https://dx.doi.org/10.4314/dujopas.v11i1c.27
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 11 No. 1c March 2025*

Volumetric Analysis of Predominant Subsurface Earth Materials and 3D Tomography for Predicting Soil Erodibility in Abotse Quarters, Auchi, Etsako West LGA, Edo State, Nigeria.

D.A. Babaiwa[1] and O.J. Airen[2]

[1] Department of Physics,
Edo State University,
Iyamho,
Nigeria.

[2] Department of Physics,
University of Benin,
Benin City,
Nigeria.

Email: akinbabaiwa@gmail.com

Abstract
Geophysical probing of the subsurface with the use of 3D electrical resistivity tomography (ERT) was done in Abotse quarters, Auchi, Etsako West LGA of Edo State. It was to ascertain the level of soil erodibility having in mind to curb the potential immense danger targeted at our natural land with its associated infrastructure. Four layers from the horizontal depth slices with the following depths: 0 to 3.5 m, 3.5 to 7.52 m, 7.52 to 12.2 m and 12.2 to 17.5 m. Their corresponding resistivity values rose from 1485 to 113614 Ωm, 624 to 113614 Ωm, 262 to 113614 Ωm and 262 to 113614 Ωm with respect to every layer. Resistivity distribution was from 358 to 217741 Ωm and a drill depth of 15.4 m was achieved. This study demonstrated that soils with an ER well above 50 Ωm have a high percentage of being regarded as highly erodible. The findings suggest that ERT can be employed to immediately identify and prioritize areas where soils near the surface are vulnerable to erosion, thereby necessitating more detailed investigations. Sandstone and lateritic sand with a volume of 536,689 m^3 and 78,393 m^3 respectively are the predominant subsurface earth materials found in Abotse quarters. These large volumes of predominant earth materials explain the persistence of erosion in the area of study.

Keywords: Erosion, resistivity, dominant occurences, 3D, Volumetric Analysis.

INTRODUCTION
Electrical resistivity imaging (ERI) is an intrinsic soil characteristic that denotes a material's ability to resist the passage of current. ER imaging is a near-surface geophysical method to collect bulk continuous ER measurements in relation to a fixed depth. ERI surveys are quick compared with laboratory erosion testing. ER tomography (ERT) is therefore a good method

*Author for Correspondence

to prioritize scour critical infrastructures premised on predicted soil erodibility (Loke, 1999; Dahlin, 2001; Vaudelet, 2011; Hossain *et al*., 2011; Chambers, 2013).
Additionally, ERT could also be used to quickly identify critical infrastructures such as abutments and bridges having high erosion potential and prioritize scour critical infrastructure monitoring (John *et al*., 2015). ERT has been a widely deployed geophysical approach in fields such as environmental science, archeology, geotechnical engineering and geology (Snapp, 2017).

Different methods employed to directly measure erosion rates are expensive and time consuming (Hurst *et al*., 2012). Therefore, reasons for erosion are well studied and better understood when areas known for erosion are observed for the purposes of remediation and precautionary activities.

It is already established that geologic factor plays critical role in the geomorphology of an area; it follows that the use of geophysical and geotechnical methods in the evaluation of geologic processes of an area, therefore, comes to play (Uhegbu and John, 2017). Geologic factors such as sediment rock type, permeability and porosity are capable of causing erosion. Additionally, other factors such as composition, compaction and moisture of soil are key factors in determining soil erosion (Nichols, 2009).

Near-surface site characterization employing geophysical methods produces important information connected with the soil characteristics and can also provide a clue into the processes that direct the geomorphic development of landscapes (John *et al.,* 2015; Santamarina *et al*., 2005). Although, confining one's investigation of an erosion site to geophysical methods solely may present a restricted approach. Integrated approach may be in order for some geoenvironmental studies (Ajayi *et al*., 2005; Choudhury and Saha 2004).
Airen and Akeredolu (2020) used 2D and 3D ERI to assess soil erodibility in Uselu quarters, Benin City. They found out that their area of study was susceptible to erosion. They then concluded that when the ERI cutoff is > 50 Ωm for sedimentary subsoil, its erodibility is termed high. Similarly, Karim and Tucker-Kulesza (2018) conducted ERT and erosion testing for fourteen bridges. Their results revealed that an ER of over 50 Ωm has a probability of 93 % to be considered as increasingly erodible.

