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Soil Resistivity Evaluation on PMS Tank Foundation in Granular Soil Lithology: A Case Study in Lekki, Nigeria

I. W. Omunguye and S. B. Akpila

Department of Civil Engineering, Rivers State University of Science and Technology, P. M. B. 5080, Port Harcourt, Nigeria

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ABSTRACT

An evaluation of soil resistivity using electrical resistivity was carried out at a PMS tank site in Lekki area of Lagos State, Nigeria. The soil profile generally consists of medium-dense and dense, brown, slightly silty SAND up to 15m depth of exploration below ground level. Resistivity survey was carried out with the purpose of determining the geo-electric parameters (i.e. layer resistivity, layer thickness, transverse resistance, longitudinal conductance) and to delineate the subsoil corrosivity zones in the cohesionless PMS tank subsurface. Five Vertical Electrical Soundings (VES) points along two profile lines were carried out and VES results showed moderate to slightly corrosive subsurface.

Keywords: Vertical Electrical Sounding, Cohesionless, Corrosivity.

INTRODUCTION

A premium motor spirit, PMS, reservoir (TAC-21) constructed over two decades ago in Lekki, Nigeria was scheduled for rehabilitation of its foundation [1]. Seepage of PMS into soil from bottom metal plate which bears on medium-dense, Slightly silty SAND formation was suspected. Consequently, soil resistivity test programme was carried out to determine the likelihood of soil corrosivity from PMS soil pollution within Tank vicinity.

Soil resistivity is a measure of soil's ability to impede the conduction of an electric current. It decreases with increase in moisture content of the material until its minimum value is obtained. This minimum resistivity value is the resistivity of the material. Soil resistivity is the key factor that determines what the resistance of a grounding electrode will be, and suggests the depth it must be driven to obtain low ground resistance. All soils conduct electrical current, with some soils having good electrical conductivity while the majority has poor electrical conductivity. The resistivity or inverse of conductivity of the soil is obtained using resistivity meter [2]. Resistivity surveys also known as resistivity imaging, measure differences in the electrical resistivity of the soil by applying small electric currents across arrangements of ground electrodes. It entails the passage of a direct current into the soil through electrodes and the measurement of the potential difference between some sections of the subsurface which gives a measure of the electrical impedance of the subsurface material [3].

Resistivity sounding involves progressively increasing the spacing between the current electrodes in order to increase the depth of investigation which helps in understanding the horizontal and vertical discontinuities in the electrical properties of the soil. Knowledge of soil corrosivity is important for predicting the lifetime of a buried steel structure or for the effective design of cathodic protection measures [4]. It is needed to estimate the corrosivity of soils for design and corrosion risk assessment purposes. Factors such as soil composition, moisture content, pore water chemistry and hydrogen potency control the soil resistivity, which is the main investigative factor.

MATERIALS AND METHODS

Electrical Resistivity Method

The electrical resistivity method involves the measurement of the apparent resistivity of soils as a function of ionic content of the pore fluids, permeability, porosity and clay mineralization. It is one of the most widely used electrical methods and is extremely important in cases of in-situ determination of the degree of corrosiveness of soils [4]. The method is mainly used in environmental and hydrogeologic investigations and its principle is quite straightforward, as it involves a measurement of potential difference across electrodes, after a direct current has been injected into the ground through current electrodes. The apparent resistivity (ρa), is what is actually evaluated since the resistivity values are averages over the total current path length. In most cases computer programs are used for the analysis and interpretation of the collected data. The resistivity of the soil subsurface is a function of the magnitude of the current, the geometry of the electrode configuration and the recorded potential difference [3].

During resistivity surveys current is introduced into the soil through a pair of current electrodes, and the potential difference is measured between a pair of potential electrodes then, the observed data is used to compute the apparent resistivity which depends on the type of array used. In recent times, more sophisticated software has been created to interpret the variation of resistivity with depth by using a forward and inverse modeling method. The two main techniques used in electrical resistivity survey are the vertical electrical sounding (VES) and the resistivity profiling techniques.

Methodology

The electrical resistivity method involving the VES technique was used for the investigation; it was used for the purpose of determining the vertical variation of resistivity. In this method, artificially generated direct current was injected into the ground through two current electrodes while the resulting potential difference is measured by another pair of potential electrodes in the vicinity of the current flow [5]. The current and potential electrodes are maintained at the same relative spacing and the whole spread is progressively expanded about a fixed central point [6]. Since one of the aims of investigation is the depth, the Schlumberger configuration is adopted for the VES investigation, as increase in the current electrode separation creates more penetration and hence reaches more depth.

