IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 1, Issue 1 (May. –Jun. 2013), PP 11-19
www.iosrjournals.org

Direct Current Resistivity Investigation of the Groundwater Potential and Basement Structure in Parts Of Pompo Village, Minna, Nigeria

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Abstract: *A direct current resistivity investigation of parts of Pompo village opposite Federal University of Technology, Gidan Kwano Campus, Minna, was carried out using conventional Vertical Electrical Sounding (VES) method. The aim of this survey is to determining the ground water potential of the area and to locate those areas that could be useful for civil engineering workers. The data obtained were interpreted using computer-based program called Zohdy, which showed a laterally and vertical varying succession of high and low resistive geoelectric layers throughout the area. The resulting (Interpreted) models were used to produce depth to basement map, regolith map, iso-resistivity contour maps at different depth and the vertical sections through each profile. The interpreted earth-layered model suggests the existence of three geoelectric layers with resistivity in the range of 20Ωm-200Ωm and 200Ωm-900Ωm for the first and second layers respectively, while the fresh basement forms the third layers with resistivity value above 1000Ωm. The aquifer system of the study area is generally characterized by relatively low resistivity value between 200Ωm and about 800Ωm in the weathered basement and supported on some VES points by fractured basement and its thickness ranges from 5m to >20m. The most promising region of the site lies on west and south-eastern part, while the civil and the environmental works will be best located at the northern and southern part where the fresh basement is uplifted.*
Keywords: *groundwater potential, vertical electrical sounding, investigation.*

I. Introduction

Cities in developing economies of the world are now in critical water supply situation due to rapid growth of economies, steep rise in living standard and concomitant exponential rise in population in the past three decades. The water needs of industrial and technological societies are much greater. The occurrence of drought roughly once in every ten years in Sahel region of Africa, suggests a cyclic pattern in rainfall distribution (Eduvie, 1998). Depending on surface waters in such unpredictable climatic conditions is an enormous risk. Groundwater is a renewable resource, it constitutes a reliable source of water, especially in arid and semi arid regions where surface water is scarce, seasonal and much of the terrain is hard rock.

The development of the community is imminent because the relocation of the university to this area will necessarily bring about the influx of population to the area within a foreseeable future. There is therefore, the need for a scientific identification of parameters governing groundwater resources, assessment and management, particularly if satisfactory living conditions of the inhabitants are to be catered for and to delineate the areas that would be suitable for possible civil engineering and environmental development. [1]

The Vertical Electric Sounding (VES) has been the most important geophysical method of water prospecting in areas of deep in situ weathering of fresh bedrock. Hence, it has been chosen for this work because it has proven to be an economic, quick and effective means of solving most groundwater problems in different parts of the world. The thickness of the overburden can also be estimated using VES method as presented in this work.[2]

The study area is located in Pompo village close to Minna in Niger State, (Figure 1.1) Pompo village is located between km 12 and 13 along Minna-Kateregi-Bida road on the opposite side of the Gidan Kwano Campus of Federal University of Technology (F.U.T) Minna, (Figure 1.2). The study area is located between latitude $9^0$31'N and $9^0$32'N and longitude $6^0$28'E to $6^0$29'E in a part of Minna SW sheet 42. The investigated site is a square of 500m by 500m, covering an area of 250,000 m^2. It is about 30m away from the major road (Minna- Keteregi- Bida road), 500m beginning from latitude $9^0$31'N and 500m eastward from the start point. [2] The rock types found in the study area consists predominantly of coarse-grained biotite granite and granodiorite. The granite types and the granodiorite together form part of the older Granite. The result of the borehole log and hand-dug wells from the area show that the area has a good potential for ground water development. The Basement Complex of Africa is a heterogeneous mixture of crystalline rocks, predominantly of a granitic or gneissose character. Groundwater occurs within these crystalline rocks in fractured or in the superficial weathered zones. [8, 9, 12].

