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APPLICATION OF ELECTRICAL RESISTIVITY METHOD FOR FOUNDATION STUDIES AND GROUNDWATER INVESTIGATION AT FEDERAL UNIVERSITY DUTSINMA, KATSINA STATE, NIGERIA

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ABSTRACT

Geophysical investigation for engineering and environmental studies has been undertaken at the permanent site of Federal University Dutsin-ma, Katsina state. The study was aimed at assisting in the planning and development of infrastructure at the University, and also to investigate the groundwater potential of the permanent site at Turare which is less than 20km south of the current site the University occupies. Twenty-four Vertical Electrical Soundings (VES) were conducted along predetermined profiles at the permanent site in Dutsin-ma. Terrameter SAS 300 system was used for data acquisition at stations interval of 100m using Schlumberger array. Maximum current electrode separation (AB) of 200m was used. Interpretation was performed using computer software (Ipi2win and surfar7). The interpreted result was used to produce geoelectric and geologic sections. The result of the study indicated that the area is underlain by three to four subsurface layers. The resistivity of the first layer range from 25.5Ωm to 429.25Ωm with an average thickness of 2m. The layer is referred to be the superficial cover, composed of sandy, clay, silt and weathered laterite. The second Layer has resistivity values between 95.5Ωm to 553.2Ωm which is the weathered basement rock and fresh laterite in some areas/places. And the third layer has relatively low resistance ranging from 81.5Ωm to 240.8Ωm. This layer is the fractured basement with varying thickness. The fourth layer is the crystalline basement rock with resistivity value much greater than 1000Ωm and infinite thickness. The investigations showed that the north-western part of the study area is dominated mainly by clayey top soil with an average thickness of 4m. It is therefore recommended that this incompetent material should be excavated before constructing any heavy structure. The southern part of the study area contains fresh basement rock mostly at shallow depth, with outcrops in some places, which could be used for construction of landfill or refuse disposal site. The northern part and central of the study area is dominated by weathered basement and mostly fractured rocks and with more groundwater potential that could be exploited for use.

Keywords: Geoelectric section, Geologic section, Aquifer, Vertical Electric Sounding (VES), Groundwater and Foundation

INTRODUCTION

The foundation of any structure is meant to transfer the load of the structure to the ground without causing the ground to respond to uneven and excessive movement. In order to achieve this, most buildings are supported on pads, strips and rafts or files. Therefore the knowledge of the probable cause of rampant failure of building foundation due to subsurface movements giving rise to cracks or structural differential settlement has been of great concern to Engineers. The need for pre – foundation studies has therefore become imperative due to failure of structures such as buildings, tarred roads, and bridges so as to prevent loss of valuable properties and lives that always accompany such failures. Foundation study usually provides subsurface information that assists civil engineers in the design of civil engineering structures (Akintorinwa and Adeusi, 2009). This has helped to distinguish between a continuing movement, which is often more like to be a problem and those of single events, which may not require repairing, depending on the extent of damage. However, adequate insight on the types and patterns of foundation – based cracks and their evaluation has necessitated the need to consider the geological and geophysical basis for building failures and adequate precaution taken to minimize such disasters. Most house settling cracks are basically caused either by the differences in expansion and compression ability of the construction materials, relative changes in the shapes and size of saturated soils or the dynamic earth (Robert, 1996).

The amount, type and direction of foundation movements are commonly noted from building of brick or masonry blocks. These in turn reveal the risk of vertical collapse or horizontal dislocation. The risk could be traced to the height of construction, materials used for the building, site factor, earth loading or water. Other factors include the seismic action, atmospheric disaster and accident (George, 2010). If cracks are old with no sign of continuing or recurrent movement, building inspectors accept monitoring rather than recommending quick repairs.

Moreover, the developments of new cities as well as new University sites generally require a detailed evaluation of the subsurface of the site so proposed. Foundation study of a new site is necessary so as to provide subsurface and aerial information that normally assist civil engineers, builders and town planners in the design and siting of foundation of civil engineering structures (Omoyoloye, *et.al.,* 2008). The aim of this research is to assist in the planning and development of infrastructures in the university using the ERT method, by determining the groundwater potential of the area.

The Study Area

Turare a village where the University permanent site is situated lies within the northern Nigerian Basement Complex, in Northern Nigeria. It lies between latitudes 12˚ 38´36´´N-12˚ 42´03´´N and longitude 7˚ 60´39´´E-7˚ 53´00´´E within the Musawa Sheet 56. The mean elevation of the area is about 680m above mean sea level.

Figure 1 is the proposed permanent site of the University location map showing the site to be investigated. The study area (university permanent site), where the profiles was laid is bounded by latitude 12˚42´64´´N-12˚ 43´11´´N and longitude 7˚66´44´´E - 7˚60´ 00´´E with an average elevation of 650m above sea level.

Climate & Vegetation

The area is in the intercontinental tropical hinterland belts of Nigeria with distinct dry and wet seasons. The dry season occurs between October to March, while the wet season occurs between April to September. Therefore, the vegetation of the area is of Sudan Savannah which is covered with grasses, sparse shrubs and large isolated trees. However, the vegetation cover helps to trap rainwater and prevent severe subsurface run-off which usually give rise to high erosion and gullying

The General Geology of the Study Area

Dustin-ma is part of the Northern Nigerian basement complex. Northern Nigeria is generally underlain by gneisses, migmatites and metasediments of Precambrian age which have been intruded by a series of granitic rocks of late Precambrian to lower Paleozoic age (Wright *et al.*, 1970).

