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Geophysical Investigations of Nekede Mechanic Village Gully, Owerri, Nigeria

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ABSTRACT

This paper investigates the possibility of expansion of Nekede Mechanic-Village gully located in Imo State Nigeria using two Resistivity Survey methods (VES and ARS). The gully site is located on longitude 7° 2’ 6”E and latitude 5° 27’ 46”N. The analysis of the VES measurements showed that VES 3 and 4 are structurally week and susceptible to erosion due to their thick sand layers in their top sections while ARS measurements and analysis showed possibility of fractures and or major cracks in the NE – SW axis rooted to the depth of about 30m.These factors endangers the structural stability of the NE-SW region with reference to the ARS point and adjoining the VES 3 and 4 areas.

Introduction

Soil erosion is an accelerated process under which soil is bodily displaced and transported away faster than it can be formed. The agents of soil erosion are principally running water, waves and wind and anthropogenic factors. Erosion usually transports rocky materials or soil particles after the process of weathering have broken them down into smaller pieces which are movable. Soil erosion starts with rainfall droplets dislodging particles of soils, removing them and eventually depositing them at a new location different from the original site. The erosion problems of an area is subject to certain factors which include the geology, the land use act, geomorphology, climate, soil texture, nature and bio diversity of the area.

Gully erosion has been recognized as one of the major causes of land degradation worldwide (Valentin *et al.* 2005). Gully erosion has attracted a growing interest as reflected by some international conferences at Leuven, Belgium (Poesen and Valentin 2003), at Chengdu, China (Li et al. 2004) and Purdue University in West Lafayette, Indiana, USA, May,2016. Some recent research works (Wu and Cheng 2005; Okoro et al. 2011; Castillo and Gomez 2016) have shown that the loess plateau of China, Orlu Nigeria and Cordoba, Spain land surfaces are being eroded, washed away and rendered sterile due to gully erosion. Gully erosion has been a growing concern to mainly the developing world which could be due to both intentional and unintentional activities of humans on the physical environment (Duke, 2012). In southeast Nigeria, gully development has become one of the greatest environmental hazards in many villages and towns (Ezezika and Adetona 2011). Ofomata (2008) observed that about 2% of the area is fast becoming hazardous to human habitation because of gully formation and subsequent degradation in the area.

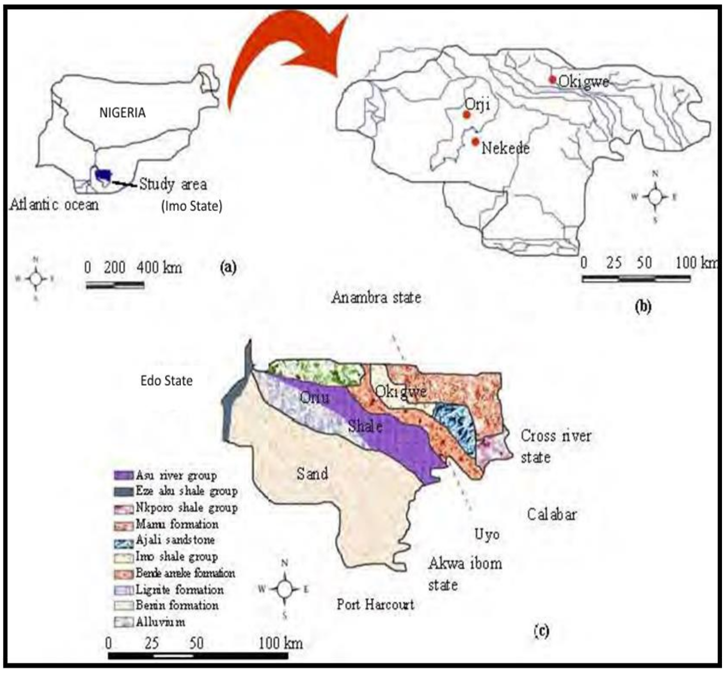

Fig 1. Map showing Location of the Study Area.

Gully erosion is a highly visible form of soil erosion or an antecedent of the removal of soil by running water that affects soil productivity, restricts land use and threaten roads fences. The issue of gully erosion in Mechanic Village Nekede (fig. 1) has remained intractable for over some years now and has done serious damage to the psychic of the local inhabitants of the area. The negative impact of gully has social, psychological, economic and health consequences. Many homes have been caused to relocate involuntarily: buildings are at the brink of collapsing into the gully. The gully has crippled communication in the affected areas as communities that were ordinary neigbours have suddenly

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become distant strangers. This has drastically affected social networks and interaction among indigenes of the affected communities.

