Journal of the Nigerian Association of Mathematical Physics
***Volume 64, (April – September, 2022 Issue*), pp39 – 44**

AQUIFER CHARACTERIZATION ANALYSIS USING GEOELECTICAL PARAMETERS: A CASE STUDY OF OLABISI ONABANJO UNIVERSITY, SOUTHWESTERN NIGERIA

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Abstract

The groundwater potential and protective capacity of road 4 Olabisi Onabanjo University premises was investigated using Electrical resistivity method. The method was used to determine the depth to basement of locations in the study area to delineate possible groundwater potential and its protective capacity. Ten (10) VES were conducted using Schlumberger configuration for the data acquisition at 5 m interval from each station using SAS 1000 terrameter. The field data were analyzed using manual and computer iterations. The Geo-electrical parameters analyzed include resistivity and thickness of Topsoil, Weathered and Fractured/Fresh basement resistivity and thickness and depth to basement. The interpretation delineates three layers overlying the fresh basement. These layers are topsoil, weathered layer and the fresh basement. The topsoil has resistivity values that range between 59.6-1013.5 Ωm with thickness range of 0.7-2.7 m, weathered layer has the resistivity value ranging from 53.4-266.2 Ωm with thickness ranging from 8.8-30.2 Ωm which is composed of medium sand with few clay. The curve types obtained were KH, HA and H with about 60% of KH curve. The last layer has the resistivity value of 307.8-2329.6 Ωm. The longitudinal conductance, hydraulic conductance, transmissivity and overburden thickness values and maps were also generated to characterize the aquifer of the study area. The protective capacity rating of the study area is rated poor, weak and moderate, but the moderate zones have the highest portion of the study area. VES 1, 2, 5 and 6 were grouped as moderate groundwater protective zones and it's located at the northern part of the study area. The depth to basement ranges between 12.5-36.1 m while the overburden thickness values ranges between 8.8 to 30.2 m. The study area is said to have good groundwater potential and protective capacity.

Keywords: Aquifer, Protective Capacity, Geo-electrical parameters, Electrical resistivity

INTRODUCTION

Groundwater is regarded as the water that lies underneath the ground surface. It is known to fill the pore spaces between grains in sedimentary rock bodies and filling cracks, crevices in all rock types [1]. The primary source of groundwater is rain and snow that falls to the ground. In this process, a portion of it finds its way down into the ground to bcome groundwater. So an aquifer can be described as an underground layer of water bearing permeable rock, rock fractures or unconsolidated materials. It can be regarded as a body of saturated rock through which water can move easily. This is the major source of water that human lives on.

Groundwater, if properly exploit is so abundant to serve the entire nation as it is freely available and remains the only source of freshwater [2]. The need for portable water supply to human health is paramount, it is important to put into consideration the quality of the geological material overlying the aquifer and its protective capacity with the use of parameters like resistivity layers and thickness to compute its longitudinal conductance and transverse resistance [3]. The combination of these parameters may be useful in detecting the protective capacity (the protection of groundwater reservoir). An effective groundwater is a function of its protective layers with enough thickness and low hydraulic conductivity. There are many factors contributing to difficulties in development of groundwater resources in hard rock

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terrains; such factors include wide and erratic variation of vital parameters (e.g. fractures, joints, porosity etc.) characterizing the groundwater regime [4]. Therefore, in hard rock terrains, groundwater aquifer depends majorly on the thickness of the weathered/ fractured layer overlying the basement. The weathered layer which constitutes the overburden has high porosity and contains a significant amount of water and likewise presents low permeability due to its relatively high clay content.

Geophysical techniques have been found useful in assessing aquifer vulnerability especially the electrical resistivity method. This method if properly analyzed can reveal the physical properties of the earth's interior as it varies vertically and laterally and reflecting the subsurface geology of the study area [5], [6].

However, this research work aimed at determining the geo-electric parameters of the subsurface layers and analyzing the geo-statistical parameters to characterize the aquifer and evaluate the protective capacity of the overburden materials of the study area.

Location and Geology of the Study Area

The study area is located at the premises of Olabisi Onabanjo University, Ago-Iwoye. The study area is Road 4 behind banks buildings in the permanent site. The study area is situated in Ago- Iwoye. Ago-Iwoye and its environs is one of the urbanized towns in Ijebu north local government of Ogun State which falls within the Precambrian Basement Complex of Nigeria. The study area lies within latitude 6.55966 to 6.55984N and longitude 3.55648 to 3.55676E. The study area is easily accessible through major road, footpaths and minor roads.

