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SEISMIC REFRACTION INVESTIGATION OF THE SUBSURFACE STRUCTURE AT THE SOUTHERN PART OF NIGER STATE COLLEGE OF EDUCATION, MINNA, NIGERIA

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ABSTRACT
This paper discussed the seismic refraction survey conducted at the southern part of Niger State College of Education Minna, in which a three-channel seismograph was used for the survey. The profiles were marked at 100m intervals, while the profiles lines traversed 1000m (1km). The exact site surveyed covers a total area of about 500,000m^2. From the data collected, time – distance curves for each shot points were drawn, the velocities of the underlying layers for each points were obtained and the depths to the refractor layer were computed. The results obtained gave an overview of the lateral variation in the lithological changes of the subsurface earth materials in the surveyed area. The basement surface varied in depth, from depths as shallow as 2.05m to a maximum of 10.13m. The rock materials identified in the surveyed area are chiefly sand, saturated clay, gravel, and granite.

Keyword: Basement, aquifer, Seismograph, time-distance curve, and velocity.

INTRODUCTION

Seismic refraction is a commonly used geophysical technique to determine depth-to bedrock, competence of bedrock, depth to the water table, or depth to other seismic velocity Boundaries (www.nga.com,20th, April,2009). Geophysical prospecting or exploration involves simply the study of those parts of the earth hidden from direct view by measuring their physical properties with appropriate instruments, usually on the surface. These physical properties when measured and properly interpreted, give useful information on the structure and composition of these concealed zones and thus help in detecting and delineating local features of distinctive physical characters, such as groundwater. Obtaining groundwater depends on the type of subsurface rock materials found in the area. Saturated permeable layers capable of providing a usable supply of water are known as aquifers. Aquifer is a body of rock or soil that is sufficiently porous and permeable to store and transfer significant amounts of groundwater. The flow of water into aquifers is called recharge and the flow of water out of aquifers is called discharge. (www.mqtinfo.org,2nd January2010). The geophysical methods most widely employed for exploration include magnetic, electrical and gravitational methods, which depends on the earth's natural fields. Others are seismic and electromagnetic methods, which depends on the introduction of artificial energy in thereof.

The seismic refraction method uses the seismic energy that returns to the surface of the earth after traveling along ray paths through the ground, to locate refractors that separate layers of different seismic velocities (Keller *et al,* 1981). Thus in hydrogeological investigation the seismic refraction method provides direct information on the level of water table, since an increase in water content causes a significant increase of seismic velocity (for a homogeneous lithology). By implication, zones of saturation (e.g. medium to coarse grained unconsolidated deposits) are therefore, excellent refractors, the upper boundary of which can be determined with a considerable accuracy by the seismic refraction method (Kearey *et al,* 2002).

The study area is part of the N-W quadrant of the 1:100,000 Minna sheets 163. Minna is bounded by approximately latitude 9^{0} 33^{1} N and longitude 6^{0} 35.2^{1} E. The exact site surveyed covers a total area of about 500,000m^2. The area falls within the metamorphic rocks of the Kusheriki area adjacent to Zungeru-Minna area. The profiles are laid in the West –East direction 1km from the reference point. The profile interval is 100m. The location of the study area is shown in figure1, while figure 2 shows the map of the study area. The rock types found in the study area are believed to be part of the older granite suite and are mostly exposed along the river channel where they appear in most cases weathered (Udensi *et al*,1986). The geological setting of the area is that of the basement complex terrain with amphibolites, biotite-granites, quartzites, gneises and schists in close association.

Niger State College of Education Minna is an academic institution with large students population which depend only on pipe water. The water supply is erratic in nature, sometimes it is non-existence for weeks. Hence, this research became necessary so as to identify some points (sites) that could be better for ground water development. As some were identified in this work, it is expected if explored to solve permanently the need for both staff and students residence in the college. Since the structural development is paramount in the college for further expansion, this is expected to identify some areas (points) for structural development. The table 1. Shows the borehole log data near the study area.