Nîr (1983) indicated that urbanization affects erosion processes by removing vegetative cover, and also makes land impervious with layer of asphalt or concrete, thus altering drainage patterns, and increasing the amount of surface runoff and surface wind speeds. This increased runoff disrupts surrounding watersheds by changing the volume and rate of water flowing through them as reported by James (1995). Four primary types of erosion resulting from rainfall occur. They are splash erosion, rill erosion and gully erosion. Splash erosion is the first and least severe stage in the soil erosion process, this is followed by sheet erosion, then rill erosion and finally gully erosion which is the most severe as indicated by Zachar (1982); and Toy (2002).

Geology and Geomorphology of the Study Area

Nekede area is located in an area underlain by Benin Formation. The units are made up of sandy to gravelly sands without any shale or swelling clays. In general, Benin Formation spans from Miocene to Recent. It is the youngest of Niger Delta sediments. Its thickness is about 6,000ft, and very little hydrocarbon accumulation has been associated with the Benin Formation. The Benin Formation comprises the top part of the Niger Delta clastic wedge, from the Benin-Onitsha area in the north to beyond the present coastline (Short and Stumble, 1967). The Benin formation consists of massive continental sands and gravels, it underlain gradationally by the delta front paralic lithofacies. The top of the formation is the recent sub aerially - exposed delta top surface and its base extend to a depth of 4600 feet. The base is defined by the youngest marine shale. Shallow parts of the formation are composed entirely of non-marine sand deposited in alluvial or upper coastal plain environments during progradation of the delta (Nwajide and Reijers, 1996). Although lack of preserved fauna inhibits accurate age dating, the age of the formation is estimated to range from Oligocene to Recent. Benin Formation covers the following areas: Benin City, Warri, Rivers State, Cross River State, Abia state (Part of Umuahia, and Aba), Imo State (some part of Aṅara, Amaimo, Ikeduru, Atta Village) it covers the entire owerri area with its outcrops at Ihiagwa behind Federal University of Technology Owerri.

The topography of the study area could generally be described as fairly steep with an average slope of about 8%; this is a continuous slope running from the upper reaches of the catchment (basin) down into the Nwokobo river valley. The drainage pattern is in agreement with the general topography of the study area, the entire study area is drained by the Imo River and its tributary, the Nwokobo River. Imo River is about 13km from the gully head which is some few meters from the Umueze-Eziala channels that convey run off into the gully which level expanded over the years. These drainage channels are fast gully fingers as some are currently up to 3m deep and about 4m wide.

The climate condition of the Mechanic Village Nekede study area is characterized by uniformly high temperature and a seasonal distribution of precipitation. A typical Wet and runs through the months of October to March and the rainy season that begins in March and ends in October. The southwards moving Sahara air mass causes the dry season which is associated with extreme aridity, a dusty atmosphere, lowering of water levels and intense leaf fall. The rainy season follows the northward advance of maritime air from the Atlantic Ocean. July and August are usually the wettest periods of the rainy season.

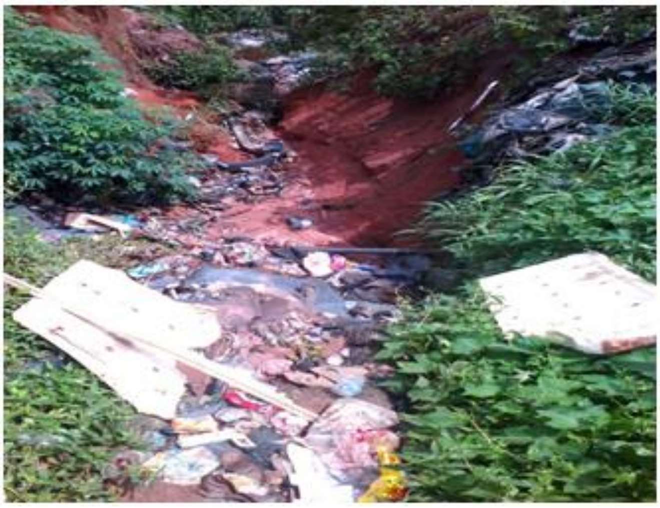


Fig 2. Dormant Part of the Gulley

Fig 3. Extension of Active Part of the Gulley

The study area lies within the humid tropical rainforest belt of southeastern Nigeria and evidences of Sahara type vegetation. The dominant vegetation of the study area is the cashier trees planted by the colonial officials in a failed attempt to check and contain the gully expansion, many of these have been uprooted and ostensibly by the gullies. The surviving trees and remnants of the original rainforest can still be seen in the unaffected area within the stabilized gully areas and the river valley. Southeastern Nigeria is a typical gully erosion region in Nigeria. The presence of gully sites is one of the hazardous features that characterize Imo State as well as other states that adjoin it (Ofomata, 2008). A conservative assessment shows the distribution of known gully sites, in different stages of development as expressed in

Table 1. Distribution of gully sites in southeastern Nigeria adopted from Igbokwe *et al* (2003).

