ASSESSEMENT OF GROUNDWATER POTENTIALS IN KAURA AND ITS ENVIRONS, PARTS OF SHEETS 167 SE AND 168 SW, KADUNA-NIGERIA.

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Abstract

Groundwater potentials in Kaura and its environs were undertaken in the crystalline hydrogeological province of northern Nigeria belonging to the Younger Granite and Basement Complex suites using geological, hydrogeological and geophysical studies. Configuration map of groundwater table and directions of flow shows that the Kagoro Hills is the major recharge area. It discharges water to all parts of the study area. Interpretations of vertical electrical sounding curves obtained in the study area suggest that the subsurface layering ranges from 3-5 layers. Typical curve types obtained include H, KH and HK. Results obtained from this research show that the fractured aquifers have 95% productive wells. They are associated mainly with Newer Basalts, although metamorphic terrains also yield moderate amount of water because of the significant thickness of the overburden aquifer. The poorest in terms of borehole yield are the Younger granite terrains with their thin overburden aquifers of a maximum of 10 m. The average aquifer parameters of the twenty (20) recently drilled boreholes consist of yield 55.728 $m/^3$ hr, static water level of 6.15 m, average drawdown of 10.40 m, average specific capacity of 7.139 m^3 hr/m and average depth of 31 m. High yields/groundwater potentials were observed in Newer Basalt terrains. Three aquifer types based on the rock types were identified namely: overburden aquifer, Newer Basalt aquifer and the weathered/fractured aquifer, but hydrogeologically two major aquifers were encountered. These are the soft overburden aquifer and the weathered/fractured aquifer which are also interconnected.

KEYWORDS: Crystalline hydrogeological province, Kagoro Hills, Newer Basalt aquifer, Younger granite, Basement Complex, Kaura and Environs

Introduction

Kaura and its environs have suffered a serious set back over the years as far as groundwater prospecting, exploration and exploitation are concerned. As surface water is exposed to several kinds of abuse, groundwater remains the only reliable source of water supply that could be developed in response to the established problems of; cholera, diarrhea, typhoid fever and long trek of distances by women and children in search for water in dry season. The study area lies within the crystalline hydrogeological province of northern Nigeria belonging to the Younger Granite and Basement Complex suites. These rocks lack primary porosity where groundwater could accumulate for exploitation. For these rocks to store water, therefore there must exist in them secondary porosity, which invariably results from weathering and fracturing. However, the spatial distribution and depth of this kind of porosity vary from one location to another. Therefore, the occurrence of groundwater in these rocks is sporadic and borehole sitting for its abstraction in this geological terrain is often difficult. Drilling of unproductive boreholes over the years has been a matter of concern to the inhabitants. The need for the exploration and exploitation of the weathered and fractured aquifers in the study area is necessary. Consequently, a combination of hydrogeological and geophysical studies in Kaura and its environs have been carried out in the assessment of groundwater potential in the study area for groundwater supply projects. The research was aimed at measuring static water levels in hand dug wells and construction of groundwater configuration and the direction of flow, boreholes data inventory and interpretation of Vertical Electrical Soundings results to be correlated with geologic sections with the aim of assessing the groundwater potentials in the study area.

Literature Review

Through the process of metamorphism, migmatization and granitization that occurred within at least two tectonometamorpic cycles, the rocks were largely transformed into migmatites and granite gneiss, with some relics of the original gneisses (McCurry ,1976). The Basement Complex was later intruded by series of intermediate and acid plutonic rocks during the Pan African Orogeny according to McCurry (1976). Oyawoye (1970), showed that there is structural similarity between the study area and the rest of West Africa. MacLeod *et al* (1971) reported that Newer Basalts often overlie alluvial deposits. The Younger Granites are high level discordant intrusions in the Basement Complex and occupy approximately 8% of the total surface area of Nigeria according to Rahaman (1976). These suites comprise non foliated alkaline granites and granitoids with basic and volcanic rocks centered mostly in the Jos Plateau region. During the Jurassic period (190 to 205 M.y), a major tectonic event occurred and principally affected the Jos Plateau and its environs, leading to emplacement of these assemblages, as Grant (1978) informs. The

Younger Granites are characterized by pin point topography and ring structures. These include rhyolite, riebeckite granite, fayalite quartz porphyry, pyroxene fayalite porphyry and granite porphyry. Some earlier workers on the Basement Complex which include Du preez and Barber (1965), who worked on the groundwater distribution in northern Nigeria. He reported that the groundwater could be extracted by open wells and boreholes located in the fracture systems of the fresh and weathered portions of the Basement Complex. Mbonu (1988) reported that the major source of groundwater in north-central Nigeria is from the weathered/fractured zones, and that 91% sampled water points both surface and groundwater sources have nitrates concentration less than 45 mg/l. Eduvie (1991), reported that the weathered/fractured zone has a depth of 60-70 m. Hazell *et al* (1992) stated that the crystalline basement exposures of northern Nigeria have areas of deeply weathered regolith estimated at 1030 m which constitute useful aquifers separated by larger areas of relative unproductive shallow aquifers. Barber and Akono (1964), did some electrical soundings in parts of the area and identified fractures in the Basement Complex on the basis of which borehole locations were identified and drilled. Dunama (2000) reported the water quality of the Kachia grazing reserve to be slightly alkaline soft water which could be used for drinking, livestock, irrigation and fish farming. Eduvie (2003) reported the water samples in the study area to be slightly alkaline with pH range of 5.85 to 7.60. Jatau and Bajeh (2007) reported the temperature of groundwater in parts of Jema'a Local Government Area to range from 22^0C to 24^0C. The area under study is located in Kaduna State within the Basement Complex rocks of north-Central Nigeria. It lies between latitudes $9^0$30' N and $9^0$45'N and longitudes $8^0$20'E and $8^0$35'E. The area has an approximately landmass of

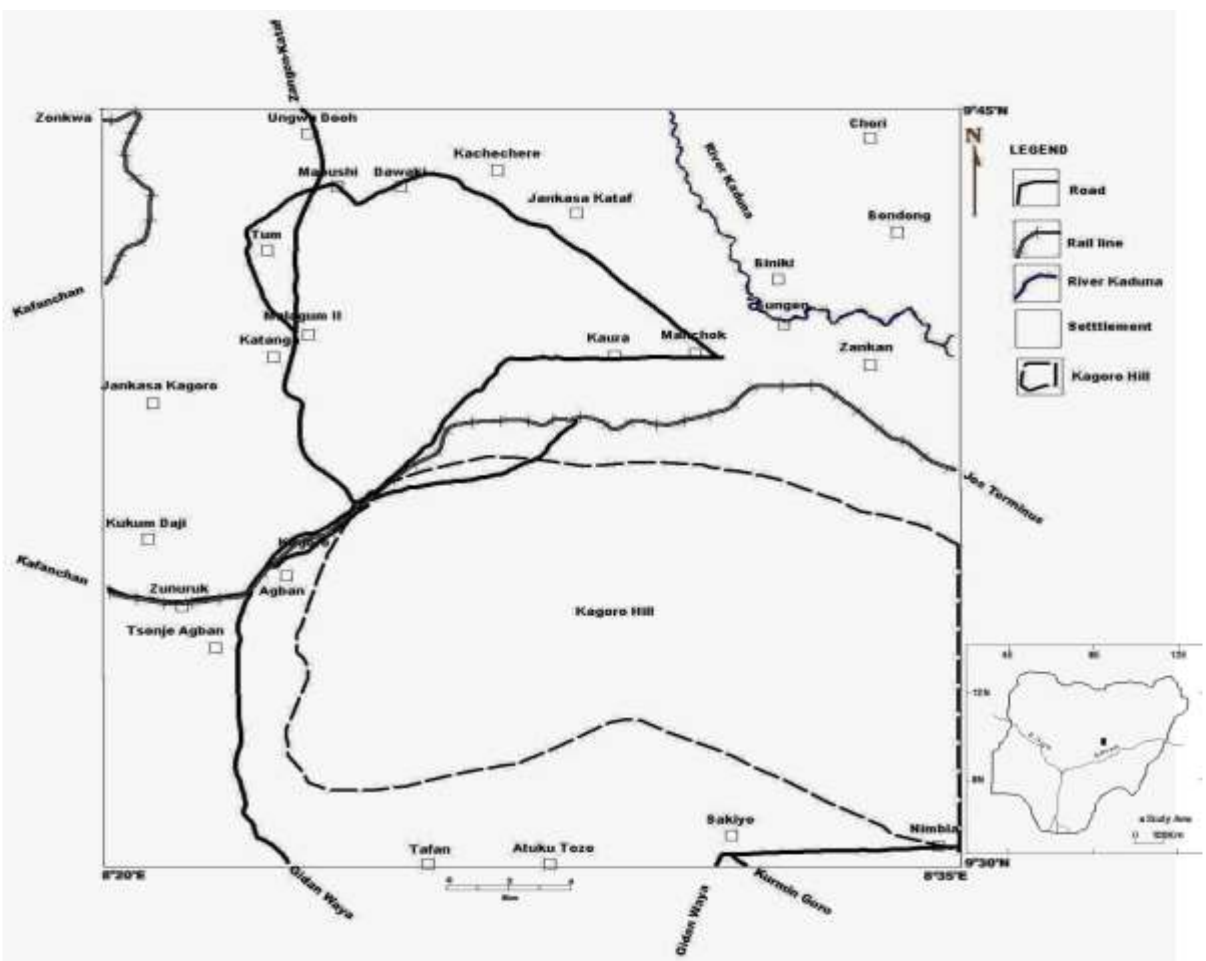


Fig. 1. Location Map of study area.

770 km^2 Fig. 1.The study area lies within the Guinea Savannah belt, which experiences the tropical savannah climate with two distinct seasons. The dry season normally begins in October/November to March/April, while the wet season occurs between April/May to October/November. The area is drained by River Kaduna and River wonderful. The area is generally part of extensive but gently undulating peneplain capped at high elevation of patches of laterised terraces of iron oxides, concentration of broken-up concretion ironstones and some quartz.

Geology of the Study Area

The study area is part of Sheet 167 SE Kafanchan and 168 SW Naraguta Sheet , 1:50,000 and is made up of the rocks of the Migmatite-Gneiss Complex, Gneiss, Younger Metasediments, Older Granites, Younger Granites and Newer Basalts (Grant, 1978, Macleod et al, 1971, Coorey,1974).

