HYDROGEOLOGICAL INVESTIGATIONS OF SHEET 102, ZARIA NW, NORTH CENTRAL NIGERIA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN GEOLOGY (HYDROGEOLOGY)

DEPARTMENT OF GEOLOGY, AHMADU BELLO UNIVERSITY, ZARIA NIGERIA

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DEDICATION

This research work is dedicated to Almighty God, the beginning and the end, the author and finisher of my faith for allowing me to witness this moment in my life. It is also dedicated to my husband and my children, Oluwaseye, Anuoluwapo and Iyanuoluwa for their enormous sacrifice toward the success of this programme.

DECLARATION

I declare that the work in this thesis entitled: "Hydrogeological Investigations of Sheet 102, Zaria NW, North Central Nigeria" has been carried out by me in the Department of Geology. The information derived from literatures has been duly acknowledged in the text and a list of references provided.

No part of this thesis was previously presented for another degree or diploma at this university or any institutions.

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CERTIFICATION

This thesis entitled "Hydrogeological investigations of Sheet 102, Zaria NW, North Central Nigeria" by Aponbiede Deborah Folake, meets the regulation governing the award of the degree of Master of Science in Geology (Hydrogeology) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Hydrogeological investigations of Sheet 102, Zaria NW, North Central, Nigeria have been carried out. This was done to determine the potability of groundwater in the area. The study area is located between latitudes $11^{o}15'00''N$ to $11^{o}30'00''N$ and longitudes $7^{o}30'00'E$ to $7^{o}45'00'$and cover an approximate area of about $748km^2$. The area is underlain by the basement crystalline rocks which comprise migmatite, schist, granitic gneiss, porphyritic biotite granite and coarse grained biotite granite. Two major aquifer units are present in the area and these are overburden aquifer and weathered/fractured aquifer. Water levels were measured from eighty-four hand-dug wells during the end of wet season and the peak of dry season using a modified surveyor's tape. Thirty groundwater samples were collected in wells in the area, using polyethylene bottles and fifteen elements were analyzed from these samples. Evaluation of hydrogeological maps has shown that the watertable in the area is similar in the shape in both seasons and resembles that of ground surface contour except where interrupted by the outcrops of the basement rocks. This shows that watertable is controlled by relief. The general direction of groundwater flow is towards the streams and their tributaries and is identical in both seasons. Watertable fluctuation varies from 2 to 10.5 m below the ground surface with an average of 6.25 m. Result of chemical analysis of the thirty groundwater samples shows that groundwater from the study area is fresh and soft. It equally has a low total dissolved solids (TDS) and low conductivity value which ranges from 5.4 to 491µS/cm. The groundwater is slightly acidic (pH varies from 5.3 to 6.4 with average value being 5.8). In addition, concentration of some of the parameters analyzed like Fe^{2+}, Pb^{2+}, Zn^{2+} and Ca^{2+} are above permissible limits of World Health Organization (WHO) standards while the concentrations of other parameters are having within the recommended levels of WHO. The abundance of the major ions can be depicted as follows: $Na^{+} > K^{+} > Ca^{2+} > Mg^{2+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2-}$. The Piper trilinear diagram shows that Mg^{2+}, Ca^{2+}, Na^{+} and K^{+} are the dominant cations, whereas HCO_3^{-} SO_4^{2-} and Cl are the dominant anion in all the waters. These aforementioned cations and anion have influenced the water chemistry of the area. This four water types were identified namely Ca + Mg, Na + K – HCO_3, Ca + Mg, Na + K – SO_4 and Na + K – SO_4 –Cl (dominants) and Na + K – HCO_3 (minor) waters. Chemical data of representative samples from the study area were plotted them on Durov diagram. The samples were concentrated on $MgHCO_3$ type. Chemical assessment indicates that groundwater from the study area is suitable for domestic purposes. The electrical conductivity value of the groundwater samples indicates low-medium salinity and low sodium hazard, pointing to good usability of the groundwater for irrigation and industrial purposes. The correlation coefficients of the chemical facies using statistical package of Aquachem V.O 4.0 soft ware explain the relationship that occurs between chemical facies. Some of the variables have strong positive correlation with each other are Na^{+} -Cl^{-}, Na^{+} - NO_3^{-}, Fe-Pb, Pb-NO_3^{-}, Cl^{-}-NO_3^{-}, Cl^{-}-SO_4^{2-} and NO_3^{-} -SO_4^{2-}, Na^{+}-SO_4^{2-}, Ca^{2+}- Zn^{2+} e.t.c. The relationships might be as a result of poor sanitation conditions and derivation of the ions from common sources (rain filtration).

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CHAPTER ONE

1.0 INTRODUCTION

Water is next to air as a major support substance to life. It is an essential part of life on earth and is something that people, plants and animals need to survive. It is important that the limited amount of fresh water that existing on earth stays safe for drinking and use for the many purposes required in everyday life. It occurs as surface water in streams, rivers, lakes and the world seas and oceans and as groundwater when it accumulates beneath the ground surface. Fresh groundwater is a precious resource which can be seriously affected by the industrial or agricultural activities. Water should be preserved to ensure that a quality supply is available for the future. Also, for the success of building and underground projects, the level of groundwater must be managed during construction or engineering works. Groundwater constitutes significant proportions of the earth's water resources. Buchanan (1983) puts the groundwater reserve of the world at about $5.0x10^{24}$ litres. This volume is more than 2000 times the volume of water in all the world's rivers. Being naturally filtered in its passage through the ground, it is usually clear, colourless and has excellent quality, being free from microbial contamination and requires minimum treatment (Babiker, *et al.*, 2007). Unfortunately, high quality groundwater can no longer be taken for granted, as a threat is now posed by ever-increasing number of soluble chemicals from urban development, industrial activities and modern agricultural practices. There has been indiscriminate exploitation of groundwater resources in Nigeria particularly in the north, leading to a decrease in groundwater potential, lowering of watertable (hence an increase in cost of groundwater withdrawal) and deterioration in groundwater quality by pollution and use of chemicals on the ground surface which affect the groundwater quality. Groundwater is almost globally important for human consumption as well as for the support of

habitat and for maintaining the quality of base flow to rivers. A significant percentage of the urban and rural developers depend on groundwater sources for their daily needs (Olarewaju *et al,* 1997).The study area is underlain by rocks of the basement complex. The complex is a heterogeneous mixture of crystalline rocks which includes metasediments and granitic or gneissic rocks. The crystalline rocks unfractured or unweathered, are totally impermeable and have no storage capacity. Therefore, the occurrence of groundwater in the basement complex depends on secondary structural features such as joints, fractures and weathered products.

Groundwater is precious natural resource: preserve it, protect it and do not pollute it.

1.1 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to investigate the hydrogeology part of Zaria, Sheet102 Zaria NW. The objectives of this study include the following:

i) Production of a detailed hydrogeological map of the study area showing groundwater table configuration for wet and dry seasons on the scale of 1:50,000.

ii) Detail Petrographic description of the various rock types in the area.

iii) Determination of major anions, cations and some heavy metals constituents in the water samples

1.2 SCOPE OF WORK

i) Measurements of static water level in hand-dug wells and locating sampled wells on the geological map.

ii) Water sampling and Measurements of temperature, pH, electrical conductivity and total dissolved solids.

iii) To determine the groundwater flow, water levels were measured in hand dug wells for both the end of the wet season and the peak of the dry season. With the data, watertable contour maps were drawn so as to determine the flow trend.

1.3 JUSTIFICATION

In the past, the geology of the study area was done on smaller scale 1: 100,000; therefore there is need to have a closer examination. In effect, field mapping was carried out to delineate the boundary various rock types and structures in the outcrops. In addition public concern about the level of pollution in groundwater intended for human consumption might have greatly increased. This necessitated for proper investigation of the chemical quality of groundwater within the rocks of the crystalline basement complex in the Zaria Sheet 102 NW.

1.4 LOCATION AND ACCESSIBILITY

The study area is located on the Precambrian Basement Complex of Northern Nigeria within the Guinea Savanna belt on one degree Sheet 21 Zaria. It is about 34 km NW of Zaria. The study area lies between latitudes 11º15'00''N to 11º30'00''N and Longitude 7º30'00''E to 7º45'00''E. It covers an area of about 748 km² (Fig 1.1).

Easy accessibility was provided by good roads network especially the Zaria – Hunkuyi – Kudan, Dabai- Danja- Gosaki roads, river channels and footpaths that link the villages with the major towns. The area of study can equally be accessed from Maraban Guga village about 10 km SW from Zaria, with footpath and river channels linking the villages with major towns. Except during the peak of the wet season, most of the stream channels are passable.

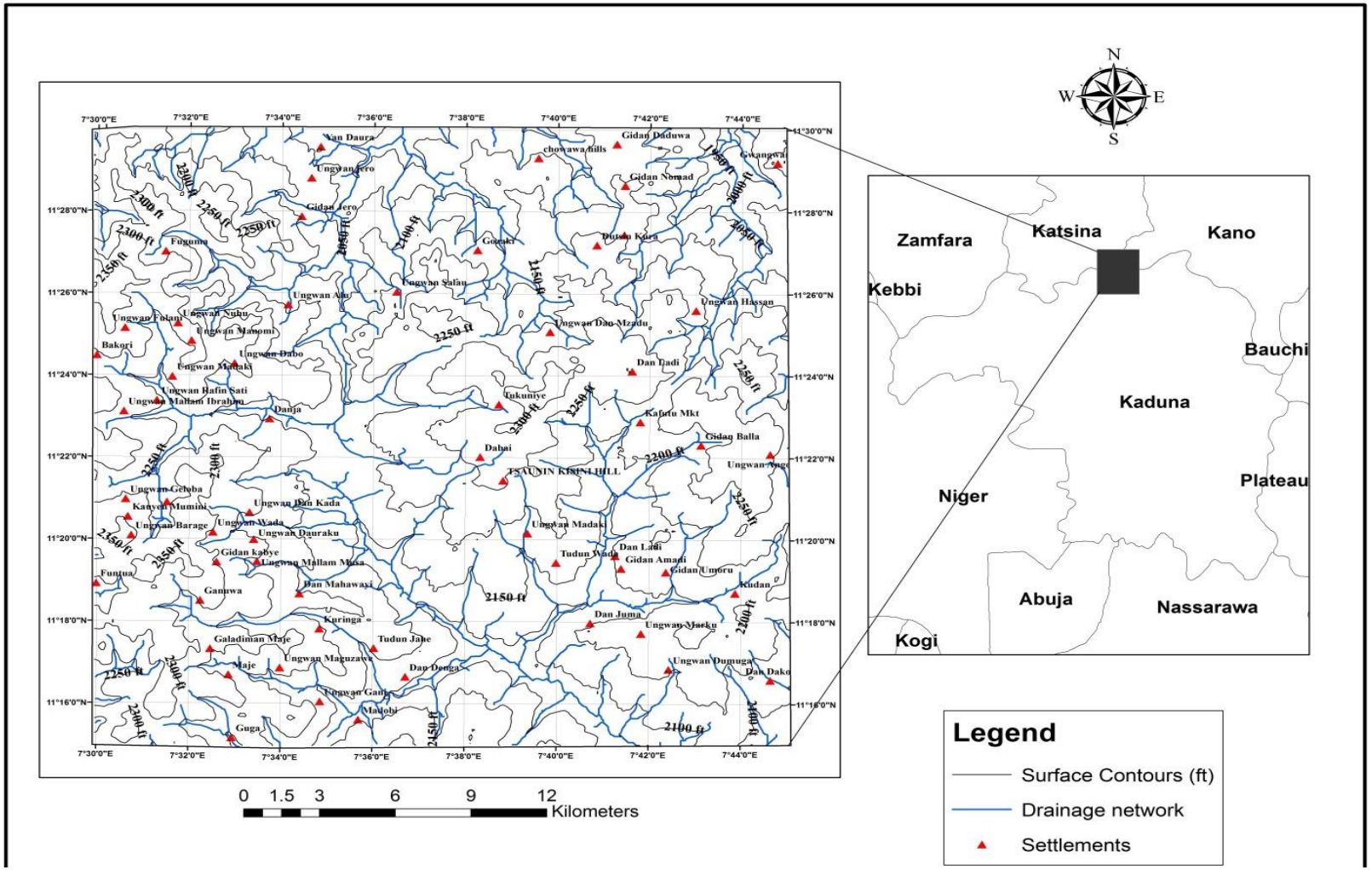


FIGURE 1.1: LOCATION MAP OF STUDY AREA SHOWING TOPOGRAPHY AND DRAINAGE

1.5 RELIEF AND DRAINAGE

The Zaria area is part of the vast, gently dissected plain of northern Nigeria. This plain is largely underlain by a thick soft overburden. The relief of the study area is generally flat to gently undulating with the altitude ranging from 650 to 783 m above sea level (1950 ft to 2350 ft) (Fig 1.2). Blocky inselbergs and whalebacks are the most conspicuous feature of the area. These belong to the general category of residual hills and are associated most commonly with porphyritic granite. The inselbergs are characteristically dome shaped as typified by the Hunkunyi Hill rising to about 731 m above sea level.

The highest peak is the Tsaunin Tsangamawa Hill at the south western edge with elevation of about 783 m above sea level. Moreover, the central and northeastern parts have low relief characterized by valleys and gullies filled with alluvium terraces. This lowland area has elevation of 650 m above sea level.

The values above reveal a regional slope from the south to the north. Hence the northwards flowing first order river Sabon Kogi, Rereya, and Tsangamawa drains the area. The drainage pattern is mainly dendritic. However, rectilinear pattern are also observed in places. The tributaries of the major rivers are seasonal; therefore, the study area is well drained.

1.6 CLIMATE

The study area lies within the sub-equatorial and guinea climatic regions with distinct wet and dry seasons. It has a short wet season (about six months). The wet season begins in April and ends in October when it becomes intensely hot. The dry season in which there is no rainfall occurs from October to March. The total mean annual rainfall in the study area is 1197.9 mm for the period of 2000-2012 (Samaru Meteorological Observation Station, Dept of soil Science)

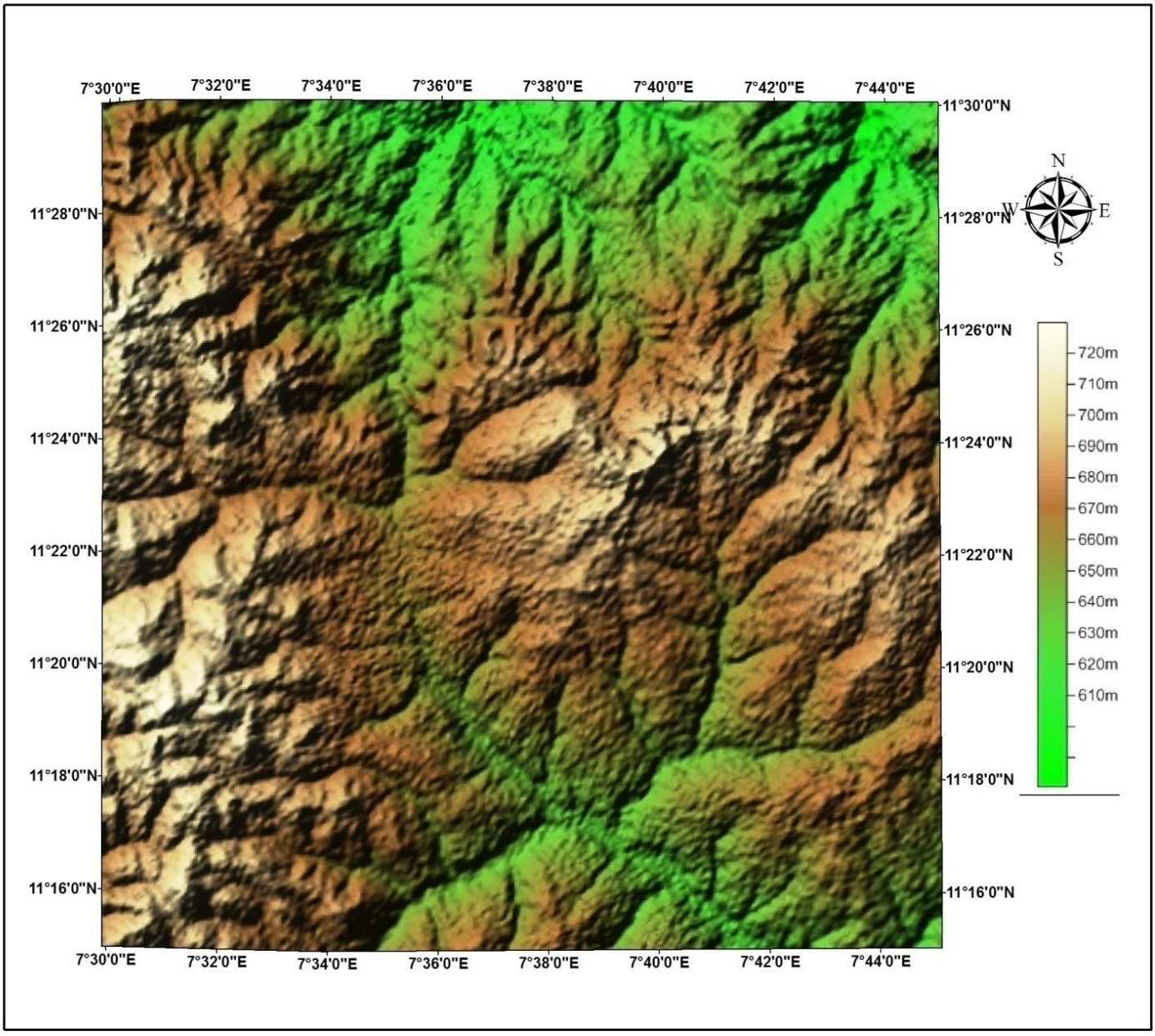


FIGURE 1.2: A DIGITAL ELEVATION MODEL OF THE STUDY AREA SHOWING RELIEF

March 2013, though there are considerable variations from year to year. Rainfall reaches its peak in mid August to early September (Fig 1.3). The mean annual temperature attains a maximum of 35ºC in March and drops to its minimum value of 13.8ºC in January. The mean daily maximum temperature rises gradually from January and shows a major peak in April and a minor one in October. The minimum temperature rises from its lowest value in December – January to its highest in July – August (Samaru Meteorological Observation Station, Dept of soil Science)

1.7 VEGETATION

The natural region in which the study area is located is in the Guinea Savannah belt of Nigeria and is characterized by open, sub-humid broad-leaved savannah woodland vegetation with short to medium grasses. The vegetation on the whole has been greatly disturbed by poor land use practice that includes overgrazing, tree felling for firewood, cultivation and bush burning which is very common with the people in the dry season and has been considered hydrogeologically disadvantageous. With burning of the vegetation the ground is devoid of vegetation, which should have retain water on the surface for percolation into the sub-surface instead of run-off causing deepening of gullies. Some of the common woody tree species in the area include *isoberlina doka, locust bean* (*Parkia biglobosa*), baobab (*Adansonia digitata*) and shear butter tree (*Vitallaria paradoxin*).

1.8 LANDUSE

Agriculture and animal husbandry are the main activities of the inhabitants of the project area. Most of the land within the study area with the exception of built up areas is used for subsistence rain fed farming. The land is cultivated for maize, yam, guinea corn, millet and sugar cane

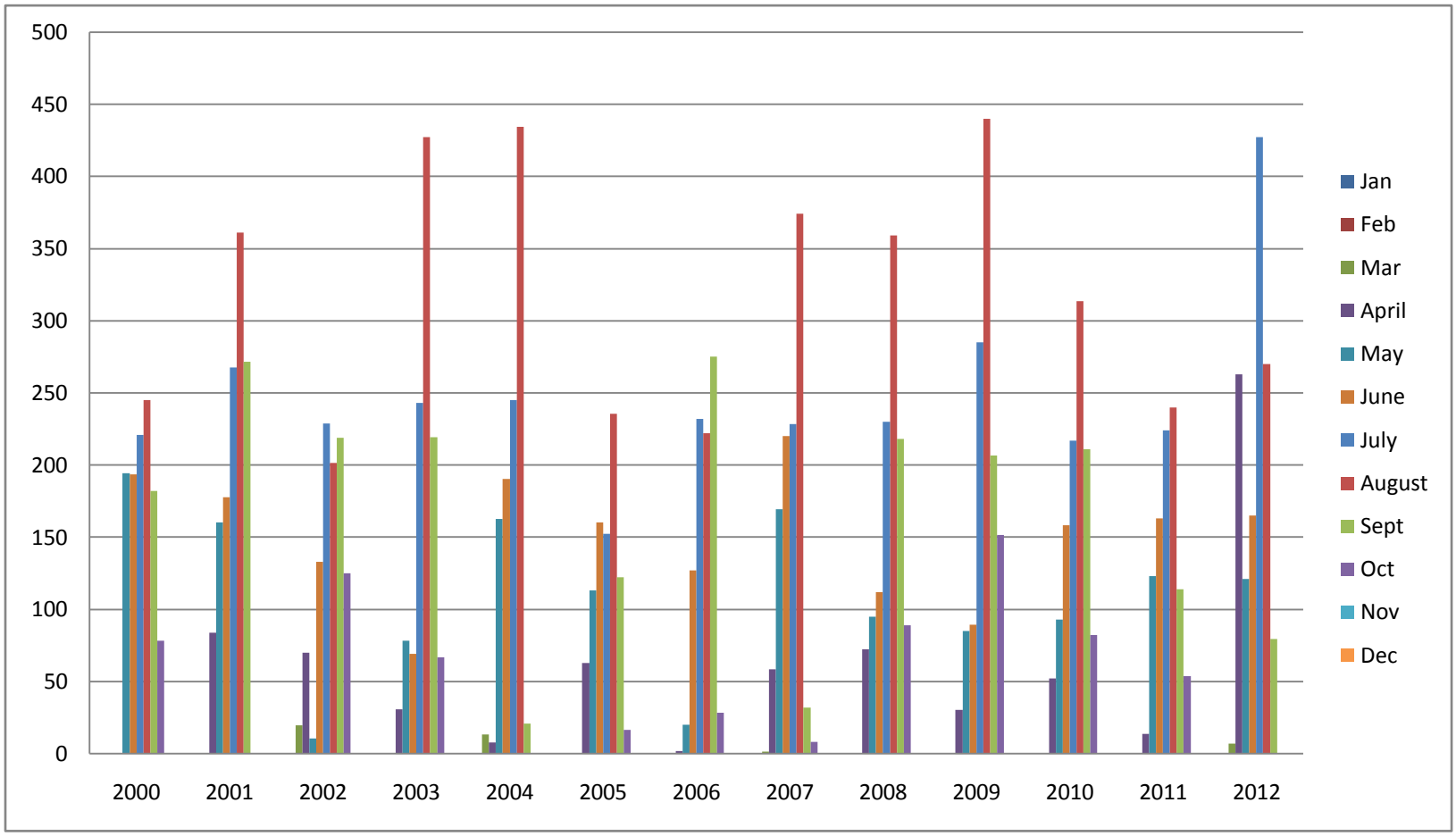


FIGURE 1.3: MONTHLY RAINFALL DEPTH IN ZARIA FOR 2000 – 2012

(Source: Meteorological Data Station, I.A.R. Samaru pers.comm).

while local swamps are used for irrigated agriculture during the dry season, mostly for the cultivation of tomatoes and other vegetables. Another form of land use in the study area is livestock grazing. Land use can be developed by the way of private water supplies.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 PREVIOUS WORK ON THE STUDY AREA

Du-Preez and Barber, (1965) were the first to work on the distribution and chemical quality of groundwater in northern Nigeria. Du-Preez (1961), also worked on the water supply for Ahmadu Bello University. Work on the groundwater condition in Zaria was done by Olowu (1967). Ososami (1968) also attempted a groundwater assessment in the Kubanni valley for the purpose of water supply to the Ahmadu Bello University campus, where he made very little mention of the geological formation of the entire area he worked on.

