VOLUME 7 NUMBER 1
APRIL, 2010

ISSN 0748-4710

JOURNAL OF SCIENCE, TECHNOLOGY AND MATHEMATICS EDUCATION (JOSTMED)

Published by
DEPARTMENT OF SCIENCE EDUCATION
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

Journal of Science, Technology and Mathematics Education (JOSTMED)
Volume 7, Number 1

April., 2010
ISSN0748-4710

TABLE OF CONTENTS

Journal of Science, Technology and Mathematics Education (JOSTMED)
Volume 7, Number 1

April., 2010
ISSN0748-4710

SUBSCRIPTION RATES

Nigeria	Rate (Personal)	1,000
	Rate (Institutions)	2,000
Other Countries	Rate (Personal)	#25.00
	Rate (Institution)	#35.00/$60.00

All Cheques should be made payable to:
The Editor JOSTMED, Federal University of Technology, Minna, Nigeria
Subscription must be pre-paid and must include 10% handling charges.

Seismic Refraction Investigation at the Northern Part of the Niger State College of Education, Minna, Nigeria

Alhassan, D. U., Udensi, E.E., and Salako, K.A.
Department of Physics, Federal University of Technology, Minna

Abstract

Niger State College of Education Minna lies in a basement complex terrain. A three-channel seismograph was used for the survey. The profiles were marked at 100m intervals, while the profiles lines traversed 1000m (1km). A Total of 66 spreads were shot. Data were collected, time – distance curves drawn, velocities of the underlying layers obtained and depths to the refractor layer 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 2.02m to a maximum of 10.83m. The rock materials identified in the surveyed area are chiefly sand, saturated clay, gravel, and granite.

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

Introduction

The demand for suitable and productive groundwater reservoirs for both domestic and industrial purpose is in the increase in Nigeria today. This is very apparent in most of the northern part of Nigeria where rainfall is rarely adequate, and the surface water source often dry up.

The use of Geophysical methods in groundwater exploration involves the delineation of potential aquifer and geological situations fovourable for the occurrence of groundwater. 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 in the Northern part of the Niger State College of Education, Shango in Minna West local government area of the state. The survey area includes the college fence at Shango and extended to the college Central Mosque, and also towards the staff quarters of the College. The profiles are laid in the West –East direction 1km from the reference point. The profile interval is 100m. The map of the study area is shown in figure1 below.

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. The area mapped, which covered a total area of half by one kilometer, (i.e. 0.5 x 1Km^2) is located at latitude 9^{0} 33'N and longitude 6^{0} 35.2'E and falls within the metamorphic rocks of the Kusheriki area adjacent to Zungeru-Minna area.

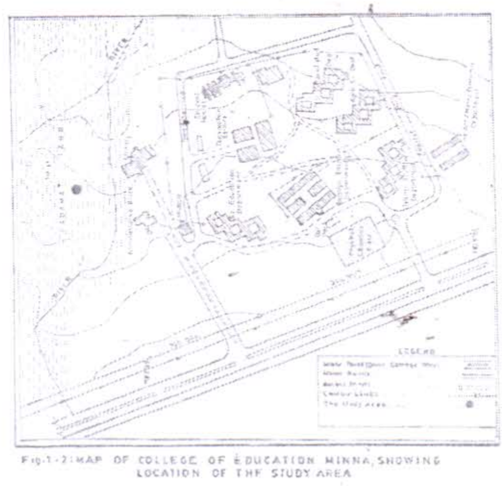

Figure 1: Map of Nigeria showing the location of the study area (After Geological Survey of Nigeria); Figure 2: Map of the study area

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 the three-channel enhancement seismograph. As shown in figure 4, the survey area was covered by six traverses profiles, each 1km long and spaced 100m apart. Eleven-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 basement.

Since the seismograph used is three-channel, the three geophones were laid three times for each shot point with 5m interval (figure 4).

