The Geology and Hydrogeology of Parts of Minna Sheet 164 NE

[1*]Yaman, A., [2]Idris-Nda, A., [2]Goro, A.I. and [2]Ejepu, J. S.

[1]Nigeria Geological Survey Agency, Minna
[2]Department of Geology, Federal University of Technology, Minna
*Corresponding Author: aishayaman22@hotmail.com 08061571808

Abstract

A study of the geology and hydrogeology of a part of Minna was conducted with the aim of determining the geological conditions controlling groundwater flow and storage and safe abstraction methods. Many boreholes have failed in this area principally as a result of poor understanding of the groundwater conditions and relying solely on geophysical surveys using Electrical Resistivity. The area is basically underlain by rocks of the Nigerian Basement Complex system comprising chiefly of granite, gneiss, migmatites and schist. Geologic mapping was conducted on a scale of 1:25,000, surface fracture orientations where mapped to determine the principal joint directions. Hydrogeologic mapping was conducted on existing dug wells and boreholes using the gridding method. This information was used to plot the water level elevation map, water level change map and depth to water map. Groundwater in the parts of Minna studied occurs mostly within weathered to fractured portions of the underlying rock. The weathering profile is shallow and mostly between 3 – 10m. Water level contour map revealed that areas with greatest potential are located within the central and northwestern portions of the area. No appreciable change was noticed in the water level change map. Sites that could be exploited for groundwater development showed target areas having the highest water level and the least depth to water levels. Groundwater potential was found to be higher in areas underlain by granite followed by gneiss with schist having the lowest potential for groundwater storage and transmission. The schist in the part of Minna studied was found to belong to the Birnin-Gwari Schist belt. This research has buttressed the need for Geological and Hydrogeological studies in choosing sites for the development of groundwater resources.

Keywords: Geologic mapping, crystalline rocks, Hand-dug wells, Hydrogeologic data, Water level map

1. Introduction

Water is one of Earth's most vital natural and essential resources which has wide ranging impacts on various aspects of life. The importance of water as a major source of living cannot be over emphasized as some communities are usually located close to reliable water supply sources (surface/groundwater). Water supply has posed serious challenges to both rural and urban populations that depend on it for various purposes, including irrigation. Water supply in rural areas is mostly from streams, rivers and hand dug wells while in urban areas it is mostly through public supplies (like Niger State Water Board). However due to failure in public water supply facilities and increasing demand as result of growing population and expansion, facilities become overstretched and supply becomes grossly inadequate. In order to meet up with demand people often buy water of questionable quality from vendors (selling in carts) and on groundwater. Those that can afford it have boreholes/wells placed in their homes, offices, factories, etc. the boreholes thrive in some areas and in other areas it does not (Idris et al, 2010). Study of the geology and hydrogeological conditions of the area will greatly aid in understanding the mechanism of groundwater occurrence and distribution for integrated water resources management (IWRM). Groundwater occurrence is a factor of climate, geology and topography, all of which together form a complex and finite system. Climate is responsible for recharge while geology is responsible for storage and transmission, (Idris, 2013).

Minna is a rapidly growing city with the population increasing from influence of people trooping in from neighbouring states. Niger state water Board (NSWB) is the agency under the Ministry of Water Resources that is responsible for supplying water to the populace, however percentage coverage of the town in terms of people networking in just about 30% (NSWB, 2014) this implies that over 60% of the city's population rely on other source for water supply, notably boreholes.

Many have lost huge amount of money on drilling of boreholes that turn out to be unsuccessful, the success or otherwise of the borehole depends on the local geology and structures contained in them that can store and transmit water in economic quantities to borehole placed in them. It is therefore significant to understand the geology of the area in relation to its groundwater transmission and storage capability. Most (over 80%) of boreholes/well owners seldom conduct geochemical analysis of the water, believing that borehole water is a very clean source of water. However, boreholes and wells can become contaminated from both natural and anthropogenic sources.