Table 1: VES conducted at Maitumbi, Minna East

VES	NO of Layers	Depth(m)	Interpreted Lithology	Characteristic Hydrogeology
	1	0-2	Topsoil	Occurences of fracture zones as from
01	2	2-10	Weathered Overburden	10 m. Recommended depth of borehole is 50m
	3	10-40	Fresh Basement	
	1	0-2	Topsoil	Occurences of fracture zones as from
02	2	2-10	Weathered Overburden	12-40 m. Recommended depth of borehole is
	3	10-40	Fresh Basement	50m

KAY DRILLING CO. (2004)

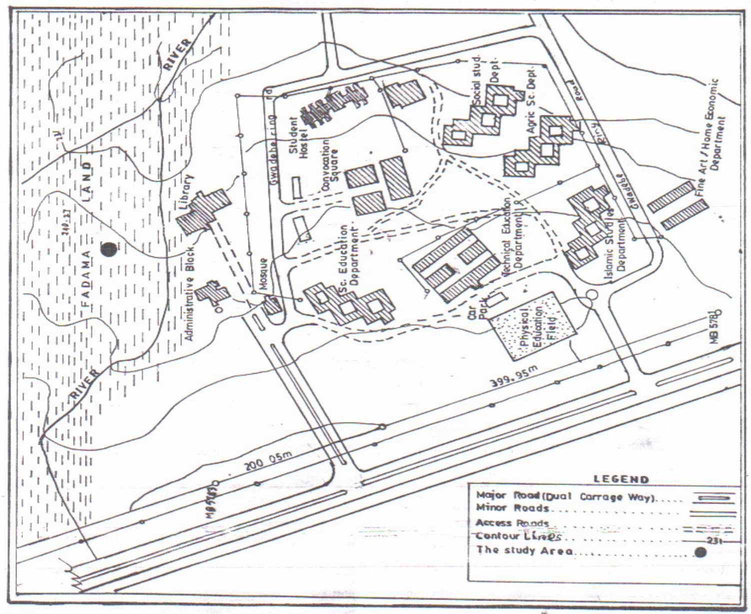


Fig.1.2: MAP OF COLLEGE OF EDUCATION MINNA, SHOWING LOCATION OF THE STUDY AREA

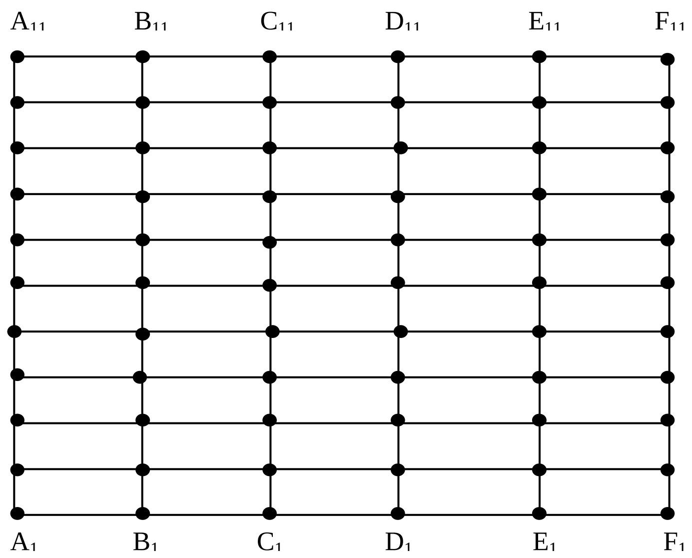
Exploration for ground water potential of the study area has not been fully undertaken. Hence information on the subsurface water is still insufficient. However, distribution and circulation of ground water are controlled by geological factors such as lithology, texture and structure of the rocks found in a particular area. It also depends on hydrological and meteorological factors such as stream flow and rainfall. The ground water is found mostly within the laterites and the weathered zones of the meta-sediments and granite gneiss (Telford, *et al*, 1976).

Seismic method, being the most versatile and widely used exploration method is employed in this survey, it has high accuracy, high resolution and great penetration ability (Dobrin, 1976). Also seismic refraction method is best suited for groundwater search and civil engineering work. These are the basic reasons why it is considered suitable for this survey (Telford, *et al*, 1976)

FIELD PROCEDURE/ DATA COLLECTION

The instrument used in this survey is a three-channel enhancement seismograph. As shown in figure 2, the survey area was covered by six traverses, each 1Km long and spaced 100m apart. Eleven uniformly spaced shot points were recorded on each profile. The wave was generated using hammer with a block metal plate. At each shot point the arrival times for each of the geophones were recorded. Successive shots were taken at uniform intervals along each line and successive detector spreads are shifted about the same distance as the corresponding shot points in order to keep the range of shot-detector distance approximately the same for all shots. This arrangement is chosen such that the first arrivals will be refracted from formations of interest such as the basement.