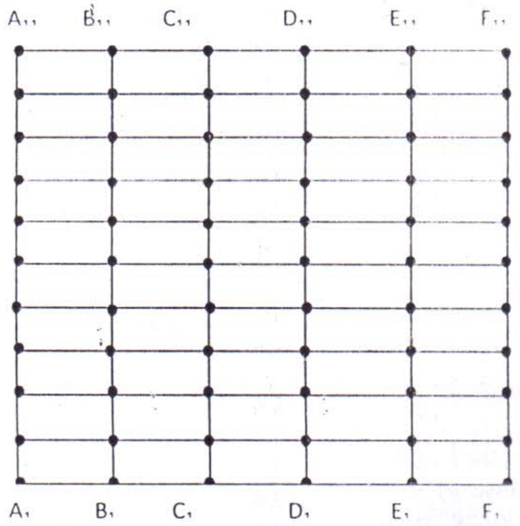

Figure 3: The survey layout

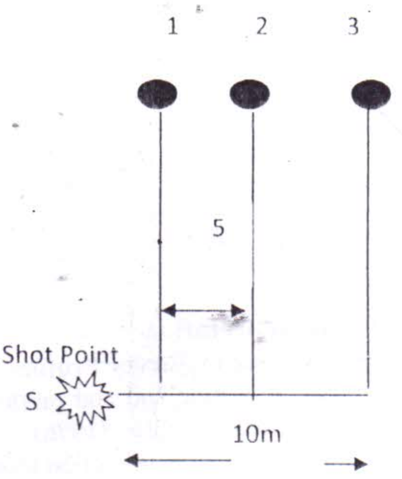

Figure 4: Field Setup of the Geophone

Data Analysis

From Table1 below, seismic velocity information can be correlated with rock type and can therefore be used in identifying subsurface materials. Due to the 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.

Table 1: Measured seismic velocity in rocks

ROCK TYPE	VELOCITY
ALLUVIUM	350 – 2000
CLAY	UP TO 2500
DRY SAND/GRAVEL	500 – 1000
SANDSTONE	1000 – 4300
LIMESTONE	1700 – 4200
SHALE	1000 – 4300
GRANITES	UP TO 7700
METAMORPHIC ROCKS	3000 – 7700

Source: Telford et al, 1976

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:

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

$$V = \frac{1}{slope}$$

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

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

Data Interpretation

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, (Table 1), 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 5 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.

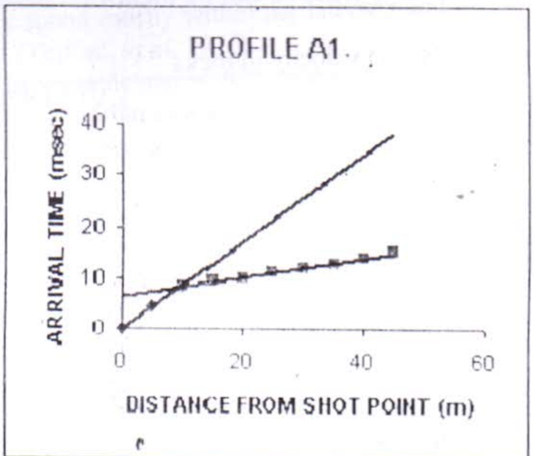

Figure 5: A Typical Time-Distance Graph

For example, table 2 shows a two-layer case for profile A. 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, however, following this process, summary table; table 3, 4 and 5 were obtained.

April., 2019
ISSN0748-4710

Table 2: Seismic Refraction Results for Profile A.

Sub Profile	Overburden Velocity V_1 (m/s)	Refractor Velocity V_2 (m/s)	Depth To Refractor Z (m)
A1	1229	2562	5.79
A2	1866	3646	3.96
A3	1053	6010	4.12
A4	1302	2447	3.93
A5	1010	6944	4.26
A6	1136	2575	2.85
A7	1250	4179	3.33
A8	1087	3221	3.47
A9	1078	3406	5.59
A10	1742	5345	5.67
A11	1613	3194	2.81

Interpretation of Contour Maps

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

Table 3, shows the summary of the first layer velocity for all the profiles. Based on the values on this table, the first layer velocity throughout the entire survey area varies between 746m/s to 1887m/s. It is clear from Table 1 that, the velocity values obtained for the first layer over the entire survey area can be easily 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.

