IJAAR PUBLISHING®

Engineering Research Journal | ISSN: **2782-8212**
Vol. 3, Issue 4 (April, 2023) | www.ijaar.org/erj

GEOPHYSICAL INVESTIGATION OF BEDROCK RELIEF FOR DAM ADEQUACY OF THE OSARA DAM USING ELECTRICAL RESISTIVITY METHODS

Mepaiyeda, S.[1, 2], Jethro, M.A[1] and Olonilebi, P .O.[3]

[1]Department of Minerals and Petroleum Resources Engineering, School of Engineering, Kogi State Polytechnic, P.M.B 1101, Lokoja, Kogi State, Nigeria
[2]Department of Geology, Faculty of Science and Agriculture, University of Fort Hare, Private Bag X1314, Alice, South Africa
[3]Department of Building Technology, School of Environmental Technology, Kogi State Polytechnic, P.M.B 1101, Lokoja, Kogi State, Nigeria

Corresponding author e-mail and phone; geospiritonline@yahoo.com, (+234) 8036490137

***ABSTRACT**: Geophysical investigation to assess the integrity and extent of damage was carried out at an existing dam site in North central Nigeria using the electrical resistivity method to determine the nature of the subsurface along the dam axis and identify general geologic conditions related to the selection of the dam site. Vertical electrical sounding (VES) measurements were taken along 8 stations at 50m interval across the dam axis, with maximum current electrode separation, (AB/2) of 40m, measured parallel to the geologic strike at each point. Results obtained from the qualitative and quantitative interpretation of the apparent resistivity values showed a 3-layered geo-electric structure namely the topsoil with high resistivity (> 300 ohm-m), weathered basement and the bedrock with low resistivity (< 100 ohm-m). There is a general decrease of resistivity with depth across the 8 stations. The geo-electric section in an E-W direction across the dam axis showed a zone of extensive weathering and erosion characterized by low resistivity values (17ohm-m to 42 ohm-m), at depths of 15-20m between VES 4 and VES 5 across the dam axis. It is recommended that to prevent seepages and differential settlement along the dam axis and nearby structures, filling of the dam beds with competent earth materials to block possible seepage pathways for water should be done in order to prolong the life span of the dam usage amongst other remediation measures.*

KEYWORDS; Dam, apparent resistivity, bedrock, geo-electric section, seepages

I. INTRODUCTION

Dams are structures which prevent the flow of water and accumulate it in a reservoir (1). Millions of people throughout the world depend on dams and reservoirs for domestic water supply, irrigation, electricity and flood prevention. Dams require significant investments for investigation, design, building and maintenance, yet their usefulness and integrity are constantly threatened by leakages and sedimentation.

Leakage and preferential flow paths are often controlled by the geology of the sites and therefore any leakage study should always include obtaining detailed geological and geotechnical information as the first step (2). Monitoring the behavior of new and old dams is a key issue in the field of dam maintenance. Early detection of precursors of malfunctioning such as leakage, erosion, relative deformation or settlement makes it possible to react very fast when necessary so as to plan maintenance works in due time.

Evaluation of an existing dam structure and safety generally requires detailed foundation data that may only be obtainable by surface and sub surface exploration through drilling, sampling and testing that is concentrated on specific site areas. The aim of the research is to examine the extent of the damage around the dam and to examine the integrity of the dam from the bedrock relief in order to detect other deficiencies. This will be achieved by the determination of the general geologic setting of the area at and near the dam site, identifying general geologic conditions related to the selection of the site, geophysical electrical resistivity measurement to delineate vertical contacts, possible fracture patterns and bedrock relief.

II. STUDY LOCATION

The Osara dam is located in Okehi Local Government area of Kogi State, North central Nigeria. It occurs between Latitude 7^0 40^1 and 7^0 47^1 North of equator and longitude 6^0 16^1 and 6^0 26^1 East. The Dam site is situated about 6km north of the NIOMCO and it is accessible through Lokoja-Okene highway and Abobo-Dam untarred road. The outcrops in this area were accessed through these routes and cattle tracks, footpaths and river and stream channels. (3).