The rocks in this (Northern Nigeria) area are divided into

(i) A crystalline complex of migmatite and gneisses probably of Dahomeyan age including relics of an ancient Berriman metasedimentary sequence,

(ii) Younger metasediments which are believed to be of upper Proterozoic in age and were deposited on the granitised basement and folded along with it during the Pan – African Orogeny.

The rocks are of low matemorphic grade and are now represented as synclinal troughs among older rocks in north western Nigeria (Wright *et al*., 1970). See figure 2.1 and 2.2.

MATERIALS AND METHODS

Vertical Electrical Sounding (VES) using DC resistivity method was carried out in the study area. The data was acquired using Schlumberger array. Profiles of 400m length that are mostly parallel to each other were established at different locations to cover the area. In this survey, the instruments used for data collection are: Terrameter SAS 300 system and its component, magnetic compass, field hammer, cutlass, ranging pole, pegs, electrodes, cable and reel, measuring tape, global positioning system (GPS), and other accessories. The terrameter SAS 300 which stand for (signal averaging system) that is where consecutive readings are taken automatically and results are averaged continuously and presented automatically on the display. When the operator presses the measure button, the microprocessor runs through check circuit and positions, it also checks the battery conditions and usability of selected parameters. This checkup takes only few seconds, if necessary information comprising beeper signals and error codes tells the operator to check circuit or change parameter. When satisfied, the micro – processors automatically start the measurement cycle and after all the readings have been taken it puts the instrument in a standby mode with the final result displayed.

The terrameter is composed of deep penetrating resistivity meter with an output for maximum current electrodes separation (AB) of up to 200 meters under favourable condition. The resistivity is calculated automatically that is $^{\Delta V}/_{I}$ and displayed in digital form i.e. in kilo – ohms or milli – ohms, up to a range of 0.5 milli – ohm to 1999 kilo – ohms.

RESULTS AND DISCUSSIONS

The data analysis for the vertical electrical sounding (VES) was performed using computer software (Ipi2win). Different geophysical and geologic works carried out in various places were considered in order to arrive at the resistivity values used for the interpretation of this present work. The work of Hassan (1987), Shemang (1990), Dogara & Ajayi (2001), Olugbenga (2009) were considered. These were compared with resistivity values given by Telford *et al*., (1990).

Table 1: Interpreted Model & Lithology

STATION	LAYER NUMBER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	LITHOLOGY
Prf 1 VES 01	1	21	1.35	0.00	sandy, clay & silt
	2	93	10	1.35	Weathered basement
	3	41837	Infinity	11.35	Fresh basement
Prf 1 VES 02	1	1421	2	0.00	Top soil (lateritic)
	2	240	42.7	2	Weathered basement
	3	72511	Infinity	44.7	fresh basement
Prf 1 VES 03	1	21	1.8	0.00	Sandy, clay
	2	567	2	2.00	Lateritic sand
	3	57	4	4.00	weathered basement(clayey)
	4	1471	Infinity	6.00	fresh basement
Prf 1 VES 04	1	1204	2	0.00	Lateritised top soil
	2	284	6.9	2.5	Weathered basement(lateritic)
	3	232	38.9	9.4	Weathered basement
	4	40519	Infinity	48.3	Fresh basement

The resistivity models at each sounding point were used to produce geoelectric & geologic sections along the profiles as detailed below.

