EVALUATION OF AQUIFER PROTECTIVE CAPACITY AND SOIL CORROSIVITY USING VERTICAL ELECTRICAL SOUNDING METHOD IN BADEGGI VILLAGE, NIGER STATE NIGERIA

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Abstract

A geoelectric survey was carried out in Badeggi under Katcha Local Government area of Niger State. The aim is to evaluate the aquifer protective capacity and soil corrosivity of the overburden units in the study area using vertical electrical sounding method. G41 Resistivity meter was employed to obtain forty VES points within ten profiles, with the interval of 50 m between the profiles. This was done using the Schlumberger electrode array to obtain the data and was modelled using computer iteration (Winresist software). The vertical electrical sounding curves with layered model comprising of the apparent resistivities, layer thicknesses, and depth were obtained from the software. The information obtained was used to evaluate longitudinal conductance and transmissivities of the layers. The results show generally low resistivities across the survey area and an average longitudinal conductance variation from 0.1171 Siemens in VES 11 to 0.925 Siemens in VES 23, almost the entire area giving values less than 1.0 Siemens. The average transmissivity values ranges between 91.62 Ωm in VES 15 to 1339.4 Ωm in VES 33. The field data gives a resolution with 4–5 geoelectric layers and the observed frequencies in curve types include: 40% of QH, 35% of Q, 17.5% of QHK and 7.5% of QKH. Using the longitudinal unit conductance (S), the protective capacities of the study area were classified as 20% weak, 0% poor, 72.5% moderate, and 7.5% as good. The corrosivity ratings of the study area show that 42.5% is slightly corrosive and 57.5% is practically non-corrosive. The results reasonably provide information on areas where any form of agricultural activities, industries can be sited and iron pipes can be laid in order to safeguard the hydrological setting for resident's safety in the study area. Regions with moderate/good protective capacity are good sites for locating boreholes.

Keywords: Aquifer, Capacity, Corrosivity, Geoelectric, Protective, Survey, Transmissivity

Introduction

The growth of any community is hinged on the availability of basic amenities such as water, good road network and electricity. The search for sustainable, clean and portable water is a struggle that will never end as it aids in the growth of any community (Salako *et al.,* 2009). Water is a gift of nature and it is in a bounteous proportion, noticeable by its presence (surface, rain, and underground), with a quality of transformation through recurrent hydrological evaporation, condensation, and precipitation (Abdullahi *et al.,* 2017). Groundwater as the main source of potable water supply for domestic, industrial and agricultural uses has been under intense pressure of degradation and contamination due to urbanization, industrial and agricultural related activities (Belmonte *et al.,* 2004). However, the present social demands are not only to detect new groundwater resources but to protect them. The potability of groundwater can be contaminated by leachate from dumpsites, salt intrusion, oil spillage, mining activities, sewage (from latrines, underlined petroleum pipes and septic tanks) (Makeig, 1982). Dumpsites and latrines are sited without considering the hydrogeological settings of the area, thereby rendering the future of groundwater at risk (Ugbaja & Edet, 2004). The rate of groundwater contamination depends on permeability, porosity, and overburden thickness of geologic formations. When the underlying geologic material is unconsolidated and uncompacted, such as coarse sand, the polluting influent are capable of escaping into the subsurface to contaminate groundwater, rendering the soil corrosive and forming a polluting plume that extends hundreds of meters (Keswick *et al.*, 1982).

The demand for water in town has been on the increase due to the growing demand in the commodity for domestic and agricultural uses. Managing existing water supplies to fully satisfy all uses has proven difficult, particularly in dry season. Groundwater is therefore, the likely source that can ameliorate the problem and hence the need to find genuine and effective way of harnessing it. Despite this seemingly important relief, there could be threats of contamination to groundwater occasioned by soil corrosivity and infiltration of contaminants from the surface through the migration paths into the aquifers.

It is in trying to monitor the quality of groundwater that we used the VES method to decipher the structure layering of the subsurface in Badeggi under Katcha local government area with a view to finding the depth to water bearing formations.

Generally, corrosive soils contain large concentrations of soluble salts, especially in the form of sulphates, chlorides and bicarbonates and may thus be characterized by high acidity (low pH) or high alkalinity (high pH) (Ahmad *et al.,* 2016). Soils with high clay and silt contents are usually characterized by fine texture, high water-holding capacity and consequently, are usually poorly aerated and drained (Bullard *et al.,* 2004). Corrosive soils contain chemical constituents that can react with construction materials, such as concrete and ferrous metals, which may damage foundations and buried pipelines (George *et al.,* 2014). The electrochemical corrosion processes that take place on metal surfaces in soils occur in the groundwater that is in contact with the corroding structure (Muraina *et al.,* 2012). Today, we are witnessing an increasing number of boreholes drilled by government, non-governmental organizations, and individuals. This shows clearly that groundwater effectively complementing other sources of water supply in the Badeggi. This is due to the rate of contamination of rivers, lakes and stream that is not save. Surface water is found to be grossly degraded in quality because of its physical, biological, or chemical contaminants (Edet & Worden, 2009).

