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## 1D modeling of aquifer vulnerability and soil corrosivity within the sedimentary terrain in Southern Nigeria, using resistivity method

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### ABSTRACT

Groundwater vulnerability/soil corrosivity was carried out within the study area, with the sole aim of classifying groundwater and soil corrosivity into various classes with the aid of the resistivity method. For this study the Vertical Electrical Sounding (VES) method was used, Schlumberger electrode configuration was used with maximum electrode spacing (AB/2) of 200 m in sixteen (16) different locations for data acquisition. Geoelectric parameters (layer resistivity and thickness) were determined from the interpreted data. Findings from Geoelectric Layer susceptibility indexing (GLSI) revealed that the northern, southern, and northeast of the study area value range of 70 to 160, 70 to 150, and 120 to 160 are considered to be highly vulnerable, vulnerable, and highly vulnerable respectively. The estimated result obtained from longitudinal unit conductance (S) showed that groundwater is considered to be slightly prone to contamination from the surface. Deduction from corrosivity revealed that VESs location showed no trace of corrosivity except for VES 15. According to findings from VES 15, underground metallic installations should be buried at a depth away from the aforementioned VES point.

**Keywords:** Resistivity, Soil, GLSI, Corrosivity, Fracture

## **1. INTRODUCTION**

Groundwater is one of the most important natural resources on the planet, a large portion of it exists at shallow depths within the study area, and it is occasionally found in fractures ranging from 10 to 40 m [1]. As a result, it's assumed that it's vulnerable to contamination because it occurs at a shallow depth. In a holistic view, the term natural vulnerability refers to an aquifer's sensitivity to being harmed by an applied pollution load [2-4]. Groundwater pollution vulnerability/soil corrosivity mapping is a useful method for identifying locations at risk of contamination. To measure groundwater vulnerability and soil corrosion, several approaches have been developed around the world. These methods were divided into three categories: (1) process-based simulation models, (2) statistical methods, and (3) overlay, index methods [5, 6] resistivity methods [7, 8], and water evaluation methods [9, 10]. This has necessitated an urgent need for groundwater resource development due to population growth and scientific advancements that have hurt groundwater/soil quality all over the world [8, 9, 11]. The VES method, which determines the vertical variation of subsurface resistivity to depth, has been very effective in determining subsurface layering, overburden thickness, depth to fractured aquifer and aquifer vulnerability, soil corrosivity among others [8, 12-14].

In the last decade, the use of geophysical methods, particularly VES, for hydrogeological site characterization has grown [4, 15, 16]. It is widely used because of the portability of equipment, rapid measurements, and fewer ambiguities in data interpretation; it is also an environmentally friendly (non-destructive) method [17], [18] and has been used to solve hydrogeological and soil corrosivity problems [8, 19, 20]. [15] used the electrical resistivity method to assess groundwater sensitivity to leachate infiltration and found that aquifers near dumpsites have low protective capacity and are susceptible to leachate contamination. [21], assessed aquifer protection capacity and soil corrosivity in Makurdi, Benue state, using the electrical resistivity method. They found sites where factories could be built and iron pipes could be placed to protect the hydrological environment. [18], used geo-electrical research to assess soil corrosivity and aquifer protective capacity in the Bwari Basement Complex area of Abuja. They classified the area into good, moderate, weak, and poor aquifer protective capacity zones. Following a large investment, several developed groundwater potential areas have been abandoned due to various reasons, including infiltration of pollutants and subsequent contamination of groundwater caused by leaching of septic tanks, refuse dumps, petroleum tanks, and improper use and disposal of pesticides. According to [22] if a well-structured vulnerability assessment had been evaluated, a huge financial loss (well abandonment) and a major health danger would have been avoided. This has necessitated an urgent need for the use of geoelectric method was utilized to determine aquifer vulnerability and soil corrosivity in this investigation, since live hood of the inhabitant of the study area depends on tilting of soil and depending on groundwater for domestic and other use [43-45].

### **1. 1. The Study Area**

### **1. 2. Location and Accessibility**

The study area covers selected towns and villages in Cross state, Nigeria see Table 1. It is bounded between latitude 6°30'N and 6°42'N and 8°18' E and 8°30' E longitudes as illustrated in Fig. 1. The study area is accessible via the Abakaliki/Ogoja route and a few other local roads.

