BILINGUAL PUBLISHING GROUP

**Advances in Geological and Geotechnical Engineering Research**

https://journals.bilpubgroup.com/index.php/agger

ARTICLE

# Geophysical Approach for Groundwater Resource Assessment: A Case Study of Oda Community Akure, Southwestern Nigeria

***S. J. Abe**, I. A. Adeyemo, O. J. Abosede-brown***

*Federal University of Technology Akure, Ondo State, 340110, Nigeria*

**ABSTRACT**

The geophysical investigation for groundwater was carried out at Oda town, Akure south local government area of Ondo State. Fourteen (14) points were sounded using a Schlumberger array with AB/2 of 80 m and the resulting geoelectric parameters were used in the estimation of the aquifer layer parameters of the subsurface. The first layer resistivity value ranges from 29 to 164 Ωm and thickness ranges from 0.6 to 2.5 m. The second layer has a resistivity value ranging from 21-1361 Ωm with a thickness ranging from 1.5 m to 14.6 m. The third layer resistivity value is from 68 to 297 Ωm with thickness ranging from 4 m to 12.4 m. The fourth layer which is the deepest layer has a resistivity value ranging from 180 to 4364 Ωm with depth ranging from 4 m to 19.5 m. The parameters interpreted from the geoelectric data were used to generate the aquifer thickness and resistivity maps, with bedrock relief which were combined to produce the groundwater potential map of the area. These maps were used to characterise the study area into low to high groundwater potential zones. The southwestern and eastern parts were identified as productive groundwater potential zones. The result was validated by taking water column depth from eight existing hand-dug wells. A significant correlation was obtained between the groundwater potential model and the well water column. The surveyed area is generally suitable for hand-dug well aside from the north-eastern part where groundwater potential is low and water volume is observed.

***Keywords:*** Geoelectric; Aquifer; Lithology; Bedrock

## 1. Introduction

Groundwater is an invaluable water supply source for agricultural, industrial and domestic use in the world. Thus, the search for excellent and quality groundwater is remarkably significant to human

*CORRESPONDING AUTHOR:
S. J. Abe, Federal University of Technology Akure, Ondo State, 340110, Nigeria; Email: jsabe@futa.edu.ng

ARTICLE INFO
Received: 19 September 2023 | Revised: 13 November 2023 | Accepted: 14 November 2023 | Published Online: 23 November 2023
DOI: https://doi.org/10.30564/agger.v5i4.5978

CITATION
Abe, S.J., Adeyemo, I.A., Abosede-brown, O.J., 2023. Geophysical Approach for Groundwater Resource Assessment: A Case Study of Oda Community Akure, Southwestern Nigeria. Advances in Geological and Geotechnical Engineering Research. 5(4): 59-69. DOI: https://doi.org/10.30564/agger.v5i4.5978

existence. It is the primary supply of fresh water in several world regions [1]. The need for water is on the rise due to its incredible quality, low vulnerability to pollution, drought resistance, relative abundance, etc.

Water is obtained from two main natural sources: surface water such as rivers, freshwater lakes, streams, etc. and underground water such as boreholes and well water [2]. It is considered to be a universal solvent due to its unique chemical properties which means it is able to alter the properties of different compounds [3]. Water covers about 71% of the earth's surface as oceans and groundwater respectively [4]. It has been found that approximately one-third of the world's population uses groundwater for drinking. The major source of freshwater is the aquifer. Aquifers contain over 90% of the total fresh water available for human use [5]. The role of geophysics is important in groundwater studies. The method has helped in detecting the availability, quality and quantity of groundwater over the years [1]. The geophysical method can be used to map sub-surface lithology sequences and concealed geological structures like fractures, faults, joints, etc., which can be favourable for the presence of groundwater especially in the basement complex environment, hence its importance in groundwater potential evaluation. Groundwater is usually associated with low yield and the increasing demand for water and the cost involved in drilling boreholes therefore requires the application and the proper use of geophysical investigation techniques to locate high-yielding aquifers [6]. Geophysical investigation using electrical method involves the measurement of geo-electric parameters such as layer resistivity, thickness and depth for each lithological unit [7]. These parameters can be used to explain the subsurface hydrological condition and groundwater potentiality assessment.

It is due to this that a geophysical survey using a vertical electrical sounding technique was employed to delineate the lithology underlying the ground surface in the area which is used to study the groundwater potential. This is an effective method of investigating the subsurface without interfering with the hydrogeological system. To this effect, the electrical method has been successfully used to characterize the subsurface, especially the Vertical electrical sounding technique. Conclusively, these geo-electric parameters are superimposed to produce a comprehensive map showing the groundwater potential of the area.