Schlumberger Vertical Electrical Sounding

The Schlumberger Array was chosen for the investigation for the following reasons; that small movement of the electrodes are needed; because lateral variations cause smaller errors when current electrodes are moved than when potential electrodes are moved; and that the duplication of readings with the same values of half current electrode spacing (AB/2) but different values of potential electrode spacing (MN/2) also allows a fairly accurate correction to be made for the effects of lateral variation [4].

The Schlumberger method uses four in-line electrodes; the inner pair for recording electrical potential as a current is passed through the outer pair. Measurements are made in a series of readings involving successively larger current electrode separations [7]. The data are plotted on a logarithmic scale to produce a sounding curve representing apparent resistivity variations as a function of half current-electrode separation (AB/2).

Field Resistivity Survey

Resistivity surveys can take different types of configuration of the current and potential electrodes. In this case, two current electrodes and two potential electrodes were used; and the potential electrodes were placed between the current electrodes. Some of the equipments used for the resistivity survey include a pair of current electrodes and pair of potential electrodes, all made of stainless steel, rills of copper cables, connecting cables, plugs and clips for fixing cables to electrodes. A power source to produce the current, tape rule for measurement of length, hammer for fixing the electrodes in the ground, water to enhance conduction and the resistivity meter (TINKER and RASOR SR 2) which is the main equipment in the survey as it sends the signal, receives incoming signals, and calculates the resistance.

A key difference between the Schlumberger configuration and others (such as Wenner and Dipole-Dipole configuration) is the spacing between the current and potential electrode. Let the potential electrodes be represented as M and N, while the current electrodes be represented as A and B as illustrated in Figure 1. In the Schlumberger arrangement, the spacing between the potential electrodes (a) is fixed, and is less than the separation between the current electrodes L which is progressively increased during survey.

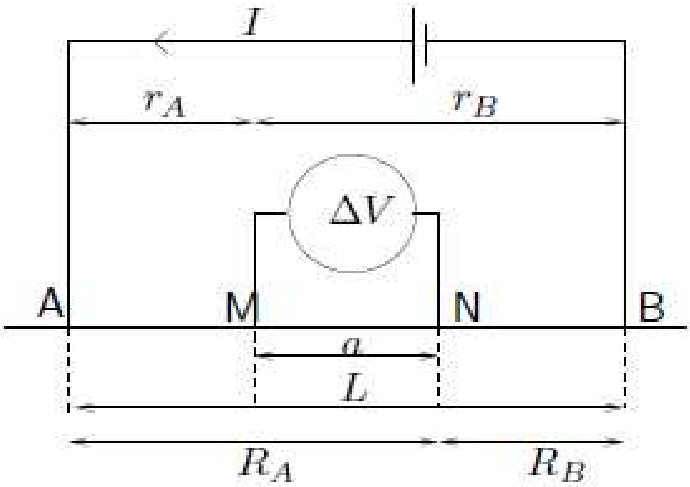

Figure 1: Schlumberger Configuration or Array

For any linear symmetric array A M N B of electrodes, the apparent resistivity (ρa) applying Schlumberger array where AM is the distance on the soil surface between the positive current electrode A, and the potential electrode M. When two current electrodes A and B are used and the potential difference (ΔV) is measured between two measuring electrodes M and N, the apparent resistivity can be written in this form:

$$\rho a = \pi\ \Delta V/I * [((AB/2)2 - (MN/2)2) / MN] \quad (1)$$

or

$$\rho a = \pi\ K\ \Delta V/I = \pi\ L^2/2a\ (\Delta V/I) \quad (2)$$

Where; ρa is the apparent resistivity (Ωm) of an equivalent soil layer, ($L^2/2a$) is the geometric factor (K) and (a) is the electrode spacing (m), ΔV is the potential difference and I is the electric current. The value of the apparent resistivity (ρa) depends on the geometry of the electrode array used, as defined by the geometric factor (K) [8].

Data Acquisition/Processing

The resistivity survey was carried out on five points in TAC-21 as depicted in Figure 2, and resistivity measurements extended up to the depth of 30m, with half electrode spread of 45m. The method used defines the Schlumberger configuration, with the following electrode intervals (AB/2): 1.5m, 2.25m, 3m, 4.5m, 6m, 7.5m, 10.5m, 15m, 22.5m, 30m, and 45m. The configuration adopted is based on reliability and convenience in the terrain to the geo-electric model across the site.