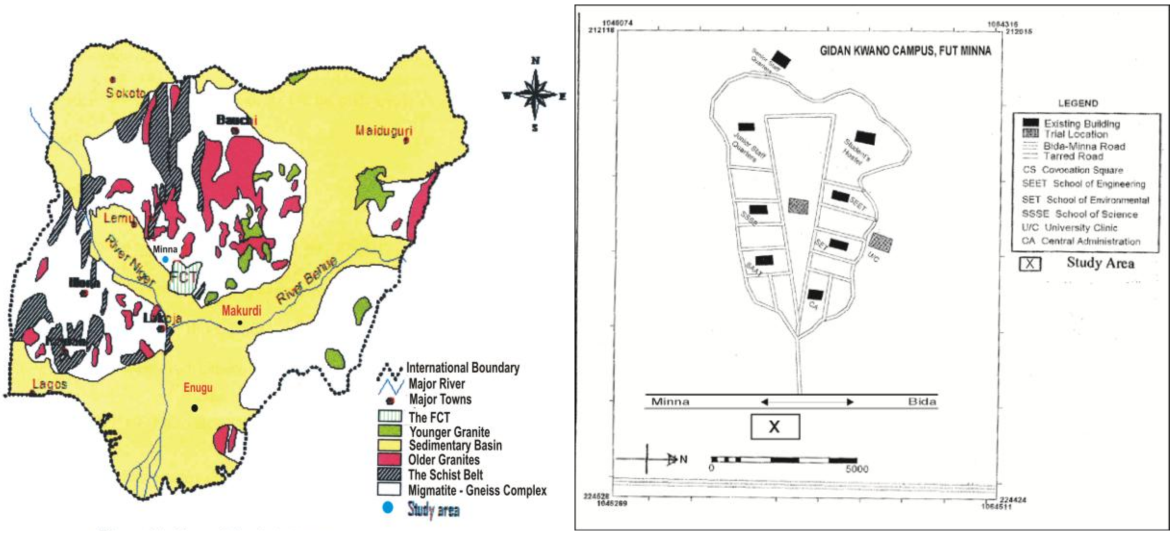

Figure 1: General Geology Map of Nigeria showing the location of Minna (Study Area) and Map of Federal University of Technology, Gidan Kwano Campus Minna showing the location and accessibility of the study area.

Data Collection

The study area was inspected and gridded as shown in Figure 2. Thirty-six (36) numbers of VES points were covered. The Terrameter SAS-4000 was the instrument uses and is capable of operating in different modes: Resistivity, Self-potential and Induced Polarization, was used. However, only electrical resistivity data were collected using VES (Schlumberger).

Data Interpretation

The interpretation was done using an iterative computer program called the Zohdy graphical method. This program performs automatic interpretation of the Schlumberger sounding curves. This curve gives the equivalent n-layer model from the apparent resistivity of each sounding. Further analyses of the interpreted VES data (Zohdy) were done using Surfer 8 and Minitab 14 to get deeper information of the subsurface.

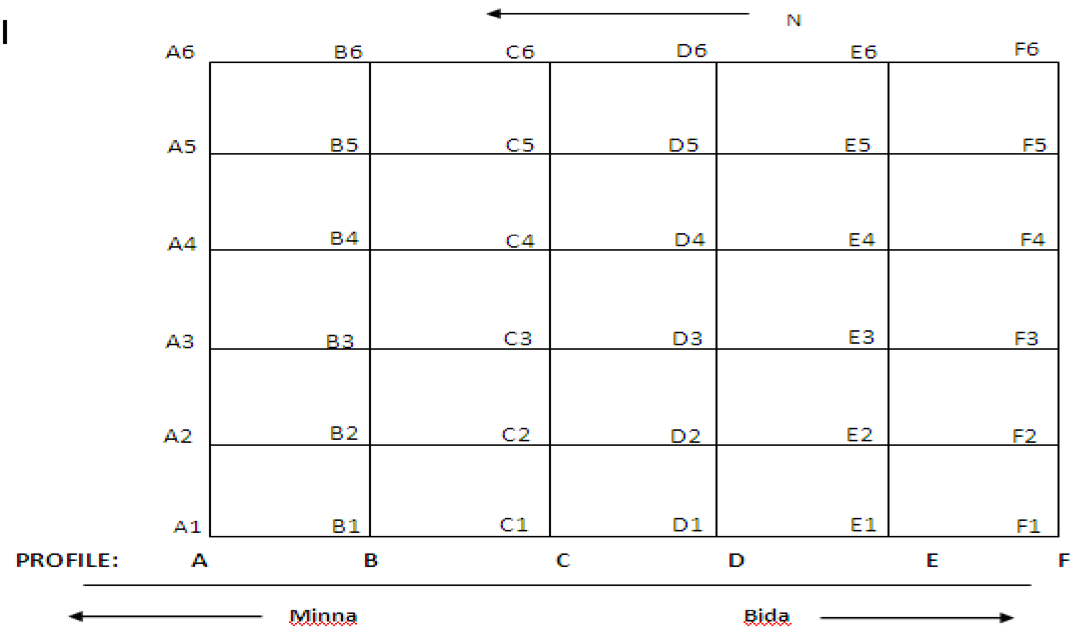

Figure 2: The profile layout for VES data collection N-S (North-South).

Data Interpretation

A continuous variation of resistivity with depth curve is easily derived from the multi-layer step function curve by drawing a curve that passes through the logarithmic mid-point of each vertical and horizontal line on the multi-step function model. This was used to construct.

i. Contour map of Geo-electric Vertical Section through profile.
ii. The Iso-resistivity maps at different depth
iii. Depth to basement or overburden contour map
iv.

Interpretation of Vertical Section through Profile

For easy interpretation of the results of the VES, the geologic sections of each of the profiles through their respective geoelectric vertical sections were deduced. This deduction was achieved through the use of contour maps of the vertical sections of each profile. The data used for these maps were obtained from Zohdy interpretations. These data were selected at various depth of interest, profile by profile for all the VES points in the area.

The aim was to get the geo-electric vertical section beneath the surface from which the geologic section could be deduced. The geo-electric and geologic interpretation were based on the available geologic information found within the study area and its environs. The approximate resistivity values associated with rock types in the basement area and the borehole log information from boreholes around the study area as presented in Table 1 were used in deriving the geologic sections.