Location of the Study Area

The study area is situated within Badeggi along Agaie-Suleja road. It is located between latitude 9^{0}3’28.039”to 9^{0}2’47.5” and longitude 6^{0}8’14.245” to 6^{0}8’10.7”with land space extent of 20 km^{2}. The areal distance estimate is about 5 km from NCRI, Badeggi of which the site is about 3 km from Government Day Secondary School Badeggi and it is spanned by a well accessible road either by foot or by vehicle. The area has a gentle topography that is covered with vegetation, trees, farms land and grasses (Figure 1)

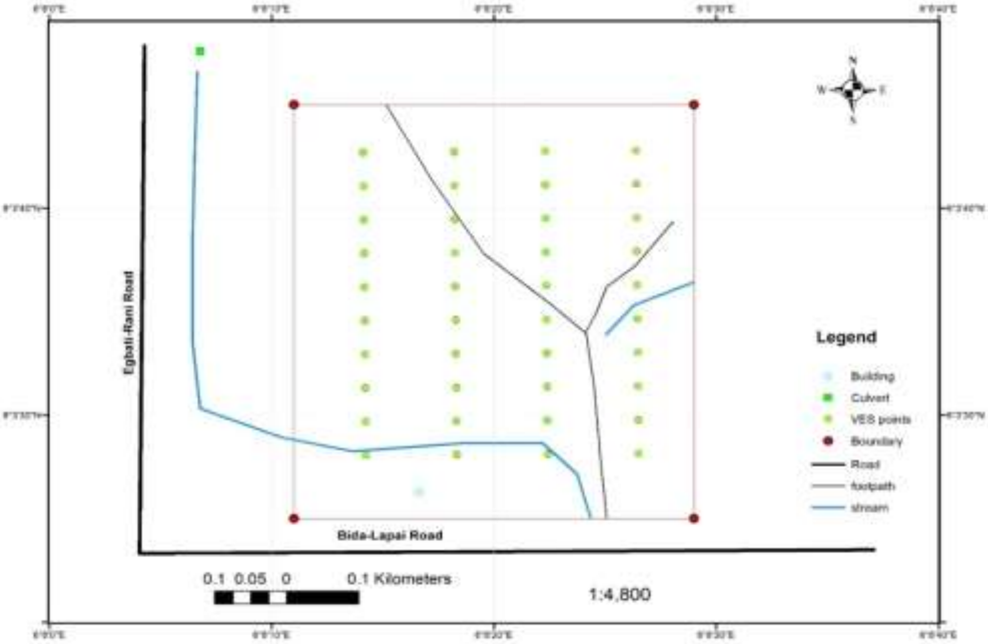


Figure 1: Location map of the study area

Geology of the Study Area

The study area is located in Badeggi which falls within the northern Bida basin. Bida basin consists of five major rock units called formations which are successively as follows (beginning from the oldest to the youngest rock): The basal conglomerates (at the base), the Bida sandstone, the Sakpe ironstone, the Enagi Siltstone and the Batati formation (at the top). The area is underlain directly by the second to the uppermost formation of the Bida basin called the Enagi Formation. This is probable due to denudation activities in the area which had strip off the uppermost Batati formation. The Enagi Siltstone consists mainly of siltstones. Other subsidiary lithologies include sandstone-siltstone admixture with some clay stone. The formation ranges in thickness between 30 and 60m. Mineral assemblage consists mainly of quartz, feldspars and clay minerals. as well as geophysical data suggest that the basin is bounded by a field in different sections of the basin showed that the average depth to basement is about 3.4 km, with sedimentary thicknesses of up to 4.7 km in the central and southern parts of the basin (Fadele *et al.,* 2013).