**Table 1.** Name of Locations

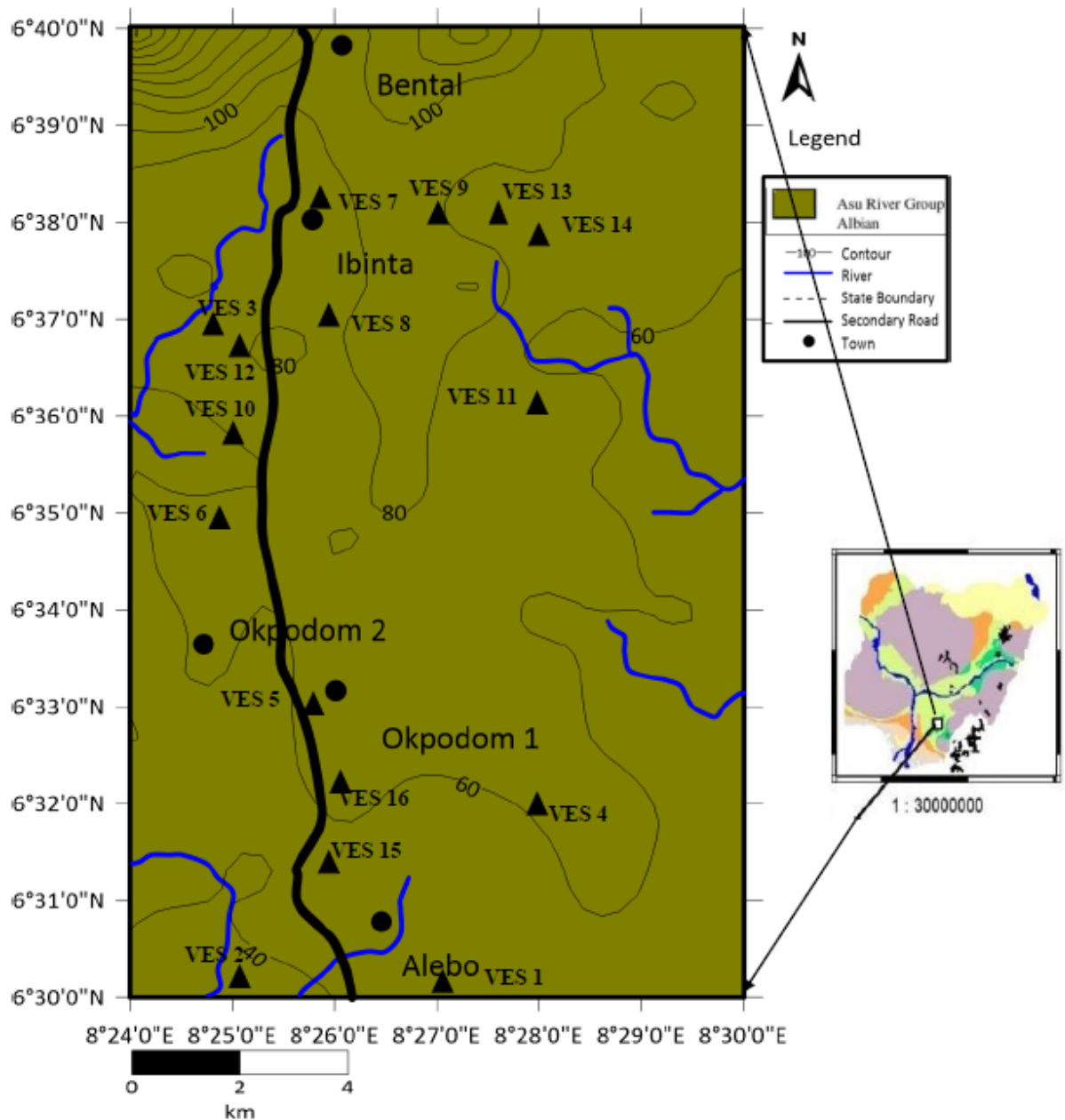
| <b>VES Points</b> | <b>Co-ordinate</b>      | <b>Location</b> |
|-------------------|-------------------------|-----------------|
| 1                 | 6°30'04//N - 8°27'13//E | Alebo           |
| 2                 | 6°30'18//N - 8°25'11//E | Ezekewe         |
| 3                 | 6°37'42//N - 8°25'24//E | Ujussim         |
| 4                 | 6°32'36//N - 8°28'09//E | Okpodom I       |
| 5                 | 6°33'50//N - 8°26'18//E | Okpodom II      |
| 6                 | 6°35'47//N - 8°25'16//E | Indingele       |
| 7                 | 6°38'34//N - 8°26'48//E | Ogbaja          |
| 8                 | 6°37'54//N - 8°26'18//E | Ibinta          |
| 9                 | 6°38'02//N - 8°27'09//E | Obetegana       |
| 10                | 6°36'48//N - 8°25'50//E | Ngidi           |
| 11                | 6°36'19//N - 8°28'42//E | Igele           |
| 12                | 6°37'07//N - 8°25'30//E | Idom            |
| 13                | 6°38'53//N - 8°27'05//E | Inno            |
| 14                | 6°38'52//N - 8°27'21//E | Bental          |
| 15                | 6°31'23//N - 8°26'25//E | Ominyi          |
| 16                | 6°32'55//N - 8°25'24//E | Eketekwe        |

## **2. GEOLOGY / HYDROGEOLOGY**

The study area lies within the Asu River Group of the Southern Benue Trough. According to [23], the Asu River Group has an average thickness of roughly 2000 m and sits awkwardly on top of the Precambrian Basement. [24] and [25] used three tectonic sedimentary cycles, namely marine transgressions, and regressions, from the Albian to the Coniacian, to provide thorough information on the Southern Benue Trough. The Asu River Group was the first marine transgression in the Benue Trough during the middle Albian era [24]; [26] According to [26] the Asu River Group sediments are mostly underlain by shales. River Abe and River Nwangele, as well as their tributaries, drain the research region (Fig. 1). Low permeability rocks such as shales, mudstones, siltstones, and tight sandstone lenses dominate the research area [27]. Low-grade regional metamorphism has occurred in these rocks [28]; [29], resulting in severely compacted sandstone and siltstone lithofacies.

The research area's drainage pattern is dendritic, groundwater circulation and storage are primarily influenced by the thickness, lithology, and structure of rock formations within the studied area [30]. Fragmented shale and limestone in the research region contain water-bearing

formations [31]. In general, shale is considered an aquiclude because it does not allow for sufficient water movement, especially when it is new and unweathered. However, when cracked, it usually acts as a water-bearing formation. Streams, hand-dug wells, manual boreholes, and motorized boreholes are the most common water sources. In the studied area, the most common lithology is shale, which typically lacks the permeability needed to supply water cost-effectively. Previous research, on the other hand, suggests that water only exists where the shales are fractured [32]. [33], further pointed out that tectonism, which is frequent in the area and occurs at shallow depths, is thought to have caused the many fracture system that exists in the area.