Raw field data was transferred to computer on completion of each day and the data was checked to verify accuracy and that the equipments were fully functional to identify which may require immediate resurvey. Data was finally analyzed by mathematical methods using appropriate constants and are presented in a tabular form by an appropriate computer spread sheet programme. Ultimately, the field data were processed using Res2dinv Computer Program and IP12Win. The VES data were then presented as sounding curves, which are obtained by plotting graphs of apparent resistivity versus half electrode spacing on the double logarithmic graph sheets. Also, a graphic plot of A log ρ = f (l) profile was presented. Geo-electric profile model summarizes the probable subsurface geo-electric zones/layers in the survey project site. The pseudo cross section gives a very approximate picture of the true subsurface resistivity distribution and it is useful as a means to present the measured apparent resistivity values in a pictorial form, and as an initial guide for further quantitative interpretation [9].

A typical resistivity data shows the various current and potential electrode distances, resistance and apparent resistivity for several stations. A plot of the apparent resistivity against electrode spacing on a bi-logarithmic paper is used to indicate vertical variations in resistivity [10]. The sounding curves is inverted by use of a computer program to give a one-dimensional (1D) layered model [11]. Interpretation of the sounding data assumes homogeneous, horizontal layering, thus, where lateral heterogeneities in resistivity exist within the influence of the energizing current field, the sounding may exhibit distortions which, when present, the computer will model as horizontal layering [12]. The curve obtained is then used to obtain the geo-electric parameters of the section such as; the depth, thickness and resistivities of the layers present within.

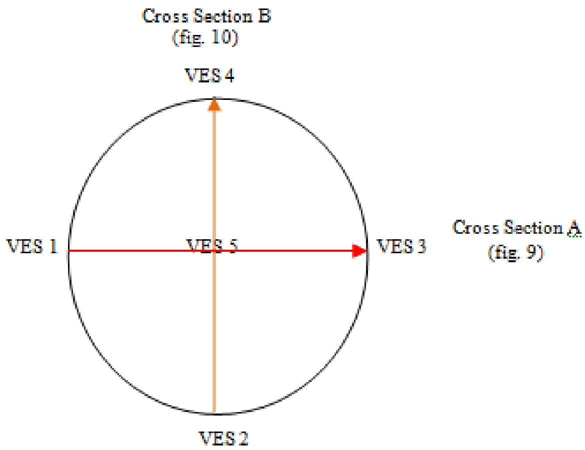

Figure 2: VES Points Layout in the Project Site at TAC- 21

RESULTS AND DISCUSSION

The field data was finally analyzed by mathematical methods using appropriate constants. The geo-electric resistivity and the calculated average resistivity of the subsurface layer are shown with corresponding depth in Tables 1 and 2, while the near surface layer corrosivity is shown in Table 3.

The VES data are presented as sounding curves, which are obtained by plotting graphs of apparent resistivity versus half electrode spacing on the double logarithmic graph sheets. A graphic plot of A log $\rho = f$ (l) profile is presented as geo-electric log model in Figures 3-8 to show the vertical or depth profile.

The apparent resistivity readings are modeled in order to provide information on the thickness of individual resistivity units within the subsurface. The observed values of the resistivity and thickness obtained from the interpretation gives an informed suggestion of the degree of corrosivity present in the subsurface, and hence a model of the surface is prepared. The modelled results are displayed as scaled resistivity-depth pseudo sections with different colours. Generally, blues represent areas of low resistivity; greens are relatively moderate, while reds are relatively higher. The pseudo section showing electrical resistivity layers, across (i) VES 1, 5 and 3, (ii) VES 2, 5 and 4 are presented in Figures 9-10; summarized the probable subsurface geo-electric layers of the survey site.

The area could be characterized with three major geo-electric resistivity zones within the shallow subsurface sounded depth of 30m. The upper subsurface geo-electric zone had 57-97Ωm which describes it as Moderately Corrosive having a thickness of about 2m. The middle geo-electric zone had 144-274Ωm indicating Slightly Corrosive with thickness of about 5m and a Lower geo-electric zone of 37-171Ωm, depicting Corrosive to Slightly Corrosive and are of sandy materials.

