Research Journal of Applied Sciences 3 (7): 484-489, 2008
ISSN: 1815-932X

Geophysical Investigation of Damsite in a Sedimentary Terrain: A Case Study

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Abstract: Geophysical investigation was carried out at a site in Okada town near Benin City, southwsetern Nigeria, in order to evaluate the suitability of the area for a damsite. The survey was conducted along the proposed dam axis (about 850 m long) and its vicinity by using Vertical Electrical Sounding to unravel the subsurface profile, which in turn determines if there would be any subsurface lithological variation (s) that might lead to structural failure in the dam foundation. To achieve the above objectives, six sounding stations were located and fully occupied along the dam axis while 2 VES were conducted close to the dam axis. The data obtained were subjected to 1-D inversion algorithm to determine the layer parameters. The results show that the subsurface is remarkably inhomogeneous in geological composition. The geoelectric section revealed four to 5 lithologic units defined by the topsoil, lateritic hard pan, dry sandy formation and various combinations of sandy clay, clayey sand and sand as constituting the subsurface of the proposed damsite. Resistivity values range from 1422-6895, 1201-10525, 1820-3606 and 105-9270 Ωm in the topsoil, lateritic hard pan, dry sand formation and the clayey sand/sandy clay/sand layer(s), respectively. Layer thicknesses vary from 0.5-2.0 m in the topsoil, 1.4-8.2 and 6.5-31.2 m in the lateritic hard pan and dry sandy formation, respectively. Based on these results, it is concluded that the subsurface material in the study area is highly competent to withstand the load of the proposed dam. However, resistivity values <200 Ωm at depths below about 31.7 m indicate high porosity, high clayey sand content and high degree of saturation, which are indicators of soil conditions requiring serious consideration in the design of the dam.

Key words: Geophysical investigation, sedimentary terrain, survey, layer parameters

INTRODUCTION

Water can be made available for various uses (domestic, industrial, etc.) by harnessing surface water through the construction of a dam across a river through which adequate volume of water flows. The construction of such structures normally requires adequate and thorough understanding of the subsurface geology and engineering properties of the material along river axes (Adeduro *et al*., 1987; Olorunfemi *et al*., 2000, 2004). The construction of a dam is considerably enhanced by carefully planned and well executed preliminary geophysical investigation (Drake, 1962; Ako, 1976; Ojo *et al*., 1990; Sharma, 1997). Geophysics is able to provide a broad, composite picture of the subsurface over large areas with speed and economy not attainable by other means. On this basis, a geophysical investigation was carried out along the proposed dam axis and its vicinity in Okada town with the aim of determining the character of the overburden, delineating the subsurface geologic sequence, determining the layer geoelectric parameters (layer resistivity and thickness) and determining if there would be any subsurface lithological variation (s) that might lead to structural failure in the dam foundation. The information provided by such investigation helps in planning a cost effective engineering/geotechnical investigation required to determine the engineering properties of the subsurface material of the damsite and consequently enhance the design of an adequately safe and economical foundation for the proposed dam.

Site description and geological setting: The study area is located in Okada town about 28 km northwest of Benin City, southwestern Nigeria. It falls within the geographical coordinates of latitude 6°40′-6°45′N and longitudes 5°20′-5°25′E (Obrike *et al*., 2007). The proposed dam axis crosses the Ewawa river in a west-east direction and is

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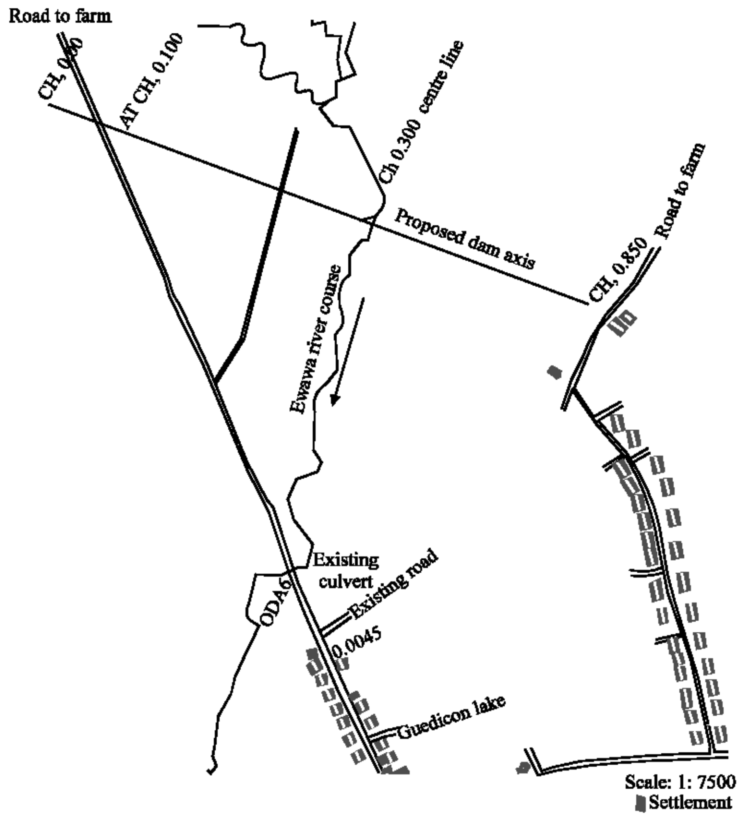