Since the seismograph used is three-channel, the three geophones were laid three times for each shot point with 5m interval (Figure 3).At each shot point, three shots ware made with geophones shifted three times successively and seismograph was fixed at shot point to cover 45m at a point. After each shot, the arrived time for three geophones ware recorded in order to have nine geophones at a point. For the second shift, the interval between the first geophone and the third geophone of the first shot was 5m. Therefore data was collected in this order until eleven points is covered in a profile.



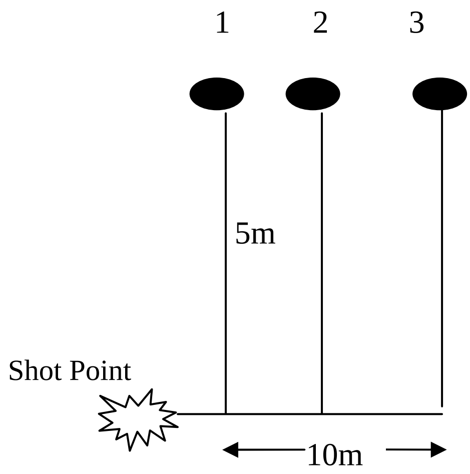


Figure 2: The survey layout

Figure 3: Field Setup of the Geophone

DATA ANALYSIS

Seismic velocity information was correlated with rock type and used in identifying subsurface materials. Due to overlapping of velocities for different rocks, it is not advisable to restrict the identification of rock type exclusively on velocity. It can however be used in a small area where range of velocity is small and therefore certain rocks can be identified based on velocity.

The processing of the data is often based on the first arrivals, since it permits accurate interpretation and easy recording of their travel times. The Wyrobek method (Telford, et al, 1976) was used to analyze the data. This uses graphic aids to facilitate the routine computations. Based on the Wyrobek approach and on the field data, a plot of the travel time (T) versus the detector position of all the receiving stations along each traverse was obtained. The slopes of these graphs were then used to obtain the average velocities, v_1 and v_2 for both the first layer and the refractor. The intercept time was also determined from the graph. To obtain the depth to refractor at each shot point, the intercept time above is divided by two to give the half-intercept time often called the delay time D. Values of the delay time D at each shot point is thus multiplied by an appropriate factor F to obtain the depth. For a homogeneous overburden as assumed for this survey:

$$\text{Slope} = \frac{\text{Change in time}}{\text{Change in distance}} \quad ....1$$

$$V = \frac{1}{slope} \quad ....2$$

This procedure is carried out for all the shot points to obtain v_1 and v_2, the velocities of the first layer and the refractor respectively. These two velocities along with the intercept time yield depth to refractor as giving in the equation below

$$Z = \frac{T_i}{2} \cdot \frac{V_1 V_2}{\sqrt{\left(V_2^2 - V_1^2\right)}} \quad ....3$$

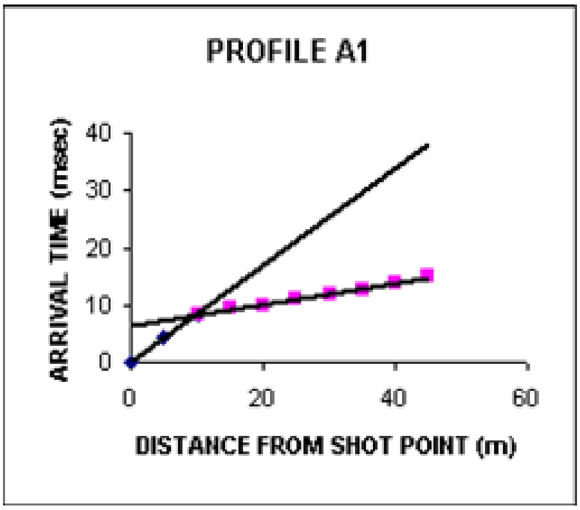
RESULTS

Interpretation of Survey Profiles

The main objective and end product of any seismic work is the ability to interpret seismic data in geological terms (Dobrin, 1976).

