EFFECTIVENESS OF ELECTRICAL RESISTIVITY SURVEY IN PRELIMINARY INVESTIGATION OF A DAM SITE: A CASE STUDY OF A PROPOSED MAYO-INE EARTH DAM, NORTH-EASTERN NIGERIA

[1]IBRAHIM ABDULRAZAQ ADESOJI, [2]ISMAIL ABDU GARBA, [3]INGOROKO TAVERSHIMA STEPHEN,

[1]Department of Groundwater, National Water Resources Institute, Kaduna-Nigeria (e-mail: ibrowodwaid@gmail.com)

[2]EPTD, National Water Resources Institute, Kaduna-Nigeria (e-mail: madaarie @yahoo.com)

[3]Department of Ground water, National water Resources Institute, Kaduna (e-mail: tingoroko@gmail.com)

ABSTRACT

This paper discusses the preliminary investigation of a proposed dam along Mayo Ine River in Mayo-Ine- Ngurore, Northeastern Nigeria. The objectives are to ascertain the competency or otherwise of the rocks and soils of the area, determine depth to rock level and to suggest appropriate treatment necessary if need be. The method used was Electrical resistivity survey, and was carried out before drilling; this was to narrow down the number of drill holes and also to cut cost of foundation investigation. It involved marking out 3nos profiles at 100m intervals along the likelihood areas to be dam axes, as centerline, upstream and downstream lines; and run 24nos vertical electrical sounding (VES) using Schlumberger array on them. Of the 24nos VES locations, 16 have 3nos layers (sandy-silty clay; gravelly- sandy- silty clay; and basement rocks), while the remaining have weathered rocks overlying the basement as 4th layer. The method revealed that the depth to basement at the river channel was about 18m.This is close to 22.2m obtained during the geotechnical investigation that followed the geophysical method. It was then concluded that few numbers of test holes be drilled along these profiles to correlate the inferred depths and lithologies.

KEYWORDS: *Basement rocks, Geophysical sounding, Schlumberger array, Lithology, alluvial*

INTRODUCTION

About 446 dams have been constructed in Nigeria (HI- TEK, 2018), and many more are under construction in different parts of the country. Between 1970 and 1995, 246 dams were constructed in the Nigeria, Uyigue.E. (2006). There has been several appeal especially in 2011 and 2012 when the country recorded worst flood incidence, that more dams be constructed to attenuate future flood water, even without considering what it takes to construct a dam aside monetary involvement. Also on food security, the effect of the sahelian drought of 1972 – 1975 aggravated the food shortage in the country prompting the various levels of government to embark on a rigorous policy to increase food production. (Imevbore et al, 1986).The infrastructure such as boreholes, tube wells and stream diversions for irrigation are not meeting public needs. The simplest and most cost-effective method to obtain the quantities needed is to increase additional storage at existing dams. To achieve this, impoundment of river basins was seen as inevitable to provide sufficient water for year-round irrigation which led to the construction of over 246 dams (Imevbore et al, 1986). An estimated 30-40% of irrigated land worldwide now relies on dams and that dams generate 19% of world electricity (World Commission on Dams, 2000).

One of such dams was proposed across river Mayo, so as to harness the potential of the river for domestic and agricultural purposes. To kick-start the engineering design, preliminary investigation of the proposed site would be carried out. During this investigation, information is required not only from the surface and near-surface bedrock, but also from the rock at depth. Drill-hole information is often complemented by geophysical surveys, which provide a means of extrapolating and interpolating drill-hole data, as well as giving useful information on the physical properties of the rock mass such as moduli of elasticity, (Best, 1981). So this paper takes a look at geophysical study as parts of preliminary investigation in the

Fig. 1: Location Map of the Study area (Adapted from Geospatial Analysis Mapping and Environmental Research solution, 2018

3. The geology of the area

The study area consists of migmatites, gneiss, granite gneiss, older granite, basalt, lateritic iron stone and pegmatite (Fig.2.0). This complex mixture of granitic rock could be as a result of intruded basalts into the host rocks. The superficial deposits include in-situ weathered rocks, sandy clayey silt, fine to medium- mature sand (alluvium), and fine- medium- coarse- immature sand (river bed).

