*FUDMA Journal of Sciences (FJS)*
*ISSN online: 2616-1370*
*ISSN print: 2645 - 2944*
*Vol. 6 No. 3, June, 2022, pp 191 - 199*
*DOI: https://doi.org/10.33003/fjs-2022-0603-993*

# EVALUATION OF AQUIFER PROTECTIVE CAPACITY USING ELECTRICAL RESISTIVITY METHOD IN LAMBATA, KWALI AREA COUNCIL, ABUJA

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**ABSTRACT**

This study evaluated the aquifer protective capacity of Lambata in Kwali area council of Abuja, using electrical resistivity method. The obtained data were interpreted manually by partial curve matching and the obtained results were iterated using WINREIST software. The first layer is the topsoil whose resistivity range from 127.7 to 562.4 Ωm and its thickness range from 0.7 to 1.6 m. The second layer is laterite and its resistivity range from 302.3 to 937.6 Ωm, the thickness of the second layer range from 3.7 to 13.3 m. The third layer is a clay formation whose resistivity range from 46.7 to 88.8 Ωm and its thickness range from 6.6 to 27.9 m. The fourth layer is a weather/ fractured basement, this layer is the aquifer and it is confined by the overlying clay formation. Its resistivity range from 59.0 to 870.2 Ωm, while its thickness range from 6.0 to 28.5 m. The fifth layer is the fresh basement whose resistivity range from 1038.5 to 4992.5 Ωm. The total longitudinal conductance values of the overburden in the study area range from 0.00143 to 0.410334 m$\Omega^{-1}$. The average aquifer thickness in the study area is 16.60 m. The aquifer protective capacity is about 93.3% moderate and 6.7% weak. The aquifer protective capacity of the study area is fairly good but not sufficient to protect the groundwater in the area from pollution. We therefore strongly suggest that there should be proper environmental and waste monitoring management in the study area to safeguard the groundwater.

**Keywords:** Anthropogenic, aquifer, groundwater, longitudinal conductance, protective capacity

## INTRODUCTION

Groundwater is the water beneath the earth surface. It is the main source of water in semi-arid and arid regions where rivers and streams are relatively scarce (Agada and Yakubu, 2022). It is a source of water for domestic, industrial and agricultural purposes. Human health are easily affected by the consumption of contaminated groundwater. Potentially toxic element in the soil often cause groundwater pollution, most of the groundwater pollutants originate from anthropogenic activities such as chemical effluents from various industries, fertilizers from agricultural activities, leachate from waste dumpsite and industrial solid waste (Agada and Yusuf, 2021). Aquifer protective capacity assessment of any given area is very important, since it enables one to understand the nature of the aquifer and its hydrogeological characteristics. Olayinka and Olorunfemi (1992) emphasized the need to carry out a geophysical survey especially Vertical Electrical Sounding (VES) to identify the aquiferous zones before siting boreholes. The proximity of aquifer to the ground surface in most basement complex areas demands proper understanding of the aquifer hydrological settings to properly manage the groundwater resources in the area. An aquifer is a geological formation which stores and transmits groundwater. Most groundwater are abstracted from the aquiferous layer in the subsurface. In view of the importance of the geological setting of an aquifer to groundwater quality, the investigation of its protective capacity cannot be over emphasized.

In Nigeria, a review conducted by Ocheri *et al.*, (2014) on the quality of groundwater indicated that majority of the groundwater sources are contaminated and their contamination is linked to the geochemistry and geology of the surrounding environment as well as urbanization. Abiola *et al*., (2009) studied the groundwater potential and aquifer protective capacity of overburden units in Ado Ekiti and their results showed that the area is composed of three groundwater potential zone (high, medium and low) and the aquifer protective capacity ranges from good to poor. Daniel *et al.* (2015) evaluated the aquifer protective capacity of overburden units and soil corosivity in Makurdi, Benue State Nigeria, using electrical resistivity method. Their results showed that the longitudinal conductance of the study area is characterized by 36.6% weak, 10% poor, 40% moderate and 13.3% good. They concluded that the regions with moderate / good protective capacity are good sites for boreholes sitting. The objective of this study is to evaluate the aquifer protective capacity of the study area in order to secure the groundwater from pollution.

The understanding of an aquifer geological settings and characteristics will help in protecting the groundwater from pollution that could lead to health complication such as constant headaches, insomnia, joint pains, cancer, renal failure and stomach disorder which are associated with the consumption of polluted groundwater. Lambata in Kwali area council of FCT, Abuja is located within the basement complex area. The area has good groundwater potential (Adeeko *et al*. 2017; Emmanuel *et al*. 2021) but the groundwater in the area might be highly susceptible to contamination due to the growth in population and increase in anthropogenic activities in the area. Considering the susceptibility of the aquifer in the area, the study is focused on determining the aquifer protective capacity in the area. Areas with low aquifer protective capacity are highly susceptible to groundwater pollution by leachate and other toxic substances (Oladapo *et al*., 2004; Oladapo *et al*., 2008; Onyenweife *et al.* 2020). In this study, electrical resistivity method involving Vertical Electrical Sounding (VES) was used to determine the protective capacity of the aquifer in Lambata, Kwali area council of FCT, Abuja.

## MATERIALS AND METHOD

### Materials

The following instruments were used for the data acquisition: ABEM SAS1000 digital Terrameter, personal computer, Global Positioning System (GPS), Hammers, Measuring tape, UPS Battery and Charger, Pegs, ABEM SAS External Battery Adapter (EBA), Electrodes, Reels of Cables and Jumpers and Laptop computer.