The vegetation comprises of Guinea savannah type, characterized by shrubs and long grasses. Rainfall ranges between 1550 mm -1900 mm, usually from May to October, with average temperatures of about 27 degrees (4). Lineament map study of the area around the dam from Landsat MSS data location showed a dominance of NE-SW trending lineament and minor NW-SE trending lineaments which indicate good groundwater potential around the area (3). Figure 1

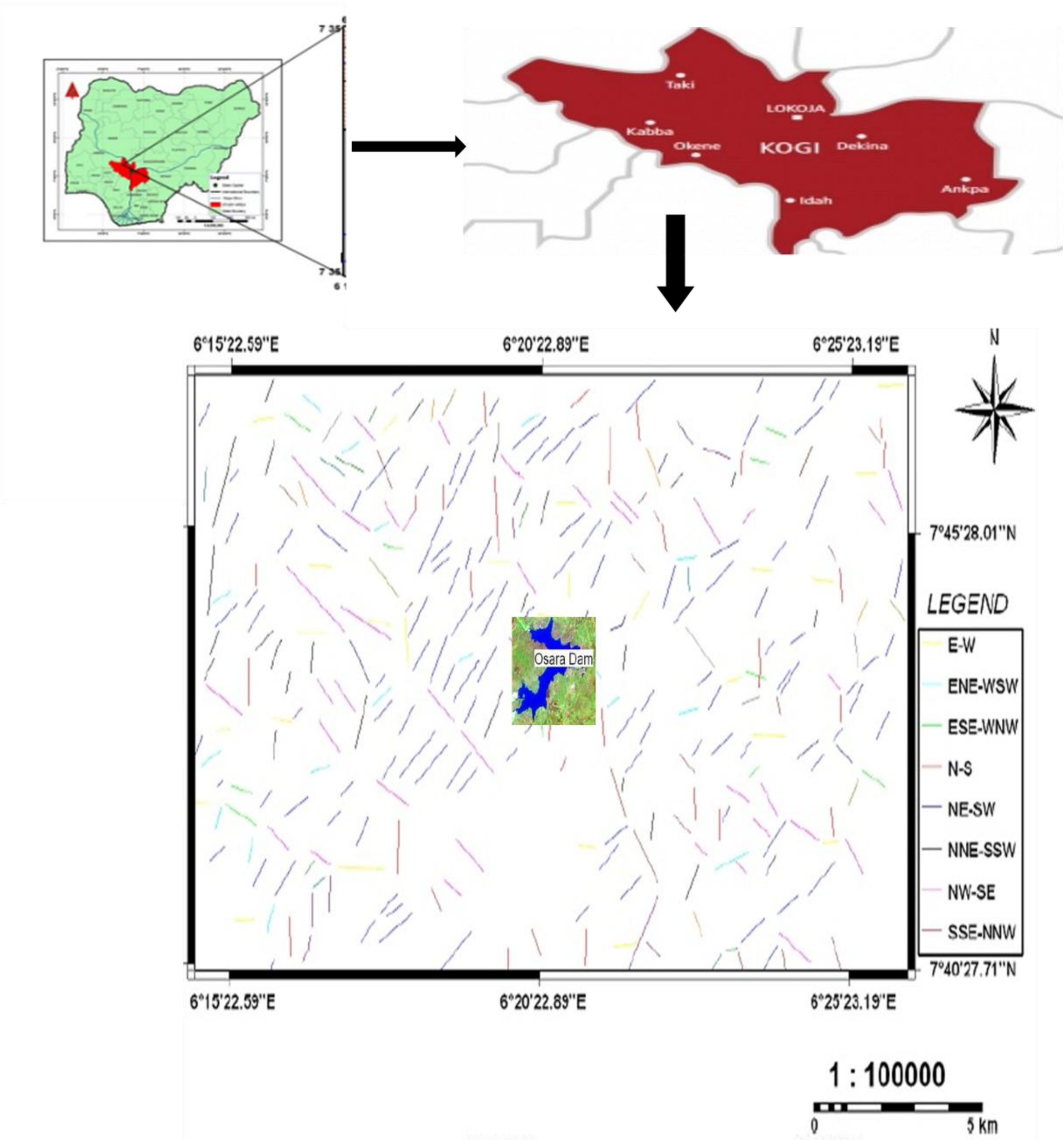

Figure 1; Location of the Osara dam showing the lineament trend in the area

III. GEOLOGY AND GEOMORPHOLOGY

The study area is underlain by rocks of Gneiss, Migmatite Gneiss and Granite Gneisses and these rocks are part of Basement complex. The Nigerian basement complex is part of the PAN African mobile belt and lies within the West African Craton and South of the Tuareg shield (4). The basement complex of Nigeria includes those of the North Central Nigeria, the South-Western Nigeria and the Eastern province (Diagram 2).

The three broad lithological groups within the Nigerian basement complex are the Migmatite gneiss complex made up largely of Migmatite and gneisses of various compositions, the low-grade sediment dominated schist belt and the granitic rocks which cut both the Migmatite-gneiss complex and the schist (4). The local geology of the dam area showed strongly foliated gneiss, predominantly made up granodiorite, made up of dark biotitic granite to light quartz-fedspathic veins. The iron bearing formation located in the area is largely made up of alternating bands of iron oxides and quartzites. Less dominant formation found around the study area include gabbro, pegmatites and biotitic granites (Figure 2).

