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GEOPHYSICAL INVESTIGATION OF PROPOSED DAM SITE ALOMG RIVER ADUNIN, OGBOMOSO, SOUTHWESTERN NIGERIA.

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ABSTRACT

Dams are vital structures that store water for consumption, irrigation, electricity production and industrial purposes. The design and construction is very important to prevent the collapse of the structure .Thirty (30) Vertical Electrical Sounding points were investigated. Very Low Frequency profiling at 5m inter station along five profiles were carried out. The interpretation of geophysical data were achieved using the following software; Res 2D, Win Resist, Surfer 11, Arc GIS 3.3 and Excel. Six resistivity sounding curve types were obtained from the study area and these are the H, HA , KH, HKH, and KHA curves. The geologic sequence beneath the study area is composed of top soil, weathered basement, fractured basement, and fresh basement. The topsoil is composed of clayey-sandy and sandy-lateritic hard crust with resistivity values ranging from 339-1971 ohm-m and thickness of 0.7-1.3 m. The weathered basement resistivity is within the range of 98-3026 ohm-m and thickness value of 0.3-7.0m. The fractured basement layer resistivity values vary from 163–4049 ohm-m while its thickness ranges from 2.7 to 17m. Fresh basement has resistivity value range of 228 to14793 ohm-m.

The bedrock is highly fractured beneath the river axis and extended toward the left abutment while fresh basement is closer to the surface at the right abutment. The fractures beneath the proposed dam axis may pose serious threat to the dam in term of future seepage. The dam should be shifted toward the right abutment by 20m and excavation should be made up to depth of about 5m, the materials so removed could be used for the construction of the embankment and the filter materials.

Introduction

Dams are among the largest and most important projects in civil engineering (Ibeneme *et al.,* 2013). Dams are used to store water for human consumption via irrigation, electricity production, industrial use and recreation. The essential need for potable water supply has been the major concern of Nigeria, which prompted the construction of dams (Olasunkanmi *et al.,* 2012). The construction of a dam is considerably enhanced by carefully planned and well executed preliminary geophysical investigation (Ako, 1976). Pre-construction site study is a prerequisite for the construction of dams and other hydraulic structures in order to avoid locating such structures on undesirable subsurface features such as buried stream channels, near-surface features, joints and fissures (Ajayi *et al.,* 2005). Geophysical methods are often used in site investigation to determine depth to the basement and map subsurface characterization prior to excavation and construction. In environmental applications, resistivity surveys are capable of mapping overburden depth, stratigraphy, faults, fractures, rock units and voids. It is no doubt, dams have contributed to the economic growth of many nations. The over 45,000 dams built round the world have played important role in helping communities and economic harness water resources for several uses (Haruna *et al.,* 2010).

However, dam failure can take several forms, including a collapse of or breach in of the structure.

It is therefore very important to carry out geotechnical and geophysical investigations on any proposed dam site (Oluwakemi *et al.*, 2011). Ogbomoso as a town is immensely faced with problem of water scarcity; hence the need for construction of a dam is very necessary. Although different measures are being put in place by individual to alleviate this water scarcity, some of which include collection of rain water, digging of shallow well and boreholes this has not been able to guarantee a perennial availability of water for the majority of the population (Bayewu *et al.*, 2012). The Adunyin River with its catchment is a possible river to be dam to ease the tension of water supply in the town. The purpose of this study is to investigate the suitability of the subsurface geological formations, ground conditions and geological structures for foundation of the proposed dam

Study Area

The study area is located in southwestern Nigeria between longitudes $4^0 17^I 00^{II}$ to $4^0 19^I 10^{II}$ and between latitudes $8^0 9^I 20^{II}$ to $8^0 10^I 42^{II}$. The study area is a low lying (low relief) and has a dendritic drainage pattern which is controlled by the topography and a sketch of VES points arrangement on the field (Figure 1a & 1b). Ogbomoso exhibits the typical climate of averagely high temperature, high relative humidity and generally two rainfall maxima regimes during the rainfall period of March to October. The main temperatures are highest at the end of harmattan (averaging 28^0c) that is, from the middle of January to the onset of the rains in the middle of March (Adegbola and Adewoye 2012). During the rainfall months, temperature varies between 25^0c and 28^0c while annual temperature average is about 6^0c. Rainfall varies from an average of 1200 mm at the onset of the heavy rains to 1800 mm at the peak. The vegetation of this area is that of the rainforest and derived savannah. The composition is basically the tall crowned trees mixed with thick undergrowth. The trees attain the height of about 20-40 m and grasses are abundant and luxuriant. The typical type of the grass here is that of elephant grass and stubborn grass. The tropical trees are locust beans and most of the trees are deciduous. The climate condition is typical of the south western part of Nigeria whose climate is influenced largely by equatorial maritime air mass. Being in the savannah zone makes farming the major occupation of the people of the area (Adetunde *et al*., 2011).

River Adunyin flows generally from Northeast to Southwest direction but at point of investigation the direction is essentially Eastwest. The depth and width of the river varies downstream, the depth averaged 4m while the width averaged 9m. At the point of investigation, the flood plain is extensive, extending to about 120m especially to the right bank of the river. River Adunyin is joined by River Pagunmo at the left side and other tributaries downstream (Figure 2). The study area is located on the Precambrian Basement rocks of Southwestern Nigeria which comprise of crystalline rocks over 550 million years old (MacDonald and Davies, 2000). Regionally, the study area lies within the Southwestern parts of the Basement rocks which is part of the much larger Pan-Africa mobile belt that lies in between the West Africa Craton and Congo Craton suspected to have been subjected only to a thermotectonic event (Sunmonu *et al*., 2012). Locally, Ogbomoso is underlain by the Migmatite- Gneiss-Quartzite Complex (Rahaman, 1982). The study area is underlain by granite gneiss as the only rock type as shown in Figure 3.

