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RESEARCH ARTICLE

USE OF THE ELECTRICAL RESISTIVITY METHOD IN THE INVESTIGATION OF THE AXIS OF A SMALL EARTH DAM, ANGWARE AREA, JOS PLATEAU, NORTHCENTRAL NIGERIA

*[1]Bulus Joseph Azi, [2]Guyit Peter Morgak and [3]Odewumi Shola Christopher

[1]Department of Geology, University of Jos, P.M.B. 2084, Jos, Nigeria
[2]Department of Civil Engineering, Plateau State Polytechnic, Barkin Ladi, Nigeria
[3]Department of Science Laboratory Technology, University of Jos, Jos, Nigeria

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ABSTRACT

An engineering geophysical investigation of the site of the proposed Jarawa Kogi small earth dam, located in Joseast Local Government Area (L. G. A), Plateau State, Nigeria, was carried out. The investigation involved the electrical resistivity method which utilized the Schaumberg array. A total of twelve (12) vertical electrical sounding (VES) stations were occupied along the proposed dam axis. Four subsurface layers were delineated. These include, from top to bottom, the topsoil, a laterite layer, a weathered basement layer and the bedrock. Overburden thickness along the axis is quite significant, with depth to the competent bedrock in the range of 4.9 - 39.3 m. Generally, the Basement slopes onto the current position of the river channel. This disposition will aid base flow into the river channel from the shoulders. The bedrock is characterized by two major depressions and two minor depressions. These depressions act as receptacles for thick accumulation of alluvium. The fracture zone delineated in the bedrock is limited, so that it may not pose serious problem to the integrity of the proposed dam. The bedrock is directly overlain by a thick layer thought to be weathered material. This material may not help prevent water seepage through the foundation of the dam embankment. Also, all metallic objects to be buried underground must be treated against corrosion.

INTRODUCTION

Dams are among the biggest and most important projects in civil engineering (Coduto 1999). For geologic, hydrologic and topographic basis, there are limited numbers of ideal sites for dam. Pre-construction site study is a precondition for the building of dams and other hydraulic structures on undesirable subsurface features such as concealed stream channels, near-surface fractures, fissures e.t.c. The unpredictability of the near-surface ground often complicates site investigations and budgetary constraints may limit the number of boreholes. Geophysics can provide powerful tools to complement other forms of site investigation. Geophysical studies carried out prior to the intrusive investigation in form of borings and trial pits may locate anomalous areas associated with significant subsurface features. The identification of anomalies allows borings and trial pits to be appropriately targeted. The suitable location of borings on the basis of previous geophysical surveys may result in borehole data being more representative of site conditions. Essentially, geophysics may enhance the value of borehole data. On a complex site, geophysics may be utilized to determine the geology between boreholes. Since interpolation between borehole logs may be ambiguous.

***Corresponding author: Bulus Joseph Azi**
Department of Geology, University of Jos, P.M.B. 2084, Jos, Nigeria

Comparison of geophysical survey results with directly obtained geological information that permits the extrapolation of geophysical results into areas where little or no borehole information is available. On large sites in particular, the design of the spatial location of direct sampling points may be contentious (Ferguson 1992) and important underground targets may be missed completely. Electrical resistivity method is one the most effective and environmentally friendly approaches to evaluating engineering sites generally and particularly for evaluating dam sites. The proposed Jarawan Kogi dam (Figure 1) is a small earth dam project intended at supplying potable water to Angware community in Joseast L.G.A. of Plateau state northcentral Nigeria. The Jarawa Kogi River took its source from the high Jarawa Hills area that drains the eastern parts of Angware town western part of Saradan and Gurgu villages. To avoid drilling of numerous boreholes through the soil into the bedrock which may enhance hydraulic contact between the proposed reservoir and any fracture at depth within the site, geophysical technique which is rapid to implement and cost effective. This geophysical investigation is thus aimed at delineating the geophysical/geologic features such as overburden thickness, concealed basement morphology, fractures/ seepage channels in the subsurface thus, enabling the evaluation of the feasibility of the area for the establishing a small earth dam and reservoir.