**The Study Area**

Lambata is a settlement in Kwali area council in Federal Capital Territory, Abuja. It is within the north central basement complex of Nigeria. Lambata is located on Longitude 7.05° E and Latitude 8.83° N.

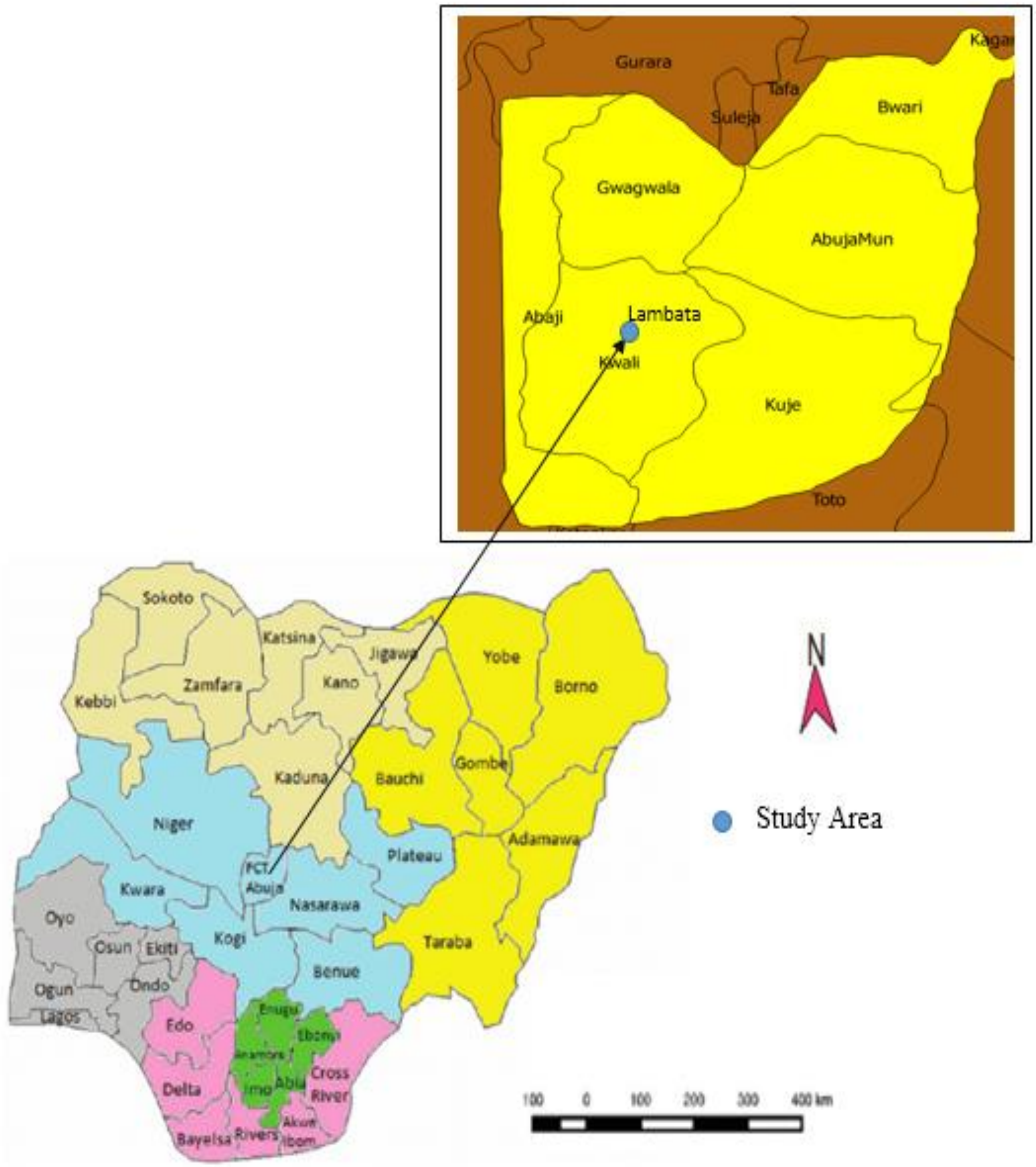


Figure 1: Map of Nigeria showing Lambata the study area in Kwali area council of FCT, Abuja.

The study area is composed of rocks such as granites, schist, pegmatite, and gneiss most of which are of Precambrian age (Figure 2). Some the basement rocks have transformed into sand, clay soil and laterite through the process of weathering.

