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Geophysical Investigation for Groundwater Potential and Aquifer Protective Capacity around Osun State University (UNIOSUN) College of Health Sciences

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Abstract Geophysical investigation was carried out around the University Health Sciences of the Osun State University, Osogbo using the Schlumberger technique of the electrical resistivity method. The aim of the study was to evaluate the groundwater potential and to access how protected the aquifer in the area could be to surface pollutants. Four (4) vertical electric sounding (VES) data were acquired within the study area. The VES data acquired were interpreted using the WinResist iterative software. The result revealed KHA-type curve in VES 2, VES 3 and VES 4 with aquifer resistivity values of 97.6 Ωm, 20.7 Ωm and 142.2 Ωm respectively and HA-type in VES 1 with aquifer resistivity of 27.5 Ωm. The area under investigation consists of a lateritic topsoil of varying thicknesses which is underlain by a weathered layer and finally the fresh basement. VES 4 is would yield considerable amount of groundwater if developed to a depth of between 15 m to 20 m to take advantage of the basement fractures due to its thick aquiferous zone and the very low resistivity exhibited by the aquifer layer. The result also shows that the aquifers in VES 1 and VES 4 shows evidence of weak aquifer protective capacity having longitudinal conductance of 0.149 and 0.129 respectively with corresponding transverse resistance of 112.75 and 780.80. This suggests that the study area might show good potential for groundwater but the groundwater is not safe. For groundwater development, adequate measure should be made to establish water treatment facility.

Keywords: *UNIOSUN, health sciences, aquifer, resistivity, protective, thickness, groundwater*

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1. Introduction

Water remains one of the vital elements in life. It is very much vital to human existence. It is one natural resource that is not only essential for the survival of mankind but also for the survival of the natural environment. The availability of water has played a key role in the development of all civilizations. Indeed, especially in the ancient times, water scarcity prevented the development of settlements [18]. Social welfare and economic development may also be hampered in the absence of reliable water supplies. This is particularly true of sub-Sahara and Sahara countries, such as Nigeria, where water resources are extremely limited and highly valued as a social and economic good. [7] observed that more than two billion people worldwide depend on groundwater for their daily water supply, and a large proportion of the world's agricultural and industrial water requirements are supplied by groundwater. Higher agricultural use of water has been in the aspect of irrigation of farmlands. Due to the limited water resources, the role of macroeconomic policies in agricultural water management is vital and undeniable. Africa has the most population growth in the world while, actual crop yield as percentage of potential yield is 40 % for North Africa and it is\30 % for Sub-Saharan Africa [5]. However, amount of irrigation-equipped areas as share of cultivated areas is low in the world. In addition, agricultural water management has been done poorly in some areas. [19] observed that the amount of irrigation-equipped areas as share of cultivated areas in Africa is significantly lower than Asia and the world. Percentage of areas actually irrigated as share of irrigation-equipped areas shows that more than 30% of irrigation-equipped areas are not used for irrigation with Africa having about 20% for Africa. [20] also stressed the relations between water and other development-related sectors such as population, energy, food, and environment, and the interactions among them require reckoning, as they together will determine future food security and poverty reduction.

According to [9], since 1960, access to pumped wells has caused a rapid worldwide increase in groundwater development for municipal, industrial, and agricultural purposes. The global use of groundwater was estimated to be

750–800 km3/a [16,17]. In recent times, many organizations worldwide depend on groundwater for use due to several factors. Some of these include increase in population, inability of government to provide adequate water supply for use and high cost of providing this resource from surface water. According to the U.S. Census in 1990, close to 80% of the water use for students ‘everyday is partly or wholly from groundwater. It was also estimated that ninety-five percent of Virginians in the suburbs harness their personal water supply from wells. In fact, 38 of Virginia’s 95 counties are completely dependent on groundwater for public water supplies. The health sector also has been affected. In the US, it is believed that water used in hospitals and other health care facilities accounts for about seven percent of the total water use in commercial and institutional facilities [4]. Within the hospital system, water is used in cooling equipment, plumbing fixtures, landscaping, and medical process rinses. However, in the last ten years, the costs of water and wastewater services have risen at a rate well above the consumer price index. And so, quite a number of hospitals have depended on harnessing their water use from groundwater. Coupled with this is the special preference given to groundwater due to its tendency to be free from contamination. Groundwater obtained from within the aquifer is believed to be free and safe from all forms of contamination due to its being confined within the subsurface. Hence, it has been the choice of those within the health sector.