**Fig. 1.** Geology Map of the Study Area showing VES Points

### 3. MATERIAL AND METHOD

The ABEM SAS 1000 Terrameter was used to investigate the subsurface. Data was collected using the VES technique and the Schlumberger electrode design. This entails injecting a low-frequency direct current (DC) into the subsurface using a pair of current electrodes (AB) and monitoring the resulting voltage drop via the second set of potential electrodes (MN). In a homogeneous subsurface, the depth of penetration is proportional to the distance between the current electrodes, while altering the distance between the electrodes offers information on the stratification of the ground [21]. The current electrode spacing (AB/2) ranged from 2 to 200 m, whereas the potential electrode separation ranged from 0.5 to 10 m. The apparent resistivity was calculated using the following formula [12, 34]:

$$\rho_a = \pi \frac{(AB/2)-(MN/2)}{MN} \cdot Ra \quad (1)$$

where:  $\rho_a$  represents apparent resistivity,  $AB$  represents the distance between the two current electrodes,  $MN$  represents the distance between the potential electrodes, and  $Ra$  represents the apparent electrical resistance observed. The layer resistivities, depths, thicknesses, and curve types were determined by plotting each apparent resistivity value obtained from the above equation on a log - log graph to the associated current electrode spacing. The field curves were matched with the auxiliary curves in the traditional quantitative interpretation method of partial curve matching. IX1D is a computer modeling program. The resistivities and thicknesses of the layers were improved using software in the inversion and iteration of each VES point.

#### 3. 1. Equation used for Assessing Aquifer Vulnerability/aquifer protective capacity

GLSI is determined by equation 2 as proposed by [35]

$$GLSI = \frac{((\rho_{1r}+h_{1r})/2+(\rho_{2r}+h_{2r})/2+(\rho_{3r}+h_{3r})/2\ldots(\rho_{nr}+h_{nr})/2)}{N} \quad (2)$$

Longitudinal unit conductance (S) was calculated using [36]. For 'n' layers, the total longitudinal conductance is

$$S = \sum_{i=1}^n \frac{h_i}{\rho_i} = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} + \ldots + \frac{h_n}{\rho_n} \quad (3)$$

where:  $h$  = thickness and  $\rho$  = resistivity.

#### 3. 2. Geoelectric Layer Susceptibility Indexing (GLSI)

According to [35] stated that the GLSI is a hydrogeologic method for indexing geoelectric parameters derived from vertical resistivity sounding and lithological sequence comparison. It's an empirical notion that was developed to supplement other vulnerability assessment techniques. Unlike the longitudinal conductance method, which assigns indices to the ratios of geoelectric parameters (layer resistivity and thickness), the GLSI assigns an index to each geoelectric parameter (layer, resistivity, and thickness) [37]. Table 2 and 3 was used in the determination of GLSI.

**Table 2.** Geoelectric layer Susceptibility index rating for resistivity Parameters [35].

| Resistivity range ( $\Omega$ -m) | Lithology      | Susceptibility |
|----------------------------------|----------------|----------------|
| <20                              | Clay/silt      | 1              |
| 20-50                            | Sandy clay     | 2              |
| 51-100                           | Clayey sand    | 3              |
| 101-150                          | Sand           | 5              |
| 151-400                          | Lateritic Sand | 2              |
| >401                             | Laterite       | 1              |

**Table 3.** GLSI Parameter Rating [35]

| Vulnerability Rating | Index      |
|----------------------|------------|
| Low                  | 1.0 – 1.99 |
| Moderate             | 2.0-2.99   |
| High                 | 3.0-3.99   |
| Extreme              | 4.0        |

#### 4. RESULT AND DISCUSSION

The results of this work are presented in the tables and figures below

**Table 4.** Resistivity value of VES Points

| VES Number | Layer | Thickness | Depth (m) | Resistivity | Curve Type                       |
|------------|-------|-----------|-----------|-------------|----------------------------------|
| VES 1      | 1     | 1.65      | 1.65      | 377.21      | H ( $\rho_1 > \rho_2 < \rho_3$ ) |
|            | 2     | 12.46     | 12.46     | 33.62       |                                  |
|            | 3     | 4.32      | 18.44     | 15.05       |                                  |
|            | 4     | 1.45      | 1.4       | 1490.3      |                                  |

|        |   |         |        |        |                                                     |
|--------|---|---------|--------|--------|-----------------------------------------------------|
| VES 2  | 1 | 2.69    | 2.69   | 536.47 | H ( $\rho_1 > \rho_2 < \rho_3$ )                    |
|        | 2 | 1.87    | 4.57   | 130.48 |                                                     |
|        | 3 | 30.49   | 35.06  | 114.92 |                                                     |
|        | 4 |         |        | 40198. |                                                     |
| VES 3  | 1 | 3.25    | 3.25   | 564.67 | HK ( $\rho_1 > \rho_2 < \rho_3 > \rho_4$ )          |
|        | 2 | 0.12    | 3.37   | 4.489  |                                                     |
|        | 3 | 11.24   | 14.62  | 660.75 |                                                     |
| VES 4  | 1 | 1.68    | 1.68   | 305.05 | HK ( $\rho_1 > \rho_2 < \rho_3 > \rho_4$ )          |
|        | 2 | 9.27    | 10.960 | 47.51  |                                                     |
|        | 3 | 45.587  | 56.546 | 87.866 |                                                     |
|        | 4 | 100.04  | 156.59 | 17.55  |                                                     |
|        | 5 |         |        | 2692.0 |                                                     |
| VES 5  | 1 | 1.27    | 1.27   | 358.06 | HK ( $\rho_1 > \rho_2 < \rho_3 > \rho_4$ )          |
|        | 2 | 21.141  | 22.416 | 93.644 |                                                     |
|        | 3 | 23.682  | 46.098 | 358.96 |                                                     |
|        | 4 |         |        | 22.933 |                                                     |
| VES 6  | 1 | 0.93    | 0.93   | 310.20 | QH ( $\rho_1 > \rho_2 > \rho_3 < \rho_4$ )          |
|        | 2 | 6.68    | 7.62   | 98.99  |                                                     |
|        | 3 | 141.02  | 148.64 | 10.26  |                                                     |
|        | 4 |         |        | 50.79  |                                                     |
| VES 7  | 1 | 1.2904  | 1.2904 | 276.64 | HK ( $\rho_1 > \rho_2 < \rho_3 > \rho_4$ )          |
|        | 2 | 87.219  | 88.509 | 111.19 |                                                     |
|        | 3 |         |        | 28.738 |                                                     |
| VES 8  | 1 | 2.0177  | 2.0177 | 1016.7 | Q ( $\rho_1 > \rho_2 > \rho_3$ )                    |
|        | 2 | 0.94351 | 2.9613 | 580.47 |                                                     |
|        | 3 | 33.513  | 36.474 | 423.68 |                                                     |
|        | 4 |         |        | 67.771 |                                                     |
| VES 9  | 1 | 1.0616  | 1.0616 | 420.20 | Q ( $\rho_1 > \rho_2 > \rho_3$ )                    |
|        | 2 | 8.8447  | 9.9064 | 173.84 |                                                     |
|        | 3 | 67.703  | 77.610 | 65.523 |                                                     |
|        | 4 |         |        | 8.7481 |                                                     |
| VES 10 | 1 | 1.5133  | 1.5133 | 392.88 | Q ( $\rho_1 > \rho_2 > \rho_3$ )                    |
|        | 2 | 2.7871  | 4.3004 | 148.96 |                                                     |
|        | 3 | 36.343  | 40.643 | 183.98 |                                                     |
|        | 4 |         |        | 43.00  |                                                     |
| VES 11 | 1 | 0.93    | 0.93   | 310.20 | QH ( $\rho_1 > \rho_2 > \rho_3 < \rho_4$ )          |
|        | 2 | 6.68    | 7.62   | 98.99  |                                                     |
|        | 3 | 141.02  | 148.64 | 10.26  |                                                     |
|        | 4 |         |        | 50.79  |                                                     |
| VES 12 | 1 | 2.60    | 2.60   | 646.33 | HKH( $\rho_1 > \rho_2 < \rho_3 < \rho_4 > \rho_5$ ) |

