HYDROGEOLOGICAL CHARACTERIZATION AND WATER SUPPLY POTENTIAL OF BASEMENT AQUIFERS IN TARABA STATE, N.E. NIGERIA

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ABSTRACT

The basement complex area of Taraba State lies within Latitude $6^0 30^I$N to $9^0 30^I$N and Longtitude $9^0 00^I$E to $12^0 00^I$E, and is about 41,200km^2. The objective of this study is to characterize the hydrological nature and water-supply potential of the basement aquifers of the study area. Borehole logs were studied and on the basis of results of lithologic logs, weathered overburden and fractured-rock aquifer units were delineated. Pumping test results analysed from 39 hand pump boreholes reveal that transmissivity values range from 0.3m^2/day to 19.7m^2/day, thus indicating aquifer of negligible to high potentials. The hydraulic conductivity value vary from 3.3 x 10^{-2} m/day to 7.0 x 10^1 m/day which correspond to moderate specific capacity values as revealed by most boreholes. The basement aquifers have a total groundwater reserve of 281.8 x 10^6 m^3 with the recoverable reserve of 201.3m^2 per annum. The recoverable reserve per capita based on the present projected population in the next 25 years is 108.4m^3. The basement aquifers, therefore, when fully developed can sustain domestic, agricultural and industrial activities. On the basis of the aquifer types and characteristics identified, it is recommended that borehole field be designed in densely populated areas and infiltration galleries constructed along perennial streams. [Nature and Science. 2009;7(3):75-83]. (ISSN: 1545-0740).

Keywords: basement complex, groundwater, aquifer, borehole, wells, Nigeria.

INTRODUCTION

The area of study covers the basement complex area of Taraba State. It lies between latitude $6^0 30^I$N to $9^0 30^I$N and longitude $9^0 00^I$ to $12^0 00^I$E and has an areal extent of about 41,200 km^2. The area is generally hilly and is largely drained by River Benue, Katsina, Ala and Donga (Fig. 1). The people of Taraba State are predominantly farmers and most of them are found in the rural areas. Groundwater is an important source of water supply and plays an important role in industry, agriculture and domestic use (Achyara, 2004, Foster et al, 2008, MacDonald et al, 2005 (a), Srinivasa et al., 2000). Water supply to the communities of the area under consideration is grossly inadequate. Recent surveys carried out in 1997 and 1998 by the Petroleum (Special) Trust Fund (PTF) under the National Rural Water Supply Programme revealed that more than 90% of the people in Taraba State lack adequate and potable water supply. This is expressly manifested by the drying-up of hand dug wells and streams which constitute the dominant source of water supply to the people. Eighty hand pump boreholes were supposed to be drilled and eighty rehabilitated under the National Rural Water Supply Programme to ease the water supply problem in the State. However, not all the boreholes were drilled or rehabilitated due to accessibility problem and subsequent winding up of the PTF. The problem however still remains due to inadequacy of the facilities and over usage. The national standard of 500 people to one hand pump borehole has not been met due to over population in the rural areas of the State. Some communities especially those in the basement complex terrain have no access to hand pump boreholes due to poor geologic environment.

The traditional sources of water supply from streams, hand dug wells and seepages are seasonal and hence unreliable (Adelana & MacDonald, 2008). This study therefore intends to evaluate the groundwater resource potentials of the basement complex terrain of the State. The study will also suggest appropriate scheme that would ensure continuous and sustainable water supply to the people.

METHOD OF STUDY

The study was carried out by conducting base line surveys in different localities covering the entire State. The baseline surveys involved identification of the different sources of water supply, rock types, accessibility and population of the communities visited. Measurement of depth to water level in hand dug wells were carried out. The aforementioned activities led to the choice of probable sites for the drilling of the proposed hand pump boreholes. Geophysical surveys consisting of the Electromagnetic (EM) and Vertical Electrical sounding (VES) techniques using EM34-3 Geonics and ABEM Terrameter SAS300C were employed to confirm the actual sites for the drilling of the boreholes. The present report involves the use of data from 43 hand pump boreholes located in the basement complex terrain. The boreholes were each pump tested for a period of 120 minutes. The results of the pumping test were analysed using Jacob and Cooper (1946) method for the purpose of evaluating the hydraulic properties of the aquifers. Storage coefficient for the aquifers could not be determined due to the short duration of the pumping test.