## 1.1 Description and geomorphology of the study area

The site is located at Oda Community, Akure South local government, Ondo State, Nigeria. It can be accessed by road from the Akure Shoprite and the area lies within the central senatorial District of Ondo state. The study area is situated within geographic grids between 746400 m to 747300 m (Eastings) and 793000 m to 794000 m (Northings) defined by Minna-Nigeria 31N datum of the Universal Traverse Mercatum (UTM) as shown in **Figure 1** with topographic elevation ranging from 362 m to 325 m. **Figure 2** is a map showing the elevation of the study area.

It has a seasonal climate characterised by dual seasons. The rainy season is from April to October, with rainfall of about 1524 mm per year. The average temperature is about 27 °C during harmattan (December-February) and 32 °C in March with an annual relative humidity of about 80%. The natural vegetation is tropical rainforest (en.wikipedia.org/wiki/Akure).

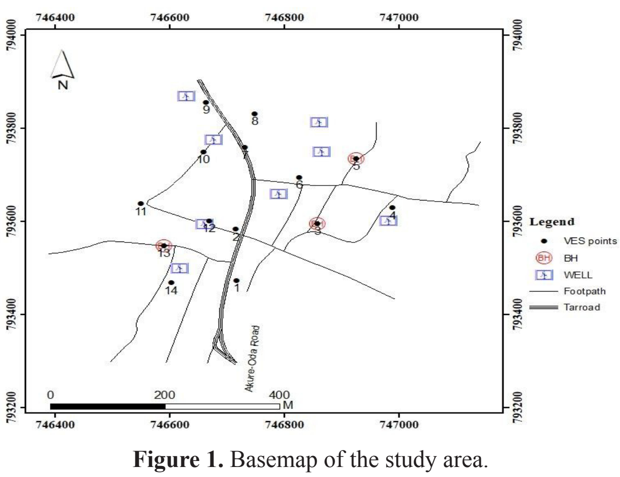


**Figure 1.** Basemap of the study area.

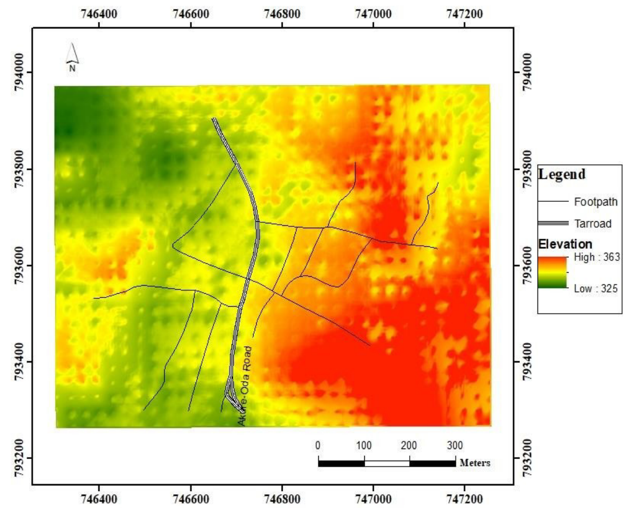


**Figure 2.** Elevation of the study area.

### 1.2 Local geology and hydrogeologic settings

Akure is underlain by the Precambrian Basement Complex rocks of Southwestern Nigeria which is typical of the Migmatite gneiss [8], comprising undifferentiated granite, Charnokitic rocks, medium to coarse granite and Migmatite gneiss rocks. The area is monolithic of Migmatite gneiss (**Figure 3**) and is highly weathered and fractured, with the prominent direction of foliation lying between 178° and 182° with easterly dips of 46° and 102° [9]. The hydrogeology system of this study area belongs to the hydrologic system of the basement complex terrain of Nigeria and groundwater is usually found in the weathered mantle, joints, and fractured bedrock in the surface. The basement rock may contain faulted areas, and incipient and fractured systems derived from tectonic activity earlier experienced. Therefore, the detection of these hydrogeologic structures may enhance the location of groundwater prospective zones in a typical basement setting.

## 2. Methodology

The vertical electrical sounding technique was used. **Figure 4** is a map showing the VES locations. Fourteen VES points in total were sounded and the electrode spread was varied from 1 to 80 m while the potential electrode ranged from 0.25 m to 5 m.