The distribution of the various rock types is as shown on (Fig.2).

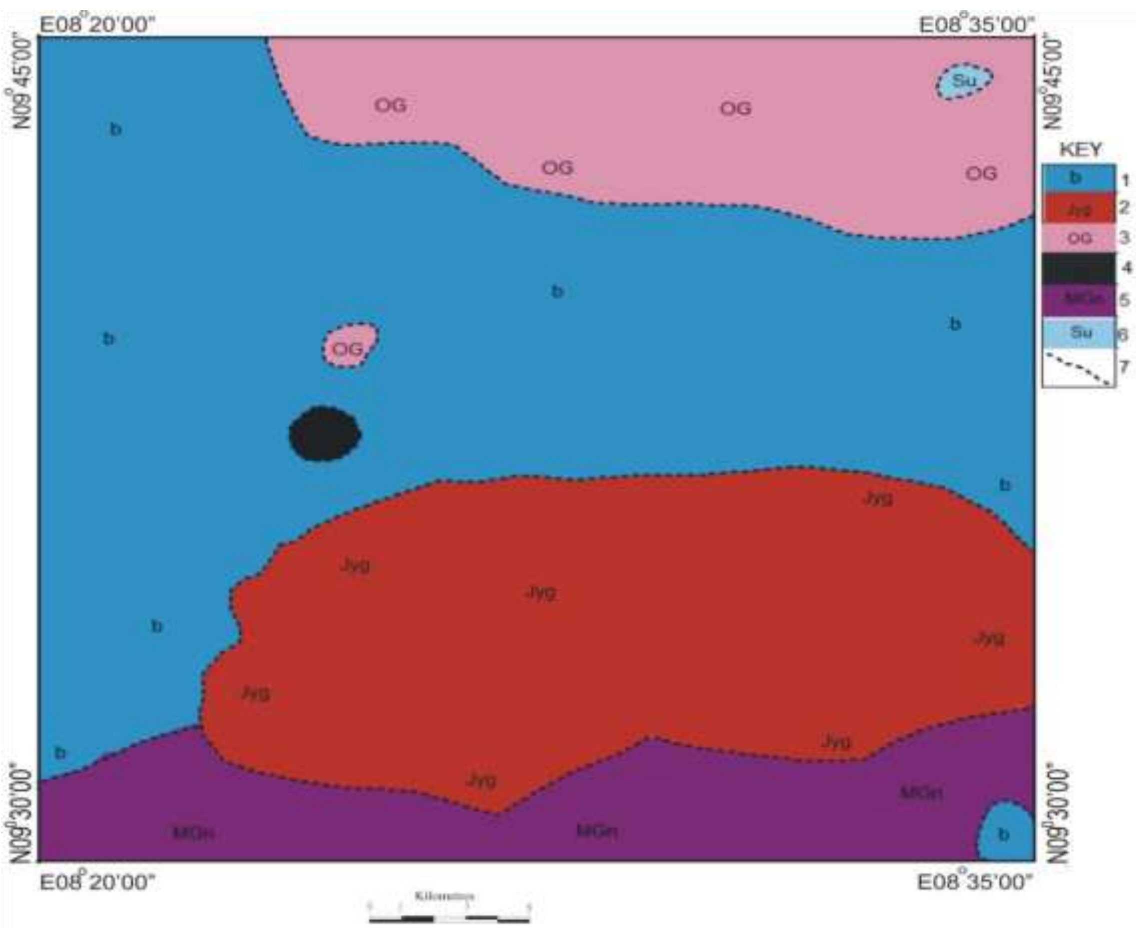


FIG 2: GEOLOGICAL MAP OF THE STUDY AREA

Explanation:
1. Newer Basalt
2. Younger Granite
3. Older Granite
4. Gneiss
5. Migmatitic Gneiss
6. Undifferentiated Schists
7. Geological Boundary

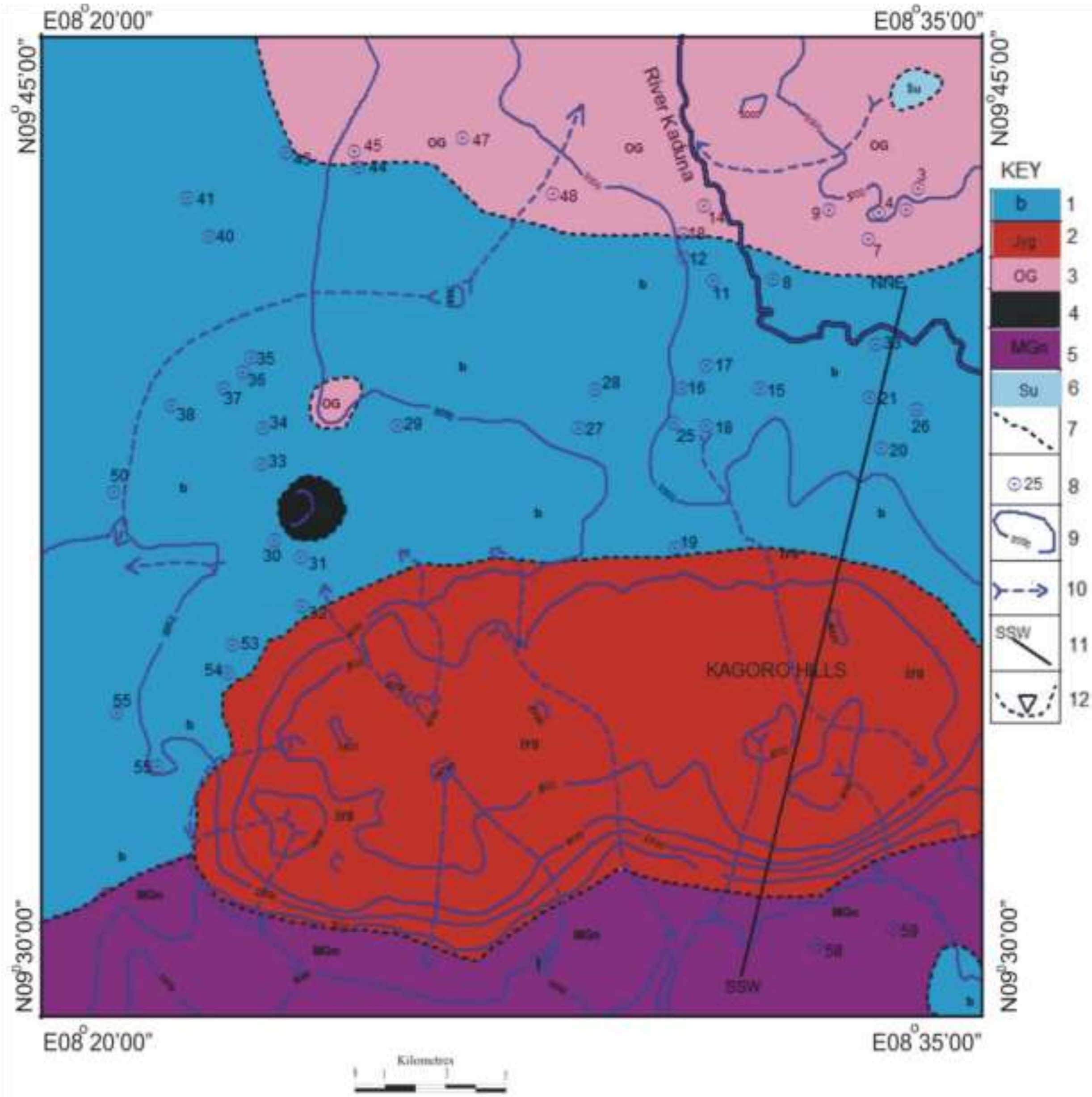
MATERIALS AND METHODS

The assessment of groundwater potentials involve study of geological maps in the study area, static water level measurements, Vertical Electrical Soundings and comparison of existing and new boreholes data. Identification of various rock units to produce an outline geological map of the study area while measurements of static water level and depth of about fifty-nine (59) selected hand-dug wells was carried out between March to April 2009 and August to September 2009 (at peak of dry season and peak of rainy season). A total of thirty-nine (39) VES soundings were carried out using Omega Resistivity Meter by the application of Schlumberger configuration with a maximum half current cable spread (AB/2) of 1 to 100 m and MN/2 from 0.3 to 5 m with a view to determining the subsurface layering thickness and resistivity to ascertained the aquiferous layer and the degree of fracturing of the bedrock. From the resistivity values the sounding curve for each point was obtained. Both the apparent resistivity and thicknesses obtained from partial curve matching were used as input data for computer iterative modeling using the computer aided IXId and IP12 WIN Software for both qualitatively and quantitatively interpretation. Existing borehole data were collected and compared with new boreholes data. Borehole profiles were also compared with Vertical Electrical Soundings to ascertain the level of correlation between the two. Pumping test operations were conducted for twenty (20) boreholes to ascertain the drawdown, yield, specific capacity, hydraulic conductivity and transmissivity using the Jacob's method. Drawdown curves and recovery phase diagrams were also established.

RESULTS AND DISCUSSIONS

The results of the study are presented as groundwater configuration map, hydrogeological cross section, correlation of VES interpretation results with geologic sections and assessment of groundwater potentials based on the rock types. Water table measurements range between 7.31 m to 14.00 m bgl (wells number 1 and 59) during the peak of the dry season. The deepest value of 14.00 m bgl in well number 59 was as a result of thick overburden that enhances the sustainability of the hand dug well. Wells that dry up completely at peak of dry season are generally as a result of thin overburden or shallow depth to basement as observed in wells number, 5, 12, 13, 17, 20, 21, 36 and 54 (Fig.3). Wells that overflow at peak of rainy season are sunk in shallow overburden over the fresh basement. They include the following; wells number 14, 25, 29 and 32. Elevations of the water table above sea level in the study area ranges between 457 m to 1219 m asl..

Configuration map of groundwater table and directions of the groundwater flow shows that the Kagoro Hills is the major recharge area. It discharges water to all parts of the study area. The hydrogeological cross section (Fig.4) along line SSW - NNE depicts the surface of erosion, overburden and the fractured crystalline aquifer across the major rock units and alluvium along River Kaduna bed.