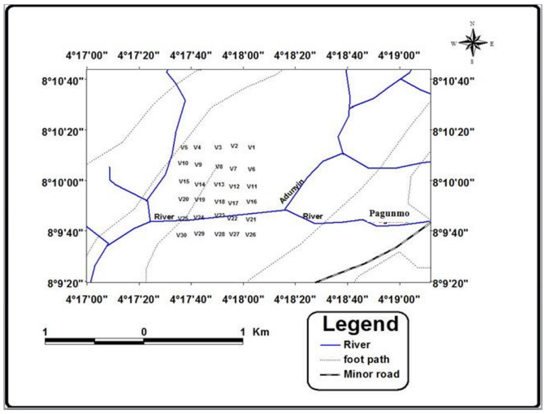

Figure 1a: The drainage and accessibility map of the study area.(Adewoye et. al. 2017)

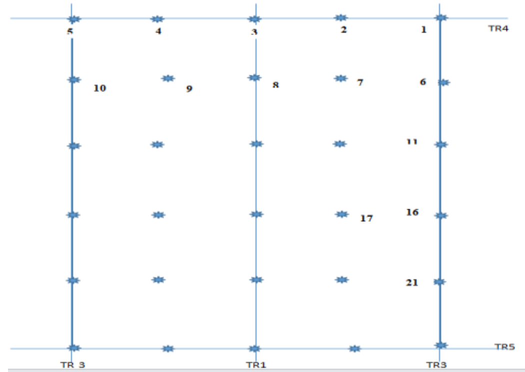

Figure 1b: A Sketch of VES points arrangement on the field.