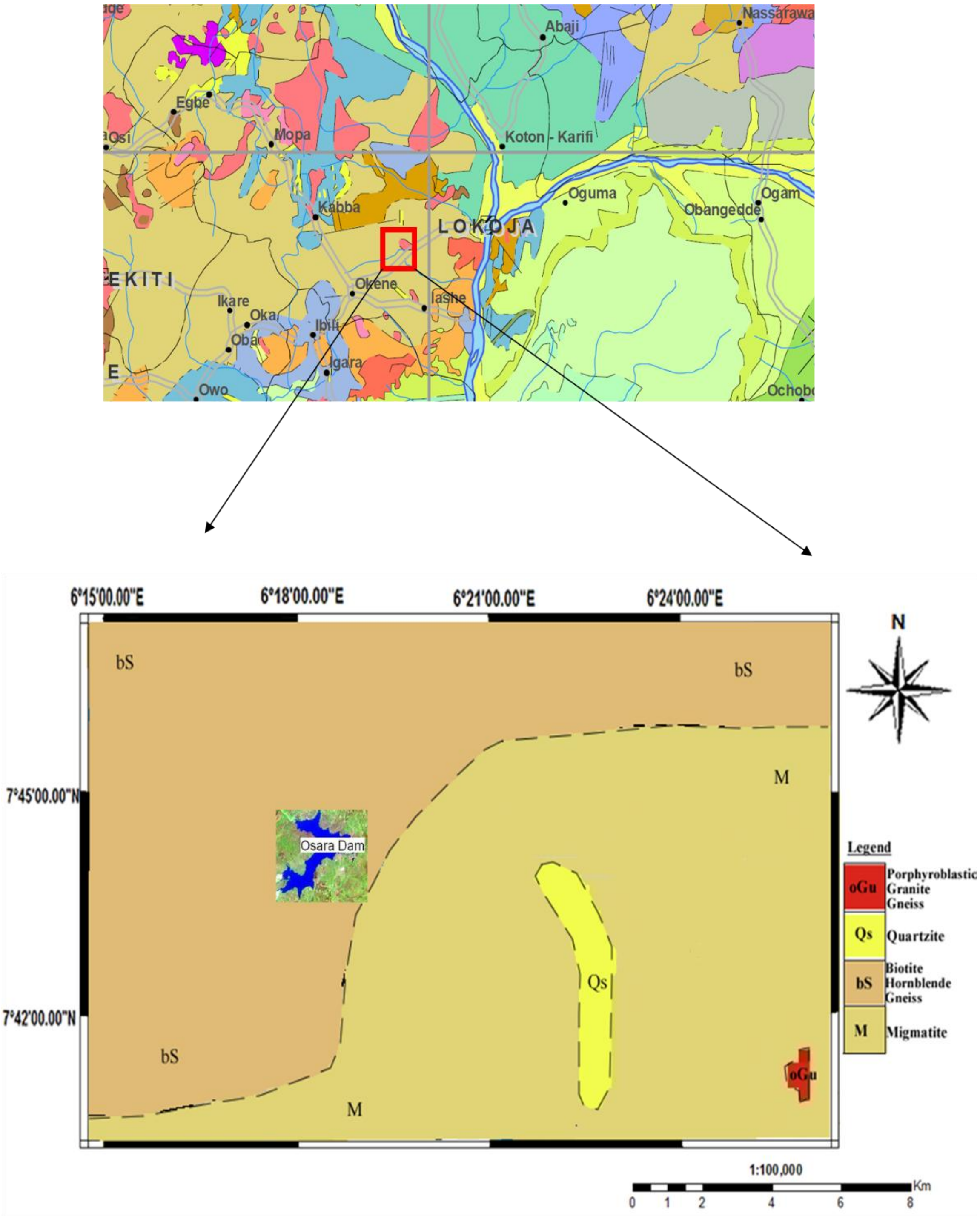

Figure 2: Geological Map of the study area (Source; Nigerian Geological Survey Agency (NGSA), Kolawole et al, 2016)

IV. MATERIALS AND METHODS

Electrical resistivity methods involve the measurements of the apparent resistivity of soils and rocks as function of depth or position (5) and (6). Actual resistivity of subsurface layer is determined from ground apparent resistivity, which is computed from the measurement of current and potential difference between the electrodes pair placed on the surface.

Some of the factors that affect this method include porosity, temperature, and rock texture in hand specimen, rock type, permeability, matrix conductivity and geological processes (6). For a homogeneous isotropic ground, the resistivity measured in the field should be constant for any circuit and electrode arrangement. But this is not true for a heterogeneous anisotropic ground (where the resistivity) depends on the direction of current flow) because with varied electrode spacing or constant spacing when the array is moved from place to place, the ratio generally changes.