Conventionally, the easiest and most convenient way to meet public demand for water are rivers and lakes, less than 0.01 percent of the world’s total water and less than two percent of the world’s fresh water. It is distributed spatially and temporarily in on an irregular manner while the sources available has often been polluted. Groundwater on the other hand accounts for about ninety eight percent of the world’s reasonably constant supply, which is not likely to dry up under natural conditions in the crust to the surface sources. The groundwater on the contrary is significantly protected from surface pollutants as earth media (composed of different subsurface layers) acts as natural filter to infiltrated water. It is very rarely cheaper to be developed. Interestingly, the volume of ground water is considerable. [14] puts its volume two thousand time that of the volume of water in all world’s river at any given time. Groundwater development therefore constitutes a viable option or supplement to the expensive earth/ concrete dam system of surface water supply where potential groundwater is good.

This study is embarked upon to provide water for use in the vicinity of the College of Health Sciences facility of Osun State University, Osogbo where health facilities require quite a large amount of water for use on a daily basis. It is used for a number of purposes that include cleaning of paramedical equipment, washing of utensils, sterilizing equipments, maintaining health and toilet facilities in the College. There exists no access to pipe borne water facility within the infrastructure due to the fact that the infrastructure is one of the newly constructed blocks within the university. Hence the need for groundwater development for their immediate use.