Table 1: Schlumberger VES Field Data

ELECTRODE SPACING		CONSTANT	VES 1@BH 1	VES 2@BH 2	VES 3@BH 3	VES 4@BH 4	VES 5@BH 5
AB/2 (m)	MN/2(m)	K	R_1(Ω)	R_2(Ω)	R_3(Ω)	R_4(Ω)	R_5(Ω)
1	0.3	10.24	4.30	6.50	5.60	5.30	6.40
1.47	0.3	22.39	2.30	3.00	2.40	2.90	3.00
2.15	0.3	48.17	1.90	2.50	2.10	2.20	1.40
3.16	0.3	104.30	0.50	1.60	1.50	1.30	0.60
4.64	0.3	225.20	0.30	1.20	0.70	1.10	0.20
6.81	0.3	485.40	0.20	1.00	0.30	0.2	0.10
10.00	1.00	313.40	0.10	0.10	0.10	0.10	0.20
14.00	1.00	678.10	0.08	0.08	0.08	0.10	0.10
21.50	1.00	1451.00	0.09	0.07	0.07	0.08	0.08
31.60	3.00	1043.00	0.10	0.09	0.09	0.10	0.10
46.40	3.00	2252.00	0.08	0.07	0.07	0.09	0.07

Table 2: Schlumberger VES Resistivity Data

SUBSOIL AVERAGE ELECTRIC RESISTIVITY MEASUREMENT							
VES 1@BH 1 ℓ_1(Ωm)	VES 2@BH 2 ℓ_2(Ωm)	VES 3@BH 3 ℓ_3(Ωm)	VES 4@BH 4 ℓ_4(Ωm)	VES 5@BH 5 ℓ_5(Ωm)		Depth (m)	Ave Res for ℓ_1 to ℓ_5 (Ωm)
44.032	66.56	57.344	54.272	65.536		0.67	57.55
51.497	67.17	53.736	64.931	67.17		0.98	60.90
91.523	120.425	101.157	105.974	67.438		1.43	97.30
52.15	166.88	156.45	135.59	62.58		2.11	114.73
67.56	270.24	157.64	247.72	45.04		3.09	157.64
97.08	485.4	145.62	97.08	48.54		4.54	174.74
31.34	31.34	31.34	31.34	62.68		6.67	37.61
54.248	54.248	54.248	67.81	67.81		9.33	59.67
130.59	101.57	101.57	116.08	116.08		14.33	113.18
104.3	93.87	93.87	104.3	104.30		21.07	100.13
180.16	157.64	157.64	202.68	157.64		30.93	171.15