Different values of resistivity are measured but the magnitude depends on the electrode arrangement used. This measured quality is called *apparent resistivity*. The vertical electrical resistivity (VES) was used to measure vertical variations in electrical properties beneath the earth surface with respect to a fixed centre of the array. It is done by increasing the electrode spacing linearly about a central position whose vertical resistivity variation is sought. Resistance measurements are made at each expansion and multiplied by the respective geometric factor (K) to give the resistivity.

The depth of investigation is dependent on the electrode spacing (expansion). It can be used to map the depth to bedrock and delineate aquifers. A Schlumberger array was used with AB/2 (electrode spacing) values of 1m to 40 m; the array length was aligned parallel to the geologic strike at each point. This is to minimize dip induced distortion on the generated sounding curves thereby reducing possible interpretation errors. As a result of measurements taken during the dry season at the time of this study, the electrode pairs were placed in shallow holes wetted with salty water to improve electrode grounding and reduce the source of noise from the lake and topsoil (7).

A total of 8 vertical electrical sounding stations at 50m inter-station spacing were established across the dam axis (figure 3). Measurements were taken using the ABEM SAS 1000 terrameter. The depth sounding data are presented as sounding curves, with the best smooth curves taken through the set of data points which were further interpreted both qualitatively and quantitatively. Quantitative interpretation was done using the curve matching method, where the obtained data were plotted on log-log graphs and matched against 2 layer master curves. By the use of auxiliary point diagrams, it was possible to interpret sequences of several layers (8). The geoelectric parameters obtained from manual interpretation of each VES data were refined using the software algorithm WIN-RESIST version 1.0 (9).

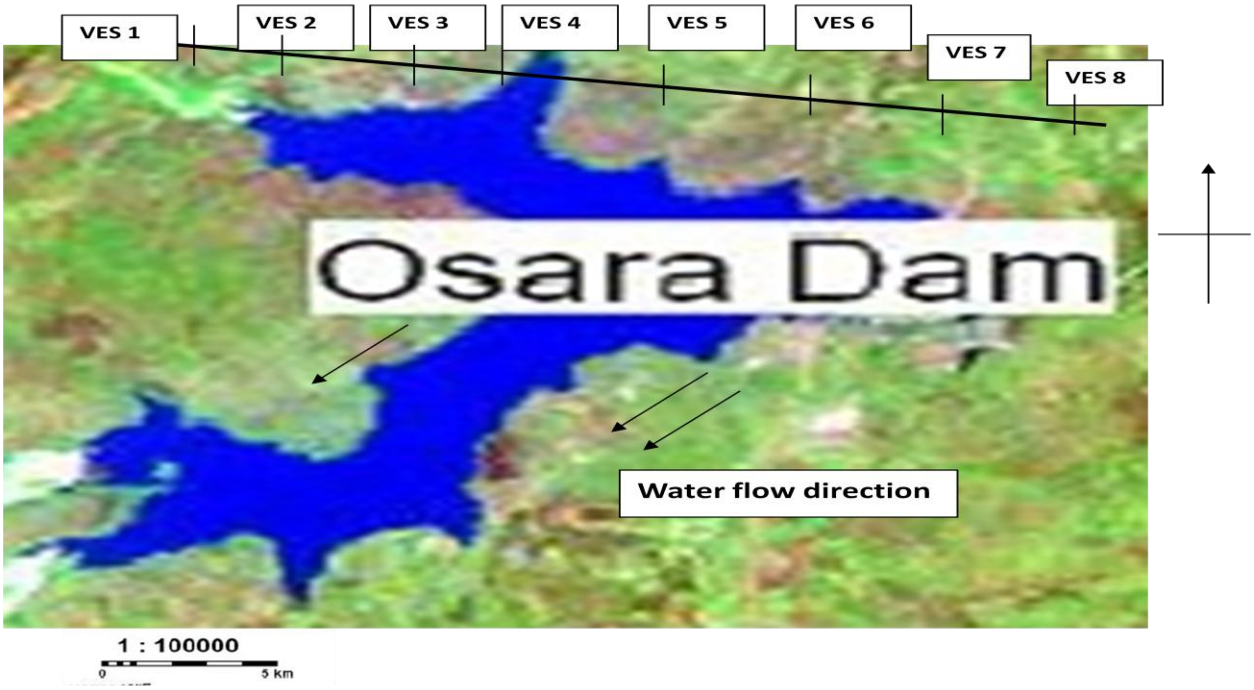

Figure 3; Data acquisition map around the dam site

V. RESULTS AND DISCUSSION

The data obtained from the study of the vertical electrical sounding carried out across the 8 VES stations at the Osara dam site is shown in table 1.