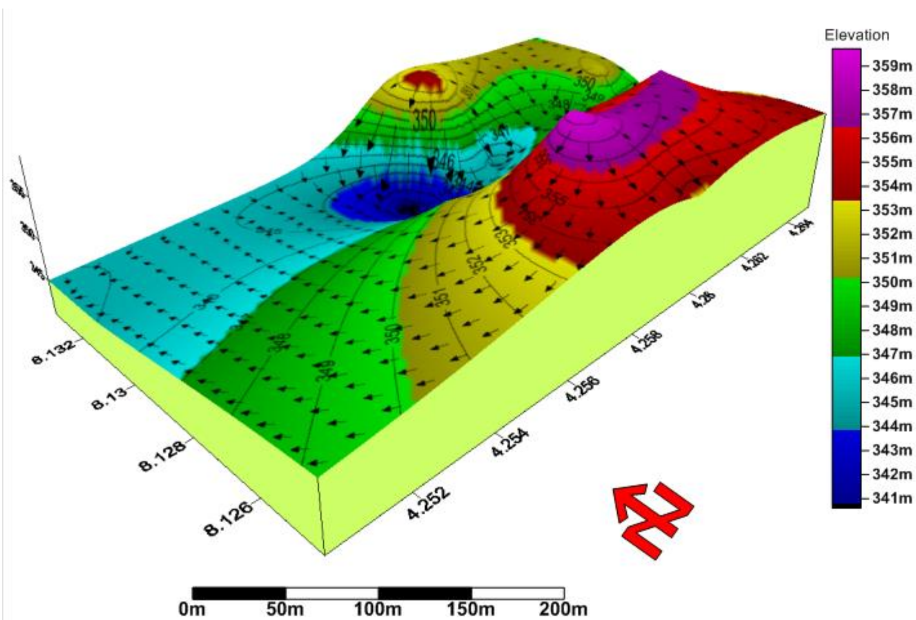

Figure 2: Geomorphological map of the study area

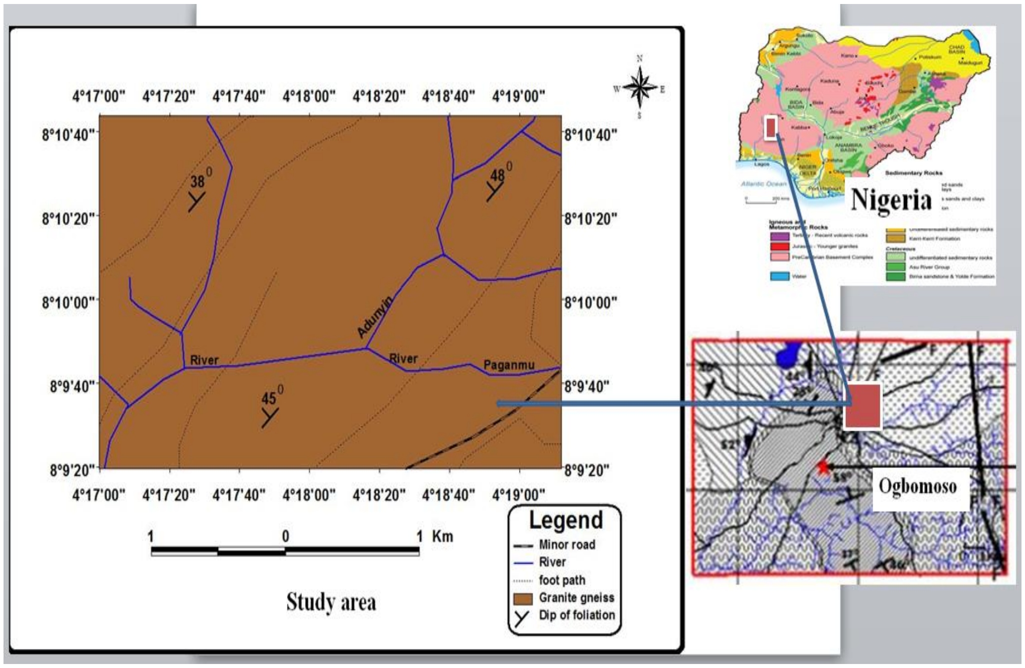

Figure 3: The geological map of the study area

Methodology

For the success of this investigation, standard materials and methods of practice were adopted. The desktop study included the study of topographical map of the area which revealed the drainage pattern of the study area .The geological map of the area was equally studied. These maps were digitized using ArcGIS 3.3. A reconnaissance survey was carried out on River Adunyin to verify the results of our desktop study and to locate the exact area or catchment where the dam was to be sited.

Geoelectrical measurements were used to determine the electrical resistivity of the ground. Electrical resistivity method involving vertical electrical sounding was used employing Sclumberger array on a single profile line of about 150 m long in a NW-SE azimuth. Vertical Electrical Sounding (VES) technique utilizing Schlumberger configuration was adopted to investigate the layering and vertical variation of resistivity of the subsurface. Thirty (30) VES points were occupied. The apparent resistivity values were plotted against the electrode spacings on a log-log graph papers to obtain the VES sounding curves using an appropriate computer software IPI2win .

The equipment used for data acquisition was ABEM WADI. The VLF method uses powerful remote radio transmitters set up in different parts of the world for military communications and broadcasting at frequency of 15-25KHz. VLF-EM method can provide information on conductivity changes, overburden thickness, depth extent of fractures, attitudes of geologic structures hence defining the subsurface geology of the area for engineering evaluation. The field procedure involves walking along the selected traverses at the proposed dam site which are upstream, dam axis, downstream, right abutment and left abutment which are 150m in length, except the right and left abutment that are 50m each in length. The signal frequency used was 15KHZ and measurements (in-phase and out-phase components of the EM field) were made at 5m interval. At the completion of the survey, the data acquired were downloaded from the ABEM WADI system. Although both real and imaginary components of the VLF-EM anomaly were recorded, the real component data were processed for interpretation. The VLF data are presented as VLF profiles.

RESULTS AND DISCUSSION

Vertical Electrical Sounding (VES)

The results of the interpreted VES curves are shown in Table 1. The results of the investigation were presented as pie chart, curves, geoelectric sections and graphs. Six resistivity sounding curve types were obtained from the studied area and these are; H type curve which accounts for 50% of total VES curve from the study area, this type of curve indicate three layers of which the middle layer is essencially a weathered. KH (ρ1>ρ2< ρ3>ρ4,): It account for 36.66% indicating four resistivity layering. HKH(ρ1> ρ2<ρ3>p4<p5)which accounts for 3.33% indicating five resistivity layering, HA(ρ1>ρ2< ρ3<ρ): It account for 3.33% indicating four resistivity layering,KHA (ρ1< ρ2>ρ3<p4>p5): It account for 3.33%HK:It account for 3.33% (Figure 4).

Table 1: Summary of VES Interpretation

Layer /VES	Curve type	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred lithology
VES 1					
1	H	1731.5	1.3	1.3	Top soil
2		201.1	5.8	7.1	Weathered layer
3		1250.9	------	--------	Basement
VES 2					
1		426.9	1.3	1.3	Top soil
2	H	164.1	6.1	7.4	Weathered layer
3		2312.0	-------	--------	Basement
VES 3					
1		625.5	1.2	1.2	Top soil
2	H	147.3	7.0	8.2	Weathered layer
3		8308.6	-------	---------	Basement
VES 4					
1		984.8	1.1	1.1	Top soil
2	H	113.5	4.1	5.2	Weathered layer
3		1475.4	-------	--------	Fractured Basement
VES 5					
1		1504.7	0.9	0.9	Top soil
2	H	97.7	4.9	5.8	Weathered layer
3		627.0	-------	---------	Fractured Basement
VES 6					
1		1107.2	1.3	1.3	Top soil
2		106.0	5.2	6.5	Weathered layer
3	H	4048.6	--------	----------	Fractured Basement
VES 7					
1		987.3	0.8	0.8	Top soil
2		1204.4	0.4	1.3	Weathered layer
3	KH	185.3	7.8	9.1	Fracture
4		2481.3	---------		Fresh Basement
VES 8					
1		1217.7	0.7	0.7	Top soil
2		2030.5	0.6	1.3	Lateritic horizon
3	KH	326.6	8.0	9.3	Weathered layer
4		2192.0	-------	--------	Basement
VES 9					
1		1131.3	0.8	0.8	Top soil
2		2035.3	0.5	1.3	Lateritic horizon
3	KH	329.6	10.7	12.0	Weathered layer
4		3342.5	------	-------	Basement (fractured)
VES 10					
1		1971.0	0.8	0.8	Top soil
2	KH	3025.9	0.5	1.3	Lateritic horizon
3		177.2	5.1	6.4	Weathered layer

