# ASSESSMENT OF SUBSURFACE CORROSION SEVERITY USING ELECTRICAL RESISTIVITY METHODS IN IGARRA, EDO STATE, NIGERIA

**Ozegin K.O.[1], Okolie. E.C.[2], Oseghale A.,[1]**

1) Department of Physics, Ambrose Alli University, Ekpoma Edo State.
2) Department of Physics, Delta State University, Abraka Delta State.

**ABSTRACT**

A geophysical survey was carried out in Igarra, Edo State Nigeria using Electrical Resistivity soundings. Schlumberger, Dipole-dipole and Electrical Resistivity Tomography (ERT) configurations were employed in order to delineate the subsurface geologic layers and determine their corrosion severity. Five transverses were mapped out along which the Schlumberger and Dipole-Dipole soundings were made. The dipole-dipole pseudo-sections along the traverses delineated low resistivity water absorbing, clay sections, linear fracture zones and joints at depths between 11 – 21 m. Three distinct geologic layers were delineated – the top soil which consists mainly of loose sand. This is followed by clay/clayey sand layer and then the weathered/fractured/fresh basement rock). It was concluded that the very low resistivity of the area investigated indicates that the subsurface structure is highly corrosive

**Key words:** Schlumberger, Dipole-dipole, Electrical Resistivity Tomography, Corrosion severity, Igarra Nigeria

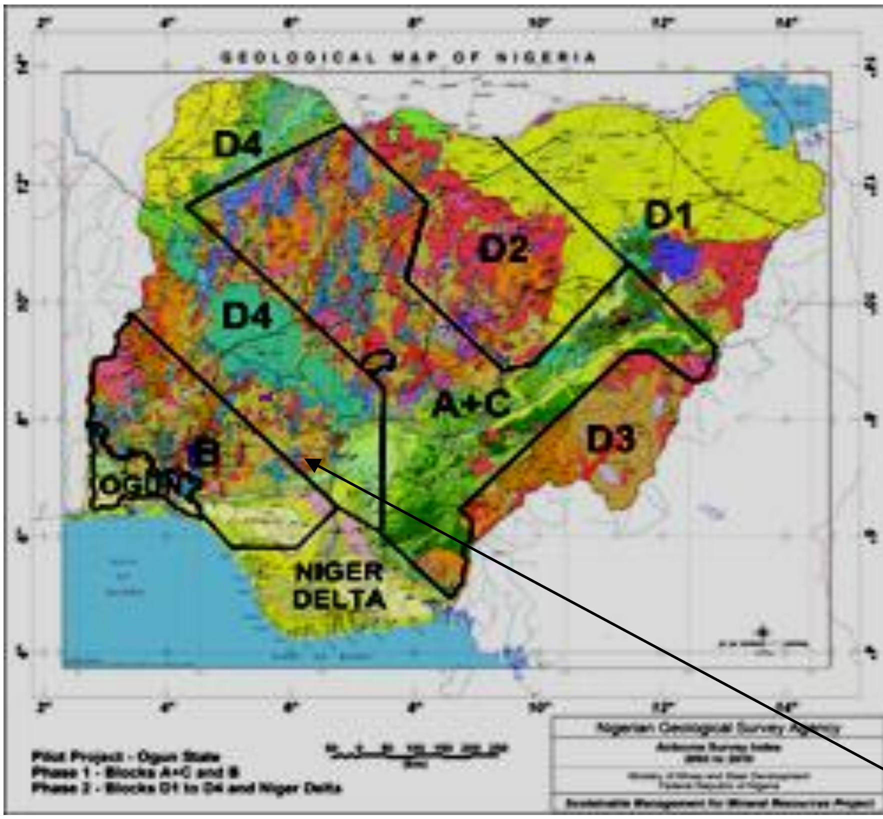
## Introduction

Geophysical methods are implemented in a wide range of applications which include road, dams and dikes constructions. Since the last decade, the involvement of geophysics in civil and environment engineering has become a promising approach (Luma and Jadi 2000, Othman 2005). At present, standard engineering practices require investigation of the subsurface at engineering construction sites. In baseline studies for pipe-laying programmes, for example, issues relating to the corrosivity of the host soil, alongside possible effects on underground pipes in an environment are investigated (Agunloye, 1984).