Table 3: First layer velocities V_1 (m/s).

Profile location	Profile Name					
(m)	A	B	C	D	E	F
0	1229	1484	1563	1471	1788	943
100	1866	1225	1754	904	746	1302
200	1053	1678	1449	1073	862	1266
300	1302	1773	943	1408	1250	1724
400	1010	1792	893	1613	833	1887
500	1136	1748	1319	1053	1299	1359
600	1250	1126	893	990	1205	1563
700	1087	704	781	901	862	1389
800	1078	1250	893	1044	1064	962
900	1742	1316	1370	1543	1980	1563
1000	1613	1205	1279	1623	990	1087

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 6). 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.

Table 4: Second layer velocities, V_2 (m/s).

Profile location (m)	Profile Name					
	A	B	C	D	E	F
0	2562	2772	3846	3002	6098	4294
100	3646	3139	3497	2851	5988	6916
200	6010	6707	3995	3341	4919	7231
300	2447	2191	2614	2509	6150	5504
400	6944	4070	3446	3238	4581	5102
500	2575	5872	5043	3627	4039	5914
600	4179	2846	3142	3163	3206	7692
700	3221	7692	3545	3024	4179	7117
800	3406	2915	3893	5244	5435	7391
900	5345	4850	3127	3754	5814	3978
1000	3194	7294	2893	4545	4941	7893

The values in table 4 shows the velocity of the second layer throughout the survey area, it vary from 2447m/s to 7893m/s.From table 4, the contour map for V_2 (second layer) was obtained, figure 7.

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.

Table 5: Depths to the Refractor Z (m).

Profile location	Profile Name					
	A	B	C	D	E	F
0	5.79	3.95	4.87	3.06	10.83	4.05
100	3.96	5.06	2.15	5.85	2.47	9.23
200	4.12	8.81	8.32	5.59	2.03	3.91
300	3.93	2.49	3.28	4.27	3.94	3.56
400	4.26	4.16	3.76	2.44	2.12	2.94
500	2.85	8.09	8.87	3.87	3.54	9.17
600	3.33	5.00	3.45	3.70	2.97	4.03
700	3.47	2.31	3.84	3.69	2.08	4.15
800	5.59	3.20	3.78	6.18	2.02	2.10
900	5.67	3.32	2.85	4.93	9.62	3.51
1000	2.81	4.13	5.05	5.47	4.03	4.36