A study of the groundwater quality will yield information on areas that are prone to contamination or have been directly contaminated and also on the source of contamination. This will provide a useful source of information for effective and sustainable water use and management.

The study area forms part of Minna Sheet 164 and lies between latitude $6^0$30'E and $6^0$32'E and longitude $9^0$37'36"E and $9^0$39'34.5"E with a total area of 14km^2 (Figure 1).

2. Methodology

2.1 Preliminary studies

Background investigation was carried out using preliminary studies on existing information of the geology and hydrogeology about the area of research likely to be met. The research was broken down into phases to offer complete background data on the study area and also for preparatory functions. Phase one involved studying available materials, which involves using information from ministries, educational institution, Federal and state government libraries, internet, journals etc.

Reconnaissance survey was done to compare data accumulated with what is on the ground by going to the study area.
Topographical map of the area was used during the mapping and gridded to a scale of 1:12,500.

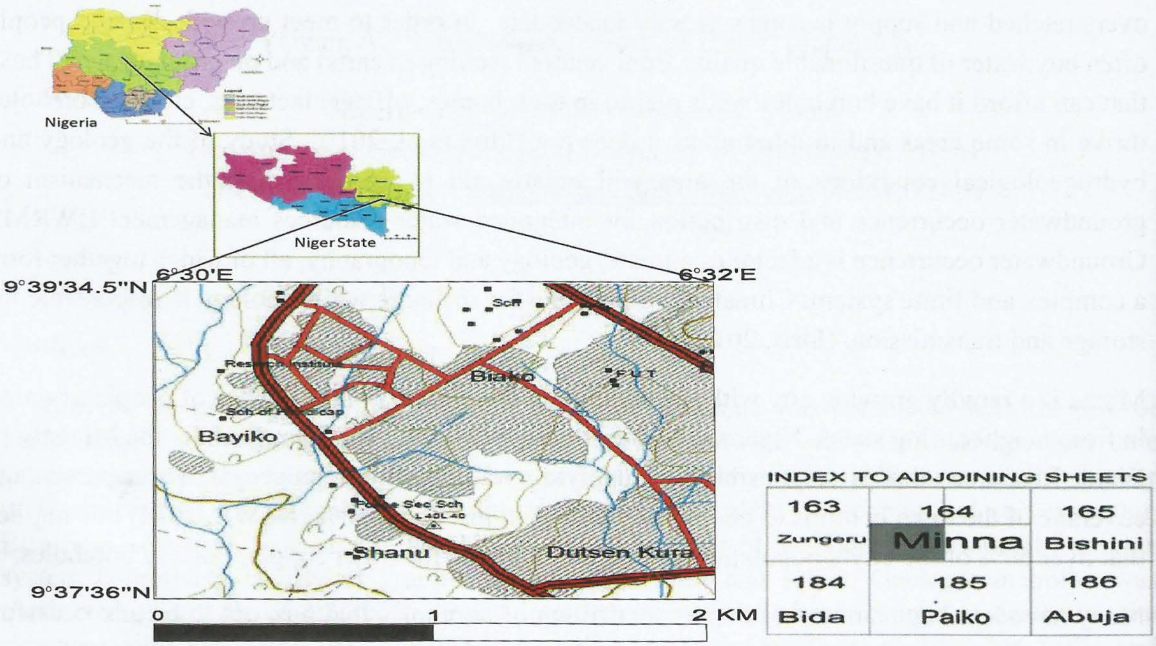

Figure 1: Map of Nigeria showing study area. (satellitecitymaps, 2016)

2.2 Field work

Field work was conducted after the reconnaissance studies, careful studies and compilation of material was completed and an intense geological and hydrogeological mapping of the area was conducted with topographical map of the area.

Geological mapping was conducted by a topographical map of the area derived from the original map of Minna sheet 164 NE in order to map various lithologies in the area with the use of GPS in locating boundary determination and outcrop location while surface fractures orientations where mapped in order to determine the principal joint direction.