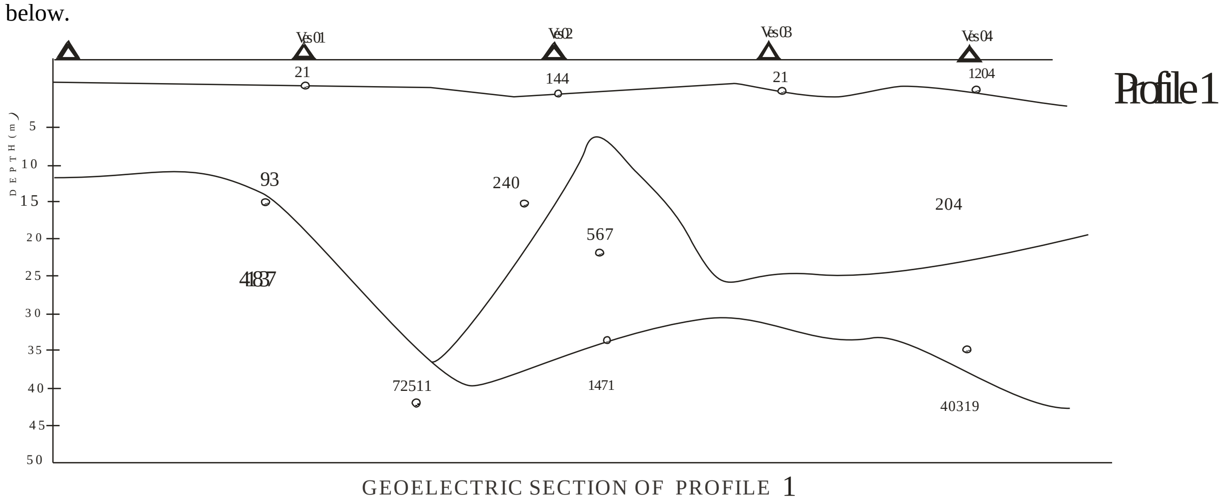


Fig.1: The Geologic and Geoelectric Section of Profile 1

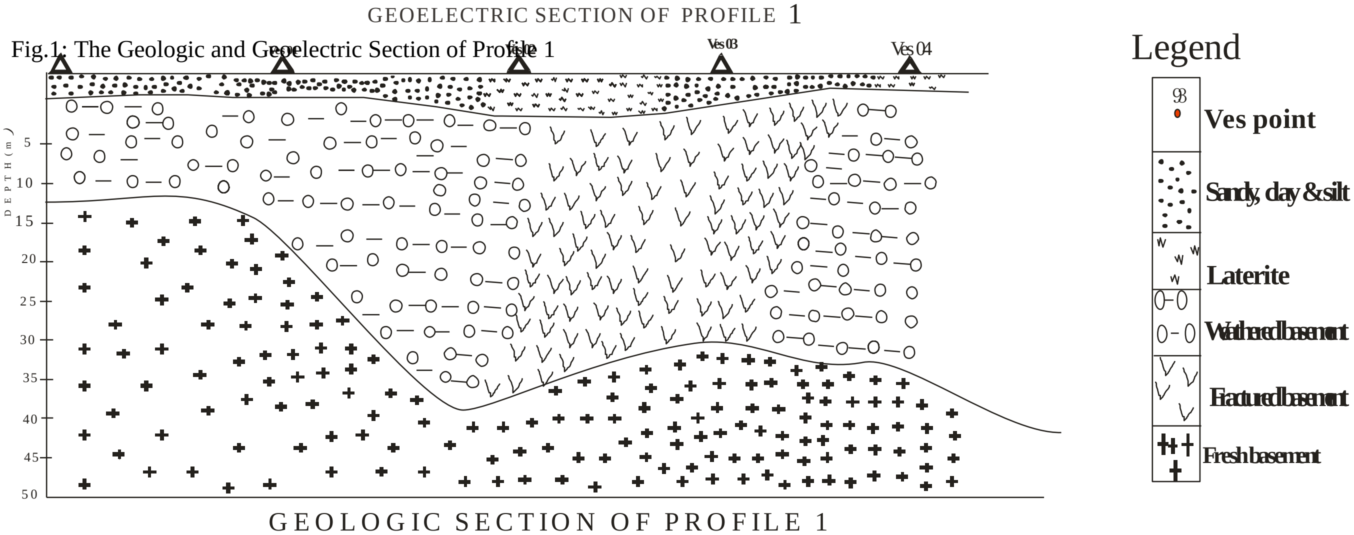
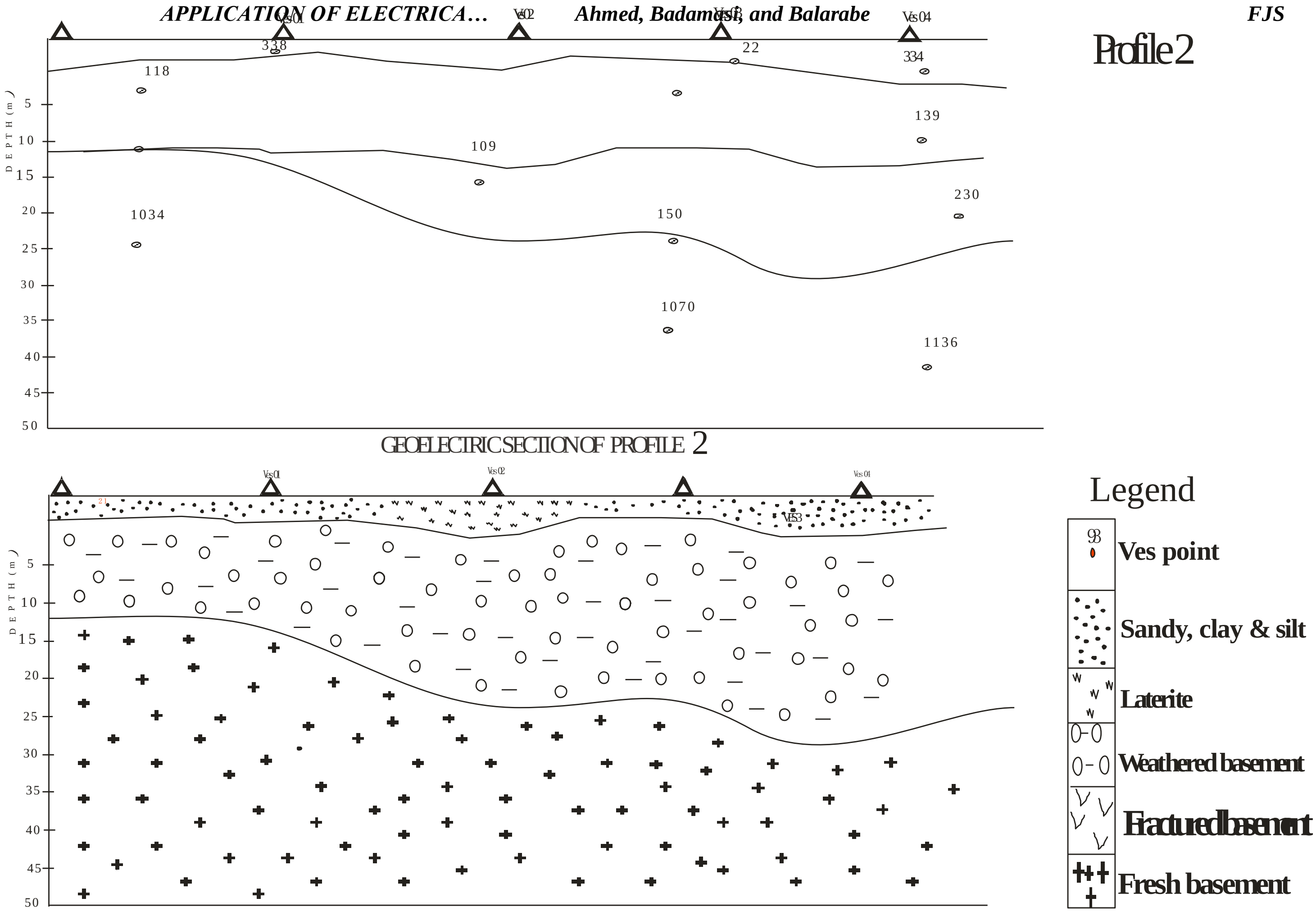