Table 1; Vertical electrical sounding data

				STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6	STATION 7	STATION 8
STN	**AB/2**	**MN/2**	**G**	**ρ**	**ρ**	**ρ**	**ρ**	**ρ**	**ρ**	**ρ**	**P**
1	1	0.5	2.36	144	318	345	804	141	332	88	355
2	2	0.5	11.8	361	292	351	1104	178	266	86	385
3	3	0.5	27.5	369	266	260	1088	170	212	80	166
4	5	0.5	77.8	350	175	113	884	161	85	48	54
5	6	0.5	112	318	133	87	856	144	54	33	14
6	6	1.0	55	278	135	89	736	147	55	35	30
7	8	1.0	88	216	74	52	534	110	24	22	34
8	10	1.0	156	158	49	33	362	80	22	16	10
9	10	2.5	588	159	53	37	364	84	13	15	06
10	15	2.5	137	88	35	22	148	48	16	15	12
11	20	2.5	247	75	42	23	84	34	22	134	17
12	30	2.5	552	83	57	28	60	34	49	184	31
13	40	2.5	1001	100	88	70	220	60	77	230	65

There are 8 VES stations marked 1,2,3….8. The corresponding resistivity value (ρ) has been obtained by multiplying the resistance by the geometric factor (G). The computer iteration was done using the WIN-RESIST software to obtain the layered parameters (figure 4a-4b). Maximum current electrode separation AB/2 ranged from 1 to 40m while the potential electrode separation between 0.5-2.5m was used. Across the 8 VES stations there is a general trend of a decreasing resistivity with depth, suggesting less compacted layers of the surface with depth. High resistivity values (> 300 ohm-m) were observed across the 8 stations at AB/2 of 5-7m while low resistivity measurements (< 100 ohm-m) were observed at AB/2 > 10m across the 8 VES stations.