The information provided by the study is expected to aid the dam embankment design process so that likely losses through seepage from the reservoir can be analyzed and prevention devices incorporated. Dams intended for water supplies require a low tolerance of seepage losses. Besides, the design of dam structures must be adapted to the existing site conditions (Ajayi *et al.,* 2005) to minimize the losses. Failure to do any of these may invariably result in unplanned seepage and/or total collapse of the structure (Olorunfemi *et al.,* 2000 a; Olorunfemi *et al.,* 2000 b). Biswas and Charttergee (Biswas and Charttergee 1971) examined causes of dam failures worldwide and discovered that 25% of the failures were due to geotechnical problems associated with seepage, inadequate seepage cut-off, faults, settlements and landslides.

Location, Physiography and Geology

The axis of the proposed Jarawan Kogi small earth dam is located on River Jarawan Kogi. This river drains the eastern part of Angware town and western part of Saradan village of Joseast Local Government Area (L.G.A.) of Plateau State, Nigeria (Fig. 1). The dam site is found about 33 km to the northeast of Josnorth, the capital city of the state. The site for the dam axis is accessible through an untarred road that branches off to the east from Jos-Bauchi main road at Ringin Gani junction. The area is characterized by the climatic conditions in the so-called high plateaux climate of north-central Nigeria. Here the rainfall is about 140 cm per annum (Iloeje 1976), and the vegetation is that of the guinea savanna belt. On account of intense farming on the flood plain in and around the dam site, the original vegetation has been