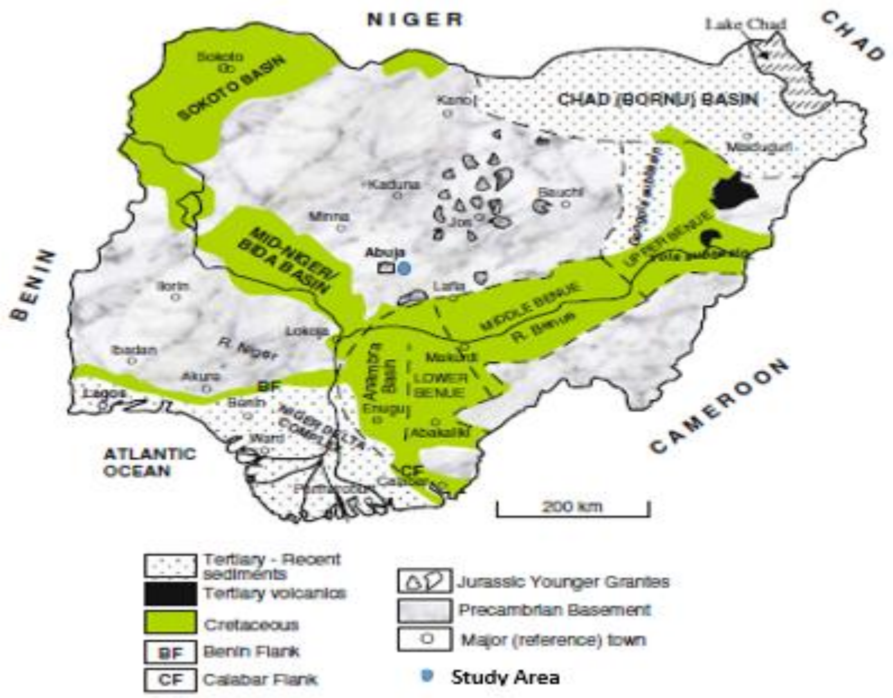


Figure 2: Geological map of Nigeria showing the study area.

**Methodology**

Electrical resistivity method involving Vertical Electrical Sounding was used to acquire the data for the study. The VES data were used to delineate the overburden thickness and the depth to the groundwater. ABEM Terrameter SAS1000 was used for the survey. The ABEM Terrameter was set for four cycle stacking and the standard error of measurement was set at 5%. At each measurement, the resistivity meter displayed resistance value and the associated room mean square (RMS) error of the reading. During the VES data acquisition, the Terrameter measures the resistance, voltage and current which are indicated by R, V, I respectively. The apparent resistivity values were obtained by multiplying the resistance by the geometric factor (*K*), that is, (*R* x *K)*, where *K* is calculated by using,

$$K = \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right] X\ 3.142}{\left(\frac{MN}{2}\right) X\ 2} \quad \text{(Agada } et\ al\text{., 2020)} \qquad (1)$$

Where AB is the current electrode spacing and MN is the potential electrode spacing. During sounding, apparent resistivity of the subsurface material was measured as a function of depth. The progressive increase in the distance between the current electrodes causes the current lines to penetrate to greater depths. The VES data were initially interpreted using apparent resistivity curves, which involves plotting of the apparent resistivity values against $AB/_2$ on a bi-logarithm sheet. A manual partial curve matching technique was adopted to obtain the initial layer parameters that were modeled using WINRESIST Software version 1.0 on a computer to obtain the true resistivity of the subsurface layers. The results obtained were constrained using nearby borehole data. The apparent resistivity and thickness data of the subsurface layers were used to determine the longitudinal unit conductance of the subsurface materials. The overburden protective capacity in the study area was evaluated using longitudinal unit conductance ($S_i$) derived from the vertical electrical resistivity sounding results. $S_i$ was calculated using the equation,

$$S_i = \sum_{i=0}^{n} \frac{h_i}{\rho_i} = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} + \frac{h_3}{\rho_3} + \ldots + \frac{h_n}{\rho_n}$$

(Agada and Yusuf, 2021) (2)

Where $\rho_i$ is the layer resistivity, and $h_i$ is the layer thickness for ith layer.

**Aquifer Protective Capacity (APC)**

Aquifer protective capacity is the ability of the overlying layers of rock above the aquifer unit (overburden) to impede, filter, and contain percolating fluids or leachate from the surface from reaching the aquifer. It was determined using the values of the total longitudinal conductance calculated from the thicknesses and the resistivity of the geoelectric layers. Impervious materials such as clay and shale are characterized by high longitudinal conductance values while pervious materials such sand and gravels have low longitudinal conductance values. The rating is categorized as poor, weak, moderate, good, very good and excellent depending on the magnitude of the total longitudinal conductance value (Table 1).

**Table 1. Longitudinal conductance / protective capacity rating**
**(Adapted from Henriet 1976, and Oladapo et al. 2004).**

| Longitudinal Conductance (mhos) | Protective Capacity Rating |
|---|---|
| >10 | Excellent |
| 5-10 | Very Good |
| 0.7 – 4.9 | Good |
| 0.2 - 0.69 | Moderate |
| 0.1 - 0.19 | Weak |
| < 0.1 | Poor |

**RESULTS AND DISCUSSION**

The results obtained from the analysis of the Vertical Electrical Sounding (VES) data showed that the study area is composed of five geoelectric layers which are: Topsoil, Laterite, Clay, Weathered basement and Fresh basement (Figure 3). The geoelectric section obtained from the study area showed good correlation in terms of number of layers when compared with an existing borehole log obtained from LEA Primary School Lambata in Kwali.