Fig. 2: The Geoelectric and Geologic Section of Profile 2

Figure 1 shows a geoelectric and geologic section obtained for VES points along profile 1. The profile consist of four subsurface layers, the first layer which is the superficial cover has resistivity values ranging from 21ohm–m around VES 03 and 01 to 1204ohm–m around VES 04. This layer has an average thickness of 2m. The underlying layer has resistivity values of 204 ohm-m to 240ohm–m which probably consist of weathered basement. The third layer has resistivity value between 93ohm–m around VES 01 to 567ohm–m around VES 02. This layer is probably the fractured basement with an average thickness of 12m. The fourth layer has resistivity value ranging between 41837ohm-m to 72511ohm –m, since these values are much greater than 1000ohm-m, the layer is probably the fresh basement rock. Synclinal features that appear at VES 01 and 02 pose a great danger to large buildings and foundations stability and must be taken care of during project implementation.

Fig 2 shows a geoelectric and geologic section of profile 2. It shows a four layer, the first layer which is the superficial cover has resistivity values ranging between 22ohm-m around VES 03 to 338ohms around VES 01 with an average thickness of 2.5m. The layer consists of sandy, clay and silt soil given the necessarily values. The underlying layer has resistivity value range between 118ohm-m to 139ohm-m, which is likely to consist of laterite and has an average thickness of 7m.
Third layer has resistivity values ranging from 109ohm –m to 230ohm-m around VES 02 and 04 respectively and it is likely consist of weathered basement rock with an average thickness of 15m. The fourth layer which has resistivity ranging between 1034ohm-m to 1135ohm –m is probably the fresh basement.



GEOLOGIC SECTION OF PROFILE 2

Fig 3: The Geoelectric and Geologic Selection of Profile 3

Fig 3. shows geoelectric and geologic section. This profile is underlain by four layers. The superficial cover (first layer) has resistivity values ranging between 353ohm-m to 624ohm-m around VES04 and 02 respectively. It has an average thickness of 2m which is probably made –up of sandy, clay and silt soil. The second layer has resistivity values between 40ohm-m around VES 02 to 113ohm-m at VES04, with an average thickness of 6m. This layer is probably the weathered layer. The third layer which is likely a fractured layer has resistivity value between 70ohm-m to 722ohm-m at VES 02 and 03 respectively. The layer beneath it, consist of the fresh basement which has resistivity value greater than 1000ohm –m.

