Geophysical Site Investigation for Groundwater Prospecting in the Permanent Site of Federal University, Dutsin-Ma, Nigeria

1 Introduction

Geophysical exploration is used to locate boundaries between different elements of the subsoil as these procedures are based on the fact that gravitational, magnetic, electrical, radioactive or elastic properties of different elements of subsoil may be different (ISSMGE TC1, 2005; Eurocode 7, 1999a; b). Groundwater is water located beneath the ground surface in soil pore spaces and in fractures of lithologic formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water (Alabi et al., 2010). Nearly all water in the ground comes from precipitation that has infiltrated into the earth. Observations have shown that a good deal of surplus rainfall runs-off over the surface of the ground while the other part of it infiltrates underground and becomes groundwater responsible for springs, lakes and wells (Oseji et al., 2006). Groundwater is often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. Groundwater is also widely used as a source for drinking supply and irrigation (UNESCO, 2004). According to Alabi et al. (2010), about 53% of all population relies on groundwater as a source of drinking water.

The availability of quality water resources has always been the primary concern of governments and societies in semi-arid and arid regions, even in areas of more abundant rainfall, the problem of obtaining adequate supply of quality water is generally becoming more acute due to ever increasing population and industrialization. As a result of this, surface water cannot be dependable throughout the year, hence, the need to look for other alternatives to supplement surface water (Alisiobi and Ako, 2012). Several methods employed in groundwater exploration include electrical resistivity, gravity, seismic, magnetic, remote sensing, electromagnetic, among others, out of which the resistivity method is the most effective for locating productive well.

Vertical Electrical Sounding (VES) technique can provide information on the vertical variation in the resistivity of the ground with depth and the Constant Separation Traversing (CST) provides a means of determining interval variation in the resistivity of the ground (USEPA, 2000; Ariyo, 2005; OPEA, 2008). A lot of geophysical investigations have been carried out in different parts of the world for groundwater investigation. Olorniwu and Olorumfemi (1987) used the electrical resistivity method for groundwater investigation in parts of the Basement terrain in Southwest Nigeria and concluded that the weathered layer and the fractured Basement constitute the aquifer zones. Sadeeq and Salahudeen (2016a; b) conducted a geophysical investigation for groundwater prospecting using SAS 300 geophysical survey instrument and dedicated geophysical software for data processing. They concluded that this method and procedure yielded acceptable results.

Anomohanran (2011) carried out a geophysical investigation in Oleh, in the Niger Delta Basin of Nigeria to determine the groundwater potential and the geological structure of the area. The method employed was the Vertical Electrical Sounding (VES) using the Schlumberger configuration. The investigation confirmed that the vertical electrical sounding is a reliable tool for underground water exploration in a sedimentary basin. ACLF (2005) used magnetic resonance sounding (MRS) method for Groundwater prospecting and concluded that it is most appropriate, because of its effectiveness in determining groundwater occurrence, whatever its conductivity. Al-Garmi (2009) used magnetic survey to delineate the basement structures of a study area which control the groundwater flow together with DC resistivity profiling and sounding techniques to investigate the potentiality of the groundwater occurrence in the structurally complex basement.

A geophysical investigation involving the seismic refraction and the vertical electrical sounding (VES) electrical resistivity methods was carried out by Alisiobi...
and Ako (2012) around Ajebandele quarters, Ile-Ife, Osun State, Southwest Nigeria. The study was carried out with a view to determine the subsurface layer parameters (velocities, resistivities, and thicknesses) and use same to categorise the ground-water potential of the area. Although the number of layers delineated differs, both methods used for the study indicate viable aquifer at a fractured zone along traverse four of the five traverses considered for the study. The interpretation of 12 Schlumberger vertical electrical sounding (VES) data was carried out by Cyril (2014) in the Kongo Campus, A.B.U, Zaria, Zaria Local government area of Kaduna State in an attempt to investigate the groundwater potential and the geologic characteristics of aquifers of the area, the Terrameter signal averaging system (SAS) model 300 instrument was used. The results of the interpreted VES data showed that the saturated groundwater bearing layer (aquifer) lie within the weathered and fractured basement of the predominantly four-layered geoelectric structure. The thickness of the aquifer varied from 3-25m with an average of 15m. Four VES points were found suitable for groundwater exploitation either by dug well or borehole.

This study is based on the geophysical and groundwater profiling of the Federal University Dutsi-Ma, Katsina state, Nigeria. The study was aimed at investigating the subsoil conditions based on geophysical site exploration methodology for field data obtainment in order to take precise engineering decisions on the best locations for water sources and ground water profile establishment.