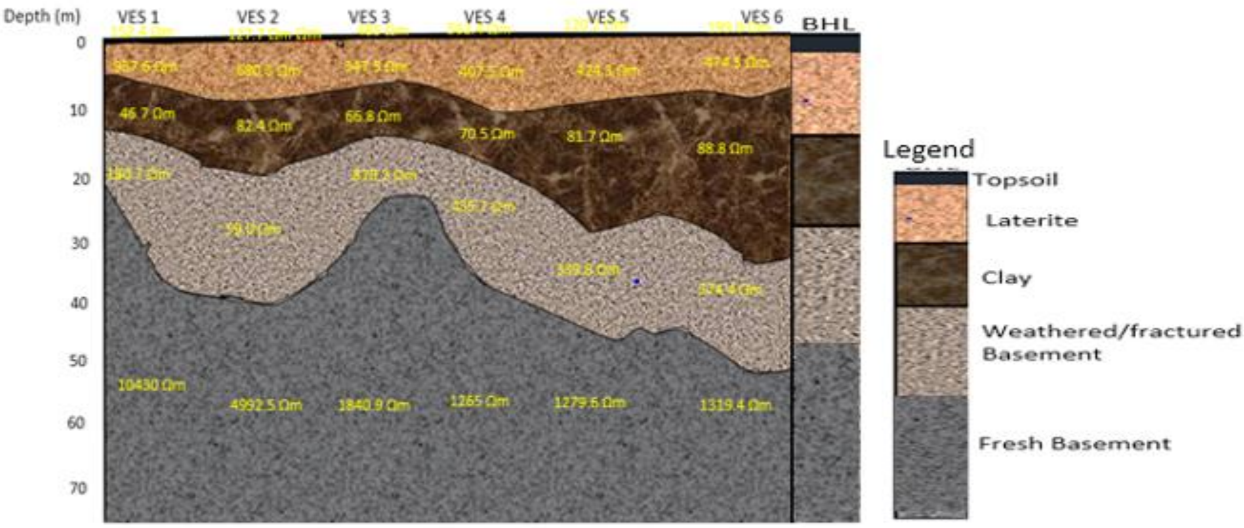


Figure 3: Correlation of the geoelectric sections of VES 1-6 with an existing Borehole Log (BHL) from LEA Primary School, Kwali.

The topsoil has resistivity values which range from 127.7 to 562.4 Ωm and thickness that ranges from 0.7 to 1.6 m. It is composed of a mixture of sand, humus, and clay. The second layer is laterite with resistivity values ranging from 302.3 to 937.6 Ωm and thickness ranging from 3.7 to 13.3 m (Table 2). The laterite sometimes degrades into ferruginized sandstone or clay stone. The laterites are separated from the weathered basement rocks by a few meters of clay. This clay is the third layer and its resistivity values range from 46.7 to 88.8 Ωm while its thickness range from 6.6 to 27.9 m. In some places the clay is several meters thick and varies from place to place in the study area (Figure. 2). The fourth layer is the aquifer in the study area, its resistivity ranges from 59.0 to 870 Ωm. It is a weathered layer with good water storage capacity (Table 2). The aquifer thickness range from 6 to 28.5 m (Table 2). The longitudinal conductance range from 0.001434 to 0.410334 $m\Omega^{-1}$ (Table 2). Typical VES curve obtained from the study area are shown in figure 3. The aquifer protective capacity range from 0.126805 to 0.471139 $m\Omega^{-1}$. In view of the number of geoelectric layers and subsurface resistivity values, the results of this study is in agreement with the reports of some other researchers (USGS, 1977; Adeeko *et al*., 2017; Emmanuel et al., 2021) who have carried out similar research in Abuja and environs.