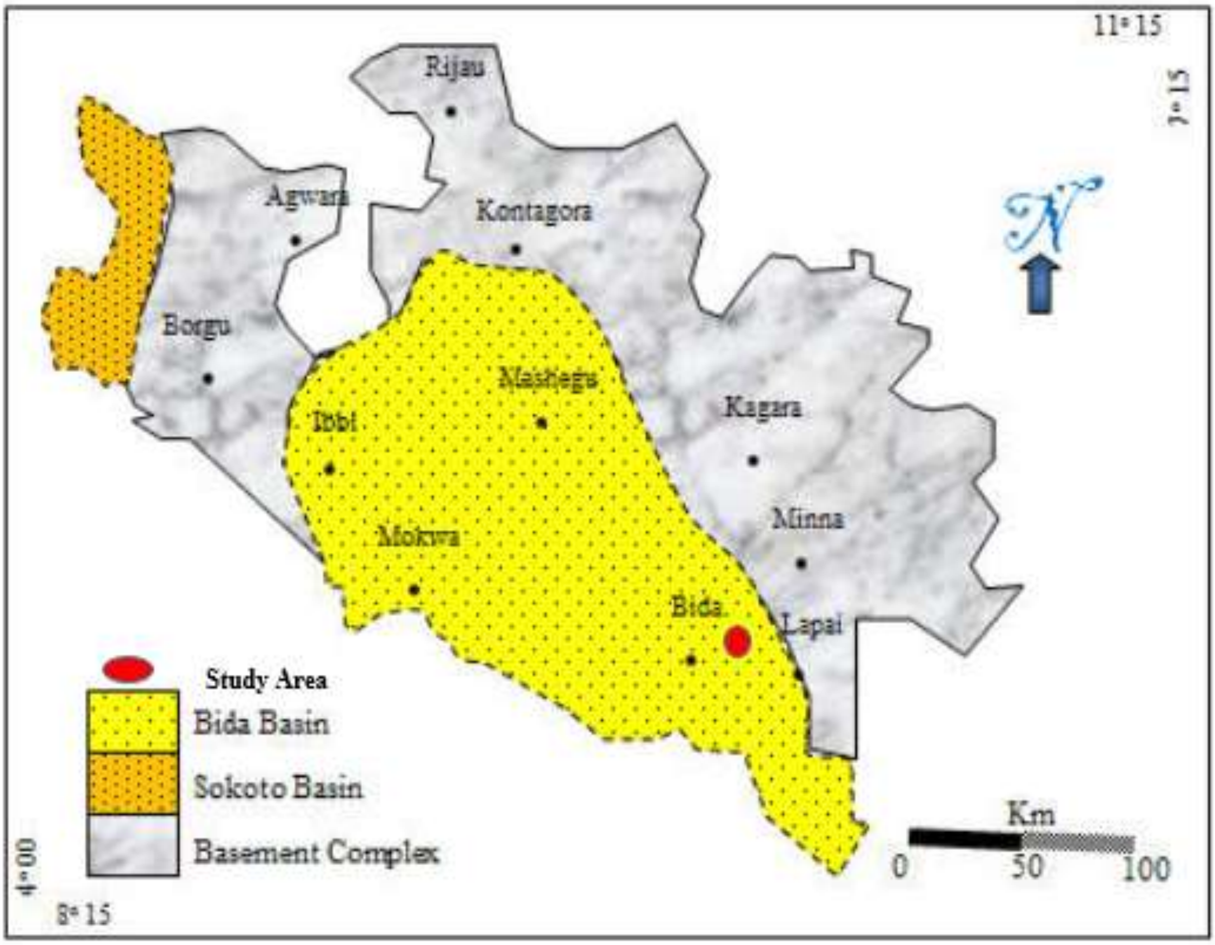


Figure 2: Map of Niger State showing the study area (Obaje, 2006)

Methodology

Electrical resistivity surveys are based on Ohm's Law which holds for simple circuits as well as earth materials. Resistivity by definition, is the product of the resistance, R and the unit cross sectional area, a of a material divided by a unit length of the material through which the current passes. i.e.

$$\rho = \frac{RA}{L} \qquad (1)$$

$$\sigma = \frac{I}{\rho} = \frac{L}{RA} \qquad (2)$$

But, V = IR (Ohms Law)

where V=potential difference, L=current electrode separation, A=cross sectional area, I=current and R= resistant

but

$$\rho = \rho a$$

Where ρa = apparent resistivity

$$\rho a = \frac{2\pi U}{I}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3}\frac{1}{r_4}\right)^{-1} \qquad (3)$$

$$\rho a = \frac{K\Delta U}{I} \qquad (4)$$

where

$$K = 2\pi(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3}\frac{1}{r_4})^{-1} \quad (5)$$

Equation (5) is known as the geometric factor.

Resistivity survey investigates horizontal and vertical variations of electrical resistance (or conductivity, the inverse of resistivity) of the subsurface by causing an electrical current to flow through the ground, using wires connected to it. The procedure is to measure potentials at other electrodes in the vicinity of the current flow on Figure 3.1. Since the current is also measured, the apparent resistivity of the subsurface can be effectively determined (Telford *et al.,* 2011).

Soil Corrosivity Evaluation

The first layer resistivity values can be used in generating corrosivity map which is used in the evaluation of the degree of soil corrosivity at shallow depth, in the area, should metal pipes/buried utilities be required for reticulation works in the groundwater development and other engineering utilities. Areas characterized by relatively low resistivity values are considered corrosive while areas with high resistivity values are considered non-corrosive (Rahaman, 1988).

Overburden Protective Capacity Evaluation

The ability of an earth medium to retard and filter percolating fluid is the measure of its protective capacity (Olorunfemi, *et al.,* 1999). Henriet, (1975) further described the protective capacity of an overburden exerted by retardation and filtration of percolating pollutants as being proportional to its thickness and inversely proportional to its hydraulic conductivity. Clayey material content is generally characterized by low permeability, low resistivity, low hydraulic conductivity, and longitudinal unit conductance values. Hence, the protective capacity can be considered as being proportional to the longitudinal conductance (S). As a result, the greater an area overburden longitudinal conductance, the greater its protective capacity.

According to Braga (2008), the electrical resistivity reflects some of the major characteristics of material different types in the geological environment, allowing the estimation of their states, regarding to the alteration, fracturing and water saturation degree. Besides, it is possible to identify the lithologies without the need for excavation or perforations, which are commonly costly and time consuming. Additionally, the author points out that the resistivity method (direct current) and the VES- Schlumberger array - offer products extremely important to preliminary steps of environmental studies, as the electrical resistivity, the depth of the groundwater level and the Dar Zarrouk parameter Longitudinal Conductance. Dar Zarrouk Parameter - Longitudinal Conductance the resistivity method is applied to establish relations between electrical resistivity and hydrogeological parameters, such as porosity, permeability, transmissivity and hydraulic conductivity. This way, the correlations are grounded in existing analogies between equations that govern the groundwater flow through a permeable medium and the electric current in a conductive medium. Starting at geoelectric measurements taken at the surface, hydrodynamic characteristics of an aquifer can be estimated (Porsani *et al.,* 2012).