Hydrogeological mapping was conducted chiefly on the present hand-dug wells in the area and their respective depths, depth to water and the well types were detected. Coordinates of such wells with elevation and location were determined by the use of GPS. Using this information to plot the water level elevation map, water level change map and depth to water map. Water level where been taken from 195 hand dug wells in the area. Table 3.1 shows general description measured wells, locations, elevation and coordinates.
Collection of water samples from wells within the study area with random sampling method, the samples were gathered in properly cleaned and dried empty bottles with a total of 28 samples collected and stored in a cooler containing ice to keep it beneath room temperature of 37^0c while at

the field prior to being sent into the lab. Physical parameter of water samples was taking from various locations within the study area which includes PH, Turbidity and colour using colorimeter DR 890 as shown in plate below. Conductivity, Temperature and TDS using Conductivity meter as shown in plate below and DO using J well as shown in plate. Samples were grouped into conductivity range of 200-400, 401-600, 601-800, 801-1000, 1001-1200, 17 representative water samples were selected and taking to the laboratory for further analysis.

2.3 Laboratory work

Analysis of water samples was done at the Regional Water Quality Laboratory of the Federal Ministry of Water Resources located at the Upper Niger River Basin Development Authority, Minna, Niger State. Set of standard procedure describing the sampling manual, (UNEP/WHO, 2011) was used to collect samples for the hydrochemical analysis delivered to the lab. Sodium (Na^{2+}), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (k^{+}) was examined with Titrimetry method of analysis.

3. Results and Discussion

3.1 Geology

Geological map of parts of Minna Sheet 164 NE in figure 4.1 shows the area is mainly underlain by rocks belonging to the Basement Complex System of Nigeria. Main lithological unit which underlie the area are the granites (over 90 %) covering virtually the entire map. The second lithological units are the Schist which occurs in the south eastern part of the area. The cross section from point A – B indicates a terrain that is not very rugged but gentle with the schists forming the higher elevations. The elevation ranges from 240 m to 300 m with the highest point occurring around Police Secondary School area which also represents a spot height and the Universal Time Mercator (UTM, WGS 84) is located at the spot height. The granites are the youngest of the two rock types.

Rose diagram of the measured joints is shown in figure 3. From this figure, the major joints direction is formed trending in the NNE/SSW and ENE/WSW directions.

Water level in the wells where observed within a period of three months apart from the previous study; and an increase was remarkably noticed showing the actual source of water in the hand dug wells is the overburden water from the surface which is subject to seasonal change.

The results of the research showed that the area is underlain by granitic rocks. Central portion of the water level contour map reveals the highest water level in the North-Western portion of the map; with values above 7m. Highest values of depth to water level map trends in the NNE/SSW and ENE/WSW directions with values ranging from 0.8m to above 1.5m. No appreciable change was noticed in the water level change map. This information is useful to the hydrogeologist, engineers, town planners and individuals wishing to prospect for water or avoid water in the area.