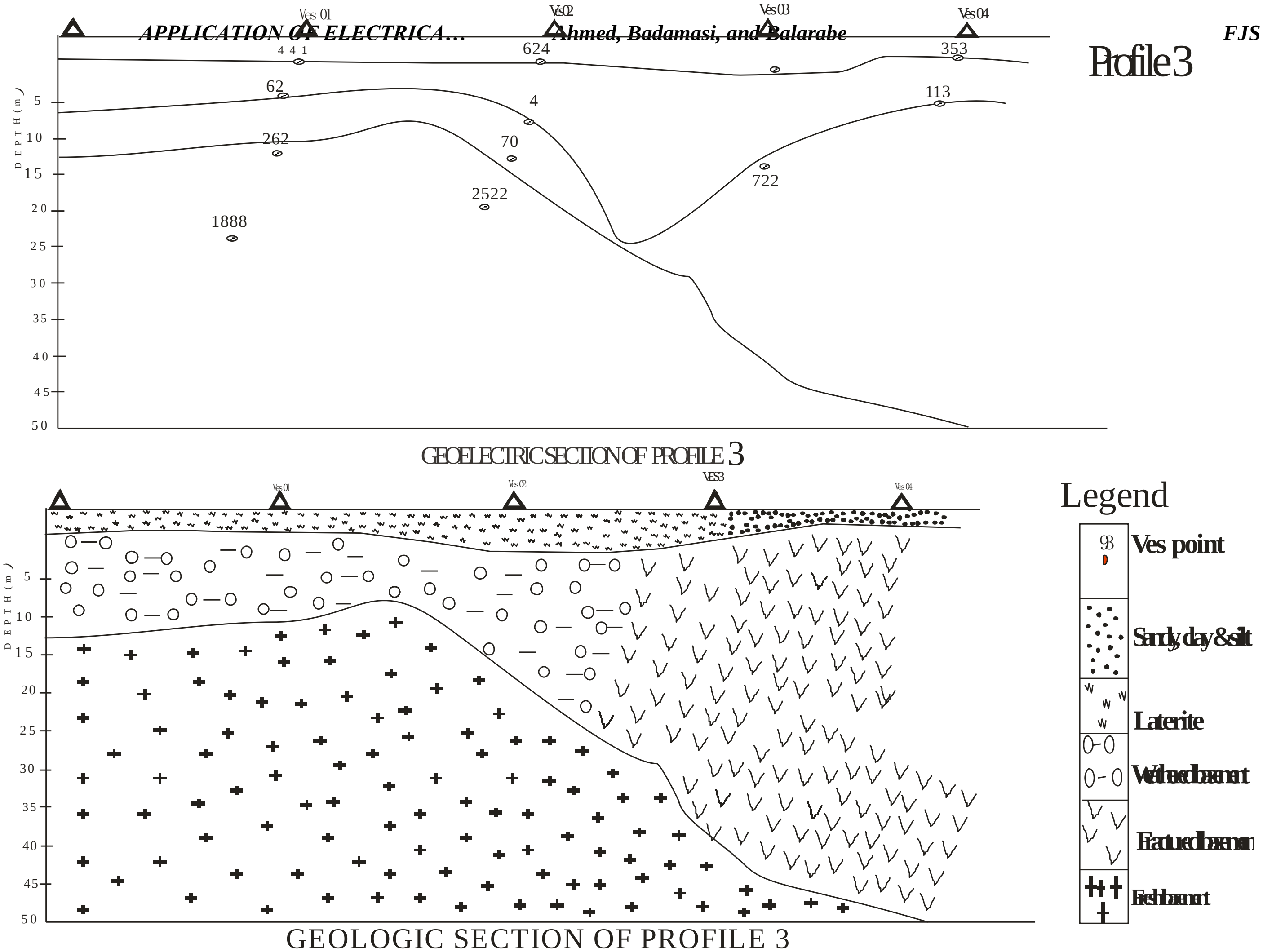
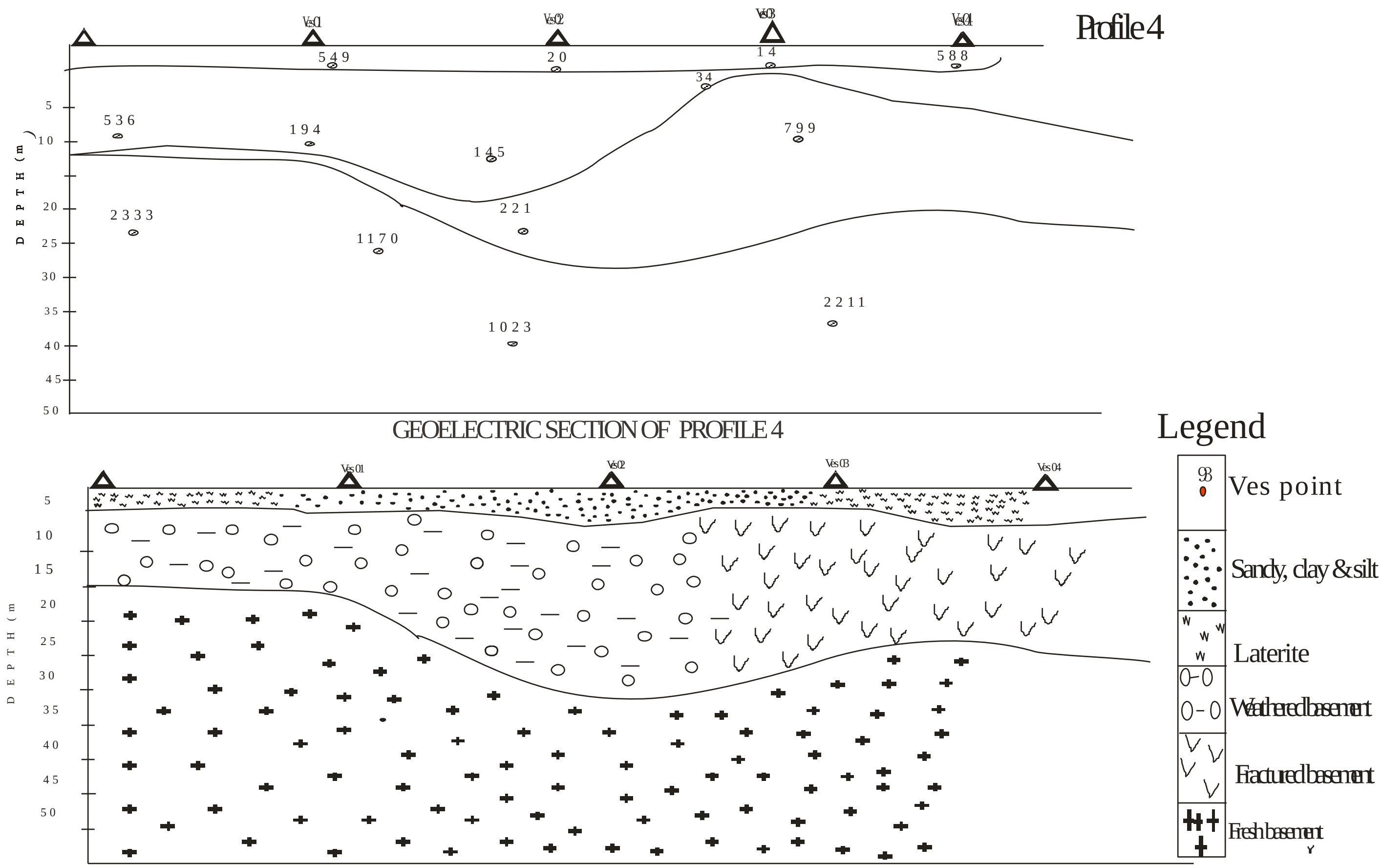