Methods

Forty vertical electrical soundings were made on ten profiles (A – J) using Getron (G41) model Terrameter and its accessories. Schlumberger array electrode configuration pattern with half inter current electrode spacing (AB/2) varying from 1 to 100 m was adopted. The apparent resistivity values obtained were plotted against the AB/2 using the winResist software. From the plots, layer resistivity, depth and thickness; number of layers and curve types were deduced, also, geologic cross sections and iso-resistivity maps were made. The geophysical investigations entail resistivity techniques: Vertical electrical sounding is employed for collection of data and traversing provides a means of studying lateral variations in the ground, while electrical sounding investigates the way in which the resistivity of the ground varies with depth.

The principle of the resistivity method is that an electric current is passed in to the ground through two electrodes, and the resulting potential difference is measured across two or more electrodes; the ratio of the potential difference to the current is display by the resistivity meter as a resistance. The electrode is arranged in a straight line, symmetrically about a centre point. A geometric factor is calculated as a function of the electrode spacing and the resistivity readings multiplied by two give an apparent resistivity value. The electrode spacing is progressively increased, keeping the centre point of the electrode array fixed.
These relations can be established using the Dar Zarrouk parameters, obtained by the division and multiplication operations between the resistivities and thicknesses of each layer of the geo-electrical model (Maillet, 1947). Fora sequence of n horizontal, homogeneous and isotropic layers with resistivity ρ_i and thickness h_i, the Dar Zarrouk parameter Longitudinal Conductance (S) unitary and total, respectively, are defined according to $s_i = \frac{h_1}{\rho_1}$siemens (longitudinal conductance) and $s = \sum_{l=1}^{n} \frac{h_i}{\rho_i}$ siemens (transvers resistance) for obtaining longitudinal conductance and transvers resistance

The Longitudinal Conductance
In granular and unconfined aquifers, the main natural protection against the contamination is related to the presence of overlapping clay layers, whose protection capability comes down to the infiltration time lag of solutions, due to their low permeability. (Braga *et al*., 2006) demonstrated that the protection degree of an aquifer may be considered directly proportional to the ratio between the thickness and resistivity. Determining the geo-electric characteristics of the aquifers and using this information to determine the soil corrosivity and aquifer protective capacity. Clay soils, especially those contaminated with saline water are on the opposite end of the spectrum. Classification of soil resistivity in terms of corrosivity is presented in Table 1. While high longitudinal conductance value corresponds to excellent, very good and good aquifer protective capacity (APC), low longitudinal conductance values are associated with poor and weak APC are presented in Table 2.

Table 1 Classification of soil resistivity in terms of corrosivity [after Baeckmann and Schwenk (1975), Agunloye (1984), and Oladapo *et al.* (2004)]

Soil resistivity (ohm-m)	Soil corrosivity
10	Very Strongly Corrosive (VSC)
10 – 60	Moderately Corrosive (MC)
60 – 180	Slightly Corrosive (SC)
>180	Practically Non – Corrosive (PNC)

Table 2 Longitudinal conductance/aquifer protective capacity rating [Oladapo *et al.* (2004) and Adeniji *et al.* (2014)]

Longitudinal conductance (mhos)	Aquifer protective capacity

rating	
> 10	Excellent
5 – 10	Very good
0.7 – 4.49	Good
0.2 – 0.69	Moderate
0.1 – 0 .19	Weak
< 0.1	Poor

Results and Discussion

The results were summarized in a tabular form, giving information about the average layer resistivity, depth of each layer, the thickness and curve types in (Table 3) while geoelectric section where the parameters in Table 1 were obtained is presented in Figure 3.

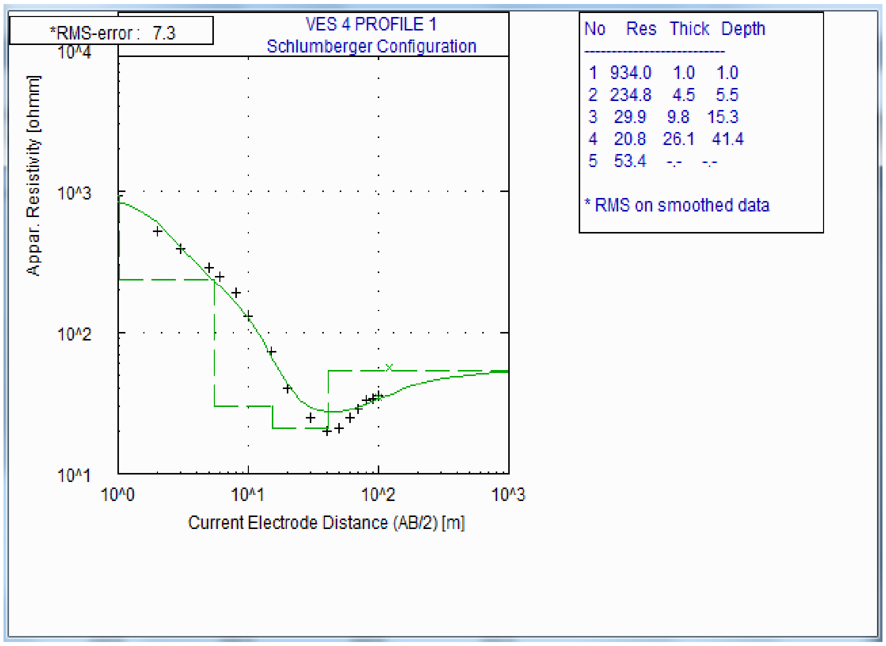
Figure 3 was produced using WinResist, which involves a forward and inverse modeling approach to generate a computer modelled curve as shown in above figure. The layer parameters, resistivity and thickness for each VES points were obtained after a series of iteration to match the field curve with theoretical curves. This iteration activity continued until the RMS error between the field data and the model data is reduced to the minimum percentage.