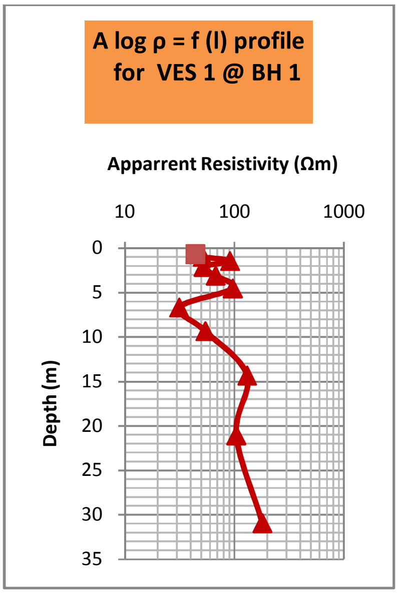

Figure 3: Resistivity log for VES 1

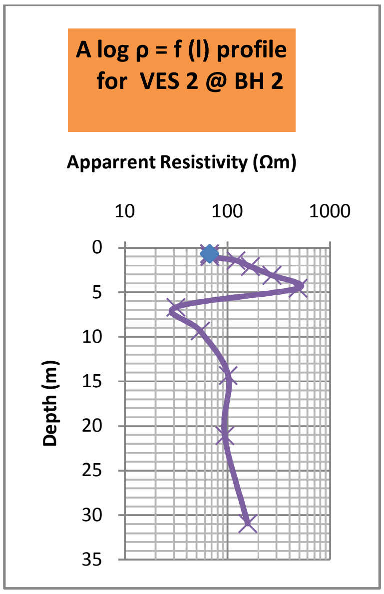

Figure 4: Resistivity log for VES 2

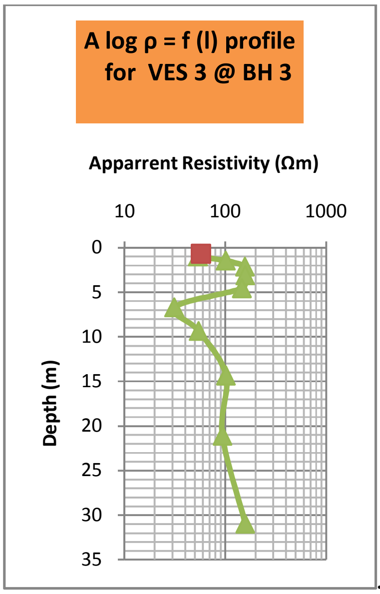

Figure 5: Resistivity log for VES 3

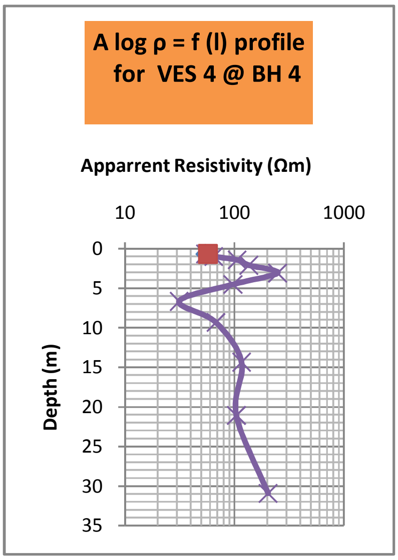

Figure 6: Resistivity log for VES 4

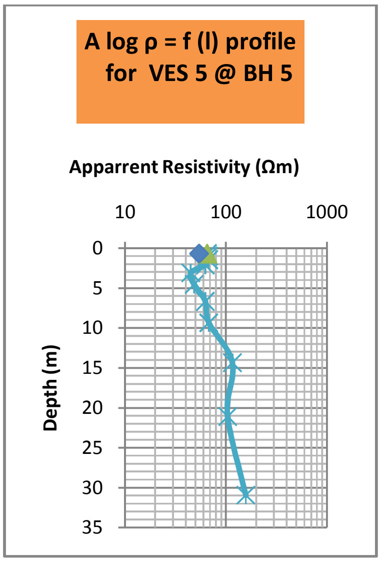

Figure 7: Resistivity log for VES 5

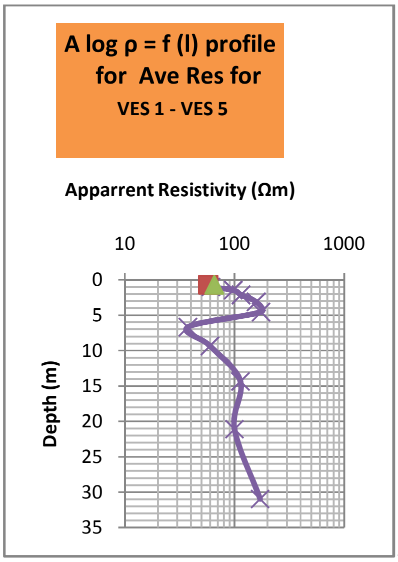

Figure 8: Resistivity log for Ave VES 1-5

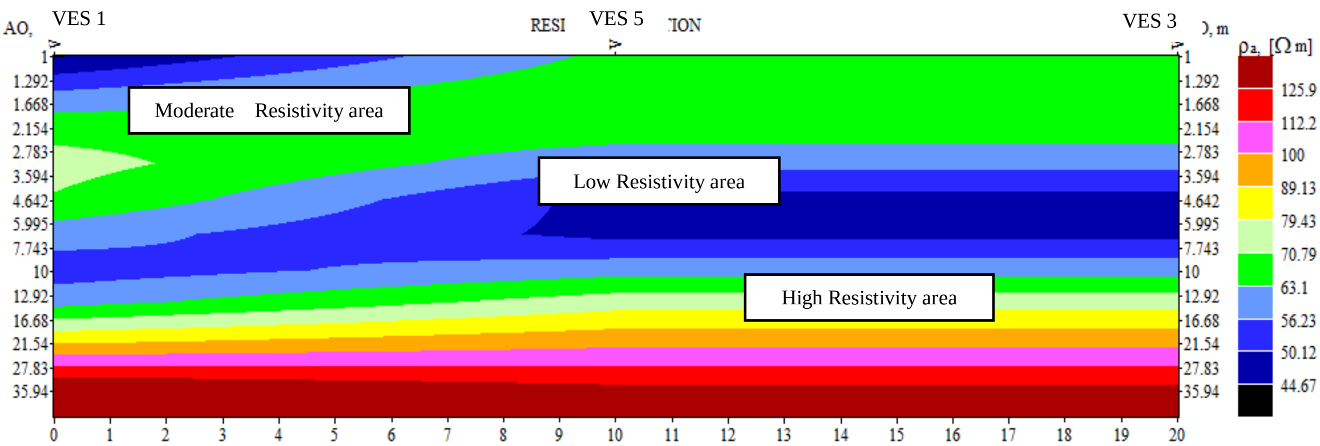

Figure 9: Pseudo Cross Section A: (VES 1, 5 & 3)