1 .Newer Basalt, forming fractured Basaltic Aquifer up to 40 m thick.
2. Younger Granite, its uppermost fractured portion, up to 30 m thick forming fractured Granitic aquifer
3. Older Granite, its uppermost fractured portion, up to 30 m thick forming fractured Granitic aquifer
4. Gneiss, its fractured uppermost portion up to 10 m thick, forming fractured crystalline aquifer
5. Migmatite-Gneiss, its fractured uppermost portion up to 10 m thick, forming fractured crystalline aquifer
6. Undifferentiated crystalline,Schist its fractured uppermost portion up to 10 m thick, forming fractured crystalline aquifer
7. Geological Boundary
8. Measured hand dug well and its identification number
9. Groundwater table contour at peak of dry season, in meters above sea level
10. Directions of groundwater flow at the peak of dry season
11. Line of hydrogeological cross section

Fig.3. Configuration of the water table map showing direction of flow, for peak of dry season.

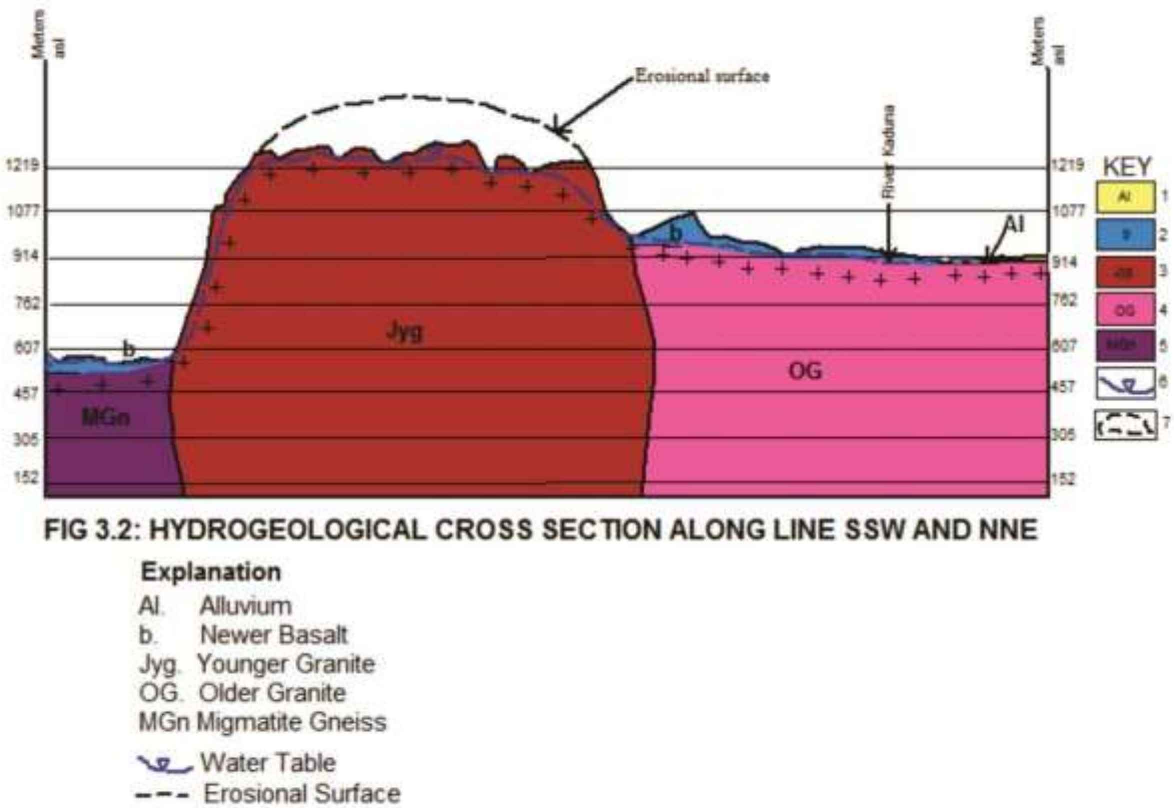


Fig. 4. Hydrogeological cross section along line SSW and NNE

Geophysical investigation results

The typical curve types obtained in the study area are, HK, KH and H types (Keller and Frischknecht,1966) as presented in Figs.5-6.

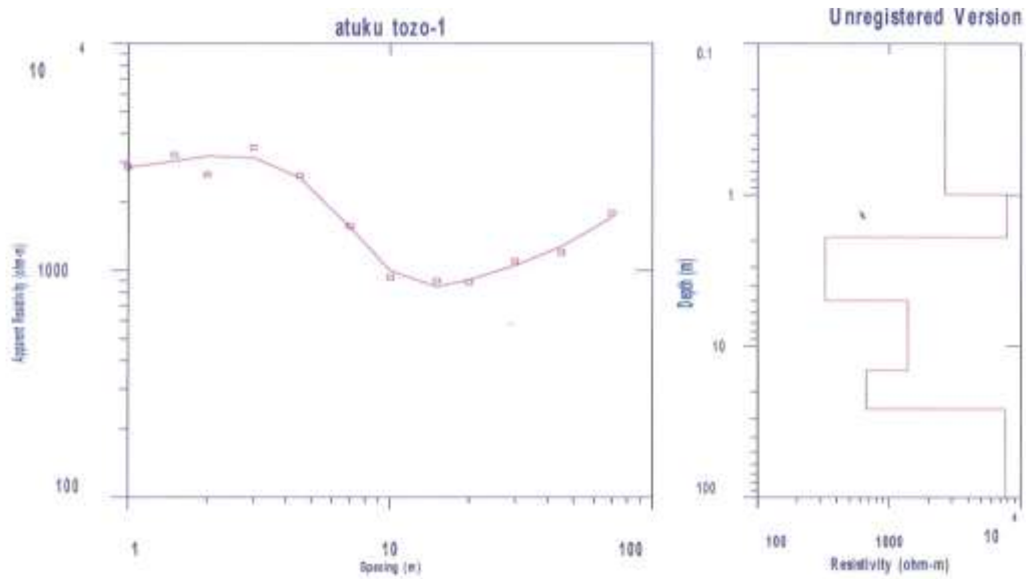
Interpretations of Vertical Electrical

layer ranges from 40 to 1880 Ohm-m with thickness ranging from 0.9-14.00 m and that of the third layer ranges from 30 to 1397 Ohm-m with thickness ranging from 4.00 to 39.60 m. In the fourth layer resistivity

Sounding curves obtained in the study area values range between 23 and 593 Ohm-m suggest a subsurface of 3-5 layers. The with thickness ranging from 4.00 to 40 m. resistivity values of the first layer ranges

This layer represents an important aquifer in from 135 to 7082 Ohm-m with thickness the study area. The bedrock, which occurs as ranging from 0.4-5.04 m, while the second

either the third , fourth or fifth layer in



different parts of the study area has relatively high resistivity values ranging from 1000 Ohm-m and above. The thickness of the fifth layer can not be measured because it is infinite. The estimated depth to basement in the study area ranges from (5 m to 40 m). The depths to bedrock obtained from the vertical electrical soundings are in agreement within 10% with that indicated by geologic sections in (Fig.7.). Emphasis was laid on locating boreholes in areas of thick overburden.

Results obtained from this research show that the fractured aquifers have 95% of productive wells. They are associated mainly with Newer Basalts although metamorphic terrains also yield moderate amount of water. The poorest in terms of borehole yield are the younger granites terrains with their thin overburden aquifers of 10m thickness.

Fig. 5. LGEA Atuku Tozo (HK – type curve).

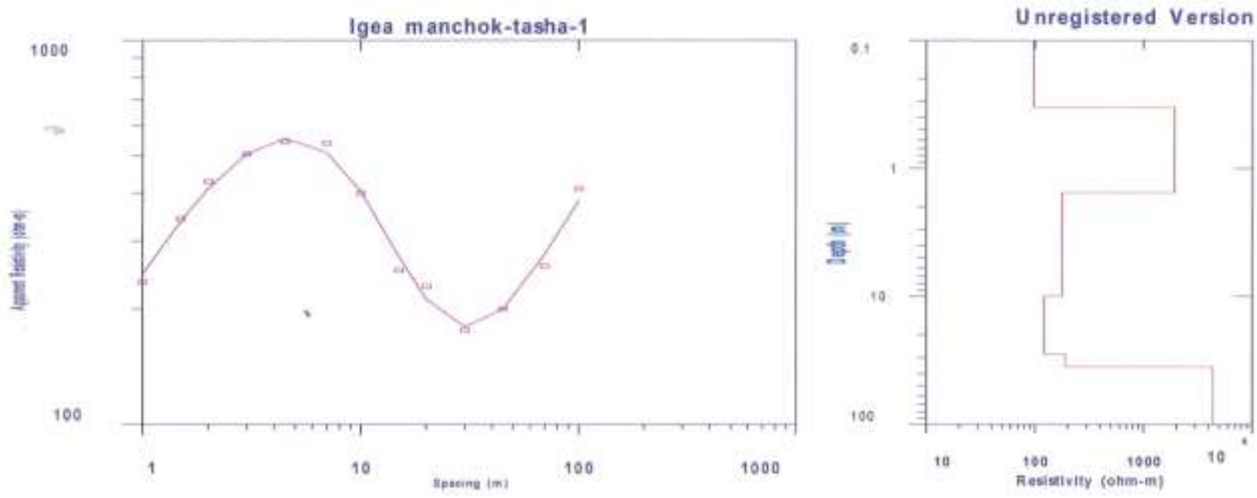


Fig. 6. LGEA Manchok Tasha (KH-types curve)