The available rocks are mainly Migmatite Gneisses, Biotite Gneisses and Hornblende Gneiss [7]. The Gneiss constitutes the major rocks intended by the other groups of rocks. The basement complex is one of the three major litho-petro logic components that make up the geology of Nigeria. The geological map of Nigeria shows the various available terrains in Nigeria (Figure 1) and the map of Ogun State showing the study area (Figure 2).

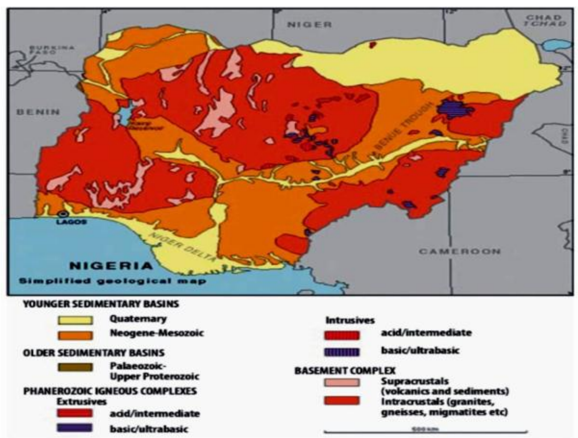

Figure 1: Geological Map of Nigeria[8] (Ajibade, 1979)

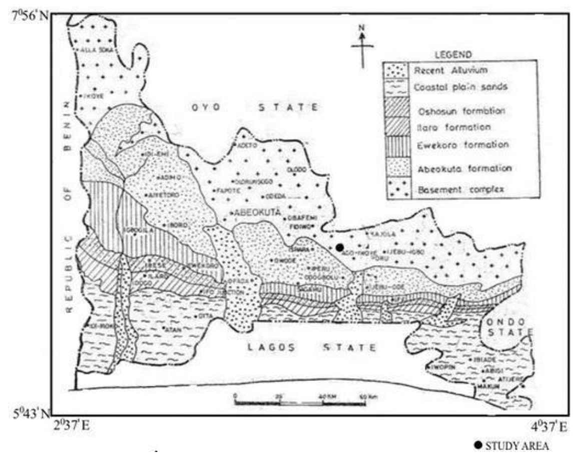

Figure 2: Geological map of Ogun State showing the study area [9]

Materials and Methods

Electrical resistivity method using the Vertical Electrical Sounding (VES) technique (Schlumberger configuration) was adopted for this research. Current were injected to the ground using the current electrode and the potential electrode for the resultant potential difference. A total of ten (10) VES stations were occupied. ABEM SAS 1000 terrameter was used for acquiring the data on site. The field procedure involved applying current to the ground through two electrodes A and B and also measuring the resultant potential difference between the potential electrodes M and N. The center point of the electrode array remained fixed but the spacing of the electrodes was increased so as to obtain information about the stratigraphy of the ground [10]. The data were analyzed by firstly plotting the data on the log-log graph sheet for smoothening and which it was subjected to WinResist computer software for iteration to obtain the best fit. This assisted in obtaining the lithology and thickness of each layer. The combination of the resistivity and layer thickness was used to compute the geo-electric parameters and the geo-statistical analysis [11].

The longitudinal conductance values were used in evaluating the protective capacity of the aquifer using the formula

$$S = \Sigma(hi|\rho i) = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} + \cdots + \frac{hn}{\rho n} \ldots\ldots\ldots\ldots(1)$$

Where

S is the total longitudinal conductance

Σ is the summation sign

h_i and ρi are the thickness and resistivity of the ith layer respectively

Table 1: Longitudinal Conductance /Protective Capacity Rating [3]

Total Longitudinal Conductance(Mhos)	Overburden Protective Capacity
< 0.10	Poor
0.1-0.19	Weak
0.2-0.69	Moderate
0.7-1.0	Good

Results and Discussion

Summary of the inferred lithology obtained from the processed VES result is presented in table 2. The result of the study area delineated three to four layers namely topsoil, sand/sandy clay, clay/sandy clay and basement. Typical forms of curves present in the study area are KH, HA and H. From table 2, the top layer has thickness and resistivity values ranges between 0.7- 2.7 m and 59.9- 1013.5 Ωm. The second layer has thickness and resistivity values ranges between 2.8-11.2 m and 62.5-905.9 Ωm respectively. It consists mainly of sand and sandy clay on other profiles. The third layer comprises of medium sand with few clay lenses, it appears to be the major water bearing layer with thickness and resistivity values ranges between 8.8- 30.2 m and 53.4- 266.2 Ωm. The last layer for this study area has resistivity values ranges between 307.8-2329.6 Ωm which is basically basement.