|        |   |        |        |        |                                                     |
|--------|---|--------|--------|--------|-----------------------------------------------------|
|        | 2 | 4.47   | 7.07   | 113.33 |                                                     |
|        | 3 | 13.053 | 20.127 | 344.58 |                                                     |
|        | 4 | 39.758 | 59.759 | 88.977 |                                                     |
|        | 5 |        |        | 15095  |                                                     |
| VES 13 | 1 | 0.6569 | 0.6569 | 2112.7 | HKH( $\rho_1 > \rho_2 < \rho_3 < \rho_4 > \rho_5$ ) |
|        | 2 | 4.4169 | 5.0738 | 301.31 |                                                     |
|        | 3 | 5.3657 | 10.440 | 28.677 |                                                     |
|        | 4 | 18.515 | 28.955 | 707.44 |                                                     |
|        | 5 |        |        | 2.1760 |                                                     |
| VES 14 | 1 | 1.79   | 1.79   | 721.81 | HK ( $\rho_1 > \rho_2 < \rho_3 > \rho_4$ )          |
|        | 2 | 0.79   | 2.59   | 7.43   |                                                     |
|        | 3 | 8.16   | 10.75  | 420.15 |                                                     |
|        | 4 | 69.71  | 80.46  | 9.50   |                                                     |
|        | 5 |        |        | 285.96 |                                                     |
| VES 15 | 1 | 167.85 | 2.6573 | 2.6573 | HK ( $\rho_1 > \rho_2 < \rho_3 > \rho_4$ )          |
|        | 2 | 29.059 | 2.2586 | 4.9159 |                                                     |
|        | 3 | 2487.6 | 1.3188 | 6.2347 |                                                     |
|        | 4 | 15.602 |        |        |                                                     |
| VES 16 | 1 | 2.4226 | 2.4226 | 2136.2 | Q ( $\rho_1 > \rho_2 > \rho_3$ )                    |
|        | 2 | 38.500 | 40.923 | 300.06 |                                                     |
|        | 3 |        |        | 127.07 |                                                     |