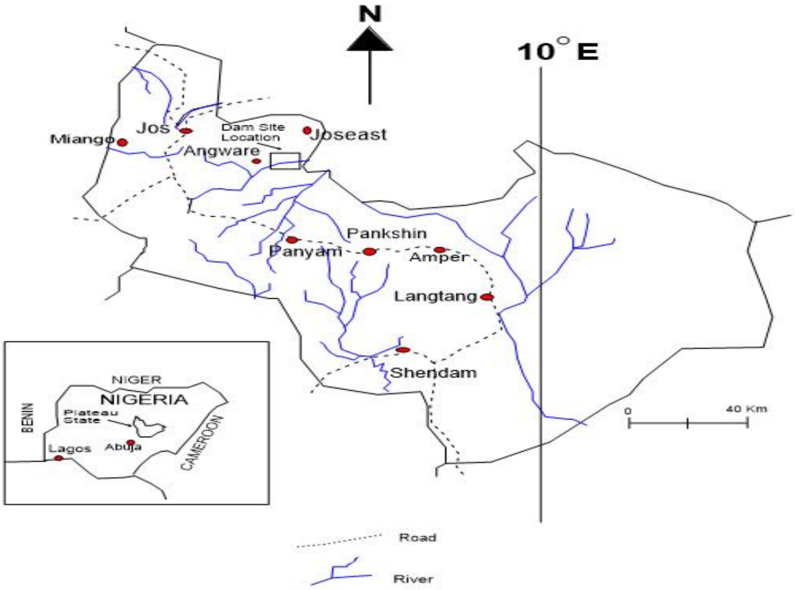

Fig. 1. Location map of the study area

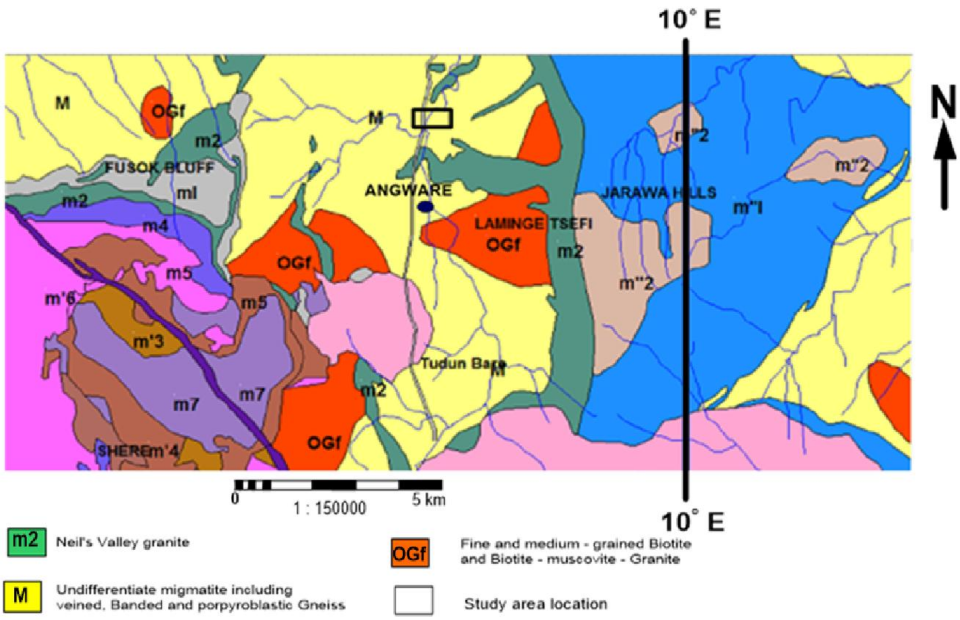

Fig. 2. Regional geology map of the study area (modified from GSD1994)

obliterated. The country around the site of the dam is characterized by highly undulating topography. Ridge-like, approximately N-S and E-W trending hills, which rise to about 1200 m above the local plain (a.i.p), border the site to the north and to the east. The intervening lowland constitutes the alluvial plain of River Jarawa Kogi. The topography along the axis varies generally between 908 and 914 m above mean sea-level (amsl). The area surrounding the dam site is drained by tributaries of River Jarawa Kogi. The drainage pattern is essentially dendritic. As Figure 2 illustrates, the study area is located within the Basement terrain in the Younger Granites Province of the north-central Nigeria. The crystalline Basement rocks underlying the immediate vicinity of the proposed dam are concealed in the subsurface around the dam site. The rocks are made up of light coloured, mesocrystalline granitic migmatites related to the Pre-Cambrian Older Granites of the Jos Plateau (McLeod *et al.,* 1971). They are composed essentially of feldspar, quartz and biotite. Enclaves of amphibolites are common in the rocks with very low fracture density. Alluvial deposits composed essentially of sandy clay and clayey sand, obviously derived from the neighbouring crystalline rocks, cover the rocks along the proposed dam axis.

METHOD OF STUDY

A geophysical traverse was established along the 220 m long proposed dam axis, twelve (12) sampling stations were marked out for occupation along the axis as shown in Figure 3.

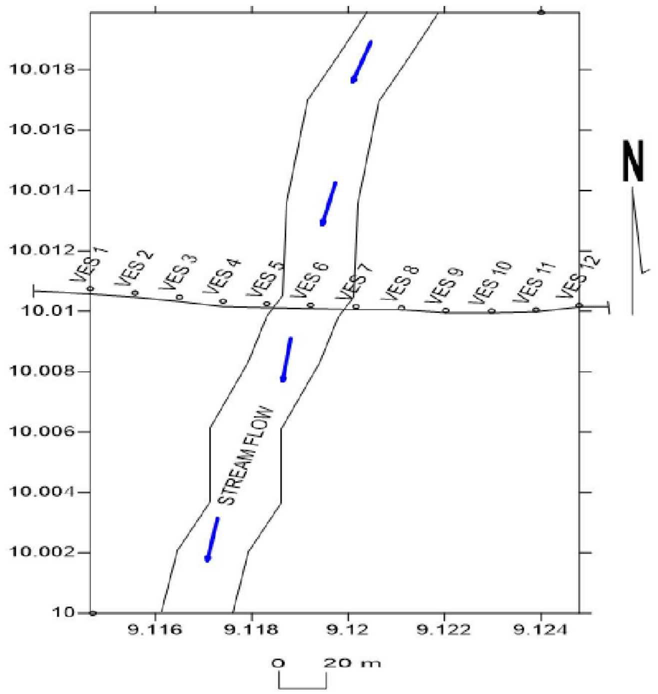

Fig. 3. Layout map of the proposed Jarawa Kogi dam project site showing geophysical transverses and vertical electrical points