S/N	State	No. of Gully Sites	Stage	Control Measures
1	Anambra	700	Mostly active	Not successful
2	Abia	300	Some active/ some dominant	Not successful
3	Ebonyi	250	Mostly minor gully sites	No records
4	Enugu	600	Some active/ some dominant	Some successful and some not successful
5	Imo	450	Some active/ some dominant	Some successful and some not successful

table 1. The studied gully has both active and dormant parts as shown in figures 3 and 2 respectively.

Materials and Methods

Nekede mechanic village gully has been seen having active and inactive gullies, this research therefore aims at investigating the active part of the gully in order to ascertain the possibility of expansion using two Resistivity Survey techniques namely; Vertical Electrical Sounding (VES) around the gully site to investigate the nature of the top soils (after correlative lithology) in the active gully region and Azimuthal Resitivity Survey (ARS) method to investigate the presence of possible cracks that may initiate gully process. Four VES measurements were therefore made in the vicinity of the Active part while one on-spot ARS measurements were made (with AB/2 = 10m, AB/2 = 20m, AB/2 = 30m, and AB/2= 40m) in the same Active part but in the region having predominant outcropped fractures and cracks.

In VES, a current is introduced into the ground through point electrodes (C_1,C_2) and the potential field is measured using two other electrodes (the potential electrodes P_1 and P_2), as shown in fig. 4. The source current can be direct current or low-frequency (0.1 - 30 Hz) alternating current. The aim of generating and measuring the electrical potential field is to determine the spatial resistivity distribution (or its reciprocal - conductivity) in the ground. As the potential between P_1 and P_2, the current introduced through C_1 and C_2, and the electrode configuration are known, the resistivity of the ground can be determined; this is referred to as the “apparent resistivity”.

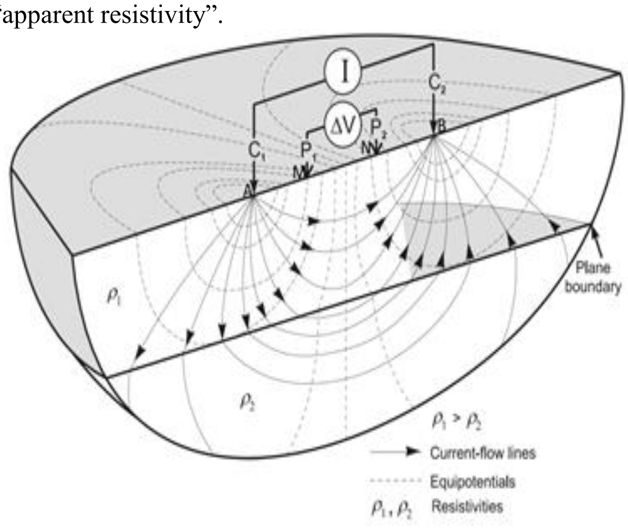


Fig 4. Principle of VES measurement with a four-electrode array (Adopted from Knodel *et al*.)

The main aim of VES methods is to determine the vertical distribution of the resistivity in the ground. A point electrode introducing an electrical current I will generate a potential V_r at a distance r from the source. If both source and measuring points are at the surface of a homogeneous half-space with resistivity ρ, this potential is given by:

$$\boldsymbol{V_r = \frac{\rho I}{2\pi r}} \quad (1)$$

In the case of a four-electrode array (fig. 4) consisting of two current electrodes (C_1, C_2) that introduce current ± I, the potential difference V between the potential electrodes P_1 and P_2 can be calculated as follows:

$$\Delta V = \rho I \left[\frac{1}{2\pi} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right) \right], \quad (2)$$

where $r_1 = C_1P_1$, $r_2 = C_1P_2$, $r_3 = C_2P_1$, and $r_4 = C_2P_2$.