Soil corrosion is a complex phenomenon with multitude variables. Several chemical actions and reactions occur between the laid pipes and its immediate environment, the host soil. Unfortunately, site engineers sometimes fail to incorporate pre-development geophysical investigations in their job schedule for reasons of cost and other logistic considerations despite their necessity (Olorunfemi et al, 2000, Olorunfemi et al, 2004).. One of the simplest measurable and empirical classifications is based on soil resistivity. Knowledge of the resistivity of the surrounding soil gives an indication of the corrosiveness of the stratum. Sandy soil is high up on the resistivity scale due to their limited water storage capacity and high porosity. Hence, it is considered the least corrosive. On the other hand, Clay soils especially those contaminated with saline water are on the opposite end of the resistivity spectrum. Thus, it is desirable to investigate and estimate the corrosivity of the subsurface structure at Igarra with a view to delineating the subsurface geologic layers and determine their corrosion severity. The area was therefore investigated using the electrical resistivity by applying Schlumberger and Dipole-Dipole tomography configurations to ascertain the resistivities of the geologic layers and their corrosive severity.

## Location and Geological setting of Study Area

The study area is located on $7^0 17'0''$ N, $6^0 6'0''$ E in Igarra, Southwestern Nigeria. It is bounded on the west by the Auchi-Ibillo road and on the South by Igarra comprehensive college road. The climate is predominantly the rainforest characterized by two seasons-the wet season (between May-October) and the dry season (between October-April); the mean annual rainfall is approximately 1250 mm with a temperature range of $18^oC$-$33^oC$. The area is accessible by roads like the Auchi-Ibillo, Okpe and Onwa roads respectively and is within the zone linking the Southwest to the Northwest of Nigeria (Fig 1). The topography is generally undulating with the highlands of granitic origin located east of the area. Geologically, the area is underlain by rocks of the Precambrian Basement Complex. Prominent among these are Syn-to-late tectonic porphyritic biotite, Low-grade meta-sediments, Migmatites, granites, quartzite and marble/limestone complex with depressions.




Area

Figure 1: Geological map of Nigeria showing the study area, Igarra

## Materials and Method

Five traverses were established for the purpose of the investigation with an inter-traverse separation of 60 m. The investigation was done in the S-N direction. The study involved the application of two separate electrical resistivity techniques. - the Schlumberger vertical electrical sounding (VES) with station separation of 25m and the Dipole-Dipole tomography which utilized an electrode spacing of 10 m along the five traverses. The resistivity survey techniques involve the passage of current into the ground by means of two current electrodes while the potential difference is measured using a second pair of potential electrodes (Figures 2 and 3).

The Schlumberger VES investigation measures the changes in formation resistivity with depth. It requires that current electrodes spacing, AB is increased after every reading while potential electrodes spacing, MN is kept constant for most readings but increased when necessary using the control $AB/2 > MN/2$ (Figure 2) (Okolie, 2010). The Schlumberger array was sounded using the terrameter from which apparent resistivity data of the subsurface under investigation were obtained with varying current electrode separations along each traverse at selected stations. The obtained apparent resistivity data were plotted against half current electrode spacing on a three decade bi-log graph and presented as sounding curves. The curves were then interpreted qualitatively by visual inspection and quantitatively by partial curve matching and modeled using computer iteration with the aid of Win-RESIST version 1.0 computer software to generate depth strata for analysis.

The apparent resistivity ( $\ell_a$ ) is obtained from Schlumberger VES configurations with the equation

$$\ell_a = \frac{RL^2}{2l} \quad \text{.............................................1}$$

Where

$\ell_a$ = the apparent resistivity (ohm-m)

R = the ground resistance (ohm)

L $\left(= {AB}/{2}\right)$ is half the current – current electrode separation (m).