Omolokun (1970) worked on the irrigation water demand from a small excavation in a dry river bed, where he limits his study to only a small portion of the Kubanni drainage basin. His main focus is, the yield of shallow well situated in a dry bed; the effective method of retaining banks in such wells, and the suitability of the water and land for irrigation practices.

The first detailed account of the basement geology of the area of study is that of McCurry (1970) and Wright and McCurry (1970). These authors studied various rock types in and around Zaria, with little emphasis on the Quaternary deposit of the area. Akpoborie (1972) and Abaa (1973) both worked on hydrogeological control of the structures along Samaru creeks.

Egbeifor (1978) worked on the evaluation of the hydrogeological properties of the Kubanni basin. He also undertook some chemical analysis of water in Samaru in order to determine their suitability for domestic, agricultural and future industrial usages. He plotted a Piper's trilinear diagram in order to establish the water types. His conclusion was based on chemical quality of major ions. Ogunrombi (1979) did some studies on the quality of the Kubanni impounded reservoir and he came out with the conclusion that the water is potable. His conclusion however

is not without some reservation. He reported iron content of 7.67 mg/l which was far exceed the World Health Organization (WHO) guideline value for iron and even Nigeria standard for drinking water quality (NSDWA, 2005). Even the guideline of iron is also 0.3 mg/l and that in the presence of oxygen, iron is precipitated which settles at the bottom; therefore such a high concentration is suspicious. Adeyemi (1983) worked on the geology and hydrogeology of Zaria. He reported that the porphyritic -coarse grained biotite granite consists of large phenocrysts of pink feldspar embedded in a groundmass of medium to coarse grained quartz, feldspar and micas. This rock was found to be locally abundant in his study area specifically in the south-eastern quadrant around Institute of Administration, Kongo and Zaria city. Outcrop of this granite also abound Tukur-Tukur area in Zaria. Adeyemi (1983) also carried out chemical analysis of Cl, Cu, Mn, NO_3, $KMnO_4$, HCO_3 and physical parameters such as pH and electrical conductivity on groundwater from the area and reported that these were within the permissible limits of World Health Organization (1973).

Hilary (1984) worked on the quality of some well water in Samaru. His conclusion is that the water is suitable for domestic use for his result showed Cd, Pb, As, Ni and Cu, to be below the detection limit for the analytical technique he used, with Fe and Zn present, in smaller concentration. The only reservation about for his result is the high Mg content of the water in the range 3 to 22 mg/l which is very high, though it is still within the permissible limit.

Udoh *et a*l. (1986), in their work, tested the raw and the treated waters from Kubanni reservoir, and reported that Hg, As and Cu were below the detection limit of the analytical method used (that is Atomic Absorption Spectrometry (AAS); However, Pb content is high for the raw water reading 0.5 mg/l if it was to be considered for the WHO (1973) drinking water guideline used (0.01mg/l).Therefore, he declaring that the water is potable.

Dahiru (1989) investigated the concentration of some heavy metals absorbed by irrigation crops using treated effluent water, with tap water as a control. He reported that the sewage effluent contains slightly more of Cd, Pb, Zn, and Mn than the tap water, so also the concentration of Mn absorbed by the various parts of the test crops were significantly higher in the tap water than the sewage effluent irrigated crops. His final conclusion is that the concentration of the metal in both the sewage effluent and the tap water are well below their permissible limit and may not be toxic to the irrigated crops, animals and man that may consume the crops. He further recommended that crops may not pose danger to their consumers or that the tap water is potable. In as much as water with a Pb concentration of 70 ppb and 10 ppb of Cd cannot be potable considering their guideline values of 10 ppb Pb and 2 ppb Cd (WHO, 1996), it is not potable.

Jeb (1996) collected water samples from three sub-basins he demarcated within the Upper Kubanni catchment area. After filtering the water samples in the field, he acidified them to pH < 2. In the laboratory, samples were further digested using concentrated nitric acid ($HNO_{3)}$ and heating the same samples prior to analysis using AAS. His conclusion shows that out of the six elements he analyzed, Pb occurs between 0.005 mg/l and 0.001 mg/l while Ca, Mg, Cu and Zn are above WHO (1973) permissible limit. However, the method used by Adeyemi of sample pre-concentration is new to this author. Samples that were initially filtered, it makes no sense to use much of HNO_3 to digest suspended solids, since the essence of filtration is to remove suspended sediment. Pre-concentration can easily be achieved by simply heating the samples in an oven at a low to moderate temperature. An alternative method is the use of chelating agents such as ammonium pyroldine dithiocarbanate (APDC).

Obamuwe, (1998) in his own work studied the trace elements content of the Kubanni impounded reservoir where he analysed almost all of the transition elements, using X-ray fluorescence

technique. His result shows that with the exception of Cd, Pb and Sb, all other elements are below the WHO permissible limit. He concluded was that the water is suitable for drinking and domestic use. A critical look of his conclusion shows that Cd content in the range 0.994 to 0.433 mg/l, Pb in the range 0.0969 to 0.0123 mg/l and Sb in the range of 0.656 to 0.307 mg/l is not at all safe for drinking considering the toxic effects of these elements.

Udoh (1999) also tested the water of Kubanni reservoir in both its raw and treated forms and concluded that the water is suitable for domestic use. However on looking at his recalculated Pb value (recalculated by the author) it shows a concentration range of 0.037 to below detection limit of the analytical technique employed. Taking the 0.037 mg/l value, one cannot say that the water is potable. (Garba 2000) investigated lead (Pb) concentration in the water of Kubanni dam, Zaria. Garba collected Twenty-four samples from three water bodies. These are:

i) The reservoir

ii) A seasonal stream that flows into the reservoir from Samaru and

iii) Samaru stream

At each of the sampling points a set of eight samples were collected and treated simultaneously. Four samples out of each set were filtered and the remaining four were unfiltered. This is done in order to determine the concentration of Pb in both dissolved and total forms. He also investigated whether there was a contribution of this element from the rocks and soil of the study area and nine samples of rock and soil were collected. He concluded that:

i) the concentration of Pb in Kubanni drainage basin, in groundwater considered as non-polluted is at level of <0.014 ppm and <0.008 ppm which is comparable with expectations of Pb concentration in non-polluted water less than 0.010 ppm

ii) Concentration of Pb in Kubanni reservoir which is the source of drinking water for the Ahmadu Bello University Main Campus was found to be less than 0.024 and less than 0.011 ppm.

Garba (2008) also investigated the natural radioactivity of groundwater in the Precambrian crystalline rocks of Zaria. He concluded that most of the groundwater in the study area (>99%) has low groundwater radioactivity for all the parameters measured. From his findings, only few results exceeded the WHO (2003) drinking water guideline value for the gross alpha and ^{228}Ra. He said for the gross alpha, three out of the four results are aligned in a NW–SE direction, thus forming an anomalous zone towards the eastern part of the area; the fourth well is located separately from these three wells. These two zones are located at lithological boundaries that separate the gneiss from the porphyritic biotite granite. The enrichment or high concentration of these radionuclides in a groundwater has been attributed geochemical processes operating in the aquifer and which later is distributed by normal groundwater flow. The gross alpha anomaly in these two zones was interpreted to be due to the presence of uranium which, unlike radium, is soluble in oxidizing water with low mineralization which is typical of his study. Onoja (2011) also investigated on the determination of natural radioactivity and committed effective dose calculation in borehole water supply in Zaria. A total of fifty (50) borehole water samples were collected for the analysis of radionuclides and gross alpha/beta radioactivity concentration. The results show that the minimum and maximum alpha and beta radioactivity concentration observed was 0.0023 and 0.037 Bq/l and 579 and 5.28 Bg/l respectively. The geometric mean for alpha and beta radioactivity measurements made was 0.1 and 0.3 Bq/l respectively. The mean value of potassium – 40 (^{40}K) concentrations was 0.416 Bq/l, uranium – 238 (^{238}U) and thorium – 232 (^{232}Th) investigated in the sample gave average concentration of 0.0011 and

0.00006 Bq/l respectively. The mean absorbed dose from intake of potassium – 40 concentration are 1.12 µGy/a or betaparticle and 0.33 µGy/a for gamma radiation. Likewise, the absorbed dose from uranium – 238 (^{238}U) and thorium – 232 (^{232}Th) concentrations were found to be 0.243 µGy/a and 0.011 µGy/a, for alpha particle, 0.013 µGy/a and 0.00042 µGy/a for beta particle, 0.010 µGy/a and 0.00056 µGy/a for gamma radiation respectively. Results show that the committed effective dose for the different age groups via ingestion were found to be less than 0.1m Sv/a and the average collected effective dose found to be 0.574 Man – Seivert, 3.78×10^{-3} Man – Seivert and 1.26×10^{-2} Man – Seivert for potassium – 40 (^{40}K), uranium – 238 (^{238}U) and thorium – 232 (^{232}Th) respectively.

Therefore it was concluded in the study that the quality of groundwater in most of the sampled area in Zaria, met the recommendation of the WHO (2003) and United State Environmental Protection Agency (USEPA) with respect to radioactivity level in potable water.

2.2 REVIEW OF THE GEOLOGY OF THE BASEMENT COMPLEX

The basement complex of Nigeria is part of an Upper Proterozoic to Lower Phanerozoic mobile belt situated between the West African and Congo Cratons.

Three lithological groups have been distinguished:

(i) A polymetamorphic gneiss-migmatite complex with ages ranging from Liberian (2800 Ma) to Pan-African (600 Ma). Metamorphism is generally in the amphibolites-facies grade. According to Rahaman (1988), the following three petrological units characterize the migmatite complex:

a) A grey foliated biotite acid or biotite hornblende quartz feldspathic gneiss of tonalitic to granodioritic composition which is now known as the grey gneiss or early gneiss.

b) Mafic to ultramafic components, which were present, often outcrop as discontinuous boudinaged lenses or concordant sheet of amphibolites with minor amount of biotite-rich ultramafite. Except where it constitutes the paleosome to the migmatite, it is present in grossly subordinate amount in the grey gneiss.

c) The felsic component which is composed of a varied group of rocks consisting of pegmatite, aplite, and quartz-oligoclase veins, fine grained granite gneiss, and porphyritic granite.

(ii) The Schist belts of low-grade (mainly green schist facies) supracrustal (and minor volcanic) assemblages, that occupy a general N-S trending synformal troughs infolded into the migmatite-gneiss complex which are considered to be Late Proterozoic. Based on structural and lithological associations Grant (19781) suggested that some of the schist belts are of Kibaran (1100-$^{+}$ 200 Ma). But Ajibade et al, (1989) disagree with the structural evidence and proposed a Pan African age for all the schist belts.

(iii) Syntectonic to late tectonic Pan African granitoids that intrude both the schist belts and the gneiss-migmatite complex. The older granites are the most obvious manifestation of the Pan African orogeny and they constitute about 40 to 50% of the basement complex rocks. They vary in composition from tonanite through granodiorites to granite and syenite. Texturally they vary from strongly foliated gneiss varieties to underformed rocks. Rahaman (1988) described the following petrographic types: magmatic granite gneiss, early pegmatite, aplites and quartz veins. The Pan African granitoids in Nigeria are referred to as the older granites to distinguish them from Mesozoic anorogenic granite ring complexes (the younger granites).

2.3 REVIEW OF HYDROGEOLOGY OF THE STUDY AREA

2.3.1 General

The term hydrogeology is used in this context to mean the study of groundwater with particular emphasis on its chemistry, mode of migration and relation to the geologic environment. Groundwater is an important source of water supply in the world as its uses in domestic; industries and agriculture continue to increase. The works done so far done on groundwater in the Zaria area include the groundwater condition in Zaria by Olowu (1967) and other researchers from Department of Geology including Akpoborie (1972) and Abaa (1973) who worked on hydrogeologic control of the "Structures along Samaru creeks." Finally Ososami and Adedeji laid emphasis on groundwater condition in the Kubanni valley (in Adeyemi, 1983).

2.3.2 Groundwater

The origin of groundwater in this area is mainly meteoric. Generally, groundwater occurs in the basement complex in the weathered and fractured zones. The presence of groundwater in any given area therefore depends on whether sufficient thicknesses exist and the extent of decomposed material is present to provide a reservoir or whether joints and fractures are present in the fresh rocks.

The basement complex on which Zaria lies generally forms a poor source of groundwater. The decomposed mantle is often too thin to harbor large quantities of water. The joints system are also too poorly developed to compensate for the inadequacy of the zone of weathering overlying them (Du preez and Barber, 1965).

2.3.3 Weathered Basement Aquifer

The weathered basement aquifer is the most important aquifer in the study area, other researchers like Du Preez (1961), Du Preez *et al* (1965), Olowu (1967), Ososami (1968), Abaa (1973) and

Adeyemi (1983) have confirmed the above statement in their work around Zaria. The groundwater in the Zaria region occurs in the weathered basement rock and fractured zones. The extent of weathering, fracturing and erosion is generally limited in the crystalline rocks. As a result, groundwater occurrence is small.

The weathered profile rarely exceeds 50 m in thickness except in valleys and in areas where faults and fractures have permitted the weathering activities to penetrate more freely (Adanu and Schneider, 1988).

2.3.4 Fractured Aquifers

Beneath the weathered zone is the fractured basement aquifer. It underlies the study area and is regarded as source of groundwater because of its extent. The permeability and storativity of the groundwater system are dependent on the volume and extent of the joints and fractures in the aquifer (Clark, 1985). Therefore groundwater in the crystalline basement rocks occurs in fracture system in unweathered rocks; these types of aquifers are generally restricted and hence have limited groundwater resources. However, some fractured aquifers are highly prolific, especially when these fractures are extensively interconnected with one another and linked to the surface for recharge. According to Du-Preez and Barber (1965), fractures in the Crystalline Basement of Northern Nigeria extend to a depth of not more than 90 m. Offodile (1992) observed that the distance between fractures increases rapidly with depth. Hence, as the depth of a borehole increases, the frequency of interception of fractures decreases. Furthermore, the processes of chemical weathering are not likely to operate below the depth of 100 m.

CHAPTER THREE

3.0 THE METHODS OF INVESTIGATION

3.1 HYDROGEOLOGICAL STUDY OF THE AREA

The hydrogeological investigation of the study area was done in three stages, using various related methods. These stages include the desk studies, field work and laboratory studies.

3.1.1 The Desk Studies

The desk studies consist of the following activities:

i) Collection and review of related literatures such as text books, bulletins, journals on hydrogeochemistry and geology, hydrology and hydrogeology and topographical maps. The topographical survey map of the study area was obtained from the Department of Geography, Ahmadu Bello University, Zaria and was used as a base map for this study.

ii) Preparation of base map was done by superimposing the geological map on the topographical map to obtain a single map to work with.

iii) Collection of hydrogeological data from hydrogeological agencies, parastatals and companies. These data are weather reports which were obtained from meteorological data station, I.A.R Samaru, Ahmadu Bello University, Zaria.

iv) Collation of the findings

v) Preparation and interpretation of various maps

3.2 FIELD WORK

The field work covered a period of one year. The field work consists of the following activities:

3.2.1 Reconnaissance Geological Survey of the Study Area

Reconnaissance geological survey of the study area was done at the peak of dry season (April). This preliminary field visit to the study area which included site specific evaluation and getting acquainted with the people of the area to have easy access to their wells and measurements of their water levels.

Wet season activities included, measuring coordinates and elevation above mean sea level of identified wells, using the global positioning system (GPS) and locating them on the map. Water level measurement in hand dug wells using a surveyor's tape.

3.2.2 Geological Mapping

Detailed geological mapping of the area was done on a scale of 1:50,000 using appropriate and suitable field instruments. This involved examining the rocks in their natural location and data obtained were plotted on the field map. Extensive traverse, using many footpaths, dry channels of rivers and streams and roads network were taken. Topographical map on the scale of 1:50,000 were used as base map for the exercise. Hammer was used to break some fresh rock samples from the outcrops in the area for petrographic study and co-ordinate were measured using a Global Positioning System (GPS). These rock samples were well labeled using waterproof markers and stored away into the sample bag for further investigation in the laboratory. Structural features such as strikes and dips using a geological compass were measured while geological boundaries were plotted and indicated on the map respectively. The hydrogeological studies involved the location of wells and the measurements of depth to watertable in hand dug wells were measured at the end of wet season and at the peak of dry season during the period of 2012-2013 hydrogeological year.

Hand specimen study and thin section analysis were carried out in the laboratory. Furthermore, from the topographical map, a geological map of the study area was produced in which various lithological boundaries were delineated and a geological cross-section was produced.

3.2.3 Watertable Measurement

The depth to the water level is also called depth to groundwater level or the standing water level (SWL). Water level measurement was done in hand dug wells from the ground surface, for both the end of wet season and the peak of dry season using a surveyor's tape. It was done by taking a reference point at the rim of the well and then lowering a weighted tape until its zero mark just touched the surface of the well. The reference point helps in determining the point at which the exact depth of the well begins. Thereafter, the depth to water level from the surface was read on the tape with respect to the reference point. The depth to water level measurement was carried out in eighty four (84) hand dug well in the study area, before every sampling event was done Fig 1.1. (Table 1 Appendix B) shows the water level depth values.

3.3 EVALUATION OF FIELD DATA HYDROGEOLOGICAL MAPS

3.3.1 Hydrogeological Maps

Groundwater table analysis is important to provide information on the behavior of groundwater at different seasons of the year as well as its association with surface water. The catchment groundwater conditions were analyzed by plotting the field groundwater data (Table 1 Appendix B) on the base maps. Based on the groundwater data collected at the end of wet season (August) and at the peak of dry season (April), the following hydrogeological maps were prepared:

(i) Watertable contour maps.

(ii) Map of the depth to water level, also called thickness of dry zone map.

3.3.2 Watertable Contour Maps

Watertable contour maps are those of the phreatic surfaces. They were prepared for the peak of dry season and the peak of the wet season. The maps were prepared by plotting the altitudes of the water levels in hand dug wells and the altitude of points of intersection of topographical contour lines with streams on a topographical map. The altitudes of the water level measured in hand dug wells were found thus: assuming a linear gradient, the altitude of the location of each hand dug well was calculated from topographical contours by interpolation. Then the altitude of the water level in each of the well was calculated by deducting the measured water level below the ground surface (depth to water level) from the altitude of the well locations. Lines were then drawn to join points of equal watertable elevation.

3.3.3 Map of Depth to Watertable (Thickness of Dry Zone Map)

This map that shows the depth to water level from the ground surface was prepared for dry season. It was prepared by plotting values of measured water levels from the ground surface on a topographical map. Also, differences between points of intersection of groundwater contours and topographical contours were plotted on the same topographical map. Lines were then drawn to join points of equal values of dry zone thicknesses. The difference between points of intersection of groundwater contours were obtained by superimposing groundwater contour map on topographical map and then deducting the groundwater contour values from the topographical contours .The thickness of dry zone along river channels was taken to be zero on an assumption that water still flows through them during the wet season but in dry season it is assumed that the water level had dropped about one metre below the river bed.

3.3.4 Water Sampling

Water sampling, being a crucial aspect of water analysis was given the adequate consideration it deserves in order to avoid the contamination of the collected samples and also to preserve their integrity prior to analysis. Therefore, in this work all the necessary precautions were applied to prevent any slightest change in the collected samples. The precautions taken include:

(i) Hand dug wells in constant use were sampled for fresh water coming from the aquifer for their groundwater content.

(ii) Purging method was used for borehole water sampling. This enabled the sampler to collect a more representative sample of the actual aquifer condition.

A total of thirty (30) groundwater samples, twenty-six (26) from hand dug wells and four (4) from boreholes were collected from the study area. The samples were collected from different residential places in the area in other to have a wider coverage of sampling .Twenty-six (26) groundwater samples were taken from hand dug wells while four (4) were from boreholes. The sampling exercise was carried out at the peak of dry season when the concentration of the salts in water was high.

3.3.5 Sample Collection

At each groundwater point, site data of samples such as pH, temperature and electrical conductivity were measured and recorded prior to collection. This was done because their values might change significantly soon after collection. Total dissolved solids were measured in the laboratory using EC/TDS/Temperature meter (Hanna Instrument), temperature and electrical conductivity were measured in the field using EC/Temperature meter and the pH was measured using pocket pH meter(model) .

Other information recorded was the time, date, locations and depth of sampling. Each water sample was collected by lowering a plastic container into the well. The drawn up water was then collected in a well labeled sample bottles which had been previously thoroughly washed and vigorously rinsed two or more times with a portion of water being sampled. Two samples of one liter each were collected from each well.

3.3.6 Water Sample Preservation and Storage

Two separate samples were collected of each water point; one was for anionic determination while the second was for cationic determination. The samples collected for cationic determination were acidified with concentrated nitric acid (HNO_3) to a pH of less than 2. This is done in order to reduce adsorption of ions from solution and the formation of bonds between the container and the ions. The second samples were free of this treatment, that set was used for the anions. The samples were preserved and the bottles were then firmly capped and loaded into coolers containing ice blocks.

On returning from the field trip, the samples were stored at the base of deep freezer for temperature reduction in the dark. The darkness was to inhibit algae activities and the freezing was to stop or at least reduce chemical reaction taking place.