In most seismic refraction techniques, the assumption lies on the value of the velocity (v_1) of the section above the refractor. This is because of the heterogeneous composition of the superficial deposits which make the overburden velocity rarely constant, Dobrin, (1976). However, in this interpretation, by combining the general geology of the area and using standard tables that provide approximate range of velocities of longitudinal seismic waves through some earth materials. A good attempt is made to obtain a reasonable geological structure for the surveyed area. The time distance graph was plotted (using Excel package). Figure 4 is a sample of the resulting time-distance graph plotted with data from shot A_1. The graphs show a two-layer case.

The slopes of the two layers were calculated, and the inverse of the slopes gives the values for v_1 and v_2. The depth to refractor was also calculated using the relation in the above equation. This was done for all the shot points.



The velocity of the first layer v_1 varies from 1010 m/s to 1866 ms^{-1} with an average of 1306 ms^{-1}. The second layer velocity varies from 2447 ms^{-1} to 6944 ms^{-1} with an average of 3957 ms^{-1}. The depth to refractor varies from.2.81m to 5.79m with an average of 4.16m. This process was repeated for all other profiles.

INTERPRETATION OF CONTOUR MAPS

Contour Map of First Layer Velocity, Second Layer Velocity and the Refractor Depth

Based on the values of the velocity obtained, the first layer velocity throughout the entire survey area varies between 746m/s to 1887m/s. The velocity values obtained for the first layer over the entire survey area was correlated with the materials found in the superficial layers. It was also observed on the field that this superficial layer is composed of clay, dry sand, alluvium and gravel.

The first layer velocity contour map showed lateral variation in velocities of the seismic waves through the different earth materials of the survey area (figure 5). There is a significant rise in seismic velocity values towards the north central of the survey area (point marked as H). High velocity values also observed at the south east part of the map (point marked as H), which coincides with course of the stream channel that cuts across the survey area. This should be expected in view of the fact that alluvium deposits appeared to form and underlie the stream channel. The alluvium deposit which is chiefly sandstone, sand gravel and clay must be either saturated or compacted. Low seismic velocity values were observed towards the southern western section, and Northern eastern sections of the survey area, (points marked as L), which is characteristic of unconsolidated rock materials, chiefly weathered earth materials and dry sand.The velocity values of the second layer throughout the survey area vary from 2447m/s to 7893m/s, and was used to obtained the contour map for v_2 (second layer) (figure 5b).

The points marked **A** on this contour map are the areas having high velocities. The points marked **B** are the areas of low velocities. High concentrations of closures were also observed around the northern part of the survey area. These are characteristics of clayish, lateritic rocks and metal-sediment zones. However, low seismic velocities were observed towards the western, middle and eastern portion of the survey area.

Contour Map of the Refractor Depth

The contour map (Figure c) shows variation in the thickness of the weathered layer across the survey area. This is an indication of the heterogeneous nature of the basement. High depths were observed at the north central towards north western and south eastern portions of the survey area. Low depths were observed at the west towards the south west parts of the study area.

Interpretation of Geological Sections of the Study Area

Figure a, b and c shows typical illustrations about the geologic sections of the study area. Only two geologic layers were observed. The first layer consists of mainly the weathered basement, while the second layer consists of the consolidated basement rock. From figure (a), the high depth of 5.59m and 5.67m was observed at points 900m and 800m respectively. Low overburden depth of 2.81m was observed at point 1000m. Average velocity of 1306m/s was observed on the first layer of this Profile. The weathered material of this profile is basically superficial deposit, which consists mainly lateratic rocks and sand. The average velocity of the second layer was 3957 m/s.This suggest that the consolidated layer is granite.