l = is half the potential – potential electrode spacing (m)

and $\pi$ = a constant $\left({22}/{7}\right)$

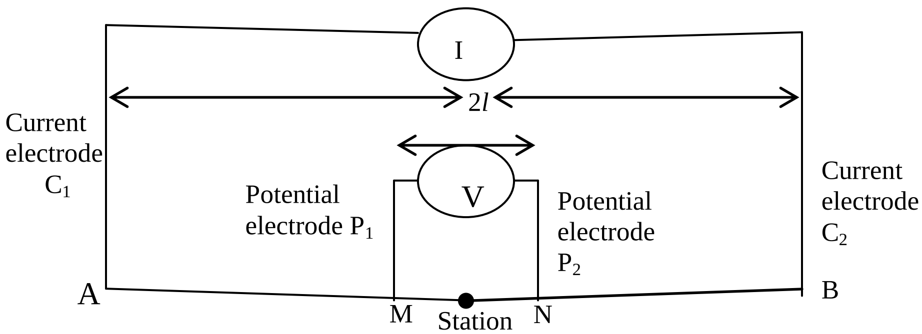



Fig. 2: Schlumberger array Electrode spacing for ${}^{AB}/_2 \geq 5\,{}^{MN}/_2$

Where"2L" is the current electrodes separation and, "2$l$" is the potential electrodes separation

The Dipole-Dipole tomography configuration has four electrodes but its array requires that potential electrodes, $P_1P_2$ are close and on one side while the current electrodes $C_1$, $C_2$ are close to each other and on the other side with each pair having a constant mutual separation "a". Moreover, the separation between the electrodes is an integer multiple of "a" (Figure 3). This implies that if the distance between the two nearest potential-current electrodes is relatively large (na>>a) in the Dipole – Dipole array, each pair closest electrodes is treated as an electric dipole so that the apparent resistivity becomes

$$\ell_a = \pi Ran\,(n+1)(n+2) \quad \text{.................................. 2}$$

Where

R = ground resistance

"a" = a constant nearest electrode separation (m)

and n = integer multiple 1 < n > 5)

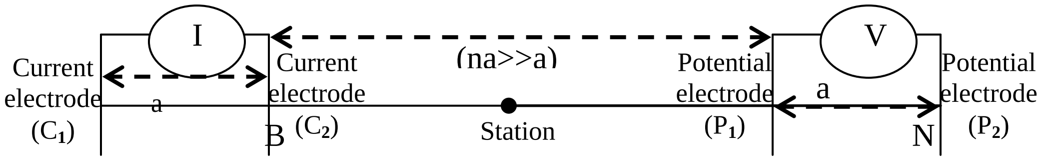



Figure 3: Dipole – Dipole configuration with (na>>a)

The vertical electrical sounding (VES) Electrical resistivity tomography (ERT) investigations were executed using multi-electrodes along the traverses as a combined sounding-profiling survey. The array has implicit system advantage of electromagnetic coupling which effectively reduces system noise since the current and potential cables are well separated from each other (Sharma, 1997). The set of data obtained from the apparent resistivity profiling were inverted for true subsurface resistivity using 2-D and 3-D inversion algorithms. The resulting estimated models were analyzed, interpreted accordingly using the DIPROfWIN version 4.0 inversion software from which 2D resistivity pseudo-sections were generated (Figure 5).

## Results and Discussion:

The Results and discussion were also treated in two parts.

(a) With the Schlumberger configuration three geologic layers having subsurface resistivity distribution of 12.3 – 5628.5 ohm-m across the traverses were delineated.

Transverse 1 has distinct three geologic layers. The topsoil consists of sand/clayey sand with resistivities and thicknesses ranging from 178.4 – 821.5 ohm-m and 0.5 – 1.0 m respectively. The second layer consists of clay and sandy clay/clayey sand indicating the presence of a high amount of water and having resistivities and thicknesses in the range of 14.4 – 74.9 Ohm-m and 1.6 – 6.1 m respectively. Its third layer consists of weathered/fractured basement having resistivities in the range of 492.5 – 2307.5 ohm-m from a depth of about 10.0 m to far depth.

Transverse 3 has topsoil consisting of sand/clayey sand with resistivities and thicknesses in the range of 17.6 – 348.5 Ohm-m and 0.5 – 5.1 m respectively; Its second layer consists of clay with resistivities and thicknesses in the range of 9.5 – 29.3 Ohm-m and 1 – 3.6 m respectively; Here there is a visible metaconglomerate outcrop of the second layer through the first layer. The third layer consists of weathered/fractured basement with resistivities ranging from 171.5 – 5628.2 Ohm-m from a debt of about 9.0 m to far depth.