3.4.0 THE LABORATORY WORK

3.4.1 Analysis of water samples

Analysis of the collected water samples for their major cation, anion and some heavy metal components was carried out in the multi-user Science Research Laboratory, Department of Chemistry and at the Soil Science Laboratory Department of Soil Science both at the Ahmadu Bello University, Zaria. The major ions analyzed and the methods used in analyzing them are as

follows; sodium (Na) and Potassium (K) were analyzed by flame photometry, calcium (Ca), magnesium, (Mg), manganese (Mn), copper (Cu), Iron (Fe), lead (Pb) and Zinc (Zn) were determined by fast sequential Atomic Absorption Spectrometry (AAS), varian product AA240FS. Turbidimetric method was used to determine sulphate (SO_4) using H18200 multiparameter Bench Photometer, chloride ion (Cl) was analyzed by the argentometric method which is silver nitrate titration using potassium chromate as indicator and phenolphthalein/methyl orange, titrimetric method was used to analyze bicarbonate (HCO_3), Turbidimetric method was used to determine phosphate (PO_4) using spectronics 20 photometer, ammonia (NH_4) was determined by steam distillation method and nitrate (NO_3) was determined by chromotropic acid method using high range test 'N' tube.

The descriptions, principles and procedures of the methods used are presented in details in (Appendix C) in accordance with the procedures described by (APHA, 1971) and HACH Chemical Company (1978).

3.5 Hydrochemical Facies

The facies of the groundwater samples analyzed were determined by plotting the concentration of the major cations and anions on Piper diagram and Durov plot using the aquachem V.4.0 soft ware.

3.6 Assessment of Groundwater for Irrigation Purpose

This is done by using aqua chem. V 4.0 soft ware for calculating the salinity index and sodium absorption ratio (SAR) using this method as expressed in the following equation:

$$\text{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where ionic concentrations of Na, Ca, Mg are in milliequivalents per litre.

The SAR was computed using the expression developed above by the US salinity laboratory staff (1954).

CHAPTER FOUR

4.0 RESULTS

4.1 INTRODUCTION

The various field and laboratory acquired data are presented in this chapter. The data were assessed with respect to the geology and hydrogeology of the study area and groundwater quality usability in the area according to World Health Organization (WHO) 2011 and Nigeria Standard for Drinking Water Quality (NSDWQ) 2005 standards. The types of groundwater in the area were determined using piper Trilinear diagram and Durov plot.

4.2 Geology of the Study Area

The area of study is underlain by rocks of the basement complex. The distribution of the various rock types is as shown in the geological map of the area (Fig 4.1) and the geological cross section (Fig.4.2). The rock units observed in the study area include: migmatite, schist, granitic-gneiss, porphyritic biotite granite and coarse grained biotite granite and minor lithologies such as microgranite, quartz and pegmatite veins.

4.3 Groundwater Configuration and Aquifer Characteristics

4.3.1 End of Wet Season

The watertable map at the end of wet season (Fig 4.2) was based on the static water level in hand-dug wells measured in August, 2012. The maximum water level elevation was 3.99m (13.1ft) while the minimum was 0.09m (0.3ft).

4.3.2 Peak of Dry Season

The watertable map at the peak of dry season (Fig 4.3) was based on the static water level in hand-dug wells measured in March, 2012. The maximum water level elevation was 11.4m (37.4ft) while the minimum was about 2.01m (6.6ft).

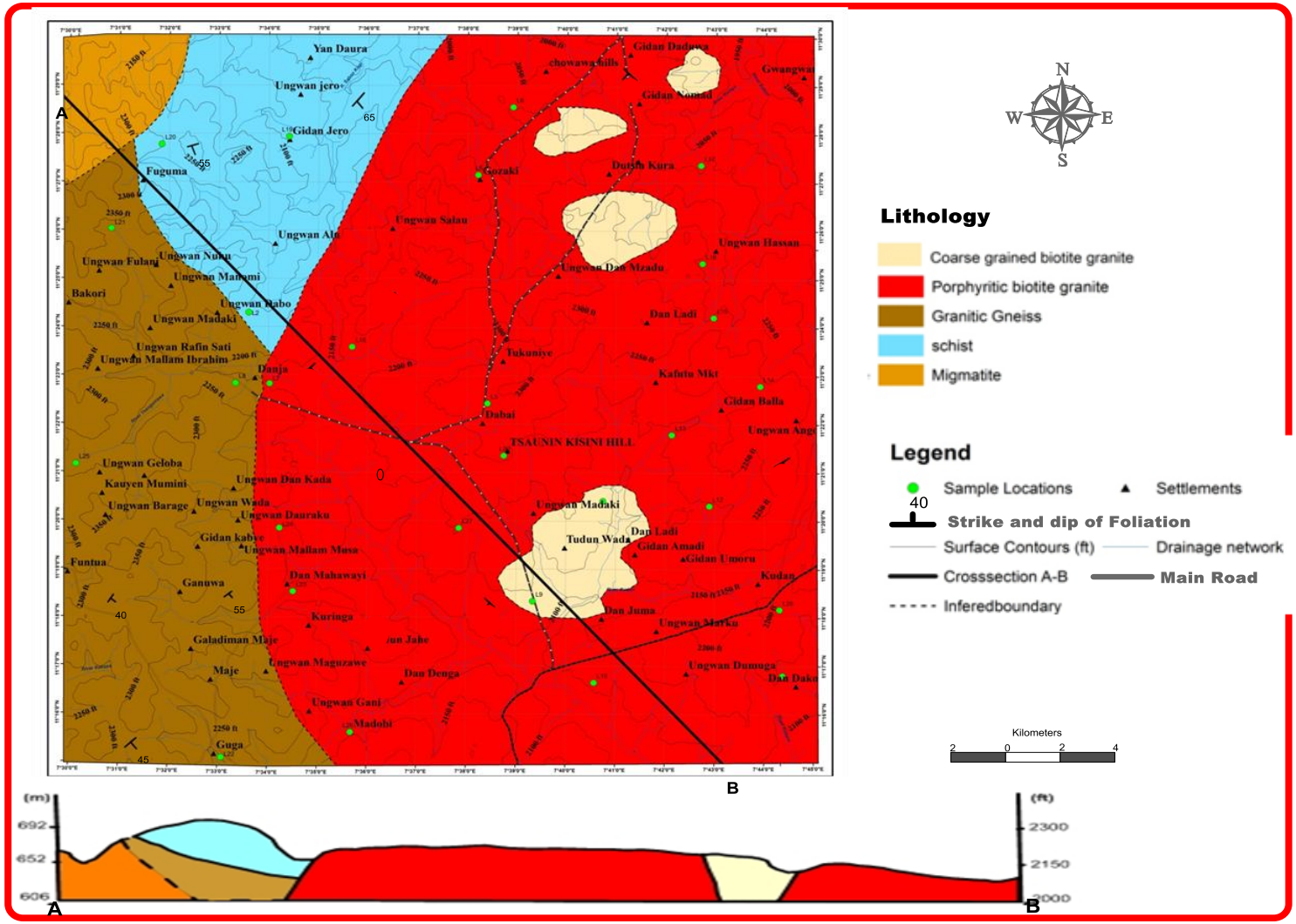


FIGURE 4.1: Geological map of the study area with sampling points (below is cross section along line a-b)

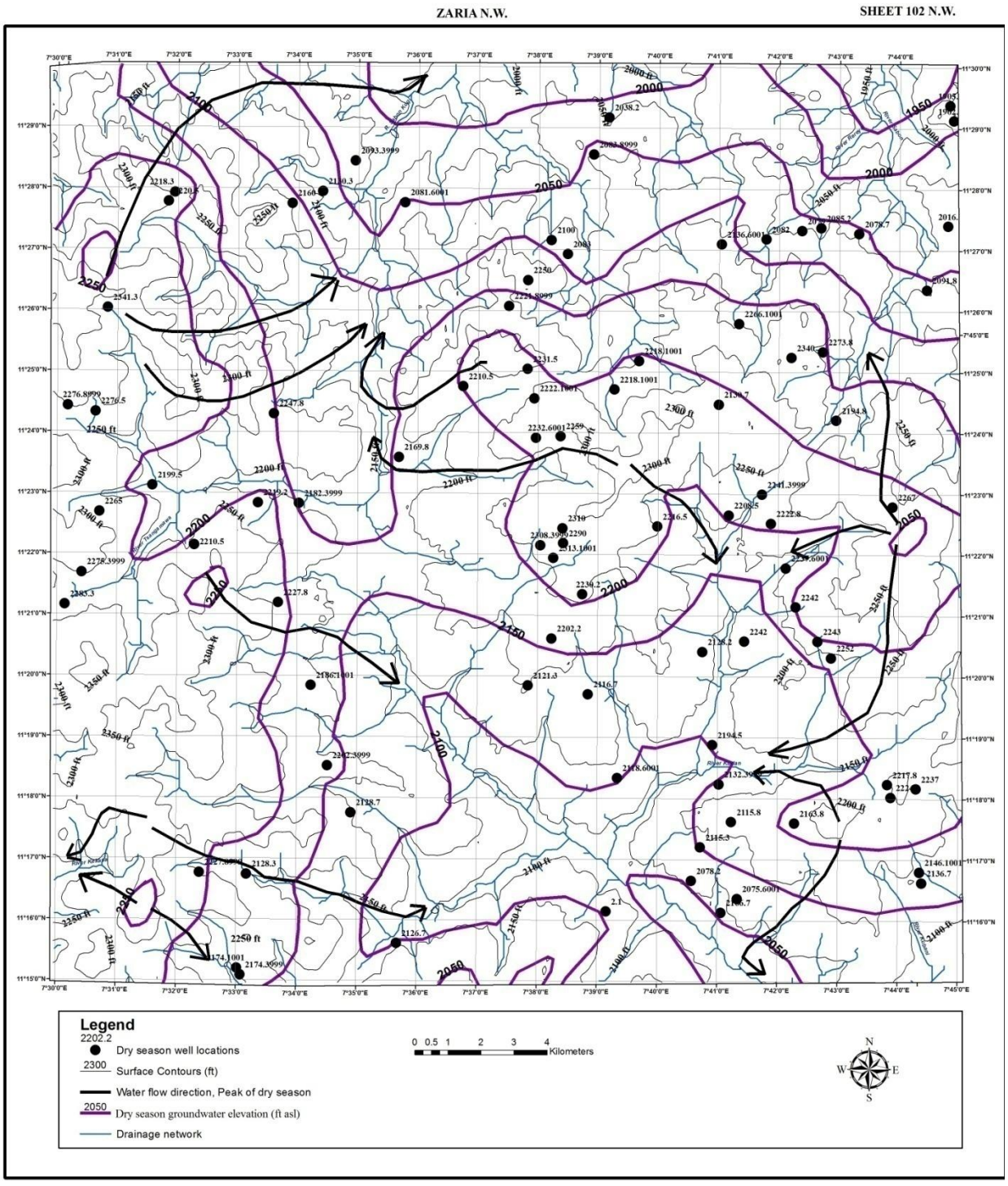


FIGURE 4.2: Hydrogeological map of the study area showing groundwater table configuration and direction of groundwater flow, peak of dry season

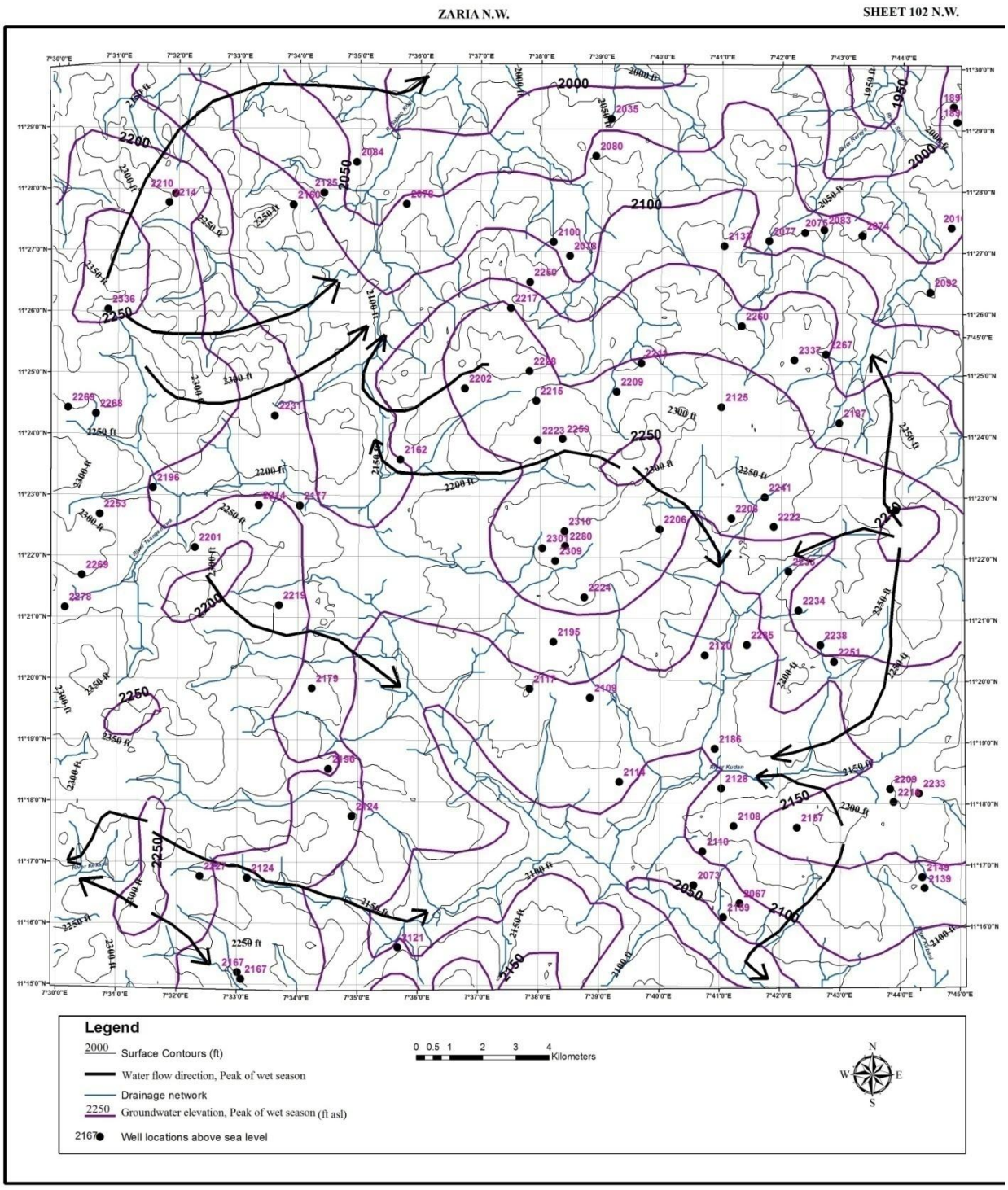


FIGURE 4.3: Hydrogeological map of the study area showing groundwater table configuration and direction of groundwater flow, end of wet season

Field data of groundwater elevation obtained in both wet and dry seasons (Appendix B) was consequently used to estimate the thickness of the dry zone (Fig 4.4)

4.3.3 Aquifer Characteristics

Due to paucity of data, only two borehole logs were obtained. Average borehole depth, static water level and transmissivity of aquifers in the area is about 33.5m, 6.4m and 4.9 m/day respectively. Average specific capacity (storativity) is 10 m^2/ day (Table 4.1)

Table 4.1: Basic Borehole Information (Source: Mev geology and Engineering Consultances Servives)

S/no	Location	Drilled Depth (m)	Recovered Depth (m)	Pump Setting (m)	Static Water Level (m)	Average Yield (L/S)	Total Drawdown (m)	Specific Capacity (m^2/day)	Transmisivity (m/day)
1.	Ungwa Malam Mailaya (near Funtua)	32	30	26	4.3	1	11.88	7.27	3.95
2.	Sabuwar Ungwa (Danja)	35	33	29	8.41	1	6.77	12.76	5.86

4.4 Results of Groundwater Sample

The pH values of groundwater samples in the area range from 5.30 to 6.40 with a mean of 5.8. Temperature of the groundwater varies between 23.9°C and 24.3°C with a mean of 23.3°C. Specific electrical conductivity values of 5.4µS/cm to 491µS/cm with an average value of 155 µS/cm were also recorded. The corresponding values of the total dissolved solids (TDS) measured in the laboratory range from11.08 mg/l to 311 mg/l with a mean of 55 mg/l.

Sodium (Na^+) occurs in concentration that range from 2.0 mg/l to 87. 0 mg/l with a mean of 18.45 mg/l. Potassium (K^+) is the next abundant cation to sodium with concentrations varying from1.2 mg/l to 34 mg/l and an average concentration of 6.88 mg/l. Following after is calcium (Ca^{2+}) ion with concentrations varying from 0 mg/l to 154.21 mg/l with an average value of 12.57 mg/l. Magnesium (Mg^{2+}) is the next abundant cation to calcium in the groundwater samples of the study area. Its concentrations range from 0.77 mg/l to 13.2 mg/l with a mean of 6.43 mg/l.

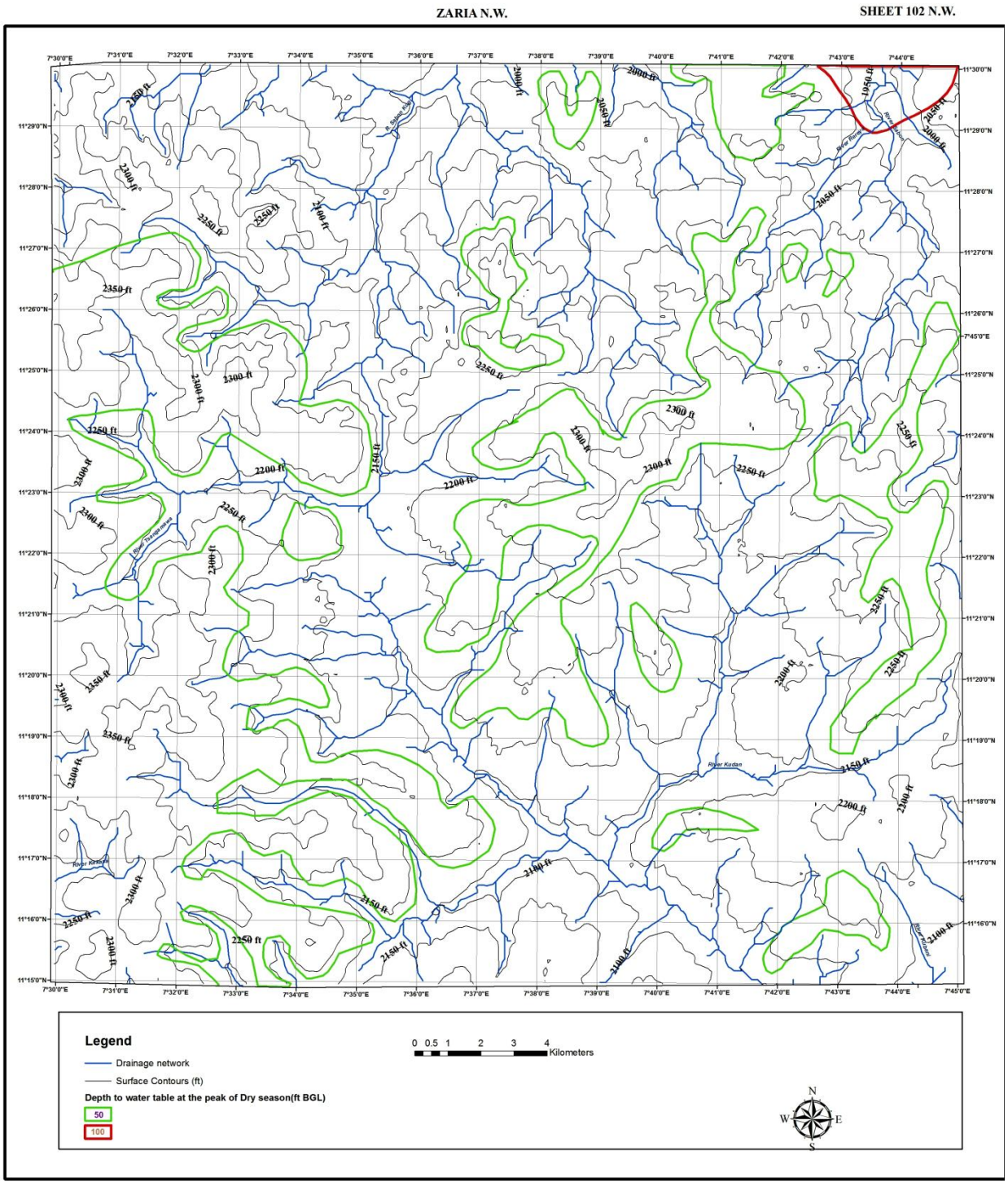


FIG 4.4: Hydrogeological map of thickness of dry zone in the study area, peak of dry season

The concentrations of Iron vary from 0.01 mg/l to 1.51 mg/l with an average concentration of 0.56 mg/l (Table 4.2).

Bicarbonate is the most dominant and abundant anion, having concentrations ranging from 0.5 mg/l to 3.5 mg/l with a mean of 1.58 mg/l. Sulphate, nitrate, chloride and phosphate ions have concentrations ranging from 0.12 mg/l to 2.66 mg/l with a mean of 0.46 mg/l, zero mg/l to 35 mg/l with a mean of 8.26 mg/l/, 0.15 mg/l to 6.45 mg/l with a mean of 0.93 mg/l and 0.27 mg/l to1.95 mg/l with an average of 0.45 mg/l respectively. Ammonia concentration ranges from 0.007 to 0.035 mg/l with an average of 0.02 mg/l, the concentration of lead varies from zero to 0.035 mg/l with an average value of 0.0025 mg/l, the concentration of copper ranges from 0.003 to 0.584 mg/l with an average of 0.06 mg/l, the concentration of manganese ranges from 0.008 to 0.822 mg/l with an average of 0.09 mg/l and the concentration of zinc varies from zero to 5.016 mg/l with an average of 0.33 mg/l (Table 4.2).