From the modelled VES data, it was observed that all the 40 VES points were having three layers, in most of the VES points QH, Q, QHK, and QKH curve types are dominating. The minimum and maximum resistivities obtained in the study area ranges from 5.0 Ωm to 1640 Ωm, representing clayey soil, silty-sand, sandstone and sandstone intercalated with gravel. There exists a resistivity overlapping values between moderately resistive and highly conductive geomaterials. The apparent thickness and depths of the geoelectric layer were established with the depth of the first geoelectric layer ranging from 0.3 m to 2.3 m, the second layer depth ranges from 2 m to 58 m, the third layer varies between 25 m to 90 m respectively. The thickness of the first geoelectric layers varies from 0.3 m to 2.3 m, the second layer thickness ranges between 2 m to 32 m, the third layer ranges between 12 m to 52 m. The depth and thickness of the fourth geoelectric layer extends beyond the depth of investigation.

VES Stations	Latitude (°)	Longitude (°)	No. of Layers	Layer resistivity, p (Ωm)			Layer depth d (m)			Layer thickness h (m)			Curve Types
				ρ_1	ρ_2	ρ_3	d_1	d_2	d_3	h_1	h_2	h_3	
A1	9.0577861	6.1372889	3	606.0	57.7	20.5	2.2	5.4	18.8	2.2	3.2	13.4	QH
A2	9.0506633	6.136425	3	637.9	117.6	30.7	1.2	4.3	12.0	1.2	3.0	7.8	Q
A3	9.0577639	6.1386139	3	686.2	49.0	33.0	1.0	8.1	26.7	1.0	7.1	18.6	Q
A4	9.0567111	6.1399389	3	934.0	234.8	9.9	1.0	5.5	15.3	1.0	4.5	9.8	QH
B1	9.0498222	6.138025	3	739.3	208.2	15.2	0.7	5.0	24.3	0.7	4.3	19.2	QH
B2	9.0500058	6.1371111	3	742.4	158.4	16.8	1.3	4.6	14.9	1.3	3.3	10.3	QH
B3	9.050305	6.1362861	3	889.1	156.8	21.1	0.8	4.6	15.6	0.8	3.8	11.0	QHK
B4	9.0602778	6.1323194	3	954.9	98.3	132.5	1.1	4.0	7.2	1.1	2.9	3.2	QH
C1	9.0499733	6.1351833	3	561.8	47.0	26.0	2.3	4.8	12.7	2.3	2.5	8.0	QHK
C2	9.0574336	6.1351833	3	615.1	76.4	29.3	1.5	5.0	38.0	1.5	3.4	33.0	Q
C3	9.04963	6.1371278	3	1654.5	175.1	11.0	0.9	6.2	21.2	0.9	5.3	15.1	QHK
C4	9.0583219	6.1479528	3	671.5	63.9	42.6	1.6	11.4	30.1	1.6	9.8	18.7	QH
D1	9.0551728	6.1379028	3	417.9	62.3	18.0	1.8	9.7	60.4	1.8	7.9	50.7	Q
D2	9.0367156	6.1486361	3	414.2	168.6	20.2	1.1	4.5	32.2	1.1	3.4	27.7	QH

D3	**91340833**	**6.1519667**	**3**	**291.4**	**26.6**	**5.7**	**1.5**	**21.6**	**38.5**	**1.5**	**20.0**	**169**	**QKH**
D4	**9.0461128**	**6.1374167**	**3**	**788.8**	**148.2**	**25.4**	**1.0**	**8.5**	**56.8**	**1.0**	**7.4**	**48.3**	**Q**
E1	**9.04828**	**6.13467**	**3**	**586.2**	**232.8**	**39.7**	**1.7**	**4.7**	**38.8**	**1.7**	**3.0**	**34.1**	**Q**
E2	**9.0490617**	**6.13487**	**3**	**1415.5**	**86.9**	**19.4**	**0.7**	**3.3**	**11.2**	**0.7**	**2.7**	**7.8**	**QHK**
E3	**9.0490617**	**6.1358533**	**3**	**964.8**	**41.3**	**173.2**	**0.7**	**3.5**	**10.8**	**0.7**	**2.8**	**7.2**	**QKH**
E4	**9.04884**	**6.1367722**	**3**	**538.7**	**158.2**	**23.0**	**0.7**	**7.1**	**32.2**	**0.7**	**6.4**	**25.1**	**Q**
F1	**9.0483**	**6.1367667**	**3**	**906.3**	**121.7**	**16.0**	**0.6**	**4.9**	**13.7**	**0.6**	**4.3**	**8.9**	**QHK**
F2	**9.0485533**	**6.1357617**	**3**	**895.1**	**151.4**	**7.9**	**0.7**	**8.1**	**32.7**	**0.7**	**7.4**	**24.6**	**QH**
F3	**9.0486533**	**6.1347867**	**3**	**336.2**	**155.7**	**75.8**	**1.9**	**2.9**	**14.6**	**1.9**	**1.0**	**11.7**	**QH**
F4	**9.048545**	**6.1431028**	**3**	**260.9**	**548.1**	**24.3**	**0.5**	**5.3**	**67.4**	**0.5**	**4.8**	**62.1**	**QKH**
G1	**9.0581381**	**6.1369583**	**3**	**1192.0**	**175.1**	**49.6**	**0.6**	**5.4**	**22.1**	**0.6**	**4.8**	**16.6**	**Q**
G2	**9.048065**	**6.1355633**	**3**	**527.2**	**111.7**	**171.3**	**0.9**	**4.1**	**8.6**	**0.9**	**3.2**	**4.6**	**QH**
G3	**9.0478967**	**6.1364361**	**3**	**875.7**	**48.0**	**16.0**	**1.0**	**12.4**	**35.2**	**1.0**	**11.4**	**22.8**	**Q**
G4	**9.0468839**	**6.1375472**	**3**	**554.8**	**521.1**	**36.8**	**1.3**	**4.6**	**35.2**	**1.3**	**3.3**	**30.6**	**Q**
H1	**9.04716**	**6.1375444**	**3**	**763.1**	**259.7**	**65.0**	**0.8**	**3.7**	**15.2**	**0.8**	**2.9**	**11.5**	**QH**
H2	**9.0467083**	**6.1374278**	**3**	**780.9**	**50.7**	**27.3**	**1.6**	**24.5**	**45.5**	**1.6**	**22.9**	**20.9**	**Q**