Transverse 5 has topsoil consisting of sand/clayey sand with resistivities and thicknesses in the range of 130.3 – 451.6 Ohm-m and 0.6 – 1.2 m respectively. The second layer consists of clay/sandy clay with resistivities and thicknesses in the range of 12.3 – 64.9ohm – m and 1 – 12.1m respectively; the third layer consists of weathered/fractured basement with resistivities in the range of 182.3 – 2316.8 Ohm-m from about 13 m to infinite thickness (Figure 4).

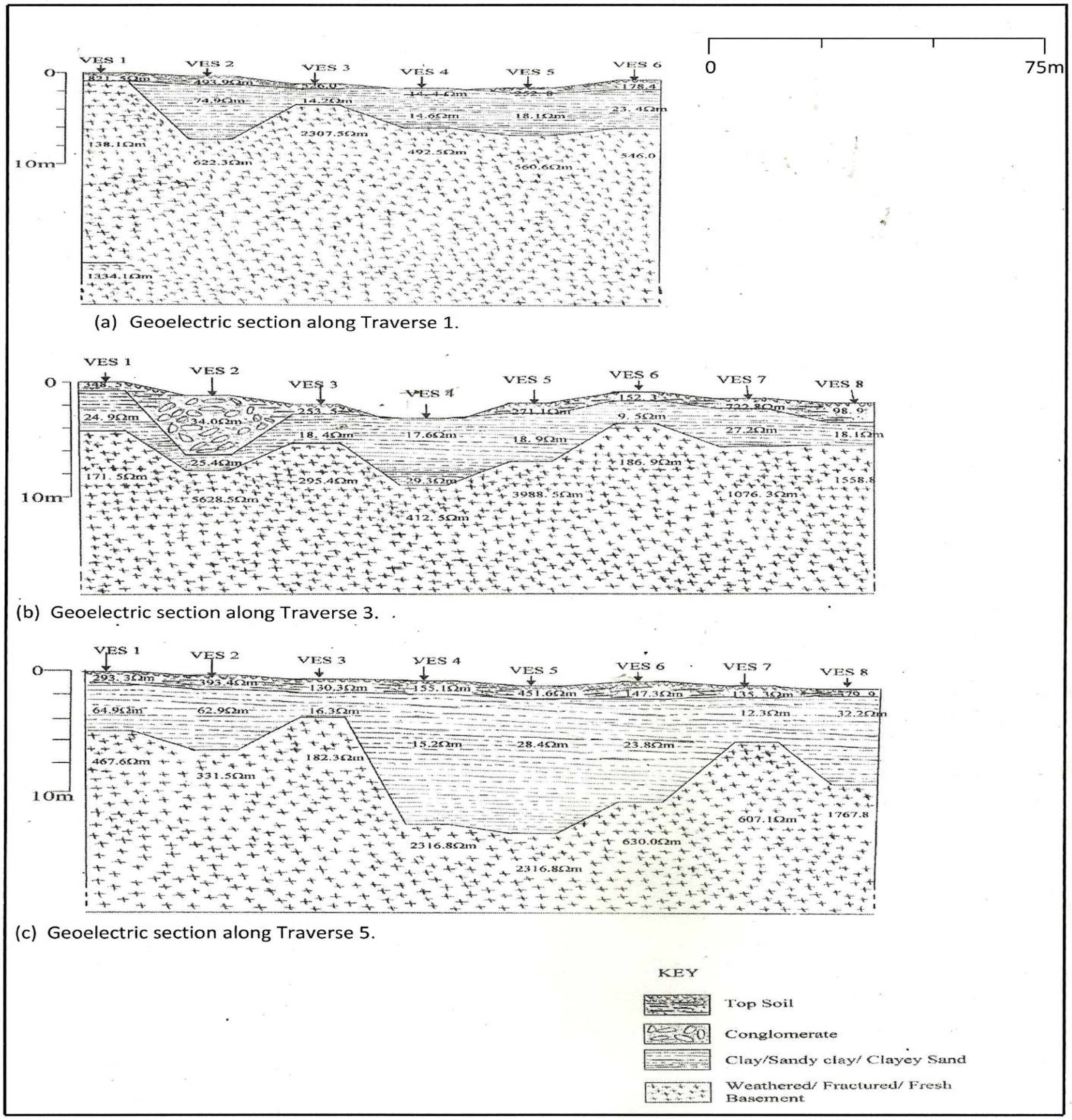
(b) Electrical Resistivitity Thermographic Pseudo-sections