Replacing the factor in square brackets by 1/*K*, we obtain the resistivity of the homogeneous half-space as follows:

$$\boldsymbol{\rho = k\frac{\Delta V}{I}} \quad (3)$$

The parameter *K*, the configuration factor or geometric factor, can be easily calculated for all practical configurations.

The Azimuthal Square Array Resistivity Survey was designed by Habberjam (1967), it employs the use of four electrodes - two current and two potential electrodes arranged at the corners of a square of size ‘a’ (fig. 5). Measurements are recorded at the center of the array. To estimate the variation of apparent resistivity with depth, the array is symmetrically expanded about its center in simple multiples, while to obtain apparent resistivity measurements along different azimuths, complete array expansions are rotated at angular increments through 180^o. The orientation of the azimuth of measurement is the line between the two current electrodes. Using the Azimuthal Square Array Resistivity Survey method, the azimuth of existing fracture zones is generally indicated by a decrease in resistivity along a particular azimuth relative to the others. Hence, plots of apparent resistivity values as a function of azimuth are used to characterize electrical anisotropy (Obiadi *et al*; 2012). Circular plots are characteristically interpreted to indicate electrical isotropy, signifying the absence of measurable fracture set of preferred orientation, or small volume of rock investigated (Busby and Peart, 1997). On the other hand, elliptical plots are generally construed to signify anisotropic response within the rock mass

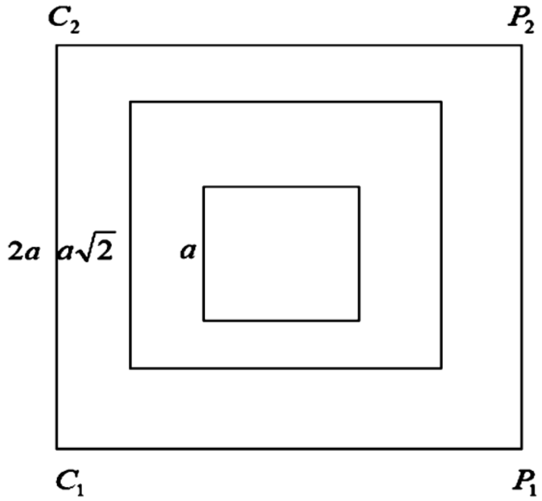


Fig 5. Symmetrical expansion of the square array about its centre (Habberjam and Watkins, 1967).

ARS data are useful in quantifying the degree of subsurface inhomogeneity and requires about 65% less surface area (LANE *et al.*, 1995) compared to the collinear arrays. By using a square array, measurements are less dependent on array orientation, yet sensitive to the position of the array center. The road map of the study area is shown in fig. 6 while the survey map (showing the positions of the VES and VRS) is expressed in fig. 7. ABEM Terrameter SAS 4000 (and accessories) was used in the surveys; GARMIN GPS (version 96) was used to ascertain the survey positions, OFFIX 3.5 and Schlumberger Automatic Analysis software (Henker 1985) were used to interpret the geo-electric curves, STRATA 3 was used to generate geo-electric (lithology) layers while ORIGIN 2018 was used to plot rose diagrams.

Fig 6. Road Map of the Study Area.

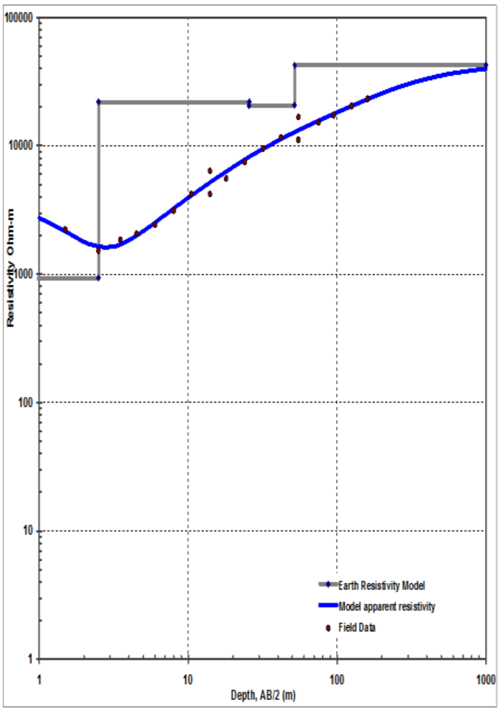
Fig 7. Survey Map of the Study Area.