4		**4367.2**	**--------**	**-------**	**Basement (fractured)**
VES 11					
1		**1042.0**	**1.0**	**1.0**	**Top soil**
2	**H**	**144.0**	**4.7**	**5.7**	**Weathered layer**
3		**7204.7**	**--------**	**-----**	**Basement**
VES 12					
1		**1343.16**	**1.1**	**1.1**	**Top soil**
2	**H**	**136.0**	**4.8**	**5.9**	**Weathered layer**
3		**2035.2**	**-----**	**------**	**Basement**
VES 13					
1		**1854.2**	**0.7**	**0.7**	**Top soil**
2		**2825.8**	**0.3**	**1.0**	**Laterite**
3	**KH**	**327.1**	**5.7**	**6.7**	**Weathered layer**
4		**1415**	**-----**	**---**	**Basement**
VES 14					
1		**1064.5**	**0.8**	**0.8**	**Top soil**
2	**KH**	**1746.9**	**0.8**	**1.6**	**Laterite**
3		**419.5**	**8.4**	**10.0**	**Weathered layer**
4		**9430.9**	**--------**	**-----**	**Basement**
VES 15					
1		**1421.0**	**0.8**	**0.8**	**Top soil**
2	**KH**	**1693.3**	**0.3**	**1.1**	**Laterite**
3		**301.6**	**6.3**	**7.5**	**Weathered layer**
4		**2495.6**	**------**	**------**	**Basement**
VES 16					
1		**996.8**	**1.0**	**1.0**	**Top soil**
2	**KH**	**1246.4**	**0.4**	**1.3**	**Laterite**
3		**301.7**	**8.0**	**9.4**	**Weathered layer**
4		**5082.9**	**----**	**-----**	**Basement**
VES 17					
1		**1533.7**	**1.0**	**1.0**	**Top soil**
2	**H**	**190.7**	**5.1**	**6.0**	**Weathered layer**
3		**2405.3**	**-----**	**-----**	**Basement**
VES 18					
1		**1296.6**	**1.3**	**1.3**	**Top soil**
2	**H**	**132.2**	**4.7**	**6.0**	**Weathered layer**
3		**8026.7**	**-----**	**------**	**Basement**
VES 19					
1		**1877.3**	**0.8**	**0.8**	**Top soil**
2	**KH**	**2190.5**	**0.5**	**1.3**	**Laterite**
3		**255.9**	**6.1**	**7.4**	**Weathered layer**
4		**2805.3**	**----**	**-----**	**Basement**
VES 20					
1		**2069.1**	**1.3**	**1.3**	**Top soil**
2	**H**	**323.3**	**5.2**	**6.5**	**Weathered layer**
3		**1285.2**	**-----**	**-----**	**Basement (fractured)**
VES 21					
1		**698.3**	**0.9**	**0.9**	**Top soil**
2	**H**	**146.9**	**3.9**	**4.6**	**Weathered layer**
3		**5371.4**	**------**	**------**	**Basement**
VES 22					
1		**874.6**	**0.9**	**0.9**	**Top soil**
2		**166.4**	**3.9**	**4.7**	**Weathered layer**
3	**H**	**2031.1**	**-----**	**-----**	**Basement (fractured)**
VES23					
1		**1692.7**	**0.8**	**0.8**	**Top soil**
2	**H**	**116.6**	**3.6**	**4.5**	**Weathered layer**
3		**994.9**	**----**	**------**	**Basement (fractured)**
VES 24					
1		**1567.5**	**0.8**	**0.8**	**Top soil**
2		**373.4**	**2.8**	**3.5**	**Weathered layer**
3	**HKH**	**1687.8**	**6.2**	**9.8**	**Fresh Basement**

4		**438.1**	**24.2**	**34.0**	**Fracture**
5		**8232.9**	**-----**	**----**	**Fresh Basement**
VES 25					
1		**1992.4**	**1.0**	**1.0**	**Top soil**
2		**923.0**	**1.9**	**2.9**	**Weathered layer**
3		**1425.1**	**16.8**	**19.7**	**Fracture**
4	**HA**	**14699.9**	**-----**	**-----**	**Fresh Basement**
VES 26					
1		**394.3**	**0.8**	**0.8**	**Top soil**
2		**450.5**	**O.4**	**1.2**	**Laterite**
3		**163.3**	**2.7**	**3.9**	**Weathered layer**
4	**KHA**	**356.4**	**5.7**	**9.6**	**Fractured Basement**
5		**4560.6**	**------**	**----**	**Fresh Basement**
VES 27					
1		**338.8**	**0.9**	**0.9**	**Top soil**
2	**H**	**168.5**	**4.2**	**5.1**	**Weathered layer**
3		**1606.1**	**----**	**----**	**Fractured Basement**
VES 28					
1		**408.6**	**0.9**	**0.9**	**Top soil**
2		**120.1**	**3.3**	**4.2**	**Weathered layer**
3	**HK**	**1878.5**	**12.9**	**17.1**	**Basement**
4		**490.9**	**----**	**----**	**Fractured Basement**
VES 29					
1		**531.3**	**0.9**	**0.9**	**Top soil**
2		**163.2**	**2.7**	**3.6**	**Weathered layer**
3	**KH**	**756.7**	**12.0**	**15.6**	**Fresh Basement**
4		**228.0**	**------**	**-------**	**Fractured Basement**
VES 30					
1		**388.1**	**1.7**	**1.7**	**Top soil**
2		**1867.0**	**6.7**	**8.5**	**Weathered layer**
3	**KH**	**665.1**	**10.9**	**19.4**	**Fracture**
4		**14793.2**	**----**	**-----**	**Fresh Basement**