The 2-D resistivity structure sections obtained from 2-D inversion of ERT data acquired along traverses 1 – 5 are shown in figure 5(a-c).

The 2-D resistivity section along traverse 1 shows a high resistivity (>100, < 200 ohm-m) zone between station 1-6 (10-35 m), to a depth of 3.3m below the surface and a high resistivity (>200 ohm-m) zone extending from 3.3m to an infinite depth below the surface. The low resistivity (< 60 ohm-m) zone lies between stations 6 – 11 (35 m – 60 m) with very low resistivity between stations 6 – 8 (35 – 45 m) extending to infinite depth below the surface.

Traverse 3 has low resistivity (<35 ohm-m) zone between stations 1 – 2 (10-15 m) reaching a depth of 3.5 m from the surface and between station 4 – 14 (25-75m) reaching depths ranging from 3 – 8m below surface; a relatively high resistivity (43.4 – 161ohm-m) zone can be found between station 2 – 4 (15-25 m) reaching depths ranging from 6-8m below the surface and between stations 4 -17 (25 – 90 m) with depth ranging between 3 -10m except between station 6.5 – 8 (38 – 45 m) where the depth extends to 20m below the surface. A highly resistive (>200ohm-m) zone can be found from depths (between 8 – 10 m) to infinity.

Traverse 5 has low resistivity (<40ohm-m) zone between station 5.5-17 (33-90 m) with depth ranging from 2 -10 m below the surface a relatively high resistivity (40-100 Ohm-m) zone surround the low resistivity layer from depth of 2-21 m below the surface; except between station 1-5(10-30 m) where it is exposed. A highly resistive (>204.7 Ohm-m) zone lies between station 1 – 6 (10 – 35 m) and between station 8.5 – 16 (47 – 85 m) with depth ranging from between 6 – 12 m, to infinity below the surface.

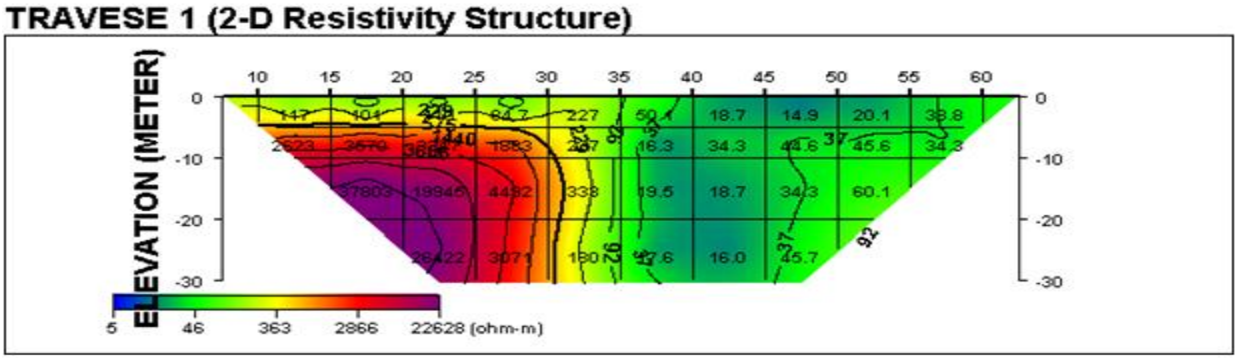



(a) Geoelectric section along Traverse 1.

(b) Geoelectric section along Traverse 3.

(c) Geoelectric section along Traverse 5.

Figure 4: Geoelectric section along Traverses 1, 3 & 5 in an S – N Direction.