The VES result was also used to compute the longitudinal conductance, hydraulic conductivity and transmissivity.

Table 2: Summary of the Inferred Lithology of the Study Area

VES	Resistivity (Ωm)	Thickness(m)	Depth (m)	Lithology	Curve Type
VES 1	250.9	0.9	0.9	Topsoil	KH
	368.8	3.9	4.8	Sand	
	79.8	20.4	25.2	Clay	
	307.8			Basement	
VES 2	418.5	1	1	Topsoil	HA
	399.8	4.7	5.7	Sand	
	61.4	12.6	18.4	Clay	
	1963.1			Basement	
VES 3	1013.5	1.9	1.9	Topsoil	HA
	116.1	11.2	13.1	Sandy Clay	
	124.9	10.7	23.8	Sandy Clay	
	1538.2			Basement	
VES 4	180.6	0.8	0.8	Topsoil	KH
	255.6	3.9	4.7	Sand	
	155	11.3	16	Sandy Clay	
	675.4			Basement	
VES 5	59.6	0.7	0.7	Topsoil	KH
	272.6	4.6	5.3	Sand	
	53.4	16	21.3	Clay	
	724.8			Basement	
VES 6	154	0.7	0.7	Topsoil	KH
	353	5.1	5.8	Sand	
	161.5	30.2	36.1	Sandy Clay	
	462.4			Basement	
VES 7	235.7	1.7	1.7	Topsoil	HA
	160.6	18.4	20.2	Sandy Clay	
	1382.5			Basement	
VES 8	284.2	2.7	2.7	Topsoil	H
	62.5	10.3	13	Clay	
	2329.6			Basement	
VES 9	511.9	1	1	Topsoil	
	905.9	3.4	4.4	Sandy	KH
	266.2	27.3	31.6	Sandy clay	
	479.4			Basement	
VES 10	170.4	0.8	0.8	Topsoil	KH
	446.9	2.8	3.6	Sandy	
	172.5	8.8	12.5	Sandy Clay	
	432.6			Basement	

Geo-electric section

The geo-electric figure presented in figure 3 represent geological or lithological layers present in the study area; it is a diagrammatic illustration of the subsurface information. The image is called geo-electric section. The geo-electric section represents the depth, thickness of the underlying lithology and their respectively resistivity values.

This profile is made up of 10 profiles from VES 1 to VES 10, the topsoil of this profile has a resistivity value ranging from 170.4 Ωm (at VES 10) – 1013.5 Ωm (at VES 3) which is an indicative of Sandy clayey to Lateritic topsoil layer and it ranges from depth of 0.7 m to 1.9 m. The weathered layer comprising of clayey, sandy clayey, clayey sand, sandy layer makes up the second layer. This layer has a resistivity value ranging between 53.4 Ωm (at VES 5) -905.9 Ωm (at VES 9). The basement layer which is the last layer shows an approximate elevated resistivity value range between 161.5 Ωm (at VES 6) -1963.1 (at VES 2).

Considering the depth to basement encountering at each of the established point it can be seen that the overburden thickness (depth to basement) has the highest value at VES 6 with depth of 36.1 m and has its lowest value at VES 10 with depth of 12.5 m

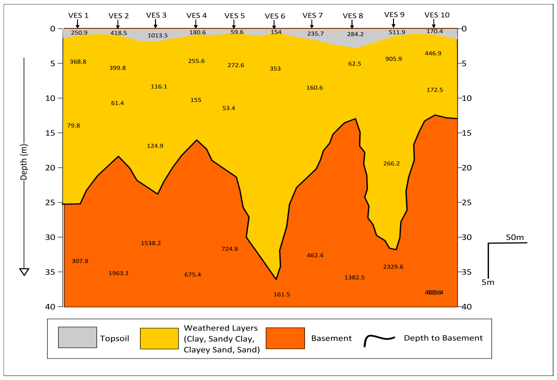

Figure 3: Geo-electric section of the study area.

Groundwater Protective Capacity Evaluation

The longitudinal conductance was deduced from the acquired data using equation 1 and parameters like the thickness and resistivity of each layer. Likewise the hydraulic conductivity and transmissivity values were also obtained. The summary of the parameters were presented in table 3. The longitudinal conductance ranged between 0.0620 to 0.328 mhos in the study area. The weak protective capacity is observed at VES 3, 7, 8 and 9 while the poor protective capacity was observed at VES 4 and 10. The VES with moderate protective capacity are 1, 2 and 5 which represents good aquifer protective capacity. The bar chart shown presents it clearly in figure 4. The overburden thickness ranged from 8-8-30.2 m (Table 3). This range of high overburden thickness indicates possible high groundwater potential and high protective capacity. The profiles with poor protective capacity may be a result of thin layer of impervious material protecting the aquifer.