Data Presentation and Discussion

The plots of VES 1- 4 are highlighted in figures 8 to 11 while the correlation of their geoelectric depths is shown in figure 12. It is evident from geolectric plots of VES 4 and 3 that their top part have thick layers of sand sections which is attributable to the known flooding existing in these regions. VES1 location has superficially rooted thick sandstone section which explains why that region is relatively stable in terms of surface erosion (Fig. 12).

Number of Layers	5		
Layer NO	Thickness (m)	Depth (m)	ρ (Ω-m)
1	0.70	0.70	3400.00
2	1.80	2.50	930.00
3	23.10	25.60	22000.00
4	26.10	51.70	20600.00
5	-		42500.00
-	-		
-	-		
-	-		

FIELD DATA	
AB/2 (m)	ρa (Ω–m)
1.5	2221.2
2.5	1517.9
3.5	1855.7
4.5	2055.5
6.0	2423.4
8.0	3120.0
10.5	4200.0
14.0	6353.0
14.0	4196.0
18.0	5560.0
24.0	7461.0
32.0	9570.0
42.0	11624.9
55.0	16710.7
55.0	11114.0
75.0	15110.9
95.0	17273.1
125.0	20327.5
160.0	23098.9



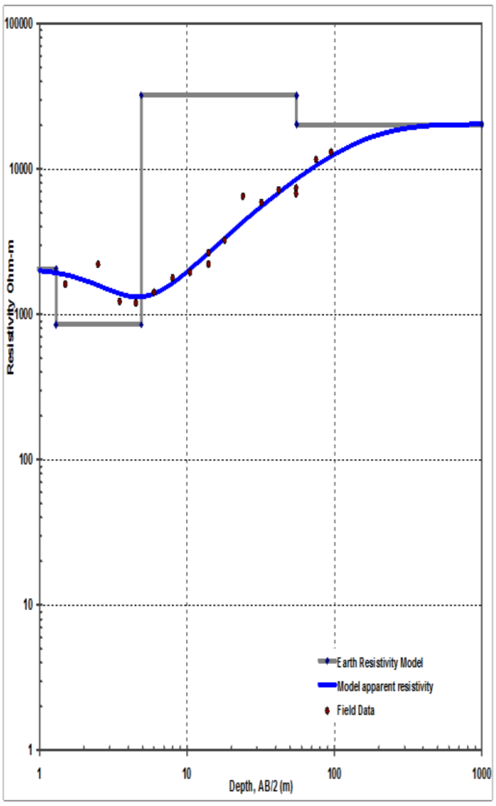
VES NUMBER: 1 DIRECTION LAYOUT: NE-SW

Fig. 8 Plot of VES 1

VES2 is a bit close to VES1 location, its geoelectric section reveals thicker Sandy clay section (about 4m) underlain by another superficially rooted Sandstone section in the top part. This area is also relatively stable and not affected by any surface erosion. See figure 12 as well.

Number of Layers	4		
Layer NO	Thickness (m)	Depth (m)	ρ (Ω-m)
1	1.30	1.30	2070.00
2	3.60	4.90	850.00
3	50.40	55.30	32000.00
4			20300.00
-			
-	-		
-	-		
-	-		

FIELD DATA	
AB/2 (m)	ρa (Ω–m)
1.5	1616.5
2.5	2213.7
3.5	1225.7
4.5	1196.3
6.0	1421.7
8.0	1778.2
10.5	1939.1
14.0	2206.0
14.0	2641.7
18.0	3248.0
24.0	6512.2
32.0	5888.4
42.0	7192.7
55.0	7398.1
55.0	6777.5
75.0	11658.9
95.0	13051.0



VES NUMBER: 2 DIRECTION LAYOUT: NE-SW

Fig. 9 Plot of VES 2

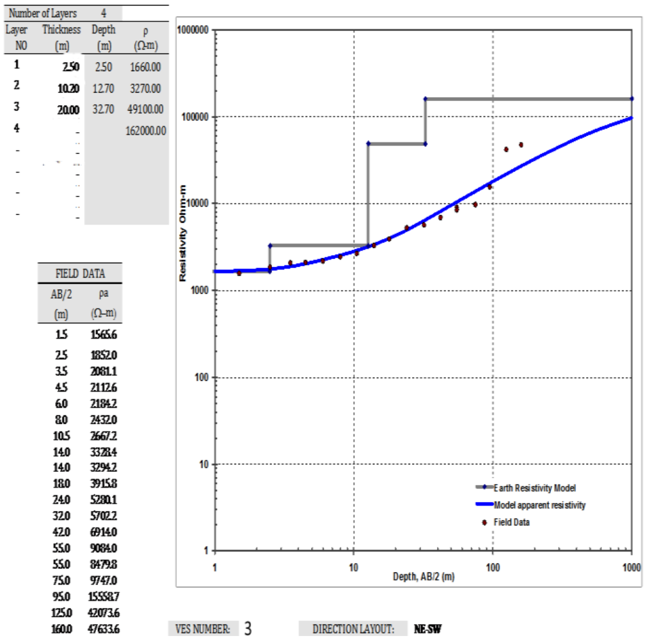


Fig 10. Plot of VES 3.