Fig. 1: Map showing the study location

about 850 m long. The area is generally low-lying with the topographic elevation varying from about 46 m to about 85 m at the highest points. The location map is shown in Fig. 1.

The study area falls within the sedimentary terrain of southern Nigeria. It consists of sedimentary rocks of the Upper coal measures and the Tertiary sedimentary rocks of the Imo clay-shale group. The northern part of the location is occupied by the False-bedded sandstone and upper coal measures while the sediments of the Imo clay-shale group cover the southern part. The sediments of the False bedded sandstone and upper coal measures consist of a sequence of false bedded sandstones, coal seams and shale, while the Imo clay-shale group consists of well laminated clayey shales with a grey to green colour. The shales contain occasional thin bands of calcareous sandstones, marls and limestone of Paleocene age. These sedimentary rocks are unconformably overlain by superficial deposits comprising clayey sands and gravelly sandy clayey soils of varying thicknesses.

MATERIALS AND METHODS

A total of eight Vertical Electrical Soundings were carried out, 6 along the dam axis, one each on the upstream and downstream side. The Schlumberger electrode configuration was used with half electrode spacing (AB/2) varying from 1-133 m and station spacing from 50-185 m. The distribution of the VES points is shown in Fig. 2. The Geopulse Tigre Resistivity meter was used for resistance measurements. Good quality data were obtained with the observational errors being <1%.

Field data were plotted on bilogarithmic graph and a preliminary interpretation was carried out using partial curve matching involving two-layer master curves and the appropriate auxiliary charts. The layered model thus obtained served as input for an inversion algorithm using the software called RESIST (Zobdy, 1989).

RESULTS AND DISCUSSION

The VES data for the dam axis (VES 1-6) show 4-5 geoelectric layers: the topsoil, lateritic hard pan/lateritic clay, dry sandy formation, clayey sand and sandy clay. The summary of the layer model interpretation and the inferred lithologies are presented in Table 1, while the VES curves are presented in Fig. 2-10. The geoelectric section across the dam axis is shown in Fig. 11. The resistivity