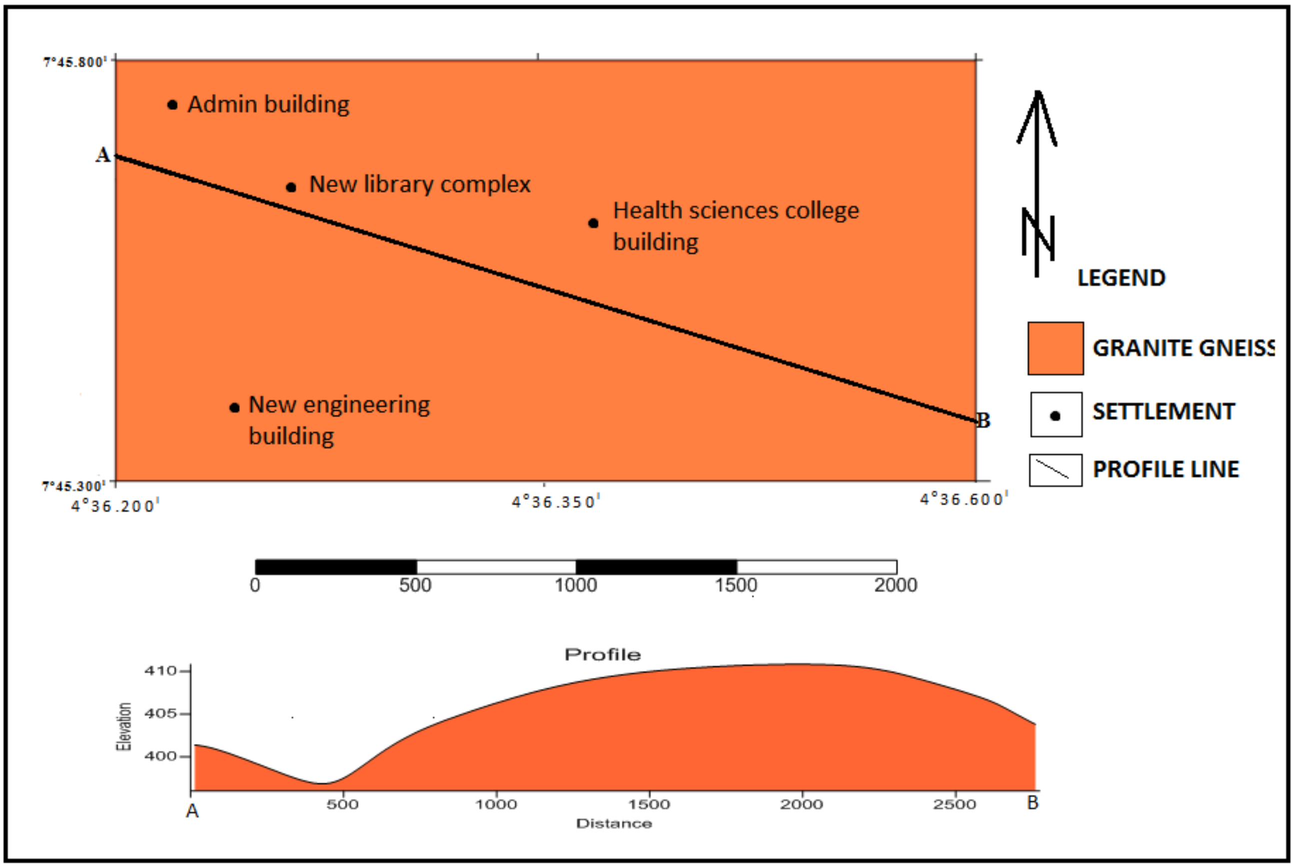


Figure 1. Map of Osun State University showing the location of VES positions

2. Location/Geology of the Study Area

The study area is a part of the south western. Nigeria, located at the College of Health Sciences, Osun State University, Osogbo. With an elevation of 330 m above sea level, it lies between the longitude $07^{o}45.595^{1}$ and latitude $004^{o}36.437^{1}$. Osogbo urban area is the capital of Osun state, made up of two local government areas (LGAs), namely Osogbo local government area and Olorunda local government area. Figure 1 shows the geological map of the study area. The town covers a total of about 47 km^{2}. Like the other parts of the south western Nigeria the area is within the tropical rain forest and is marked with two prominent seasons the wet season and the dry season, experienced between April and October and between November to March respectively. Geologically, the study area belongs to the migmatite-gnesis of the quartzite zone of the basement complex of complex of south western Nigeria and lies within the zone of Pan African reactivation of 600±150m.y. Greater proportion of the top soil is lateritic soils. Usually lateritic soils are formed as a result of the weathering of parent sedimentary rocks (limestone), metamorphic rocks (schists, gneisses, migmatites); igneous rocks (granites, basalts, gabbros, peridotite). In this case, the lateritic soils are formed as a result of the weathering of metamorphic rocks (schists, gneisses, migmatites) leaving the more insoluble ions, which are predominantly iron and aluminium. Hence, lateritic soils are rich in aluminium and iron and it is commonly found associated with tropical environment especially in the basement complex terrains of Nigeria.

3. Materials and Methods

The geophysical prospecting method adopted for this study is the Vertical Electrical Sounding (VES) techniques of the electrical resistivity method. The ABEM SAS-1000 terrameter was employed. For adequate depth penetration, the Schlumberger electrode configuration was used with maximum current electrode separation (AB/2) of 100 m. A total of four VES soundings were carried out. Results from the field data were subjected to interpretation using the WinResist iterative software in order to model the data and to deduce the true resistivity, true thicknesses of each geo-electric layers as well as the lithology of the area under investigation. The thicknesses of the aquifer (h) and the apparent resistivity (ρ_a) of the aquiferous layer were obtained from the interpreted data and were employed in the determination of the transverse resistance (Tr) and the longitudinal conductance (Lc). The Lc and Tr are employed to deduce the aquifer protective capacity of the study area.