In this area of study, Abotse quarters, Auchi, Etsako West Local Government Area of Edo State, are bedeviled with recurrent erosion menace in the past years. The challenge has posed untold hardship on the residents and hampered their land infrastructure. This paper is aimed at presenting the total volume of sandstone and lateritic sand as the predominant earth materials in the study area as it relates to how tomography can be used to predict soil erodibility with a view to mitigating their future occurrences.

MATERIALS AND METHOD

Data Acquisition

The 3D resistivity representation forms a square plot across the investigation area. This location was chosen to support inclusion in the central, northern and western parts of the study area. The area surveyed starts from 0 to 200 m east (y-axis) and 0 to 200 m northwest (x-axis); electrodes were 10 m apart and between cross sections of 50 m from each other. The 3D form includes 10 cables, five (5) lines perpendicular to the x-axis at 10 m distance from 0 to 200 m and five (5) lines oriented in the horizontal plane at 10 m from 0 to 200 m separately. The 3D form is shown in Figure 5.

Data Processing
No additional height correction was applied in the measurement because the measured area is approximately flat. All square 2D beams (10 wires) were combined to form a 3D profile. This was achieved by organizing the 2D measurement data into a 3D file that is easily read by the RES3DINV software. The co-ordinates of each 2D wire, line path, quantity of electrodes and data level information were used to combine the actual results with the help of input data that can be read by the computer program code (Li and Oldenburg, 1992; White *et al.*, 2001).

Expectedly, the electrodes used for these measurements are arranged in a squared pattern. The earth imager 3D was used to create a 3D cube by joining the square matrix of 2D lines together to form a simple 3D data set.

Setting of the area of study
The geophysical survey was carried out in Abotse quarters with the following coordinates: Latitude 07° 03′ 42.2′′and Longitude 006° 16′ 14.7′′. These coordinates were obtained using Garmin 12 Global positioning system (GPS).