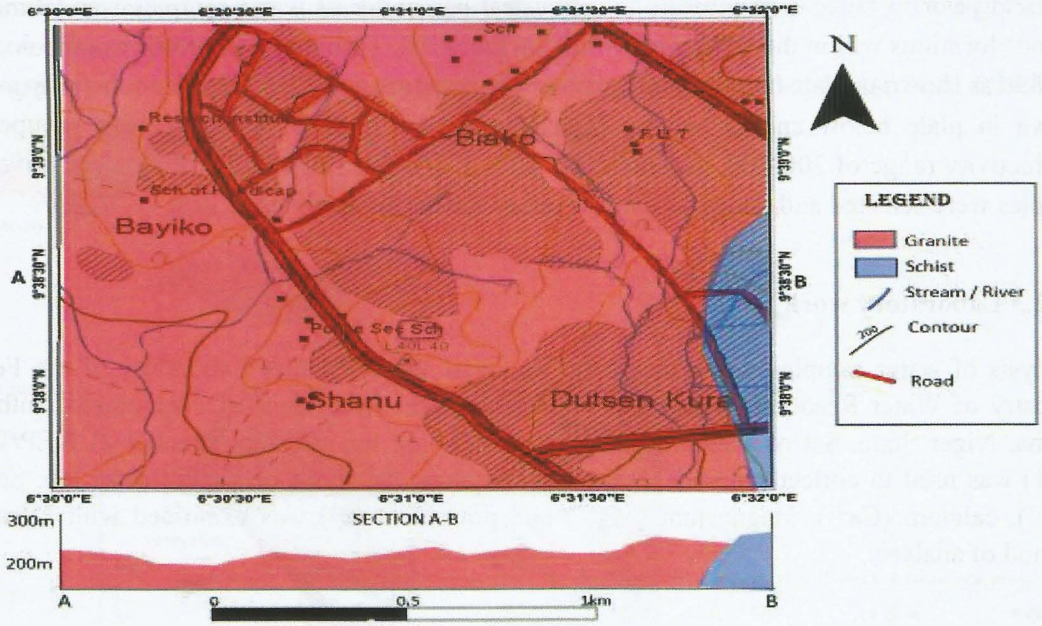

Figure 2: Geological Map and Cross Section of parts of Minna Sheet 164NE

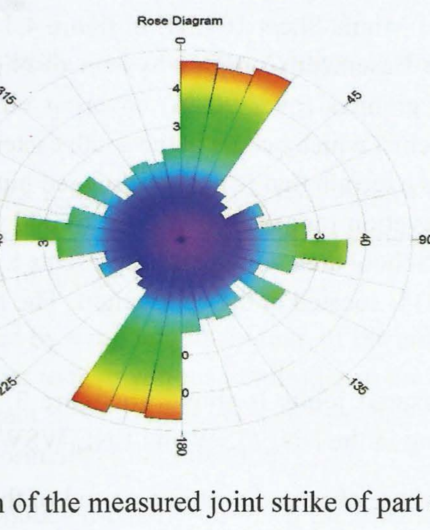

Figure 3: Rose diagram of the measured joint strike of part of Minna sheet 164NE

3.2 Hydrogeological maps

The following hydrogeological maps where produced from data gathered from well inventory: depth to water maps for both dry and raining season and water level elevation maps.

Figure 4 shows dry season water level map, the central part of the map shows that wells in this area generally dries up as a result of very low water level which is > 3.7meters. However, the northern part of the mapped area shows water level been shallow and is obtainable all year round, cutting across from northeast to southwest shows clear zone of high-water level which is almost reflecting presence of shallow fracturing. Potential for deeper wells exits in this area aa result of fracture forces shown by the shallow water level sources. The raining season water level elevation map shown in figure 5 shows that water level is generally closer to the surface in the northeastern part of the area. Specifically, however, water level is high in the eastern part, medium or fair in the northern part and very poor in the southern part. The map also shows indication of the northwest, southwest trending fracture earlier seen in the dry season water level map. Water level elevation map shown in figure 6 indicate areas with higher groundwater potential from which wells that are less than 10meters deep can get water all year round such areas includes parts of Bosso estate, Bosso Low-cost, Bajego, Dutsen Kura and parts of Fadipe. Other areas like Shanu, Tudun Fulani and parts of Dutsen Kura and Bosso have deeper water levels which tends to dry up at the onset of dry season.