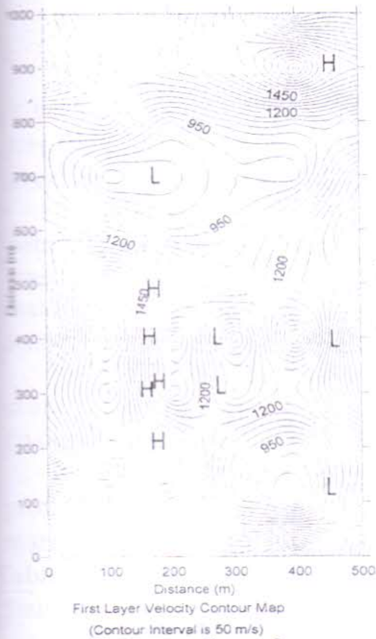

Figure 6

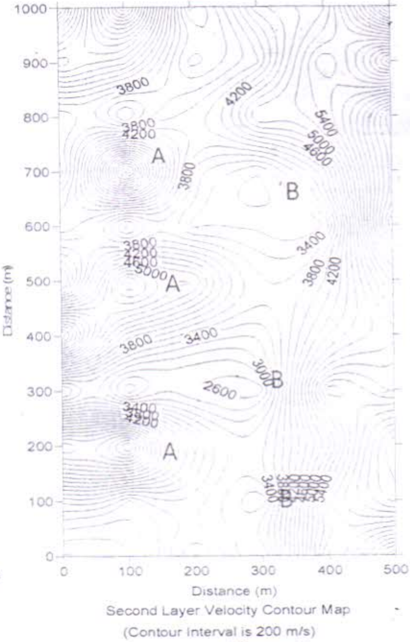

Figure 7

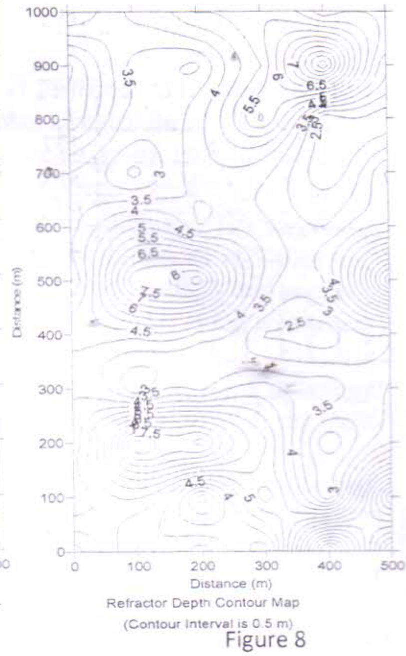

Figure 8

Figure 6, 7 and 8: First layer velocity, Second layer velocity and Depth to Refractor contour maps

Contour Map of the Refractor Depth.

The contour map (Figure 8) 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 9, 10 and 11 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 9, 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).