Table 1: Resistivity values of Rock types in basement Area

Rock Type	Resistivity (Ωm)
Fadama loam	30-90
Sandy	100-200
Sand and Gravel	100-180
Weathered Laterite	150-900
Fresh Laterite	900-3500
Weathered Basement	20-200
Fractured Basement	500-1000
Fresh Basement	>1000

The subsurface vertical sections through profiles A, B, C, and D are shown in figure 3, 4, 5, and 6 respectively. These maps were contoured at an interval of 50Ωm except profile C that was contoured at 100Ωm. The first layer has resistivity value ranging between 50Ωm to about 550Ωm. It consists of dry laterite topsoil, fadama loam, sandy-clay and gravel as the lithology with thickness between 0.39m to 10.0m. The highest thickness of 1.05m occur at A_5 and C_4 of figure 3&5 which shows a very great overburden while the least thickness of about 0.39m is found on C_1 and D_3 (figure 5&6) where the layer got terminated.

The second layer consists of weathered and fractured basement. The resistivity characteristics of this layer range between 300Ωm and about 900Ωm. The highest thickness occurs at A_8 of figure 3; the second layer consists of weathered and fractured basement with thickness between 21.0m to about 24.0m.

The third layer has resistivity value above 1000Ωm and constitutes the fresh basement. It is deepest at A_4, B_3, and C_3 and shallowest at B_4.

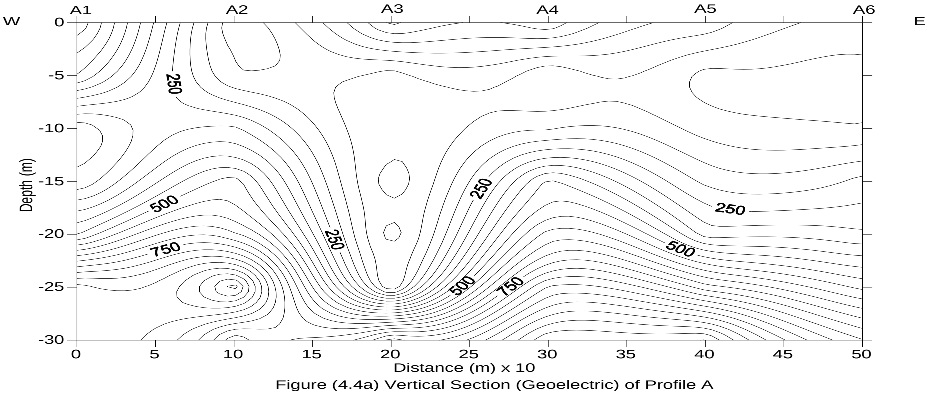

Figure (4.4a) Vertical Section (Geoelectric) of Profile A
(Contour interval is 50 Ohm-meter)