3.1 Theoretical Background

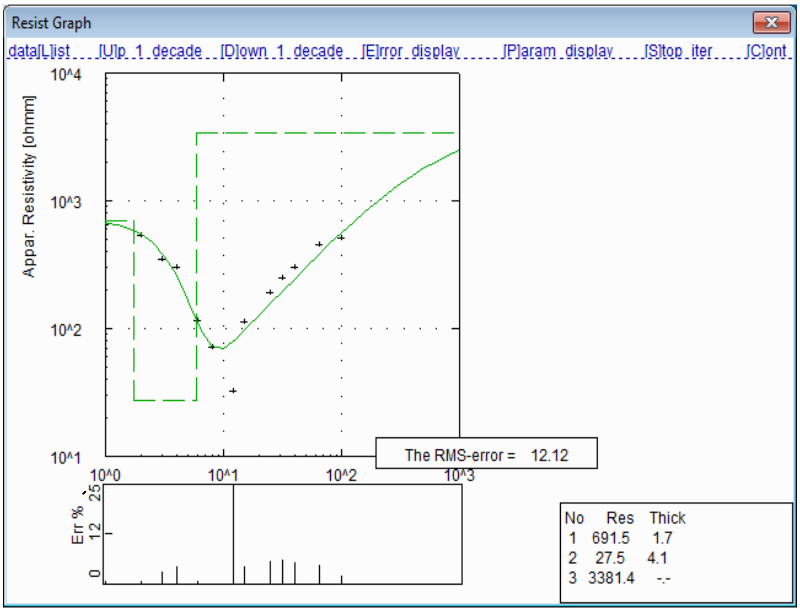
Electric resistivity is an intrinsic property of all materials. The properties that affect the resistivity of all soil or rock include; porosity, water content, composition (clay, mineral and metal content), salinity of the pore water, and grain size distribution. Therefore, electrical resistivity method is ideally suited to provide information for groundwater surveys and bedrock topography. The electrical resistivity method is primarily deployed on land. However, in addition to terrestrial surveys, marine electrical resistivity surveys can help delineate stratigraphy below a lake bottom. In an electrical resistivity method, electric current is applied to the ground surface through two electrodes. Two or three additional electrodes are placed in the ground to measure variations in the potential of the electric field (voltage) that is set up within the earth by the current electrodes. There are two basic field procedures which are commonly used in electrical resistivity exploration. These include the vertical electrical sounding technique and the horizontal profiling technique. Electrical sounding is designed to provide information on the variation in subsurface condition with depth. Sounding is typically used to help determine the depth to the water table, the thickness of sand, gravel and rock layers, and the actual value of electrical resistivity versus depth. The fundamental equation for resistivity survey is derived from Ohm's law [6],

$$\rho = \frac{RA}{L} \tag{1}$$

Where ρ is the resistivity, R is the resistance, L is the length and A is the cross sectional area. Surface electrical resistivity surveying is based on the principle that the distribution of electrical potential in the ground around the current carrying electrode depends on the electrical resistivity distribution of the surrounding soils and the rocks. The usual practice in the field is to apply an electrical (direct or alternate) current between two electrodes implanted in the ground and to measure the difference of potential between two additional electrodes.Data from resistivity surveys are customarily presented and interpreted in the form of values of apparent resistivity ρ_a. Apparent resistivity is defined as the resistivity of an electrically homogeneous and isotropic half-space that would yield the measured relationship between the applied current and the potential difference for a particular arrangement and spacing of electrodes. An electrode array with constant spacing is used to investigate lateral changes in apparent resistivity reflecting lateral geologic variability or localized anomalous features. To investigate changes in resistivity with depth, the size of the electrode array is varied. The apparent resistivity is affected by material at increasingly greater depths (hence larger volume) as the electrode spacing is increased [15]. Because of this effect, a plot of apparent resistivity against electrode spacing can be used to indicate vertical variations in resistivity. The types of electrode arrays that are most commonly used (Schlumberger, Wenner, and dipole-dipole). There are other electrode configurations that are used experimentally or for non-geotechnical problems or are not in wide popularity today. Some of these include the Lee, half-Schlumberger, polar dipole, bipole dipole, and gradient arrays.