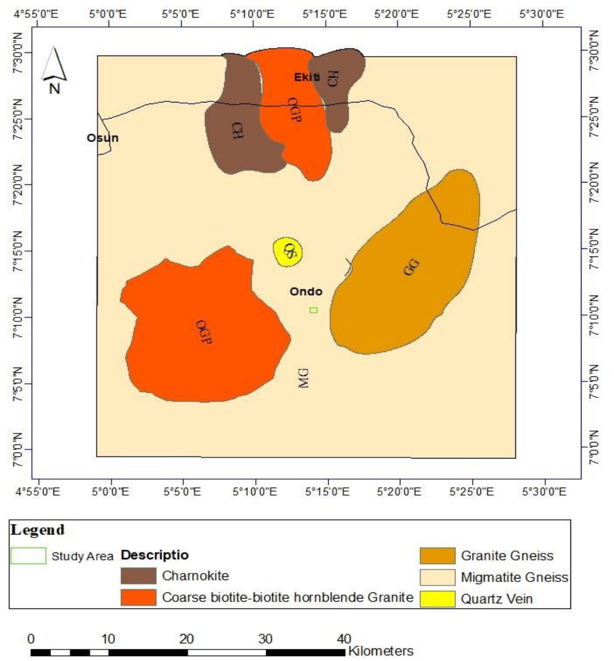


**Figure 3.** Geology map of Akure showing the study area (After NGSA 2008).

The apparent resistivity data generated from the VES survey were presented as depth sounding curves on bi-log paper. After acquiring all the data, it was then checked and corrected for error in order to have a good result. The data was manually curve matched and interpreted with WINRESIST software.

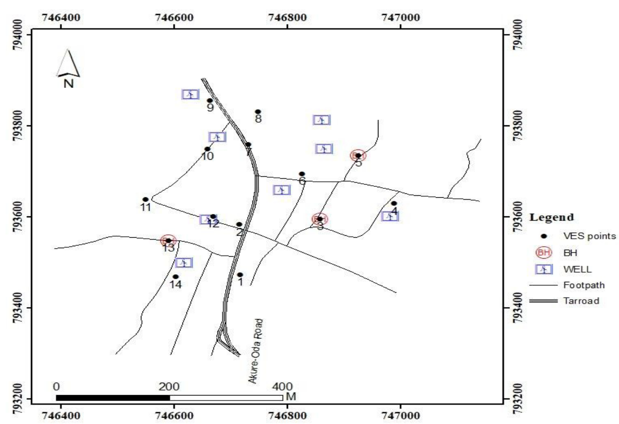


**Figure 4.** VES location map.

## 3. Results and discussion

### 3.1 Geoelectric sounding results

The geoelectric layers delineated across the study area ranged from three to four layers. The first layer resistivity value ranges from 29 to 164 Ωm and thickness ranges from 0.6 to 2.5 m. The second layer has a resistivity value ranging from 21-1361 Ωm with a thickness ranging between 1.5 m to 14.6 m. The third layer resistivity value is from 68 to 297 Ωm with thickness ranging between 4 m to 12.4 m. The fourth layer which is the deepest layer has a resistivity value ranging from 180 to 4364 Ωm with a depth ranging from 4 m to 19.5 m as shown in **Table 1** below.

The sounding curve types obtained from the study area are A, AA, H, HA and KH curve types. A and H curve types have three layers while the four layers comprise AA, HA and KH. The A and H type curves are the predominant curve type in the area, accounting for 36% each, and KH type curve accounts for 14% each and AA, HA curve type accounts for 7% of curve type in the study area. The KH curve type indicates a fractured or weathered layer between the second layer and basement rock which is often associated with groundwater possibilities. The H curve has a weathered layer as the middle layer which is usually regarded as the saturated zone in the basement complex and the aquifer varies depending on the material that overlain it. The resistivity values of the layers alone are not sufficient enough to serve as a guide during the investigation of areas for groundwater, the thickness and depth of each layer are also carefully considered in the assessment of groundwater.

**Table 1**. Geo-electric resistivities and thicknesses.

| VES NO | Layer NO | Layer resisitvity (Ωm) | Thickness (m) | Depth (m) | Curve type | Nature of rocks |
|---|---|---|---|---|---|---|
| 1 | 3 | 94<br>21*<br>247 | 1.1<br>3.3<br>---- | ----<br>1.1<br>4.4 | H | Top soil<br>Weathered layer<br>Fresh basement |
| 2 | 4 | 46<br>356<br>68*<br>344 | 1.4<br>1.5<br>4.5<br>---- | ---<br>1.4<br>2.9<br>7.4 | KH | Top soil<br>Weathered layer Weathered basement Fresh basement |
| 3 | 3 | 44<br>105*<br>965 | 1.7<br>11.6<br>----- | ----<br>1.7<br>13.3 | A | Top soil<br>Weathered layer<br>Fresh basement |
| 4 | 4 | 57<br>530<br>88*<br>664 | 2.5<br>4.6<br>12.4 | ----<br>2.5<br>7.3<br>19.5` | KH | Top soil<br>Weathered layer Weathered basement Fresh basement |
| 5 | 4 | 49<br>66<br>297*<br>470 | 0.8<br>2.1<br>1.1 | ----<br>0.8<br>2.9<br>4.0 | AA | Top soil<br>Weathered layer Weathered basement Fresh basement |
| 6 | 3 | 29 | 1.1 | ----- | A | Top soil |
| | | 113*<br>340 | 8.0 | 1.1<br>9.1 | | Weathered layer<br>Fresh basement |
| 7 | 3 | 49<br>16*<br>460 | 2.7<br>7.3<br>----- | ----<br>2.7<br>10.0 | H | Top soil<br>Weathered layer<br>Fresh basement |
| 8 | 3 | 83<br>106*<br>338 | 0.9<br>3.9<br>------ | ----<br>0.9<br>4.7 | A | Top soil<br>Weathered layer<br>Fresh basement |