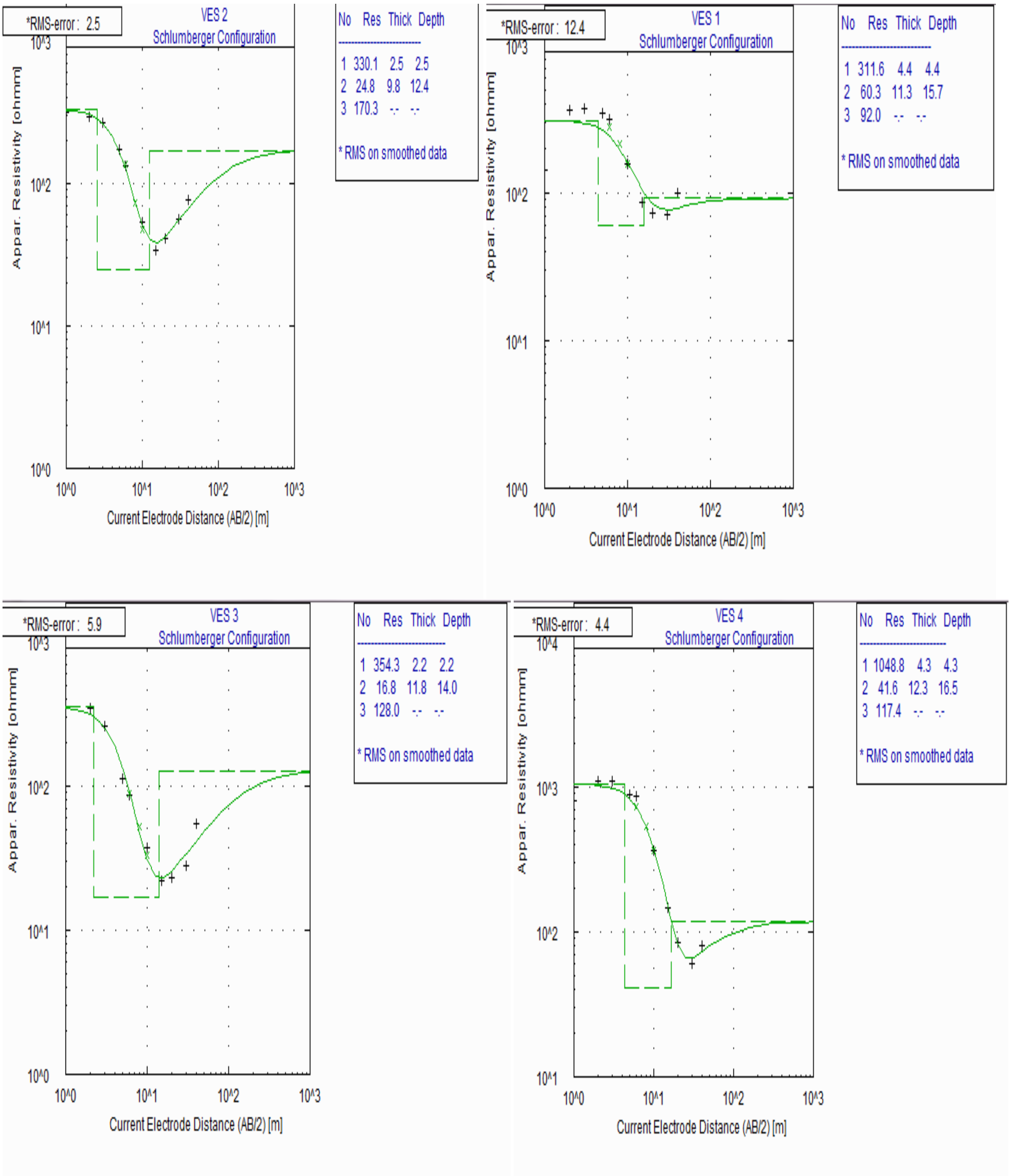

Figure 4a; Vertical Electrical Sounding (VES) curves for VES 1-4

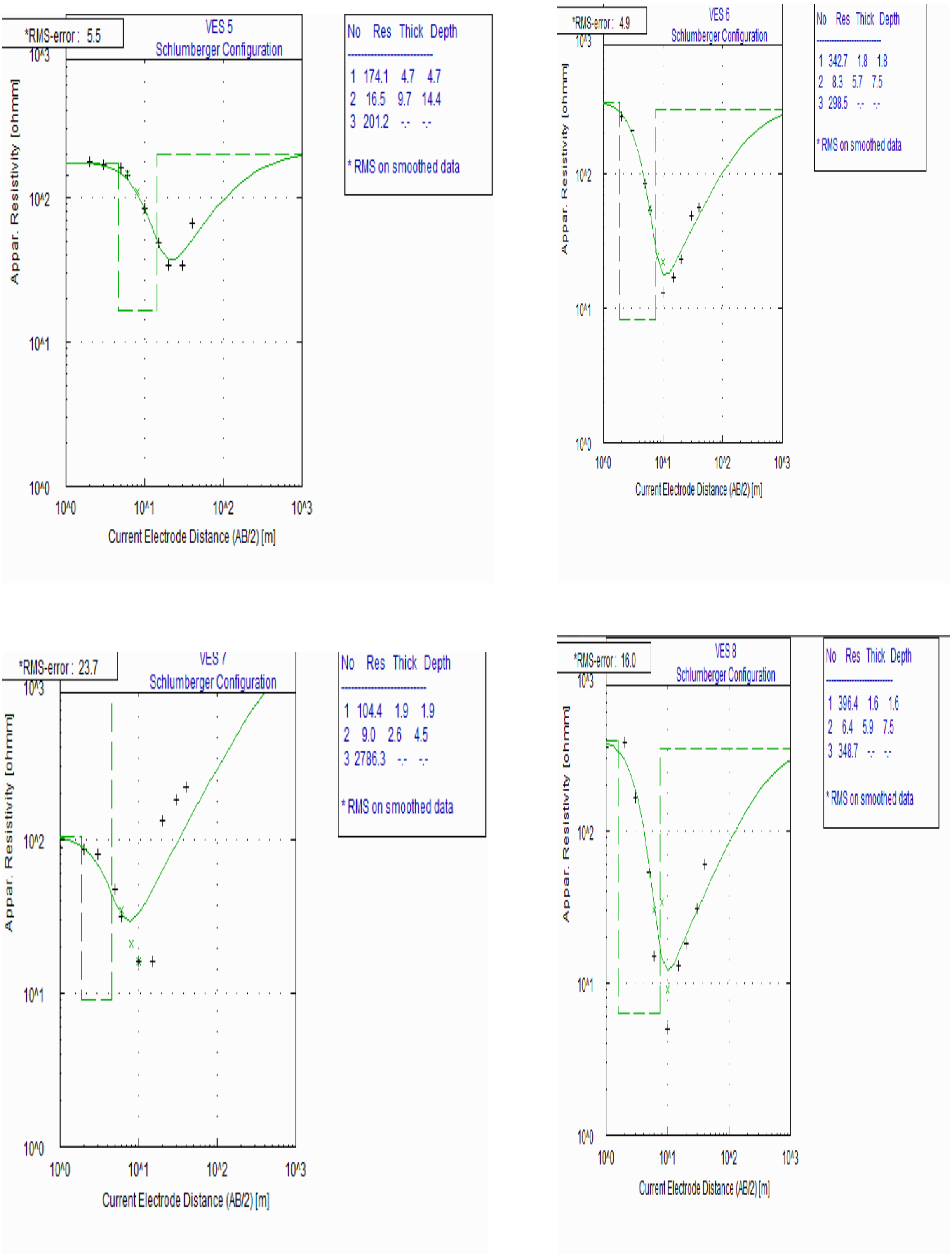

Figure 4b; Vertical Electrical Sounding (VES) curves for VES 5-8

From the graph plotted, it was deduced that the 8 locations has a three- layered structure in which stations 2,3,4,6 ,7 and 8 has H- type curves. Station 1 has a Q –type curve while station 5 has a Q-type curve. (Table 2)

