed that the resistivity range in VES 4 across all layers is much smaller than in other profiles. It can be deduced therefore that this section is most likely to be contaminated due to presence of Leachate.

Longitudinal Conductance (S)

The Longitudinal Conductance ranges from 0.125 to 0.339(Table 1), these values were used in evaluating the aquifer protective capacity rating of the study area according to (Oladapo and Akintorinwa 2007). The area with longitudinal unit conductance less than 0.1 mhos is rated as having poor aquifer protective capacity, the zones which have conductance value ranging from 0.1 and 0.19 mhos is classified as zones of weak protective capacity, where the conductance value ranges between 0.2 and 0.69 mhos is classified as zones of moderately protective capacity and where the longitudinal unit conductance value is greater than 0.7 mhos, the layers are adjudged zones of good protective capacity (Oladapo and Akintorinwa, 2007).

Areas that are classified poor and weak are vulnerable or susceptible to contamination and areas that are classified moderate are less susceptible to contamination.

VES 7 and 8 towards the western side of the study area have conductance 0.125 and 0.129 mhos respectively hence it is classified as zone of weak protective capacity, these zone is unprotected and vulnerable to contaminants. It implies therefore that the aquifer in these locations are vulnerable and unprotected to contamination from infiltration of Leachate from decomposed.

The aquifer overburden protection capacity rating in the vicinity of VES 1,2,3,4,5,6,9 and 10 is moderate (0.212 - 0.339), implying that the aquifer in these locations are less vulnerable to pollution through infiltration of leachate.

V. Conclusion

The electrical resistivity an efficient non invasive geophysical method has been used to investigate the aquifer protective capacity in Odo-Ona Elewe, Ibadan, The result of the apparent resistivity measurement and interpretation gave a four layered resistivity structure made up of a sandy top soil, clay, sandy and fresh basement. This study has identified area with good groundwater potential and moderate aquifer protective capacity. The depths of the aquifers from the geosections were within the range 6.5 to 14.0m. VES1, 2, 3, 4,5,6,9 and 10 have were recommended because they have relatively high thickness of both weathered zone and fractured zone respectively, because it has thick sequence of weathered zone and fractured basement, a relatively high transmissivity value which imply good groundwater yield and it has moderate protective capability against pollution

VES 7 and 8 towards the cannot be recommended for borehole drilling because of its low groundwater yield and its weak aquifer protective rating.

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