Stations 1-10 have an inter-station spacing of 20 m, this segment constitutes the main dam embankment, and the spillway is expected to be located between Station 10 and Station 12. Table 1 contains the coordinates of the geophysical stations as established with the aid of the Garmin Extrex Global Positioning System (GPS) unit. The geophysical investigation involved the vertical electrical sounding (VES) technique for which the Schlumberger electrode configuration was adopted. The current electrode spacing (AB/2) was between 1 and 125 m. The electrode array was oriented perpendicular to the dam axis at measurement points. The ABEM SAS 1000 digital terrameter was used for the collection of the VES data. The field data were presented as depth sounding curves and their resultant resistivity cross – sections, some of which are shown in Fig. 4 A-D. The sounding curves were interpreted quantitatively. The interpretation involved manual partial curve matching and subsequent computer iteration. The curve matching results and apparent resistivity data recorded in the field were used for the iteration process. The IPI2Win V.2.1 computer software package (2001 version) developed in Moscow, Russia was used for the iteration.

RESULTS AND DISCUSSION

Subsurface Layers and their Geoelectric Characteristics

The VES curves obtained from the investigation include the H, Q, KH, and QH types, with the H most predominant. The depth sounding results are presented as a geoelectric section in Figure 5. As this figure illustrates, four subsurface layers with distinctive geoelectric characteristics were delineated. These include the topsoil, laterite layer, weathered basement layer and fresh basement bedrock. The topsoil is composed of gravelly sand, sandy clay and clayey sand. The resistivity values of this layer range from 100.8 to 226.4 ohm-m. The thickness of the layer is not uniform with a range of 0.4 - 4.7 m. The topsoil was map on VES 2, VES 3, VES 4, VES 5, and VES 9 only. The laterite layer is encountered on VES 1, VES 6, VES 7, VES 8, VES 10, VES 11 and VES 12. The resistivity ranges between 326.5 and 4309 ohm-m. Its thickness is quite variable between 0.9 - 7 m. The weathered/fracture basement has resistivity values which is remarkably low, ranging from 20.76 to 271.8 ohm-m. This is the thickest of all the layers overlying the bedrock. It is characterized by a thickness range of 8.7 - 39.3 m. Although missing in VES 7 the layer spans the entire length of the axis, its thickest values are found in the bedrock depression that was mapped on VES 6 and VES 9. The rockhead occurs between 4.9 - 39.3 m depth.

Bedrock Relief and Structural Disposition

The bedrock is characterized by two major depressions and two minor depressions. Generally, the shoulder slopes onto the river channel; this may aid base flow into the river. The delineated depressions act as receptacles for thick accumulation of weathered rocks. The valves of the depth to competent bedrock at the VES locations are shown in Table 3. The bedrock displays evidence of unconfined fracturing beneath VES 6. The fracture zone delineated in the bedrock is isolated and apparently limited in extend, so that it may not pose serious problem to the integrity of the dam.

Table 1. Location of geophysical observation points

Station	Easting	Northing	Remarks
1	9.11465	10.01075	
2	9.11558	10.01061	
3	9.1165	10.01047	
4	9.11740	10.01034	
5	9.11831	10.01025	
6	9.11922	10.01021	River channel
7	9.12016	10.01016	
8	9.12110	10.01011	
9	9.12202	10.01003	
10	9.12297	10.01001	
11	9.12389	10.01005	
12	9.12479	10.01020	