Engineering Research Journal | ISSN: **2782-8212**
Vol. 3, Issue 4 (April, 2023) | www.ijaar.org/erj

Table 2; Lithological units in each layer with their resistivity, thickness and depth

VES NO	TYPE OF CURVE	NO OF LAYERS	RESISTIVITY (Ohm-m)	THICKNESS(m)	DEPTH(m)	LITHOLOGICAL UNIT
1	Q ($\rho_1 > \rho_2 › \rho_3$)	3	311.6 60.3 92.0	4.4 11.3 -	4.4 15.7 -	topsoil Weathered basement Fresh basement
2	H ($\rho_1 > \rho_2 < \rho_3$)	3	330.1 24.8 170.3	2.5 9.8 -	2.5 12.4 -	Topsoil Weathered basement Fresh basement
3	H ($\rho_1 > \rho_2 < \rho_3$)	3	354.3 16.8 128	2.2 11.8 -	2.2 14.0 -	Topsoil Weathered basement Fresh basement
4	H ($\rho_1 > \rho_2 < \rho_3$)	3	1048 41.6 117.4	4.3 12.3 -	4.3 16.5 -	Topsoil Weathered Basement Fresh basement
5	Q ($\rho_1 > \rho_2 › \rho_3$)	3	174.1 16.5 201.2	4.7 9.7 -	4.7 14.4 -	Topsoil Weathered Basement Fresh basement
6	H ($\rho_1 > \rho_2 < \rho_3$)	3	342.7 8.3 298.5	1.8 5.7 _	1.8 7.5 -	Topsoil Weathered basement Fresh basement
7	H ($\rho_1 › \rho_2 ‹ \rho_3$)	3	104.4 9.0 2786.3	1.9 2.6 -	1.9 4.5 -	Topsoil Weathered basement Fresh basement
8	H ($\rho_1 › \rho_2 ‹ \rho_3$)	3	346.4 6.4 348.7	1.7 5.9 -	1.7 7.6 -	Topsoil Weathered basement Fresh basement