Table 3: Summary of the geo-electric parameters

VES NO	**Top layer Resistivity(Ωm)**	**Top layer Thickness(m)**	**Weathered layer res(tivity Ωm)**	**Bedrock restivity (Ωm)**	**Aquifer thickness (m)**	**Overburden Thickness(m)**	**Long. cond.(S)**	**Hydraulic Cond.x10-^{23}(m/s)**	**Transmissivityx10^{24}**
1	250.9	0.9	79.8	307.8	20.4	20.4	0.270	1.760	3.65
2	418.5	1.0	61.4	1963.1	12.6	12.6	0.219	1.308	1.65
3	1013.5	1.9	116.1	1538.2	10.7	10.7	0.184	3.057	3.27
4	180.6	0.8	155.0	675.4	11.3	11.3	0.0925	3.957	4.47
5	59.6	0.7	54.4	724.8	16.0	16.0	0.328	1.107	1.77
6	154	0.7	161.5	462.4	30.2	30.2	0.206	4.156	1.38
7	235.7	1.7	160.6	1382.5	18.4	18.4	0.122	4.130	1.25
8	284.2	2.7	62.5	2329.6	10.3	10.3	0.174	1.337	7.8
9	511.9	1.0	266.2	479.4	27.3	27.3	0.108	7.550	1.38
10	170.4	0.8	172.5	432.6	8.8	8.8	0.062	4.497	2.06

Table 4: Geo-statistics of Aquifer Protective Capacity Rating

Range	Mean	Median	Mode	S.D	Variance	Skewness
59.6-1013.5	327.88	243.3	1013.5	274.285	75232.28	1.994087
0.7-2.7	1.22	0.95	0.7	0.664664	0.441778	1.505731
53.4-266.2	128.9	135.55	266	67.28151	4526.802	0.731589
307.8-2329.6	1029.58	700.1	2329	719.941	518315	0.809776
8.8- 30.2	16.6	14.3	30.2	7.430567	55.21333	0.899867
0.062- 0.328	0.17655	0.179	0.219	0.083175	0.006918	0.437143
1.38- 4.47	2.868	1.915	1.38	2.05622	4.22804	1.759564
1.10- 7.55	3.288	3.505	7.55	2.009211	4.036929	0.88628

Table 4 shows the Geo-statistics of Aquifer protective capacity rating. The longitudinal conductance obtained from the study area ranges from 0.062- 0.328 mhos and from the table 3, it is seen that about four VES Points has protective capacity. The standard deviation ranges from 0.08-719 which is an indication of positively skewed preference.

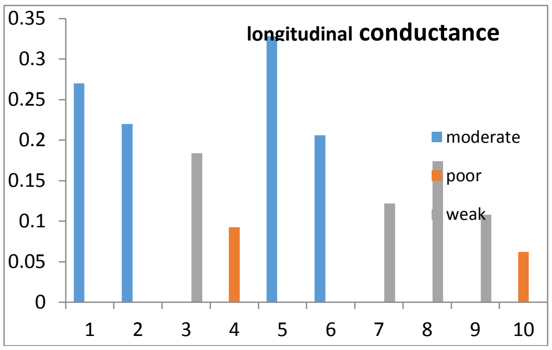

Figure 4: Bar chart of the longitudinal conductance

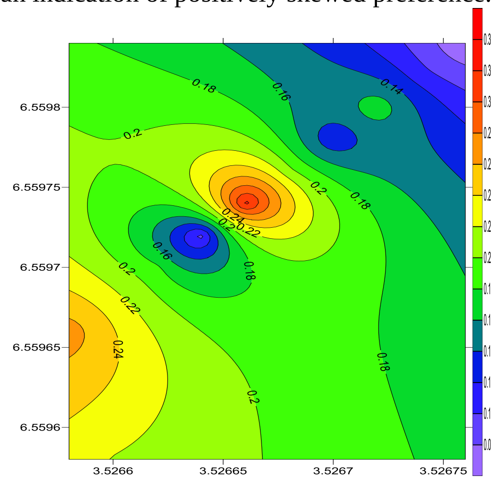

Figure 5: Longitudinal conductance map of the study area

Hydraulic Conductivity (K)

Hydraulic conductivity (K) is the measure of flow under a unit hydraulic gradient through a unit cross section area of an aquifer. It measures the ability of underlain materials to transmit water.