H3	**9.0473733**	**6.1364417**	**3**	**872.1**	**76.9**	**73.2**	**0.6**	**5.9**	**11.9**	**0.6**	**5.3**	**6.0**	**Q**	
H4	**9.0475833**	**6.1355**	**3**	**823.2**	**295.3**	**29.8**	**0.5**	**4.3**	**21.2**	**0.5**	**3.8**	**16.9**	**Q**	
I1	**9.0477222**	**6.1345278**	**3**	**1339.4**	**196.2**	**30.4**	**0.5**	**3.6**	**25.0**	**0.5**	**3.1**	**21.4**	**QH**	
I2	**9.04725**	**6.134444**	**3**	**1167.3**	**331.8**	**16.5**	**0.5**	**4.2**	**21.3**	**0.5**	**3.7**	**17.1**	**QH**	
I3	**9.0471389**	**6.1355**	**3**	**1120.5**	**192.5**	**19.7**	**0.6**	**5.0**	**28.5**	**0.6**	**4.4**	**23.5**	**QH**	
I4	**9.0468889**	**6.1365556**	**3**	**1647.5**	**169.1**	**93.7**	**0.4**	**6.4**	**9.7**	**0.4**	**6.0**	**3.3**	**QKH**	
J1	**9.0458889**	**6.13825**	**3**	**620.5**	**115.5**	**26.7**	**2.1**	**12.5**	**37.1**	**0.4**	**6.0**	**3.3**	**QHK**	
J2	**9.0450833**	**6.1400556**	**3**	**880.6**	**282.7**	**17.1**	**0.4**	**5.0**	**23.8**	**0.4**	**4.7**	**18.8**	**QH**	
J3	**9.0462778**	**6.1374167**	**3**	**372.4**	**118.9**	**61.1**	**0.7**	**6.6**	**19.4**	**0.4**	**4.7**	**18.8**	**QH**	
J4	**9.0465278**	**6.1363056**	**3**	**1031.6**	**220.2**	**37.4**	**0.4**	**3.6**	**32.7**	**0.4**	**3.2**	**29.1**	**Q**	



No	Res	Thick	Depth
1	934.0	1.0	1.0
2	234.8	4.5	5.5
3	29.9	9.8	15.3
4	20.8	26.1	41.4
5	53.4	-.-	-.-

* RMS on smoothed data

Figure 3: Graph of VES Point

In order to ascertain the aquifer protective, transmissivity and soil corrosivity of the area under consideration, the longitudinal conductance and transverse resistance values were evaluated from the measured resistivity values and the thicknesses of the layers using table 1 and 2 respectively as show in Table (4).

The longitudinal conductance also shows a variation from 0.001 Siemens in VES 4 to 4.465 Siemens in VES 23. On average, all the VES points show values of longitudinal conductance that are less than 1.0 Siemens, suggesting that the overburden rock materials have no significant quantity of impermeable clay overlying strata which demonstrates high infiltration rates of surface contaminants into the aquifer.

Table 4 Summary Interpretation of soil corrosivity and aquifer protective capacity of all the profiles.

	Average Transverse Resistance Per VES Points (Ωm^2)	Soil Corrosivity	Average Conductance Per VES Points	Aquifer Protective Capacity Rating
1.	174.32	**Slightly Corrosive (SC)**	**0.215**	**Moderate**
2.	165.82	**Slightly Corrosive (SC)**	**0.348**	**Moderate**
3.	166.56	**Slightly Corrosive (SC)**	**0.420**	**Moderate**
4.	254.58	**Practically Non-Corrosive (PNC)**	**0.321**	**Moderate**
5.	255.62	**Practically Non-Corrosive (PNC))**	**0.333**	**Moderate**
6.	233.00	**Practically Non-Corrosive (PNC)**	**0.169**	**Weak**
7.	234.84	**Practically Non-Corrosive**	**0.171**	**Weak**