Table 1 continued

| VES NO | Layer NO | Layer resisitvity (Ωm) | Thickness (m) | Depth (m) | Curve type | Nature of rocks |
|---|---|---|---|---|---|---|
| 9 | 3 | 77<br>361*<br>1308 | 0.6<br>6.9 | ----<br>0.6<br>7.5 | A | Top soil<br>Weathered layer<br>Fresh basement |
| 10 | 3 | 54<br>29*<br>180 | 1.1<br>5.6<br>---- | ----<br>1.1<br>6.7 | H | Top soil Weathered layer Fresh basement |
| 11 | 3 | 164<br>332*<br>4364 | 0.6<br>5.7<br>---- | ----<br>0.6<br>6.3 | A | Top soil Weathered layer Fresh basement |
| 12 | 4 | 148<br>59<br>145*<br>244 | 0.6<br>1.2<br>4.0<br>---- | ----<br>0.6<br>1.8<br>5.9 | HA | Top soil<br>Weathered layer Weathered basement Fresh basement |
| 13 | 3 | 215<br>62* | 0.9<br>14.6 | ----<br>0..9 | H | Top soil<br>Weathered layer |
| | | 1392 | ---- | 15.5 | | Fresh basement |
| 14 | 3 | 64<br>29*<br>234 | 1.0<br>5.9<br>---- | ----<br>1.0<br>6.9 | H | Top soil<br>Weathered layer<br>Fresh basement |

Note: * = aquifer layer.

## 3.2 Geo-electric section results

***Geo-electric section 1***

**Figure 5** shows the geo-electric section observed on each VES point along the southwest-northeast trend. VES11, VES 10, VES 7, and VES 8 were shown. It comprises 3 layers. The resistivity of the top soil is from 49 to 164 Ωm and a thickness of 0.6 to 2.7 m, the weathered layer had a resistivity range of 16 to 332 Ωm and a thickness of 3.9 to 7.3 and the resistivity of the fresh basement ranged from 180 to 4364 Ωm with a depth range from 4.7 to 10 m. VES 8 is observed at a higher elevation which is a basement ridge indicating the region is of low groundwater potential.

***Geo-electric section 2***

**Figure 6** shows the geoelectric section along the southwest-northeast trend drawn through VES 13, 12, 2, 6 and 5. It comprises three to four geoelectric layers. The resistivity of the top soil ranged from 39 to 215 Ωm and thickness between 0.6 to 1.4 m, the weathered layer had a resistivity range of 59 to 356 Ωm and thickness of 1.2 to 14.6 m. Beneath this layer in VES 13 and 6 is the fresh basement while the other VES 12, VES 2 and VES 5 have beneath them the weathered basement with a resistivity range of 68 to 297 Ωm and thickness range of 1.1 to 4.5 m. VES 6 is seen to be on a depressed elevation and with the highest thickness. It has a good groundwater potential.

***Geo-electric section 3***

**Figure 7** is a geoelectric section drawn through VES points 1, 3, 4 and 14 in the southwest to northeast trend comprising three to four geoelectric layers. The top soil has resistivity values ranging from 44 to 94 Ωm and thickness values between 0.6 and 2.5 m. Beneath the top soil layer, the layer identified as the aquifer unit characterized by resistivity values between 21 and 104 Ωm and thickness ranging from 3.3 and 11.6 m respectively, diagnostic of the weathered basement.

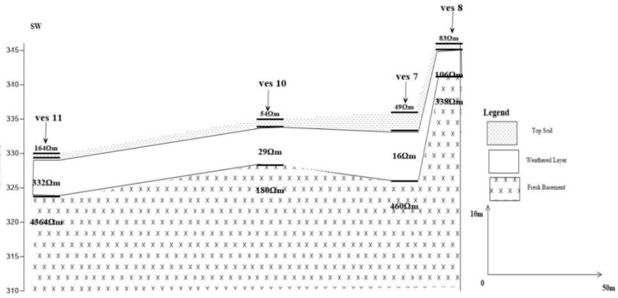

Figure 5. Geo-electric section 1.