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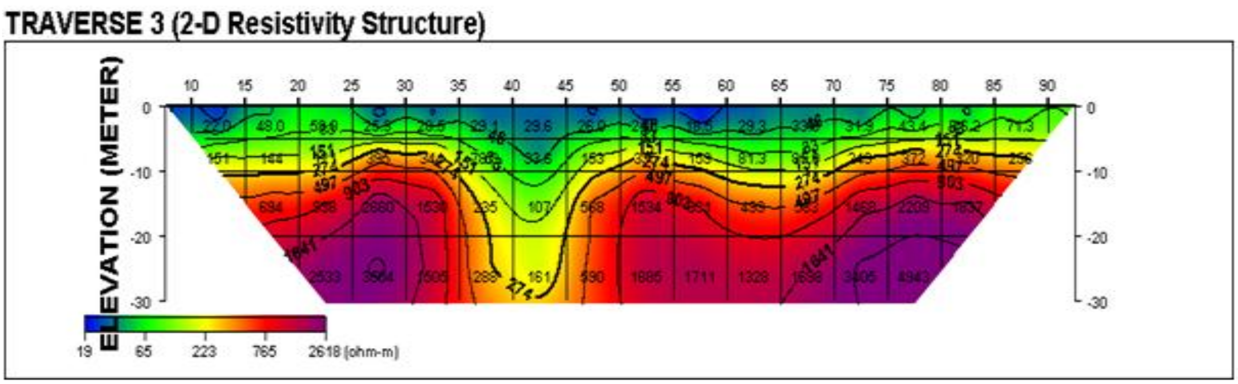
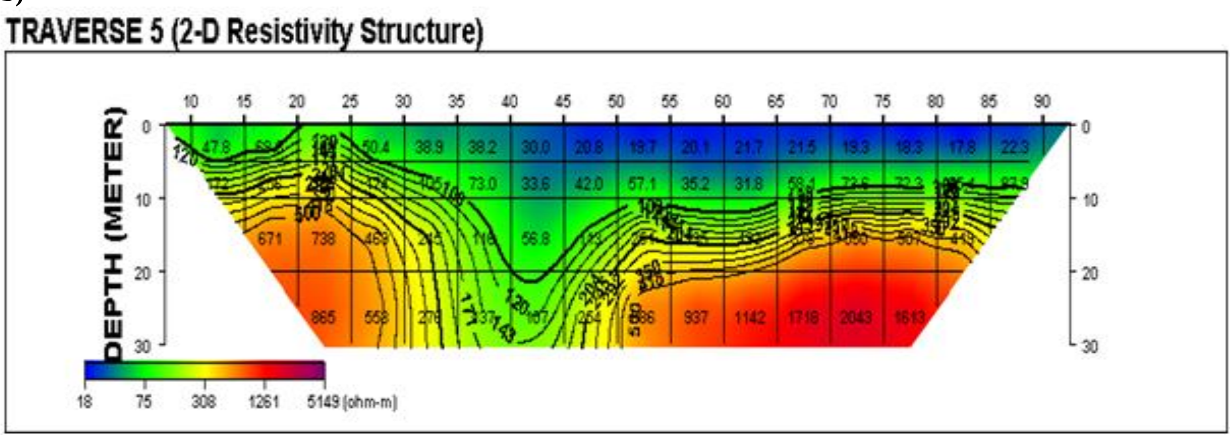



**b)**




**c)**

Figure 5: 2-D resistivity pseudo-sections along the traverses 1, 3 & 5.

## Conclusion

Vertical electrical sounding and electrical resistivity tomography were used to delineate the subsurface strata in some sites at Igarra. The geoelectric sections delineated three distinct layers which include the topsoil made up of sand/clayey sand; the second layer made up of clay/ sandy clay and the weathered/fractured basement bedrock. A good correlation was found between the geoelectric section and the 2-D resistivity Pseudosections. Results of analysis from both methods show that although the top layer of the surveyed area is non corrosive, it is a corrosive environment because; the second layer which is relatively very thick with respect to the first layer is moderately to highly corrosive. Hence, appropriate measures must be employed when underground steel structures are to be laid in the area because they are most likely to be concealed in the second layer.

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