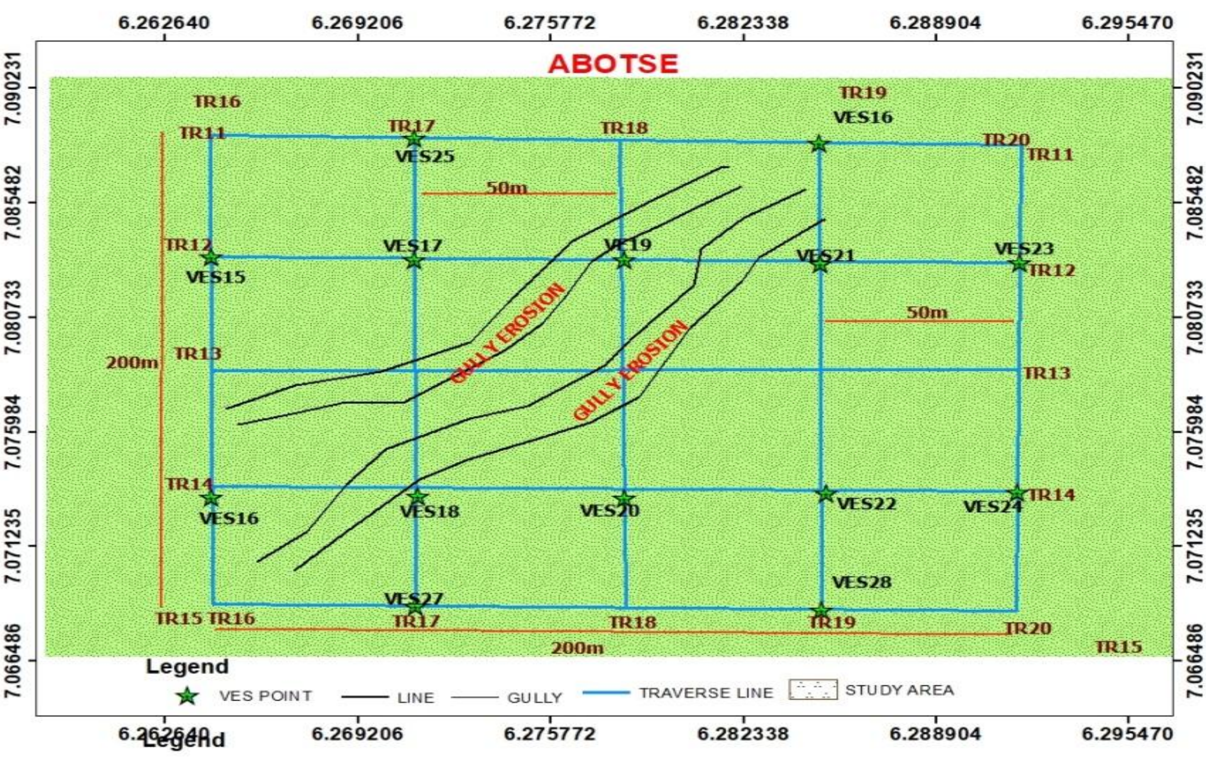

Figure 1: Basemap of Abotse Quarters, Auchi

RESULTS AND DISCUSSION

Volumetric Analysis of the Dominant Occurrences
In Abotse, the predominant geologic earth materials are the sandstone and lateritic sand. Presented in Table 1 is the approximated estimate of the volume of sandstone.

Table 1: Approximated Estimate of Volume of Sandstone

Layers	Layers depth(m)	Area ΔA (m^2)	Depth ΔZ(m)	Volume ΔV (m^3)
1.	0 – 3.5	28,500	3.5	99,750
2.	3.5 – 7.52	36,100	4.02	145,122
3.	7.52 – 12.2	32,400	4.68	151,632
4.	12.2 – 17.5	26,450	5.3	140,185
Total				**536,689**

Table 2: Approximated Estimate of Volume of Lateritic Sand

Layers	Layers depth(m)	Area ΔA (m^2)	Depth ΔZ(m)	Volume ΔV (m^3)
1.	0 – 3.5	3,850	3.5	13,475
2.	3.5 – 7.52	6,400	4.02	25,728
3.	7.52 – 12.2	4,630	4.68	21,668
4.	12.2 – 17.5	3,306	5.3	17,522
Total				**78, 393**

Volume of dominant occurrences

Tables 1 and 2 show impressively high volumes of the dominant earth materials (Sandstone and lateritic sand). These large volumes make them susceptible to erosion. Sediments made up of more clay have a tendency to be more resistant to the occurrence of erosion compared with sand or silt, since clay can bind soil particles together (Nichols, 2009).

3D Horizontal Depth Slice.

The 3D level depth cut is introduced in Figure 2. The subsurface is cut into four layers which are 0 – 3.5 m, 3.5 – 7.52 m, 7.52 – 12.2 m and 12.2 – 17.5 m. The comparing resistivity figures of each layer are 1485 – 113614 Ωm, 624 - 113614 Ωm, 262 - 113614 Ωm and 262 - 113614 Ωm separately (Figure 3). Abotse depth cuts uncover high resistivity figures like Oredide (Babaiwa and Ikpomwen, 2021b), yet the scope of resistivity across each cut layer in Abotse is unique. The cut uncovers high resistivity figures describing the dry and close-surface unconsolidated sand and the sandstone of Ajali Formation (Adekoya *et al.,* 2011; Aleke *et al.,* 2016; Chinyem, 2017; Babaiwa *et al.,* 2020).

The depth of erosional effect in Abotse may likewise be pretty much as profound as 12 m. At an increased depth, disintegration is unlikely because of the presence of solidified sandstones.