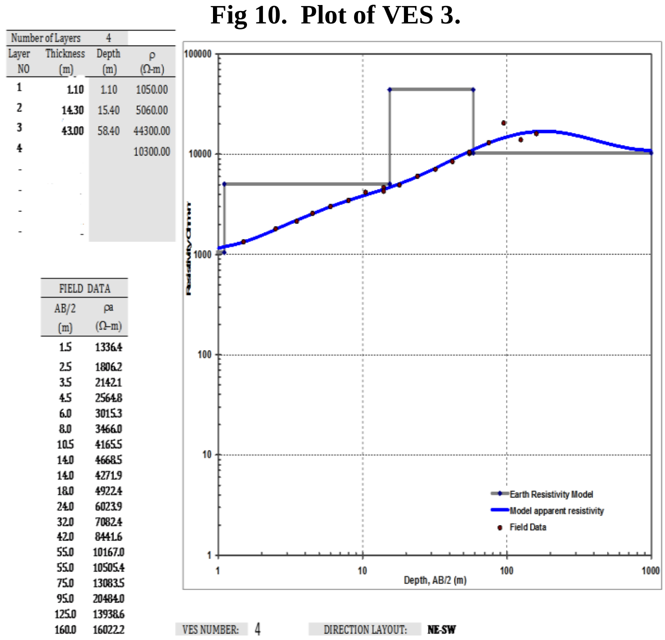


Fig 11. Plot of VES 4.

The ARS measurements were made with AB/2 values ranging from 10m to 40m (table 2). The computed rms resistivities ranged from 552.5Ωm to about 865.5Ωm while the coefficient of anisotropy values were from 1.1256 to 1.4913.The Rose diagrams of the AB/2 values are shown in fig. 13 (a - d) from which one can deduce pronounced reduction in resistivity values in the NE – SW axis down to the depth of approximately 30m. This abrupt reduction in resistivity values in this axis means there will be significant increase in the porosity of this path down to the same depth, hence the possibility of fracture in NE-SW axis from about the surface down to about 30m.

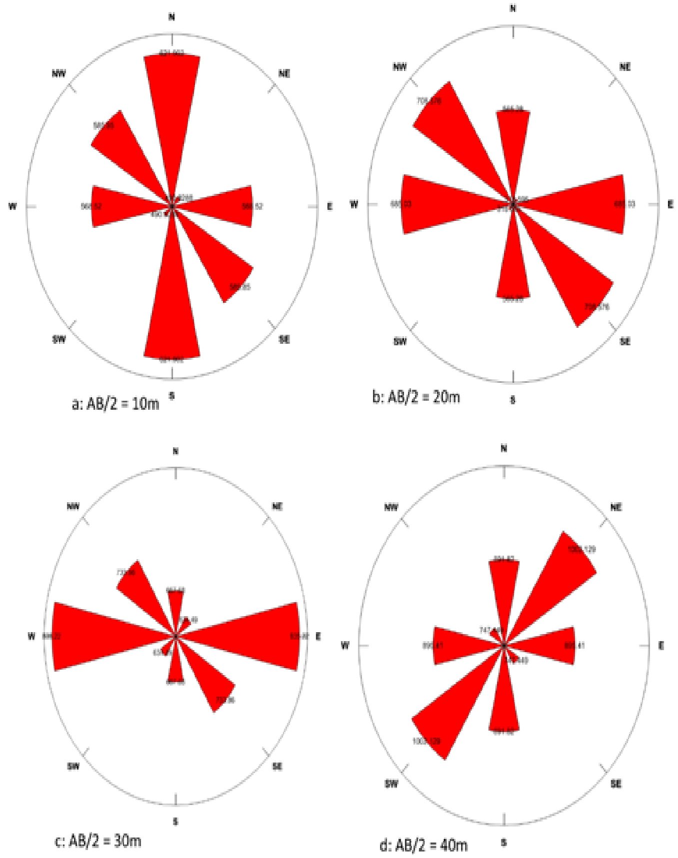


Fig 13. Rose diagrams of ARS evaluations.