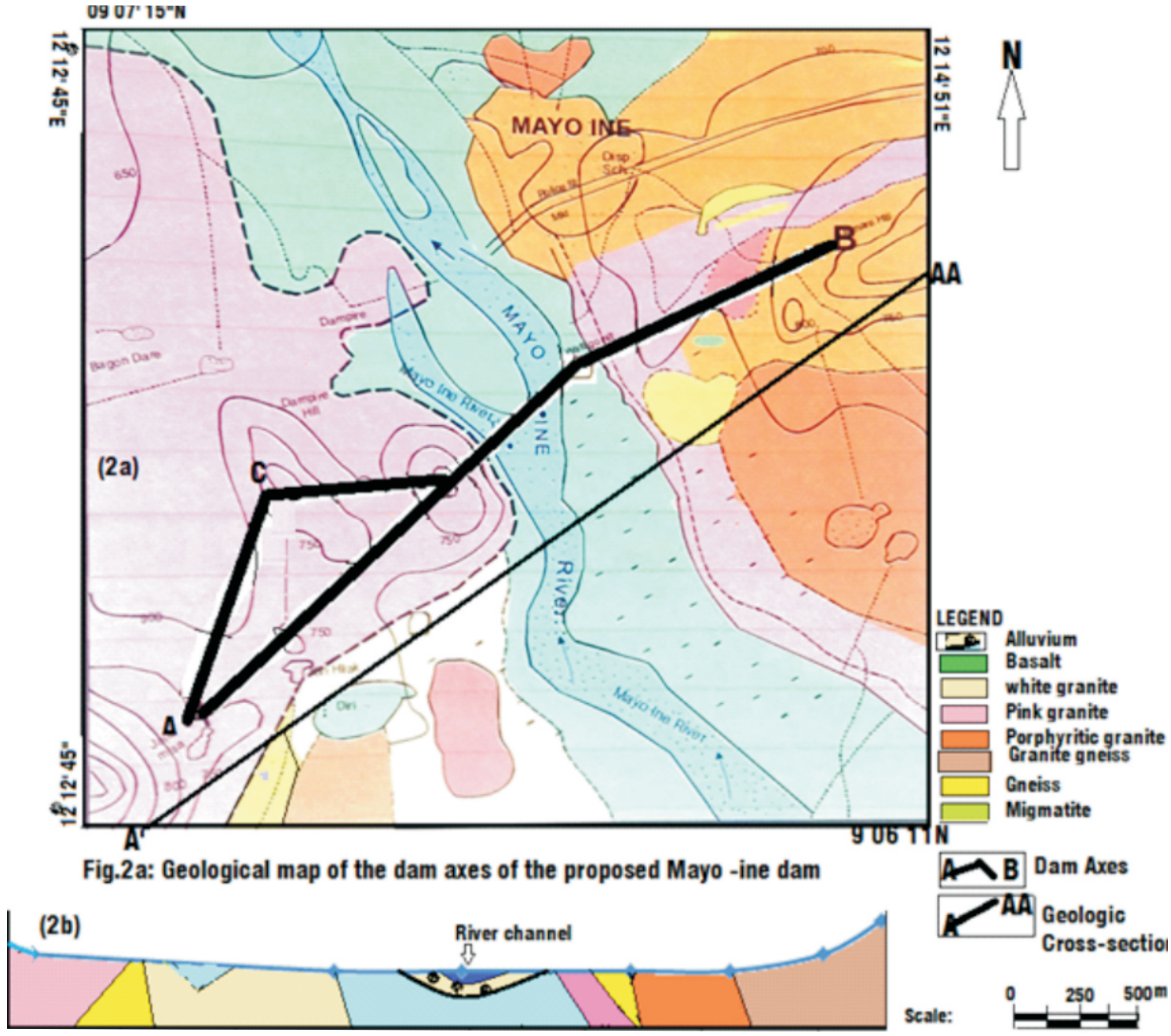

Fig.2a: Geological map of the dam axes of the proposed Mayo -ine dam

Fig 2b: Geologic cross of the Dam Axes

4. Methodology

The geophysical survey employed Vertical Electrical Sounding (VES) method using ABEM SAS 300 Terrameter adopting Schlumberger array at 24Nos different points along the area marked as the dam axes as shown in Fig. 3.0. Three profiles were run at 100m intervals; the first was along the centerline, followed by that of upstream side and lastly, the downstream side. The results obtained from the exercise were used as the input-model for the eventual computer aided iteration using WINRESIST program. The results obtained were used to characterize the lithology and the overburden thickness. Each of the lithology was hatched using AutoCAD to bring out the real geological representations.