TABLE 4.2: Results of Groundwater Analysis

Locations	Dutsen Kura	Kafur L.G.A.	UBE, Sani Dabai	Dabai Mosque	Angwan Wanzamai	Maraba Kaya	Ranging Danja	Hayan Hasibiti	Masalachi Majedo	Duzunrini
Coordinate	11°24'46.2"N 007°39'16.0"E	11°24'17.8"N 007°33'36.3"E	11°22'25.7"N 007°38'24.8"E	11°22'11.0"N 007°38'25.6"E	11°27'09.5"N 007°38'12.8"E	11°28'33.8"N 007°38'54.7"E	11°27'44.9"N 007°33'53.9"E	11°22'50.1"N 007°33'20.7"E	11°18'20.2"N 007°39'20.2"E	11°16'39.1"N 007°40'34.6"E
Date of Sampling	25/3/2013	25/3/2013	25/3/2013	25/3/2013	27/3/2013	28/3/2013	28/3/2013	29/3/2013	30/3/2013	30/3/2013
Types of Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Borehole	Concrete Lined Well	Borehole	Unlined Hand-Dug Well	Borehole	Concrete Lined Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well
Depth of Sampling (m)	7.6	15.9		9.15		4.9		7.85	6.53	6.7
pH	6.4	5.9	5.9	5.7	5.8	5.6	5.3	5.8	5.7	5.8
TEMP (°C)	24.1	24	24	24	24.1	24.2	24.1	24.1	24.3	24.2
TDS(mg/l	28.1	42.6	80.4	70.2	59.5	29.2	34.4	27.8	37.1	39.3
CONDUCTIVITY (µ/cm)	92.8	62.2	88.7	44.2	91.7	183	241	84.9	137.5	136.7
Na(Mg/l)	5	9.1	4.1	2	4.6	17	31	8.4	7.1	5.6
K(Mg/l)	2.4	5.4	2.5	2.1	2.5	1.2	28	4.3	2.2	6.6
Ca(mg/l)	0	1.175	1.24	0.668	1.173	0.574	33.301	1.336	2.558	2.485
Mg(mg/l)	0.777	0.767	6.031	7.624	6.593	4.751	13.202	5.465	6.904	6.851
Cu(Mg/l)	0.026	0.047	0.041	0.023	0.05	0.048	0.039	0.021	0.059	0.109
Fe(Mg/l)	0.195	0.556	1.394	1.03	0.429	0.532	0.891	0.488	1.093	0.756
Mn(Mg/l)	0.195	0.062	0.013	0.016	0.022	0.043	0.011	0.016	0.033	0.136
Zn(Mg/l)	0.021	0.051	0.039	0.002	0.096	0.128	0.055	0.036	0.239	0.042
Pb(Mg/l)	0.035	0.005	0	0	0	0	0	0	0.026	0
HCO_3(Mg/l)	3.1	1.2	1.2	1.2	1.3	1.3	2.4	2.4	0.9	1.3
SO_4(Mg/l)	0.362	0.242	0.121	0.242	0.242	0.242	0.121	0.302	0.302	0.302
Cl(Mg/l)	0.3	0.75	0.35	0.4	0.4	0.5	1.8	0.25	0.65	0.6
PO_4(Mg/l)	0.312	0.468	0.39	0.373	0.468	0.312	0.312	0.273	0.897	0.429
NH_3(Mg/l)	0.021	0.014	0.0105	0.0105	0.0105	0.007	0.0105	0.007	0.014	0.0105
NO_3(mg/l)	0.5	2.8	6	0.6	2.8	8.5	9.1	1.5	7.3	3.3

TABLE 4.2: Results of Groundwater Analysis Continued

Locations	Dandoko Massalachi	Barmo Kwari	Danmai Guta	Chediya	Dan Gusau	Furgu Village	Kawo Allah	Gangari	Angwan Gyara	Huguma Village
Coordinate	11°16'48.1"N 007°44'22.2"E	11°20'18.7"N 007°42'53.3"E	11°20'24.6"N 007°40'44.7"E	11°22'47.6"N 007°43'54.1"E	11°24'12.6"N 007°42'57.6"E	11°25'20.0"N 007°42'44.0"E	11°27'22.0"N 007°42'41.7"E	11°23'35.4"N 007°35'21.3"E	11°27'56.7"N 007°34'24.4"E	11°27'46.5"N 007°31'50.6"E
Date of Sampling	1/4/2013	1/4/2013	1/4/2013	4/4/2013	4/4/2013	4/42013	6/4/2013	6/4/2013	8/4/2013	8/4/2013
Types of Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Concrete Lined Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well
Depth of Sampling	4.25	2.43	9.7	7	9.2	8.0	4.5	9.22	6	9
pH	5.8	5.5	5.4	6	5.8	5.8	5.6	5.8	6	5.9
TEMP (°C)	24.1	24	24	24.1	24.1	24.1	24.1	24.1	24	24
TDS(mg/l	28.1	47	24.6	30	22.3	11.08	37.1	12.9	31.2	46.1
CONDUCTIVITY (µ/cm)	120.1	75	30.6	181	148.5	443	491	183	193.5	26.4
Na(Mg/l)	2.5	3.9	19	9.4	25	27	87	48	30	9.2
K(Mg/l)	3.2	2.6	3.7	2.7	2.5	2.1	6.6	4.4	18	5.5
Ca(mg/l)	0	7.404	0.093	3.558	10.515	15.177	39.168	3.251	1.682	2.564
Mg(mg/l)	4.551	6.484	4.687	7.341	4.976	7.002	10.054	7.38	5.116	3.25
Cu(Mg/l)	0.584	0.096	0.012	0.02	0.228	0.096	0.02	0.043	0.023	0.021
Fe(Mg/l)	0.284	0.555	0.602	1.51	1.26	0.438	0.848	0.272	0.498	0.282
Mn(Mg/l)	0.011	0.013	0.015	0.014	0.008	0.015	0.022	0.013	0.012	0.011
Zn(Mg/l)	0.039	0.023	0.016	0.029	0.547	0.115	0.762	0.327	0.658	0.137
Pb(Mg/l)	0	0.005	0	0	0	0	0	0	0	0
HCO_3(Mg/l)	1.5	1.9	1.5	1.8	2.5	3	3.5	2.3	1.1	1
SO_4(Mg/l)	0.242	0.362	0.362	0.483	0.302	0.362	2.656	0.302	0.423	0.364
Cl(Mg/l)	0.5	0.15	0.4	0.45	0.4	0.85	6.45	2.35	0.85	0.5
PO_4(Mg/l)	0.351	0.312	0.312	0.273	0.663	0.312	0.39	0.351	0.312	0.351
NH_3(Mg/l)	0.0175	0.0245	0.0245	0.0171	0.0175	0.0175	0.014	0.014	0.014	0.021
NO_3(mg/l)	3.4	2.1	1.3	8.5	13.6	12.3	35	7.5	4.5	1.5

TABLE 4.2: Results of Groundwater Analysis Continued

Locations	Huguma Hayan Stami	Tashan Guga	Dan Mahawayi	Angwan Duhula	Baraye	Madubi Massalachi	Pankau	Kudan Bayan Gari	Gwandari	Hunkuyi
Coordinate	11°26'01.7"N 007°30'50.2"E	11°15'05.1"N 007°33'04.8"E	11°18'31.5"N 007°34'31.0"E	11°19'50.4"N 007°34'14.3"E	11°21'09.5"N 007°30'08.5"E	11°15'36.8"N 007°35'40.6"E	11°19'50.9"N 007°19'50.9"E	11°18'10.1"N 007°44'18.4"E	11°20'34.9"N 007°41'26.5"E	11°16'20.0"N 007°39'20.0"E
Date of Sampling	8/4/2013	9/4/2013	9/4/2013	9/4/2013	10/4/2013	10/4/2013	11/4/2013	11/4/2013	11/4/2013	11/4/2013
Types of Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Concrete Lined Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Concrete Lined Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well	Unlined Hand-Dug Well
Depth of Sampling (m)	5.7	7.9	8.4	8.5	5.1	7.1	5.7	5.5	8.54	
pH	5.7	6	5.3	5.5	5.9	5.6	5.7	5.7	5.7	6.4
TEMP (°C)	23.9	24.1	24	24.1	24.1	24	24	23.9	24	24
TDS(mg/l	78.5	90.4	12.79	16.4	16.4	23.1	71.7	262	30.8	311
CONDUCTIVITY (µs/cm)	169.9	44.5	5.4	164	59.4	171	110.3	151.6	284	423
Na(Mg/l)	16	14	6.4	3.9	6.9	6	20	47	6.4	72
K(Mg/l)	8.5	9.6	3.3	3.2	2.5	1.8	8.2	34	1.9	25
Ca(mg/l)	3.448	1.308	0.608	0	0.61	15.067	22.313	4.355	47.22	154.21
Mg(mg/l)	7.605	4.484	4.403	6.596	7.588	5.659	11.523	7.754	5.496	11.833
Cu(Mg/l)	0.05	0.065	0.085	0.012	0.019	0.022	0.005	0.004	0.003	0.013
Fe(Mg/l)	0.329	0.771	0.263	0.217	0.333	0.444	0.273	0.253	0.012	0.013
Mn(Mg/l)	0.097	0.176	0.014	0.822	0.345	0.017	0.013	0.534	0.012	0.013
Zn(Mg/l)	0.622	0.554	0	0.147	0.021	0	0	0	0.043	5.016
Pb(Mg/l)	0	0	0	0	0	0	0	0	0	0
HCO_3(Mg/l)	0.9	1	0.9	0.5	1	1.8	0.9	0.9	1	2.1
SO_4(Mg/l)	0.302	0.423	0.242	0.302	0.362	0.302	0.302	1.57	0.422	1.208
Cl(Mg/l)	0.65	0.8	0.8	0.65	0.4	0.4	0.3	1.5	1	2.55
PO_4(Mg/l)	0.546	0.39	0.312	0.351	0.429	0.39	0.429	0.39	0.39	1.95
NH_3(Mg/l)	0.014	0.0105	0.035	0.0315	0.0175	0.0175	0.007	0.007	0.0105	0.0105
NO_3(mg/l)	5.8	2.7	0	2.4	1.3	4.1	11.3	35	21.1	32.1

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 GEOLOGY AND STRUCTURES OF THE STUDY AREA

The study area (Sheet 102 Zaria NW) is located in north central and Nigeria is underlain by rocks of the basement complex. The distribution of the various rock types is as shown in the geological map of the area (Fig 4.1). The rock units observed in the study area include: migmatite, schist, granitic-gneiss, porphyritic biotite granite and coarse grained biotite granite and minor lithologies such as microgranite, quartz and pegmatite veins.

5.1.1 Migmatites

This shows granoblastic texture and foliation which is characterized by light and dark bands with characteristic flow structures in the rock mapped in the study area. Visible minerals in the hand specimen include quartz, biotite and plagioclase. Migmatite was on the extreme end of northwestern part of the study area around Ungwan Waziri (Fig 4.1). Sharp contact between the granitic gneiss and migmatite was observed in places.

5.1.2 Schists

Undifferentiated schist, gneiss and fine grained flaky quartzite occur at the North Western part of the study area. Flaky minerals mostly muscovite and biotite with small interstitial quartz grains could be observed in the field. The quartzites mostly occur as ridges trending NE-SW (Plate I).



Plate I: An Exposure of Schist at Huguma. Location: 11°28´10˝N, 007°32´06˝E

5.1.3 Granitic Gneisses

This light-coloured, usually greyish rock is generally poorly exposed without crop the more resistant to weathering type occurring as low whale backs and ridges. It varies in texture from medium, equigranular to coarse porphyroblastic (Plate II). The rock is composed of feldspars, quartz, and biotite with foliation defined by biotite flakes. Feldspar is the most abundant mineral. The rock composes of small porphyroblasts in the ground mass up to 5 cm or more can be seen in some samples of the granitic gneisses. Xenoliths are common and in some cases solution cavities occur along joints.

In hand specimens, the rock is light to dark grey. The rock carries small porphyroblasts in the ground mass. Major minerals present are feldspars, biotite and quartz. Orthoclase feldspars seem

to be abundant than the other minerals. The more weathered samples showed the presence of muscovite.



Plate II: Porphyroblast of Pinkish Feldspars within the Granitic Gneiss at Tsangamawa. Location: 11º19´ 15.6˝N, 007°33´22.9˝E

In thin section, the rock is fine to medium grained. It is composed of orthoclase and microcline, anhedral fractured quartz and relict biotite. Biotite displayed lepidoblastic foliation pattern, perfect cleavage with moderate to high relief and brown colouration (Plate III). The biotite altered to chlorite with traces of faint green around the grain edges. The biotite is brittle and when tensile stress is applied the biotite was folded. Biotite is pleochroic from colourless to brownish- green. Microcline exhibits cross arch twinning. There seem to be an equal proportion of biotite and microcline in the granitic gneisses

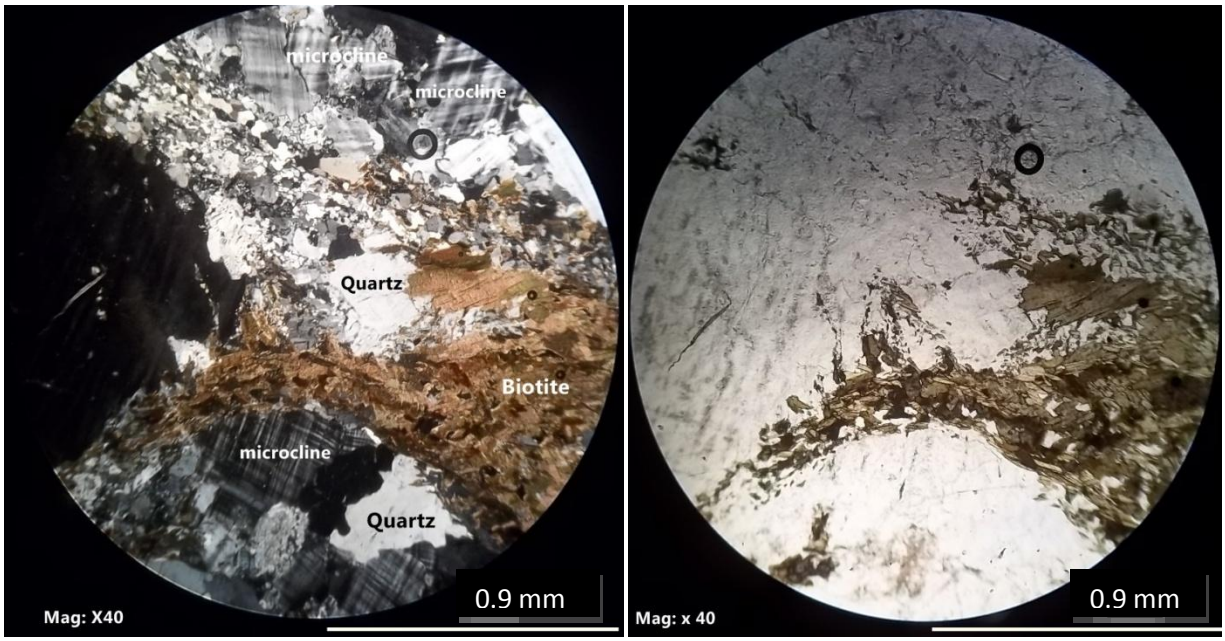


Plate III: Photomicrograph showing lepidoblastic texture in granitic gneiss in XPL and PPL respectively.

It consists of quartz (20%), microcline (30%), plagioclase (15%), biotite (30%) and (5%) accessories mineral.

5.1.4 Porphyritic Biotite Granite

This forms the most prominent topographic features in the study area (Fig.4.1). It covers the entire eastern half of the study area. It forms groups of inselbergs which are dome-shaped and lensoid bodies generally trending N-S (Plate IV). The porphyritic biotite granite is greyish in colour and consists of large phenocrysts of orthoclase and plagioclase feldspars, measuring between 5 and 7 cm along the long axis (Plate V). The porphyritic biotite granite is found in the eastern part of the study area (Fig. 4.1). Joints are prominent features and strike in a NS and NS-EW principal direction. Pegmatite, microgranite, and xenoliths are also present. In hand specimen, it is compose of feldspar, quartz and biotite. Feldspar is the most abundant of these major minerals. Large phenocrysts of feldspar are set in the matrix.



Plate IV: A North- South trending Lensoidal outcrop of Porphyritic Biotite Granite at Furgu Katsina. Location: 11°25′01.9″N, 007°42′13.5″E

In thin-section (Plate VI) the rock is composed of feldspars (microcline, orthoclase and plagioclase), quartz and biotite as major mineral constituents. Feldspar is the most abundant and is colourless but cloudy, in cross polarized light (xpl); microcline is grey and exhibit tartan twinning pattern. The plagioclase displayed polysynthetic twinning after albite law while orthoclase also display twinning after Carlsbad law. Quartz is fractured and displays a wavy extinction. In plain polarized light (ppl); it is colourless with low relief. Quartz is euhedral while the feldspars (microcline, plagioclase and orthoclase) are euhedral to subhedral in form. Biotite flakes are brown and green in colour having pleochroic haloes in some places, and showing evidence of deformation and alteration in other places. The porphyritic biotite granite consists of microcline (40%), quartz (30%), biotite (15%) and kaolinite with opaque and non- opaque minerals (15%).



Plate V: Phenocryst of Pinkish Feldspar in Porphyritic Biotite Granite at Dan Gusua.Location:11°24´12.6˝N, 007°42´57.6˝E

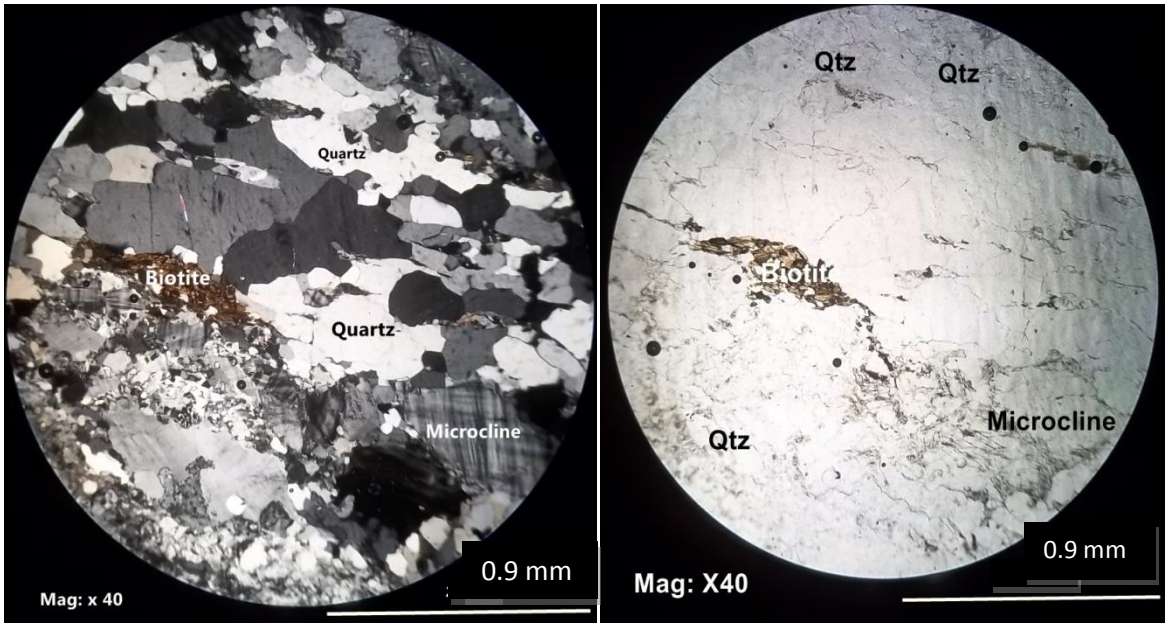


Plate VI: Photomicrograph of Coarse-Porhyritic Biotite Granite in XPL and PPL respectively showing the inter locking of the grains

5.1.5 Coarse Grained Biotite Granite

The coarse grained biotite granite was observed along river channels; around Tudunwada there exist a sharp contact between coarse grained biotite granite and porphyritic biotite granite (Plate VII). At Dan Gusau and Furgu Kastina, these outcrops were also seen. The rock is dark to light grey and is coarse grained in texture. Some of coarse grained outcrops carry feldspar phenocrysts and quartz veins. Weak foliation with N-S trend is characteristic of this rock. Joints are prominent and strike in the N-S and E-W directions at Hunkuyi Hill (Plate VIII). The rock is composing of orthoclase and plagioclase feldspars, quartz and biotite as the major minerals. Outcrops at Tsangamawa have been intruded by a few pegmatite, quartz and microgranite veins. The pegmatites are composed of megacrysts of feldspars with some quartz and less biotite. In the hand specimen, the granite is compose of feldspar, quartz and biotite. Some small–sized phenocrysts of feldspar are set in a finer matrix of quartz, feldspar and biotite.



Plate VII: Photograph showing a sharp contact between coarse grained biotite granite and porphyritic biotite granite defined by red line at Hunkuyi Hill. Location: 11°17′35.7″N, 007°41′32.6″E

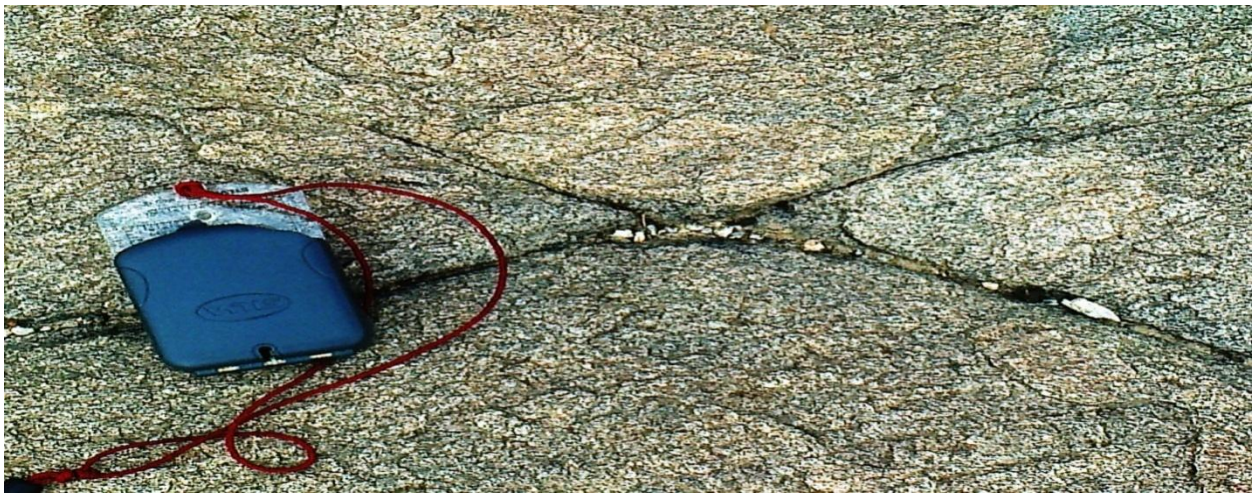


Plate VIII: N-S trending strike direction and almost horizontal dipping joints in the coarse grained biotite granite. Locality: Hunkuyi Hill. Location: 11°17´00.6˝N, 007°41´25.7˝E

5.2 Minor Lithologies

5.2.1 Quartz and Pegmatite Veins

These are more resistance than the granitic gneisses .Cross-cutting sheet and irregular masses of quartz and pegmatite veins are wide spread. They are found in almost all the outcrops in the study area, and vary in size from infilling of irregular fractures; to massive veins generally parallel to the N-S foliation strike direction. The most prominent minerals are quartz and feldspars, (Plate IX A) biotite, muscovite and garnet are also common. Pegmatite veins are generally not more than 10 cm across and coarse grained in width textures. The feldspar content of the pegmatite is microcline, albite and oligoclase (Plate IX B).