**Table 2. Summary of interpreted longitudinal conductance and the aquifer protective capacities**

| VES No. | Layer | Resistivity (Ωm) | Thickness (m) | Depth (m) | Longitudinal Conductance ($m\Omega^{-1}$) | Protective Capacity ($m\Omega^{-1}$) | Protective Capacity Rating |
|---|---|---|---|---|---|---|---|
| | 1 | 152.4 | 0.8 | 0.8 | 0.005249 | | |
| | 2 | 937.6 | 5.0 | 5.8 | 0.005333 | | |
| 1 | 3 | 46.7 | 8.3 | 14.1 | 0.177730 | 0.240885 | Moderate |
| | 4 | 180.7 | 9.5 | 23.6 | 0.052573 | | |
| | 5 | 10430.0 | ---- | ---- | ----- | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 127.7 | 0.9 | 0.9 | 0.007048 | | |
| | 2 | 680.3 | 10.2 | 11.1 | 0.014993 | | |
| 2 | 3 | 82.4 | 8.2 | 19.3 | 0.099514 | 0.440199 | Moderate |
| | 4 | 59.0 | 18.8 | 38.1 | 0.318644 | | |
| | 5 | 4992.5 | ---- | ---- | ------ | | |
| | 1 | 485.0 | 1.0 | 1.0 | 0.002062 | | |
| | 2 | 347.5 | 3.9 | 4.9 | 0.011223 | | |
| 3 | 3 | 66.8 | 6.9 | 11.8 | 0.103293 | 0.126805 | Weak |
| | 4 | 870.2 | 8.9 | 20.7 | 0.010227 | | |
| | 5 | 1840.9 | ---- | ---- | ----- | | |
| | 1 | 562.4 | 1.0 | 1.0 | 0.001778 | | |
| | 2 | 407.5 | 10.3 | 11.3 | 0.025276 | | |
| 4 | 3 | 70.5 | 10.4 | 21.7 | 0.147518 | 0.203032 | Moderate |
| | 4 | 435.7 | 12.4 | 34.1 | 0.028460 | | |
| | 5 | 1265.0 | ---- | ----- | ----- | | |
| | 1 | 120.2 | 1.5 | 1.5 | 0.012479 | | |
| | 2 | 424.3 | 7.0 | 8.5 | 0.016509 | | |
| 5 | 3 | 81.7 | 21.2 | 29.7 | 0.259486 | 0.323789 | Moderate |
| | 4 | 339.8 | 12.0 | 41.7 | 0.035315 | | |
| | 5 | 1279.6 | ---- | ---- | ----- | | |
| | 1 | 199.0 | 1.3 | 1.3 | 0.006533 | | |
| | 2 | 474.5 | 8.8 | 10.1 | 0.018546 | | |
| 6 | 3 | 88.8 | 25.5 | 35.6 | 0.287162 | 0.336814 | Moderate |
| | 4 | 374.4 | 9.2 | 44.4 | 0.024573 | | |
| | 5 | 1319.4 | ---- | ---- | ----- | | |
| | 1 | 425.7 | 0.9 | 0.9 | 0.002114 | | |
| | 2 | 1132.0 | 5.1 | 6.0 | 0.004505 | | |
| 7 | 3 | 32.9 | 13.5 | 19.5 | 0.410334 | 0.471139 | Moderate |
| | 4 | 430.0 | 23.3 | 42.8 | 0.054186 | | |
| | 5 | 2620.8 | ----- | ----- | ------ | | |
| | 1 | 265.5 | 1.1 | 1.1 | 0.0041431 | | |
| | 2 | 502.2 | 14.6 | 15.7 | 0.0290721 | | |
| 8 | 3 | 73.1 | 9.2 | 24.9 | 0.1258550 | 0.2072651 | Moderate |
| | 4 | 570.6 | 27.5 | 52.4 | 0.0481949 | | |
| | 5 | 1370.0 | ---- | ----- | ------- | | |
| | 1 | 330.6 | 0.7 | 0.7 | 0.0021174 | | |
| | 2 | 781.8 | 9.7 | 10.4 | 0.0124073 | | |
| 9 | 3 | 77.3 | 27.9 | 38.3 | 0.3609314 | 0.391503 | Moderate |
| | 4 | 373.9 | 6.0 | 44.3 | 0.0160471 | | |
| | 5 | 4689.3 | ---- | ---- | ------ | | |
| | 1 | 282.5 | 1.6 | 1.6 | 0.005664 | | |
| | 2 | 518.6 | 12.6 | 14.2 | 0.024296 | | |
| 10 | 3 | 69.9 | 25.2 | 39.4 | 0.360515 | 0.447573 | Moderate |
| | 4 | 190.9 | 10.9 | 50.3 | 0.057098 | | |
| | 5 | 2849.7 | ---- | ---- | ------ | | |
| | 1 | 507.1 | 1.4 | 1.4 | 0.002761 | | |
| | 2 | 349.4 | 3.7 | 3.7 | 0.010589 | | |
| 11 | 3 | 34.1 | 6.6 | 6.6 | 0.193548 | 0.250519 | Moderate |
| | 4 | 486.0 | 21.2 | 21.2 | 0.043621 | | |
| | 5 | 1645.6 | ----- | ---- | ----- | | |
| | 1 | 557.7 | 0.8 | 0.8 | 0.001434 | | |
| | 2 | 675.6 | 4.5 | 5.3 | 0.006661 | | |
| 12 | 3 | 49.5 | 14.2 | 19.5 | 0.286868 | 0.366827 | Moderate |
| | 4 | 147.5 | 10.6 | 30.1 | 0.071864 | | |
| | 5 | 1038.5 | ----- | ----- | ----- | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 265.2 | 1.2 | 1.2 | 0.004525 | | |
| | 2 | 398.7 | 12.8 | 14.0 | 0.032104 | | |
| 13 | 3 | 80.0 | 22.5 | 36.5 | 0.281250 | 0.396265 | Moderate |
| | 4 | 347.0 | 27.2 | 63.7 | 0.078386 | | |
| | 5 | 1276.0 | ---- | ----- | ----- | | |
| | 1 | 282.5 | 0.9 | 0.9 | 0.003186 | | |
| | 2 | 302.3 | 13.3 | 14.2 | 0.043996 | | |
| 14 | 3 | 75.9 | 26.4 | 40.6 | 0.347826 | 0.465833 | Moderate |
| | 4 | 402.4 | 28.5 | 69.1 | 0.070825 | | |
| | 5 | 1128.7 | ---- | ---- | ----- | | |
| | 1 | 204.9 | 1.0 | 1.0 | 0.004880 | | |
| | 2 | 455.0 | 10.7 | 11.7 | 0.023516 | | |
| 15 | 3 | 64.3 | 20.8 | 32.5 | 0.323484 | 0.432765 | Moderate |
| | 4 | 289.3 | 23.4 | 55.9 | 0.080885 | | |
| | 5 | 2833.6 | ---- | ----- | ------ | | |

The analysis of the results showed that the aquifer protective capacity rating in the study area is about 93.3% moderate and 6.3% weak (Table 2).The aquifer protective capacity rating in the study area showed that the aquifer in the study area is susceptible to contamination considering the nature of the overburden thickness (Figure 4). The aquifer protective capacity is more towards the southeastern part of the study area (Figure 4). The northeastern part is characterized with weak protective capacity which indicates that the area is susceptibility to groundwater pollution (Figure 4).