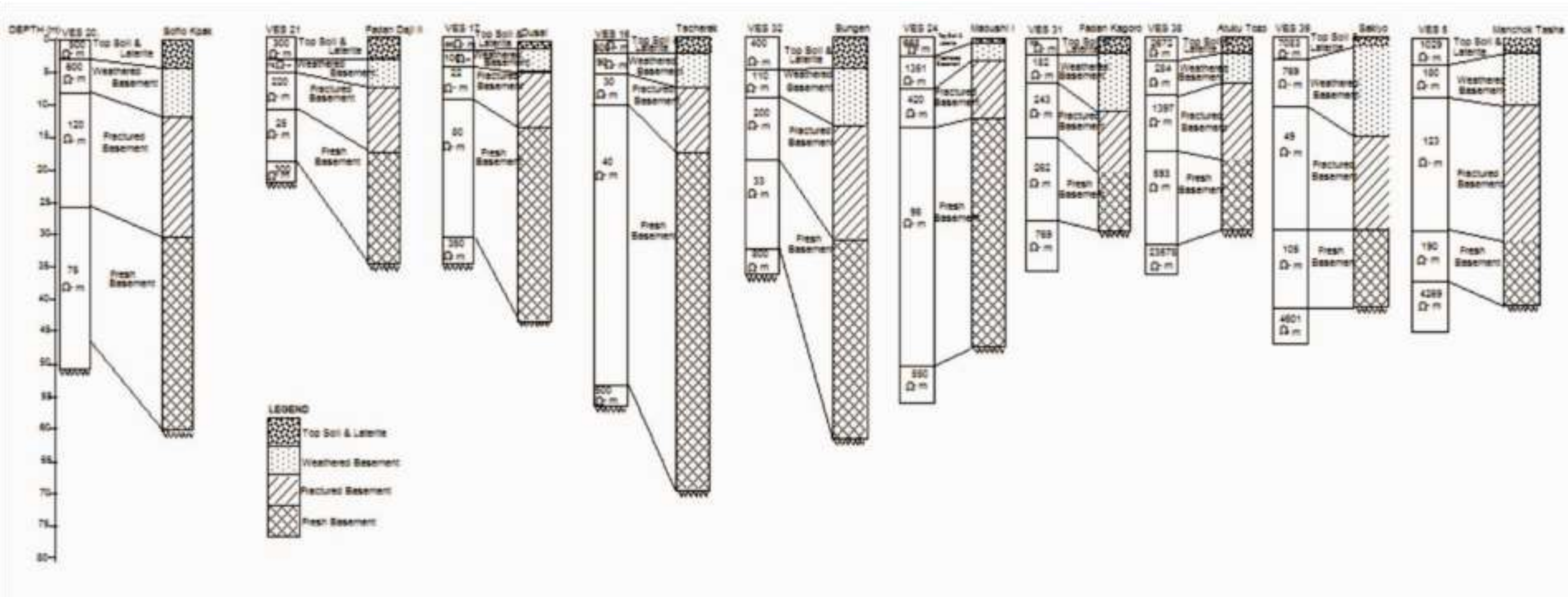


Fig.7. Comparison of VES interpretation result with geologic section as deduced from the quantitative analysis

The occurrence of groundwater in the study area is classified as the overburden aquifer, the Newer Basalts aquifer and the weathered /fractured aquifer which correlate with some earlier workers (Eduvie, 1991, 2003, Jatau and Bajeh, 2007). The overburden 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 thin, then this type of aquifer in most instances dries up at the beginning or peak of the dry season. In areas of thin overburden few of these wells survive up to the beginning of the rainy season. This aquifer is also interconnected with the weathered/ fractured aquifer in boreholes. Deep hand dug wells in the study area, indicating thick overburden aquifer, were observed in the south-eastern part of the study area; 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 Younger Granites terrains. The Newer Basalts contain vesicles and fractures that allow percolation of water. Basalts often overlie alluvial deposits. Zones of weathering and beds of alluvium also occur between individual basalt flows.A borehole (GWR/21/1) drilled in Tum, within the Newer Basalts aquifer yielded 12.6 m^3/h. The present research conducted shows that a borehole drilled at Sofio Kpak on the Newer Basalt terrain, yielded 198.70 m^3/hr, this is a better yield. This aquifer is composed of fresh, brittle, medium to coarse grained crystalline rocks that have reacted to tectonic stresses to cause fracturing and jointing. There is interconnectivity between the overburden and the weathered/fractured aquifers; this contributes to the rate of recharge and yield of the weathered/fractured aquifer. The main source of groundwater from the comparison of VES interpretation results with geologic sections conducted in the study area is the weathered zone/ fractured aquifer (Clark, 1985; Adanu, 1989; Carruthers and Smith, 1992; Olurumfemi and Fasuyi, 1993; Bala and Ike, 2001). From old boreholes data, it was observed that borehole yield is independent of depth, this shows that fractures tends to close up at depth. This is well illustrated at borehole ZK 4 A at Jankasa I, with 100 m depth and yield of 24.192 m^3/hr compared to borehole KU 33 B at Sofio Kpak, 50 m depth with yield of 198.720 m^3/hr .The aquifer parameters of the new twenty (20) boreholes revealed that the average yield is 55.728 m^3/hr, average static water level is 6.15 m, average draw down is 10.40 m, average Specific capacity is 7.139 m^3hr/m and the average depth of 31 m. It was observed that 31m borehole yield of 103.680 m^3/hr. 37m depth borehole yield 60.480 m^3/hr revealing both variations in depth and yield. Typical draw down-time obtained from computations of the pump test were plotted in Figures 8and 9 for the various locations.

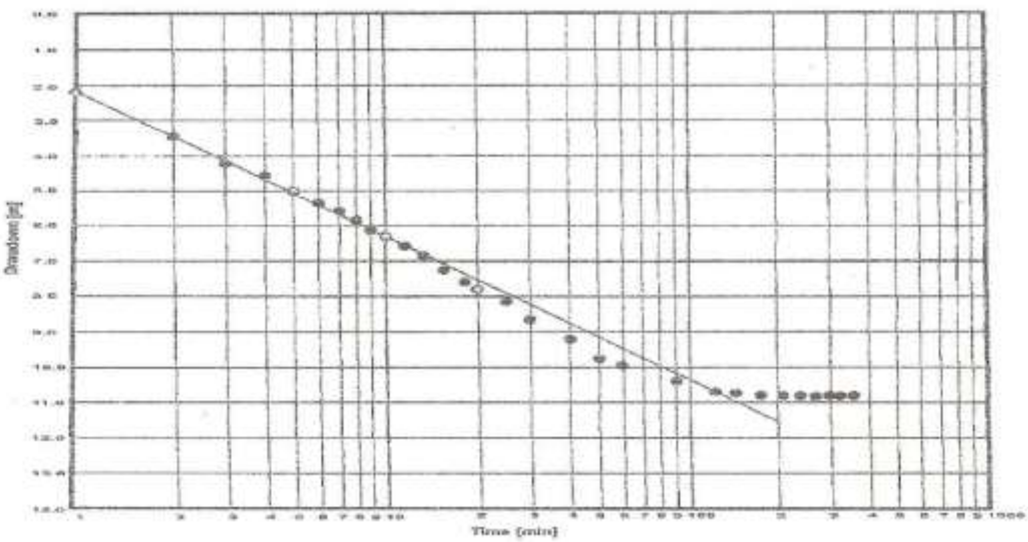


Fig.8 Drawn down-Time for Bondong.

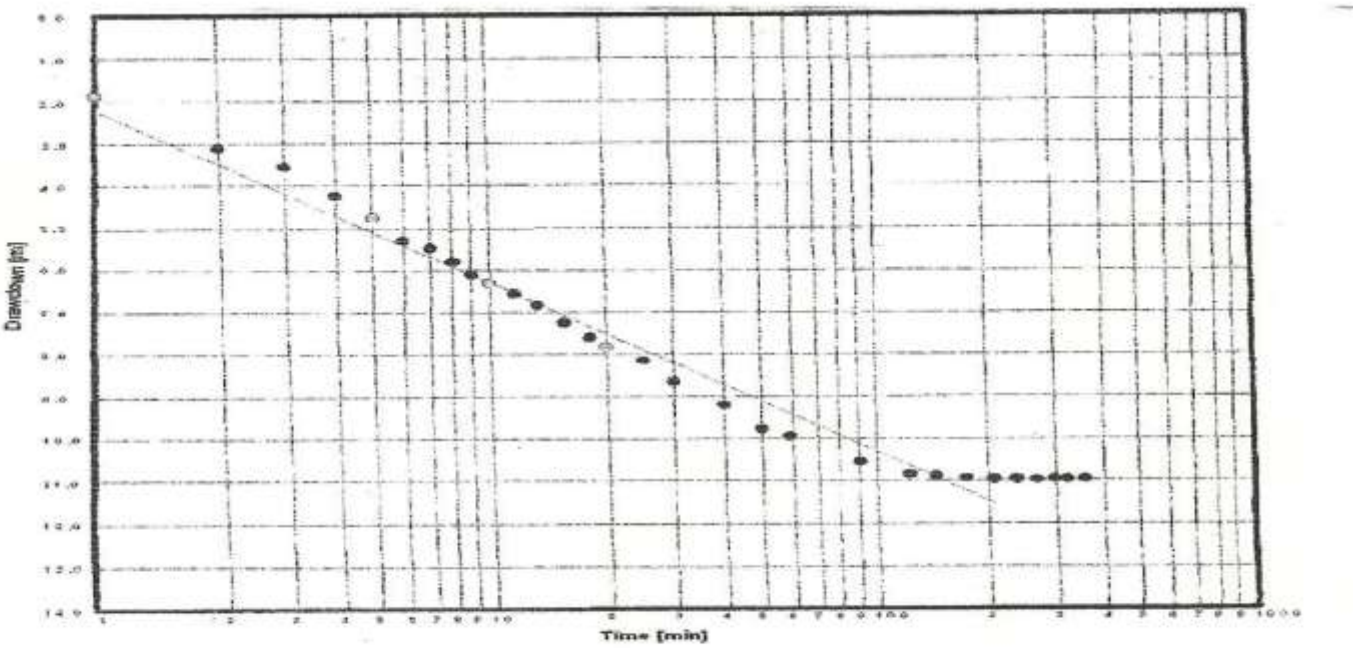


Fig. 9. Draw down –Time curve for PHC Tsonje.