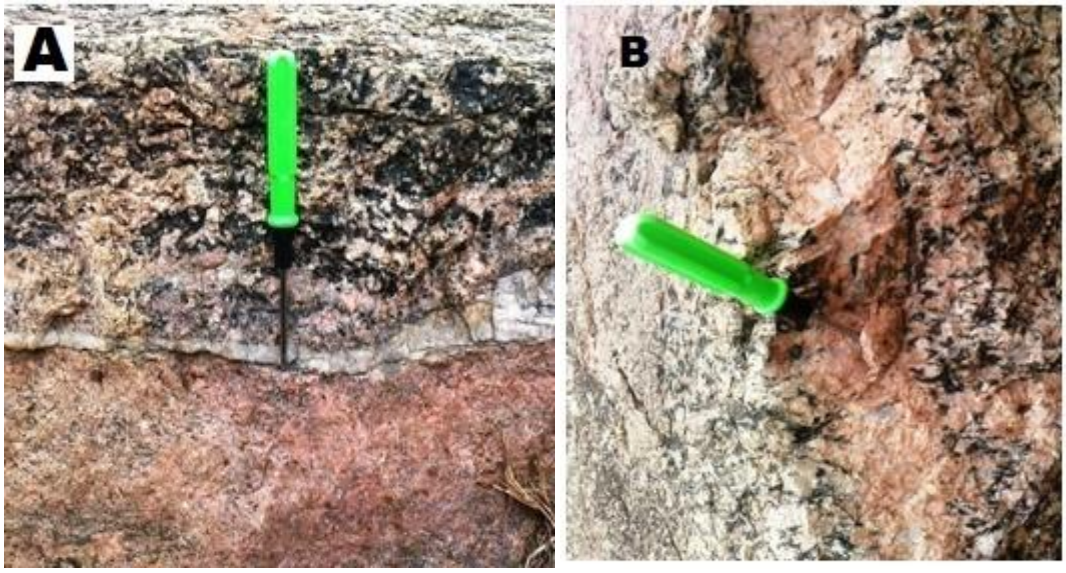


Plate IX: Quartz (A) and Pegmatite (B) veins in an Outcrop of Granitic Gneiss at Tsangamawa.Location:11°19´15.6˝N, 007º33´22.9E

5.2.2 Microgranite: It usually occurs within the main granitic body as late intrusions possibly infilling tensional cracks (Plate X). It is fine grained granite. Figure 5.1 shows strikes of joints in microgranite as shown in Table 5.1. The quartz veins occur as small veins and veinlets and are almost exclusively composed of quartz. They range in thickness from less than a centimeter to about ten centimeters and occasionally cross-cutting the pegmatites.



Plate X: A Microgranitic dyke within coarse grained biotite granite defined by red line at Dabai. Location: 11º24´26.0˝N, 007º39´27.6˝E

5.2.3 Xenolith

This is accidental inclusion into the porphyritic biotite granite at Dan-Gusau . This confirms the granite is relatively younger than country rock in the area (Plate XI).



Plate XI: Dark coloured xenolith in porphyritic biotite granite at Dan Gusua. Location: 11º24´12.6˝N, 007°42´57.6˝E

5.3 STRUCTURES

Regional N-S structural trend is prominent in the study area and it represents the final inprint of the Pan-African Orogeny which affected much of West Africa (Grant, 1969). Generally, all the rock types are fractured. The structures present in the outcrop found in the study area are fractures mainly joints and faults. These structures affect the permeability of the crystalline rocks. Prominent joint sets are common over the whole area with fractures running approximately N- S and NW- SE (mainly), and NE – SW (slightly). This structural trend has also been noted by Oden *et al.*, (2015). They joints are frequently filled with quartz to form quartz veins in the porphyritic biotite granite (Figs 5.1 and 5.2). Some of these joints are open while others are in filled with quartz and feldspar, forming veins and pegmatites. Some of the open ones are weathered and sustain light vegetation or water courses.

Faults with strike trends ranging from 120° to 132° are frequent (040° to 055°, less frequent). They show sinistral displacement though slight dextral displacement was also noted (Plate XII A and B). Joint system is among the structures which contribute immensely to underground storage. The Precambrian complex rock which underlies the weathered basement is impervious, but the numerous joints which formed channels have helped in the recharging of the aquifer in the study area. Also weathering has proceeded along joint planes in porphyritic biotite granite leaving open gap in the outcrop thus loosening up minerals that make up the rocks. Some of the joints direction recorded in the field is shown in Tables 5.1 and 5.2.

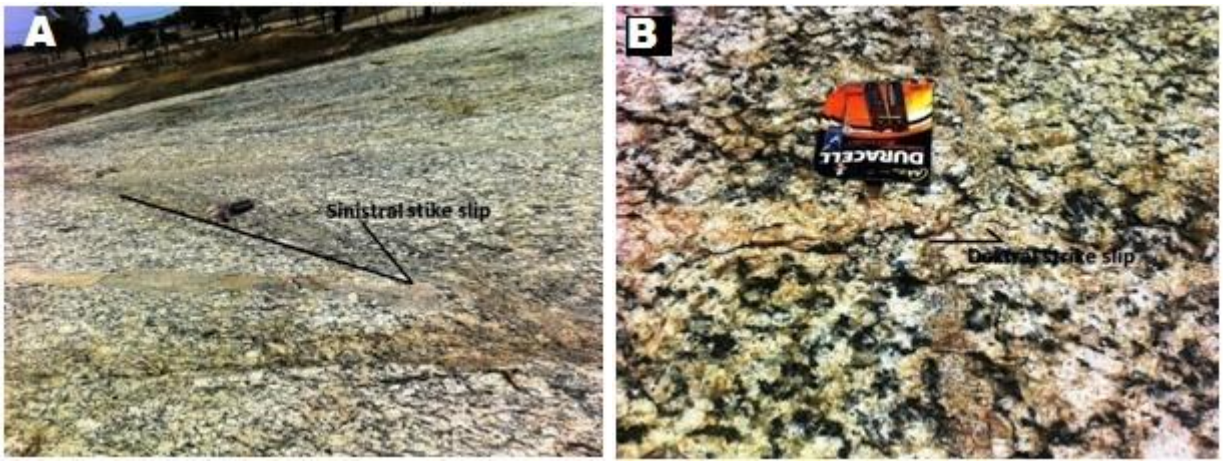


Plate XII: A) Sinistral strike slip fault in granitic gneiss. B) dextral strike slip fault in porphyritic biotite granite

Table 5.1: Strike of Joint in Microgranite

56^0	310^0
120^0	332^0
138^0	305^0
150^0	360^0
122^0	297^0
42^0	290^0
130^0	350^0
140^0	352^0

Table 5.2: Strike of Joint in Porphyritic Biotite Granite

001^0	350^0
002^0	352^0
006^0	358^0
040^0	358^0
040^0	360^0
050^0	360^0
052^0	360^0
052^0	360^0

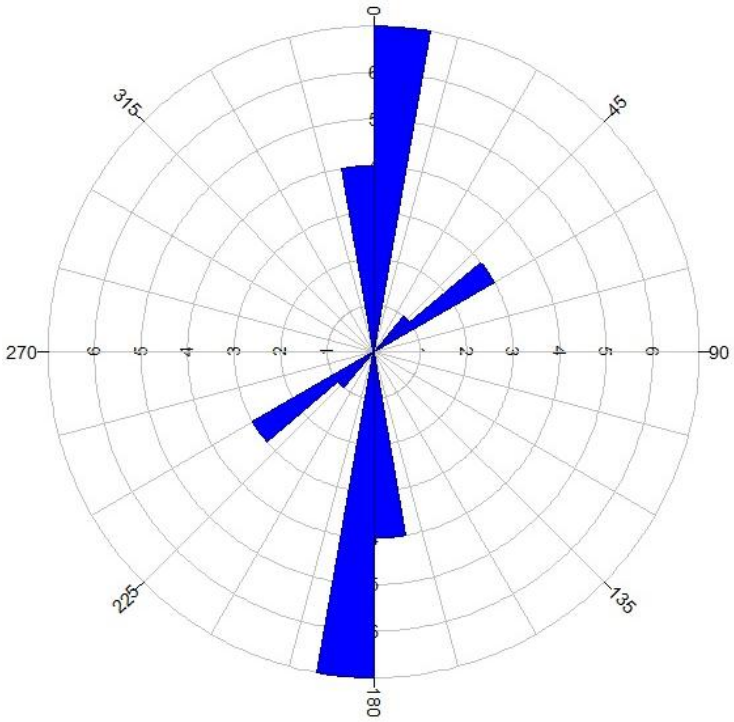


Figure 5.1: Rose diagram of trends of joints in microgranite

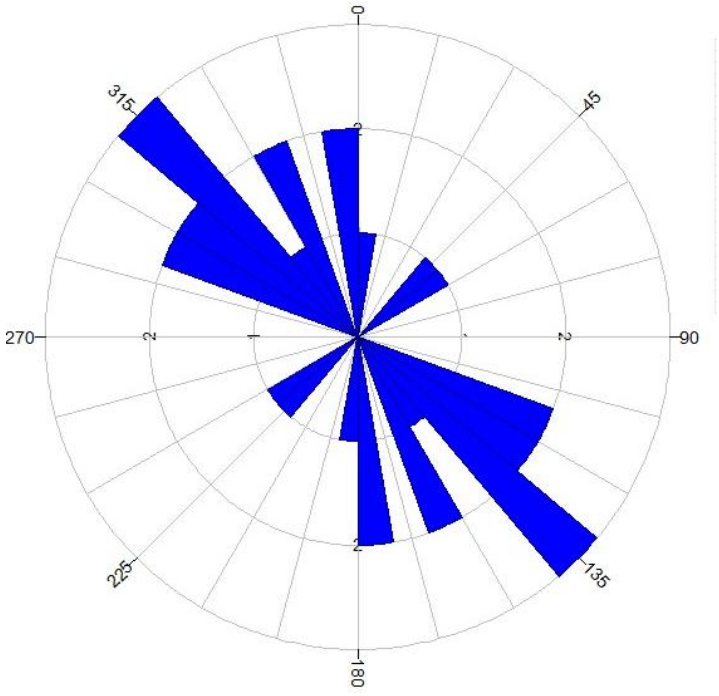


Figure 5.2: Rose diagram of trends of joints in porphyritic biotite granite

5.4 HYDROGEOLOGY

In order to have good knowledge of the hydrogeological characteristics of both surface and groundwater in the study area, one has to study the factors which influence their occurrence such as rainfall, vegetation and the rate of evaporation. The first two factors have been mentioned in chapter one, but the mode of movement of groundwater as influenced by these factors will be discussed briefly in this section. Rainfall is the source of both surface and groundwater. Rain on falling to the ground surface flows either as surface runoff into streams and rivers, as infiltrations into the ground to join the stream, while part of it is stored in the ground as groundwater. Part of it also remains as soil moisture. A large portion of precipitation is returned again to the atmosphere by evapotranspiration.

During the dry season the vegetation of Zaria reduces groundwater depletion and hydrogeological advantage, and also in the wet seasons when the vegetation is denser, but not enough to stop runoff and evaporation. Evaporation is a very important factor in groundwater study, in Zaria region, the dry season temperature is so high resulting in very high rate of evaporation. Also, the north-east trade wind from the Sahara desert causes relative increase in the total evaporation. During the wet season evaporation rate could be as high as 8.666 mm per day (Meterological data station Samaru, 2012). Furthermore, hydrogeological setting of an area is generally controlled by factors such as geology, climate and structural features. This is due to the facts that geological formations underlying an area and the associated structures do determine the type of aquifers to be encountered while climate determines the amount and rate of recharge of the aquifer (Todd, 1980)

5.4.1 Groundwater Occurrence in the study area

The study area is underlain by the Nigerian Basement Complex. This complex is a heterogenous mixture of crystalline rocks such as coarse grained biotite granite, porphyritic biotite granites, granitic-gneisses, migmatites and schists. Groundwater occurs throughout the high storage, low permeable regolith and the low storage, high permeable bedrock. Crystalline rocks generally have porosity less than 3% (Bouwer, 1978). These rocks are overlain by the overburden deposit except in a few places where they are exposed as platforms, whaleback etc. As such rocks of the basement complex, when not weathered are practically impermeable and have no storage capacity. However, appreciable porosity and permeability might have been developed in the rocks through fracturing and weathering processes (Davis *et al*, 1966), depending on the lithology and texture of the original rock. Offodile (1983), Jones (1985) and Egboka (1988) described the basement rock units to be more productive at the base of the weathered zone where the rocks have been broken down to sand size and larger fragments that are not subjected to extensive weathering process i.e. sap rock zone. Two types of aquifers were identified in the study area.

i) Overburden aquifer

ii) The weathered/fractured aquifer

5.4.1.1 Overburden Aquifer

This type of aquifer is predominantly tapped or exploited through hand-dug wells in areas where the overburden is sufficiently thick to contain water until the end of the dry season. Its thickness enhances the sustainability of hand-dug wells. If thickness is low, then this type of aquifer in most instances dries up at the beginning or at the peak of dry season. In areas of thin overburden aquifer very few of these wells survive up to the beginning of the wet season. This aquifer is

also interconnected with the weathered/fracture aquifer in boreholes. Deep hand-dug well in the study area, indicating thick over-burden aquifer, were observed in the SWgradient of the study area and these provide water at all seasons. Very thick overburden in the study area is normally associated with the metamorphic rocks, while thin overburden characterized by poor groundwater conditions was observed on the granites terrains.

5.4.1.2 Weathered/Fractured Aquifer

The weathered/fractured aquifer is structurally controlled and underlies the overburden aquifer. This aquifer is composed of fresh, brittle, medium to coarse grained crystalline rocks that have reacted to tectonic stresses to cause fracturing and jointing. The interconnectivity between the overburden aquifer and the weathered/fractured aquifer contributes to the rate of recharge and yield of the weathered/fractured aquifer. The main source of groundwater from the study area is weathered zone/fractured aquifer. Transmissivity of aquifers in the study area fall within the low potential class of Krasny (1993) which ranges from 1-10m^2/day. Such range is usually requisite for small local supply with limited consumption.

5.5 Evaluation of Groundwater Table Configuration Maps

Groundwater table configuration maps were prepared for both the end of wet season (August) and the peak of dry season (April). Figures 3.1 and 3.2 show the configuration, their corresponding groundwater flow directions as well as crystalline outcrops in the area. From evaluation of the maps, the following important information was deduced:

5.5.1 Map of Configuration of Watertable

The watertable contours in the study area have been drawn at 50 m interval for both seasons and the contours are to a large extent very similar to the ground surface except where they are interrupted by the crystalline outcrops. They are controlled by the relief of the area because the

watertable is higher under hills than the adjacent valley areas. The shape of the watertable contours is identical in both seasons. The groundwater occurs at 680 m above sea level (2250 ft).

5.5.2 Direction of Groundwater Flow

Direction of groundwater flow is also known as direction of groundwater movement which is indicated in the map of the study area by the arrows drawn perpendicular to the groundwatertable contours (equipotential lines). Groundwater in the study area flows from the higher groundwater elevation contour to lower groundwater elevation contour and the flow is largely towards NE direction.

5.5.3 Recharge Pattern in the Study Area

Fluctuations in groundwater level are caused by changes in groundwater storage capacity and due to other influences such as aquifer deformation, changes in atmospheric pressure and disturbances within the well (Wartena, 1962). These changes are the net result of the prevailing recharge and discharge pattern. Rising water levels in the study area indicates the periods when recharge is exceeding the discharge. Natural groundwater recharge in the study area is from seasonal rainfall which infiltrate through the unsaturated zone into the saturated zone as well as from influent streams. Adanu (1991) used environmental isotope method to show that a large amount of recharge takes place during a period of heavy rainfall. The general rise in groundwater levels during the wet season also attests to this. The recharge is easily identified mostly during wet season when water levels in hand-dug wells rose.

5.5.4 Discharge Pattern in the Study Area

Declining water levels in the study area indicate periods when discharge is exceeding recharge. This occurs during dry season when water levels receded than during the wet season by 2 m

below the ground surface. In an aquifer, discharge can be natural or artificial. Natural discharge is a discharge through streams, springs and evaporation where groundwater table is at or close to the surface. Artificially occurring discharge is by pumping or withdrawal through hand-dug wells and boreholes. Hence, the discharge in the study area is both natural (from effluent stream), artificial pumping through wells and boreholes) and most of the streams are seasonal (Figure 4.2 and Fig 4.3).

5.6 GROUNDWATER QUALITY

5.6.1 Groundwater Chemistry Sheet 102 Zaria NW

Geology of an area imposes its chemistry on groundwater of that area, thereby forcing it to acquire a prevalent chemical character that determines its quality utilization. Solutions of substances take place in the course of percolation through the rocks where it acquires certain salinity. The physical, chemical and biological composition of groundwater is an important consideration if the water is intended to be used for domestic, agriculture, industrial or other purposes.

The geochemical properties determined are total dissolved solids (TDS) and the principal inorganic chemicals which occur in groundwater are the cations namely calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}) and anions such as sulphate (SO_4^{2-}), bicarbonate (HCO_3^{-}) chloride (Cl^{-}), nitrate (NO_3^{-}), phosphate (PO_4^{2-}), ammonia (NH_4^{+}) and some heavy metals such as lead (Pb^{2+}), copper (Cu^{2+}), manganese (Mn^{2-}), iron (Fe^{2+}) and zinc (Zn^{2+}). Excess of some of these elements indicate enrichment/mineralization or pollution. The study of groundwater chemistry also helps in determining the geological history of the enclosing rocks, the velocity and direction of water movement.

The principal physical properties and inorganic chemicals found in the groundwater of the Zaria Sheet 102 NW will now be examined on the basis of their possible origin and how they affect usage in domestic purposes and industrial use.

5.6.2 Physical Properties of Water

5.6.2.1 Temperature

Cool water is generally more palatable than warm water, and temperature will impact on the acceptability of a number of other inorganic constituents, its physical and chemical characteristics that may affect quality of the water found at the source. High water temperature enhances the growth of micro-organisms and may increase taste, odour, colour and corrosion problems. The temperature range of sampled water in the study area (23.9^{o}C to 24.3^{o}C) is higher than the permissible range of 15^{o}C to 22^{o}C for refreshing potable water. The temperature of the groundwater in the study area is high than the possible unit of WHO standard (Table 4.2, 5.3). The water in the study area must be allowed to cool down to normal temperature. If it is going to be use for drinking while for cooking and other domestic use, it can be used directly. These temperature variations are probably caused by seasonal changes as data are from shallow groundwater

5.6.2.2 Colour

The water samples were colourless and clear to the unaided eye though no measurement was carried out to determine the unit value of the colour.

5.6.2.3 pH

Hydrogen ion exponent was given a concise description that the pH reflects equilibrium and non-equilibrium relations between solute present in the water. Groundwater pH is a fundamental property that influences the acidity and alkalinity and largely controls the amount and chemical form of many organic and inorganic substances dissolved in groundwater. Groundwater in the study area is slightly acidic with all the water samples having pH values ranging from 5.30 to 6.40 with an average of 5.80 (Tables 4.1, 5.3). This is slightly lower than the World Health Organization (WHO) (2011) and Nigeria Standard for Drinking Water Quality (NSDWQ) (2005) recommended minimum for pH range of 6.5 to 8.5. The effect of acidic water is that the water can have sour taste. The primary way to treat low pH water is with the use of neutralizer. A typical neutralizing chemical is soda ash (Sodium carbonate). Most groundwater has pH values between 6.0 and 8.0 (Davis and De Wiest 1966). The low pH may be attributed to solution of carbon dioxide (CO_2) dissolved from the atmosphere and from the abundant decaying vegetation in the soil zone (Morgan and Winner 1962).

5.6.2.4 Electrical Conductivity

A measure of electrical conductivity of groundwater is an expression of its total dissolved solids which includes all solid materials in solution, whether ionized or not. It is measured in µS/cm. It does not include suspended sediment, colloids, or dissolved gases. The value of electrical conductivity of the water samples of the study area ranges from 5.4 to 423 µS/cm with an average 155 µS/cm. This is lower than the NSDWQ (2005) recommended level of 1000 µS/cm. Hence, the study area has low conductivity.

5.7 Chemical Properties

5.7.1 Total Dissolved Solids (TDS)

The value of TDS of groundwater samples are very low and vary from 311 mg/l to 11.08 mg/l with an average of 55.07 mg/l. According to Chilton and Smith-Carington (1984), this low mineralization indicates that the weathered zone has been highly leached of soluble minerals and /or groundwater is likely derived from relatively recent recharge. Hence, with the low level of mineralization as indicated by low TDS of less than 1000 mg/l, the groundwater from the study area is fresh using the classification scheme of Davis and De Wiest (1966) (Table 4.2).

5.7.2 Sodium

The concentration of sodium ions ranged from 2 to 87 mg/l with an average of 18.45mg/l. These values are higher than the WHO (2011) recommended level and within NSDWQ (2005) permissible level (Table 5.3). The high concentration of sodium ions in water is capable of causing foaming of the water in the presence of suspended matter (Todd, 1980). Hence, it is geogenic in nature. This ion could have been released into the groundwater from the soluble products of weathered orthoclase feldspar. Some part of sodium could have been derived from dust washed down by rain.

5.7.3 Potassium

The concentration of potassium ions range from 1.2 to 34 mg/l with an average of 6.88 mg/l (Table 4.2). Potassium in the groundwater could have derived their origin possibly from the products of weathered orthoclase, microcline and biotite (geogenic). Others could have been from rain water and leaching of fertilizers (anthropogenic).