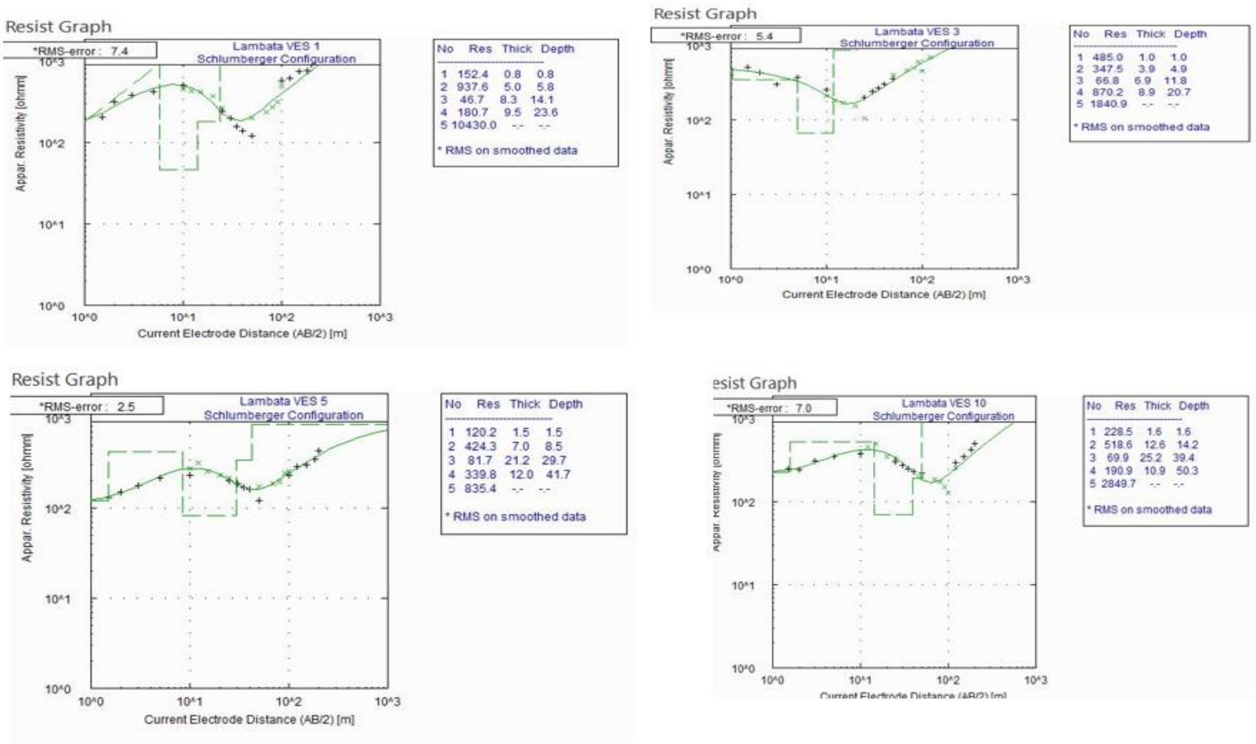


Figure 4: Typical VES curves obtained from the study area

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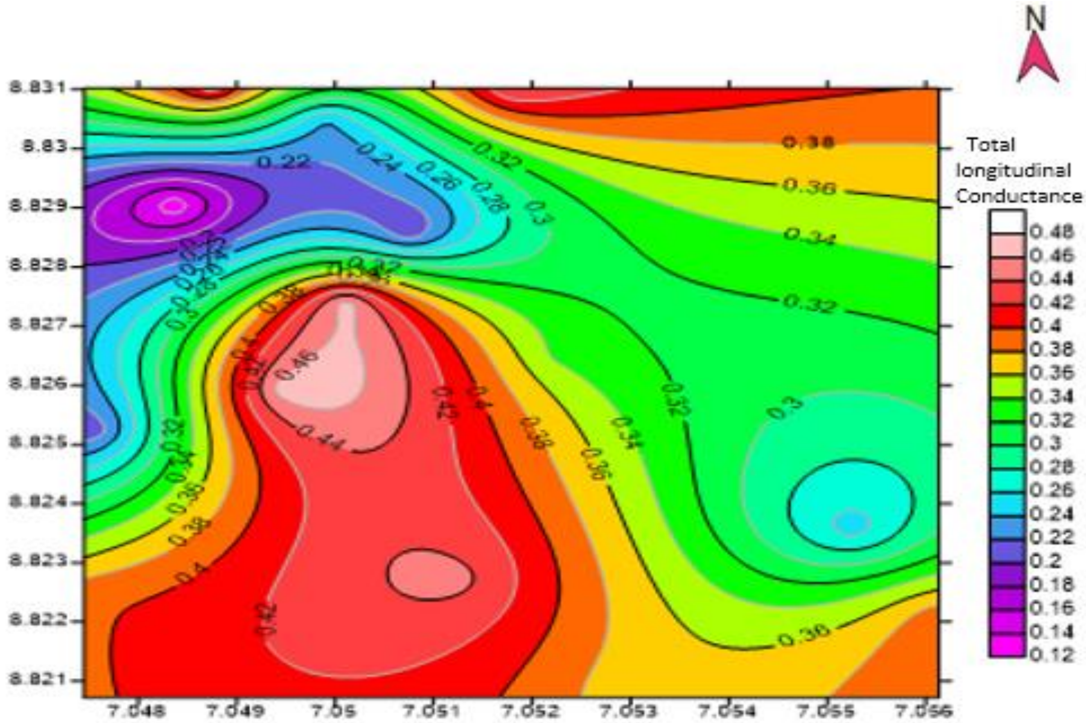


Figure 5: Spatial distribution of the aquifer protective capacity in the study area.

There is a need for proper waste management in order to avert possible contamination of the groundwater resources in the study area. The aquifer which is composed of weathered / fractured basement has higher resistivity values towards the northeastern part of the study area while the remaining parts are characterized with moderate resistivity values (Figure 5).