4. Results and Discussions

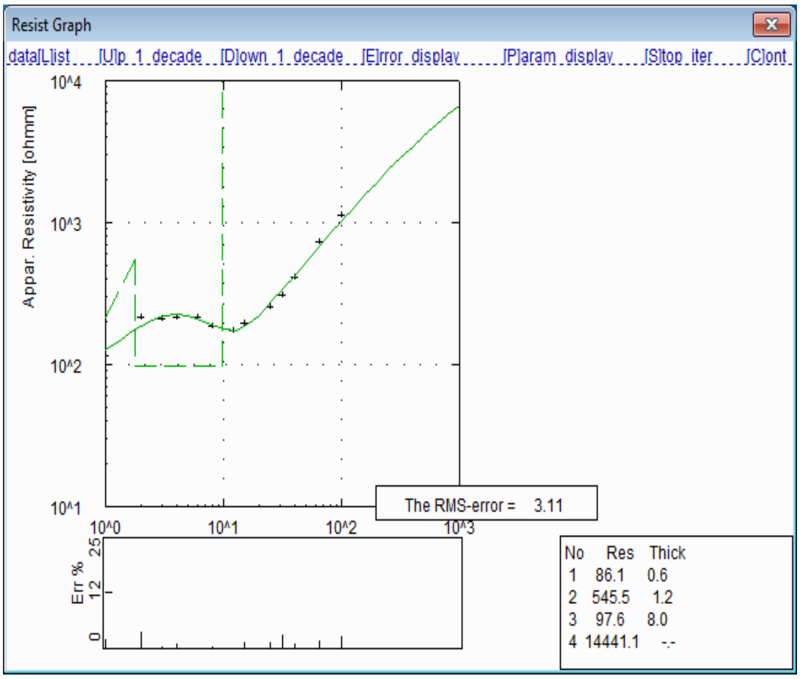
Table 1 shows the summary table of the resistivity and thicknesses of the geo-electric/lithological layers within the subsurface as well as the longitudinal conductance as well as the transverse resistance of the aquifer. Table 2 shows the aquifer protective capacity ranges as modified by [12]. Figure 1, Figure 2, Figure 3, and Figure 4 are iterative curves generated for the apparent resistivity data using the WinResist software. From the interpretation, the result shows that VES 1 shows typical HA curve having its resistivity as low as 123 Ωm to as high as 32517 Ωm while VES 2 shows typical KHA curve having resistivity of as low as 52.9 Ωm to as high as 46959 Ωm. However, VES 3 and VES 4 shows typical KHA curves with resistivity values of as low as 48.2 Ωm in VES 3 to as high as 2118 Ωm in VES 4. Lithologically, the topsoil was observed to be made up of clayey materials in VES 1 and lateritic materials in VES 4 but having varying thickness. It is about 1.7 m thick in VES 1 and about 0.2 m thick in VES 4. This is underlain by a clayey layer is VES 2 and VES 3 but a basement layer in VES 4 having a resistivity of as low as 545 Ωm in VES 2 to as high as 1089 Ωm in VES 4, except in VES 1 where the topsoil is underlain by weathered interval of resistivity vales of 123 Ωm. The third geo-electric layer constitute the aquifer/fractured interval having resistivity values of 97.6 Ωm , 20.7 Ωm and 142.2 Ωm in VES 2, VES 3 and VES 4 respectively. The thickness of this layer varies from one VES station to another. It is about 9.7 m in VES 2, 3.2 m in VES 3 and 19.9 m in VES 4. The VES 3 station position was observed to be in the vicinity of dried water-logged environment. This probably accounts for the low resistivity value of 83.2 ohm within the topsoil. The weathered layer is 3.2 m thin, which might not produce groundwater in large quantity. At this VES point, any hand dug well or borehole might experience failure due to caving since the area is water logged (Figure 2, Figure 3, Figure 4 and Figure 5).



The RMS-error = 12.12

No	Res	Thick
1	691.5	1.7
2	27.5	4.1
3	3381.4	-.-

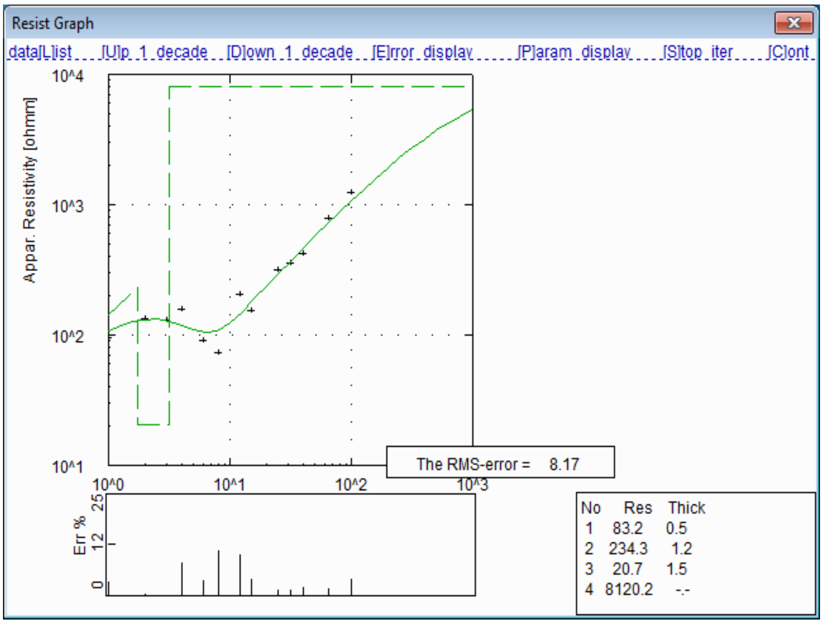
Figure 2. Typified KHA-curve in the study area