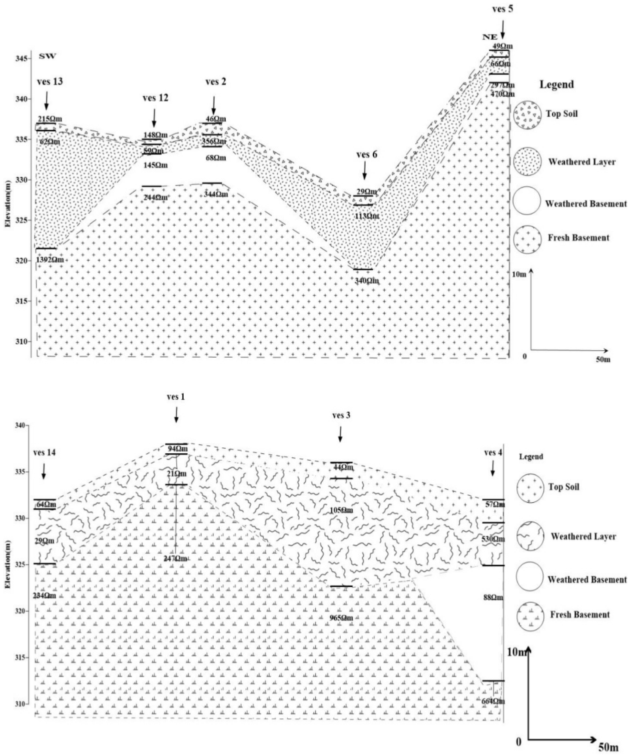


**Figure 7.** Geo-electric section 3.

## 3.3 Isopach and iso-resistivity map of the study area

### *Aquifer resistivity map*

This is a contoured map that depicts the resistivity of the aquifer layer in the study area. The area was characterised into four zones very high resistivity, high resistivity, moderate and low resistivity. These zones have been indicated by different colour types as presented in **Figure 8**. Areas of low resistivity values between 16 to 100 Ωm on the map are depicted in green colour indicating highly saturated zones. This occupies the major zones in the study area. These areas occupy the central southern part and northern part of the area.

Areas with very high resistivity values are indicated by the red colour and range from 251 to 360 Ωm. These areas occupy the extreme western, eastern, northern parts of the study area excluding the location of VES 12 which has moderate resistivity value of 145 Ωm and is indicated by the light green colour. Areas with high resistivity have low conductivity which indicates low moisture content while areas with low resistivity value have high conductivity which indicates high moisture content. Hence these values give insight into the hydrogeological features.

### *Aquifer thickness map*

The thickness varies from 1.1 to 14.5 m (**Figure 9**). The aquifer unit in the entire area is generally characterized by moderate thickness ranging from 6 to 10 m. They are indicated with light green colour on the map. Zones of low thickness are observed in the northern, north-eastern and southern parts of the area. They are indicated with green colour. However, some areas have relatively thick aquiferous units with thickness greater than 10 m i.e., VES points 3, 4, and 13. They are indicated in yellow colour on the map. Thickness plays an important role in groundwater abstraction, areas with high aquifer thickness are considered of good potential in hydrogeology.

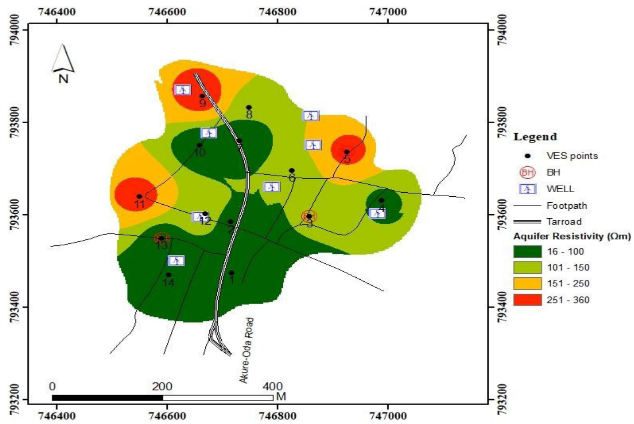


**Figure 8.** Aquifer resistivity map of the study area.

### *Bedrock relief map*

This shows the relief of the basement rock in the area (**Figure 10**). It was derived by subtracting the overburden thickness values from the elevation values all measured in meter. This indicates the hydro-topographic condition of the basement rock underlying the study area. According to Adiat et al., (2009), groundwater flows from areas of high pressure (such as bedrock ridge) to areas of low pressure (such as bedrock depression) [9]. The study area is divided into basement ridges, slopes and depressions. The basement depression areas are indicated with green colour on the map and they are found in the western and eastern part of the study area while the slope area is observed in the central part indicated with yellow colour. The ridge is indicated with red colour and is located in the southern part and north-eastern part of the study area. Areas with depressions on the map have a significant role in groundwater potentiality because they act as groundwater collection points as a result of flow directed towards these areas from the basement ridge through the slope area which is an intermediate between the two.

### 3.4 Groundwater potential mapping

The groundwater potential map was generated by overlaying the aquifer parameters extracted from the geoelectric results above using the weighted overlay algorithm in ArcGIS and by assigning weight to the three parameters using Analytical Hierarchy Process (AHP).