5.7.4 Calcium

The concentration of calcium ions range from 0 to 47.22 mg/l with an average of 12.57 mg/l except one sample that had a concentration of 154.21 mg/l (sample number 30) having its value higher than the recommended level of 100 mg/l (WHO, 2011). Two of the thirty samples tested do not contain this ion (Table 4.2). Most of these calcium ions could possibly have been derived from weathering products of orthoclase feldspars and mafic minerals. Others could have been from rain water and leached from fertilizers.

5.7.5 Magnesium

The concentration of magnesium ranges from 0.76 to 13.20 mg/l with an average of 6.42 mg/l. The concentration of magnesium ion (Tables 4.1, 5.3) is within the WHO (2011) recommended concentration levels for drinking water. Magnesium is probably derived from mafic minerals present in the rocks. Magnesium may combine with sulphate or carbonate to form thick solid scales in boilers and in other heat-exchange equipment especially when such water is evaporated from boilers.

5.7.6 Sulphate

The concentration of sulphate ranges from 0.12 to 2.66 mg/l with an average of 0.46 mg/l. Sulphate occurred in minor quantity in the study area due to the geology. Most sulphate concentration in groundwater occur from sedimentary rocks derived from beds of gypsum, sodium sulphate deposits and some type of shale which were not present in the study area.

5.7.7 Bicarbonate

The concentration of bicarbonate is very low and the range is from 0.5 to 3.5 mg/l with an average of 1.58 mg/l. Most of these bicarbonate ions could have been derived from the carbon

dioxide in the atmosphere and in the soil absorbed by water during percolation.

5.7.8 Chloride

The concentration of chloride ranges from 0.15 to 6.45 mg/l with an average of 0.93 mg/l. the possible source of chloride in the study area might be possibly from the dry fallout from atmosphere or result from external pollution from thrown out food containing salt and since sodium chloride (NaCl) is very soluble, this can then be washed down into the ground by rain. Chloride in drinking water also originates from natural sources, sewage and industrial effluents.

5.7.9 Nitrate

The concentration of nitrate varies from 0 to 35 mg/l with an average of 8.26 mg/l. This is within WHO (2011) and NSDWQ (2005) recommended levels. Nitrate can reach groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures) which is most common in the study area. Another source of nitrate might be from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Some groundwater may also have nitrate contamination as a consequence of leaching from natural vegetation. An additional minor source is from nitric oxides produced by lightning discharges.

5.7.10 Phosphate

The concentration of phosphate ranges from 0.27 to 1.95 mg/l with an average of 0.45 mg/l. Phosphate is an essential radical in the growth of plants and animals. Some sources that contribute nitrates, such as organic wastes are also important source of phosphate. Also, phosphate in fertilizers which is most common practice in the study area may yield some certain percentage to groundwater in the area. Concentrations of phosphate found in trace amount are

not toxic to man and animals. However, phosphate in water can stimulate the growth of algae, which may cause taste and odour problems.

5.7.11 Ammonia

The concentration of ammonia ranges from 0.007 to 0.035 mg/l with an average of 0.02mg/l. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. The source of ammonia might be from external source of contamination. Out of the thirty groundwater sampled, one sample (sample number 23) has high concentration value because the well was by the discharge of urine around the mosque which might be responsible for the high content of ammonia in the water of that location (Dan Mahawayi).

5.7.12 Lead

It is a serious cumulative body poison. Natural waters seldom contain more than 5µg/l. Lead in water supply could come from either industrial; mine, smelter discharges and/or forms from the dissolution of old lead plumbing.

The concentration of lead varies from 0 to 0.035 mg/l with an average value of 0.0025 mg/l. Out of the thirty samples analyzed, only four showed traces of lead in the study area. Two out of the four (samples number 1 and 9) exceed the recommended level of 0.01mg/l WHO (2011) and NSDWQ (2005) and the other two are within the limits. The possible origin is natural which is due to mobilization from soil, vegetation, alluvium or bedrock and also from hamattan dust.

5.7.13 Copper

The concentration of copper ranges from 0.003 to 0.584 mg/l with an average of 0.06 mg/l. Copper is both an essential nutrient and a drinking-water contaminant. The value of copper in the groundwater for the study area is in trace concentration. The possible source of copper might be from leaching of natural deposit underground. The copper occur as trace element in the

granite which come from leaching the product of rock weathering might be another possible source of copper in the groundwater. Some people who drink water containing copper in excess of the permissible level with short term exposure, experience gastrointestinal distress and with long-term exposure may experience liver or kidney damage.

5.7.14 Manganese

The concentration of manganese ranges from 0.008 to 0.822 mg/l with an average of 0.09 mg/l. Two samples exceeded the recommended level of 0.4 mg/l WHO (2011) for safe drinking water. The possible source of manganese in groundwater might be from rain water and leach from the product of rock weathering. At concentration levels higher than 0.4 mg/l, manganese imparts a bitter taste to water, stains cloths and metal parts and precipitate in foods when used for cooking and it also promotes the growth of algae in reservoirs (Todd, 1980).

5.7.15 Iron

The concentration of iron (total) varies from 0.012 to 1.51 mg/l with an average of 0.56 mg/l. Some of these values are higher than the WHO (2011) and NSDWQ (2005) recommended level of 0.1 mg/l for safe drinking water. The major sources of iron could have been derived from dissolution of ferromagnesian minerals during weathering. If it becomes necessary, the iron could be removed by aeration.

5.7.16 Zinc

The concentration of zinc varies from 0 to 5.061 mg/l with an average of 0.33 mg/l except in one sample in which a concentration of Zn is 5.016 mg/l. The reason for this high value can be attributed to the closeness of the well to a vulcanizer workshop where remaining of burnt tyre are washed down by rain into the well. This is the only value that exceed WHO (2011) permissible

level of 0.01 mg/l for drinking water (Table 4.2, 5.3). The abundance of the major ions can be depicted as follows: $Na^{+} > K^{+} > Ca^{2+} > Mg^{2+}$ and $HCO_3^{2-} > Cl^{-} > SO_4^{2-}$.

Minimum, maximum, average values and standard deviation of physical and chemical parameters of groundwater samples are presented in Table 5.3.

5.8 Hydro-Chemical Facies

(i) The piper tri-linear graphical representation of chemical data of representative samples from the study area for the dry season reveal the analogies, dissimilarities and different types of waters bring out chemical relationships among groundwater samples in more definite term . Plots of the hydrochemical parameters of the water samples on the Piper (1944) Trilinear diagram (Fig. 5.3) classified the groundwater system in the study area into Ca + Mg, Na + K – HCO_3, Ca + Mg, Na + K – SO_4 and Na + K – SO_4 –Cl and Na + K – HCO_3 waters.

(ii) The Durov diagram was used to also infer hydrochemical facies of the study area. Chemical data of representative samples for the study area are presented by plotting them on Durov plot (Fig 5.4). The samples were concentrated in Mg-HCO_3^{-} type.

Table5.3: Statistics summary of the analytical data of groundwater samples of the Study area with 2011 WHO Standard and 2005 NSDWQ for drinking purposes.

Para-meter	Units	Minimum	Maximum	Average	StandardDeviation(S.D)	2011 WHO Standard		2005 NSDWQ	
						Recommended level	Max permissible level	recommended level	Max permissible level
pH	-	5.3	6.4	5.767	0.254	6.5-8.5		6.5-8.5	
TDS	mg/l	11.08	311.0	55.069	66.716			500	
EC	µs/cm	5.4	491.0	154.597	120.36			1000	
Temp	°C	23.9	24.3	23.337	3.955	15	22		
Na	mg/l	2.0	87.0	18.45	20.718	50		200	
K	mg/l	1.2	34.0	6.883	8.295				
Ca	mg/l	0.0	154.21	12.569	29.432	100			
Mg	mg/l	0.77	13.2	6.425	2.755	50		0.2	
Fe t0tal	mg/l	0.01	1.51	0.56	0.389	0.1		0.3	
Mn	mg/l	0.01	0.82	0.085	0.179	0.4			
Cu	mg/l	0.003	0.584	0.063	0.108	2.0		1.0	
Zn	mg/l	0.0	5.016	0.326	0.914	0.01		3.0	
Pb	µg/l	0.0	0.026	0.001	0.005	0.01		0.01	
NH_4	mg/l	0.007	0.035	0.02	0.009				
Cl	mg/l	0.15	6.45	0.932	1.193	250		250	
HCO_3	mg/l	0.5	3.5	1.58	0.764				
NO_3	mg/l	0.0	35.0	8.17	9.977	50		45	
PO_4	Mg/l	0.27	1.95	0.45	0.310				
SO_4	mg/l	0.12	2.66	0.46	0.506	250		100	

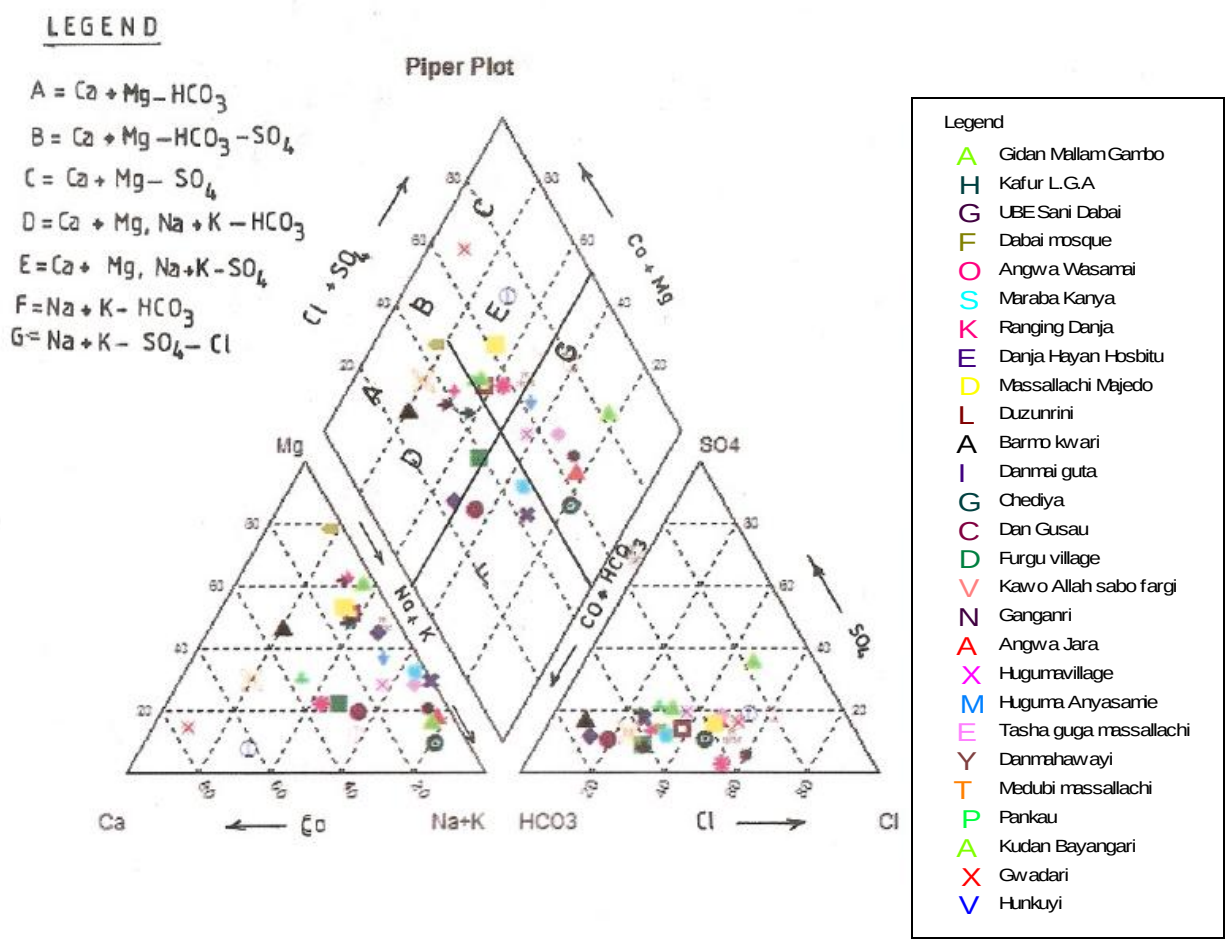


Figure 5.3: Water types of the study area based on piper trilinear diagram

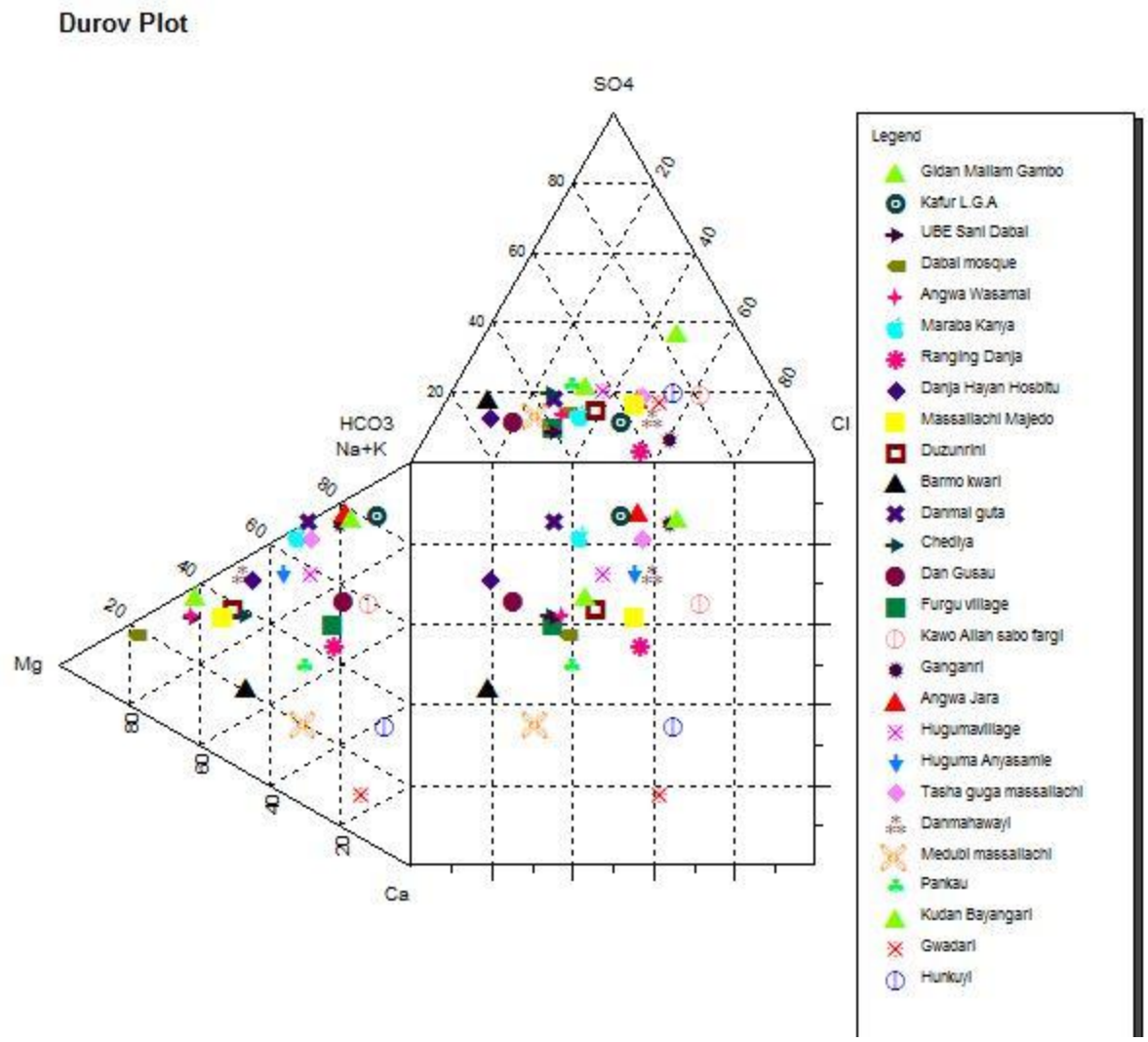


Figure 5.4: Classification of water in the study area after durov plot diagram

5.9 Groundwater Quality Analysis for Irrigation

Water quality, soil types and cropping practices play an important role for suitable irrigation practice. Excessive amount of dissolved ions in irrigation water affect plants and agricultural soil, both physically and chemically, thus reduce its productivity. The physical effects of this ion are to lower the osmotic pressure in the plant structural cells, thus preventing water from reaching the branches and leaves. The chemical effects disrupt plant metabolism. The development and maintenance of successful irrigation projects involve not only the supplying of

irrigation water to the land but also the control of salt and alkali in the soil (Haritash *el al*; 2008) Salinity hazard and sodium absorption ratio are important parameters for determining the suitability of groundwater for agricultural uses. While total hardness and total dissolved solids (TDS) are used to determine groundwater quality for drinking and industrial purposes (Table 5.4).

Table 5.4: Salinity hazard, sodium absorption ratio, total hardness and total dissolved solids of groundwater in the study area (after Todd,1980)

Sample No.	Salinity hazard µs/cm	Sodium Absorption Ratio	Total Hardness mg/l	Total Dissolved Solids mg/l
SL1	92.8	1.21	0.18	28.1
SL2	62.2	1.60	0.34	42.6
SL3	88.7	0.34	1.56	80.4
SL4	44.2	0.15	1.85	70.2
SL5	91.7	0.37	1.68	59.5
SL6	183	1.61	1.18	29.2
SL7	241	1.51	7.71	34.4
SL8	84.9	0.72	1.45	27.8
SL9	137.5	0.52	1.95	37.1
SL10	136.7	0.42	1.93	39.3
SL11	120.1	0.25	1.05	28.1
SL12	75	0.25	2.53	47
SL13	30.6	1.83	1.09	24.6
SL14	181	0.65	2.19	30
SL15	148.5	1.59	2.62	22.3
SL16	443	1.44	3.74	11.08
SL17	491	3.21	7.80	37.1
SL18	183	3.37	2.16	12.9
SL19	193.5	2.60	1.42	39.2
SL20	26.4	0.90	1.11	46.1
SL21	169.9	1.10	2.24	78.5
SL22	44.5	1.31	1.22	90.4
SL23	5.4	0.63	1.10	12.79
SL24	164	0.33	1.52	16.4
SL25	59.4	0.52	1.84	16.4
SL26	171	0.33	3.41	23.1
SL27	101.3	0.86	5.78	71.7
SL28	151.6	3.13	2.40	262
SL29	284	0.23	7.88	30.8
SL30	423	1.50	24.31	311

5.9.1 Salinity hazard

On the basis of chemical characteristics analysis, the groundwater samples have been classified into various classes (Handa, 1969) as presented in Table 5.5. It was found that all the samples collected during the peak of dry season (April, 2013) were categorized under low to medium extensive salinity classes. The majority of samples (86.7%) belong to low salinity category, indicating that the water is of excellent quality.

Table 5.5: Classification of water in the study area based on electrical conductivity (EC) (after Handa, 1969)

EC µs/cm	Water Quality	Number of Samples	Percentage (%)
0 – 250	Low (Excellent quality)	26	86.7
251 – 750	Medium (Good quality)	4	13.3
751 – 2250	High (permissible quality)		
2251 – 6000	Very high		
6001 – 10,000	Excessively high		
10,001 – 20,000	Brines weakly concentrated		
20,001 – 50,000	Brines moderately concentrated		
50,001 – 100,000	Brines highly concentrated		
>100,000	Brines extremely highly concentrated		

5.9.2 Sodium Absorption Ratio (SAR)

Another important factor for water quality is Sodium Absorption Ratio (SAR) and this is considered as a better measure of sodium (Alkali) hazard in irrigation water as it is directly related to the adsorption of sodium on soil particle which is a valuable criterion for determining the suitability of the water for irrigation. Excessive sodium content relative to the calcium and magnesium reduces the soil permeability and thus inhibit the infiltration of water needed for the crops. The SAR measures the relative proportion of sodium ions in a water sample to those of calcium and magnesium. The SAR is used to predict the sodium hazard of high carbonate water

especially if it contains no residual alkali. The excess sodium or limited calcium and magnesium are evaluated by SAR (Kalru *et al.*, 1991) which is computed as equation (1).

$$SAR = = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where all cationic concentrations are expressed in meq/l.

The classification of groundwater samples from the study area with respect to SAR is presented in Table 5.4. The sodium absorption ratio varies from 0.15 to 3.37 meq/l. The SAR value (Table 5.6) of all the samples is found to be less than 10 and the groundwater are classified as being excellent for irrigation on all soil types and most crops.

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Table 5.6: Classification of groundwater based on SAR values in the study (Source: Adopted from Richards, 1954, Todd, 1959).

SAR Value	Remark on Quality	Sample No.
< 10	Excellent	All Samples
10 – 18	Good	
19 – 26	Doubtful/Fairly poor	
> 26	Unsuitable	

Also, the major factors considered for the suitability of any water for livestock farming is the total dissolved solids (TDS). This is based on the Australian and UNESCO Standards for livestock water (Hamill and Bell 1986) which stated that the TDS values from 0 to 2900 mg/l are suitable for all animals; thus all the waters from the study area are of best quality for livestock farming since the total dissolve solids range from 11.08 to 311 mg/l (Table 4.2).

5.9.3 Total Hardness

Hardness is an important criterion in determining the suitability of groundwater for domestic and industrial purposes. Water hardness has no known adverse effects; however, it causes more consumption of detergents at the time of cleaning and some evidence indicates its role in heart disease (Schoeller, 1960). According to Todd, 1980, Hem, 1985, Ragunath, 1987 the total hardness could be determined by the following equation (2).

$$TH = 2.497\ Ca^{2+} + 4.115\ mg^{2+} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where Ca^{2+} and Mg^{2+} concentrations are expressed in meq/l.

The classification of groundwater in the study area based on hardness (Sawyer and McCarthy 1967) is presented in Table 5.7. The TH values vary from 0.34 to 24.31 meq/l. All the samples collected from the study area are classified as soft water.

Table 5.7: Classification for Groundwater based on Hardness (Source: Adoption from Sawyer and McCarthy 1967)

TH meq/l	Water class	No. of Sample	Percentage (%)
< 75	Soft	30	100
75 – 150	Moderately hard		
150 – 300	Hard		
> 300	Very hard		

5.9.4 Total Dissolved Solids (TDS)

The total dissolved solids content for most agricultural purposes should not be above 3000 mg/l. Table 4.2 shows that all the water samples have total dissolved solids value vary from11.08 to 311 mg/l in the study area.