Fig. 4: The Geoelectric and Geologic Section of Profile 4

Figure 4 which suggest four subsurface layers with the first layer having resistivity values between 14ohm-m to 588ohm –m. The average thickness of this layer is 2m. It is made –up of sandy, clay and silt soil. The underlying layer has resistivity values ranging from 340hm –m to 194ohm –m. The layer is probably the weathered basement (lateritic) with an average thickness of 10m. The third layer has resistivity value ranging between 221ohm –m to 799ohm –m. This is probably the fractured basement; this shows that the region is most likely favourable for ground water exploration based on the thickness of the weathered layer. Evidence of this, is the existence of the borehole around VES02. The fourth layer has resistivity value greater than 1000ohm-m and is of infinite thickness. This layer is the fresh basement rock.



GEOLOGIC SECTION OF PROFILE 4

Fig. 5: The Geoelectric and Geologic Section of Profile 5

Fig 5 show geoelectric and geologic section along profile 5. This profile suggests four subsurface layers. The first layer is the superficial cover with an average thickness of 2m and the resistivity value ranges between 145ohm-m to 358ohm-m. The underlying layer consist of weathered basement with resistivity value range between 36ohm-m to 338ohm-m. The third layer which is a fractured basement has resistivity values between 43ohm-m to 797ohm –m. The last layer (fourth) has resistivity value greater than 1000ohm –m with an infinite thickness, this layer is the fresh basement rock.