Conclusions

greater parts of the study area, while the
The general geology comprises Younger least portion was occupied by schists. Granites,
Migmatite-Gneiss, gneisses,
Configuration map of groundwater table
Older Granites and schist which is and directions of the groundwater flow undifferentiated
with phyllites. Newer shows that the Kagoro Hills is the major
Basalts and the Younger Granites occupy

parts of the study area. Interpretations of Vertical Electrical Sounding curves obtained in the study area suggest that the subsurface layering ranges from 3-5 layers. It was observed that borehole yield is independent of depth, this shows that fractures tends to close up at depth. The average aquifer parameters obtained from the study area are include yield of 55.728 m^3/hr, static water level of 6.15 m, draw down of 10.40 m, Specific capacity of 7.139 m^3hr/m and depth of 31 m. High recharge area. It discharges water to all yields/groundwater potentials were observed to be predominant in Newer Basalt terrains. Three aquifer types were identified namely; overburden aquifer, Newer Basalt aquifer and the weathered/fractured aquifer, but hydrogeologically two major aquifer types were encountered. These are the soft overburden aquifer and the weathered/fractured aquifer which are also interconnected.

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CLIMATE CHANGE AND WATER EXTRACTION IN QUAAN-PAN LGA, PLATEAU STATE, NORTH CENTRAL NIGERIA

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ABSTRACT

Climate change is significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. This study looks at the impact of climate change on surface and ground water storage and its extraction in the study area. A reconnaissance survey was undertaken with the aid of a Global Positioning System (GPS) to define the geographical locations of hand dug wells, streams/rivers and recent boreholes. The depth of the hand dug wells were determined using a measuring tape against a long string with a weight tight to one end, while the depth of the recent boreholes estimated from geophysical survey reports. The study revealed that, there has been a change in the buoyancy of old hand dug wells and streams/ rivers which hitherto where perennial have become too seasonal. Most of the river courses have been narrowed as a result of formation of terraces and in some cases covered by gallery forest. As result, people within the area have no choice than to depend on water from borehole sources.

Key words: Climate, Measurement, Survey, Water, Well.

INTRODUCTION

Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years (Wikipedia encyclopedia, 2012). It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e. more or fewer extreme events). Climate change is characteristic of our time, has brought a lot of new demands on our natural resources as well as our physical environment. The evidence is obvious. There are already issues of increase in droughts and desertification in North Africa, floods, desertification and droughts in western Africa, and serious floods affecting the Southern part (Choji and Gabriel, 2012). The resultant effect is that climate change in Africa has brought with it a lot of challenges to the people of the continents. These challenges will include famine, water scarcity, poverty, diseases, hunger, low production in the agricultural sector leading to food in security, conflicts, lost of wealth and infrastructure, energy in security, deterioration of the natural environment etc.

Nigeria is experiencing adverse climate conditions with negative impacts on the welfare of millions of people. Persistent droughts and flooding, off season rains and dry spells have sent growing seasons out of orbit, on a country depended on rain fed agriculture. Alarm bells are ringing with lakes drying up and reduction in river flows in the arid and semi-arid regions. The result is fewer water supplies for use in agriculture hydro power generation and other uses
(Nasiru, 2012)

EVIDENCES OF CLIMATE CHANGE IN NIGERIA

Climate change is already having an impact in Nigeria and this impact is negative. Weather related disasters have become more frequent in the last four decades and the trend continues in Nigeria. The nation's natural and agricultural ecosystem, including fresh water and coastal water resources, are highly susceptible to the effects of climate change (NASPA-CCN, 2011). Nigeria is experiencing adverse climate conditions with negative impacts on the welfare of the populace.

Odjugo, (2011), provided information on temperature between 1901 and 1938 increase in Nigeria. The increase became more rapid in the 1970s. The mean temperature between 1901 and 1938 was 26.04°C, while the mean temperature between 1971 and 2008 was 27.8oc. This indicates a mean increase of 1.78°C for the two climatic periods. This is significantly high considering the global increase of 0.74°C. This situation requires urgent attention in order to avoid the middle (2.5°C) and the high (4.5°C) risk temperature increase by 2100. There is a clear indication that Nigerian is experiencing global warming at the rate higher than the global mean temperatures.

The temporal rainfall pattern in Nigeria has shown a declining trend between 1901 and 1938, while rainfall decrease has been negligible. By 1971-2008 the decline became so pronounced. The mean rainfall value for the 1901 and 1938 period was 1571mm while it decreased to1480mm in 1971-2008 period (Odjugo, 2011) .This shows a decrease of 91mm between the two climatic periods. The decreasing rainfall and increasing temperatures of global warming and climate change.

Another disruption in climatic patterns of Nigeria which shows evidence of climatic change and global warming is the shift in short-dry-season (popularly known as August break). In the 19011938 climatic period, short- dry season experienced much more during the month of august but since the 1970s,it is been experienced more during the month of July (Odjugo,2011).

CLIMATIC CHANGE AND THE WATER SITUATION IN NIGERIA

Climate change has brought about change in rainfall patterns, variability in rainfall, changes in the water level volume of ponds, lakes, rivers and streams and the frequency of drought and storms in Nigeria, reduced water volume in streams and rivers arising from different scales of water diversion for rudimentary irrigation activities, situation of stream beds due to deposition of materials by water runoff, as well as evapotranspiration (Building Nigeria's response to climate change (BNRCC), 2008).

In Nigeria many rivers have been reported to have dried up or are becoming more seasonally navigable while Lake Chad shrunk in area from 22.902km2 in 1963 to a new mere 13.04km2 in 2000. Lake Chad and so many rivers in Nigeria, especially in Northern Nigeria are in danger of disappearing (Odjugo, 2010).

Arid and semi arid areas in Northern Nigeria are becoming drier while the southern part of the country is getting wetter. Global warming means that many dry areas are going to get wetter. They are going to be caught between the devil of drought and the deep blue seas of floods (Saidu, 2012).

STATEMENT OF THE PROBLEM

The main objective of the study was to determine how climate change has affect water extraction in Quan-Pan LGA of Plateau State. The research questions raised include:

I. What is the average house hold size in the study area?

II. What is the per capital consumption of water in the study area?
III. What are the evidence(s) of climate change in the study area?
IV. What are the adaptive measures already in use to cope with the effects of climate change on water extraction?

RESEARCH OBJECTIVE

1. To determine the average household size in the study area.
2. To determine the per capital consumption of water in the study area.
3. To identify the evidence of climate change in the study area.
4. To identify the adaptive measures employed by the people to cope with water extraction problems in QuanPan LGC.

SCOPE OF THE STUDY

The study covered six of the eight districts in the Local Government Area namely, Kwande, Kwalla, Doemak, Kwang, Kwa, and Dokan Kasuwa.
Other districts in the study area are Bwal and Jepjan. Selected hand-dug wells constructed in the 1990s and the 1980s were used to access their yield within a changed climate.

THE STUDY AREA

Qua'an-pan L.G.A lies between latitude 8^0 30' N and latitude 9^0 15'N, longitude 9^0 00' to 9^0 45'E. It comprises the districts of Bwal, Doema, Dokan Kasuwa, Kwa, Kwang, Kwalla, Kwande and Jepjan. The study area borders Nasarawa to the west and southwest, Bokkos and Mangu in the north, Pankshin in the northeast and Mikang and Shendam in the east
(Daloeng, 2006).

The adjoining lowlands of the Jos plateau falls within the Benue –trough (Udo, 1978), with an average elevation of 300m above sea level, It is a wide expanse of plain dotted with isolated hills and the area faces the Jos plateau escarpment to the north (Daloeng, 2006).All the rivers take their source from the Jos plateau except the three (from kwang district) that take their source from springs within the study area. Also, all the rivers in the study area flow in a southwest direction to join river Shimankar which develop into river Gongola that terminate into the Benue at Ibi, Taraba state (Daloeng, 2006). The low plains are predominantly areas of moist forest vegetation but activities of man have moderated this to semi savannah suitable for agriculture (Jeje, 1983).

There is no pipe-borne water in the L.G.A, however, people use surface water sources (rivers and streams), rainwater, Groundwater (including water from spring sources.