Figure 3: Vertical Section (Geoelectric/Geologic) of Profile A

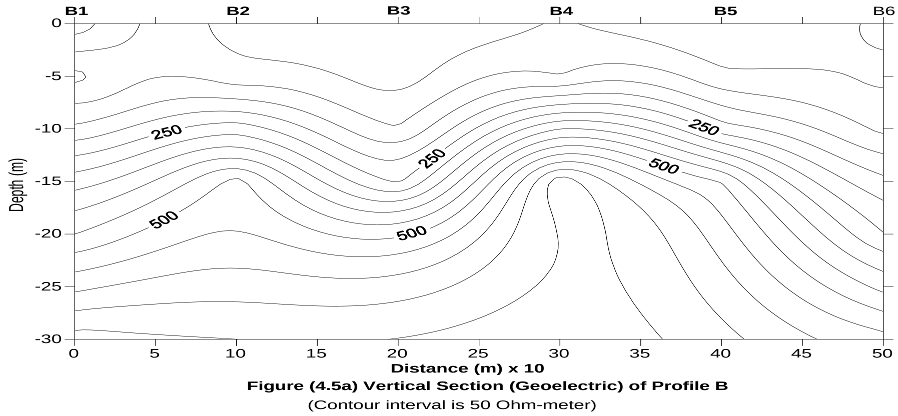

Figure 4: Vertical Section (Geoelectric/Geologic) of Profile B

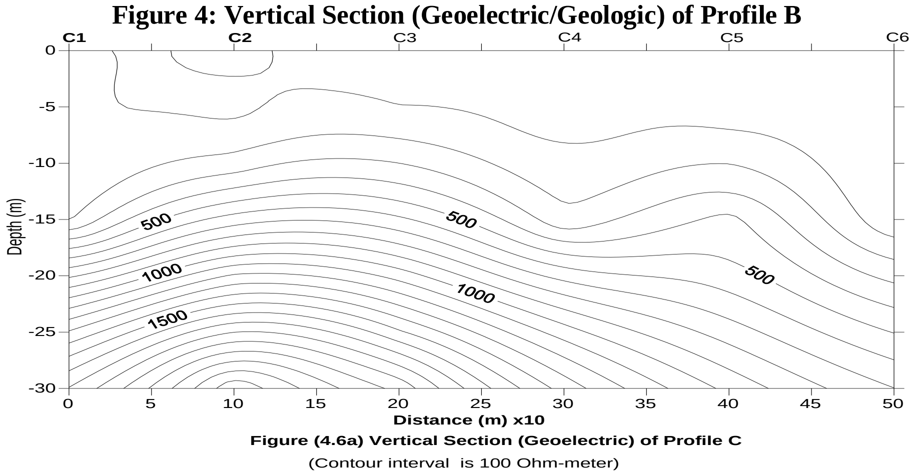

Figure 5: Vertical Section (Geoelectric/Geologic) of Profile C

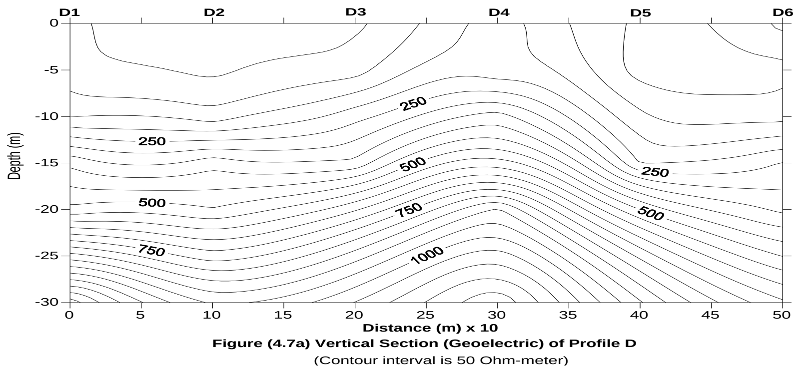

Figure 6: Vertical Section (Geoelectric/Geologic) of Profile D

Interpretation of Iso-Resistivity Contour Map at Various Depths and Deductions

For overall investigation of the continuous variation of resistivity with depth, the iso-resistivity contour maps at various depths were produced. These were carried out by plotting the resistivity data of n-layered model of Zohdy VES beneath the sounding location at depth of interest. Data were picked in a similar way with that of vertical section except that the data for each depth were picked for the entire area (36 VES points covering the whole area) before moving to the next depth or layer. This process was repeated until the depths of interest were covered for the whole area. These maps contoured using surfer 8.0 version, shows the conductivity pattern with depth through slicing of the entire study area horizontally.

These maps give a detailed and qualitative interpretation of hydro-geophysical aspect of the study area. These maps include the iso-resistivity map of the topmost layer and iso-resistivity maps at depth of 5m, 10m, 15m, 20m, 25m, and 30m. Deductions from these maps in turn give the isopach map of the overburden. These deductions are discussed in detail in the following sections.

The Iso-resistivity contour map at the topmost layer and 5m.

The iso-resistivity contour map was produced at 20Ωm contour interval as shown in Figure 7. The map is aimed at showing the spatial variation of resistivity of the topmost layer and 5m, which could be used to compare with the surface features like streams and exposed outcrops. The entire surface of the study area shows low resistivity values ranging from 20Ωm to 620Ωm which covers most part of the area except at VES A_1, which shows slightly high resistivity values. These could be due to lateritic topsoil or near surface outcrop. Those areas of low resistivity values as observed on the field were covered with Fadama Loam, which may likely have some level of water saturation. These maps show the reflection of what was obtained or deduced from the vertical section of the profiles. Based on these resistivity values the rock types at the surface could be Fadama loam, sand or gravel.

The Iso-Resistivity Contour Map at Various Depths and Basement Contour Map

The Iso-resistivity contour map at the 10m depth (Fig 8) was contoured at 50Ωm interval. The map obtained at this depth is quite similar to that obtained at 5m and 15m depth; the map shows an increase resistivity values up to 1250Ωm. The range of resistivity values found at this depth is between 50Ωm to 1250Ωm. Just as the 5m depth contour map, VES F_4 has the highest resistivity value which could be near surface outcrop. The southern parts of this maps shows high resistivity value while the rest show low resistivity (between 50Ωm to 250Ωm. Based on the resistivity values, the rock types at this depth could be lateritic soil or weathered laterite.

The Iso-resistivity contour map at 20m depth was contoured at 100Ωm interval as shown in Fig 9. The map is very similar to map obtained at 15m and 25m depth only that some areas that were said to be weathered and fractured basement got consolidated to fresh basement at this depth with resistivity values above 1000Ωm. The range of resistivity values found at this depth is between 100Ωm to 1900Ωm. The southern part of the map is fresh basement while areas such as VES D_5, C_5, E_5, C_4, and F_2 are fractured basement.

The Iso-resistivity contour map at 30m depth Fig 10 was contoured at 100Ωm interval. This map is similar to that obtained at 25m depth and their resistivity values are apparently similar. Areas of fractured and weathered basement get consolidated to fresh basement.