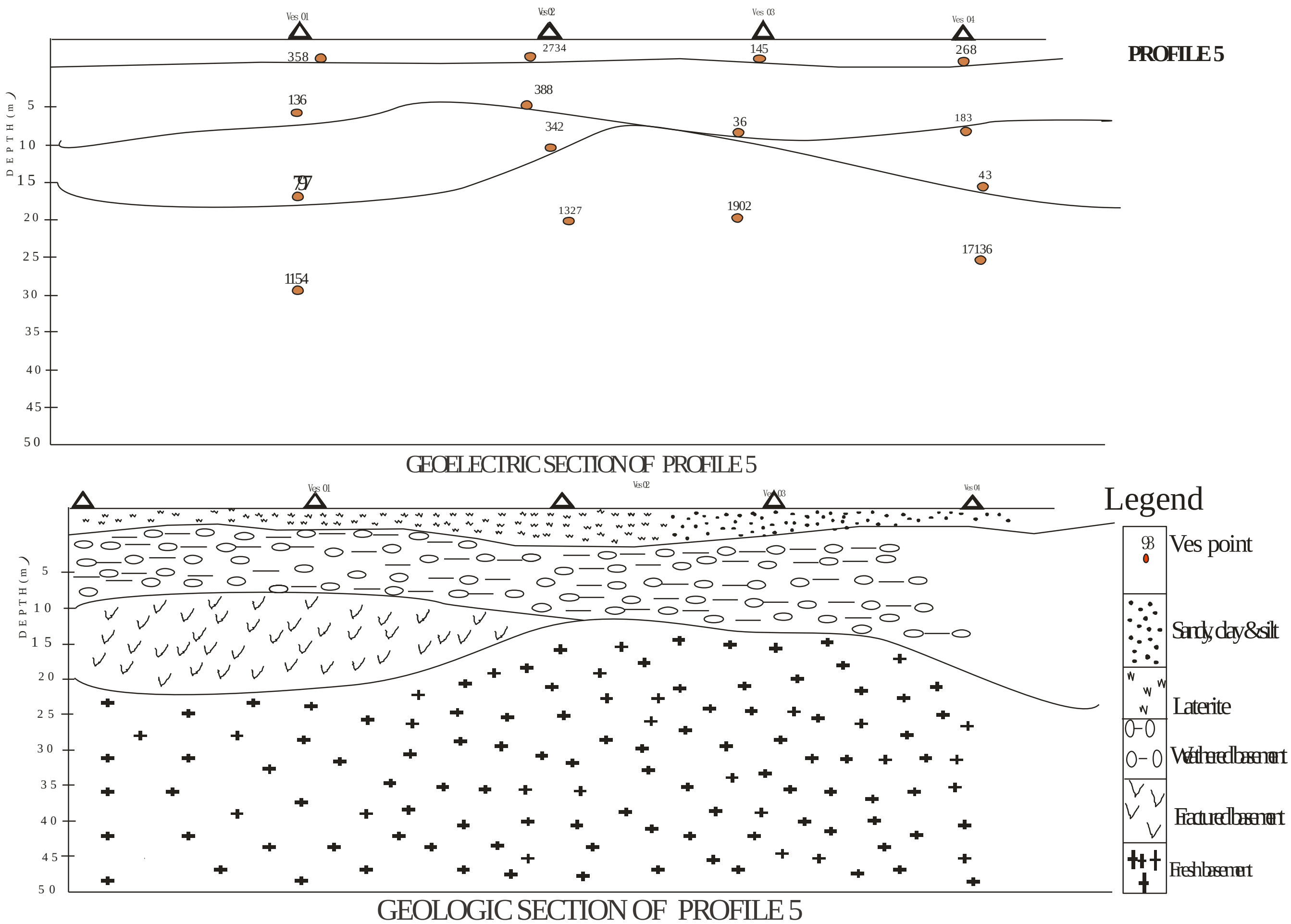


Fig. 6: The Geoelectric and Geologic Section of Profile 6

Fig 6b depicts the geologic section derived from geoelectric shown in fig 4.6a. The profile suggests subsurface layers. The first layer has an average thickness of 1.5m with resistivity value ranges between 39ohm-m to 167ohm. Below this layer is the second layer with resistivity value ranges between 15ohm-m to 204ohm –m. This layer is a weathered basement. Beneath this layer, is the layer with resistivity value of 30646ohm-m which is most likely is the fresh basement intruded the layer and a thickness of 6m. The third layer is the fresh basement rock with the thickness running to infinity and resistivity value much greater than 1000ohm-m.

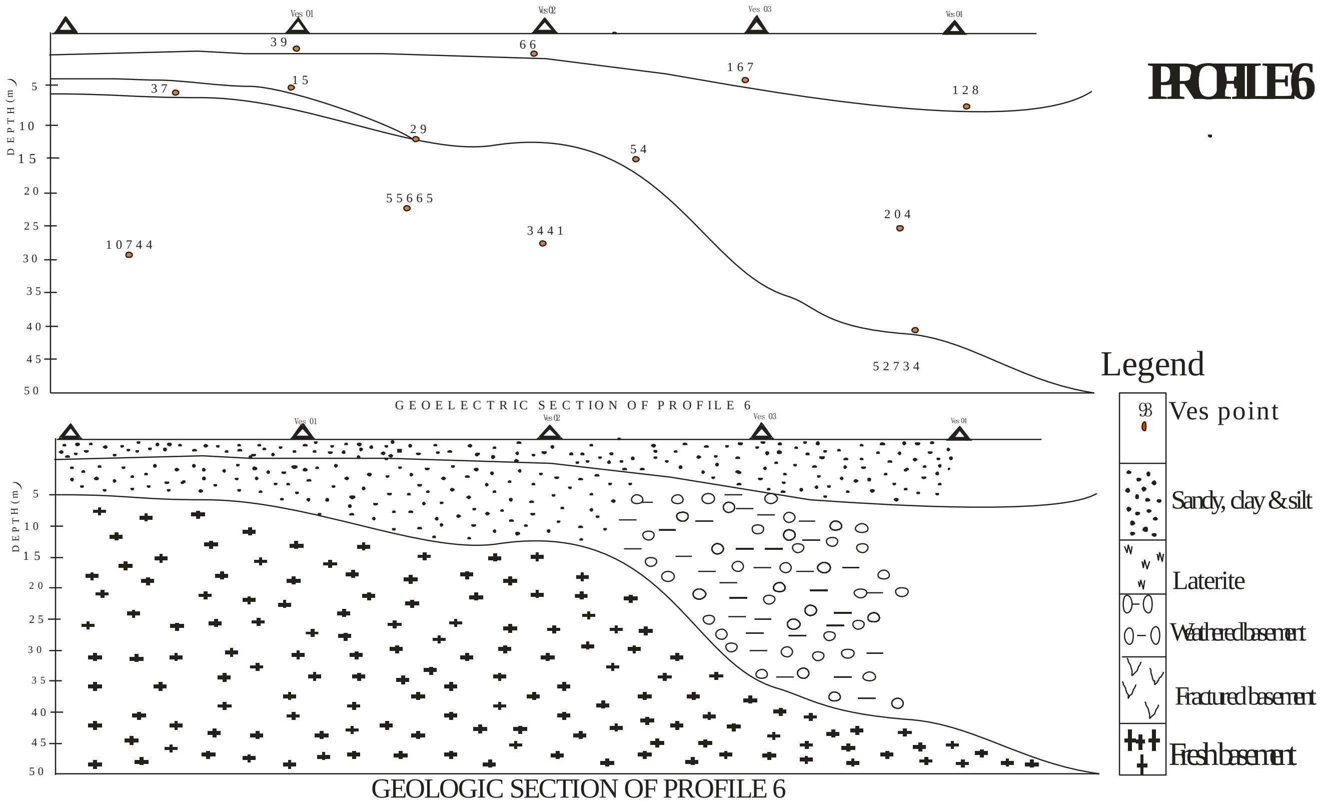


Fig. 7: Aquifer Thickness Map

The aquifer thickness Map was produced by subtracting the thickness of the first layer from the total depth to the basement. The thickest part of the aquifer was found to be region around Northeastern and southwestern part in the study area. According to Ariyo and Oguntade (2009), in basement complex terrain, areas with overburden thickness of 15m and above are good for groundwater development. Therefore, around VES p1v1 and p5v3 with thickness of 34m and 28m respectively. These points were recommended for drilling of borehole.