2 STUDY METHODOLOGY

In this geophysical investigation, the major instruments used in carrying out the fieldwork include: SAS 300, Reels of cables, sets of electrode, hammer, tapes and sealed battery. The length of each of the survey profiles were 200m. The point on the red line labelled on the image map (see Figure 1) marks the starting point where the measurement began. Sets of electrodes were laid out at consecutive interval along the 200 m profile. When all the connections were completed, four electrodes were selected each time during the measurement. Two of the four electrodes served as the current electrode, by means of which current was ejected into the ground. The remaining two electrodes were the potential electrodes that were used to measure the results. The measured resistivity values are regarded as the apparent resistivity values, which will be used later to generate the true resistivity using inversion method. Figure 1 shows the survey area with the profile line indicated in red lines. P1, P2, P3, P4, P5 and P6 stands for Profile 1, 2, 3, 4, 5 and 6 respectively. The procedure used in this study is detailed in Eurocode 7 (1999b).

The coordinate points for the various profiles are shown in Table 1. The coordinate points were taken at the beginning, the centre, and at the end of the various profile. These coordinates measured in degree, minutes, and seconds were converted to degrees in order to generate the various 3D surfaces.

3 LOCATION AND GEOLOGY OF THE STUDY AREA

The study area, which is the permanent site of the Federal University, Dutsi-Ma is about 25Km south of the temporary site along Katsina-Kankara highway. The land, which is about 1120.29 hectares, is used as grazing reserve. It is bordered by the Katsina-Kankara highway on the east and by footpath on the north and south ends while to the west it shares border with land used for farming by the villagers. The land is generally flat in topography with rock outcrops dotted around the centre and to the north of the area. The geology of the soils in the study area is generally crystalline from the basement complex (Ola, 1983).

4 RESULTS AND DISCUSSION

The geophysical investigation results include the processing of the resistivity imaging data and analysis of the results.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Profile</th>
<th>Start point</th>
<th>Centre Point</th>
<th>End point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P1</td>
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<td>12°19'14.43&quot;N 7°27'32.74&quot;E</td>
<td>12°19'13.67&quot;N 7°27'29.40&quot;E</td>
</tr>
<tr>
<td>2</td>
<td>P2</td>
<td>12°18'47.60&quot;N 7°27'35.90&quot;E</td>
<td>12°18'46.30&quot;N 7°27'32.60&quot;E</td>
<td>12°18'45.70&quot;N 7°27'29.60&quot;E</td>
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<td>3</td>
<td>P3</td>
<td>12°18'31.70&quot;N 7°27'37.10&quot;E</td>
<td>12°18'31.70&quot;N 7°27'34.20&quot;E</td>
<td>12°18'31.45&quot;N 7°27'30.43&quot;E</td>
</tr>
<tr>
<td>4</td>
<td>P4</td>
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<tr>
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<td>P5</td>
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<td>6</td>
<td>P6</td>
<td>12°16'54.00&quot;N 7°26'54.70&quot;E</td>
<td>12°16'56.60&quot;N 7°26'52.60&quot;E</td>
<td>12°16'59.00&quot;N 7°26'50.40&quot;E</td>
</tr>
</tbody>
</table>
4.1 PROCESSING RESISTIVITY IMAGING DATA

Dedicated geophysical software was used for the data processing. In processing the data the observed (measured) apparent resistivity was subjected to inversion using the forward modelling procedure. This involves generating a calculated model from the field observed apparent resistivity by assuming an initial model. This calculated model was iteratively compared with observed apparent resistivity, until a very good fit was observed between the two. The resulting true model at the point of close agreement between the observed and calculated was adopted as the true resistivity model that gave rise to the observed. Figure 2 (a) – (c) shows the observed apparent resistivity, the calculated apparent resistivity and the generated true model.

![Fig. 2: Resistivity imaging section showing: (a) Observed apparent resistivity (b) Calculated apparent resistivity (c) True mode](image1)

4.2 RESISTIVITY IMAGING RESULTS ANALYSIS

The results of the 2D resistivity imaging section for profile 1 to 6 are shown in Figure 3 - 8, with only the true resistivity model shown. Each of the sections shows the distribution of true resistivity within the subsurface. It should be noted that the resistivity sections are not to be interpreted base on their colours but base on the resistivity value attached to the representative colours. A close examination of the 2D resistivity imaging sections shows a level of discontinuous layering structure, which is basically a characteristic of the resistivity structure of the basement complex. The resistivity values ranges from as low as 9.25 Ωm, which represent area of very low resistivity to 1535 Ωm that represent the fresh basement structure within the subsurface (Schuppener, 2008). This observed result is in conformity with the observation of Al-Garni (2009), Anomohanran (2011) and Sadeeq and Salahudeen (2016a; b).