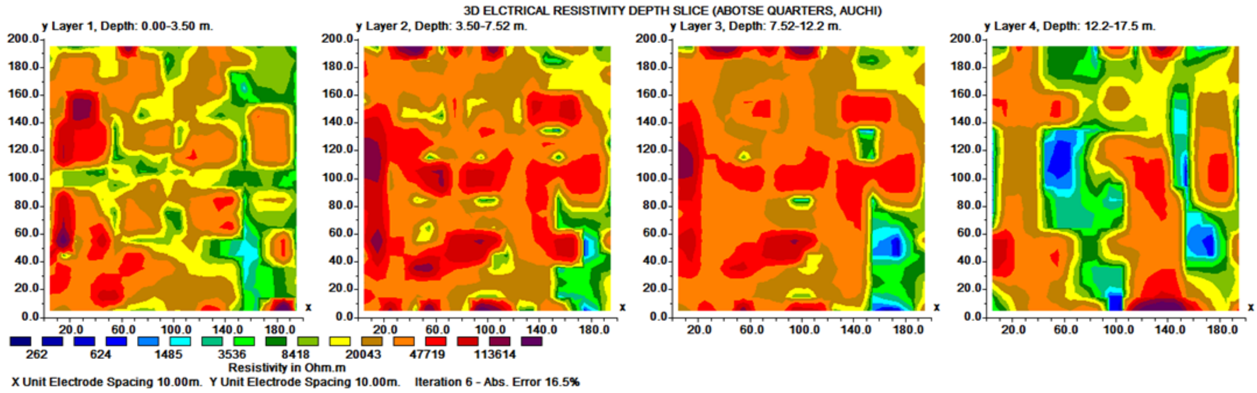

Figure 2: Horizontal Depth Slices obtained from the 3D Inversion of Square 2D Profiles.

3-D Electrical Resistivity Modelling.

Figure 3 presents the 3D resistivity block distribution of Abotse. Resistivity values vary from 1357 – 78632 Ωm. 3D depth of 15.4 m was imaged. The Y-axis of the 3D block of Abotse where the resistivity varies from 28502 - 78632 Ωm and is diagnostic of dry and near-surface unconsolidated sand and the sandstone of Ajali Formation (Adekoya *et al.*, 2011; Aleke *et al.*, 2016; Chinyem, 2017; Babaiwa *et al.*, 2020). It indicates a possibility of an intense erosional impact whose depth could be 15 m across the area (Figure 2) . The entire Abotse is suspected to be prone to intense erosion. The apparent resistivity crossplot of Abotse is revealed in Figure 3 with an iteration of 3 and RMS value of 11.5%.

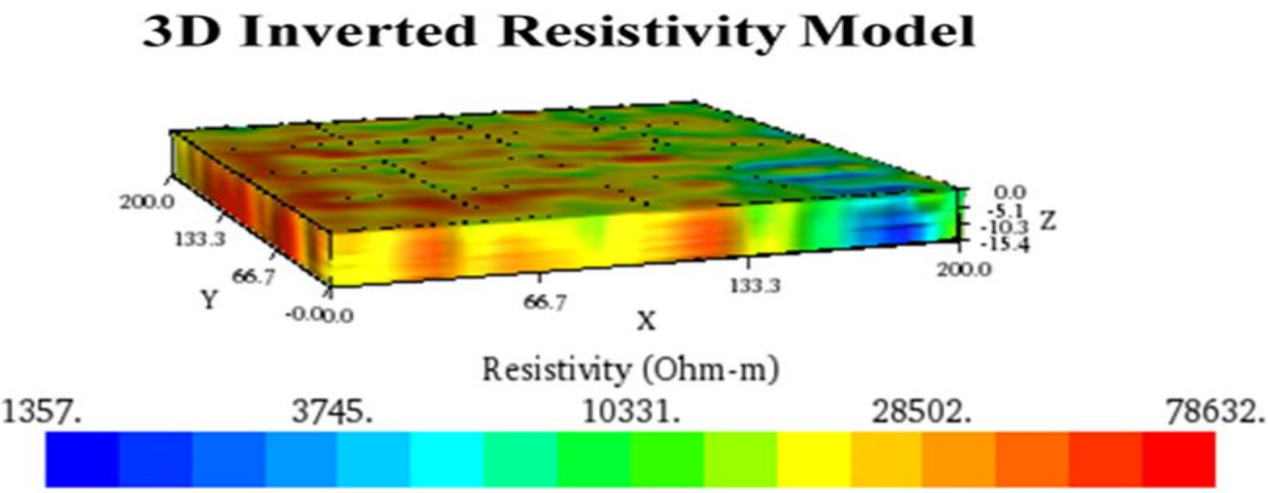

Figure 3: 3-D Electrical Resistivity Model.