Mathematically, it is expressed as

$K = 95.5 \times 10^{9} \rho^{1.195}$……….. (2)

Where ρ is the resistivity of the porous layer in Ωm [12]

The hydraulic conductivity obtained for the study area has a range of $1.1\text{x}10^{23}$ to $7.5\text{x}10^{23}$ m/s. From literature, we understand that hydraulic conductivity is directly proportional to resistivity, therefore, as hydraulic conductivity K increases; the resistivity ρ also increases unlike in longitudinal conductance. According to [13], hydraulic conductivity values ranging from 1.0 to 10.0 and resistivity value range between 100 to 300 Ωm is said to be good potential water zone, it can be concluded that this study area has good potential water zone has it falls within the range especially points around VES 1,4,5 and 6 and 8.

Transmissivity

It is the rate of flow under a unit hydraulic gradient through a unit width of aquifer of thickness h. it is directly proportional to hydraulic gradient with the equation T= Kh where h is the thickness. The range of transmissivity for the study area is 1.38×10^{24} to $7.8 \text{ x}10^{24}$ m^2s^{-1} . The transmissivity value increases towards the northern part of the map (Figure 6). The value is high at VES 1, 4 and 8 which is almost similar to the hydraulic conductivity analysis.

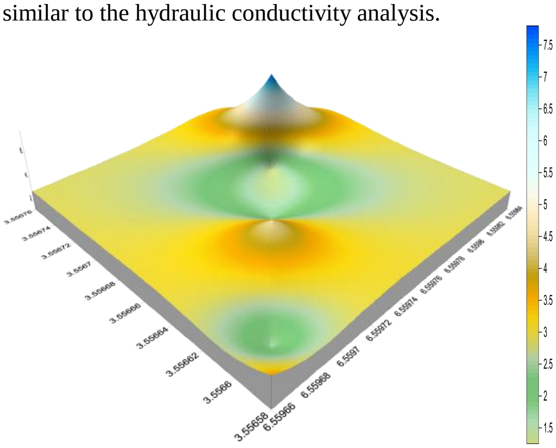

Figure 6: 3D Transmissivity map of the study Area

Overburden Thickness Map

In general, areas having thick overburden and low amount of clay in which the inter-granular flow is dominant are said to be areas of high groundwater potential; and it is particular in basement complex terrains [14]. The materials above the fresh basement are the overburden. In most cases, it is used in ranking geology formation that has enough water as the volume of water from each VES points is a function of aquifer thickness [15]. Figure 7 shows the overburden map and its thick at the northern and western part of the map depicting good groundwater potential zone as shown in the map.

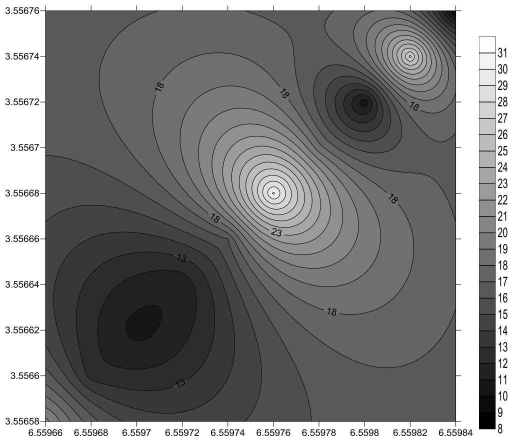

Figure 7: Isopach Map (Overburden thickness)

Conclusion

Electrical resistivity method using the Vertical Electrical Sounding techniques has been used to carry out ten (10) stations in road 4 of Olabisi Onabanjo University, Ago-Iwoye, and Southwestern Nigeria. The fractured and weathered layer horizons constitute the aquifer zones and as such have been identified in the area underlying the VES stations. Good prospects exist for groundwater development in the study area and the protective capacity of the aquifer are classified as high, moderate and weak, where 80% of the VES points are moderate from the result analysis. The depth to basement is relatively thick and exhibit low resistivity values. Based on the interpreted results of the VES survey conducted, the geo electrical parameters (longitudinal conductance, transmissivity and hydraulic conductivity) were deduced to characterize the aquifer. The weathered resistivity has a range of 53.4-266.2 Ωm while the overburden thickness ranges from 8.8-20.8 m.

In conclusion, the study reveals that larger percentage of the study area has good groundwater potential and good protective capacity. A well conducted geophysical survey is encouraged to promote the prospect of locating high yield zones and protective capacity rating. It is also needed to minimize failures, dry holes and loss of money.

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