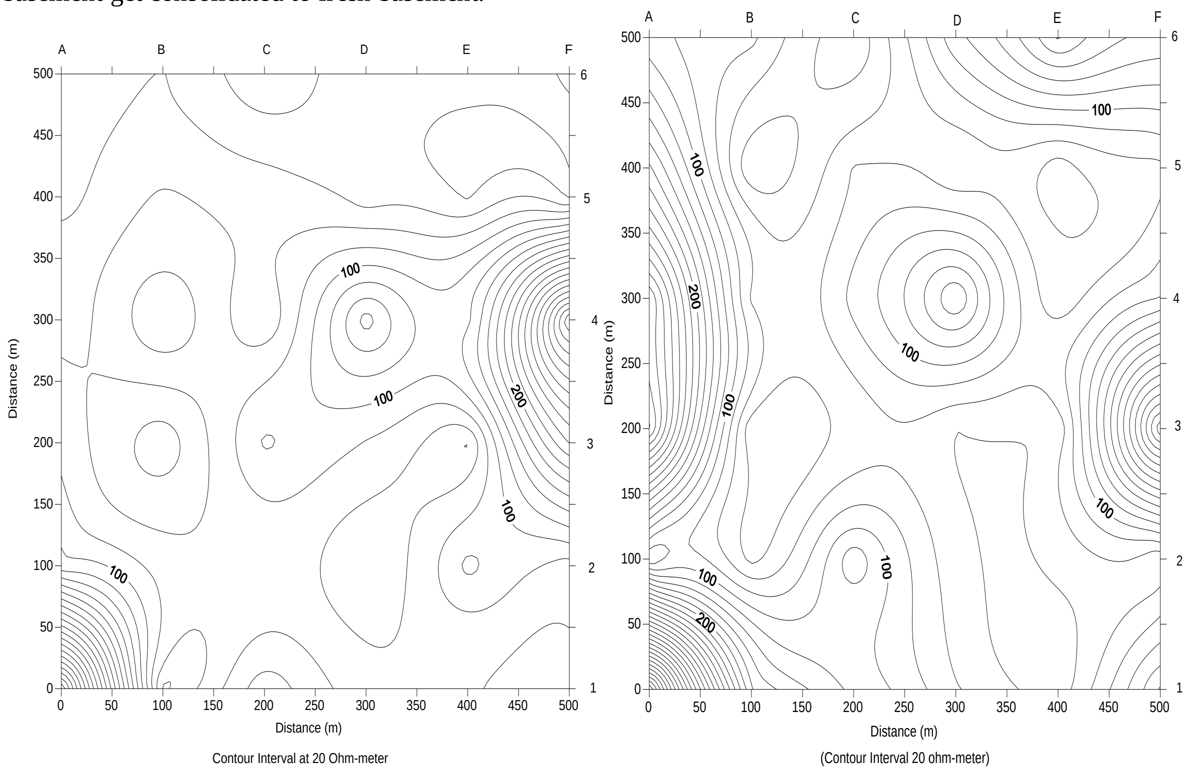

Figure 7: Iso-Resistivity Contour Map at the topmost layer and 5m

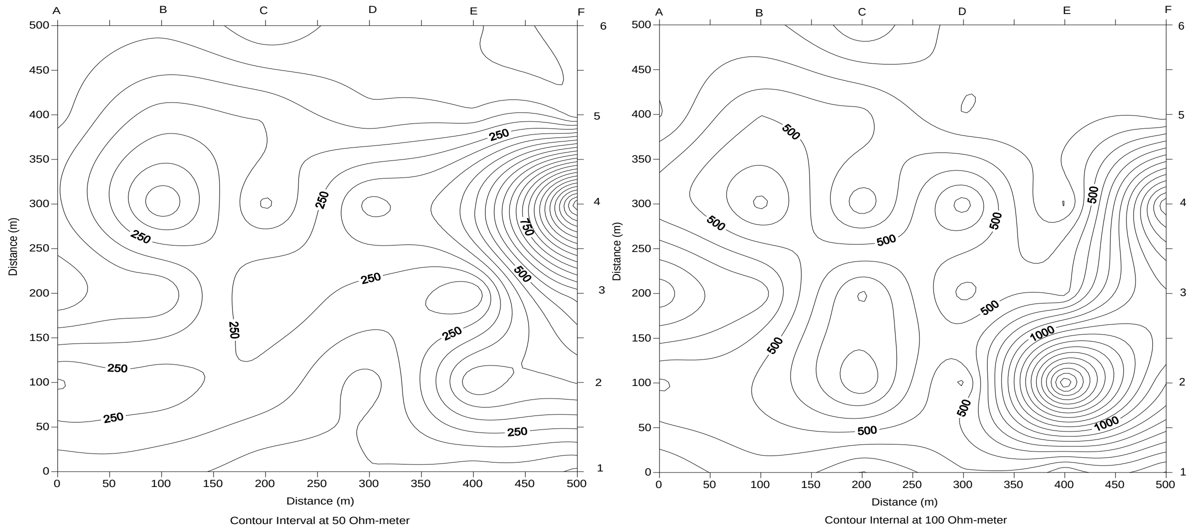

Figure 8: Iso-Resistivity Contour Map at 10m and 15m

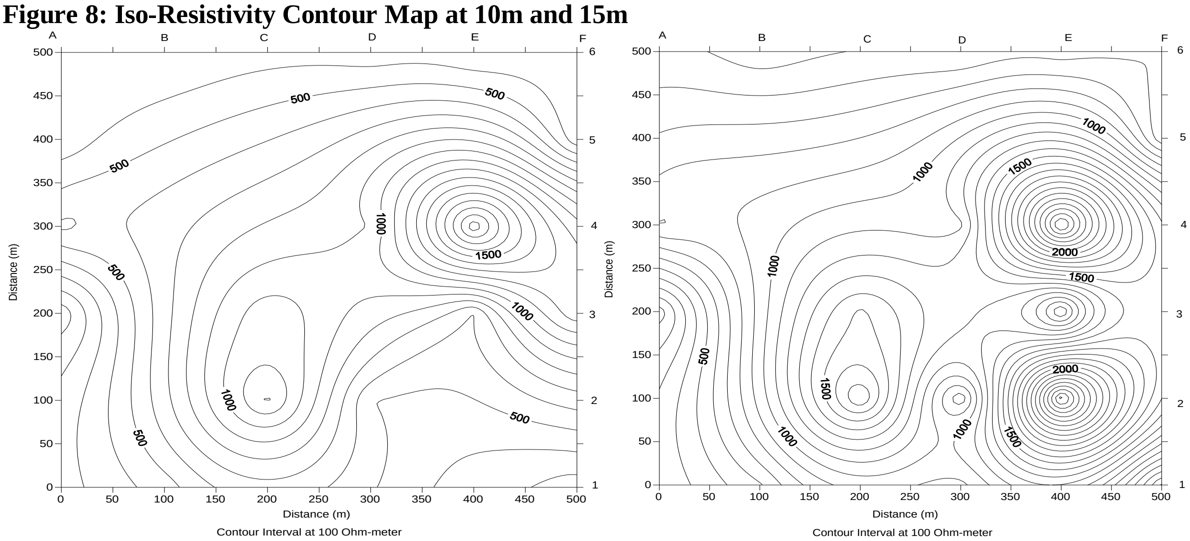

Figure 9: Iso-Resistivity Contour Map at 20m and 25m

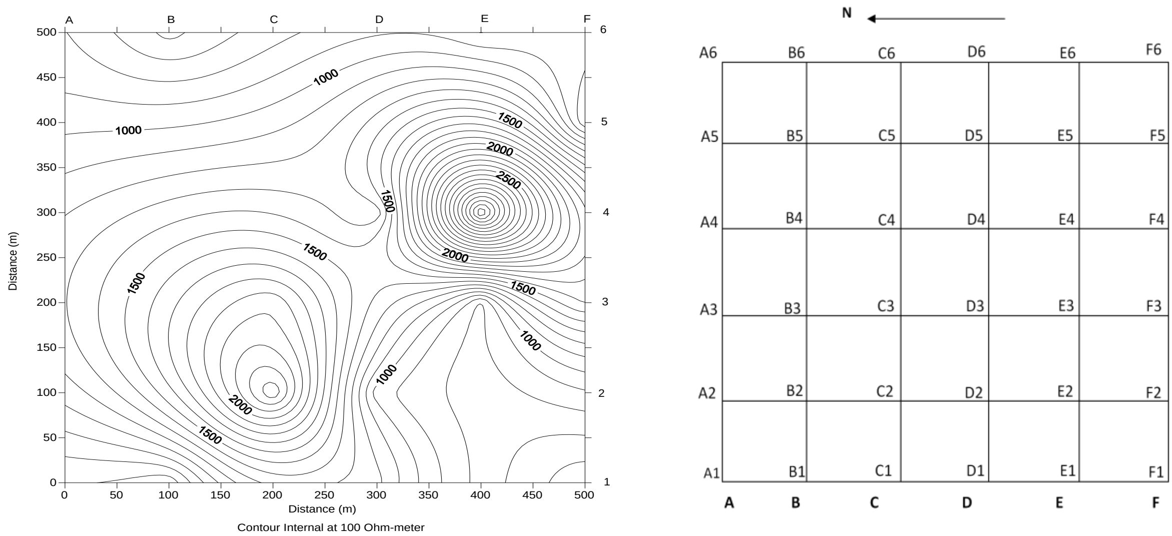

Figure 10: Iso-Resistivity Contour Map at 30m and profile layout

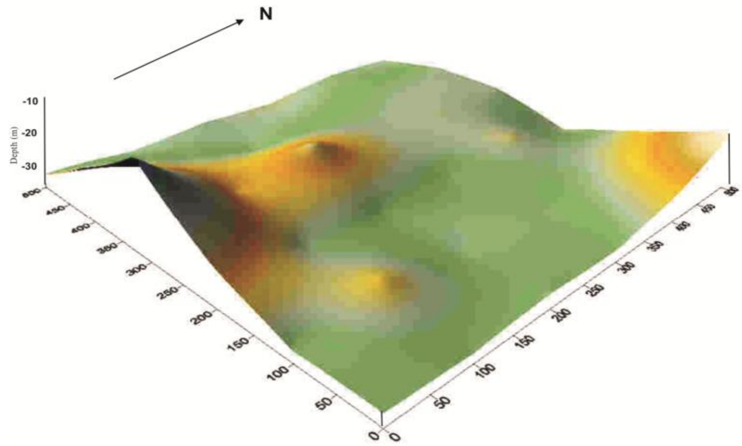

Figure 11: Depths to Basement Structure Map

A three dimensional form (wire frame) of the basement depth structure is as shown in Fig 11. The aquifer performances in the weathered basement are determined by its thickness at the drilling point. Similarly, areas of deep depressions of shallow basement may probably serve as research points for underground water, those areas with elevation could be used for civil engineering works.

Depth to Basement Contour Map. The depth of basement contour map is as shown in Figure 12. It is contoured at interval of 2.5m and gives the depth of basement from the ground surface. The data used to produce this map were obtained from Zohdy interpretations. The depth values corresponding to the last layers were picked until the entire (36) VES points were covered. The map shows that the basement varies from 2.68m to 20.30m. The basement gets shallow from the south to north. It is shallowest in the south where it is generally less than 5m. The basement is also deep in the west