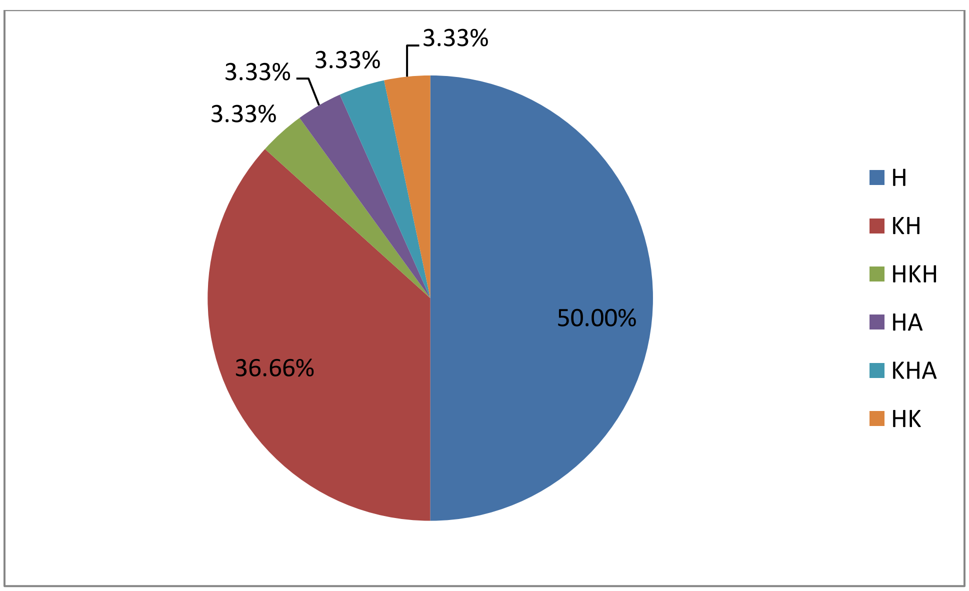

Figure 4: Pie chart of curve type obtained from the study area

H-type Apparent Resistivity Curve

The associated geoelectrical signature of H-type apparent resistivity curve is as shown in Figure 5a. It is a 3-layer earth model comprising 0.9 to 3.9m thick top soil having resistivity of 874.6 Ωm; weathered layer with resistivity 166.4 Ωm having 3.9 to 4.7m thick and fractured basement being third layer with resistivity of 2031.1 Ωm. (Table 2a).

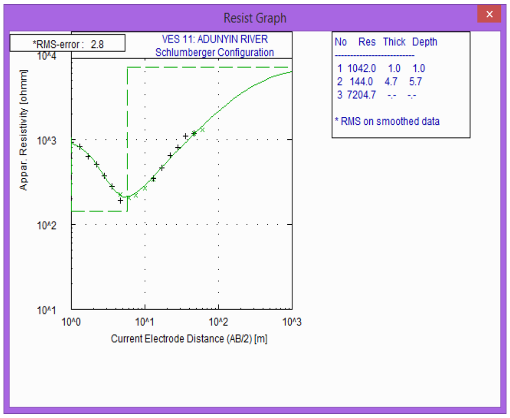

Figure 5a: Sample H-type Resistivity Curve .

Table 2a: Summary of Layering Parameters of H-type

Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)
1.	**1042.0**	**1.0**	**1.0**
2.	**144.0**	**4.7**	**5.7**
3.	**7204.7**	**-**	**-**

KH – type Apparent Resistivity Curve

KH-type apparent resistivity curve is a 4-layer earth model having conductive –resistive – conductive – resistive geoelectrical signature (Figure 5b). It comprises of conductive top soil with resistivity 1131.1Ωm with 0.8m thick; resistive second layer having resistivity 2035.3Ωm with 0.5m thick ; water-bearing third layer having resistivity between 329.8 Ωm with 10.7m thick and made-up of weathered layer; and fractured basement fourth layer. (Table 2b).

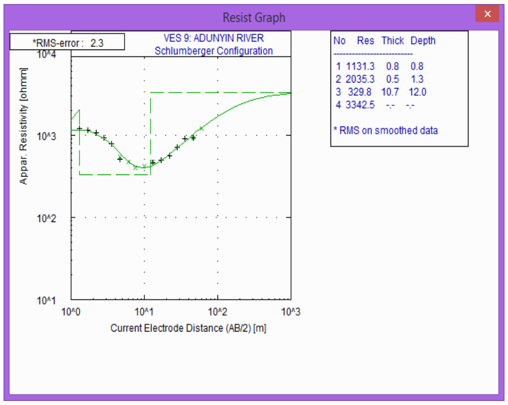

Figure 5b: Sample KH-type Resistivity Curve

Table 2b: Summary of Layering Parameters of KH-type

Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)
1.	1131.3	0.8	0.8
2.	2035.3	0.5	1.3
3.	329.6	10.7	12.0
4.	3342.5	-	-

HK – type Apparent Resistivity Curve

The associated geoelectical signature of a HK-type apparent resistivity curve is a reverse of that of KH-type, that is, resistive-conductive-resistive-conductive (Figure 5c). It is also a 4-layer earth model comprising 0.9 – 3.3 thick with 408.6Ωm resistive top soil; conductive second layer with resistivity of 120.1Ωm and 0.9 to 4.2m thick; resistive basement which is the third layer of resistivity 1878.5Ωm and fractured basement with resistivity of 490.9Ωm (Table 2c)