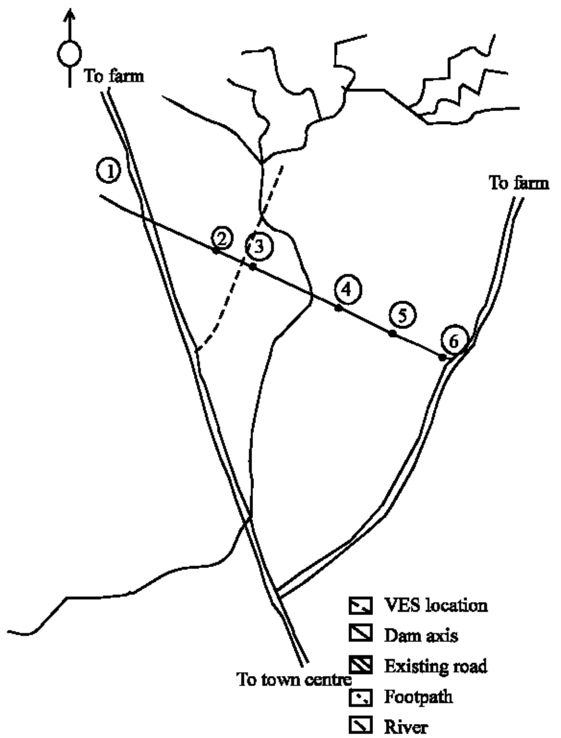

Fig. 2: Map showing the VES stations

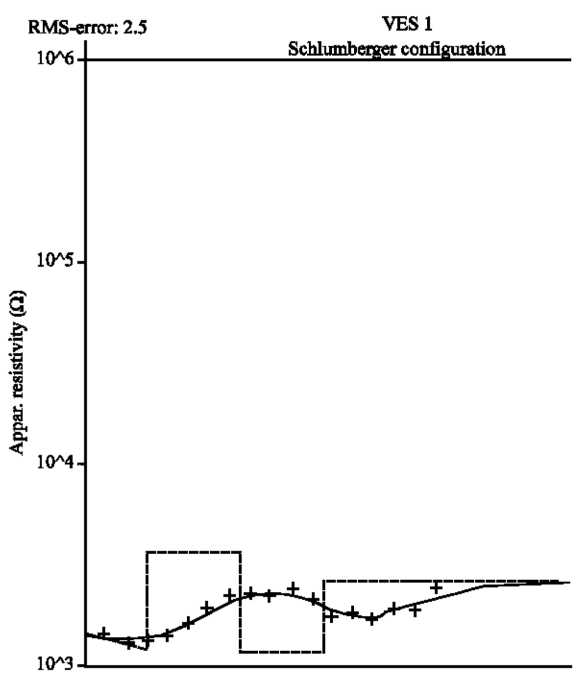

Fig. 3: VES curve for station 1

of the topsoil varies from 1422 and 6895 Ωm. While, its thickness varies from 0.5-2.0 m The lateritic hard pan

Table 1: Summary of ves interpretation

Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred lithology
VES 1				
1	1422	0.8	0.8	Topsoil
2	1201	1.6	2.4	Lateritic clay
3	2544	6.5	8.9	Sandy formation (dry)
4	1196	20.1	29.0	Clayey sand (dry)
5	2592	---	---	Sandy formation (dry)
VES 2				
1	2900	0.8	0.8	Topsoil
2	2475	8.0	8.8	Lateritic hard pan
3	4161	24.0	32.8	Sandy formation (dry)
4	708	---	---	Clayey sand (saturated)
VES 3				
1	2745	0.9	0.9	Topsoil
2	4107	2.7	3.6	Lateritic hard pan
3	3606	28.1	31.7	Sandy formation (dry)
4	105	---	---	Sandy clay (saturated)
VES 4				
1	2720	0.5	0.5	Topsoil
2	10525	2.2	2.7	Lateritic hard pan
3	2687	31.2	33.9	Sandy formation (dry)
4	265	---	---	Clayey sand (saturated)
VES 5				
1	6895	2.0	2.0	Topsoil
2	10496	2.1	4.1	Lateritic hard pan
3	2989	20.4	24.5	Sandy formation (dry)
4	1272	---	---	Sandy formation (wet)
VES 6				
1	2102	0.7	0.7	Topsoil
2	3748	1.4	2.1	Lateritic hard pan
3	1820	7.6	9.7	Clayey sand (dry)
4	9270	25.1	34.8	Sandy formation (dry)
5	734	---	---	Clayey sand (saturated)
VES 7				
1	1257	1.0	1.0	Topsoil
2	3766	4.2	5.2	Lateritic hard pan
3	1440	8.0	13.2	Clayey sand (dry)
4	3439	29.6	42.8	Sandy formation (dry)
5	36	---	---	Clayey sand (saturated)
VES 8				
1	316	0.4	0.4	Topsoil
2	2148	1.3	1.7	Lateritic hard pan
3	354	2.6	4.3	Sandy clay
4	1733	7.5	11.8	Clayey sand (dry)
5	147	---	---	Clayey sand (saturated)

horizon (2nd layer) has resistivity and thickness values which range from 1.4-8.2 m and 1201-10525 Ωm, respectively. The 3rd layer, which is dry sandy formation has resistivities ranging between 1820 and 3606 Ωm and thicknesses between 6.5 and 31.2 m. The resistivity of the 4th layer varies from 105-9270 Ωm. This layer has mixed lithologies which vary from dry clayey sand (VES 1) to saturated clayey sand (VES 2 and 4), saturated sandy clay (VES 3), wet sand formation (VES 5). The highest resistivity value (9270 Ωm) is indicative of dry sand formation at VES 6. The 5th layer as delineated at VES 1 and VES 6 indicates dry sandy formation and saturated clayey sand, respectively.