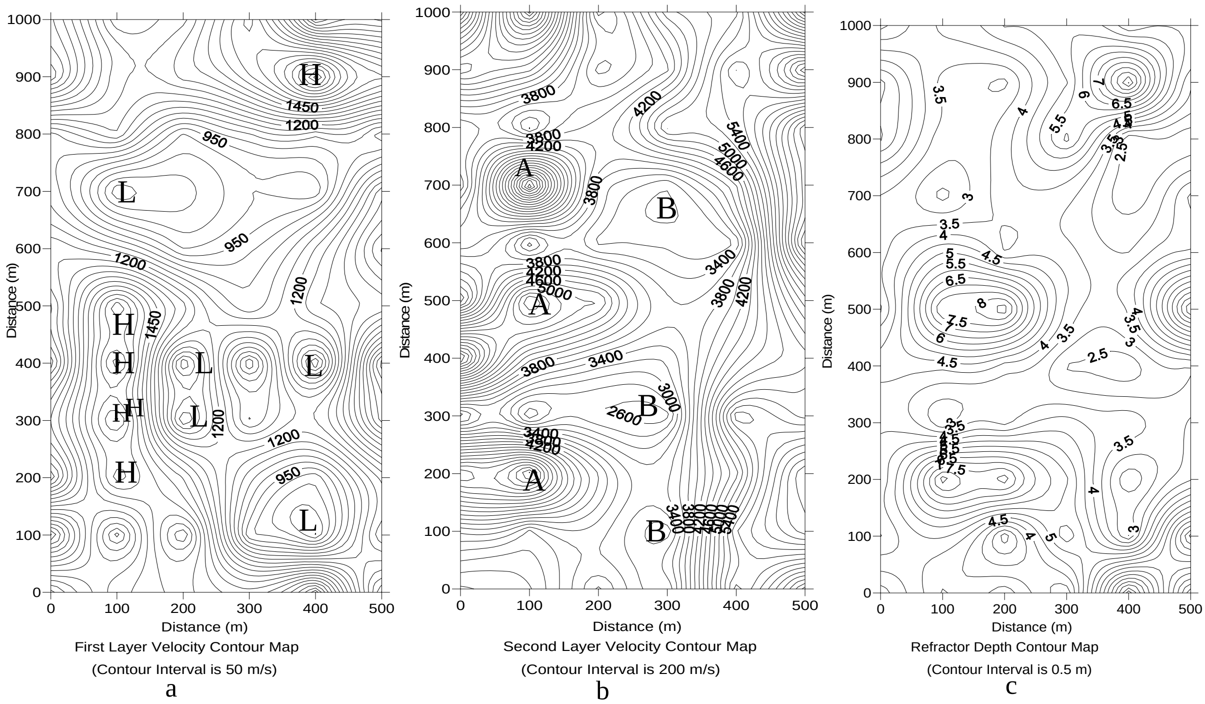


Figure 5, layer velocities and Depth to Refractor contour maps

Figure (b) represents the geologic section of profile B, the higher overburden depth of 8.09m and 8.81m were observed at point 500m and 200m respectively. Low refractor depth 2.31 and 2.49m were observed at point 700m and 300m respectively. Average velocity of 1391m/s was observed at the first layer of this profile and the refractor velocity of 4577m/s was observed. The high depth recorded at this profile could be due to change in the lithology. High velocity recorded at the first layer of this profile might be due to compactment of the earth materials (wet clay and laterite).

Figure (c) recorded high depth of 8.32m and 8.87m at point 200m and 500m respectively. The higher overburden depth of 8.09m and 8.81m were observed at point 500m and 200m respectively. The low depth of 2.15m and 2.85m were observed at point 100m and 900m respectively. The overburden velocity recorded for this profile was 1194m/s and the refractor velocity of 3549m/s was observed, this suggests that the composition of this layer is granite (Udensi *et al*,1986). The overburden materials of this section consist of granite, lateritic rocks, gravels and sand.