GEOLOGY OF THE STUDY AREA

The study area is underlain by the undifferentiated Basement Complex rocks which consist mainly of the migmatites, gneisses and the Older Granites. Tertiary to Recent basalts also occur in the area (Fig. 1). The undifferentiated Basement Complex particularly the migmatites, generally vary from coarsely mixed gneisses to diffused textured rocks of variable grain size and are frequently porphyroblastic (Macleod, et al 1971). This rock unit constitutes principally the undifferentiated igneous and metamorphic rocks of Precambrain age (Grant, 1971.)

The Pan African Older Granites are equally widespread in the area. They occur either as basic or intermediate intrusives (Turner, 1964). Different kinds of textures ranging from fine to medium to coarse grains can be noticed on the Older Granites (McCurry, 1976). Other localized occurrences of minor rock types include some doleritic and pegmatitic rocks mostly occurring as intrusive dykes and vein bodies. These occurrences are common to both the undifferentiated Basement Complex and the Older Granite rocks (Carter et al., 1963, McCurry, 1976). The Tertiary basalts on the other hand are found in the

Mambila Plateau mostly formed by trachytic lavas and extensive basalts which occur around Nguroje (du Preez, 1965).

RESULTS

Aquifer types

In basement terrain, groundwater development is met with difficulties due to lack of primary porosity in the bedrock. The secondary porosities such as joints, fault and weathered zones are the sources of groundwater occurrence and movement (Chiton and Foster, 1995, Foster et al 2008, Srinivasa, 2000, Wright and Burgess, 1992). Hence, the secondary porosity and weathered zones constitute the different aquifer systems. Borehole lithologic logs revealed two water bearing zones in the area; namely the weathered zone and the fractured-rock zone (Fig. 2). The basement complex rocks of the study area were subjected to different degrees of weathering which led to the formation of thick weathered materials in some places. The weathered materials range in thickness from 3m to 37.73m with an average of 17.8m, and consist of sandstone, clays and silts. The fractured-rock zone is overlain by the weathered zone and acts as conduct for groundwater movement. The zone is recharged by infiltration through the upper weathered zone.

Aquifer Properties

Available data on thirty-nine (39) hand pump boreholes were analysed for the determination of Transmissivity (T) and hydraulic conductivity (K). Attempts were not made to isolate the aquifer properties of the weathered overburden aquifers and that of the fractured-rock aquifers. This is because in the course of drilling these boreholes, both aquifers were merged and screened. Results from Table 1 reveal that transmissicity values (MacDonald et al, 2005 (b)) vary from 0.3m^2/day to 19.7m^2/day with an average of 2.9m^2/day. Most values are below 5.0m^2/day.

The hydraulic conductivity is simply computed from the relationship T = Kb where b represents the aquifer thickness. This was obtained by subtracting static water level from overburden and fractured-rock zone. The hydraulic conductivity values range from 3.3 x 10^{-2}m/day to 7.0 x 10^{-1}m/day with an average of 1.78 x 10^{-1}m/day. The specific capacity values computed for the boreholes vary from 0.60m^3/day/m to 31.30m^3/day/m. Higher values occur in BH7, BH8, BH9, BH24, BH37 and BH43 with low drawndown values (Table 1).

The specific capacity can be related directly to aquifer properties K and T (Dike, 1994). Though, specific capacity data do not show correspondence with transmissivity, hydraulic conductivity and borehole yield, but here two boreholes (BH6 and BH19) exhibit such a relationship (Table 1). The performances of the boreholes have been classified into 4 groups based on the range of specific capacity values (Table 2). Seventy-nine per cent (79%) of the boreholes have moderate performance. This also corresponds to moderate hydraulic conductivity values (3.3. x 10^{-2}m/day to 7.0 x 10^{-1}m/day) and negligible to high transmissivity values (0.3m^3/day to 19.7m^2/day). Borehole yields range from 6.77m^3/day to 21.6m^3/day with an average of 14.41m^3/day.