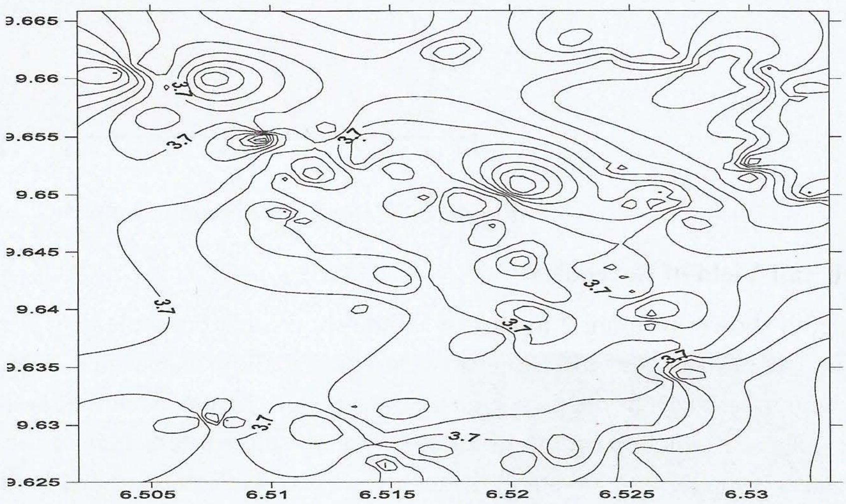

Figure 4: Dry season water level map

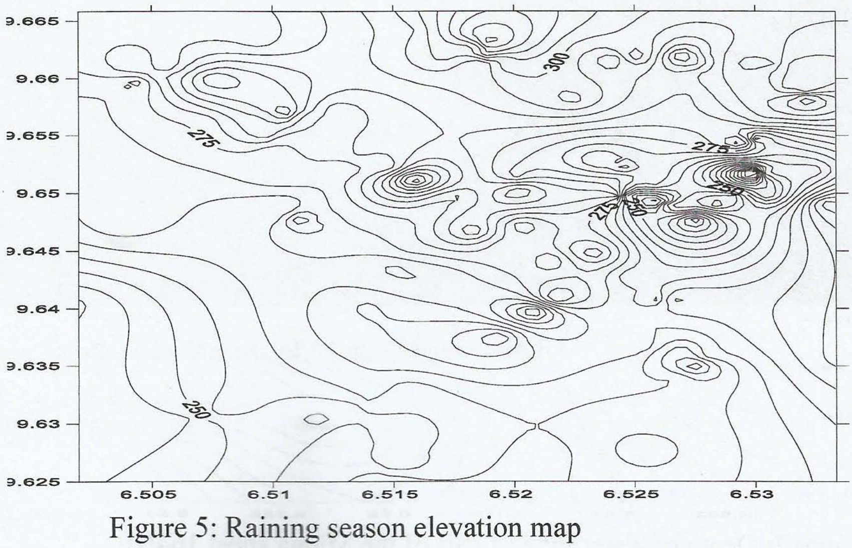

Figure 5: Raining season elevation map

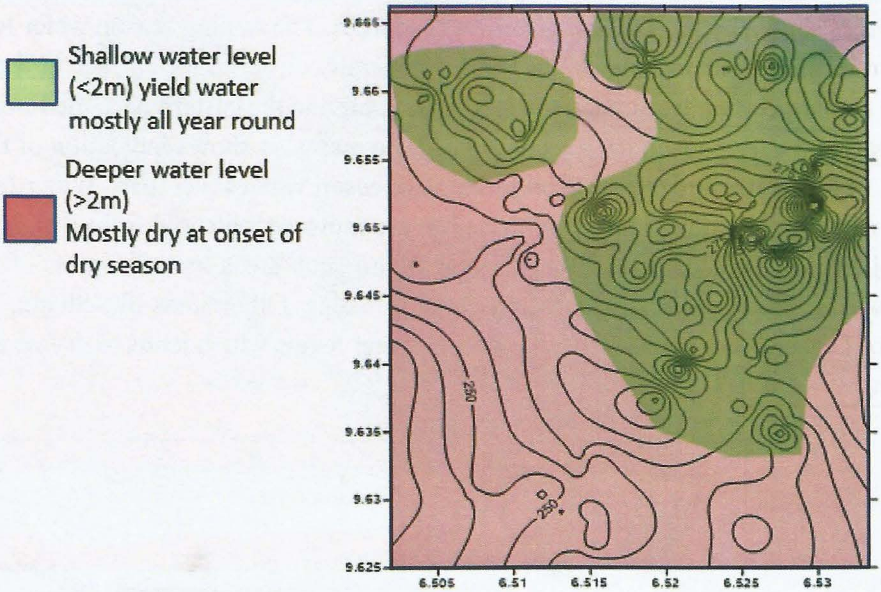

Figure 6: Water level elevation map

3.3. Depth and Yield of Boreholes

Borehole depth shown in figure 7 in part of Minna shows that borehole or water wells drilled in this area ranges from 70meters to 150meters deep while shallow ones which is less than 120meters occurs in the northern part of the area such as Dutsen Kura Shanu, Tudun Fulani and Bosso. And the deeper ones < 120meters occurs in the northern to southeastern part of the area like Bosso estate, Lowcost, Bajego, London street, Zarumai, parts of Dutsen Kura and Fadipe. The yield of the borehole in contour value of meter per day m^3/d as shown in figure 4.4.1 shows that those with higher depths > $100m^3/d$ tends to have greater yield while those with shallow depth have reduced yield < $50m^3/d$.