4.1. Theory of Vertical Electrical Sounding (VES)

The method known as sounding is used when the variation of resistivity with depth is required. This enables rough estimates to be made of the types and depths of strata; as it can locate changes in the weathered zone and differences in geology; and also useful for identifying thickness of sand or gravel within superficial deposits, MacDonald *et al.* (2001). The technique assumes that there are no large lateral variations in the rock types.

When carrying out a resistivity sounding, current is led into the ground by means of two electrodes. With two other electrodes, situated near the centre of the array, the potential field generated by the current is measured. From the observations of the current strength and the potential difference, and taking into account the electrode separations, the ground resistivity can be determined, Namwamba, (2012). The Schlumberger Array method, where separation between the electrodes is step-wise increased was employed, thus causing the flow of current to penetrate greater depths. The observed resistivity values is plotted against depth on double logarithmic paper, a resistivity graph is formed, which depicts the variation of resistivity with depth. This graph can be interpreted with the aid of a computer, and the actual resistivity layering of the subsoil is obtained. The depths and resistivity values provide the hydrogeologist with information on the geological layering and thus the occurrence of groundwater, Namwamba, (2012).

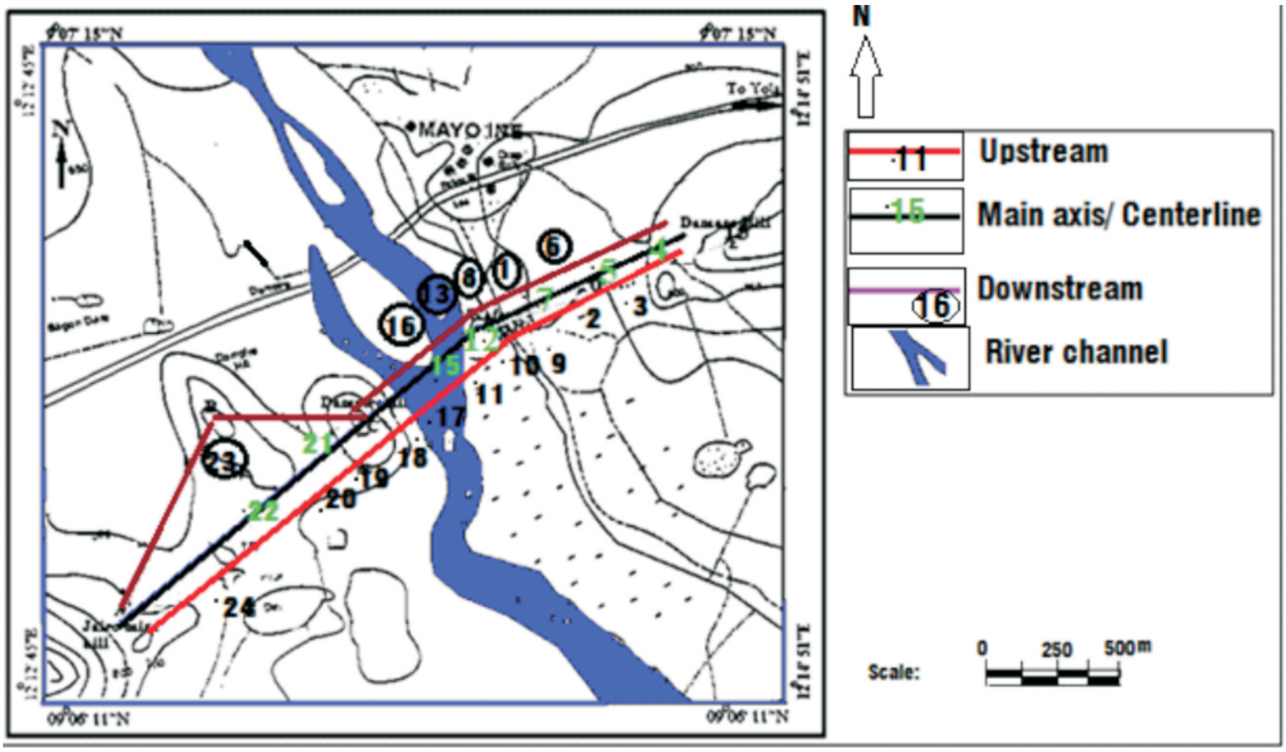

Fig. 3.0: VES Points along the Proposed Dam Axes

5.0. Result and Interpretation

The plots of VES (sample of which is Fig.4.0) show that of the 24nos points, 16 have 3nos layers, while 8 have 4nos layers. The 3 layers, (spread across all 4 possibilities as: 8nos A type, $\rho 1 < \rho 2 < \rho 3$); 2nosK type (

$\rho 1 > \rho 2 < \rho 3 < \rho 4$); *and 1no KH*, ($\rho 1 < \rho 2 > \rho 3 < \rho 4$).