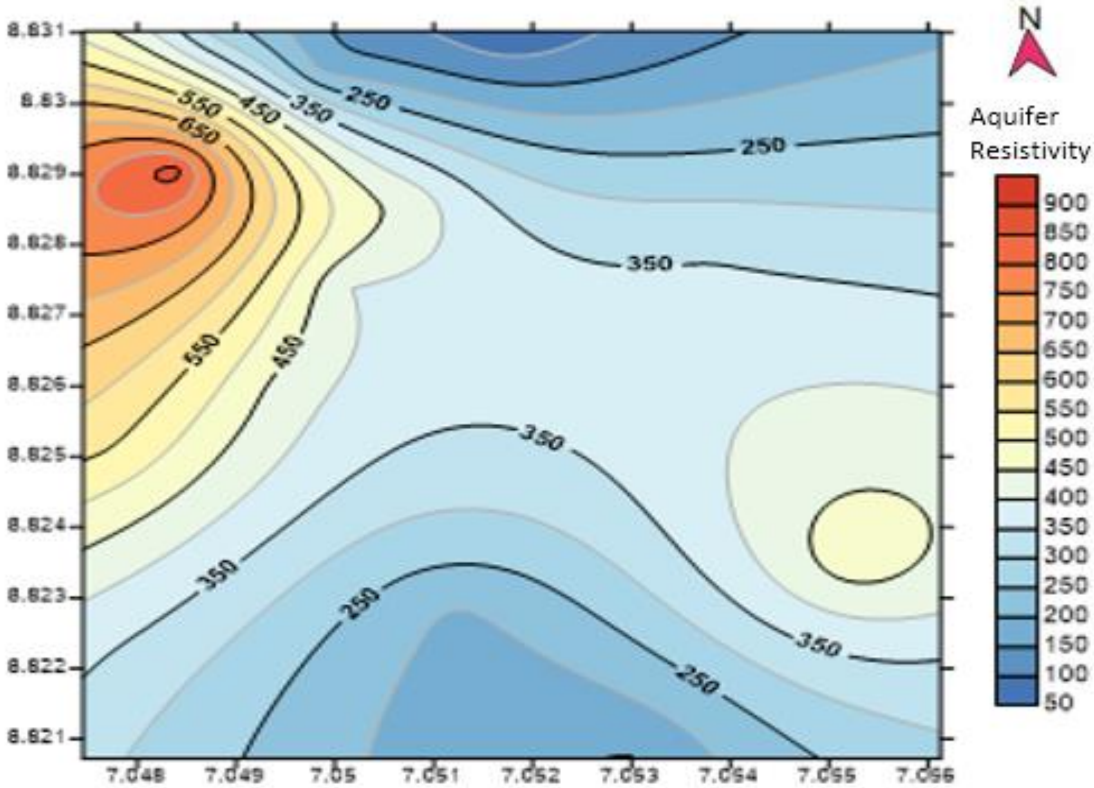


Figure 6: Spatial distribution of the aquifer resistivity in the study area.

The study area has good water bearing potential considering the aquifer thickness and its nature. The aquifer thickness is higher towards the western part of the study area (Figure 6). The aquifer thickness ranges from 6 to 29 meters and it varies from one place to another across the study area due to the heterogeneity and anisotropic nature of the study area. The average aquifer thickness is 16.60 m.

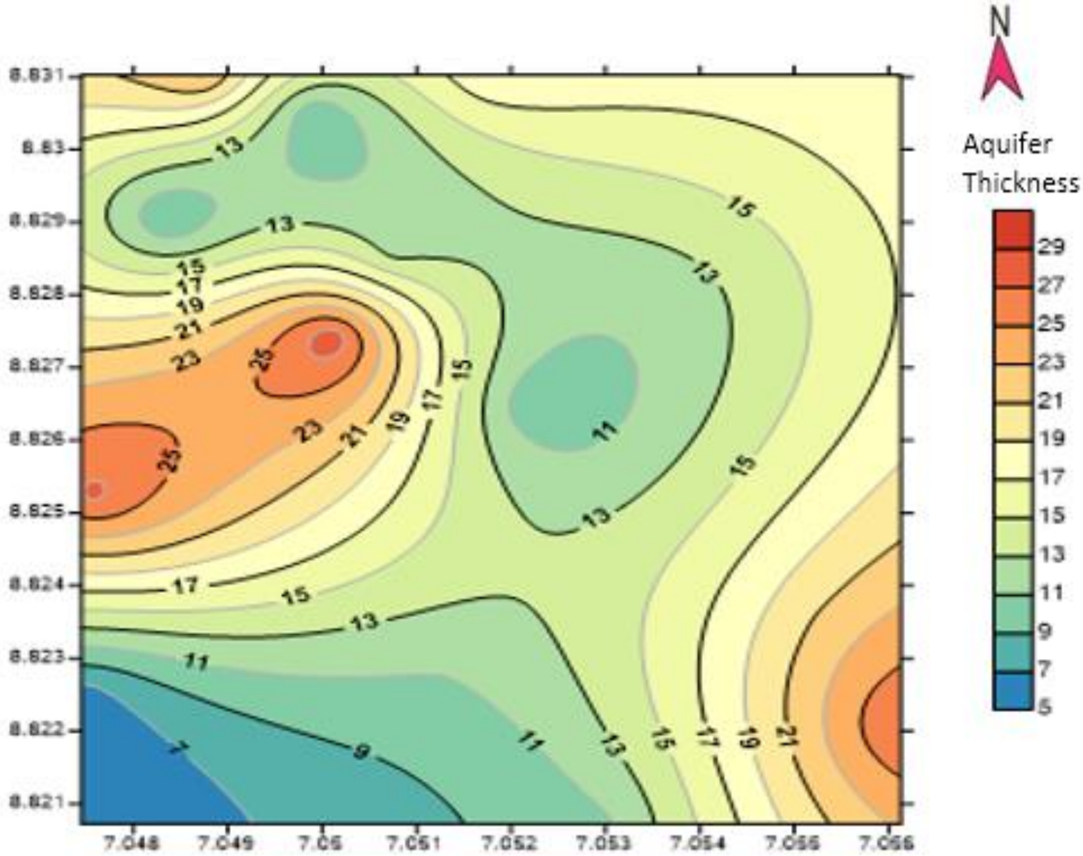


Figure 7: Spatial distribution of the aquifer thickness in the study area.