The RMS-error = 3.11

No	Res	Thick
1	86.1	0.6
2	545.5	1.2
3	97.6	8.0
4	14441.1	-.-

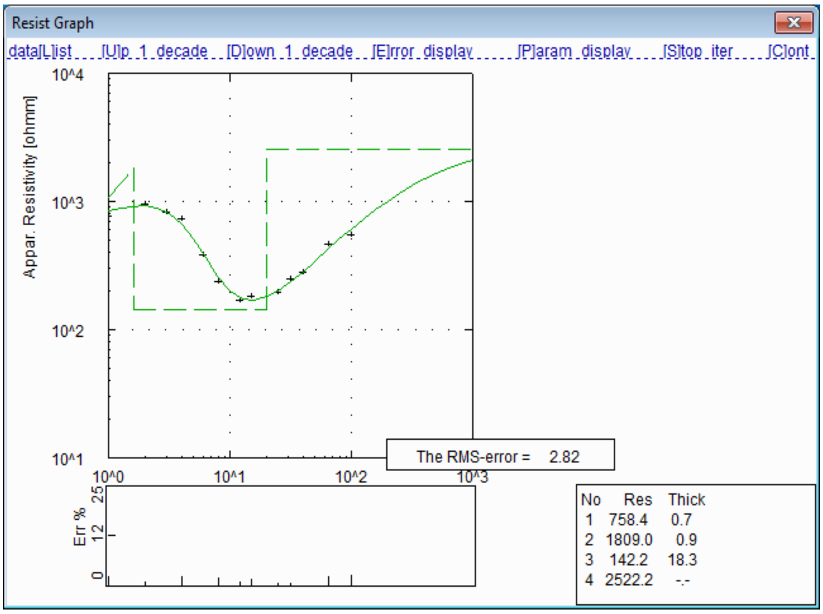
Figure 3. Typified KHA-curve in the study area



The RMS-error = 8.17

No	Res	Thick
1	83.2	0.5
2	234.3	1.2
3	20.7	1.5
4	8120.2	-.-

Figure 4. Typified KHA-curve in the study area



The RMS-error = 2.82

No	Res	Thick
1	758.4	0.7
2	1809.0	0.9
3	142.2	18.3
4	2522.2	-.-

Figure 5. Typified KHA-curve in the study area

Table 1. Summary Table for the Vertical Electrical Sounding Interpretation

	VES 1				VES 2			
	ρa (Ωm)	h (m)	Depth (m)	Remark	ρa (Ωm)	h (m)	Depth (m)	Remark
Layer 1	691.5	1.7	1.7	Clayey Topsoil	86.1	0.6	0.6	Unconsolidated Top Soil
Layer 2	27.5	4.1	5.8	Weathered Layer	545.5	1.2	1.8	Clayey layer
Layer 3	3381.5	-	-	Fresh Basement	97.6	8.0	9.8	Fracture layer
Layer 4					14441.1	-		Fresh Basement
	VES 3				VES 4			
Layer 1	83.2	0.5	0.5	Unconsolidated Top Soil	758.4	0.7	0.7	Lateritic Topsoil
Layer 2	234.3	1.2	1.7	Clayey layer	1809.0	0.9	1.6	Basement
Layer 3	20.7	1.5	3.2	Weathered Layer	142.2	18.3	19.9	Fracture layer
Layer 4	8120.2	-	-	Fresh Basement	2522.2	-	-	Fresh Basement

Table 2. Table showing Aquifer Protective Capacity Rating (Oladapo et al, 2004)

Rating	Remark
Greater than 10	Excellent
5 to 10	Very good
0.2 to 4.9	Moderate
0.1 to 0.19	Weak
Less than 0.1	Poor