($\rho 1 < \rho 2 < \rho 3 < \rho 4$

$\rho 1 < \rho 2 > \rho 3$) ;5*nos H type*($\rho 1 > \rho 2 < \rho 3$) *and*; 1*no Qtype* ($\rho 1 > \rho 2 > \rho 3$)

$\rho 1 < \rho 2 < \rho 3 > \rho 4$)

$\rho 1 > \rho 2 > \rho 3 < \rho 4$)

. The 4 layer types are 2nos ;2nos HA,(

;1noAAtype);2nosAKtype,(

The resistivities of first,second and third layers range from 12.7 to 1915.8Ω-m, 16.9 to 2512Ω-m, and 14.7 to 5756.98Ω-m respectively.While, their thicknesses between 2.5- 8.0m; 1.0 - 11.0m, and 2.5- 15.0m respectively.(Table 1A to 1D) show the interpreted readings for the centerline, upstream, downstream and the river channel.The inferred lithogies all the profiles are shown in Fig.4.0.

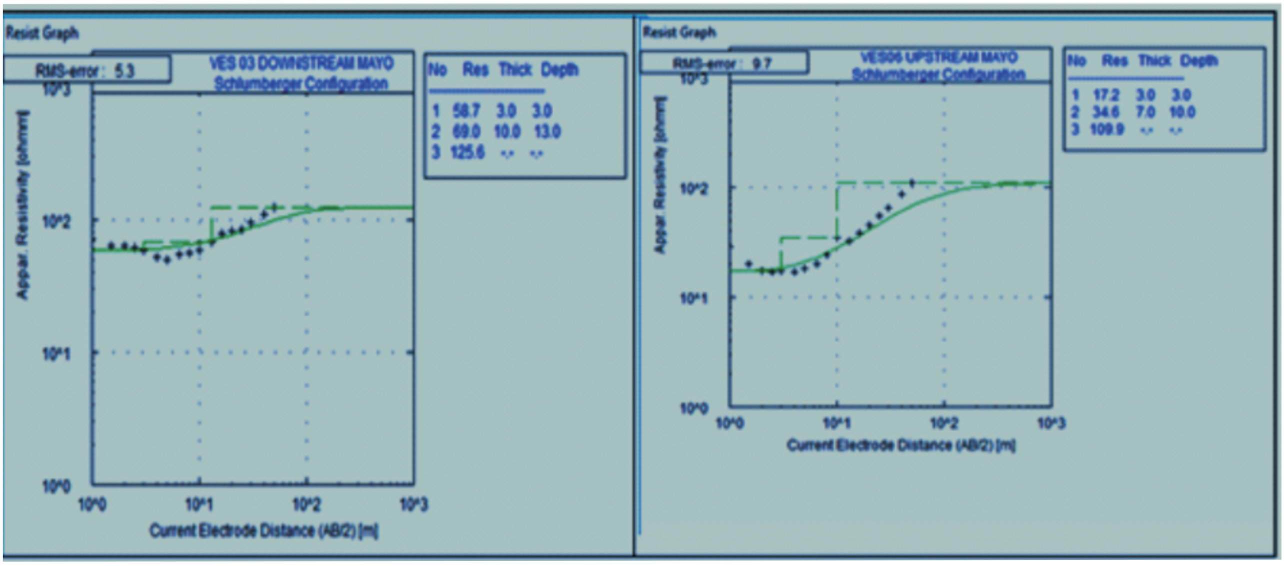

Fig 4: A typical VES Curves in the study area for VES03 and VES 05

Table 1 : Interpretation of Vertical Electrical Sounding (VES) along the dam Axis of the Mayo-ine Dam

A. Interpretation of VES Curves along the Downstream side of the proposed Dam

VES	LAYER No	CURVE TYPE	RESISTIVITY (Ohm-)	DEPTH TO INTER-FACE (m)	LAYER THICKNES (m)	VES	LAYER No	CURVE TYPE	RESISTIVITY (Ohm-m)	DEPTH TO INTERFACE (m)	LAYER THICHNESS (m)
V1	3	H	95.30	2.5	2.5	V13	3	H	129.9	4.0	4.0
			29.60	13.0	10.5				127.0	13.0	9.0
			125.6	-	-				183.1	-	-
V6	3	A	17.2	-	3.0	V16	4	AK	34.3	3.0	3.0
			34.6	10.0	7.0				43.5	10	7.0
			109.9	-	-				672.9	25	15.0
									484.0	-	-
V8	4	AA	23.1	8.0	8.0	V23	4	HA	179.9	4.0	4.0
			30.7	10.0	2.0				54.5	10.0	6.0
			35.9	16.0	6.0				60	25.0	15.0
			120.3	-	-				502.3	-	-