**CONCLUSION**

The study investigated the aquifer protective capacity of Lambata in Kwali area council of Federal Capital Territory, Abuja. Five geoelectrical layers were delineated in the study area and they are; topsoil, laterite, clay, weathered/fractured basement and fresh basement rocks. The results of the study showed that the total longitudinal conductance values of the overburden in the study area range from 0.00143 to 0.410334 m$\Omega^{-1}$. The average aquifer thickness in the study area is 16.60 m. The results of the study showed that the aquifer protective capacity is about 93.3% moderate and 6.7% weak. Therefore, the aquifer protective capacity of the study area is fairly good but not sufficient to protect the groundwater in the area from pollution that might be caused by leachate from domestic and industrial wastes. We therefore strongly suggest that there should be proper environmental and waste monitoring management in the study area. The Environmental Protection Agency in FCT should put much emphasis in safeguarding the groundwater in the area considering its susceptibility to contamination.

**REFERENCES**

Abiola, O., Enikanselu, P.A., & Oladapo, M.I. (2009). Groundwater potential and aquifer protective capacity of overburden units in Ado Ekiti, Southwestern Nigeria. *Int. J of Phys. Sc.* 4(3), 120 – 132.

Adeeko, T.O., Hassan, M. & Bello, M.A. (2017). Geoelectrical study of groundwater potential in Kwali area of Abuja, Nigeria. Special issue on Applied Physics in Africa. *Africa Review of Physics,* 12*, pp.* 71-78*.* (2017) 12: 0008.

Agada, L.E., Adetola, S.O., & Osita, C.M. (2020). Investigation of the effects of leachate from solid waste dumpsite on groundwater using electrical resistivity method. *Global Scientific Journal,* 8(1), pp. 2371-2401.

Agada, L.E., & Yakubu, M.S. (2022). Investigation of Groundwater Potential in Lambata, Kwali Area Council of FCT Abuja, using Electrical Resistivity Method. *Communication in Physical Sciences Journal,* 8(1), pp.128-137.

Agada, L.E., & Yusuf, M.A. (2021). Investigation of Aquifer Protective Capacity and Groundwater Corrosivity in Gashua Northeast Nigeria, using Geophysical and Hydrochemical Methods. *Communication in Physical Sciences Journal,* 7(3), pp.147-164.

Daniel, N. O., Ajala, A.E., Ibuot, J.C. (2015). Evaluation of aquifer protective capacity of aquifer unit and soil corrosivity in Makurdi, Benue State Nigeria using electrical resistivity method. *J Earth Syst Sci*. 124(1):125–135.

Emmanuel, D. S., Basiru, M. K., & Mohamed, A. (2021). Hydro-geophysical appraisal of groundwater potential in the fractured basement aquifer of the federal capital territory, Abuja, Nigeria *Results in Geophysical Sciences*, 5: 100012, doi.org/10.1016/j.ringps.2021.100012.

Henriet, J.P. (1976). Direct application of Dar Zarrouk parameters in groundwater survey. *Geophys. Prospect*. 24, 344-353.

Ocheri, M.I., Odoma, L.A. and Umar, N.D. (2014) Groundwater Quality in Nigerian Urban Areas: A Review. *Global Journal of Science Frontier Research*, 14, 35-46.

Oladapo, M.I., Mohammed, M.Z. & Adeoye, O.O. (2008). Engineering geophysical study of Adagbakuja Newtown development, southwestern Nigeria. *J. Earth Sci.* 2 (2), 55-63

Oladapo, M.I., Mohammed M.Z., Adeoye, O.O., Adesola, O.O. (2004). Geoelectric investigation of the Ondo State housing corporation Estate Ijapo Akure southwestern Nigeria. *J Min Geol*. 40(1):41–48.

Olayinka, A.I., and Olurunfemi, M.O. (1992). The inversion of geoelectrical data for hydrogeological applications in crystalline basement areas of Nigeria. *Journal of Applied Geosciences*. 37(2). Pp. 103-105.

Onyemweife, G.T., Nwozor, K.K., Nwike, I.S., Onuba, I.N., Egbunike, M.E., & Anakor, S.N (2020). Application of electrical resistivity method in estimating aquifer protective capacity of Awka and its environs, Anambra State, Nigeria. *Int. J of Innovative Environ. Studies Res*. 8(4).pp 1-17.

Omosuyi, G .O. (2010). Geoelectric assessment of groundwater prospect and vulnerability of overburden aquifers at Idanre, Southwestern Nigeria. *Ozean Journal of Applied Sciences*. 3(1), pp. 19-28.

United States Geological Survey, (1977). The United States Preliminary Engineering geologic report on the selection of Urban sites in the Federal Capital Territory, Abuja.