Table 2. VES Interpretation results

VES	Depths (m) d1/d2/……../dn-1	Resistivity (Ω-m) ρ 1/ ρ 2/……../ ρ n-1	Remarks	TYPE CURVE
1	0.4/7.0/26.7	2056/446.5/271.8/968.4	Fresh bedrock	QH
2	1.8/23.2	181/37.9/11563	Fresh bedrock	H
3	1.0/14.9	210.3/20.8/7107	Fresh bedrock	H
4	5.5/30.2	101/51.1/27100	Fresh bedrock	H
5	2.3/21.1	100.8/91.9/543.6	Fresh bedrock	H
6	2.1/4.7/39.3	226.4/1184/48.5/1313.7	Fresh bedrock	KH
7	0.9/4.9	4309/1691/1119.4	Fresh bedrock	Q
8	1.65/6.98/12.05	326.5/106.7/25.81/1389.2	Fresh bedrock	QH
9	4.7/33.7	146.8/99.2/1811	Fresh bedrock	H
10	1.6/12.2	513.5/59.5/1309.7	Fresh bedrock	H
11	1.7/18.7	333.8/68.7/1555	Fresh bedrock	H
12	0.9/8.7	439.7/75.4/717.3	Fresh bedrock	H

Table 3. Depth to Competent Bedrock at VES Points

VES	Depth to Rockhead (m)	Remarks
1	26.67	
2	23.2	
3	14.86	
4	30.17	
5	21.09	
6	39.32	Unconfined fracture (39.32m)
7	4,91	
8	12.81	
9	33.7	
10	12.24	
11	18.65	
12	8.69	

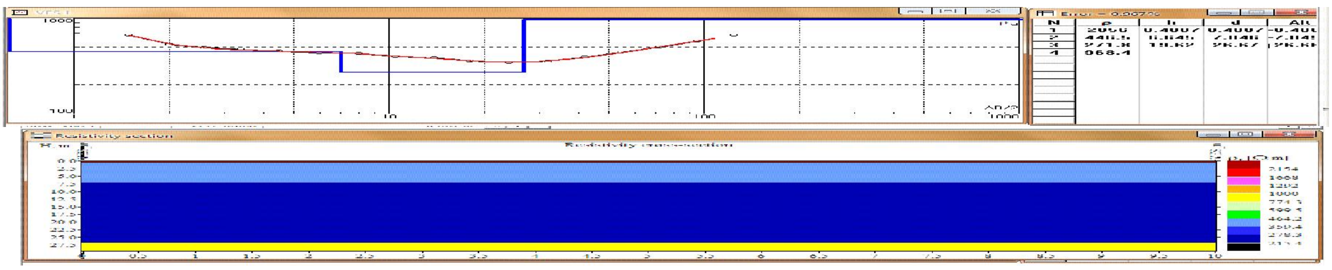

Fig. 4 A. Typical depth sounding curves and resistivity cross-sections recorded along the proposed dam axis for VES 1

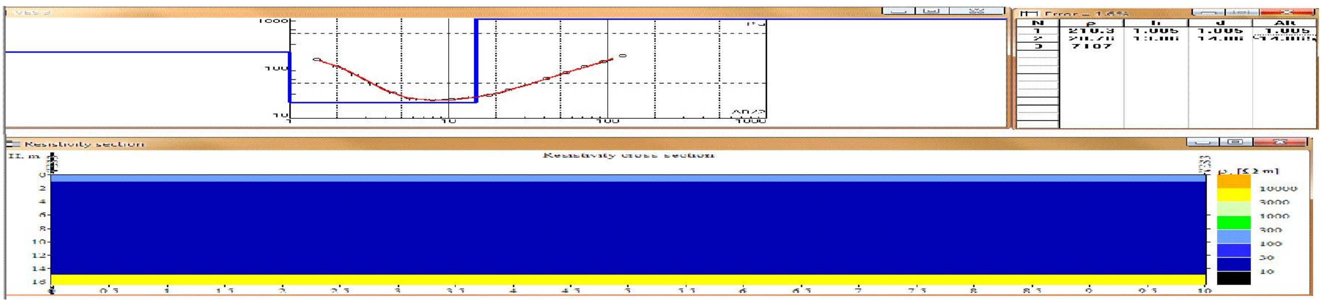

Fig. 4B. Typical depth sounding curves and resistivity cross-sections recorded along the proposed dam axis for VES 3