and south –east. The basement topography favours ground water flow west ward. The south-east portion is ground water collection point. There is a wide region of deep basement in the west. The western part of the study area constitutes a wide size for ground water collection. The central portion along the north-south line is shallow, thus ground water flows away from central portion preferably to the west or south-east side of the study area. The western and south-east part of study area is chosen area for sitting water borehole, those areas with elevation could be used for civil engineering works.

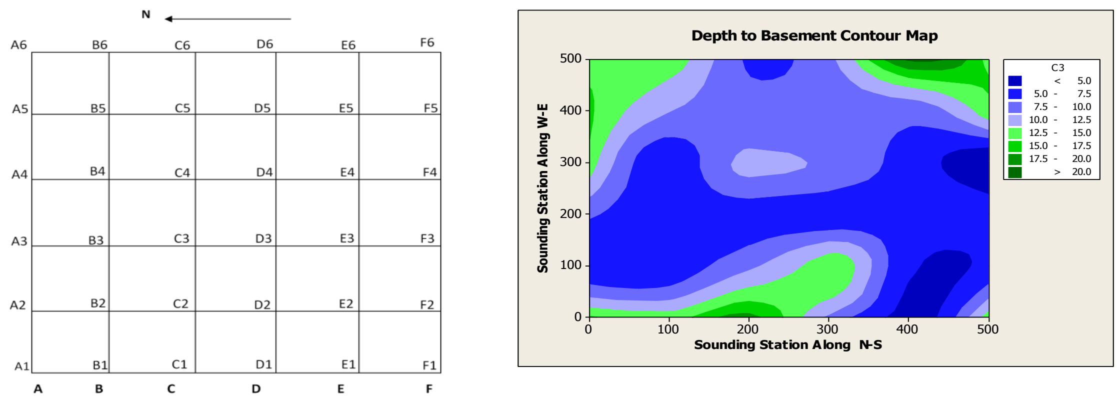

Figure 12: Depths to Basement Contour Map

II. Discussion

From VES data, thickness and the resistivity values of different layers were determined. There are three geologic units found beneath VES station, which revealed various lithological compositions. The geologic sections revealed that the first layer consists of lateritic topsoil, fadama loam, sandy clay and gravel. The second layer suggests the presence of sandy clay, highly weathered and fractured basement. The third layer consists of fresh basement. The map of depth of basement shows that, areas with shallow basement are uplifted and hence have shallow overburden. The areas with basement depth between 17.5m and >20m are areas characterized by lowland and fadama, this area could be found predominantly in south-east and western part with thick overburden.

Table 2: Summarizes the aquifer potential as a function of bedrock resistivity

Fractured Bedrock Resistivity (Ω-m)	Aquifer Potential
< 750	Highly fractured, high permeability as a result of weathering
750-1500	Reduced influence of weathering medium aquifer potential
1500-3000	low effect of weathering, low aquifer potential
>3000	Little or no weathering of bedrock negligible potential

There are about three main factors that determine the areas suitable for ground water exploitation, these are:
The Conductivity of the Subsurface:- The presence of ground water will result in low resistivity value hence high conductivity: clayey subsurface could equally be highly conductive. Therefore, water (aquifer) could be delineated by further application of geological controls (Aboh, 1996).
The thickness of the aquifer and
The presence of suitable aquifer (weathered and fractured basement)
We can deduce from the above information that areas or zones considered suitable for groundwater exploitation are weathered basement, which is the major component for aquifer system in basement terrain. Ajayi and Hassan (1990) and Salako and Udensi, (2005) classified aquifer components in the basement area to be weathered and fractured basement. Thus where the fractured zone is saturated, relatively groundwater yield can be obtained from borehole penetrating such sequence of weathered and fractured basement. The second layer in survey area satisfies these three conditions.