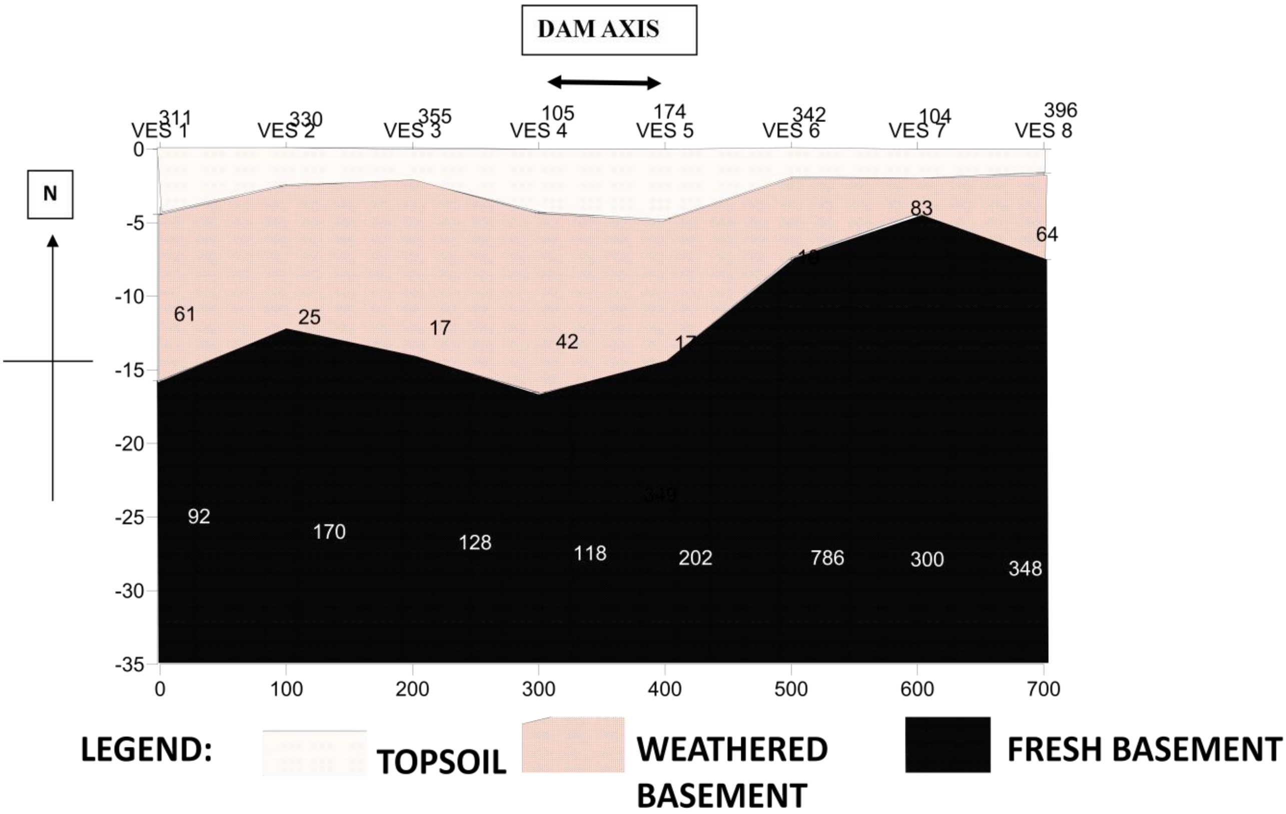

Figure 5; Geo-electric section in the E-W direction

The geo-electric section of the vertical electrical sounding along the east-west direction of the study area (Figure 5) showed a high and low resistivity contrast in which high resistivity values depict dry, lateritic soils and shallow weathering while low resistivities indicated deep weathering, wet and clayey soils. The geo-electric section showed that the cross section has 3- geo-electric layer section namely, the topmost layer made up of topsoil, having a resistivity range of 104 ohm-m -396 ohm-m and an average thickness of 5m (Figure 5). The second layer having dry lateritic soils which are highly weathered has a resistivity range of 17 ohm-m – 84 ohm-m and a thickness of about 15m. The bedrock or third layer has a resistivity range of 92 ohm-m -384 ohm-m.

The dam axis occurred between VES 4 and VES 5 (Figure 3) and from the geoelectric section (Figure 5), the lowest values of resistivity (17 ohm-m -42 ohm-m) were observed along the dam axis at a depth of between 15m -20m. This shows extensive erosion and weathering of the underlying bedrock along the dam axis. The bedrock relief is also lowest at this point (Figure 5).

VI. CONCLUSION

Investigation through electrical resistivity measurement was used to map the subsurface at Osara Dam, North central Nigeria and a relationship was established between the lithologic, the geo-electric section and the bedrock relief. The interpretation of the electrical resistivity data showed extensive erosion and weathering of the bedrock layer along the dam axis characterized by low resistivity values between VES 4and VES 5 along the dam axis. It is recommended that to prevent seepages and differential settlement along the dam axis and nearby structures, filling of the dam beds with competent earth materials to block possible seepage pathways for water should be done in order to prolong the life span of the dam usage amongst other remediation measures.

REFERENCES

1. Goldsmith, E., Hildyard, N. The social and environmental effects of Large Dams. 1992. Wadebridge Ecological Centre, Bodmin, UK pp 113-116
2. Lorie, E. Small-scale irrigation dams, agricultural production, and health: theory and evidence from Ethiopia. 2005. Washington DC.
3. Kolawole, M.S, Ishaku, J.M, Ayodele, D and Omoniyi, D.O. Lineament mapping and groundwater occurrence within the vicinity of Osara dam, Itakpe-okene area, North-central Nigeria using LANDSAT data. 2016. Journal of Geoscience and Geomatics, 2016, Vol. 4 No 3, 42-52
4. Ajibade, A. C., Rahaman, M. A. and Woakes, M. Proterozoic Crustal Development in PAN African Region of Nigeria.1980. Kroner .A. (Ed) Union 17:259-271
5. M. B. Dobrin and F. Savit, “Introduction to Geophysical Prospecting,” McGraw-Hill Company Ltd., NewYork. 1988.
6. W. M. Telford, L. P. Geldart and R. E. Sheriff, “Applied Geophysics,” Cambridge University Press, New York, 1990. doi:10.1017/CBO978113916
7. G. Z. A. Aal, A. M. Ismail, N. L. Anderson and E. A. Atekwana, “Geophysical Investigation of Seepage from an Earth Fill Dam, Washington County, MO,” *Journal of Applied Geophysics*, Vol. 44, 2004, pp. 167-180
8. Dahlin T. The development of DC resistivity imaging techniques. Computers & Geosciences. 2001. Pergamon Press, 27: 1019-1029.
9. Vander V.B.P.A. Resist version 1.0 M.Sc Research project.1988. ITC, Delft, Netherlands.