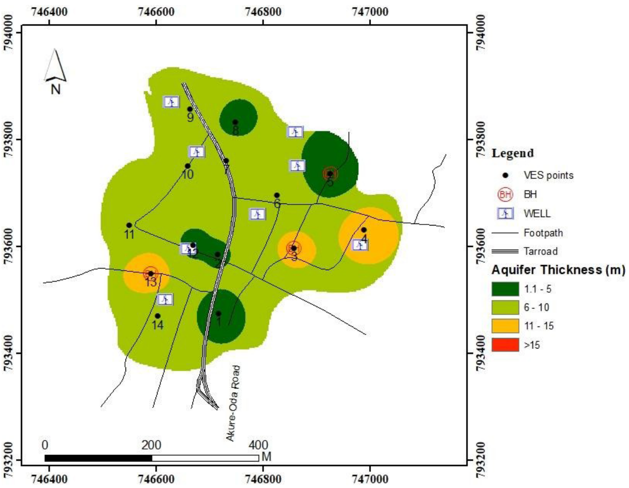

**Figure 9.** Aquifer thickness map of the study area.

### 3.5 Weight assignment

Weights were assigned to the isopach and iso-resistivity maps of the study area using Analytical Hierarchy Process (AHP) in order to overlay them to produce the groundwater potential map of the study area. Weight describes the degree of influence of each factor with respect to the groundwater potential of the study area. The resulting priority vector and weights obtained by estimating the average of all the elements of each row, **Tables 2 and 3** respectively below indicate that in terms of criterion aquifer thickness is prioritized, with alternatives bedrock relief ranking second aquifer resistivity ranking third and the assigned weight for the parameters from the AHP process are 0.48, 0.41 and 0.11 respectively. The result has a consistency ratio of 3% which shows that the result is accepted and the decision is valid. The result was used to assign weight to the geo-electric parameters.

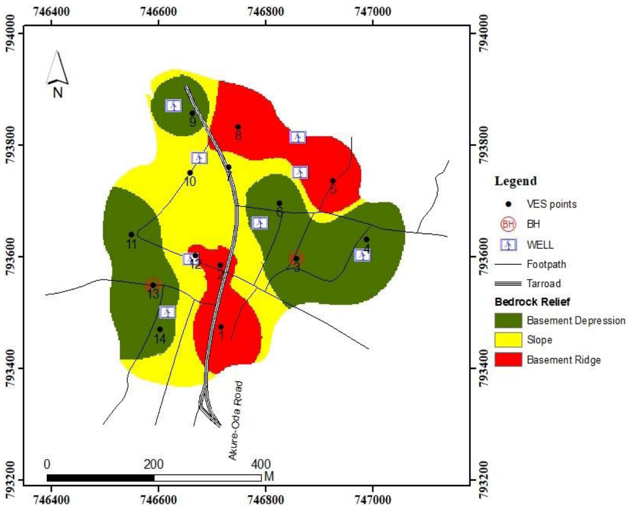

**Figure 10.** Bedrock relief map of the study area.

### 3.6 Estimation of groundwater potential index

This is the sum of products of weights (W) and ratings (R) overall factors used for the estimation. Mathematically, it is expressed as:

$$\text{Groundwater Potential Index} = ArR * ArW + AtR * AtW + BrR * BrW \quad (1)$$

where A.R = aquifer resistivity, A.T = aquifer thickness, B.R = bedrock relief and subscript R and W represent rating and weight respectively.

The weights were substituted into (1) to become:

$$\text{Groundwater Potential Index} = 0.11Ar + 0.48AtR + 0.41BrR \quad (2)$$

### 3.7 Groundwater potential index map

This was generated using Equation (2) in the ArcGIS environment using the weighted overlay algorithm. The individual maps were reclassified first into 4 rates depending on their contribution factor. The weighted overlay was used to classify the groundwater potential of the study area into our areas; namely the low, moderate, high and very high potential regions. Areas of low potential were indicated by the colour blue. These areas occupied the north-eastern part of the area and the area VES 5 and 10 were sited. Areas of moderate potential were indicated by the colour green and it is predominant in the area. These areas mostly occupied the central area covering the western, north-western and north-eastern parts. The southwestern and eastern parts are occupied by high to very high groundwater potential zone which is indicated by the colours red and orange. VES 13 and 3 are very high potential points and they also coincide with the existing borehole in the area, this indicates the accuracy of the model (**Figure 11**).

### 3.8 Groundwater potential index map validation

The groundwater potential index map was validated by taking the hydrological parameters of 8 existing hand-dug wells in the area. The parameters include static water level, well depth and water column. The water column level was obtained by subtracting the static water level from the well depth. These parameters are valuable in validating the accuracy of the calculated groundwater potential index map taking into cognizance the relationship between the map and the well parameters.

**Table 4** shows the results of the validation parameters and their groundwater potential category. The hand-dug wells depth ranges from 6.27 to 12.6 m, static water level ranges from 6.36 to 15 m and the water column varies between 0.09 to 4 m. The water column which implies the volume of water present in the well was used for the final validation. It was categorized into three classes namely low, moderate and high depending on the column length in meter. This was superimposed on the established groundwater potential index map for correlating both results (**Figure 12**).