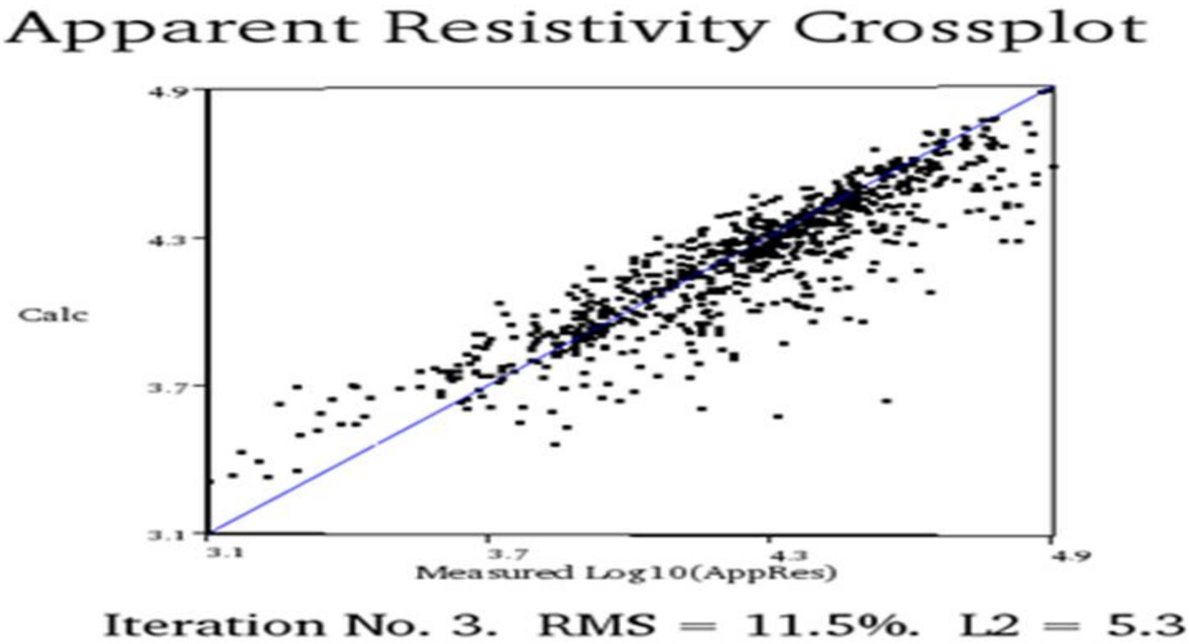

Figure 4: Apparent resistivity crossplot.

CONCLUSION

From the results, Abotse quarters is characterised by the following lithology: topsoil, lateritic sand, sand and sandstone. The resistivity of the topsoil changed from 632.7 – 87383.7 Ωm, lateritic sand went from 3820.1– 83094.2 Ωm, for sand it was from 585.2 – 11969.6 Ωm and sandstone, was from 17852 – 35732.4 Ωm. Clearly, intense erosion is likely in Abotse owing to the remarkably high subsurface resistivity values. Soils with electrical resistivity greater than 50 Ωm have an 87 % likelihood of being named exceptionally erodible (Karim andTucker-Kulesza, 2018; Karim *et al.,* 2019; Airen and Akeredolu, 2020). The scouring depth ranges from 10 – 12 m.

Total volume of dominance of sandstone estimated stood at 536, 689 m^3 whereas it was 78, 393 m^3 for lateritic sand. These large volumes of predominance of sandstone and lateritic sand also accounts for the soil erodibility.

REFERENCES

Abu-Hassanein, Z., Benson, C. and Blotz, L. (1996). Electrical resistivity of compacted clays. *J Geotech Eng*; 5(397): 397–406

Adekoya, J.A., Aluko, A.F. and Opeloye, S.A. (2011). Sedimentological characteristics of Ajali Sandstone in the Benin flank of Anambra Basin, Nigeria. *Ife Journal of Science*; 13(2): 327-337

Airen, O.J. and Akeredolu, T. (2020). Geophysical assessment of soil erodibility using 2D and 3D electrical resistivity imaging: A case study of Mela Road, Uselu, Benin City, South – South Nigeria. *Australian J. Sci. Tech.* 4. 4

Ajayi, O; Olorunfemi, M. O, Ojo, J. S, Adegoke, C. W, Chikwendu, K. K, Oladapo, M.I. (2005) Integrated geophysical and geotechnical investigation of a dam site of River Mayo Ini,

Adamawa state, Northern Nigeria. *Afr Geosci Rev*; 12: 179-88.

Aleke, C.G., Okogbue, C.O., Aghamelu, O.P. and Nnaji, N.J. (2016). Hydrogeological potential and qualitative assessment of groundwater from the Ajali Sandstone at

Ninth mile area, southeastern Nigeria. *Environmental Earth Sciences*; 75(290): 1-16 DOI 10.1007/s12665-015-4843-3

Babaiwa, D.A. and Ikpomwen, M.O. (2021b). Application of 2D and 3D Electrical Resistivity Tomography (ERT) in Predicting Soil Erodibility in Oredide Village, Auchi in Etsako West LGA of Edo State, Southern Nigeria. *Journal of Applied Science and Environ. Manage.*,Vol. 25(6), 1043-1049.