Table 1B. Interpretation of VES curves along the Upstream side of the Proposed Mayo-ine Dam											
V2	3	A	142.8	3.0	3.0	V3	3	A	58.7	3.0	3.0
			172.2	6.5	3.5				69.0	13.0	10
			261.6	-	-				125.5	-	-
V9	3	A	23.6	3.0	3.0	V10	3	A	203.0	3.0	3.0
			35.5	9.0	6.0				231.1	10.0	7.0
			217.1	-	-				266.8	-	-
V 11	3	H	126.2	2.0	2.0	V17	4	AK	1689.5	2.0	2.0
			63	10.0	8.0				2512.5	4.0	2.0
			177.8	-	-				5756.9	6.5	2.5
									123	-	-
V18	3	H	354.6	5.0	5.0	V19	4	HA	165.6	1.5	1.5
			311.2	10.0	5.0				1.0	6.5	5.0
			133.4	-	-				360.5	10.0	3.5
									188.4	-	-
V20	3	K	247.0	2.5	2.5	V24	3	K	42.8	2.5	2.5
			303.9	10.0	7.5				151.8	10.0	7.5
			169.2	-	-				102.0	-	-
			32.5	6.5	4.5				27.2	6.5	2.5
			256.1	-	-						
C. Interpretation of VES curves along the Centerline of the Axis of the Proposed Mayo-ine Dam											
V4	3	A	21.1	2.0	2.0	V5	4	QH	30.1	4.0	4.0
			32.5	6.5	4.5				27.2	6.5	2.5
			256.1	-	-				24.8	10.0	3.5
									115.1	-	-
V7	4	KH	12.7	2.5	2.5	V14	3	A	34.0	2.5	2.5
			16.9	6.5	4.0				76.0	13.0	10.5
			14.7	10.0	3.5				172.7	-	-
			78.5	-	-						
V12	4	QH	239.3	2.0	2.0	V15	3	A	33.8	3.0	3.0
			205.1	3.0	1.0				42.0	10.0	7.0
			110.4	13.0	10.0				107.3	-	-
			259.0	-	-						
V21	3	Q	1915.8	2.0	2.0	V22	3	H	383.2	2.0	2.0
			402.0	13.0	11.0				243.0	10	8.0
			136.0	-	-				2563.7	-	-
D. Interpretation of VES curves along the Mayo-ine River											
V12	4	QH	239.3	2.0	2.0	V15	3	A	33.8	3.0	3.0
			205.1	3.0	1.0				42.0	10.0	7.0
			110.4	13.0	10.0				107.3	-	-
			259.0	-	-	V17	4	AK	1689.5	2.0	2.0
V13	3	H	129.9	4.0	4.0				2512.5	4.0	2.0
			127.0	13.0	9.0				5756.9	6.5	2.5
			183.1	-	-				123.0	-	-