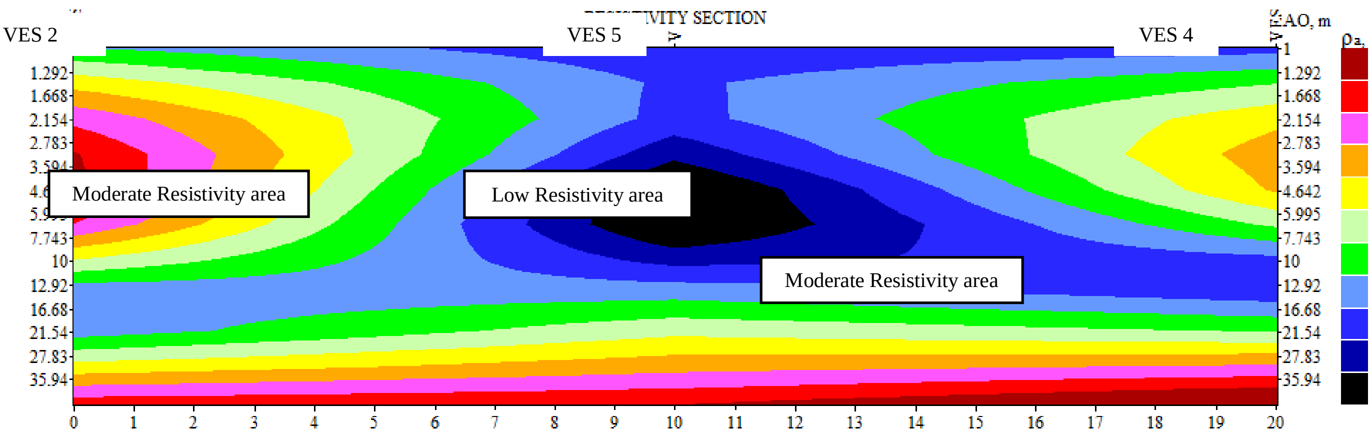

Figure 10: Pseudo Cross Section B: (VES 2, 5 & 4)

Table 3: Summary of Near Sub-surface layer Corrosivity model in TAC-21; VES 1-5:

VES No	Geo-electric Resistivity (Ωm)	Corrosivity
1 - 5	57 – 174 Ωm	Moderately Corrosive to Slightly Corrosive