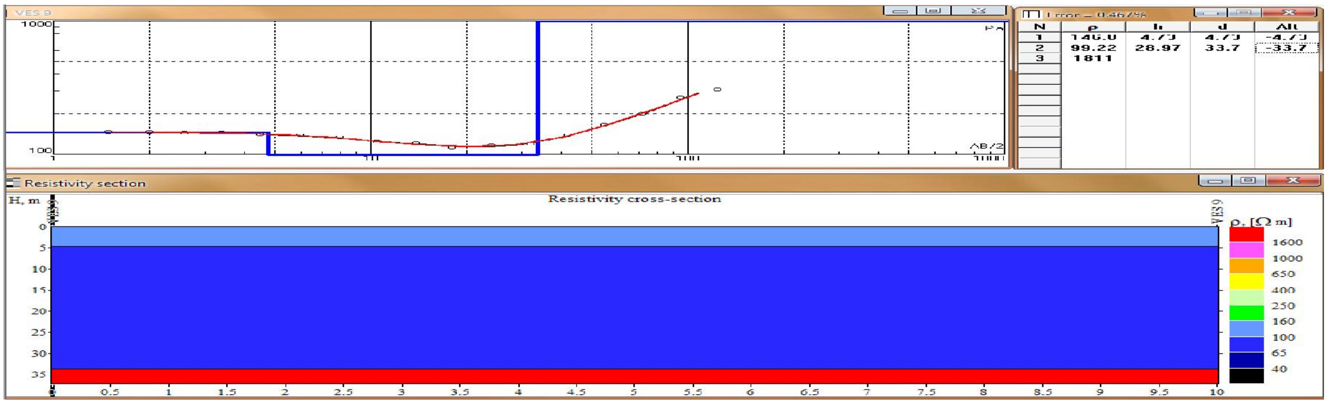

Fig. 4C. Typical depth sounding curves and resistivity cross-sections recorded along the proposed dam axis for VES 9

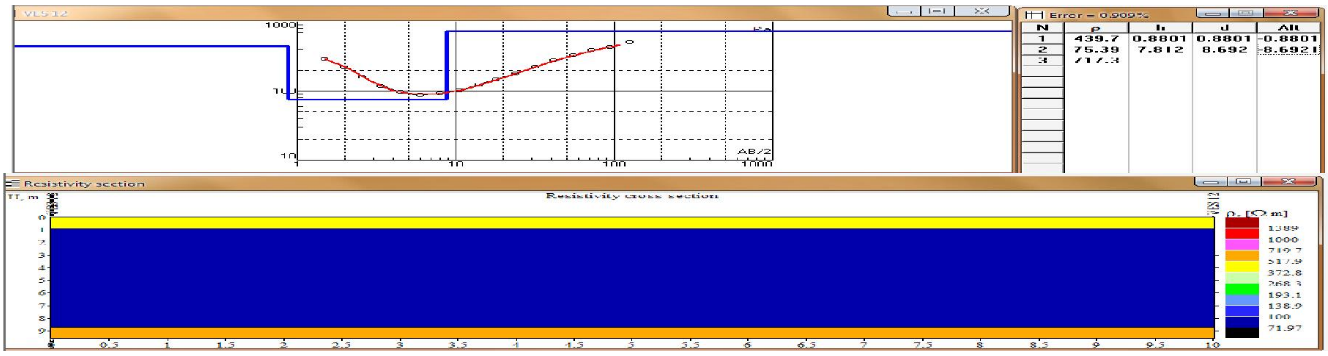

Fig. 4D. Typical depth sounding curves and resistivity cross-sections recorded along the proposed dam axis for VES 12