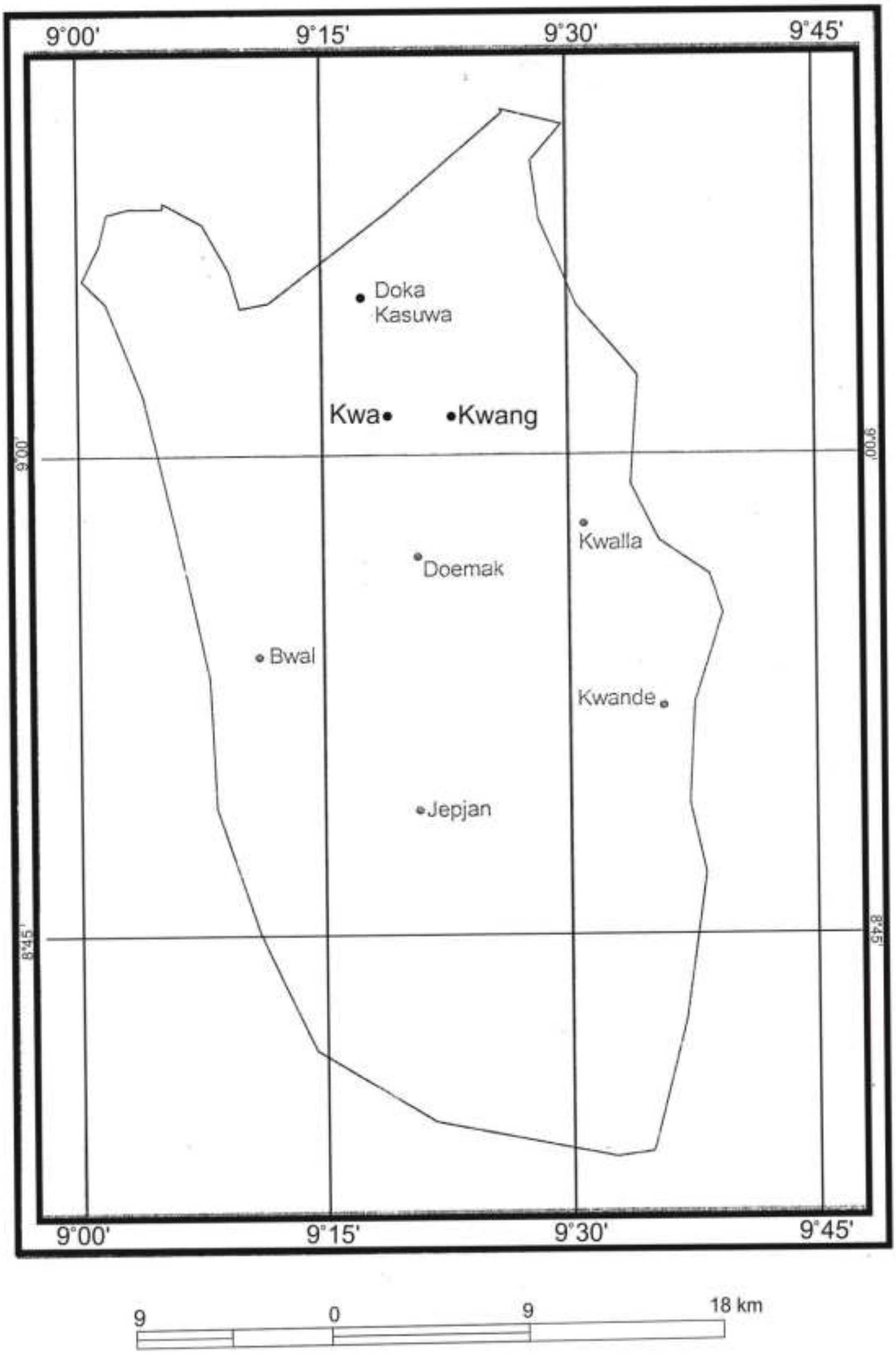

Fig. 3.3: Study Locations, QuaanPan

Fig. 1. Map showing plateau state and the Study area

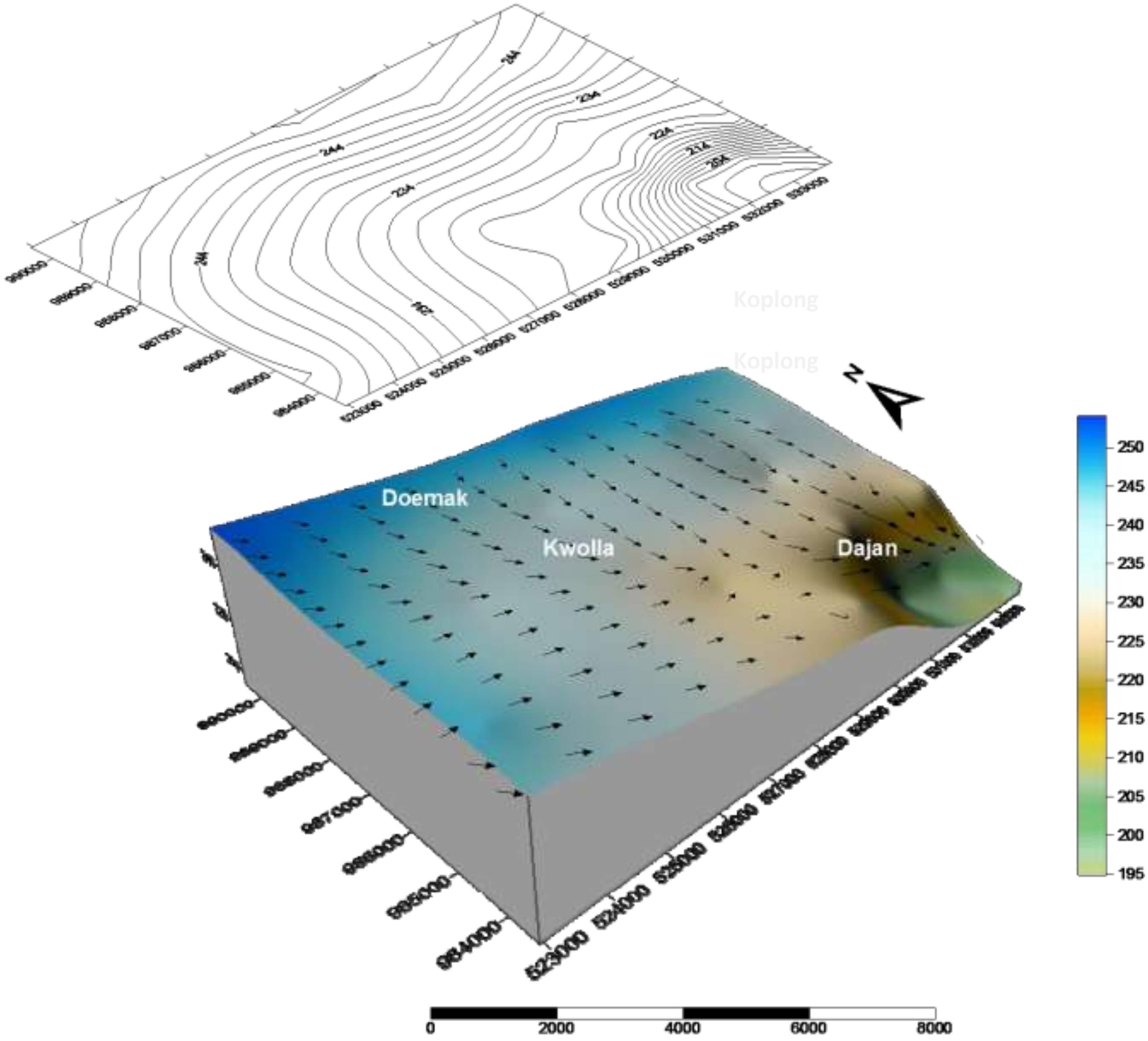

Fig. 2. Direction of flow of rivers in the study area.