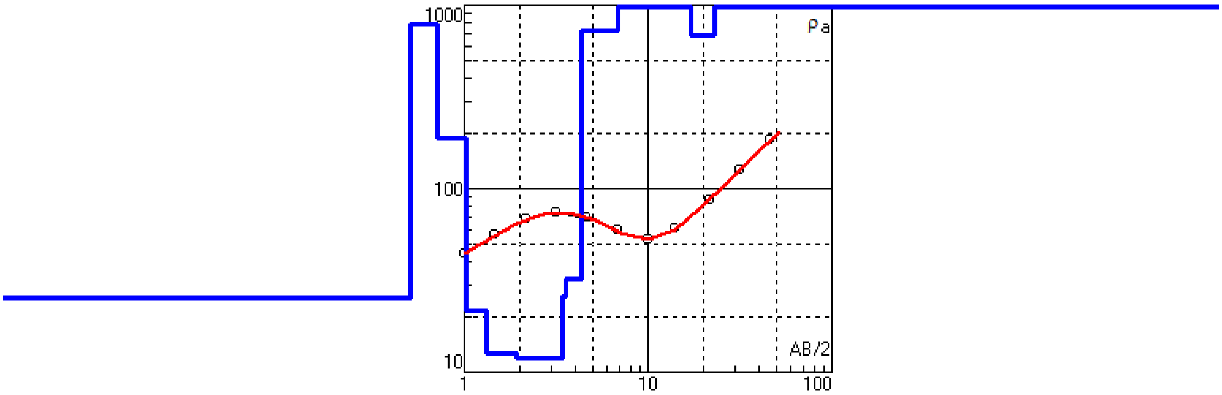

Figure 11: Schlumberger VES Curve (Resistivity Vz AB/2) for VES 1

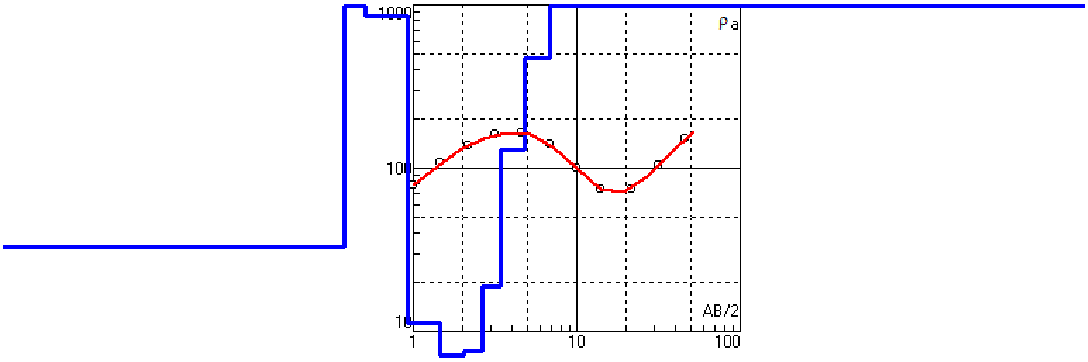

Figure 12: Schlumberger VES Curve (Resistivity Vz AB/2) for VES 2

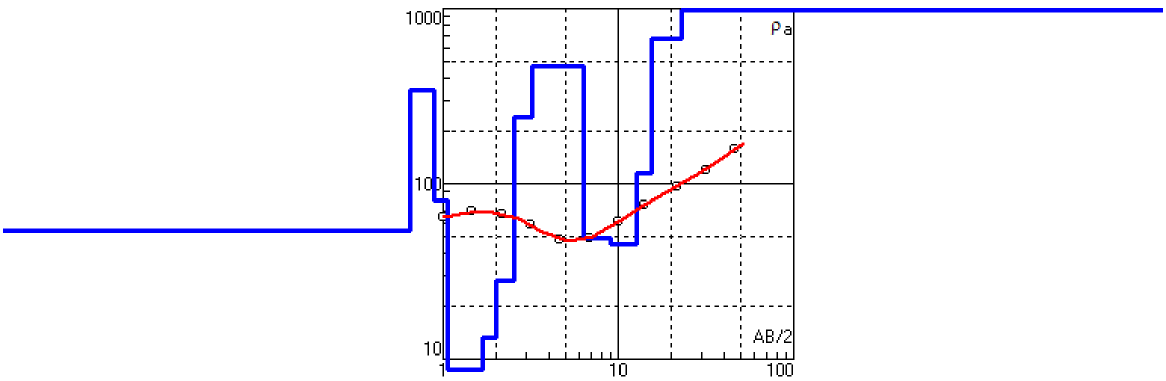

Figure 13: Schlumberger VES Curve (Resistivity Vz AB/2) for VES 3

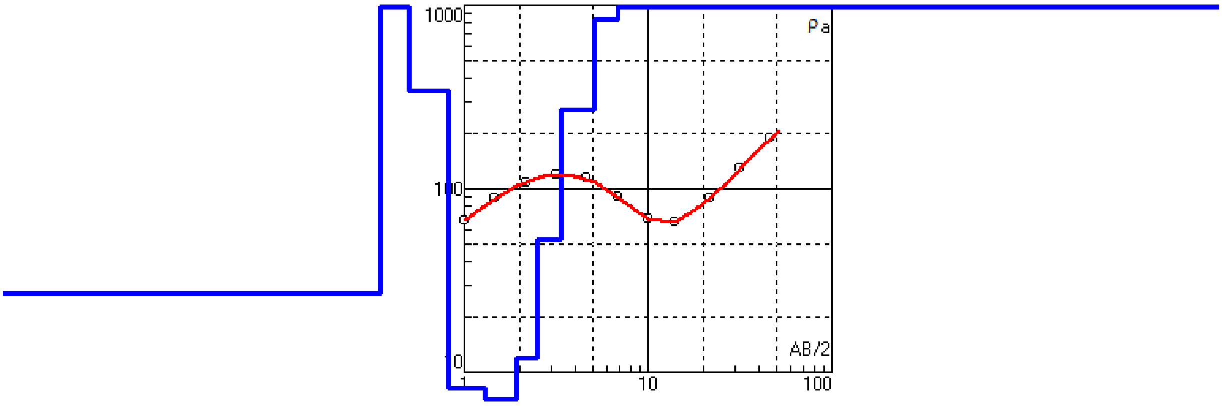

Figure 14: Schlumberger VES Curve (Resistivity Vz AB/2) for VES 4

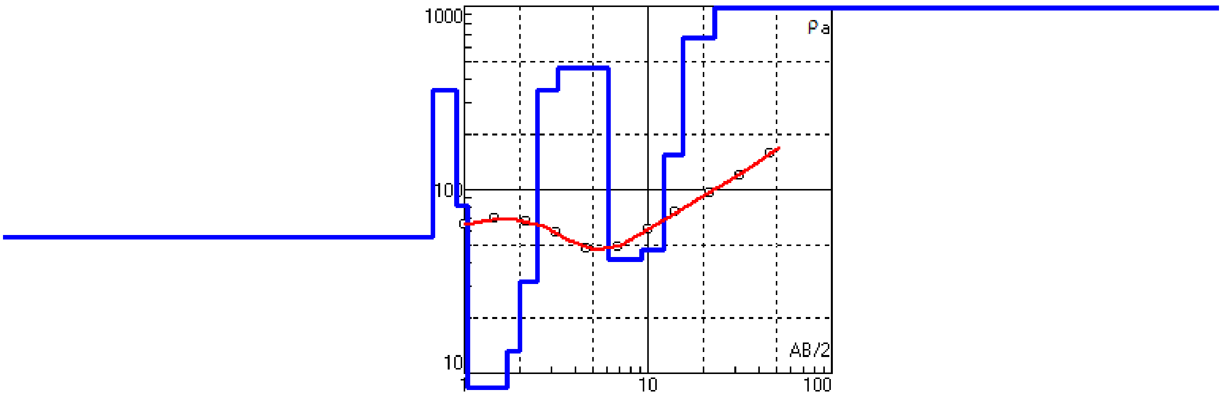

Figure 15: Schlumberger VES Curve (Resistivity Vz AB/2) for VES 5

CONCLUSION

The following conclusions can be drawn from the study:
1. The vicinity of TAC 21 could be characterized with 3 major geo-electric resistivity zones within a depth of 20m below ground level.
2. An upper subsurface geo-electric zone of 2m thickness had resistivity range of 57-97Ωm.
3. A middle geo-electric zone with resistivity range of 144-274Ωm with thickness of about 5m.
4. A lower geo-electric zone with resistivity range of 37-171Ωm.
5. Soil corrosive property in the area is minimal, showing corrosive to moderate corrosive to slight corrosive.
6. A cathodic protection system in the area may be monitored regularly to improve corrosion control on facilities.

REFERENCES

[1] Akpila, S.B., *American Journal of Engineering Science and Technology Research*, **2013**, 1, (4), 68- 78.
[2] Igboama, W.N., and Ugwu, N.U., *American Journal Scientific and Industrial Research*, **2011**, 2, (5), 713-717.