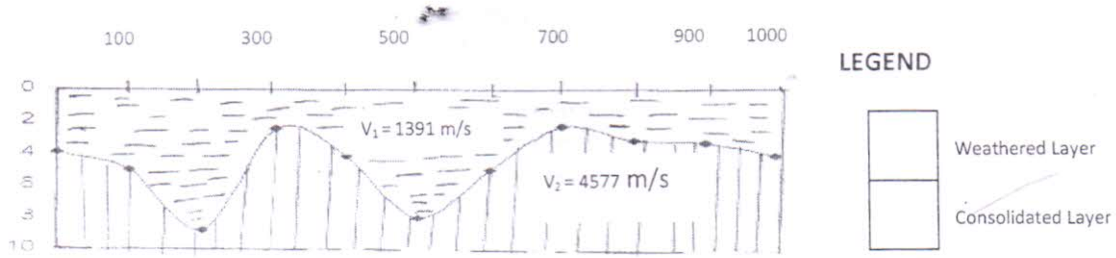

Figure 9: The geological cross section for profile B

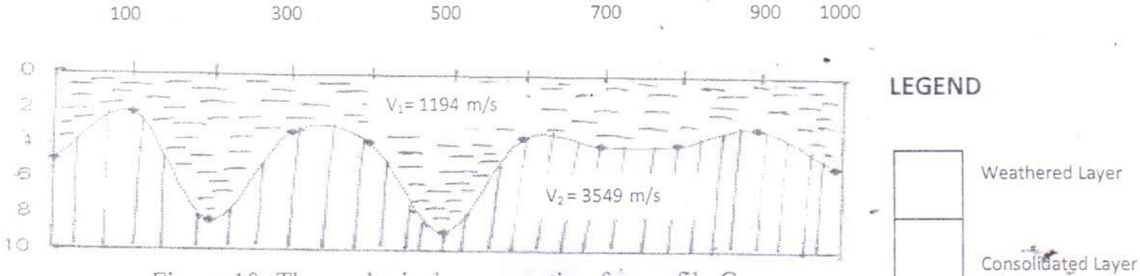

Figure 10: The geological cross section for profile C

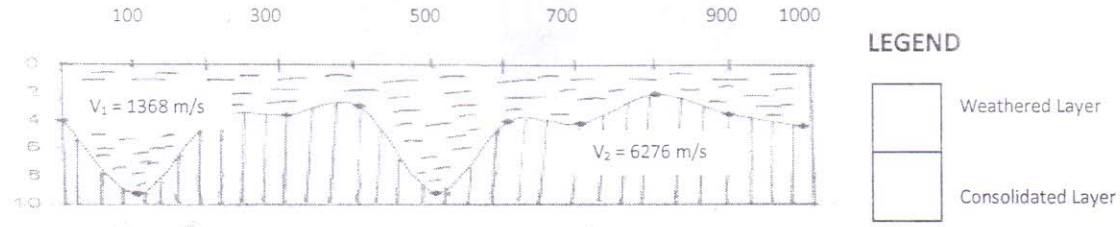

Figure 11: The geological cross section for profile F

This profile (Figure 10) 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. The overburden materials of this section consist of granite, lateritic rocks, gravels and sand.

Figure 11 represents the geologic section of profile F, the overburden thickness of this profile appears to have its greatest depth of about 9.23m and 9.17m at point 100m and 500m respectively. The first layer velocity of 1368m/s was observed and the second layer velocity of 6276m/s was recorded. The weathered materials of this section consist of lateritic rocks, gravels and sand. The average velocity of the consolidated layer was 6276m/s. this suggests that the composition of this layer is granite, Udensi *et al* (1986).

Discussion

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 suggests that it could be good or favorable for engineering and environmental construction. This profile has least weathered layer velocity to be 862mls and maximum velocity of 1980m/s with an average velocity of 982m/s.

The point E1 and E10 has the refractor depth of 10.83m and 9.62m respectively. The remaining points of this profile 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 profile E is favorable for engineering and environmental constructions, and this is the area where school central mosque, administrative block and college library were situated.

The shot points tabulated below (Table 6) could be interpreted to mean a lithology characterized by granites, clayish and lateritic rock zones and can therefore be considered as the most favourable aquifer in the study area.

This suggests that the aquifer zone of the study area could be the point 3, 200m marked of profiles B and C, also point 6, 500m marked of profiles B, C and F and perhaps profile F2 marked 100m from the reference point.

Table 6: Probable Ground water potential points

Station Name	Weathered Layer Velocity V_1(m/s)	Refractor Velocity V_2 (m/s)	Weathered Layer Thickness Z (m)
B3	1678	6707	8.81
B6	1748	5872	8.09
C3	1449	3995	8.32
C6	1319	5043	8.87
F2	1302	6916	9.23
F6	1359	5914	9.17

Conclusion

Total of 66 seismic shots were carried out along six profiles (A to F) in a west – east direction.

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. Two points along profile B, two points along profile C and also two points along profile 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. The alluvial deposits found along the banks of the stream channel is (believed to extend through deeper layers of the college land) having very high aquifer potential, since most developed aquifers consist of unconsolidated rocks chiefly granite, sand and gravels.

Recommendation.

The seismic refraction method has been proved to provide direct information on the level of the water table for a homogenous lithology. This is a result of its high resolution, high accuracy and greater penetration. The result of the investigation is therefore recommended as a useful guide to individuals, agencies and managers of water resources in ground water searches, also as a guide in any civil engineering planning and development of the area.

Finally, further investigation using the electrical method is recommended in the survey area.

References.

Dobrin, M.B. (1976). Introduction to geophysical prospecting. New York: Mc Graw-Hill Book C.O.

Keller, G.R, Sinno, Y.A and Sbar, M.L (1981): Seismic refraction in West and central Arizona, Journal of Geophysical Research, New York, 86(36) 5023.

Kearey, P., Brooks, M., and Hill, I. (2002) An Introduction to Geophysical Exploration. United Kingdom Third edition.Blackwell

Telford, W.M; Geldart, L.P; Sherriff, R.E; and Kays D.A (1976) Applied Geophysics. New York: Cambridge University Press

Udensi, E. E; Ojo, S. B; and Ajakaiye, D. E. (1986). A three Dimensional Interpretation of the Bouguer Anomalies over the Minna Batholith in Central Nigeria. Precambriam Res.32:1-15.