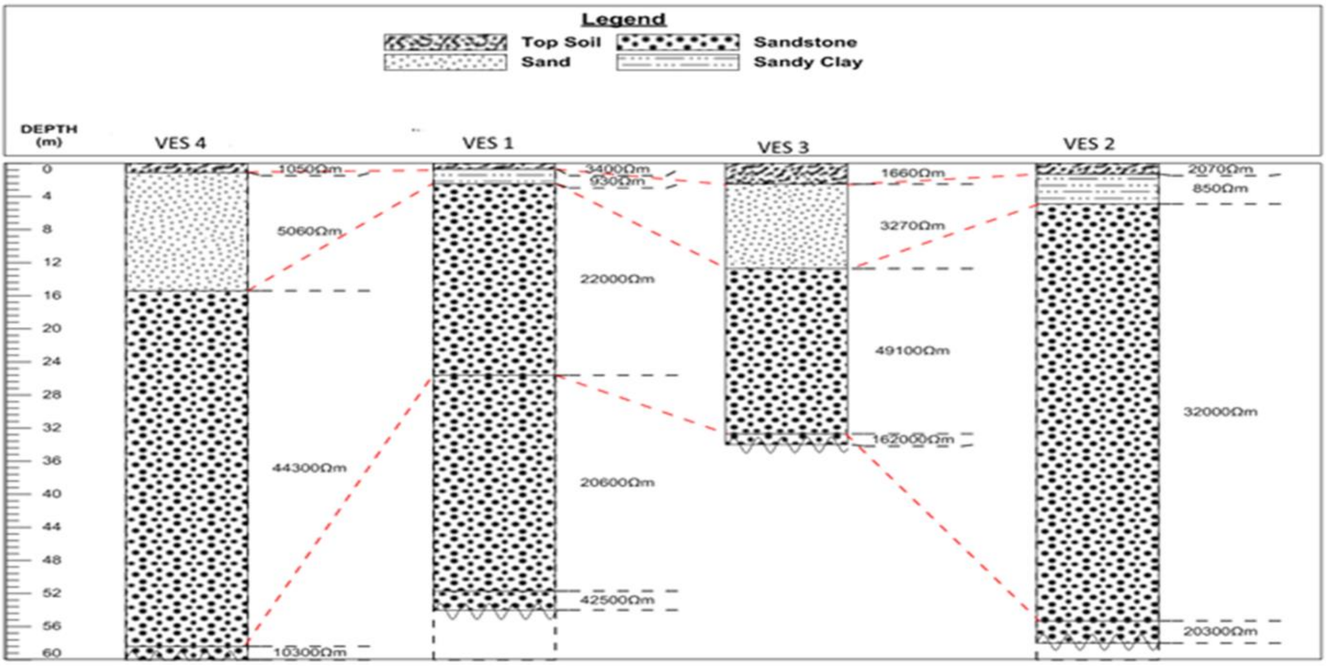


Fig. 12 Geoelectric sections of the VES points.

Table 2. ARS measurements and computations.

				Resistance (Ω)				Resistivity (Ωm)					
S/N	**AB/2 (m)**	**MN/N (m)**	**K**	**N-S**	**E-W**	**NE-SW**	**NW-SE**	**N-S**	**E-S**	**NE-SW**	**NW-SE**	**Co-efficient of anisotropy**	**Root mean sruare resistivity (Ωm)**
1	10	5.5	19.92	31.22	28.54	24.64	29.41	621.902	568.52	490.8288	585.85	1.1256	552.501
2	20	5.5	106.60	5.353	6.487	3.017	6.71	565.28	685.03	318.595	708.576	1.4913	475.22
3	30	5.5	248.43	2.6876	3.362	2.554	2.954	667.680	835.22	634.49	733.86	1.1473	727.962
4	40	5.5	448.38	1.989	1.997	2.235	1.667	891.82	895.41	1002.129	747.449	1.1579	865.459
5	50	5.5	7132.27	-	-	-	-	-	-	-	-	-	-

Conclusion

This work expressed the possibility of confirming the existence of cracks and fractures near a gully erosion site which could lead to the expansion of the gully thus posing great danger to lives and property in the vicinity of the active gully. The Four VES measurements revealed that VES 3 and 4 locations have erodible top sections with depth range of 8m to 16m while ARS measurements revealed NE–SW fracture/cracks existence to the depth of about 30m.