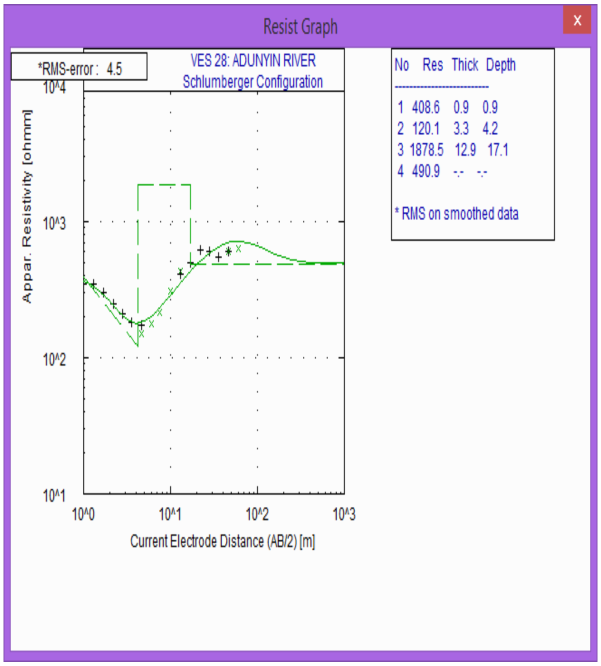

Figure 5c: Sample HK-type Resistivity Curve

Table 2c: Summary of Layering Parameters of HK-type

Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)
1.	**408.6**	**0.9**	**0.9**
2.	**120.1**	**3.3**	**4.2**
3.	**1878.5**	**12.9**	**17.1**
4.	**490.9**	**-**	**-**

HA – type Apparent Resistivity Curve

The sample HA-type apparent resistivity curve is shown in figure 5d. Its geoelectrical sequence comprises of 1.0 to 1.9m thick top soil with resistivity value of 1992.4 Ωm; weathered layer which is the second layer has resistivity 923Ωm with 1.9m thick ; and fractured /fresh basement resistivity varied from 1425.1-14699.9 Ωm comprising 16.8 to 19.7m thick (Table 2d)

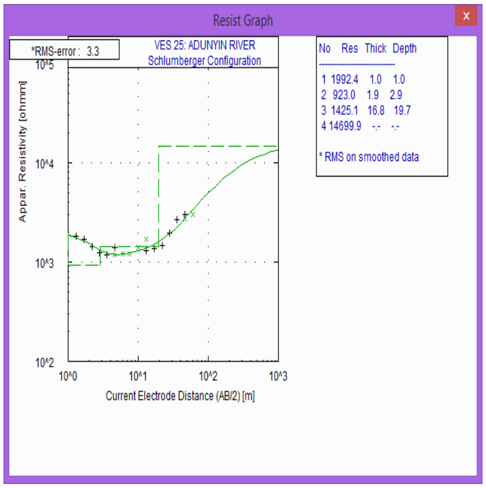

Figure 5d: Sample HA-type Resistivity Curve

Table 2d: Summary of Layering Parameters of HA-type

Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)
1.	1992.4	1.0	1.0
2.	923.0	1.9	2.9
3.	1425.1	16.8	19.7
4.	14699.9	-	-

HKH – type Apparent Resistivity Curve

HKH – type apparent resistivity curve obtained (Figure 5e) is a 5-layer earth model comprising 1.0m thick top soil; second layer of resistivity 373.42Ωm; 6.2m thick third layer; conductive fourth layer of resistivity 438.1Ωm ; and fractured basement resistivity 8232.9 Ωm (Table 2e)

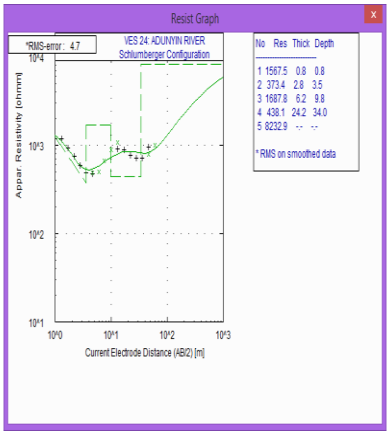

Figure 5e: Sample HKH-type Resistivity Curve

Table 2e:Summary of Layering Parameters of HKH-type

Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)
1.	**1567.5**	**0.8**	**0.8**
2.	**373.4**	**2.8**	**3.5**
3.	**1687.8**	**6.2**	**9.8**
4.	**438.1**	**24.2**	**34.0**
5.	**8232.9**	**-**	**-**

HKA – type Apparent Resistivity Curve

HKA – type apparent resistivity curve is obtained (Figure 5f) is a 5-layer earth model comprising 0.4m thick top soil; second layer of resistivity 450.5Ωm; 2.7m thick third layer; conductive fourth layer of resistivity 356.4Ωm ; and fractured basement resistivity 4560.6 Ωm (Table 2f)

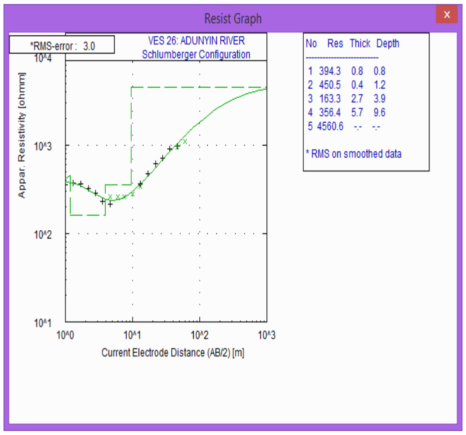

Figure 5f: Sample HKA-type Resistivity Curve

Table 2f:Summary of Layering Parameters of HKA-type

Layer	Resistivity (Ωm)	Thickness (m)	Depth(m)
1.	**394.3**	**0.8**	**0.8**
2.	**450.5**	**0.4**	**1.2**
3.	**163.3**	**2.7**	**3.9**
4.	**356.4**	**5.7**	**9.6**
5.	**4560.6**	**-**	**-**