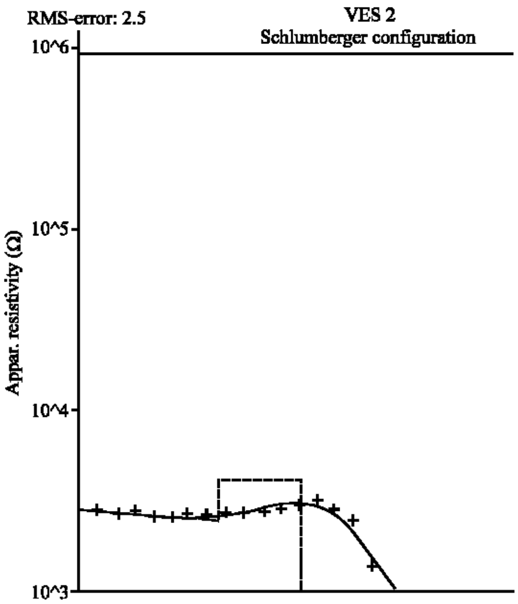

Fig. 4: VES curve for station 2

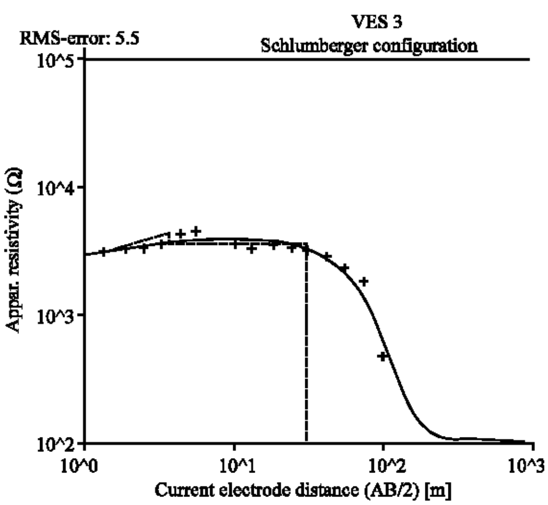

Fig. 5: VES curve for station 3

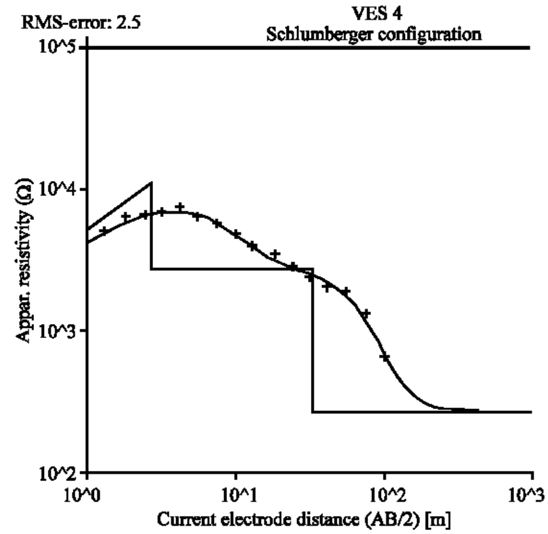

Fig. 6: VES curve for station 4

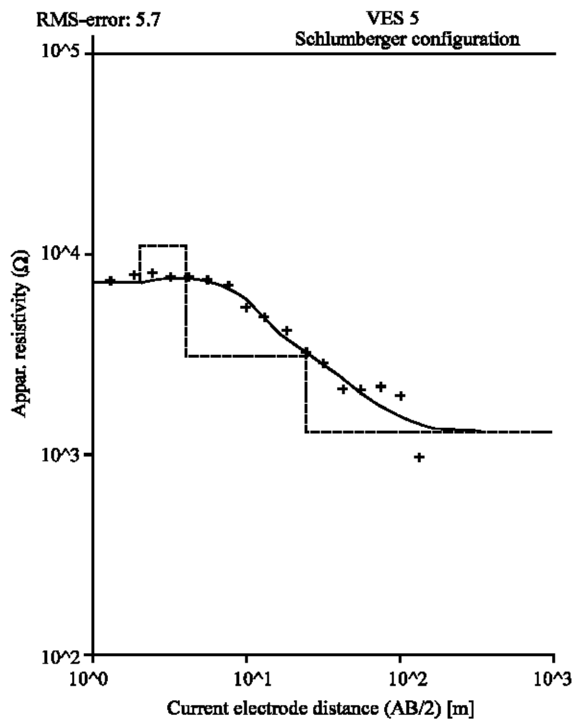

Fig. 7: VES curve for station 5

The Vertical Electrical Sounding upstream (VES 7) delineates five lithological units: the topsoil, lateritic hard pan, dry clayey sand, dry sandy formation and saturated sandy clay. The Vertical Electrical Sounding downstream (VES 8) also defines 5 lithologic units: the topsoil, lateritic hard pan, sandy clay, dry clayey sand and saturated sandy clay. The depth of the saturated zone at VES 8 appears to be shallower (by about 20 m) than other VES points also shown in Table 1. This is due to the fact that the elevation of this point is about 20 m below other VES points. It is therefore safe to adduce that the depth to the saturated layer within the study area is greater than 25 m depending on the elevation of the point under consideration.