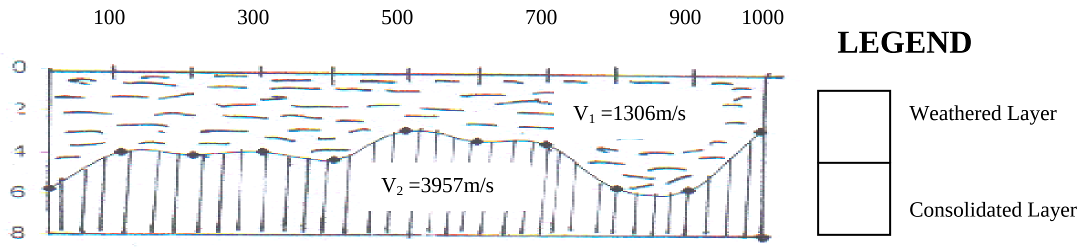


Figure a: The geological cross section for profile A

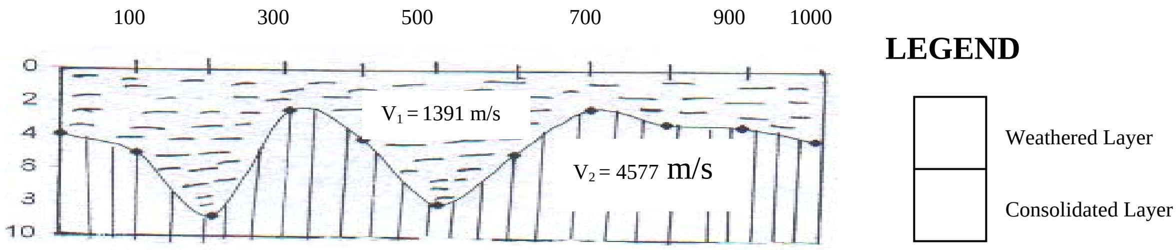


Figure b: The geological cross section for profile B

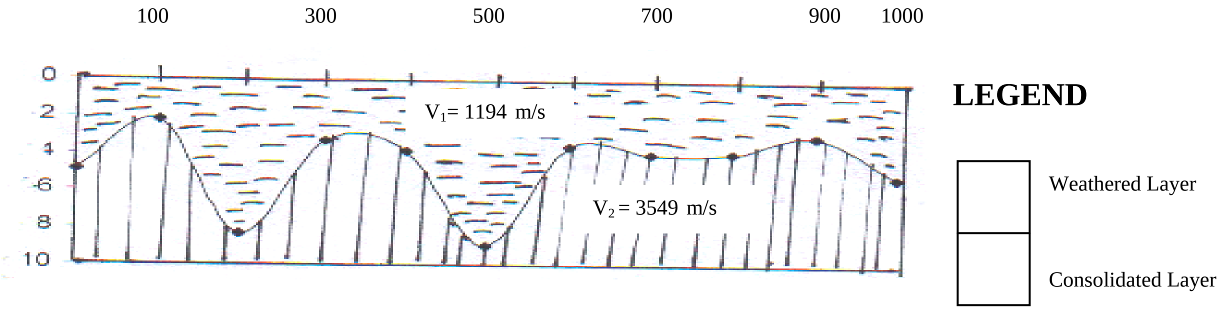


Figure c: The geological cross section for profile C

DISCUSSION AND CONCLUSION

The field data interpretation showed two geological layers over the entire study area. The overburden layer with seismic velocity range from 704m/s to 1980m/s and the consolidated layer velocity range between 2191m/s and 7893m/s. This wide range of velocity values may be attributed to the heterogeneous nature of the top soil due to the collective effects of long periods of erosions and weathering suffered by rocks, which has led to some rock exposures.

Due to the compactment nature and the heterogeneous nature of the weathered layer, it showed abnormally high velocities compared to the velocities of the bedrock in a basement complex. Its thickness ranges from a few meters to about 10.83metres.

The interpretation of the seismic refraction results has enabled the establishment of a two layer subsurface lithological composition in the survey area.

The seismic responses of the weathered layer along profile A in the West – East direction are characteristic of clay, gravel and schist. The variations in the seismic velocity responses of the weathered basement suggest the heterogeneous nature of the layer. The maximum depth of 5.79m and minimum depth of 2.81m observed along profile A might be an indication of intrusion of the overlying layer by the weathered basement. The seismic velocity of the weathered basement recorded along this profile (profile A) suggests that weathered basement is composed of consolidated earth materials.

High velocities and shallow refractor depths were recorded at profile E. This profile has least weathered layer velocity to be 862mls and maximum velocity of 1980m/s with an average velocity of 982m/s.It have the maximum refractor depth to be 4.03m and minimum of 2.02m and averaging at 2.63m. This means that the weathered layer of this profile is very shallow and suggests that it could be good or favorable for engineering and environmental constructions.

The interpretation of the results showed that two layers underlie the study area. The upper layer consists of alluvium, sand, clay, sandy clay and laterite. The second layer is the weathered basement. The overburden-weathered basement constitutes a major component of the aquifer system in this study area. The weathered basement revealed its composition to be chiefly, granites and undifferentiated basement complex rocks. Some points along profile B, C, and F which could form good reservoir for ground water potential were identified. Also points along profiles A and E which could form good sites for engineering and environmental constructions were identified.

RECOMMENDATION

The result of the investigation is therefore recommended as a useful guide for civil engineering planning and development of the area, and to managers of water resources in ground water searches. Finally, further investigation using the electrical method is recommended in the survey area.

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