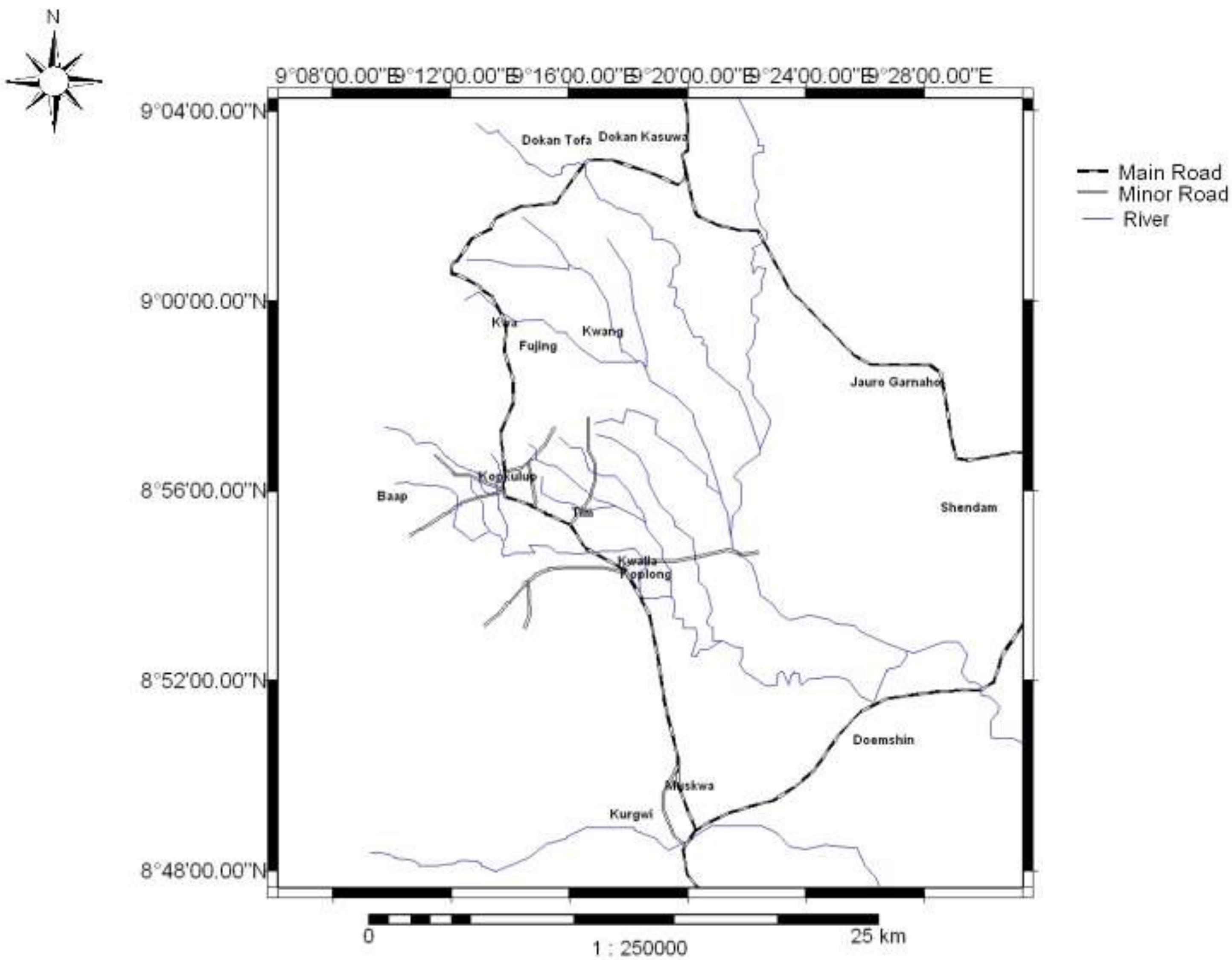

Fig. 3. Drainage map of the study area

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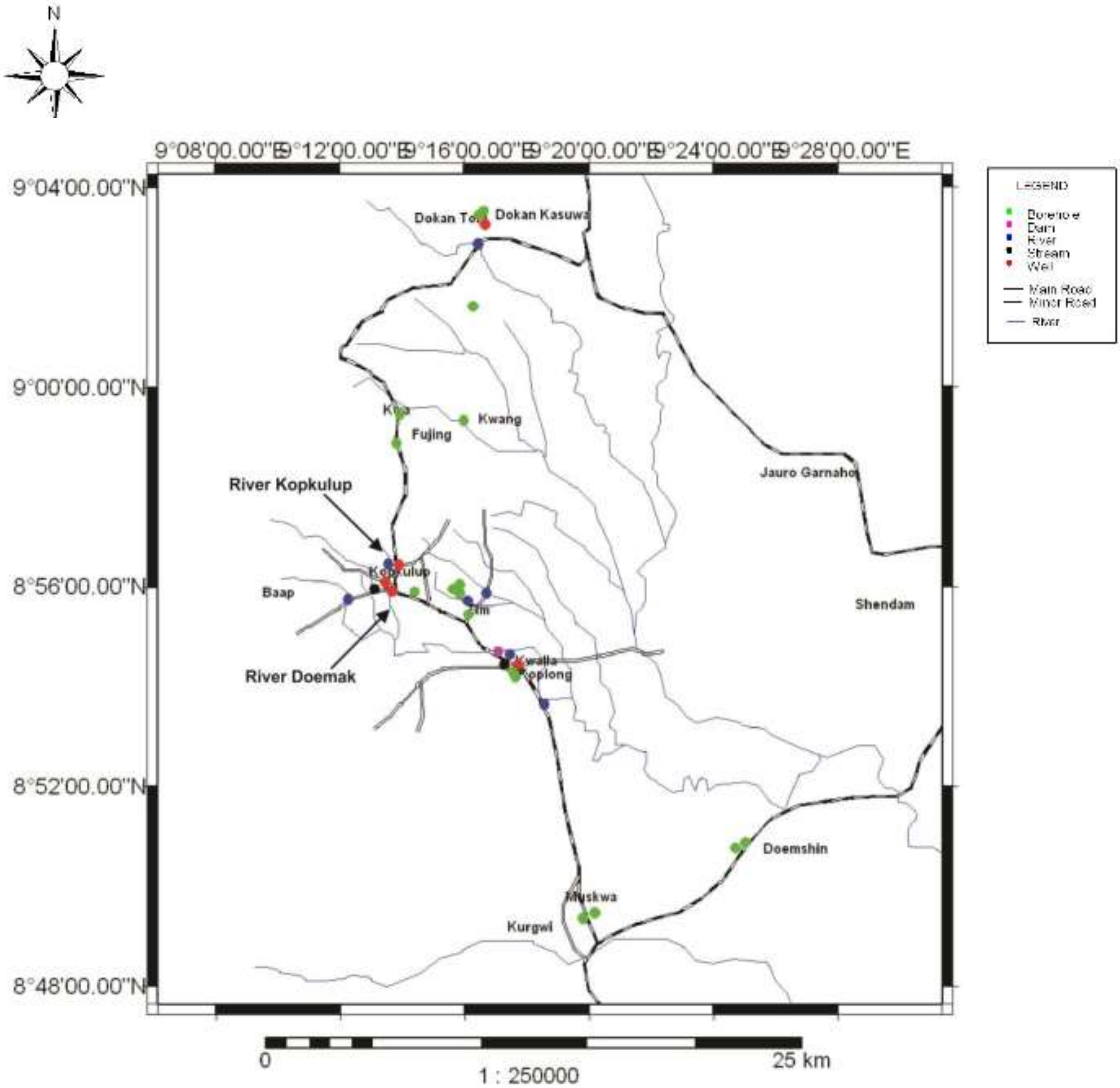

Fig. 4. Sample location map of the study area

RESEARCH METHODOLOGY

Both primary and secondary data were combined to understand water extraction in Qua'an-Pan LGA of Plateau State.

Primary data where obtained via measurement of certain parameters, (e.g. measuring of the depth of wells using a measuring tape, mapping well locations and certain points on rivers using the Global Positioning System(GPS) device. Two hundred questionnaires were administered in five districts in the local government. The use of questionnaire was to determine the situation of wells, rivers in historic time (within the last 42 years 1970 – till date).

The questionnaires were administered to only respondents who are forty years and above. And this was done randomly and at their individual homes.

A reconnaissance was undertaken within the study area. This is in order to have a general idea of the area under study.

RESULTS AND DISCUSSION

Household Size

Household sizes are strong determinants of water demands and water use. It is also important when comparing per capital consumption and standards amount that an individual supposed to use per day. For instance, Gleick (1996) submitted that, the minimum amount of safe water suggested for improved human health is 50 liters per capital per day (lpc pd), which includes use of safe water for washing, bathing, food preparation etc but excluding water use for livestock, gardening etc. An average household size in the area is 9 per sons per family.

Estimated Water Quantity of Water Obtained Per Day per Family

Generally, a 20 liter bucket is used in the study area for fetching, buying and storing of water as the case may be. Hence, it was easy for the respondents to answer the question on how much water is used or obtained per day for family use. Table 4 show that, the average per capita consumption of water is 36.7 liters, This is very low compared to 50 litres provided by Gleick (1996).

The Status of Size of Rivers within the Period 1970 and 2012

The result shows that 91.5% indicated the valleys shranked between 19702012. There were three spots on three rivers (Kwalla, Doemak and Tim) that had small lakes along the river course. All of these lakes have disappeared. At Tim, the lake was use for an annual fishing festival. No one was allowed to fish in the lake until a day specified by the Community for a fishing festival that comes up once in year. The festival was later abandoned because of illegal fishing. The last time the festival held was in 1980(personal contact). From observation, the area earlier covered by the lake and some parts of the river left after continuous shrinking has been covered by alluvial deposits and gallery forest.(see satellite image on 18)

Within the period (1970-2012) so many terraces have formed along rivers within the study area. An average of three platforms of terraces where identified along the river courses at certain points. (See pix 2) However, river Doemak have showed five order terraces found along the river. (See pix 2) Most of the terraces have been found to be fertile and hence are cultivated for Rice, maize and Guinea corn. Alluvial terraces and also river deposition takes place in areas where rainfall intensity has dropped. There will be no much water to transport sediments along the river channel. Already existing deposits are now exposed on the river. After along time of not been transported, they now form plains of alluvial deposits in the valleys which subsequently were taken over by vegetation to form gallery forest.

Average Depth of Boreholes/Wells as It Affects Surface and Groundwater Sources in Quan-Pan LGA

Table four supplies information on the depth, yield, year of drilling, and location of the borehole, The result shows that the average depth of a borehole within the study area is 33.5m while that of wells is 19m. Wells provide low water yield than boreholes, and many wells have been abandoned because of low water yield. Hence, there is preference for boreholes provided either by philanthropist, politicians, government or by community's effort. Rainfall has dropped both in intensity and period of stay. This was confirmed by respondents who observed that the rainy season normally start from April and terminate either in October or November. However, the rainy season for some few years now start in may and most times terminate in September. This has affected groundwater recharge and the level of the water table. Perhaps the persistent water scarcity and the subsequent low per capital consumption of water could be linked to the change in rainfall pattern.

Evidence of Climate Change in the Study Area as it affects surface and ground water sources

There is no single weather station within or near the study area, and so climatological data was not available to access climate change or variability. However, the following provide a summary of clear evidence of climate change in the area.

- The development of sand bars along river beds within the last 42 years (from Questionnaires).
- The development of terraces on river beds along some rivers. - Changing pattern of rainfall.
- The drop in the water table as a result of drop in the density and period of stay of rainfall.
- Rivers have become more seasonal even those rivers that use to be perennial are now seasonal.
- The disappearance of small lakes along rivers Tim.
- The development of gallery forest along shrinking rivers.

Picture 1: Showing vegetation taking over river channel that has been narrowed by decrease in volume of water as a result of climate change as seen in river Doemak.

Picture 2: Showing successive terraces formed as a result of continuous reduction in the size of the river channel in response to climate change as seen in river Kopkulup.

Picture 3: Showing gallery forest along river channel at a tributary of river Kwang

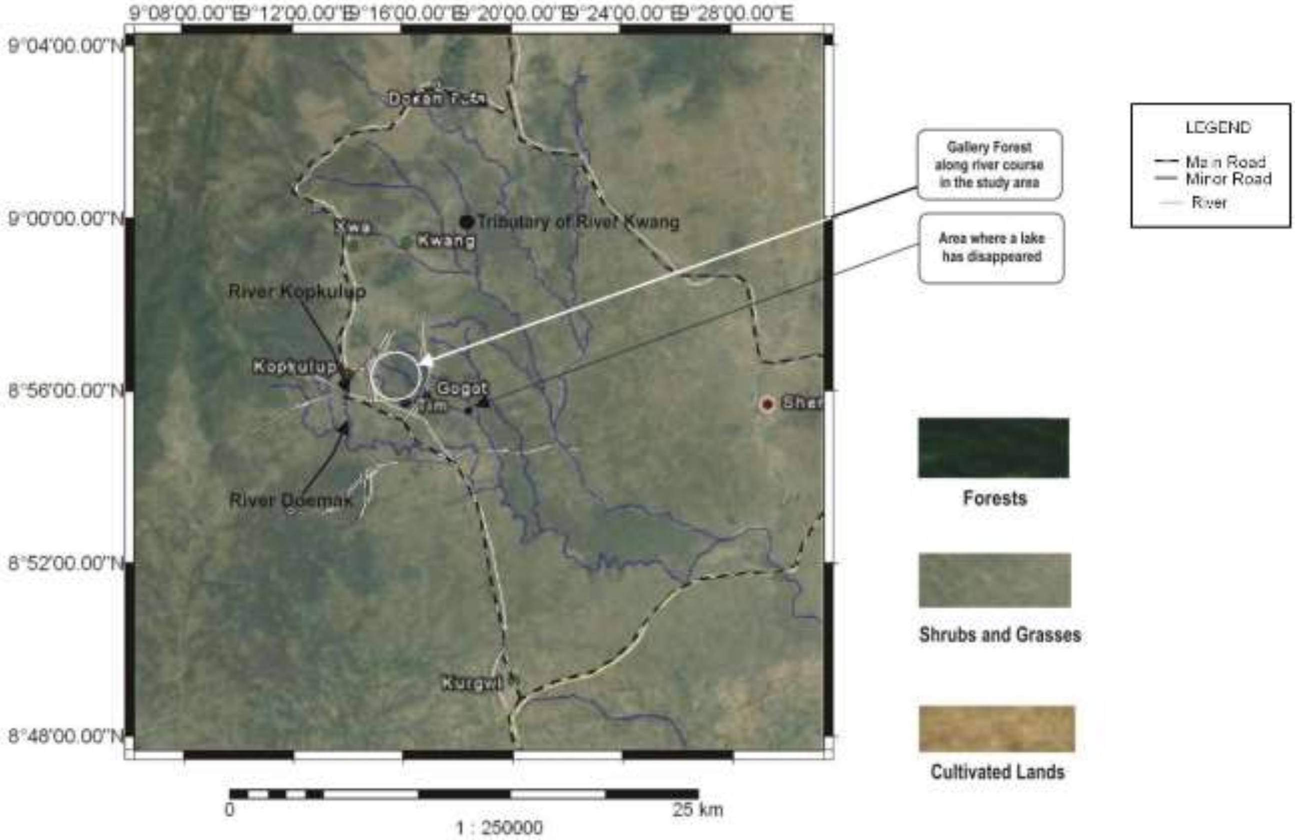

Fig. 5. Satellite image showing gallery forest along river courses in the study area