It then means that VES 3 and 4 vicinities should be under watch because the existing gully might expand in these directions so the government agencies concerned should advise people not to site buildings (or structures that might involve soil excavation) around these areas while at the same time preventing the expansion of the active part of this gully using some recommended engineering practices.

References

Busby, J. P. and Peart, P. J (1997). Azimuthal resistivity and seismic measurements for the determination of fracture orientations. Geological Society, London, Engineering Geology Special Publications, 12, 273–281.

Castillo C and Gomez J .(2016). A century of gully erosion research: urgency, complexity and study approaches. Earth Sci Rev, 160: 300–319.

Duke M. (2012). Erosion and Depositions in Akamkpa Cross River state, Nigeria Environmental Society Team Nigeria. June Ed. Pp 20-25

Ezezika, O. C., O Adetona. (2011). Resolving the Gully Erosion Problem in Southeastern Nigeria. Journal of Soil Science and Environmental Management, 2, pp. 286 – 291, 25th October.

Habberjam, G. M., (1967). On the application of the reciprocity theorem in resistivity prospecting. Geophysics, 32, 918–919.

Habberjam, G. M. and G. E. Watkins, (1967). The use of a Square configuration in resistivity prospecting. A paper presented at the twenty-ninth meeting of European Association of Exploration Geophysicists (EAEG), Stockholm.

Henker C.J. (1985). Schlumberger Automatic Analysis Software. University of Amsterdam, version 0.92

Igbokwe J.I., Ojiako J.C, and Nnodu V.C (2003) Monitoring Characterization and controlling of floodwater erosions using remote sensing techniques proceedings of the technical session of 38th annual conference of Geological Society of Nigeria

James W. (1995); Channel and habitat change downstream of urbanization. In Herricks, Edwin E. & Jenkins, Jackie R. Stormwater Runoff and Receiving Systems: Impact, Monitoring, and Assessment. CRC Press. 105.

Knodel K., Lange G., and Voigt H. E. (2007). Environmental Geology; Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover Federal Institute for Geosciences and Natural Resources Germany.

Li W., C. J. Rehmeyer, C. Staben and M. Farman. (2004). Terminus –Telomeric End-Read Mining in Unassembled Sequences. University of Kentucky, Lexington. Bioinformatics Advance Access published December 7.

Nîr Dov. (1983); Man, a Geomorphological Agent: An Introduction to Anthropic Geomorphology. Springer. 121–122.

Nwajide C. S and Reijers T. J. A. (1996); Sequence Architecture in outcrops: Example from the Anambra Basin, Nigeria. NEPE Bull. **11**/01, Nov. p. 23-32

Obiadi, I. I. , Onwuemesi, A. G., Anike, O. L. , Ajaegwu, N. E., Anakwuba, E. K., Nwosu, C. M., Akpunonu, E. O., Onuigbo, E. N. and Onuba O. L. (2012); Determining Subsurface Fracture Characteristics from the Azimuthal Square Array Resistivity Survey at Igarra, Nigeria

Ofomata G.E. K .(2008). Soil erosion in the Enugu area of Nigeria, Niger Geography. J. 8(1): 45-59.

Okoro B. B, Tansi, N. M and Ibe G. Y .(2011). Soil erosion problem in Eastern Nigeria: Journal of Soil and Environmental Management Vol. 3(10), pp. 266-271,2 October

Poesen J. and C. Valentin. (2003). Gully Erosion and Global Change. Proc. First International Symposium on Gully Erosion, Leuven, Belgium, April 2000. Catena 50 (2–4): 87–562

Short, K.C. and Stauble, (1967). A.J. Outline of geology of Niger delta. Bull.Am.Ass.Petrol.Geol. **54**, p. 761-779.

Toy T.J, Forster G.R, Renard K.G. (2002); Soil Erosion: Processes, Predicition, Measurement, and Control. John Wiley and Sons. 338:1. ISBN 978-0-471- 38369-7.

Valentin C, J. Poesen and Y Li. (2005). Gully erosion: Impacts, factors and control. Science Direct. Catena, Vol. 63, pp 132 – 153

Wu Y.,and H. Cheng. (2005). Monitoring of gully erosion on the Loess Plateau of China using a global positioning system. Catena;63(2-3):154–166.

Zachar D. (1982); Classification of soil erosion. Soil Erosion. Elsevier. 10:48.