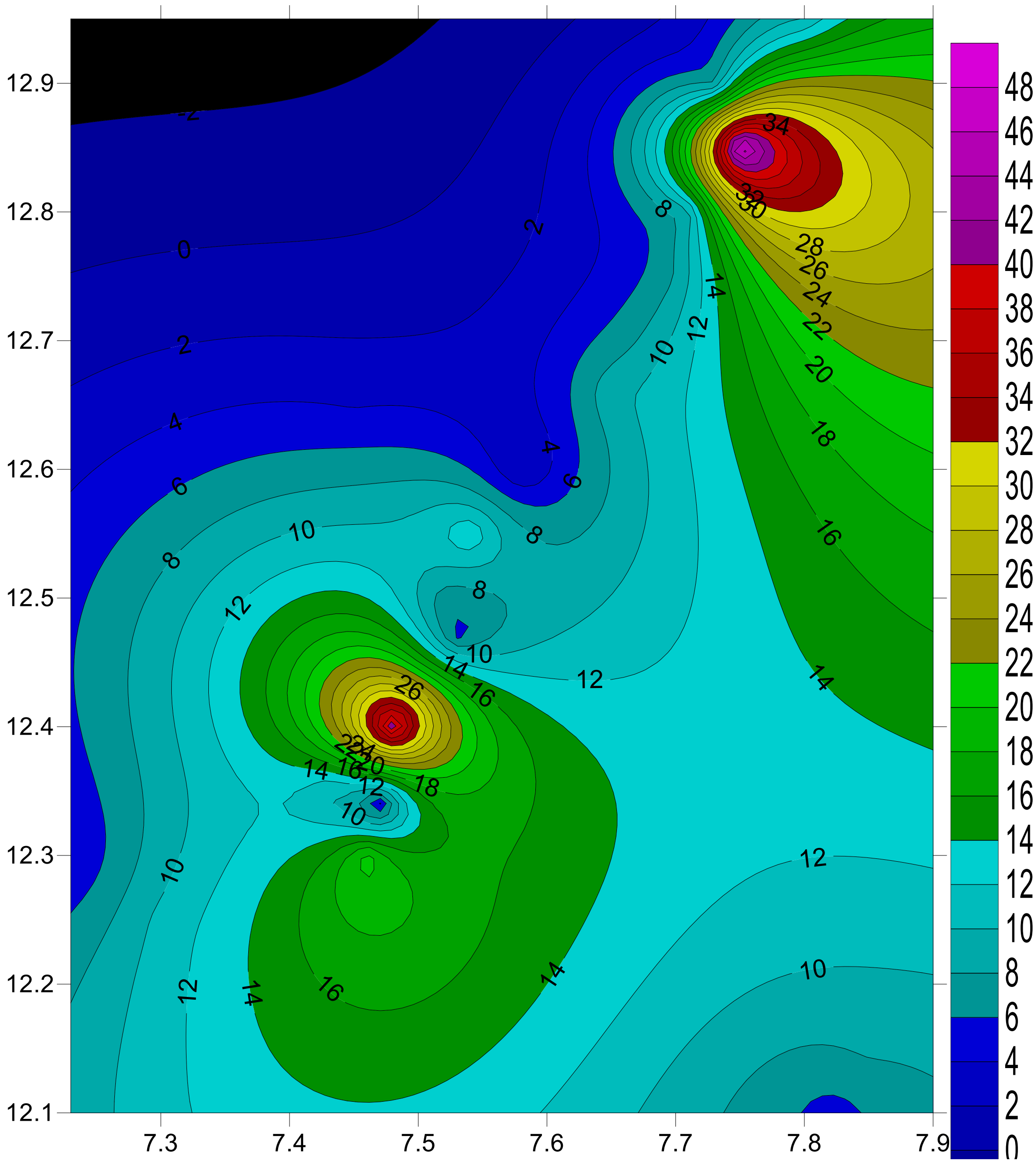


Fig. 8: Aquifer Thickness Map

CONCLUSION

The result of geophysical study undertaken at Federal University Dutsin–ma permanent site shows that the study area is underlain by three to four layers of different lithological composition, namely the superficial cover consisting of sandy, clay silt, weathered laterite/fresh laterite/weathered basement, fractured basement and fresh basement shown from the geoelectric and geologic section profile maps. The laterite in the first layer shown in some location is of great importance as it reduces surface run-off and aid infiltration into the underlying aquifer.

The bedrock in the area is mostly characterized by high resistivity values indicative of medium and fine –grained rock bodies suitable for massive load bearing sustainability. Based on the resistivity values of the different geoelectric layers, it has been concluded that the various geologic units, up to a depth of 40m are fairly competent and can support large civil engineering structures.

The thickness of the weathered basement in the northern and central part of study area is large enough to harbour substantial quantity of water.

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