5.10 Correlation Analysis

Statistical correlation method is used for determining the degree of water relationship between the following parameters TDS, Na^{+}, K^{+} Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2-}, Cu^{2+}, Zn^{2+}, Pb^{2+}, NH_4^{+}, Cl^{-},

HCO_3^-, NO_3^- and SO_4^{2-} to see their relationship (Table 5.8). There is a strong positive correlation exists between TDS and Zn, TDS and K^+, Na^+ and Cl^-, Na^+ and NO_3^-, Na^+ and SO_4^{2-}, Ca^{2+} and Zn^{2+}, Fe^{2+} and Pb^{2+}, Zn^{2+} and Pb^{2+}, Pb^{2+} and NO_3^-, Cl^- and NO_3^-, Cl^- and SO_4^{2-} and NO_3^- and SO_4^{2-}. In addition, it can be deduced, that for most of the groundwater samples these parameters originate from rain filtration (common sources). Leaching giving rise to elemental enrichment is a primary factor and the issue of pollution is a secondary factor.

Table 5.8: Correlation Analysis results for the Chemical Parameters of the study area

	TDS	Na	K	Ca	Mg	Fe	Mn	Cu	Zn	Pb	NH_4	Cl	HCO_3	NO_3	SO_4
TDS	1.000	0.484	0.717	0.630	0.372	0.212	0.190	0.168	0.920	0.002	0.334	0.213	0.114	0.628	0.451
Na		1.000	0.556	0.597	0.528	0.102	0.038	0.178	0.635	0.112	0.338	0.869	0.489	0.809	0.810
K			1.000	0.429	0.494	0.171	0.222	0.173	0.598	0.490	0.347	0.313	0.015	0.548	0.391
Ca				1.000	0.541	0.326	0.164	0.190	0.905	0.129	0.199	0.443	0.301	0.629	0.409
Mg					1.000	0.073	0.049	0.192	0.434	0.755	0.383	0.441	0.127	0.493	0.339
Fe						1.000	0.230	0.028	0.270	0.914	0.094	0.020	0.139	0.130	0.059
Mn							1.000	0.152	0.082	0.125	0.233	0.034	0.405	0.076	0.140
Cu								1.000	0.102	0.207	0.206	0.132	0.077	0.140	0.168
Zn									1.000	0.962	0.223	0.373	0.146	0.631	0.431
Pb										1.000	1.000	0.314	0.608	0.999	0.077
NH_4											1.000	0.246	0.140	0.322	0.222
Cl												1.000	0.490	0.710	0.856
HCO_3													1.000	0.262	0.370
NO_3														1.000	0.819
SO_4															1.000

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This study investigated some aspects of groundwater conditions in Zaria Sheet 102NW, North Central Nigeria. The area is underlain by rocks of the basement complex which are essentially porphyritic biotite granite, coarse grained biotite granite, granitic gneiss, migmatite and schist.

Two major aquifer units are present in the study area and these are the overburden aquifer and weathered/fractured crystalline aquifer. The weathered/fractured crystalline aquifer is overlain by overburden aquifer. Groundwater occurs in the pore spaces of the overburden aquifer as well as in the fractures and joints of the weathered/fractured crystalline aquifer. The weathered/fractured crystalline aquifer plays a significant supporting role for groundwater abstraction in localized zones while overburden aquifer forms the major aquifer unit.

Evaluation of the hydrogeological maps has shown that the watertable is dynamic (Figs 3.1 and 3.2). Their configurations which are similar in both seasons resembles that of the ground surface contour lines except where interrupted by the outcrops of the basement rocks. This indicates that the watertables are controlled by relief. The directions of groundwater flow for dry season diverge from water shed and converge towards the drainage channels.

Also the thickness of dry zone map drawn for the study area which indicates groundwater watertable at different points on the map can help to decide where wells can be sited.

The chemical quality of groundwater from the study area has very low mineralization. The highest TDS value is 311mg/l and the lowest is 11.08mg/l. The groundwater is slightly acidic (pH varies between 6.40-5.30). It has low electrical conductivity and the temperature range of

the water samples varying between 23.9 and 24.3^{o}C which is above the permissible limit. Interpretation of hydro-chemical analysis reveals that the groundwater in the study area is fresh and equally soft.

The sequence of the abundance of the major ions is in the following order: $Na^{+} > K^{+} > Ca^{2+} > Mg^{2+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2-}$. Alkalis slightly exceed alkali earths and strong acids exceed the weak acid. Plots of the hydrochemical parameters of the water samples on the Piper (1944) Trilinear diagram (Fig 5.1) classified the groundwater system in the study area into D, E, F and G as Ca + Mg, Na + K – HCO_3, Ca + Mg, Na + K – SO_4 and Na + K – SO_4 –Cl (dominants) and Na + K – HCO_3 (minor) waters. In the porphyritic biotite granite, nine water samples obtained were plotted as D, F and G water types (5D, 3F and 1G), for the coarse grained biotite granite, one water type plotted as E water type, in the granitic gneiss, three water types as D, E and G while in the schist, the three water samples obtained plotted as F and G (F and 2G). Hence,there is no particular water types that is associated with any rock. The Durov diagram was used to also infer hydrochemical facies of the study area. Chemical data of representative samples for the study area are presented by plotting them on Durov plot (Fig 5.2). The samples were concentrated in Mg-HCO_3^{-} type.

Groundwater of chemical composition found in the study area show low level of total dissolved solids, and very low concentration of chloride with fairly low sulphate indicate rapid recharge taking place primarily from the surface. Based on the high concentration of iron in the study area the water has potential of staining clothes and the metal parts container. The concentration of nitrate is within the permissible limit of World Health Organization (WHO) 2011 and Nigeria Standard for Drinking Water Quality (NSDWQ) 2005 while lead is found in the groundwater sample from two locations and the values are above the permissible limits of WHO and

NSDWQ. Based on electrical conductivity, the groundwater is of low –medium salinity hazard and equally low SAR. The groundwater of all the samples is classified as being excellent for irrigation on all soil types and most crops. Based on the chemical quality of groundwater, the water in the study area is generally good. Statistical analysis has shown strong positive correlation coefficient between the variables. The pattern of correlation might be due to ion exchange, poor sanitation conditions and that these ions are derived from rain filtration (common source). The general assessment of water samples fall within the permissible limits by WHO and NSDWQ for drinking purposes. Whereas some of the ions analyzed like Mn^{2+}, Fe^{2+}, Pb^{2+}, Zn^{2+} and Ca^{2+} having some samples concentration above permissible limits of World Health Organization (WHO) 2011 standards. It is therefore recommended for drinking and general purposes usage domestic and the likes.

6.2 RECOMMENDATION

(i) The bacteriological quality of the water from the study area should be carried out in future as this work does not cover that area.

(ii) Other harmful substances such as cyanide, cadmium, mercury and selenium among other should be checked as these elements pose risk to health of people.

(iii) The sources of external pollution should be checked periodically in the study area in order to ascertain that the quality of groundwater is maintained.

(iii) More accurate geophysical method such as electrical resistivity/EM method and specifically the advanced high resolution seismic refraction tomography provide very reliable information with respect to the thickness of the aquifer as well as the configuration of the underlying bed rock topography which will guide the accurate citing of boreholes.

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Appendix A

Rainfall data for the period of Twelve (12) years 2000-2012

Appendix A

Table 1: Rainfall data for the period of Twelve(12) years 2000-2012

Mnth/Yr	2005	2006	2007	2008	2009	2010	2011	2012
Jan	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0
March	0	0	1.7	0	0	0	0	7.3
April	63.1	1.8	58.7	72.6	20.3	52.4	13.9	263.4
May	113.1	202.5	169.4	95.2	85.1	92.9	123.3	120.7
June	160.2	126.5	220.2	111.7	89.5	158.3	162.5	165.3
July	152.6	232.2	228.6	229.8	285	216.8	223.9	426.7
Aug	235.5	222	374.3	359	439.7	313.4	239.9	270.3
Sept	122.4	275	31.9	217.8	206.7	211.2	113.8	79.6
Oct	16.8	28.5	8.3	89	151.7	82.3	54	0
Nov	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0

Appendix B

Table 1: Measurement of Depth to Watertable in Hand Dug Wells and some Bore Hole at the peak of Dry Season and at the end of Wet Season

Appendix B

Table 1: Measurement of Depth to Water level in Hand Dug Wells and some Bore Hole at the peak of Dry Season and at the end of Wet Season

Location	Sample location	Well Elevation (GPS) (masl),(ftasl)	Coordinates N-Latitude E-Longitude	Date	SWL(m, ft) Dry season	Well Elevation(map) (masl),((ftasl) (GPS)	Groundwater Elevation (m, ft)	Date	SWL(m, ft) Wet season	Well Elevation (m, ft)	GWE (m ft) Wet Season	Watertable Fluctuation (m ,ft)
Dusten Kura	SL1	659 2175	N11^0 24′42.6″ E007^{0}39′16.0″	25/3/2013	7.6 24.9	680 2243	672 2218.1	15/8/2012	2.8 9.2	669 2209	666.2 2199.8	4.8 15.7
Kafur L.G.A	SL2	696 2297	N11^{0}24′17.8″ E007^{0}33′36.3″	"	8.2 27.2	697 2300	688.8 2272.8	"	3.1 10.23	676 2231	672.8 2220.8	.5.1 16.97
UBE, Sani Dabai	SL3	684 2257	N11^{0}22′25.7″ E007^{0}38′24.8″	"	0.0 0.0	700 2310	700 2310.0	"	0.0 0.0	700 2310	700 2310	0 O
Dabai mosque	SL4	664 2191	N11^{0}22′11.0″ E007^{0}38′25.6″	"	9.15 30.0	703 2320	694 2290.0	"	3 9.8	691 2280	688 2270	6.15 20.2
Sai Danawa	SL5	679 2241	N11^0′21′56.5″ E007^{0}38′15.7″	26/3/2013	5.14 16.9	706 2330	701 2313.1	"	1.2 3.9	700 2309	699 2305.1	3.94 13.0
Adua Dabai	SL6	688 2270	N11^{0}22′09.0″ E007^{0}38′02.6″	"	7.2 23.6	707 2332	700 2308.4	"	2.3 7.5	697 2293.5	695 2301	4.9 16.1
Dabai Junction Massalachi Hdw	SL7	671 2214	N11^{0}21′20.9″ E007^{0}38′44.8″	"	6.05 19.8	682 2250	676 2230.2	"	2 6.6	674 2224	672 2217.4	4.05 13.2
Tasha kaide masallachi	SL8	681 2247	N11^{0}20′37.2″ E007^{0}38′14.1″	"	6.96 22.8	674 2225	667 2202.2	16/8/2012	2.2 7.2	665 2187.8	663 2195	4.49 15.6
Kokami seriki kasuwa	SL9	659 2175	N11^{0}19′42.5″ E007^{0}38′50.9″	"	8.64 28.3	650 2145	641 2116.7	"	2.4 7.9	639 2109	637 2101	6.24 20.4
Gozaki	SL10	600 1980	N11^{0}26′55.8″ E007^{0}38′28.9″	27/3/2013	6.7 22.0	638 2105	631 2083.0	"	1.5 4.9	630 2078	628 2073	5.2 17.1
Angwa Wasami	SL11	647 2135	N11^{0}27′09.5″ E007^{0}38′12.8″	"	0.0 0.0	636 2100	636 2100.0	"	0.0 0.0	636 2100	636 2100	0 0
Gozaki Massalachi	SL12	659 2175	N11^{0}26′29.9″ E007^{0}37′49.5″	"	0.0 0.0	682 2250	682 2250.0	"	0.0 0.0	682 2250	682 2250	0 0
Angwa Sabo ECWA	SL13	670 2211	N11^{0}26′04.4″ E007^{0}37′30.7″	28/3/2013	5.53 18.1	679 2240	673 2221.9	"	1.35 4.4	672 2217	671 2213	4.18 13.7
Maraba Kanya	SL14	604 1993	N11^{0}28′33.8″ E007^{0}38′54.7″	"	4.9 16.1	636 2100	632 2083.9	"	1.2 3.9	630 2080	628 2073	3.7 12.2
Saka	SL15	624 2059	N11^{0}29′10.4″ E007^{0}39′09.9″	"	3.6 11.8	621 2050	618 2038.2	17/8/2012	1 3.3	617 2035	616 2032	2.6 8.5

Ranging Danja	SL16	675 2228	N11^{0}27′44.9″ E007^{0}33′53.9″	"	0.0 0.0	655 2160	655 2160.0		0.0 0.0	655 2160	655 2160	0 0
Massalachi Idi	SL17	668 2204	N11^{0}22′49.6″ E007^{0}34′01.7″	29/3/2013	5.35 17.6	667 2200	661 2182.4	"	1.7 5.6	660 2177	658 2171	3.65 12.0
Danja Kofan Kudu	SL18	679 2241	N11^{0}22′40.9″ E007^{0}30′42.7″	"	10.68 35.0	697 2300	686 2265.0	"	3.8 12.5	683 2253	679 2241	6.88 22.5
Danya Hayan Hospibitu	SL19	676 2231	N11^{0}22′50.1″ E007^{0}33′20.7″	"	7.85 25.8	680 2245	673 2219.2	"	1.75 5.7	671 2214	669 2208	6.1 20.1
Line Kwari	SL20	685 2261	N11^{0}23′07.0″ E007^{0}31′35.2″	"	7.76 25.5	674 2225	667 2199.5	"	1.16 3.8	666 2196	664 2192	6.6 21.7
Corner Daura	SL21	694 2290	N11^{0}24′19.6″ E007^{0}30′38.3″	30/3/2013	8.7 28.5	698 2305	690 2276.5	"	2.5 8.2	749 2268	645 2260	6.2 20.6
Majedo	SL22	700 2310	N11^{0}24′25.6″ E007^{0}30′10.7″	"	8.56 28.1	698 2305	690 2276.9	18/8/2012	2.3 7.5	688 2269	685 2262	6.26 20.6
Massalachi Majedo	SL23	659 2175	N11^{0}18′20.2″ E007^{0}39′20.2″	"	6.53 21.4	648 2140	642 2118.6	"	1.32 4.3	641 2114	639 2110	5.21 17.1
Duzunrini	SL24	645 2129	N11^{0}16′39.1″ E007^{0}40′34.6″	31/3/2013	6.7 22.0	636 2100	630 2078.0	"	1.52 5.0	628 2073	627 2068	5.18 17.0
Hanyin Dobuga	SL25	630 2079	N11^{0}16′07.9″ E007^{0}41′04.1″	"	8.64 28.3	665 2195	657 2166.7	"	2.3 7.5	654 2159	652 2152	6.34 20.5
Angwa seriki	SL26	650 2145	N11^{0}16′21.5″ E007^{0}41′20.2″	"	8.96 29.4	638 2105	629 2075.6	"	2.5 8.2	626 2067	624 2059	6.46 21.2
TashaKastimia	SL27	648 2138	N11^{0}17′12.1″ E007^{0}40′43.4″	"	7.53 24.7	648 2140	641 2115.3	"	1.7 5.6	640 2111	638 2105	5.83 19.1
Kudan Hayin Dadanko Rd.	SL28	653 2155	N11^{0}18′01.7″ E007^{0}43′53.2″	1/4/2013	9.45 31.0	683 2255	674 2224.0	"	2.53 8.3	672 2216	669 2208	6.92 22.7
Dadanko	SL29	658 2171	N11^{0}16′37.5″ E007^{0}44′24.1″	"	7.1 23.3	655 2160	647 2136.7	19/8/2012	1.5 4.9	646 2132	645 2127	5.6 18.4
Dadanko Massalachi	SL30	653 2155	N11^{0}16′48.1″ E007^{0}44′22.2″	"	4.25 13.9	655 2160	650 2146.1	"	1 3.3	649 2143	648 2140	3.25 10.6
Barmo Kwari	SL31	665 2195	N11^{0}20′18.7″ 007^{0}42′53.3″	"	2.43 8.0	685 2260	682 2252.0	"	0.25 0.8	682 2251	682 2251	2.18 7.2
Barmo Massalachi	SL32	670 2211	N11^{0}20′35.1″ E007^{0}42′39.8″	"	5.18 17.0	685 2260	680 2243.0	"	1.53 5.0	678 2238	677 2233	3.65 12.0
Barmo 2 Gidan Alh. Gambo	SL33	670 2211	N11^{0}21′08.7″ E007^{0}42′17.8″	"	5.8 19.0	685 2260	679 2241.0	"	2 6.6	677 2234	675 2228	3.8 12.4
Gwadari	SL34	658 2171	N11^{0}20′34.9″ E007^{0}41′26.5″	"	8.54 28.0	689 2270	679 2242.0	"	2.25 7.4	677 2235	675 2227	6.29 20.6
Danmaiguita	SL35	655 2162	N11^{0}20′24.6″ E007^{0}40′44.7″	"	9.7 31.8	655 2160	645 2128.2	"	2.55 8.4	642 2120	640 2111	7.15 23.4
Saleee	SL36	669 2208	N11^{0}21′47.0″ E007^{0}42′07.7″	"	6.83 22.4	685 2260	678 2237.6	20/8/2012	1.42 4.7	678 2233	675 2228	5.41 17.7

Kahutu	SL37	685 2261	N11^{0}22′31.0″ E007^{0}41′52.8″	2/4/2013	8 26.2	683 2255	675 2228.8	"	2 6.6	673 2222	671 2216	6.0 19.6
Kahutu Village	SL38	675 2228	N11^{0}22′59.6″ E007^{0}41′43.6″	"	2 6.6	681 2248	679 2241.4	"	0.0 0.0	680 2241	679 2241	6 19.6
Kudan junction	SL39	669 2208	N11^{0}18′14.3″ E007^{0}43′49.7″	"	9.8 32.2	682 2250	672 2217.8	"	2.56 8.4	669 2209	667 2201	2 6.6
Kudan Bayangari	SL40	665 2195	N11^{0}18′10.1″ E007^{0}44′18.4″	3/4/2013	5.5 18.0	683 2255	678 2237.0	"	1.34 4.4	677 2233	675 2228	4.16 13.6
Tasha Kade	SL41	671 2214	N11^{0}17′36.0″ E007^{0}42′17.2″	"	8 26.2	664 2190	656 2163.8	"	1.98 6.5	654 2157	652 2151	6.02 19.7
Gidan Audi	SL42	656 2165	N11^{0}17′37.2″ E007^{0}41′14.3″	"	8.9 29.2	650 2145	641 2115.8	"	2.3 7.5	639 2108	637 2101	6.6 21.7
Maruku	SL43	651 2148	N11^{0}18′14.3″ E007^{0}41′01.7″	"	6.9 22.6	653 2155	646 2132.4	21/8/2012	1.43 4.7	645 2128	643 2123	5.47 17.9
Tudun Kanawa	SL44	654 2158	N11^{0}18′52.8″ E007^{0}40′55.2″	"	9.3 30.5	674 2225	665 2194.5	"	2.5 8.2	662 2186	660 2178	6.8 22.3
Gidan Magaji	SL45	684 2257	N11^{0}22′27.9″ E007^{0}39′59.5″	4/4/2013	10.2 33.5	682 2250	672 2216.5	"	3.3 10.8	668 2206	668 2205	6.9 22.7
Kahutu Outsket	SL46	669 2208	N11^{0}22′38.9″ E007^{0}41′10.7″	"	5 16.4	674 2225	669 2208.6	"	0.75 2.5	668 2206	668 2204	4.25 13.9
Chediya	SL47	675 2228	N11^{0}22′47.6″ E007^{0}43′54.1″	"	7 23.0	694 2290	687 2267.0	"	1.5 4.9	668 2262	648 2257	5.5 18.1
Dan Gasau	SL48	673 2221	N11^{0}24′12.6″ E007^{0}42′57.6″	"	9.2 30.2	674 2225	665 2194.8	"	2.5 8.2	663 2187	660 2178	6.7 22.0
Furgu Village	SL49	674 2224	N11^{0}25′20.0″ E007^{0}42′44.0″		8 26.2	697 2300	689 2273.8	"	2.1 6.9	687 2267	685 2260	5.9 19.3
Furgu Massalachi	SL50	675 2228	N11^{0}25′14.3″ E007^{0}42′12.5″	5/4/2013	6.1 20.0	715 2360	709 2340.0	22/8/2012	1 3.3	708 2337	707 2333	5.1 16.7
Gidan Wula	SL51	672 2218	N11^{0}25′47.5″ E007^{0}41′20.3″	"	7.3 23.9	694 2290	687 2266.1	"	1.98 6.5	685 2260	683 2253	5.32 17.4
Sabon Kasua	SL52	693 2287	N11^{0}24′28.0″ E007^{0}41′00.2″	"	7.4 24.3	653 2155	646 2130.7	"	1.88 6.2	644 2125	642 2118	5.52 18.1
Angwa Samia	SL53	674 2224	N11^{0}25′10.7″ E007^{0}39′40.5″	"	8.2 26.9	680 2245	672 2218.1	"	2.2 7.2	670 2211	668 2204	6.0 19.7
Massalachi Dustenkura	SL54	667 2201	N11^{0}27′05.9″ E007^{0}41′02.6″	"	4.07 13.4	652 2150	647 2136.6	"	1 3.3	646 2133	646 2130	3.07 10.1
Gidan Maijumuna Massalachi	SL55	643 2122	N11^{0}27′10.9″ E007^{0}41′47.1″	6/4/2013	5.5 18.0	636 2100	631 2082.0	"	1.4 4.6	629 2077	628 2073	4.1 13.4
Guidan Riga Rogo LGA Kano State	SL56	644 2125	N11^{0}27′19.2″ E007^{0}42′22.8″		6.4 21.0	636 2100	630 2079.0	"	1.2 3.9	629 2075	628 2071	5.2 17.1
Kawo Allah Sabon FargiRLGA Kano State	SL57	639 2109	N11^{0}27′22.0″ E007^{0}42′41.7″	"	4.5 14.8	636 2100	632 2085.2	23/8/2012	0.59 1.9	631 2083	631 2081	3.91 12.9