Geoelectric Section

The results of the interpreted Vertical Electrical Sounding (VES) curves were used to generate geoelectric sections along some preferred. The geoelectric sections show both vertical and lateral variations in layer resistivity. The geologic sequence beneath the study area is composed of top soil, weathered, and basement. The proposed dam axis is underlain by three geologic layers comprising the topsoil, the weathered layer, and the fresh basement (Figure 6a). The layer parameters from the VES interpretation show that the topsoil has resistivity and thickness values ranging from 409 Ωm to 1692 Ωm from 0.7m to 2.3m, the weathered layer has resistivity and thickness values ranging from 117Ωm to 326Ωm and 4m to 8m, while fresh basement has resistivity and thickness values ranging from 491 Ωm to 2192 Ωm respectively.

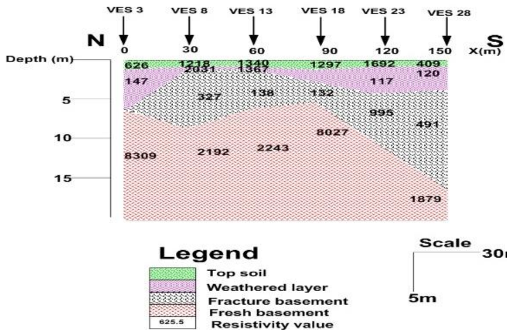

Figure 6a: Geoelectric section for the Dam Axis

The left Abutment flank is underlain by three layers representing the topsoil, the weathered layer and the fresh basement (Figure 6b). The first two units is the overburden comprising the topsoil and the weathered layer with resistivity and thickness values ranging from 625.5Ωm to 1731.5 Ωm / 0.9 m to 1.3 m and 97.7 Ωm to 202.2 Ωm / 5.2 m to 8.2 m respectively. The basement resistivity is relatively high, ranging from 627 Ωm to 1950.9 Ωm.

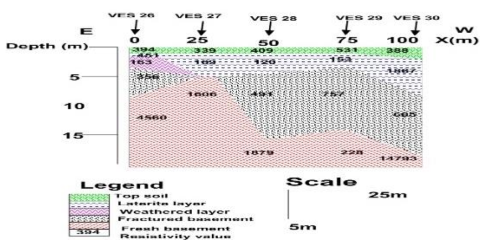

Figure 6b: Geoelectric Section for the Left Abutment

The right abutment is underlain by three geologic layers comprising the topsoil, the weathered layer, and the basement (Figure 6c). The layer parameters from the VES interpretation show that the topsoil has resistivity and thickness values ranging from 427Ωm to 1732Ωm/1m to 2m, the weathered layer has resistivity and thickness values ranging from 98Ωm to 201Ωm /0.1m to 2.5m, and basement has resistivity and thickness values ranging from 827Ωm to 8308Ωm respectively. The topsoil and lateritic layer interface have a near horizontal geometry.

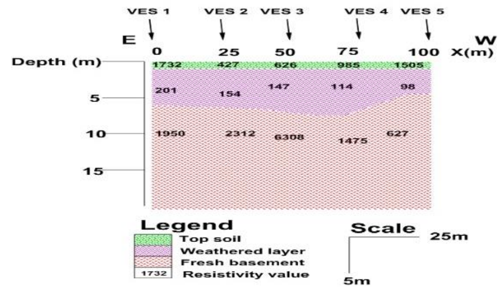

Figure 6c: Geoelectric Section for the Right Abutment

Very Low Frequency Electromagnetic (VLF-EM) Interpretation

The results of the analysis of the Very Low Frequency (VLF) data from the study area were interpreted and discussed quantitatively. The quantitative interpretations of the data involve the estimation of depths to the anomalous bodies. Plots of the filtered imaginary and filtered real in percentages (%) were made against the distance in meters (m). The graphs and plots are shown in Figure 8a to 8e respectively. In Profile 1 (Figure 8a), there is presence of positive peaks at distance of about 40m, 60m, 125m and 145m along the profile but the most prominent area is the distance 145m. These peaks reveal the presence of possible weak zones i.e. fractured zones in the bedrock. These zones are characterized by high conductivities implying that the area has low resistivity indicating fracture or weathered layer. There are positive peaks in the Profile 2 (Figure 8b). They occur at distance of 10m.These peak indicate that the zone is a weak zone and is probably fractured and thus will allow fluids to infiltrate into the basement and into the aquifer. In Profile 3 (Figure 8c), there are positive peaks at distances 25m, 35m, 55m, 70m, 90m, 110m and 125 m, respectively.

The zones are possibly weak zones, i.e. fractured zones. The most prominent of these areas occurs at distance 25 and 90m. In Profile 4 (Figure 8d), positive peak at distance 5 m which is the only suspected for fracture along the profile This weak zone is probably due to fracture or faulting of the bedrock. In Profile 5 (Figure 8e), there is presence of positive peaks at distance of about 5m while the remaining part of the profile is moderate. This peak reveals the presence of possible weak zones i.e. fractured zones in the bedrock. The results from the Vertical Electrical Sounding (VES) and Very Low Electromagnetic frequency (VLF) indicated sharply the nature of subsurface geology of the study site which are interpreted as mainly consist of the top soil, followed by weathered layer and the basement. The three layers that were observed at all point of investigation through the three methods employed for the study were consistent, making the result viable with a vivid conclusion. The Very Low Electromagnetic frequency (VLF) gave some positive peaks of filtered real variation along each profile,these peaks reveal the presence of possible weak zones i.e. fractured zones in the bedrock.