From this survey, the areas that satisfy the three conditions, and have overburden thickness up to 15m can be found at the south-east, western parts of the map. The areas that have overburden thickness of 17.5m are found within VES C_1, E_6 and could be good for ground water development. The dark greenish region of fig 13 shows those areas with over burden thickness of up to 20m.

III. Conclusion

The results obtained from the interpretation of the data for this survey have shown the efficiency and suitability of electrical method (resistivity) in probing for the geological subsurface structures and underground water in the basement complex area. The results of the investigation show that the study area is underlain by three geological units (layers). The first layer consists of lateritic topsoil, fadama loam, sandy clay and gravel. The second layer is characterized by sandy clay weathered and fractured basement rock while the third layer consist of fresh basement. Sandy clay, weathered and fractured basement constitute the aquifer system found in the study area. The best areas identified as suitable for ground water exploitation are the western and south-east parts of the study area. Similarly, northern and southern parts of the study area are identified as most suitable for civil engineering works.

References

[1]. Aboh O. H, 1996: A Regional Geophysical Investigation of the Groundwater Potential of Iyara, Ijumu Local Government Area, Kogi State using the Electrical Resistivity and VIF methods. Unpublished M.Sc. Thesis, Almadu Bello University, Zaria.

[2]. Adeniyi, J. O, Udensi, E. E. and Okosun, E. A., 1988: Site selection Survey for a Seismic Observatory Station using Geological and Geophysical Techniques. Unpublished Report; Pp 1-5.

[3]. Ajayi, C. O. and Hassan, 1990: The Delineation of the Aquifer Overlying the Basement Complex in the Western part of the Kubanni Basin of Zaria, Nigeria.

[4]. Ajibade, A. C., 1976: Provisional Classification and Correlation of the Schist Belt in Northwestern Nigeria. Elizabethan Publishing Col, Ibadan, Pp. 85-90.

[5]. Dogara, M. D., 1995: D. C. Resistivity Investigation of the groundwater potential in Romi, Chikun Local Government, Kaduna State, Nigeria. Unpublished M.Sc. Thesis ABU, Zaria.

[6]. Golden Software Inc., 2002: Surface Mapping System, Surfer Version 8.01 Golden Software Inc, Golden Colarado 80401-1866.

[7]. Instruction Manual: ABEM Terrameter SAS 4000/SAS 1000: ABEM Printed Matter No. 93101.

[8]. Jimoh, M. O. 1998: Six functional boreholes drilled at Federal University of Technology Minna, Permanent Site. Unpublished Report; Pp 6-14.

[9]. Kearey, P., Brooks, M. and Ian, H., 2002: An Introduction to Geophysical Exploration, Third Edition. Blackwell publishing.

[10]. Makama, B.S. and Shekwolo, P.D (1999). Appropriate Bore Hole Design and Construction in Basement Complex Rocks of Niger State. *Journal of Geology 8.* Pp 4-6.

[11]. Russ, P. H., (1975). The Geology of parts of Niger, Zaria and Sokoto Provinces. Geological Survey of Nigeria bulletins 27.

[12]. Olayinka, A.C Obere, F.O and David, Jr. L.M, (1997): Estimate of longitudinal resistivity from Schlumberger sounding curves. University of Ibadan, Nigeria.

[13]. Parasnis, D. S., 1987: Principle of Applied Geophysics. Chapman and Hall Ltd., London.

[14]. Salako, K A. and Udensi, E. E., 2005: Vertical electrical Sounding Investigation of Western part of the Federal University of Technology Gidan Kwano campus, Minna Ist Annual S.S.S.E Conference F.U.T. Minna Book of reading Vol.1 pp 69-75.

[15]. Telford, N. W., Geldart, L. P., Sherriff, R. S. and Keys, D. A., 1976: Applied Geophysics, Second Edition, Cambridge University Press, Cambridge.

[16]. Udensi, E.E., Ogunbanjo, M.I, Nwosu, J.E, Jonah, S.A, Kolo, M.T, Onuduku, U.S, Crown, I.E, Daniyan, M.A, Adeniyi, J.O and Okosun, F.A 2005: Hydrogeological and Geophysical Surveys for ground water at designated premises of the main campus of the Federal University of Technology, Minna; *Zuma*: *Journal of Pure and Applied Science (ZJ PAS),* Vol.7 (1), pp 52-58.

[17]. Udensi, E.E., Ojo, S.B and Ajakaiye, D.E (1986). A three dimensional interpretation of the Bouger Anomalies over the Minna Batholith in central Nigeria. Precambrian Res. 32:1-15.

[18]. Works Department, Federal University of Technology, Minna, 1983: Site Investigation of Permanent site of Federal University of Technology, Minna. Unpublished Report; pp 297-300.

[19]. Zohdy, A.A.R. and D. B. Jackson, 1989: Schlumberger Sounding data processing and Interpretation (Version 1.88) U.S. Geological Survey, Denver Co.