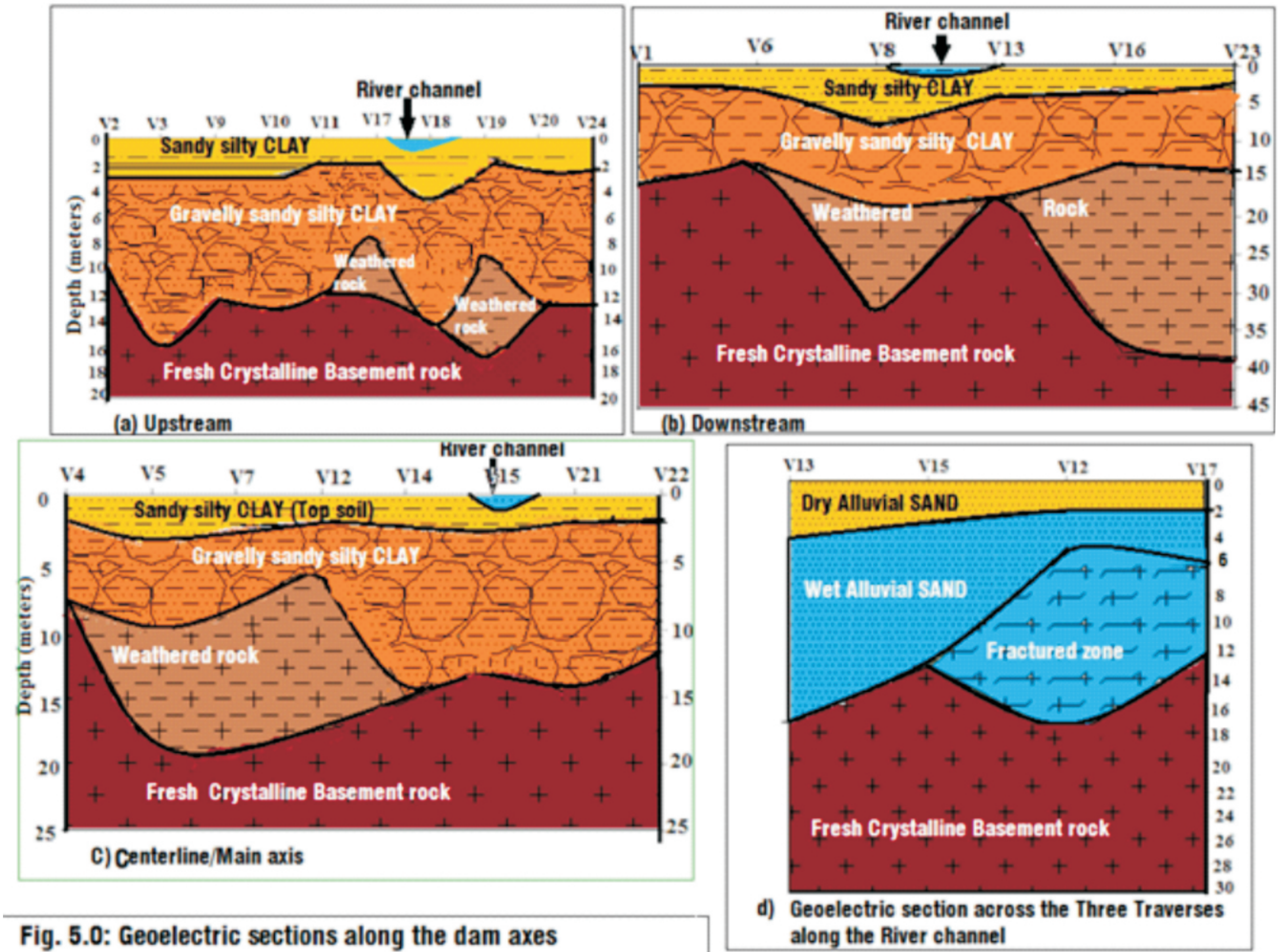

Fig. 5.0: Geoelectric sections along the dam axes

6.0 Discussions

The bulk of the area according to the VES contains three layer lithologies: topsoil, underlain by gravelly sandy clay; (in which mostly gravel increases with depth) and basement rock. The V5, V7, V8, V12, V16, V17, V19 constituting about 29% of the total VES have four layers. These cut across the upstream, centerline and the downstream. The weathered layer in this four layers occurred at about 15.0 to 35.0m depth at the downstream; 5.0 to 20.0m centerline; 6.0 to 16.0m at the upstream; It was observed that the areas with four layers are those plains intervening between hills and areas towards the river channel.

Along the river channel, the result of VES shows that the river sand measured an average thickness of 18.0m at the center. This could be interpreted that the river is structurally controlled; as it also meanders around Damare hill, Dampire hill, and Wofago hills.

7.0 Conclusion:

The preliminary investigation carried out using vertical electrical sounding (VES) approach of the geophysical methods reveals major 3nos layer strata in all the proposed axes; few locations along the axes however have four layers. The inferred lithologies with varying thicknesses are: Topsoil, followed by sandy-silty-clay; this is underlain by gravelly sandy-silty- clay, with gradations to weathered basement. Across the river channel, the thickness of alluvial sand varies from 12.0m to 20m and as such a complete cut off wall is required. The superficial materials include: silty clay, alluvial sand and laterites. Depth of water table varies from less than 1.0-18.0m. The sand is a good concrete material. On the final note, all the proposed axes examined are free from major geophysical challenges-like faults; and few test holes should be drilled to correlate this finding /interpretation.

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