		(PNC)		
8.	257.68	**Practically Non-Corrosive (PNC)**	**0.399**	**Moderate**
9.	148.36	**Slightly Corrosive (SC)**	**0.117**	**Weak**
10.	153.02	**Slightly Corrosive (SC)**	**0.388**	**Moderate**
11.	417.78	**Practically Non-Corrosive (PNC)**	**0.280**	**Moderate**
12.	186.78	**Practically Non-Corrosive (PNC)**	**0.118**	**Weak**
13.	105.22	**Slightly Corrosive (SC)**	**0.589**	**Moderate**
14.	128.96	**Slightly Corrosive (SC)**	**0.278**	**Moderate**
15.	91.62	**Slightly Corrosive (SC)**	**0.902**	**Good**
16.	199.66	**Practically Non-Corrosive (PNC)**	**0.288**	**Moderate**
17.	174.14	**Slightly Corrosive (SC)**	**0.175**	**Weak**
18.	3470.90	**Practically Non-Corrosive (PNC)**	**0.167**	**Weak**
19.	244.62	**Practically Non-Corrosive (PNC)**	**0.205**	**Moderate**
20.	148.92	**Slightly Corrosive (SC)**	**0.648**	**Good**
21.	244.84	**Practically Non-Corrosive (PNC)**	**0.198**	**Weak**
22.	232.40	**Practically Non-Corrosive (PNC)**	**0.732**	**Good**
23.	121.82	**Slightly Corrosive (SC)**	**0.925**	**Good**
24.	170.08	**Slightly Corrosive (SC)**	**0.513**	**Moderate**
25.	293.30	**Practically Non-Corrosive (PNC)**	**0.582**	**Moderate**
26.	173.94	**Slightly Corrosive (SC)**	**0.457**	**Moderate**
27.	189.70	**Practically Non-Corrosive (PNC)**	**0.333**	**Moderate**
28.	224.50	**Slightly Corrosive (SC)**	**0.168**	**Weak**
29.	242.34	**Practically Non-Corrosive (PNC)**	**0.248**	**Moderate**
30.	173.32	**Slightly Corrosive (SC)**	**0.244**	**Moderate**
31.	209.12	**Practically Non-Corrosive (PNC)**	**0.483**	**Moderate**
32.	239.98	**Practically Non-Corrosive (PNC)**	**0.233**	**Moderate**
33.	336.20	**Practically Non-Corrosive (PNC)**	**0.323**	**Moderate**
34.	326.70	**Practically Non-Corrosive (PNC)**	**0.209**	**Moderate**
35.	284.08	**Practically Non-Corrosive (PNC)**	**0.243**	**Moderate**
36.	415.38	**Practically Non-Corrosive (PNC)**	**0.236**	**Moderate**

37.	170.24	**Slightly Corrosive (SC)**	**0.374**	**Moderate**
38.	253.18	**Practically Non-Corrosive (PNC)**	**0.332**	**Moderate**
39.	123.76	**Slightly Corrosive (SC)**	**0.443**	**Moderate**
40.	268.38	**Practically Non-Corrosive (PNC)**	**0.603**	**Moderate**

The electrical resistivity (Vertical Electrical Sounding) method is an efficient tool for most groundwater studies. It was used in this study to investigate the protective capacity and corrosivity of overburden units in the study area. The curve types indicate regular presence of QH and Q curves. This indicates the translation of layers with limited hydrologic significance into prolific units in which the selection of the best near surface and economic groundwater aquifer repository is, based on thickness and its degree of exposure to surface contaminants. Areas of thick overburden units and low resistivity values constitute zones of high longitudinal conductance. Regions with poor protective capacity are vulnerable to pollution and contamination during oil spillage, leakage in buried storage tank, petroleum pipelines, and infiltration of leachate from decomposed dump or waste site.

Regions of weak protective capacity (VES 6, 7, 9, 12, 17, 18, 21 and 28) are less vulnerable to groundwater pollutant or contaminant but can be more vulnerable with time as pollutant persists. Moderate protective capacity regions (VES 1, 2, 3, 4, 5, 8, 10, 11, 13, 14, 16, 19, 24, 25, 26, 27, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39 and 40) and good protective capacity (VES 15, 20, 22 and 23) will serve as a sealing potential for the underlying hydrogeological system. This makes the contamination of groundwater in such regions almost impossible. Areas that are slightly corrosive (VES 1, 2, 3, 9, 10, 12, 13, 14, 15, 17, 20, 23, 24, 26, 28, 30, 37 and 39) are characterized by low resistivity values and high moisture content of the soil. Practically non-corrosive areas (VES 4, 5, 6, 7, 8, 11, 12, 16, 18, 19, 21, 22, 25, 27, 29, 31, 32, 33, 34, 35, 36, 38 and 40) are absolutely good for burying of iron underground tanks without deterioration which has a good groundwater potential as revealed by the geoelectric parameters.