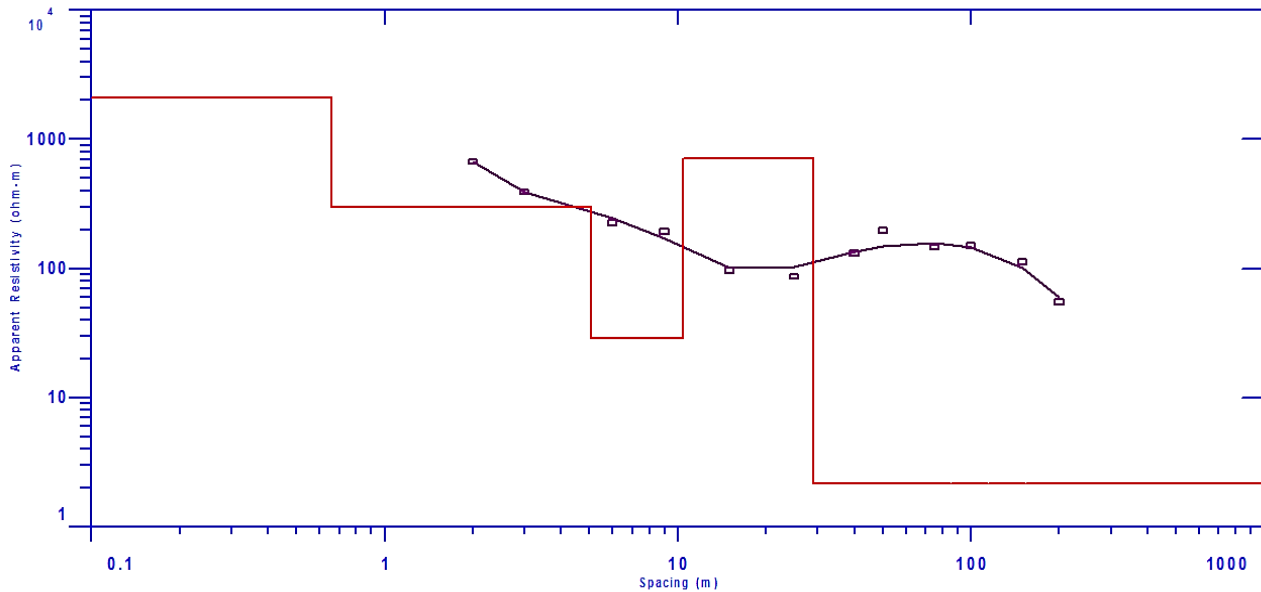


Fig. 2. Modeling of a sounding point of VES 13

**Table 5.** Values of Resistivity, Thickness and depth for VES 13.

| Layer | Resistivity ( $\Omega\text{m}$ ) | Thickness (m) | Depth (m) |
|-------|----------------------------------|---------------|-----------|
| 1.    | 2112.7                           | 0.65690       | 0.6569    |
| 2.    | 301.31                           | 4.4169        | 5.0738    |
| 3.    | 28.677                           | 5.3657        | 10.440    |
| 4.    | 707.44                           | 18.515        | 28.955    |
| 5.    | 2.1760                           |               |           |

**Table 6.** Results of GLSI and LC of the Study area.

| S/N    | GLSI    | LC (S) | Remarks |           |
|--------|---------|--------|---------|-----------|
|        |         |        | GLSI    | LC        |
| VES 1  | 150.93  | 4.79   | Extreme | Very good |
| VES 2  | 74.05   | 0.66   | Extreme | Moderate  |
| VES 3  | 152.43  | 1.77   | Extreme | Good      |
| VES 4  | 125.3   | 0.23   | Extreme | Weak      |
| VES 5  | 150.49  | 0.29   | Extreme | Moderate  |
| VES 6  | 68.38   | 0.07   | Extreme | Good      |
| VES 7  | 71.02   | 0.39   | Extreme | Moderate  |
| VES 8  | 121.63  | 0.19   | Extreme | Weak      |
| VES 9  | 123.93  | 0.78   | Extreme | Good      |
| VES 10 | 257.162 | 0.08   | Extreme | Poor      |
| VES 11 | 182.91  | 0.13   | Extreme | Weak      |
| VES 12 | 93.58   | 1.43   | Extreme | Good      |
| VES 13 | 61.172  | 5.71   | Extreme | Very Good |
| VES 14 | 161.84  | 1.71   | Extreme | Good      |

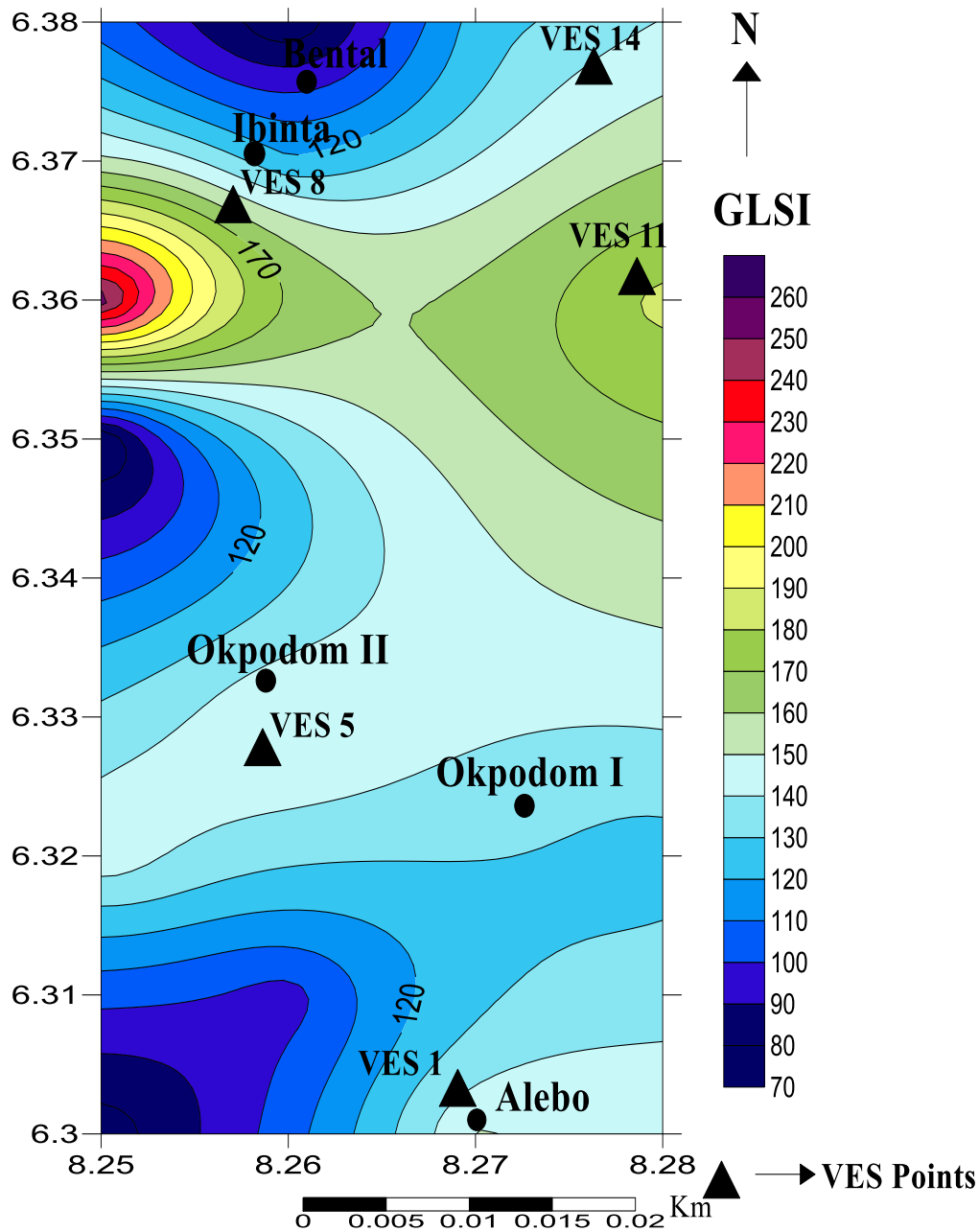
|        |        |      |         |          |
|--------|--------|------|---------|----------|
| VES 15 | 95.7   | 0.52 | Extreme | Moderate |
| VES 16 | 147.04 | 0.1  | Extreme | Poor     |