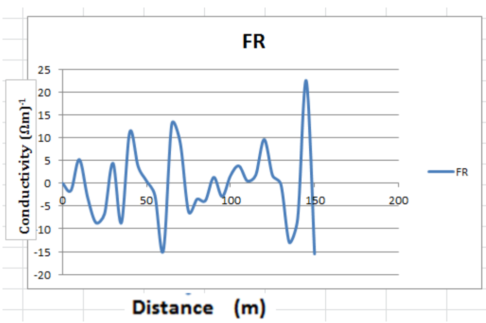

Figure 8a: VLF-EM plot of profile 1 along the Dam axis

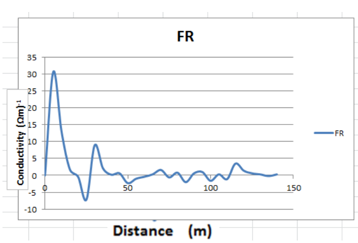

Figure 8b: VLF-EM plot of profile 2 Downstream

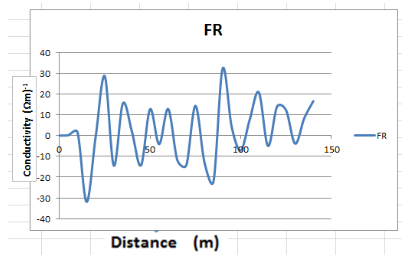

Figure 8c: VLF-EM plot of profile 3 Upstream

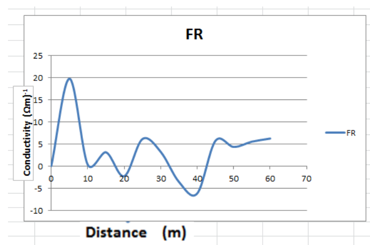

Figure 8d: VLF-EM plot of profile 4 Right Abutment

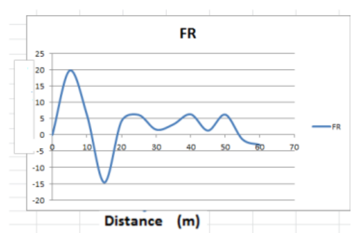

Figure 8e: VLF-EM plot of profile Left Abutment

Fence Diagram

This represents three dimensional views of the geo-electric sections. The basement relief as revealed from the fence diagram (Figure 7) slopes from the dam axis to the abutments. The bedrock is closer to the surface along the dam axis with thin overburden. However, at the abutments, the overburden is relatively thick. The bedrock is highly fractured beneath the river axis and extended toward the left abutment while fresh basement is closer to the surface at the right abutment. The fractures beneath the proposed dam axis may pose serious threat to the dam in term of future seepage; The dam should be shifted toward the right abutment by 20m and excavation should be done up to depth of about 5m, the materials so removed could be used for the construction of the embankment and the filter materials.

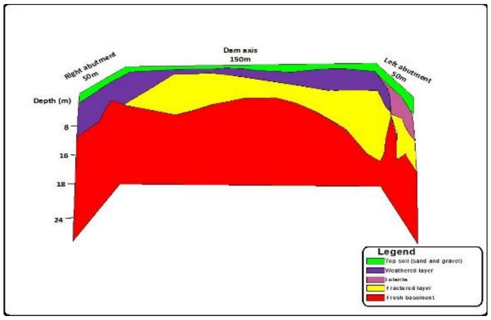

Figure 7: Fence diagram of Proposed Adunin River.

Conclusion

Six resistivity sounding curve types were obtained from the study area and these are the H, HA , KH, HKH, and KHA curves. The geologic sequence beneath the study area is composed of top soil, weathered basement, fractured basement, and fresh basement. The topsoil is composed of clayey-sandy and sandy-lateritic hard crust with resistivity values ranging from 339-1971 ohm-m and thickness of 0.7-1.3 m. The weathered basement resistivity is within the range of 98-3026 ohm-m and thickness value of 0.3-7.0m. The fractured basement layer resistivity values vary from 163–4049 ohm-m while its thickness ranges from 2.7 to 17m. Fresh *basement has resistivity value range of 228 to14793 ohm-m.* The quantitative interpretation of the VLF data involves the estimation of depths to the anomalous bodies. Plots of the filtered imaginary and filtered real in percentages (%) were made against the distance in meters (m) to produce graphs /plots. In all the Profiles, there is presence of positive peaks at some distances but the most prominent area is that of 145m. These peaks reveal the presence of possible weak zones i.e. fractured zones in the bedrock. These zones are characterized by high conductivities implying that the area has low resistivity indicating fracture or weathered layer. The bedrock is highly fractured beneath the river axis and extended toward the left abutment while fresh basement is closer to the surface at the right abutment. The fractures beneath the proposed dam axis may pose serious threat to the dam in term of future seepage. The dam should be shifted toward the right abutment by 20m and excavation should be done up to depth of about 5m, the materials so removed could be used for the construction of the embankment and the filter materials. Further investigation is recommended for the site for proper and accurate understanding of the subsurface. The outcome of this proposed additional investigation might help to reveal to what extent a well selected grouting curtain of lean concrete would be done to reduce the envisaged seepage to the barest minimum.

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