Table 3. Table showing the Longitudinal Conductance and Transverse Resistance of the Aquifer

	VES 1	VES 2	VES 3	VES 4
(Lc)	0.149	0.082	0.072	0.129
(Tr)	112.75	780.8	31.05	2602.26

5. Aquifer Protective Capacity Determination

The earth subsurface is considered to be a natural filter to percolating fluid. Hence, its ability to retard and filter percolating ground surface polluting fluid is a measure of its protective capacity [14]. The highly impervious clayey overburden, which is characterized by relatively high longitudinal conductance, offers protection to the underling aquifer [1,11]. This protective property is vested in the longitudinal conductance and the transverse resistance of the aquifer and they are both estimated by using the apparent resistivity (ρ_a) and the thickness (h) of the aquifer. These two are obtained from equations given by:

$$\text{Longitudinal conductance } (\mathrm{Lc}) = \frac{h}{\rho_a} \tag{2}$$

where Lc is the longitudinal conductance, h is thickness and ρ_a is apparent resistivity of the aquiferous layer; and

$$\text{Transverse resistance } (\mathrm{Ts}) = h * \rho_a \tag{3}$$

where Ts is the transverse resistance, h is thickness and ρ_a is apparent resistivity of the aquiferous layer. These parameters Ts and Ls constitute the “Dar – Zarrouk parameters as described by [10]. [11] modified and summarized the longitudinal conductance (mhos)/protective capacity ratings using Table 3 and the table was employed to interpret the data obtained after interpretation. Using results obtained from study area in Table 1, estimation of the aquifer transverse resistance as well as the longitudinal conductance were made. The result from this study is as shown in Table 3: The result shows that the aquifers in VES 1 and VES 4 shows evidence of weak aquifer protective capacity having Lc values of 0.149 and 0.129 respectively with corresponding Tr values of 112.75 and 780.80. However, in VES 2 and 3, the Lc values obtained were far less than 0.1. The values observed were 0.082 in VES 2 and 0.072 in VES 3, an indication of poor protective capacity. The aquifer in this area may be prone to contamination resulting from short residence time in the sandy layers. None of the aquifer is protected from percolating fluids although the groundwater in the study area is given slight protection by the presence of thin covering layers of clayey, topsoil which have insufficient thickness. Usually, groundwater is given protection by geologic barriers having sufficient thickness also called protective layers and low hydraulic conductivity. Silts and clays are suitable protective layers and when they are found as thick layers above an aquifer, they constitute a protective cover. The thin overburden clayey layer in VES 2 and VES 3 with average thickness of 1.8 m and 1.7 m respectively, could serve could help protect the aquifer in the VES stations from surface and near surface contamination but for their close proximity to a swampy environment where intermittent infiltration from the surrounding waters could interact with the content of the aquifer as depth. During a protracted percolating period, contaminant degradation can occur by mechanical, physic-chemical and microbiological process [8]. This therefore suggests that the study area might show good potential for groundwater but the groundwater is not safe. This attribute could be as a result of a number of factors such as its close proximity to swamp which allows for infiltration of mud water loaded with microbial contaminants into the aquifer. Table 2 shows the aquifer protective rating according to [11] while Table 3 shows the result of the Lc and Tr estimate in the study area.

6. Conclusion and Recommendation

Geophysical investigation for groundwater potential was carried out and the aquifer protective capacity determined within the College of Heath Science facility of the Osun State University. Analysis and interpretation of VES data obtained from the study area showed VES 4 to be the most appropriate VES location to be explored for borehole development due to the low resistivity of the weathered/fractured aquiferous layer coupled with the relatively high thickness of the weathered layer compared to other VES stations. However, the aquifer is not well protected due to the very low aquifer protective capacity parameters in the VES station. Thus, there is high tendency of obtaining an appreciable groundwater quantity in this VES position which would be enough for clinical use, though it might not be of good quality. The depth of any borehole sited in this VES station should be to a depth of about 23 m to take advantage of the basement fractures. It is recommended that if any groundwater development is to be sited in this VES position, adequate measure must be taken to ensure the procurement of water treatment facilities to treat the groundwater as it is explored before use. Further efforts should be geared towards investigating not only the quality of groundwater within the study area but also the aquifer hydraulic dynamic in order to understand groundwater flow path within the subsurface.

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