**Table 7.** Corrosivity value of the study area.

| S/No   | Name of Location | Soil Corrosivity values | Remarks                        |
|--------|------------------|-------------------------|--------------------------------|
| VES 1  | Alebo            | 3722.2                  | Practically noncorrosive (PNC) |
| VES 2  | Ezekewe          | 536.4                   | PNC                            |
| VES 3  | Ujussim          | 564.6                   | PNC                            |
| VES 4  | Okpodom I        | 305.0                   | PNC                            |
| VES 5  | Okpodom II       | 358.0                   | PNC                            |
| VES 6  | Indingele        | 310.2                   | PNC                            |
| VES 7  | Ogbaja           | 276.6                   | PNC                            |
| VES 8  | Ibinta           | 1016.7                  | PNC                            |
| VES 9  | Obetegana        | 420.2                   | PNC                            |
| VES 10 | Ngidi            | 392.8                   | PNC                            |
| VES 11 | Igele            | 310.2                   | PNC                            |
| VES 12 | Idom             | 646.3                   | PNC                            |
| VES 13 | Inno             | 2112.7                  | PNC                            |
| VES 14 | Bental           | 721.8                   | PNC                            |
| VES 15 | Ominyi           | 2.6                     | Very strongly corrosive (VSC)  |
| VES 16 | Eketekwe         | 2136.2                  | PNC                            |

#### **4. 1. Geoelectric layer susceptibility indexing (GLSI)**

The overlay index map of lithology and vadose zone thickness of the study area is shown in Fig. 3. The role of vadose zone thickness in assessing aquifer susceptibility is critical because a suitably thick vadose zone might delay pollutant passage to the aquifer zone, causing the contamination to degrade [35]. These variables were combined to create a GLSI overlay index map, Fig. 3 was plotted on basics on Table 2 and 3. The map depicts a high level of vulnerability (70-160) in the northern section of the research area. The NE and NW areas of the area have high vulnerability zones (120 – 160). The southern section is similarly vulnerable to pollution (70–150) as shown in Fig. 3.



**Fig. 3.** Spatial Distribution of GLSI within the Study Area.

#### 4. 2. Longitudinal unit conductance (S)

The measure of an earth medium's protective capability is its ability to slow and filter percolating fluid [38]. This parameter describes the aquifer's protective capacity. The greater the protective capacity of a region, the higher the overburden unit of a geological formation such as clay, shale, and compact sandstone [30, 36]. According to [40] arise in S could lead to an average increase in clay content and hence a high protective capability for the underlying aquifer, as well as a decrease in contamination. From Table 8 it was observed that VESs

locations 13, and 1, 3, 9, 12, and 14 are considered to be a very good and good category, hence they are considered to be less vulnerable to surface contamination. While VESs locations 2, 4, 5, and 15 are considered to be of moderate protective capacity, hence considered to be fairly vulnerable to surface contamination. Lastly, it was also observed that VESs locations 6, 7, 8, 11, 10, and 16 were considered to be weak and poor, which implies that VESs points within the aforementioned points are considered vulnerable to surface contamination as shown in Fig. 4.