The two wells with low water volume (0.09-0.1 m) coincide with low-moderate groundwater potential zones in the north-eastern part of the study area, while the remaining wells have water volumes ranging from 1.18 to 4 m fall and are categorized as moderate to high potential. These wells coincide with the moderate to high groundwater potential zones.

The ratings of the well water column significantly coincide with the groundwater potential index map of the study area, which implies that the groundwater potential index validates the groundwater productivity of the study area. Hence, the generated groundwater potential map has good prediction accuracy.

**Table 2.** A matrix of pair-wise comparisons of the parameters for the AHP process.

| | A.R | A.T | B.R |
|---|---|---|---|
| **A.R** | 1 | 1/5 | 1/3 |
| **A.T** | 5 | 1 | 1 |
| **B.R** | 3 | 1 | 1 |
| **Column sum** | 9 | 2.2 | 2.33 |

Note: A.R = Aquifer Resistivity, A.T = Aquifer Thickness, B.R = Bedrock Relief.

**Table 3.** Weight determination.

| | A.R | A.T | B.R | Weights |
|---|---|---|---|---|
| **A.R** | 1/9=0.11 | 0.2/2.2=0.091 | 0.333/2.33= 0.143 | 0.344/3 = 0.11 |
| **A.T** | 5/9=0.556 | 1/2.2=0.455 | 1/2.33=0.429 | 1.44/3=0.48 |
| **B.R** | 3/9=0.333 | 1/2.2= 0.455 | 1/2.33=0.429 | 1.217/3=0.41 |
| **Column sum** | 1 | 1 | 1 | 1 |

Note: Consistency ratio = 3.0.

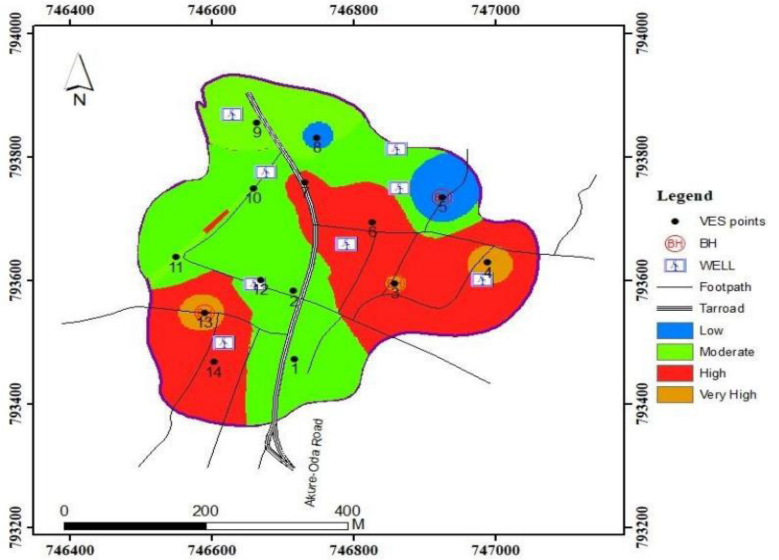


**Figure 11.** Groundwater potential map of the study area.

**Table 4.** Hydrological parameters of the hand-dug wells in the study area.

| S/N | Longitude | Latitude | Well depth (m) | Static water level (m) | Water column (m) | Groundwater potential category |
|---|---|---|---|---|---|---|
| 1 | 5.2353 | 7.1754 | 12 | 15 | 3 | High |
| 2 | 5.2357 | 7.1761 | 11 | 15 | 4 | High |
| 3 | 5.2362 | 7.1739 | 12.6 | 12.7 | 0.1 | Low |
| 4 | 5.2346 | 7.1746 | 11.81 | 13.6 | 1.18 | Moderate |
| 5 | 5.2328 | 7.1736 | 8.18 | 10 | 1.18 | Moderate |
| 6 | 5.2335 | 7.1740 | 6.27 | 6.36 | 0.0 | Low |
| 7 | 5.2336 | 7.1757 | 8.18 | 9.54 | 1.36 | Moderate |
| 8 | 5.2332 | 7.1765 | 7.27 | 9.09 | 1.81 | Moderate |