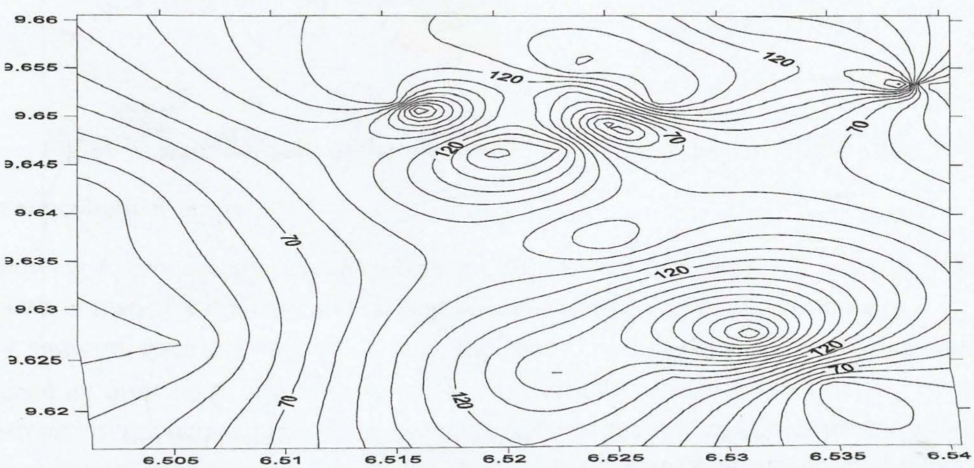

Figure 7: Depth of water map of part of the Minna sheet 164NE

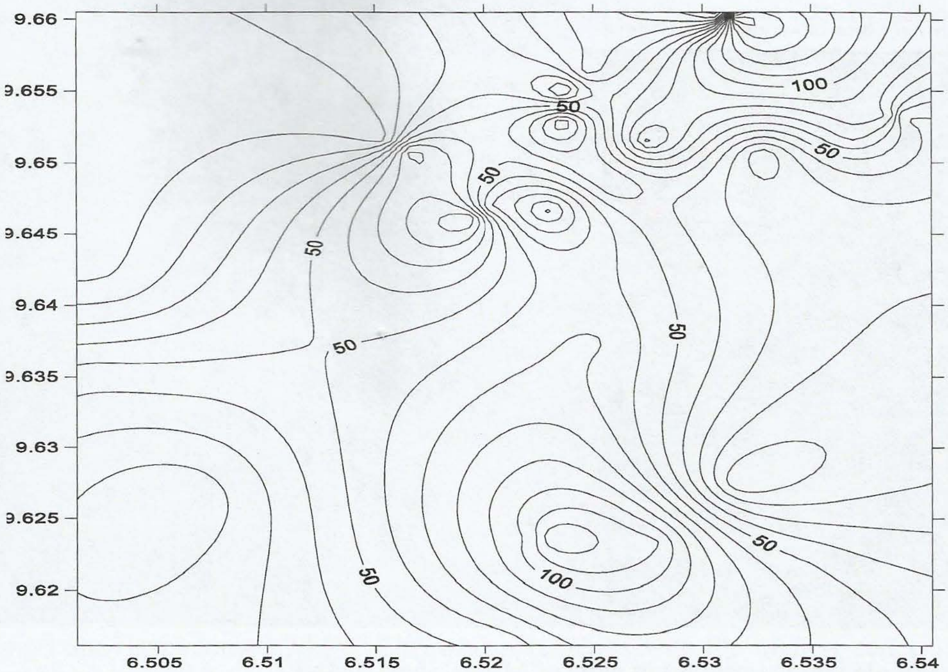

Figure 8: Water yield contour map of parts of Minna sheet 164NE

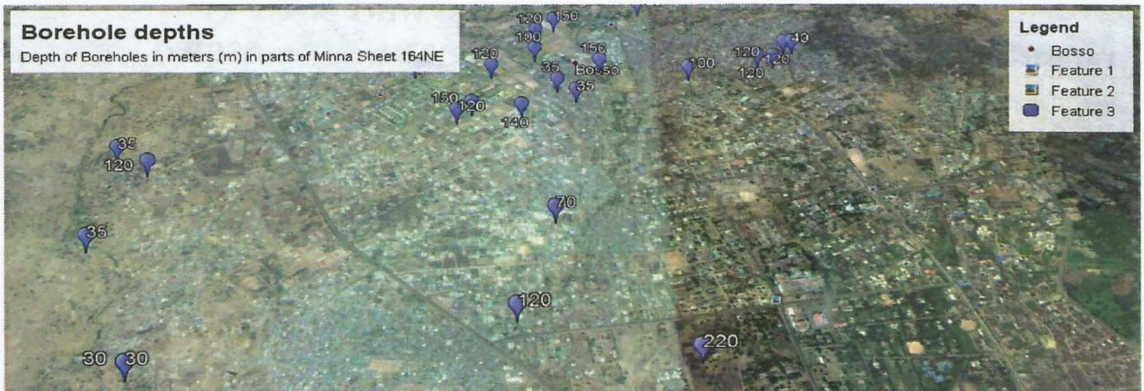

Plate 1: Borehole Depths (m) in parts of Minna Sheet 164NE

4. Conclusion

80% of the part of Minna Sheet 164NE studied is underlain by granite and 20% by Schist belonging to the Birnin Gwari Formation. Weathering profile between 3 – 10m. Groundwater occurs mostly in the fractured zones. Fracturing in the rock occurs at 30 – 50m at shallow levels and 80 – 140m at deeper levels. Depth of hand dug wells in the study area varies in different locations from 1m to 8.8m. Hand pump boreholes have an average depth of 35m while motorized boreholes have an average depth of 140m.

Conclusively Water level contour map revealed that highest water levels are located within the central portion of the map and the North-Western portion of the mapped area; with values above 7m. there is a trend in the depth to water level map as highest values are formed trending in the NNE/SSW and ENE/WSW directions with values ranging from 0.8m to above 1.5m. No appreciable change was noticed in the water level change map. Most hand dug wells dries up at the peak of dry season since high rates of annual rainfall in this area results in high recharge rates.

Groundwater yield in boreholes placed in them is between 0.342lt/s (12.5m^3/d) and 0.825 (71.25m$^{3/}$d). Groundwater use is mostly for domestic (household level) and light industrial purposes (water vending). Mean pH of the water is 7.3 (neutral), Conductivity 637.5μS/cm, TDS 390.5 mg/l and Temperature 28.5°C.Chemical parameters with the highest concentrations are; Chloride (82.35mg/l), Bicarbonates (70.18mg/l), Sodium (58.18mg/l), Calcium (46.16mg/l).Heavy metals with high concentrations are; Zinc (1.15mg/l), Fluoride (0.32mg/l) and Copper (0.30mg/l)

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