Babaiwa, D.A., Aigbogun, C.O. and Umoru, A.T. (2020). Aquifer characterization using vertical electrical sounding in Auchi Polytechnic, Auchi, Edo State, Nigeria. *Nigerian Journal of Technology* (NIJOTECH). 39(3): 925–931.

Chambers, J.E . (2013). River terrace sand and gravel deposit reserve estimation using three-dimensional electrical resistivity tomography for bedrock surface detection. *J Appl. Geophys.*93:25-32.

Chinyem, F. I. (2017). Evaluation of groundwater potentials for borehole drilling by integrated geophysical mapping of Auchi, South Western Nigeria using very low frequency electromagnetic profiling (VLF-EM) and vertical electrical sounding (VES). *Journal of Applied Science and Environmental Management*; 21(4): 693-700

Choudhury, K. and Saha, D.K. (2004). Integrated geophysical and chemical study of saline water intrusion. *Groundwater*; 42: 671-7.

Dahlin, T. (2001). The development of DC resistivity imaging techniques. *Compute. Geosci*. 27:1019-29.

Hossain, M. S; Khan, M. S, Hossain, J, Kibria, G, Taufiq, T (2011). Evaluation of unknown foundation depth using different NDT methods. *J Geotech. Geoenviron. Eng*. 27:209-14.

Hurst, M. D; Mudd, S. M, Walcott, R, Attal, M and Yoo K (2012). Using hilltop curvature to derive the spatial distribution of erosion rates. *J Geophys Res*; 117. DOI: 10.1029/2011JF002057.

John, U. J, Igboekwe, M. U and Amos-Uhegbu, C (2015). Geophysical evaluation of erosion sites in some parts of Abia state, Southeastern Nigeria. *Phys. Sci. Int. J,* 6:66-81.

Karim, M.Z. and Tucker-Kulesza, S.E. (2018). Predicting soil erodibility using electrical resistivity tomography. *J. Geotech Geoenviron Eng*;144(4):04018012. https://doi.org/10.1061/(ASCE)GT.1943-5606.0001857

Karima, M.Z., Tucker-Kuleszaa, S.E. and Bernhardt-Barry, M. (2019). Electrical resistivity as a binary classifier for bridge scour evaluation. *Trans Geotech*; 19:146-157

Li, Y and Oldenburg, D. W (1992). Approximate inverse mappings in DC resistivity problems. *Geophysical J. Inter.* 109, 343-362.

Loke, M. H (1999). Electrical Imaging Surveys for Environmental and Engineering Studies 2017.Availablefrom:http://www.moho.ess.ucla.edu/?pdavis/ess135_2013/literature/%20lokedcresistivity.pdf. [Last accessed on 2017 Feb 22].

Kibria, G. and Hossain, M.S. (2012). Investigation of geotechnical parameters affecting electrical resistivity of compacted clays. *J. Geotech Geoenviron Eng*; 10:1520–1529

Nichols, G. (2009). Sedimentology and Stratigraphy. New York: John Wiley & Sons; 93.

Santamarina, J. C; Rinaldi, V. A, Fratta, D, Klein, K. A, Wang, Y. H, Cho, G. C, *et al*., (2005) Survey of elastic and electromagnetic properties of near surface soils. In: Near Surface Geophysics. Investigation in Geophysics, No. 13.

Snapp, M, Tucker-Kulesza, S, Koehn, W (2017). Electrical resistivity of mechanically stabilized earth wall backfill. *J Appl. Geophys,* 141:98-106.

Uhegbu, CA, and John, UJ (2017). Geophysical and geotechnical evaluation of erosion sites in Ebem-Ohafia area of Abia state, Southern Nigeria. *Adv Res*; 10:1-14.

Vaudelet, P (2011). Mapping of contaminant plumes with geoelectrical methods. A case study in urban context. *J. Appl. Geophys.* 75:738-751.

White, R.M.S; Collins, S, Denne, R, Hee, R and Brown, P (2001). A new survey design for 3D IP modelling at Copper hill. *Exploration Geophysics*, 32, 152-155.