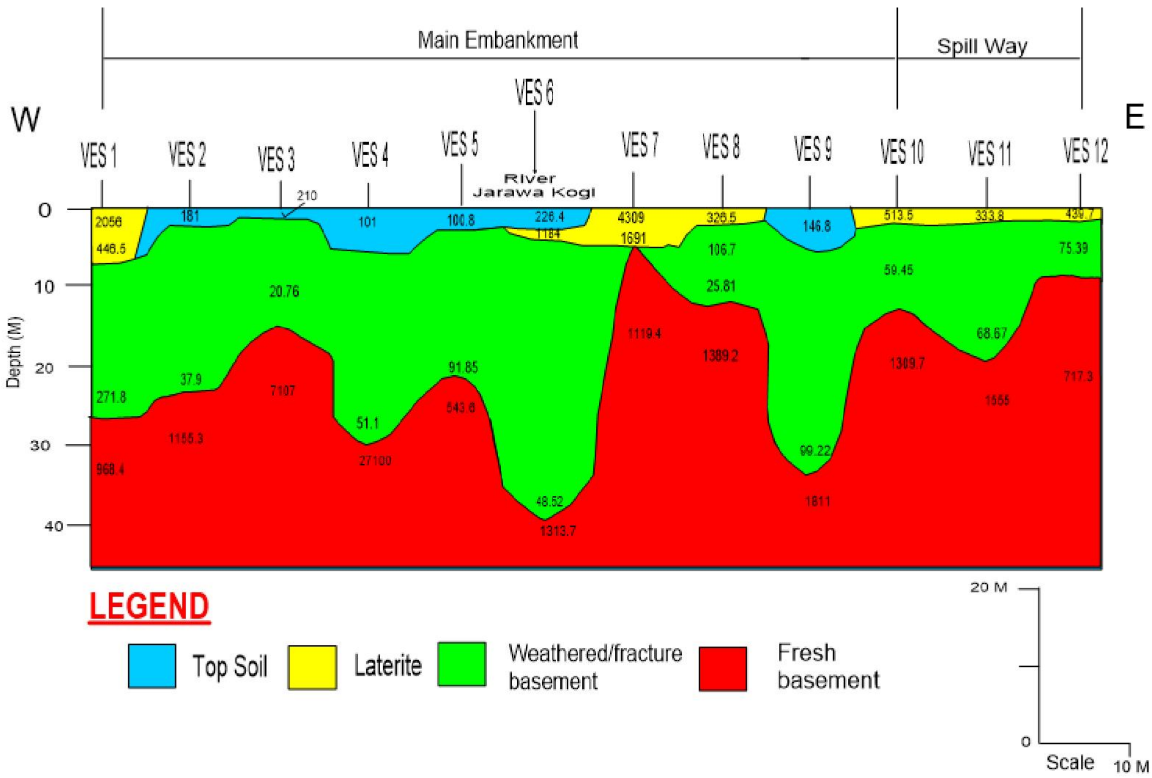

Fig. 5. Geoelectric section along the proposed dam axis

Engineering Nature of Subsurface Layers

As the geoelectric section (Fig. 5) shows, the bedrock is directly overlain for the entire length of the proposed axis by a thick layer of materials whosed geoelectric signatures are indicative of weathered rocks. This material cannot prevent water seepage through the foundation of the dam embankment

Conclusion

An engineering geophysical investigation of the site of the proposed Jarawa Kogi earth dam was carried out. The investigation, which involved the electrical resistivity method, aimed at obtaining information on the subsurface engineering geological conditions of the proposed dam site. This information is a sine qua non for dam site engineering. The study concludes that the site is made of up of four geological layers in the subsurface. The layers include the topsoil, a laterite layer, a weathered basement layer and the crystalline bedrock. The layers were distinguished on the basis of diagnostic geoelectric characteristics. It is also concluded from the study that the depth to the competent bedrock is relatively considerable. With a range of 4.9 - 39.3 m. The Basement surface generally slopes onto the river channel from both shoulders; this disposition will aid base flow into the channel. The Basement dose not displays evidence of severe fracturing.
Finally, the thick layer of the weathered basement, which spans the entire length of the proposed dam axis but missing in VES 7, is incompetent with resistivity values ranging from as low as 20.76 to 271.8 ohm-m. Although this material is not appropriate for filling the core of the embankment.

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