[3] Felix, O.O., Comparison of Resistivity and Electromagnetics as Geophysical Techniques, Institute for Mathematical Sciences, University of Cape Town, South Africa, **2008**, 1-31.
[4] Bayowa, O.G., and Adigun, O.A., *Greener Journal of Physical Sciences*, **2012**, 2, (1), 10-15.
[5] Adepelumi, A.A., Ako, B.D and Ajayi, T.R., *Hydrogeology Journal*, **2001**, 9, 611-622.
[6] Philip, K., and Michael, B., An Introduction to Geophysical Exploration. Blackwell, London, **1984**.
[7] Keller, G.V., and Frischknecht, F.C., Electrical Methods in Geophysical Prospecting, Pergamon Press, Oxford, **1966**, p 519.

[8] Reynolds, J.M., An Introduction to Applied and Environmental Geophysics, John Wiley and Sons, Inc., New York, USA, **2000**.
[9] Loke, M.H., Electrical imaging surveys for environmental and engineering studies: A practical guide to 2-D and 3-D surveys, Penang, Malaysia, **1999**, 8.
[10] Sabet, M.A., *Virginia Water Resources Research Center*, **1975**, 73, 1-28.
[11] Zohdy, A.A.R., A computer program for automatic interpretation of Schlumberger sounding curves over horizontally stratified media, National Technical Information Service, Springfield, Virginia, **1973**, PB-232703, 25.
[12] Senterfit, R.M., Hoover, D.B., and Chornak, M., Resistivity Sounding Investigation By The Schlumberger Method in The Yucca Mountain and Jackass Flats area, Nevada Site, U.S Geological Survey Open-File Report, **1980**, 82-1043, 1-9.