Adaptation Measures Used By People to Cope With Climate Change Related Water Scarcity in Quaan-Pan LGA

- Mostly families engaged in collection and storing of rain water in large containers (mostly the 100 and the 120 litre containers), especially, the water use for drinking and occasionally in cooking. Modern rainwater harvesting systems have been constructed by the

  Catholic Mission NonGovernmental Organization (NGO) at Kuru, an estimated capacity of between 27000 liters and 46000 liters to cope with climate change induced water scarcity. However, these are found either at parish houses or in homes of wealthy individuals as these systems are costly.
- Water vendors also help to distribute water by fetching from boreholes and selling to the people. But they are not always there for would be buyers at the exact time of need
- Wealthy people drill boreholes in their homes instead of hand dug wells. Politicians and government do not construct wells as was done in the 1970 s and 1980s. Boreholes are mostly

preferred because they yield more water and are active throughout the year. However, borehole construction may not be less than ₦1, 000,000, which may not be affordable to average income earners

Table 1. Household size in Quan-Pan LGA of Plateau state

Number of people in the household size	Number of respondents	Percentage
0 – 4	18	9
5 -9	115	57.5
1- 14	32	16
15 – 19	35	17.5
Total	200	100

Source: Author's field work, 2012

According to the respondents, family 57.5% of the population. This will size that is mostly common is between demand a lot of water for domestic 5 and 9 people. And they constitute purposes

Table 2. An average family size in Quan-Pan LGA Plateau State

Class interval	F	×	F×
0 – 4	18	2	36
5 – 9	115	7	805
10 – 4	32	12	384
15 – 9	35	17	595
Total	200	38	1820

Source: Authors field work, 2012

But mean $(\bar{\times}) = \frac{fx}{f}$

Where f = Frequency

X= Class mark

Fx = The product of frequency and class mark

Hence mean = $\frac{1820}{200} = 9.1$

Therefore, the average household size in Qua'an-pan town is 9. That is nine persons per household.

Table 3. Estimated quality of water obtained per day per family in Quan – Pan LGA Plateau State.

Estimated quality of water obtained per day (in liter)	Frequency	Percentage
100 – 199	15	7.5
200 – 299	83	41.5
300 – 399	58	29
400 – 499	20	10
500 – 599	17	8.5
600 – 699	7	3.5
Total	200	100

Source: Author's field work, 2012

Table 4. Aerage quality of water obtained by each house hold in Quan – Pan LGA Plateau State

Class interval	F	×	F×
100 – 199	15	149.5	2242.5
200 – 299	83	249.5	20708.5
300 – 399	58	349.5	20271
400 – 499	20	449.5	8990
500 – 599	17	549.5	9341.5
600 - 699	7	649.5	4546.5
Total	200	2397	66100

Source: Author's field work, 2012

But mean $(\bar{\times}) = \frac{fx}{f}$

Where f = frequency

X= class mark

Fx= the product of frequency of a class mark

Hence, $x = \frac{66100}{200} = 330.5$ liters

Therefore, the average quantity of water obtained by beach household per family per day in Quan –Pan LGA is 330.5 per day.

But the water consumption per capital per day

= 330.5/9 = 36.7 liters

Table 5. Respondents observation of the status of river size within the period 1970-2012

What is your own observation on the river size of rivers around your	Frequency	Percentage
1. Rivers have increased in size over time	0	0
2. Rivers have reduce in size over time	183	91.5
3. Don't know	17	8.5

From table 5 above majority of correspondents had observed over time that, the rivers within the study area have shrunk gradually between 1970 and 2012. That many years ago, there were some ponds along the rivers and today those places are no more in existence. These were used for swimming washing and some cases fishing. The respondents also provided that, some of the rivers are more perennial as they use to be.

Table 6. Location, depth and yields of some boreholes in the study area

S/No	Location of boreholes	Depth (m)	Year	From	Status
1	N8^{0} 48^{1} 419^{11} E 9^{0} 22^{1} 145^{11} Maraba Doemshin	35	2002	Senator constituency project	Good yield
2	N8$_{0}$ 48$_{1}$ 420$_{11}$ E 9$_{0}$ 22$_{1}$ 399$_{11}$ Kwalla (Laguma)	34	2012	Private	Poor yield
3	N 8^{0} 54^{1} 030^{11} E9^{0} 17^{1} 407 Kwalla	35	2009	House of rep's constituency project	Good yield
4	N8$_{0}$ 54$_{1}$ 192$_{11}$ E9$_{0}$ 16$_{1}$ 599$_{11}$ G.SS Kwalla	28	2009	,,	Abortive
5	N8^{0} 55^{1} 747^{11} E9^{0} 16^{1} 393^{11} Tim	30	2002	Senator's constituency project	Good yield

6	$N8_0\ 56_1\ 464_{11}\ E9_0\ 16_1\ 393_{11}$ Tim	34	2011	MDG's project	Good yield
7	$N8^0\ 56^1\ 464^{11}\ E9^0\ 16^1\ 393^{11}$ Tim	35	2011	private	Good tield
8	$N8^0\ 56^1\ 560^{11}\ E9^0\ 16^1\ 497^{11}$ Tim	30	2002	PADP	Good yield
9	$N8^0\ 56^1\ 919^{11}\ E9^0\ 16^1\ 497^{11}$ Tim	34	2002	PADP	Good yield
10	$N8^0\ 57^1\ 082^{11}\ E\ 9^0\ 16^1\ 064^{11}$ Loegeot	33	2005	private	Good yield
11	$N9^0\ 00^1\ 538^{11}\ E9^0\ 15^1\ 761^{11}$ Fujing	35	2003	House of assembly constituency project	Moderate yield
12	$N9^0\ 0^{11}\ 106^1 1E9^0\ 15^1\ 958^{11}$ Kwa	35m	2003	,,	Moderate yield
13	$N9^0\ 05^1\ 635^{11}\ E9^0\ 19^1\ 24^{11}$ Dokan kasuwa	35m	2011	MDG;s project	Good yield
14	$N9^0\ 05^1\ 974^{11}\ E9^0\ 19^1\ 235^{11}$ Dokan kasuwa	34	2009	Senator's constituency project	Moderate yield
15	$N9^0\ 03^1\ 655^{11}\ E9^0\ 18^1\ 420^{11}$ Dung Niegoen	35	2009	MDG's project	Moderate yield
16	$N9^0\ 00^1\ 857^{11}\ E9^0\ 17^1\ 579^{11}$ Kwang	32	2009	House of reps constituency project	Good yield
17	$N8^0\ 57^1\ 387^{11}\ E9^0\ 14^1\ 982^{11}$ Doemak	32	2010	Senator's contituency project	Good yield
18	$N80\ 56^1\ 564^{11}\ E\ 90\ 15^1\ 297^{11}$ Doemak	34	2003	Senator's constituency project	Good yield
19	$N80\ 47^1\ 535^{11}\ E90\ 181\ 047^{11}$ Muskwani Kurgwi	35	2010	MDG's project	Good yield
20	$N8^0\ 47^1\ 316^{11}\ E9^0\ 17^1\ 850^{11}$ Kurgwi	35	2010	MDG's project	Moderate yield

Source: Choji and Mandong, 2012, after Pan-Geo-informatics, 2012.

From table 6 above, sum of depth of 20 boreholes is 670m.

Average depth of boreholes in the study area = 670/20 =33.5m

Table 7. Location, depth and yields of some wells in the study area

1	$N8_0 54_1 284_{11}\quad E9_0 17_1 386_{11}$ Koplong Danjan	22M	1972	,,	Yielding
2	$N8_0 54_1 187_{11}\quad E9_0 17_1 518_{11}$ Kasuwa (Kwalla)	20M	1972	,,	Not yielding
3	$N8_0 56_1 166_{11}\ E9_0 17_1 518_{11}$ Tim	15M	1973	,,	Partially yielding
4	$N8_0 56_1 810_{11}\quad E9_0 14_1 688_{11}$ Doemak Koplong	18M	1972	,,	Not yielding

5	N8$_0$56$_1$934$_{11}$ E9$_0$14$_1$615$_{11}$ Doemak kopkulup	20M	1972	,,	Not yielding
6	N9$_0$05$_1$829$_{11}$ E9$_0$19$_1$230$_{11}$ Dokan Kasuwa	15M	1973	,,	Partially yielding
7	N8$_0$57$_1$384$_{11}$ E9$_0$14$_1$975$_{11}$ Doemak Kopkulup	20M	1073	,,	Not yielding

Source: 2012.

From table 7 above, sum of depth of 7 wells is 130m.

Average depth of wells in the study area= 130/7 =33.5m

CONCLUSION

Studies abound to prove the fact that climate change is evident in Qua,an Pan LGA, as rivers which where hitherto perennial have now become too seasonal. However, study also show that, all the rivers in the study area are seasonal except three of them at (Kwang) which remain perennial. All perennial rivers are all recharged by springs which are basically the main source of the rivers.

Rivers also responded to climate change by shrinking in size, evidence is seen in the development of terraces along the rivers.

Long time exposure to sand deposits in these shrinking rivers has been taken over by vegetation and thus the development of gallery forest. There is also the issue of a disappearance of a lake along river Tim. Water from the lake was initially used for domestic purposes, swimming and for fishing festival; all these are no more since the lake disappeared. Ground water table dropped to an average 33.5m (see below table 6 and 7)

Meanwhile, because of the effects of climate change on both surface and ground water as evident in the study area, there is the issue of water stress. People are really suffering as they depend on water from boreholes which are not enough and are not evenly distributed. The per capita consumption of water is less than standard per capita consumption of 50 liters per capita per day.

RECOMMENDATION

There is however a great and urgent need to pursue an aggressive gathering of meteorological data for not only Quan-pan but all the local government areas in Plateau state. There is no single meteorological station located in the entire southern senatorial district of the state. The climate of the area is changing and the impact is obvious. Meteorological data will help to study, monitor and subsequently prepare for further impacts.

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