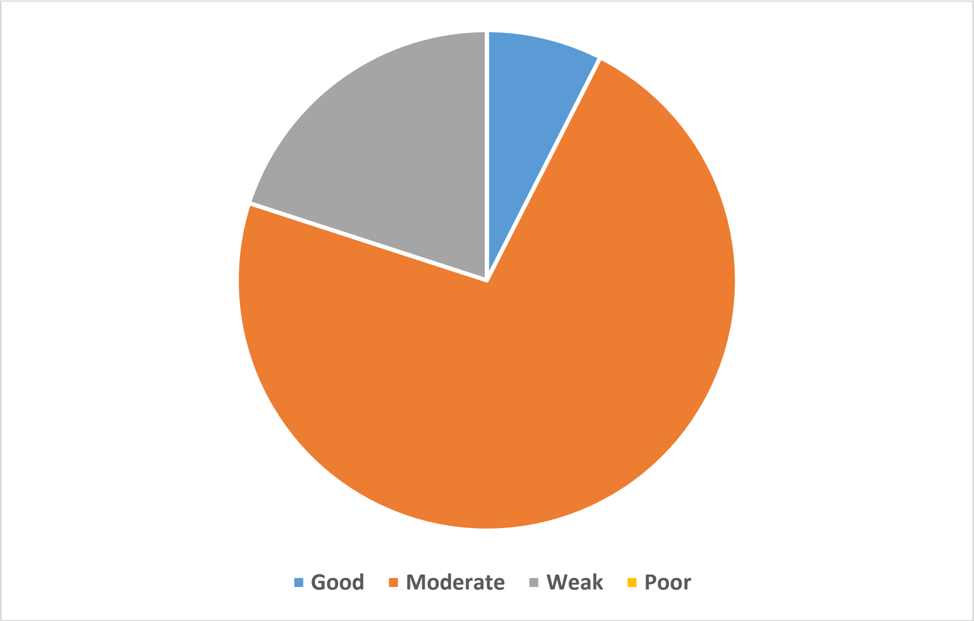


Figure 4: Soil corrosivity rating of study area.

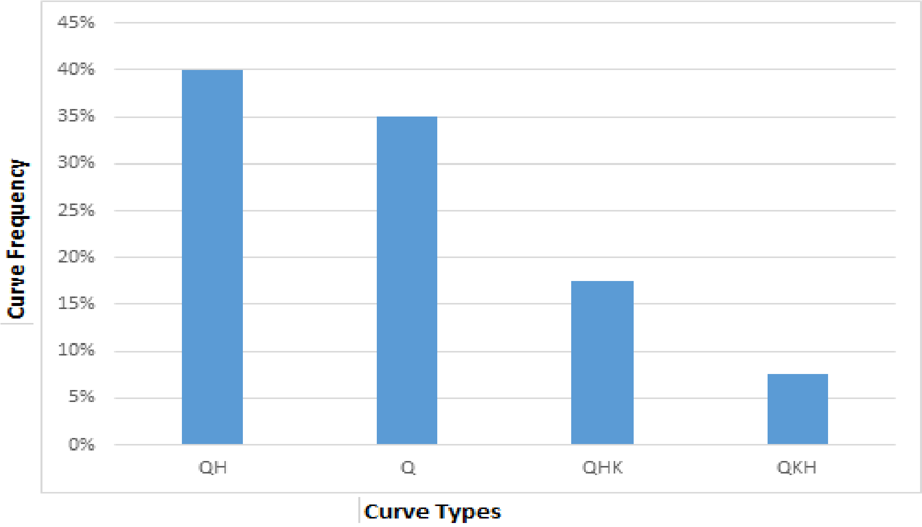


Figure 5: Frequency curve types

Summary and Conclusion

The lithological variability of the subsurface lithology of the study area is sponsored by the variability in the geoelectric properties of these geomaterials. The minimum and maximum resistivities obtained in the study area ranges from 5.0 Ωm to 1640 Ωm, representing clayey soil, silty-sand, sandstone and sandstone intercalated with gravel. There exists a resistivity overlapping values between moderately resistive and highly conductive geomaterials. The apparent thickness and depths of the geoelectric layer were established with the depth of the first geoelectric layer ranging between 0.3 m and 2.3 m, the second layer depth ranges from 2 m to 58 m, the third layers range between 25 m to 90 m respectively. The thickness of the geoelectric layers also varies as the first geoelectric layer expresses a thickness range of 0.3 m to 2.3 m, the second layer thickness ranges from 2 m to 32 m, the third layer ranges from 2 m to 62 m. The depth and thickness of the fourth geoelectric layer extends beyond the depth of investigation.

Water is key to daily human activities hence, without water, there cannot be human, animal or plant life. It is in view of this that the geoelectric investigation for the evaluation of the subsurface for optimal groundwater production was undertaken in the study area.

Areas that are slightly corrosive (VES 1, 2, 3, 9, 10, 12, 13, 14, 15, 17, 20, 23, 24, 26, 28, 30, 37 and 39) are characterized by low resistivity values and high moisture content of the soil, underground iron storage tanks are not to be buried in those areas. Reticulation of water, transmission of oil and gas using galvanized pipes could deteriorate, rupture or leak due to the reactions of corrosive materials with buried pipes, which can cause serious hazards to mankind and its environment. The geoelectrical properties of the subsurface lithologies was used to classify the area into low, medium and high groundwater potential zones and save for drinking without no effect to human and animals and also save for any form of agricultural activities within the study area. Three subsurface geoelectric units were delineated beneath the VES sections.

Recommendations.

1. Government, individuals or estate developers who wish to site borehole within the study area are strongly advised to consider the VES points 7, 13, 14, 17, 18, 28, 31 and 32.
2. Laboratory checks can be conducted in order to access the protective capacity of aquifers within regions described as poor and weak before carry any form of activity there.
3. Areas with poor aquifer protective capacity should be avoided for sinking borehole to reduce leachates infiltration to the groundwater.
4. Plastic pipes are more preferable in the areas of good and moderate aquifer protective capacity.

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