![Fig. 3: 2D subsurface distribution of true resistivity along profile 1](image2)

![Fig. 4: 2D subsurface distribution of true resistivity along profile 2](image3)

![Fig. 5: 2D subsurface distribution of true resistivity along profile 3](image4)

![Fig. 6: 2D subsurface distribution of true resistivity along profile 4](image5)

![Fig. 7: 2D subsurface distribution of true resistivity along profile 5](image6)

![Fig. 8: 2D subsurface distribution of true resistivity along profile 6](image7)

Base on the resistivity values the overburden thickness from the various 2D resistivity sections were extracted along with their coordinate points. Also extracted with their coordinate points from the various 2D resistivity profiles are the depth to the fresh basement, and the resistivity values of a specific depth that represent the average depth to water table. These extracted values for the overburden thickness, depth to fresh basement and average depth to the resistivity of the water table along with their coordinate points, were used to build the 3D surfaces for easy visualization of the results. 3D surface for the
thickness of the overburden in the survey area is shown in Figure 9.

![Overburden Thickness](image)

**Fig. 9:** 3D surface showing the general overburden thickness within the survey area

It is quite obvious that the thickness of the overburden is more in the southern part of the area under investigation, compared to the northern part. A close observation also revealed that the overburden thickness is more in the south eastern region compared to the north western region under investigation. The overburden thickness ranges between 2 m to 35 m. The thickness of overburden in a given area determines the amount of interconnecting pores within the subsurface where the underground water resides. This goes a long way to influence the water potential of a given area. The 3D surface for the depth to fresh basement in the survey area is shown in Figure 10. A similar observation was made by Alisiobi and Ako (2012) in their geophysical investigation in Ile-Ife, Osun State, Southwest Nigeria.

![Depth to Fresh Basement](image)

**Fig. 10:** 3D surface showing the depth to the fresh basement of the survey area

From Figure 10, the depth to the fresh basement range from 1 m in area where the fresh basement is close to the surface, to the areas where it is 35 m below the surface. Also a close examination of the 3D surface shows that the fresh basement is shallower in the northern part of the survey area that is under investigation compared to the southern part where the fresh basement is deeper, below the subsurface. Figure 11 shows the 3D resistivity surface generated by averaging the depth to the water table from the various 2D profiles. The average depth from which the resistivity values were extracted is 22 m.

![Resistivity Surface](image)

**Fig. 11:** 3D surface showing the distribution of resistivity at an average depth

A very close observation of the distribution of resistivity values within the 3D surface, revealed that there is lower resistivity values in the southern part of the area under investigation, compared to the northern part. The resistivity distribution within the southern part is in close agreement with the resistivity of underground water which lies within the range of 10 Ωm to 150 Ωm. The resistivity distribution in the northern part matches with the basement (weathered and Fresh) resistivity which lies in the range of 450 to 1000 Ωm. This section is in close agreement with the 3D surface of overburden thickness in Figure 9, giving an indication that a larger part of the underground water lies within the southern part of the survey area (TGMGWI, 2008). In a similar study carried out by Cyril (2014) in A.B.U, Zaria, Kaduna State, in an attempt to investigate the groundwater potential and the geologic characteristics of aquifers of the area, a thickness of the aquifer varied from 3-25m with an average of 15m was reported. In general, the results of this study follow similar trend with studies carried out in Nigeria and reported in the literatures.

### 5 Conclusion

The results of this study show that:

- The thickness of the overburden which ranges between 2 m to 35 m is more in the southern part of the survey area than the northern part that has thin overburden thickness. This suggests that the thickness of the underground water aquifer will be more in the southern part than in the northern part of the survey area.

- The depth to the fresh basement ranges between 1 m to 35 m. The result also revealed that the fresh basement is very shallow, occasionally outcropping in the northern part and deeper in the southern part, as a result of the thick overburden cover. The 3D resistivity surface has confirmed the fact that a greater percentage of the aquiferous layers under investigation lies within the southern and the south eastern part.

### 6 Recommendations

Based on the results of this study, the following are hereby recommended:

- It is recommended that, in the event of siting boreholes for municipal use, 40 m along profile 4 with coordinate point 12° 17’ 58.4” N, 7° 27’ 28.91’
E (12.29948° N, 7.45803° E) and 70 m along profile 6 with coordinate point 12° 16’ 55.78” N, 7° 26’ 53.20” E (12.28216° N, 7.44811° E), will serve as the best points for drilling borehole that will result in very good yield of water. The boreholes should be drilled beyond 35 m.

- Possibly, the water from the boreholes may not sufficiently meet the need of the university community. To this end, an alternative source of water would be the Dam which lies opposite the university site.
- Other methods of geophysical investigation like vertical electrical sounding (VES) should be used together with SAS 300 used in this study to validate the observations herein.

7 References