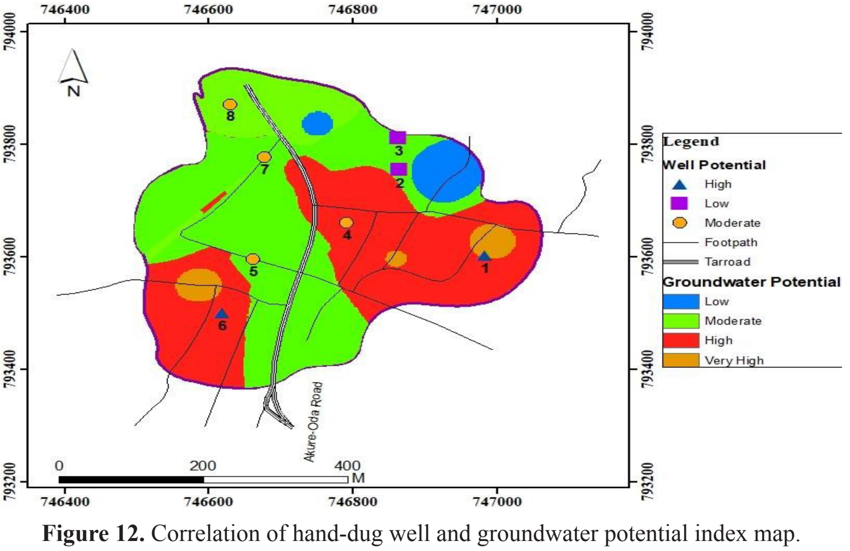


**Figure 12.** Correlation of hand-dug well and groundwater potential index map.

## 4. Conclusions

The electrical method using vertical electrical soundings technique was carried out at several locations with the aim of evaluating the groundwater potential of the study area. The study area is characterized by fresh basement rocks. A total of 14 VES data were acquired from the study area using a Schlumberger array with a maximum spacing (AB/2) of 80 m. The first layer resistivity value ranges from 29 to 164 Ωm and thickness ranges from 0.6 to 2.5 m. The second layer has a resistivity value ranging from 21-1361 Ωm with a thickness ranging between 1.5 m to 14.6 m. The third layer resistivity value is from 68 to 297 Ωm with thickness ranging between 4 m to 12.4 m. The fourth layer which is the deepest layer has a resistivity value ranging from 180 to 4364 Ωm with depth ranging from 4 m to 19.5 m. The geoelectric parameters obtained were used to generate and evaluate the groundwater potential in the study area. The parameters interpreted from the geoelectric data were used to generate the aquifer resistivity map, aquifer thickness map and bedrock relief which were combined to produce the groundwater potential map of the area. These maps were used to classify the study area into zones ranging from low to high groundwater potential zones. The southwestern and eastern parts are identified as productive groundwater potential zones. VES 13 and 3 coincide with the existing borehole in the area, this is indicating a good accuracy of the model.

In order to validate the results, water column depth was taken from 8 existing hand-dug wells. Major parts of the study area fall within the moderate to high potential while the rest has low potential. Therefore, the area can be concluded to have moderate groundwater potential.

The ratings of the well water column significantly coincide with the groundwater potential index map. Hence, the generated groundwater potential map has good prediction accuracy.

## Authors Contributions

The first and the third authors Abe, S.J. and Adeyemo, I.A. supervised and provided the technical direction for the research while the second author was a student. He acquired the data and did the interpretation.

## Conflict of Interest

There is no conflict of interest.

## References

[1] Khan, Q., Liaqat, M.U., Mohamed, M.M., 2022. A comparative assessment of modeling groundwater vulnerability using DRASTIC method from GIS and a novel classification method using machine learning classifiers. Geocarto International. 37(20), 5832-5850.

[2] McMurry, J., Fay, R., 2004. Hydrogen, oxygen and water. Pearson Education: New Jersey. pp. 575-599.

[3] A Snapshot of Drinking Water and Sanitation in Africa [Internet]. WHO/UNICEF; 2008. Available from: https://sswm.info/sites/default/files/reference_attachments/UNICEF%20WHO%202008%20A%20Snapshot%20of%20Drinking%20Water%20and%20Sanitation%20in%20Africa.pdf

[4] The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk [Internet]. FAO; 2011. Available from: https://haseloff.plantsci.cam.ac.uk/resources/SynBio_reports/FAO2011-i1688e.pdf

[5] Oluyemi, E.A., Makinde, W.O., Oladipo, A.A., 2009. Potential groundwater contamination with toxic metals around refuse dumps in some parts of Lagos metropolis, Nigeria. Toxicological & Environmental Chemistry. 91(5), 933-940.

[6] Adagunodo, T.A., Akinloye, M.K., Sunmonu,

L.A., et al., 2018. Groundwater exploration in Aaba residential area of Akure, Nigeria. Frontiers in Earth Science. 6, 66.
DOI: https://doi.org/10.3389/feart.2018.00066

[7] Olusola, E.F., Ayodele, Y.G., 2021. Geophysical investigation of groundwater potential of a site in Obale area of Akure, Nigeria. International Journal of Engineering Applied Sciences and Technology. 6(1), 88-93.

[8] Rahaman, M.A., 1976. Review of the basement geology of SW Nigeria in geology of Nigeria. Elizabithan Publishing Company: Lagos. pp. 41-58.

[9] Adiat, K.A.N., Olayanju, G.M., Omosuyi, G.O., et al., 2009. Electromagnetic profiling and electrical resistivity soundings in groundwater investigation of a typical Basement Complex—a case study of Oda Town Southwestern Nigeria. Ozean Journal of Applied Sciences. 2(4), 333-359.