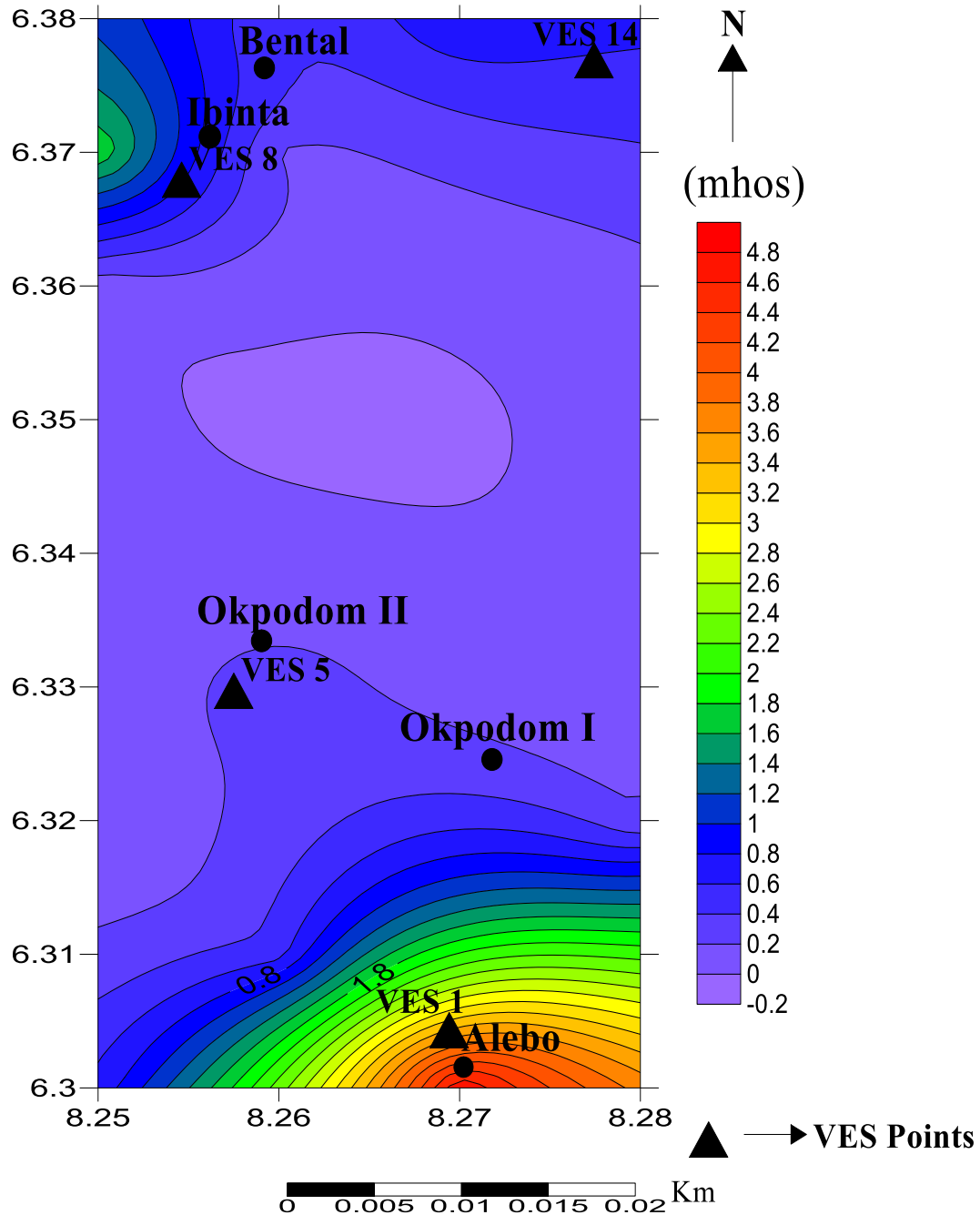


Fig. 4. Spatial distribution of LC within the study area.

**Table 8.** Based on [41] longitudinal conductance scale, a modified aquifer protective capacity rating of the analyzed form [36]

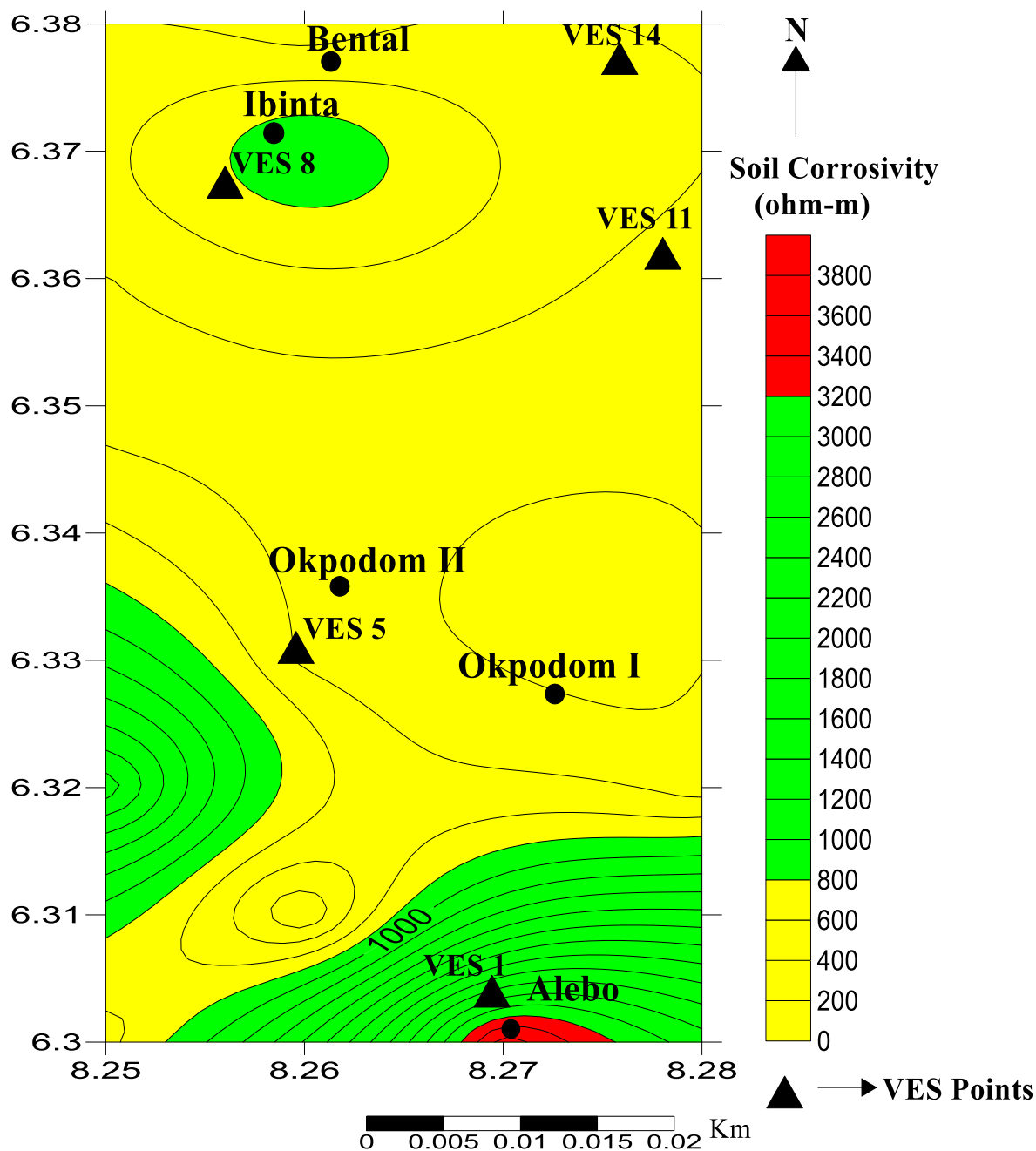
| Longitudinal conductance (mhos) | Protective capacity rating | VES Locations   | %     |
|---------------------------------|----------------------------|-----------------|-------|
| >10                             | Excellent                  |                 |       |
| 5-10                            | Very Good                  | 13,             | 6.25  |
| 0.7 – 4.9                       | Good                       | 1, 3, 9, 12, 14 | 31.25 |
| 0.2 – 0.69                      | Moderate                   | 2, 4, 5, 15,    | 25    |
| 0.1- 0.91                       | Weak                       | 6, 7, 8, 11     | 25    |
| < 0.1                           | Poor                       | 10, 16          | 12.5  |