Based on the resistivity values of the different geoelectric layers, it can be concluded that the various geologic units up to depth of 25 m are competent and can support the proposed project.

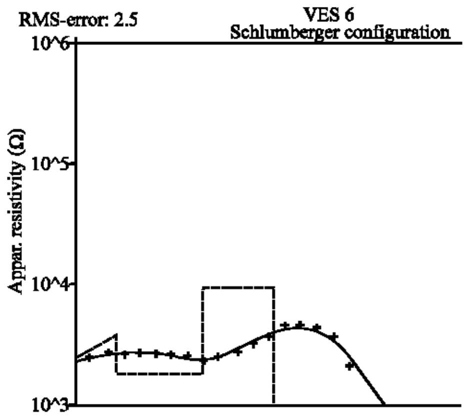

Fig. 8: VES curve for station 6

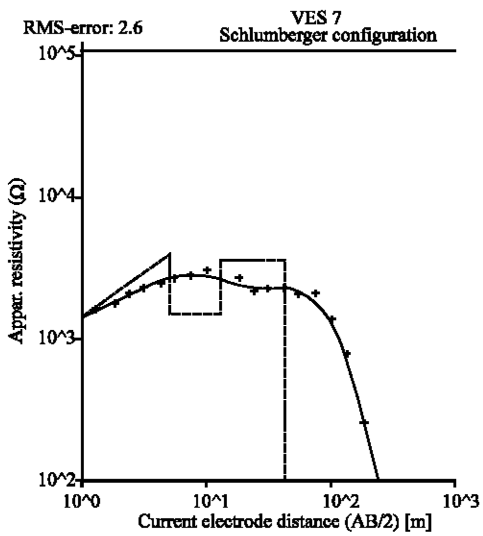

Fig. 9: VES curve for station 7

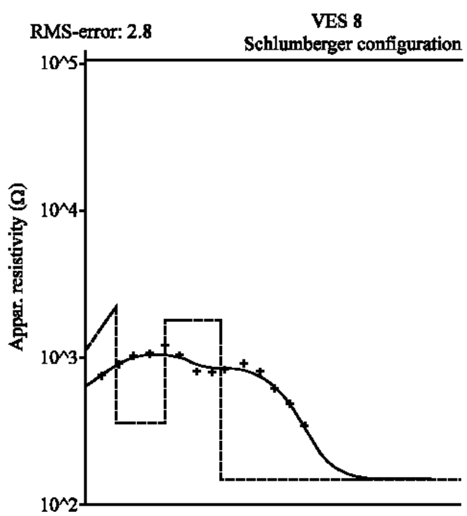

Fig. 10: VES curve for station 8

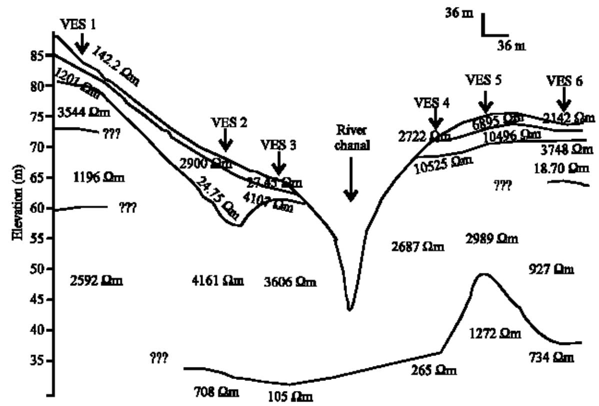

Fig. 11: Geoelectric cross-section along the dam axis

CONCLUSION

The results of the interpretation of vertical electrical sounding data for the study area show that the subsurface is remarkably inhomogeneous in geological composition. The geoelectric section revealed 4 to 5 lithologic units defined by the topsoil, lateritic hard pan, dry sandy formation, sandy clay and clayey sand.

It was observed that the depths to the saturated layer within the study area are >25 m depending on the elevation of the point under consideration.

Based on the resistivity values of the different geoelectric layers, we have concluded that the various geologic units, up to depth of about 25 m are fairly competent and can support the proposed project. The findings of this study are envisaged to provide reliable background information for geotechnical/engineering investigation and guide in the design of dam structure in the area.

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