Danmakuma	SL58	637 2102	N11^{0}27′16.4″ E007^{0}43′19.8″	"	6.5 21.3	636 2100	630 2078.7	"	1.3 4.3	628 2074	627 2070	5.2 17.0
Gidan Makashi RLGA	SL59	640 2112	N11^{0}26′21.2″ E007^{0}44′27.5″	"	2.5 8.2	636 2100	634 2091.8	"	0.0 0.0	634 2092	634 2092	2.5 8.2
Ranging Gwagwan Rogo LGA Kano State	SL60	633 2089	N11^{0}27′24.1″ E007^{0}44′48.4″	7/4/2013	7.3 23.9	618 2040	611 2016.1	"	2 6.6	609 2010	607 2003	5.3 17.3
Gwangwan Dukawa	SL61	632 2086	N11^{0}29′07.8″ E007^{0}44′53.8″	"	11.35 37.2	588 1940	577 1902.8	"	4 13.1	573 1890	569 1877	7.35 24.7
Gwangwan Karopi	SL62	627 2069	N11^{0}29′22.8″ E007^{0}44′50.0″	"	10.53 34.5	588 1940	577 1905.5	"	3 9.8	575 1896	572 1886	7.53 24.7
Danbagudu	SL63	702\ 2317	N11^{0}23′56.4″ E007^{0}38′22.6″	8/4/2013	9.45 31.0	694 2290	685 2259.0	"	2.9 9.5	682 2250	679 2240	6.55 21.5
Agwanjajae	SL64	705 2322	N11^{0}23′54.8″ E007^{0}37′57.8″	"	11.4 37.4	688 2270	677 2232.6	24/8/2012	3 9.8	674 2223	671 2213	8.4 27.6
Digan Bubu	SL65	691 2280	N11^{0}24′33.6″ E007^{0}37′56.1″	"	8.5 27.9	682 2250	673 2222.1	"	2.3 7.5	671 2215	669 2207	5.2 20.4
Mashekari	SL66	688 2270	N11^{0}25′02.5″ E007^{0}37′49.2″	"	5.65 18.5	682 2250	676 2231.5	"	1 3.3	675 2228	674 2225	4.65 15.2
Elalawa	SL67	672 2218	N11^{0}24′45.2″ E007^{0}36′45.2″	"	9 29.5	679 2240	670 2210.5	"	2.5 8.2	667 2202	665 2194	6.5 21.3
Ganganni	SL68	759 2505	N11^{0}23′35.4″ E007^{0}35′41.3″	9/4/2013	9.22 30.2	667 2200	658 2169.8	"	2.32 7.6	655 2162	653 2155	6.9 22.6
Line Bauche	SL69	636 2099	N11^{0}27′46.0″ E007^{0}35′46.6″	"	5.6 18.4	636 2100	631 2081.6	"	1.2 3.9	630 2078	628 2074	4.2 14.5
Angwa Nuhu	SL70	629 2076	N11^{0}28′26.9″ E007^{0}34′56.8″	"	9.63 31.6	644 2125	634 2093.4	"	3 9.8	632 2084	628 2074	6.63 21.8
Angwa Jara	SL71	636 2099	N11^{0}27′56.7″ E007^{0}34′24.4″	"	6 19.7	652 2150	646 2130.3	"	1.5 4.9	644 2125	643 2121	4.5 14.8
Huguma	SL72	695 2294	N11^{0}27′55.5″ E007^{0}31′56.8″	"	9.65 31.7	682 2250	672 2218.3	25/8/2012	2.5 8.2	670 2210	667 2202	7.15 23.5
Huguma Village	SL73	694 2290	N11^{0}27′46.5″ E007^{0}31′50.6″	10/4/2013	9 29.5	682 2250	673 2220.5	"	2 6.6	671 2214	669 2207	7.0 22.9
Huguma Anyasamie	SL74	707 2333	N11^{0}26′01.7″ E007^{0}30′50.2″	"	5.7 18.7	715 2360	709 2341.3	"	1.7 5.6	708 2336	706 2330	4.0 13.1
Maraba Guga	SL75	676 2231	N11^{0}16′46.1″ E007^{0}32′23.6″	"	3.7 12.1	679 2240	675 2227.9	"	0.25 0.8	675 2227	675 2226	3,45 11.3
Tasha Guga	SL76	669 2208	N11^{0}15′12.0″ E007^{0}33′01.4″	"	7.9 25.9	667 2200	659 2174.1	"	2.3 7.5	672 2167	654 2159	5.6 18.4
Tasha Guga Masalachi	SL77	665 2195	N11^{0}15′05.1″ E007^{0}33′04.8″	11/4/2013	7.8 25.6	667 2200	659 2174.4	"	2.25 7.4	657 2167	655 2160	5.55 18.2
Maje	SL78	675 2228	N11^{0}16′44.4″ E007^{0}33′10.8″	"	6.6 21.7	652 2150	645 2128.3	"	1.22 4.0	644 2124	643 2120	5.38 17.7
Danmahawayi	SL79	673 2221	N11^{0}18′31.5″ E007^{0}34′31.0″	"	8.4 27.6	676 2230	667 2202.4	26/8/2012	2.1 6.9	665 2196	663 2189	6.3 20.7

Angwa Duhula	SL80	674 2224	N11^{0}19′50.4″ E007^{0}34′14.3″	"	8.5 27.9	671 2214	662 2186.1	"	2.3 7.5	660 2179	658 2171	6.2 20.4
Kanwa Power	SL81	682 2251	N11^{0}21′11.8″ E007^{0}33′41.2″	12/4/2013	9.8 32.2	685 2260	675 2227.8	"	2.75 9.0	672 2219	670 2209	7.05 23.2
Rafinsabo	SL82	684 2257	N11^{0}22′08.4″ E007^{0}32′17.5″	"	9 29.5	679 2240	670 2210.5	"	2.98 9.8	667 2201	664 2191	6.02 19.7
Kandayan	SL83	698 2303	N11^{0}21′41.3″ E007^{0}30′25.0″	"	7.5 24.6	697 2300	690 2275.4	"	2.1 6.9	688 2269	685 2262	5.4 17.7
Baraye	SL84	695 2294	N11^{0}21′09.5″ E007^{0}30′08.5″	"	5.1 16.7	697 2300	692 2283.3	"	1.5 4.9	690 2278	689 2273	3.6 11.8
Medubi Massalachi	SL85	655 2162	N11^{0}15′36.8″ E007^{0}35′40.6″	13/4/2013	7.1 23.3	652 2150	644 2126.7	"	1.72 5.6	645 2127	634 2121	5.38 17.7
Kurunga	SL86	671 2214	N11^{0}17′45.2″ E007^{0}34′54.6″	"	6.5 21.3	652 2150	645 2128.7	"	1.5 4.9	644 2124	642 2119	5.0 16.4
Pankau	SL87	665 2195	N11^{0}19′50.9″ E007^{0}19′50.9″	"	5.7 18.7	648 2140	643 2121.3	"	1.2 3.9	642 2117	641 2114	4.5 14.8
Hunkunyi	SL88	639 2109	N11°16′20.5″ E007°39′20.5″	"	2.5 8.2	636 2100	634 2091.8	"	0.1 0.33	634 2092	634 2091	2.4 7.87

APPENDIX C

PRINCIPLES AND PROCEDURES OF THE METHODS USED IN THE WATER SAMPLE'S ANALYSIS

APPENDIX C

3.3.2 PRINCIPLES AND PROCEDURES OF THE METHODS USED IN THE WATER SAMPLE'S ANALYSIS

3.3.3 ANALYSIS OF PHYSICAL PROPERTIES OF WATER SAMPLES

3.3.4 COLOUR DETERMINATION BY LOVI BOND COMPARISM METHOD

Colour in natural waters result from metallic salts, organic matter and other dissolved or suspended organic materials from decaying vegetation and certain inorganic matter. This is called an apparent colour caused by scattering of light by suspended particles.

True colour on the other hand results from absorption by coloured material present in water of certain wavelength of light. Only true colour remains in water after removing turbidity in process Measurement of colour in Insitu as regards this analysis is based on visual comparison with standards using Lovibond comparator.

PRINCIPLE OF THE METHOD

Colour is measured with Lovibond comparator in True Colour Units, so called TCU, or Hazen Units. One TCU is produced by lmg/l of platinum in form of chloroplatinic acid, in the presence of 2 mg/l of cobalt chloride.

Procedure for analysis: A test tube is filled with 10ml of water sample and 10ml of distilled water is filled in another test tube. The two test tubes are then inserted inside a Lovibond comparator and colour is estimated using the standard disc provided for the test (Colour disc). The values of colour recorded from the disc will then be read from the book index (the complete Lovibond analytical tests).

3.3.3.2 Turbidity Determination by using turbidimeter

Principle:

It is based on the principle of Nephelometric measurement of the turbidity with automatic range selection and Signal Average On. When Signal Average is on, the Turbidimeter's microprocessor compiles a number of readings and averages the result. The average value is calculated and displayed approximately once every second.

Procedure for Analysis

A representative sample of water is collected in a clean container. The sample is filled into the sample cell to approximately 30ML. the sample cell is carefully handled by the top and caped. The sample cell is held by the cap and wiped to remove water spots and finger prints. A thin bead of silicon oil is applied from the top to bottom of the cell - Just enough to coat the cell with a thin layer of oil. This oil is spread uniformly using the oiling cloth provided and its excess is wiped off to an extent that the cell will appear nearly dry with little or no visible oil. EPA filter is inserted in the sample cell and the sample cell is then placed on the Turbidimeter cell compartment and the lid is closed. Manual or automatic range is selected by pressing the RANGE key. Appropriate; signal averaging setting is turned on by pressing the SIGNAL AVG key. An Appropriate Ratio Setting is selected on by pressing the RATIO key with appropriate FNU unit selected by pressing the UNITS key. The measurements displayed or the results are read and recorded or printed by pressing the PRINT key.

3.3.3.3 Alkalinity Determination by H_2S0_4 Titrimetric Method

Alkalinity of water is the capacity of that water to accept hydrogen ions (H''). It is usually imparted by the bi-carbonate (HCO_3^-), Carbonate (CO_3^-), hydroxide (OH^-) ion components of the natural or treated water.

Principle: The basic principle of this titrimetric method is such that a sample of water is titrated with standard acid solution e.g. H_2SO_4 (0.02N) using suitable indicators like phenolphthalein and methyl-orange. Phenolphthalein is used to determine that portion of alkalinity contributed by all the hydroxide and half of the carbonation, corresponding to a pH of 8.2 at the end of titration Methyl-orange is used to determine the all alkalinity forms corresponding to pH of 4.3 at the end of titration.

Procedure for analysis:

Exactly 100ml of water ample is measured in to a conical flask and three (3) drops of phenolphthalein indicator s added to the sample. After the addition, no pink coloration is produced, then three drops: of methyl-orange indicator is added to the same sample in the 'flask and the sample becomes yellow. After the sample becomes yellow, 0.02N of Sulphuric acid from burette is added to the sample until the first change is noted from yellow to orange to indicate the end point of the titration. The Ml of acid used is recorded and the concentration of total alkalinity is thus calculated as:

$$\text{Total Alkalinity} = \frac{B\,x\,N\,x\,50{,}000}{Ml\,of\ sample} \text{ (as mg.CaCO}_3\text{)}$$

$\therefore$ B = ml o f titration for sample to reach meth - orange end point.

N = Nornality of acid = 0.02N

3.3.3.4 Hardness Determination by EDTA Titrimetric method

Hardness is the traditional 'measure of capacity of water to react with soap. Hard waters require more soap to produce lather than soft waters because certain materials in the water react with soap, causing a precipitation which appears as a scum or curd on the water surface. Total hardness of a sample is of two types (i) Temporary hardness which is the portion of total hardness that is deposited when water is boiled (ii) Permanent hardness is the remaining hardness

after the temporary hardness is-deposited. This means that total hardness is made by salts of main alkaline earth elements, magnesium and calcium.

Principle of the Method

Principally, it is based on the titration of a quantity of water sample with ethylene Diamine Tetra Acetic acid (EDTA) using Eriochrome Black T as an indicator which gives blue colouration at the end point as well as a buffer solution which adjust the sample pH to 10.

Procedure for analysis

The water sample is shaken thoroughly and a 25 ml of it is taken and diluted to 50ml with distilled water. 2ml of butter solution is added to it to adjust its pH to 10 and immediately 2 drops of Eurochrome Black T indicator is added to it. The solution is then titrated with EDTA within five (5) minutes interval. A blue colour is seen which is the end point after which the titre is read and recorded.

Calculation

$$\text{Mg/l } CaCO_3 = \frac{A\,x\,B\,x1000}{Ml\ of\ Sample}$$

Where A = Ml of Titran

B = $MgCaCO_3$ to 1.00ml EDTA titrant

3.3.3.5 Total Dissolved Solids (TDS) Determination by Instrumental method

Total Dissolved Solids (TDS) also known as mineralization of water is the term used to describe inorganic salts and small amounts of organic matter present in solution in water.

A high content of dissolved mineral salts may affect the taste of drinking water and have a laxative effect.

Principle of the Method

Total Dissolved Solid (TDS)'s measurement with H19835 Auto Ranging meter HANNA Instruments is based on insertion of the instrument in the water sample and the corresponding reading is taken and recorded from a displaying screen in the instrument.

Procedure for Analysis

The H19835 Auto Ranging meter is inserted inpto the water sample. This Hanna instrument has ability of measuring three parameters depending on which parameter is selected or switch on to. Then meter was switched on to the Total Dissolved Solids (TDS) parameter where the reading of TDS measured is recorded in mg/1 each sample water.

3.3.4 Analysis of Chemical Characteristics of Water Sample

3.3.4.1 Determination `of Sodium (Na^+) and (K^+) by flame photometer or flame

Photometry method

Flame photometry is a method used in determining the concentration of some cations in group I and II (alkaline and alkaline earth metals) of the periodic table that have -low ionization energy, of which Sodium (Na^+) and Potassium (K^+) are among.

Principle of the Method

The basic principle of flame emission is such that a sample in liquid form (water) is presented to a nebulizer which delivers a quantity of the sample as a fine aerosol on to a mixing chamber where it is combined and mixed with fuel. This mixture (aerosol and fuel) is directed to a burner for ignition and burning. The flame is positioned in a simple optical chamber where the emission from the flame is collected and directed through an optical filter system and on to a light detection device. The intensity of the light falling on the detector is measured and displayed on a meter.

Procedure for Analysis

The fuel supply of the flame photometer is turned on at source and the "power" switch is depressed to switch on the 410. The "power on" LED will start and an ignition cycle will commence. If the "flame on"LED is not illuminated at the end of the ignition, set the filter selection to the required element of interest. The nebulizer inlet-tube is inserted in a beaker containing approximately 100m1 of diluents and 15 minutes is allowed for the operating temperature to stabilize. This will ensure a stable burner temperature when solutions are aspirated, after the warm up period. During the warm up period, a set calibration solutions is prepared to cover the required measurement range. 30ppm for Sodium (Na^+) and l0ppm for potassium (K^+) were used as the highest standard concentration in order to obtain maximum linearity corning recommend. The diluents are aspirated into the flame and the "blank" control of the instrument is adjusted so that the display read zero while aspirating diluents. The highest concentration standard is aspirated and each of the remaining calibration standards is aspirated for 20 seconds (Starting with the lowest concentration to avoid carry over). 10 seconds is again allowed between measurements and 20 seconds is allowed for a stable reading than "coarse" and "five" controls are adjusted for a convenient reading. E.g. 20 Na can be set to read 20.0. Samples, standard and blank are aspirated at 20 seconds per sample to check the drift.

3.3.4.2 Determination of Calcium (Ca^{2+}), Magnesium (Mg^{2+}) Manganese (Mn^{2+}), Copper (Cu), Iron (Fe^{2+}), Lead (Pb) and Zinc (Zn) by Atomic Absorption Spectrophotometer (AAS) method

Principle of the method

The principle is based on the absorption of radiant energy of various wavelengths by atoms present in the sample in their ground states. The atoms of elements strongly absorb -radiation at

certain characteristic wavelengths that coincide with the emission lines of spectral wavelengths of the particular element.

Procedure for analysis

Sample solution is aspirated through a nebulizer and sprayed as a fine aerosol in to the mixing chamber where it is mixed, with fuel and oxidant gases. The mixture is then carried to the head of a flame or burner for sample vaporization and atomization. The sample is then passed through the light beam which is a hollow - Cathode lamp. These cathode lamps are designed to emit the atomic spectrum of a particular element and the specific lamps are selected for use depending on the element to be determined. For example, if calcium is to be measured, a calcium lamp is selected to be used. The atomic vapour of the sample absorbs some of the energy from a cathode lamp used as a radiant source. The energy absorbed and the remaining energy are passed into the monochromator which selects and isolate the wavelengths of energy of elements of interest. The wavelength of light isolated by the monochromator is then directed to the detector, which serves as the eye of the instrument. This detector is a photo-multiplier tube; produce an electrical F current dependent on the light intensity.

The electrical current is then amplified and processed by the instrument electronics to produce a signal, which is a measure: of the light attenuation occurring in the sample cell. This signal is further processed to produce instrument readout directly in concentration units.

3.3.4.3 Determination of Chloride (Cl^-) by Argentmetric Method

Principle of the method

The simplest and most widely used method for the estimation of chlorides in water is Argentimetric method. Thin method is based on the titration of a halide. Such as Chloride (CL^- with standard Silver nitrate (AgN03) in the presence of Potassium chlorate (KZCr04) as

indicator. The end point of the titration is indicated when the solution changes from pure yellow to reddish brown. This is caused by the start of the precipitation of insoluble reddish brown silver chromate when all the chloride has reacted with Silver nitrate solution.

The reactions involved in the process are:

$$NaCl \quad x \quad AgNO_3 \rightarrow AgCl_4 \; x \; NaNO_3$$

(In water) (Std-solut) (In-soluble white ppt)

$$AgNO_3 \; x \; K_2CrO_4 \rightarrow Ag_2CrO_4 \; x \; 2KNO_3$$ (In-soluble reddish brown ppt)

Procedure for analysis

A 100m1 of water sample: is exactly measured in to a conical flask of 250m1 and l.0 ml of potassium chromate indicator solution is added to it. The sample in the flask is then titrated with standard silver nitrate solution of 0.0141N until there is a perceptible colouration end point. The A concentration of chloride is, calculated from this below expression.

The expression goes thus:

$$Cl\ (Mg/l) = \frac{A \times N \times 35450}{Ml\ of\ sample\ taken\ for\ analysis}$$

Where:

A = Ml o f titration for ample

N = Normality of Silver nitrate solution (N = 0141)

3.3.4.4 Determination of Carbonate and Bi-Carbonate by Titrinetric Method

Principle of the method

This technique is based on titration of water sample with standard solution of Sulphuric acid (H_2SO_4) in the presence of phenolphthalein and methyl orange as indicators. The end point of the titration will be indicated when the colour of the solution changes from orange - yellow to red.

Procedure for analysis: Carbonate ($C0_3^-$) 0.0ml of water sample is measured in a conical flask and 2–5 drops of phenolphthalein indicator is added to it. The solution is then titrated with 0.02N H_2S0_4 till the pink colour disappears. The volume of acid used is recorded and the concentration of $C0_3^-$ is calculated as:

$$\frac{2\,x\,Normality\,of\;Acid\;x Volume\,of\,Water\,used\,x100}{Aliquot taken(mls\,of\;acid\,used)}$$

Bicarbonate (HCO_3^-): To the same solution as above 2-5 drops of methyl – orange is added and then titrated until the colour changes which indicates the end point of the titration. The volume of acid used is recorded.

$$\frac{2\,x\,Normality\,of\;Acid\;x Volume\,H_2O\,x100}{Aliquot taken(mls\,of\;acid\,used)}$$

N.B: 2 = constant values given

3.3.4.5 Determination of Sulphate $S0_4^{2-}$ and- Nitrate (NO_3^-) by photometric method

Determination of Sulphate (SO_4) by precipitation method using photometer

Principle: This method is based on precipitation of Sulphate (SO_4^{2-}) with barium chloride crystals in which the light absorbance of the suspension is measured.

Procedure for Analysis

A suitable sulphate method is selected. A cuvette is filled with l0ml of unreacted sample and its cap is replaced after filling.' The cuvette is placed into the holed andthe lid is closed. The ZERO key is pressed and the display shows "O" when the meter is zeroed and ready for measurement. The content of one packet of H193 751 - O indicator reagent. The cap of the cuvette is replaced after the addition and it is inverted gently to mix for 1 minute (about 30 inversions). The cuvette is reinserted into the instrument (H18300 multiparameter Bench Photometer). TIMER key is pressed and 5 minutes waiting is exercised and then. READ key is pressed. When the timer ends,

the meter will perform the reading. Hence the instrument displays concentration on mg/1 of $SO_4^{2\neg}$.

Determination of (NO_3^-) Nitrate by Cadmelium reduction method using Bench photometers

Principle: this method is based on adaptation of the cadmium reduction method. This method explains the reaction between nitrate and the reagent which causes an amber tint in the sample.

Procedure for analysis

A suitable nitrate method is selected. A cuvette is filled with 6ml of the sample up to half of its height using the pipette and its cap is replaced after filling. The cuvette is then placed in to the holder and the lid is closed. The ZERO key is pressed and ready for measurement. The cuvette is removed from the instrument and content of one packet of H193728-0 reagent is then added to it. The cuvette's cap is replaced and immediately shaken vigorously up and down for exactly 10 seconds. The mixing continues by inverting the cuvette gently for 50 seconds, while taking care not to induce air bubbles.

Powder will not completely dissolve and time as well as way of shaking could sensitively affect the measurement. The cuvette is then reinserted into the instrument taking care not to shake it. The TIMER key is pressed and 4 minutes and 30 seconds waiting is exercised after which the READ key is pressed. When the timer ends, the meter will perform the reading. The instrument displays the results in mg/l of nitrate-nitrogen. The key CHEM FRM is then pressed to convert the result in mg/1 of nitrate (NO_3^-).

3.3.4.6 Determination of Phosphate ion (PO_4^{2-})

Phosphate was determined by the molybdenum yellow (yellow method). A hetero-polyammonium and ammonium banadate was added to nitric acid to form a solution. Nitric acid was used as a developer. The reduction of this complex gave a light yellow colour in both the

standard solution and the aliquote sample. This complex compound was added to water sample to detect the presence of phosphate which produces a thick yellow colour this will be read on the spectrometer

3.3.4.7 Determination of Ammonia

This was done by steam distillation method. 10mls of water sample was pipette into a distillation flask. The flask was connected to the boiling unit and distilled the content into a (20ml) 2% boric acid under the condenser. About 30mls distillate was collected. A few drops of mix indicator were added before titration with 0.025N H_2SO_4. The colour would change from green to purple then the result was taken.

%NH4 = 0.014 x 0.025 x100/10mls = 3.5 x 10^{-3}