#### 4. 3. Soil Corrosivity Level

The resistivity values of these strata were employed in the evaluation of the corrosivity potential because utility pipes for conveying water, hydrocarbons, trash, and gas are buried within the earth's uppermost layer. Topsoil resistivity values were classified in terms of soil corrosion based on soil resistivity as shown in Table 4. Findings from Table 7, revealed that VES's locations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 16 showed little or no trace of corrosion. From Table 9 it was observed that 93. 75 % showed little or no trace corrosivity, while 6.25 % of groundwater showed soil corrosivity. VES location 15 showed a high tendency of corrosivity, this could be caused as a result of chemical composition of parent material, soil tends to become acidic over a long period of time, decaying of organic matter produce  $H^+$  is responsible for soil acidity leaching

**Table 9.** Corrosivity ratings for soil [15, 42]

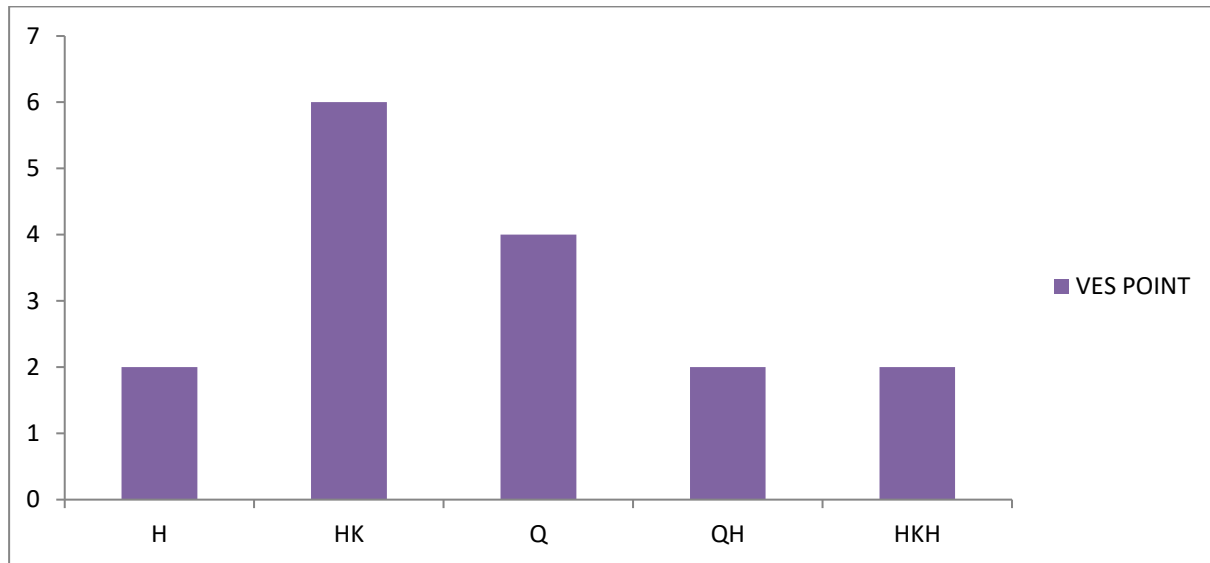
| Soil Resistivity ( $\Omega m$ ) | Soil Corrosivity               | VES's Locations                                       | Remarks                                | %     |
|---------------------------------|--------------------------------|-------------------------------------------------------|----------------------------------------|-------|
| <10                             | Very strongly corrosive (VSC)  | VES 15                                                | Showed high Tendency of been corrosive | 6.25  |
| 10-60                           | Moderately corrosive (MC)      |                                                       |                                        |       |
| 60-80                           | Slightly corrosive (SC)        |                                                       |                                        |       |
| <180                            | Practically noncorrosive (PNC) | VES 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16 | Showed little or no trace of corrosion | 93.75 |



**Fig. 5.** The study area's spatial distribution of soil corrosivity.

## 5. ANALYSIS OF VES CURVES OF THE STUDY AREA

From Table 4, it was observed that five major curve exist within the study area, H, HK, Q, QH, and HKH. Findings from Table 4 showed that HK curve type is the most dominant curve within the study area as shown in Fig. 6. Fig. 2 showed VES 13 has HKH curve type.



**Fig. 6.** Graph of VES locations versus curve type

## 6. CONCLUSIONS

The research area's aquifer vulnerability, aquifer protective capacity, and soil corrosivity were all satisfactorily assessed utilizing the electrical resistivity method involving vertical electrical sounding (VES) using the Schlumberger setup. The vulnerability index, aquifer protection, and corrosivity maps for the research area are all aided by geoelectric data acquired from the VES. Based on their predicted values, the maps allowed the area to be divided into various vulnerability zones, aquifer protective zones, and corrosivity zones. Groundwater in the research area is particularly prone to contamination, according to GLSI findings. According to LC, 37.5 % of the groundwater in the studied region had low aquifer protection capacity. Estimated result obtained from soil corrosivity revealed that 93.75 % of soil showed no trace of soil corrosivity, while 6.25 % showed trace of corrosivity close to Okpodom I, SW part of the study area. From the study it is recommended that efforts should be made in groundwater resource management to research the susceptibility of the designated aquifers to contamination, as this would aid in limiting the hazard that contaminated water poses to human health and the environment. Prior to the installation of structures in the study area, thorough geotechnical and geochemical investigations are recommended to avoid corrosion damage.

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