DISCUSSION

The basement aquifer properties evaluated reveal that the transmissivity values range from 0.3m^2/day to 19.7m^2/day with an average of 2.90m^2/day. According to Offodile (2002), a transmissivity range of 5 to 50m^2/day could be regarded as high potential in crystalline rock situations. By the above standard, the basement aquifers in the area are classified as aquifers of negligible to high potentials. The hydraulic conductivity values vary from 3.0 x 10^{-2}m/day and 7.0 x 10^{-1}m/day with an average of 1.90 x 10^{-1}m/day. The range of values reveals moderate hydraulic conductivity (Todd, 1980). The specific capacity values for the boreholes do not show correspondence with transmissivity, hydraulic conductivity and borehole yields. This could be attributed to differences in the degree of weathering, presence or absence of fractures in some places and method of construction of the wells. Based on specific capacity values, most of the boreholes have moderate performance which corresponds to moderate hydraulic conductivity and negligible to high transmissivity values. Borehole yields range from 6.77m^3/day to 21.6m^3/day with an average of 14.41m^3/day. The total yield of the boreholes is about 620.04m^3/day which can sustain a population of 24, 802 based on water supply standard of 25 litres per day for rural communities (Babatola, 1997).

Water supply situation is grossly inadequate in the area covered by this study. Water supply from the hand pump boreholes is supplemented by water from streams, ponds and hand dug wells. The existing hand pump boreholes are over-stretched due to over population in the rural area. Frequent breakdown of the boreholes occur thereby creating acute water shortages. This situation compels the villagers to resort to the traditional system of water supply through streams, ponds and hand dug wells. Where water cannot be obtained due to the seasonal nature of these sources, water supply is obtained through groundwater mining few metres below the stream beds. Where such streams do not exist, people have to trek several kilometers in search of water.

Table 1: HYDRAULIC CHARACTERISTICS OF SOME HANDPUMP BOREHOLES IN THE STUDY AREA

BH Na	LOCATION	DEPTH (m)	YIELD (m^3/day	SWL (m)	DRAWDON (m)	SC (m^3/day/m)	AQUIFER THICKNESS (m)	TRANSMISSITY (m^3/day)	HYDRAULIC CONDUCTIVITY (M/day
1.	Mararaba Baissa	19.00	6.77	6.97	11.25	0.60	ND	0.39	ND
2.	Nasarawa	12.90	14.40	5.90	2.00	7.20	ND	ND	ND
3.	Bunduwa	48.18	12.96	5.86	7.21	1.80	ND	0.51	ND

4.	Chanchanji	96.10	17.28	6.80	4.60	3.76	ND	2.57	ND
5.	Kwambai 2	24.80	11.52	8.51	3.30	3.49	ND	1.75	ND
6.	Muji 2	4.00	12.10	7.00	4.51	2.68	8.00	1.29	1.60×10^{-1}
7.	Jenuwarikya	50.76	12.67	6.71	0.63	20.11	22.29	5.80	2.6×10^{-1}
8.	Basang	48.00	17.28	4.50	0.91	18.99	19.50	5.00	2.6×10^{-1}
9.	Kpakye	45.00	17.28	3.20	1.71	10.11	14.80	18.10	1.22×10^{-1}
10.	Kpambo Yirom	54.20	12.67	5.00	7.26	1.75	14.00	0.61	4.4×10^{-2}
11.	Sabongida	59.00	11.23	6.30	11.30	0.99	12.40	0.43	3.4×10^{-2}
12.	Nzurkwem	80.00	12.96	13.55	ND	ND	34.50	0.97	2.8×10^{-2}
13.	Lissam	51.60	11.23	5.20	13.40	0.91	8.50	0.38	$4.5\ 4.4 \times 10^{-2}$
14.	Yelwa	49.18	12.96	4.36	9.50	1.36	19.64	0.64	$3.3\ 4.4 \times 10^{-2}$
15.	Kwaitab	50.67	15.84	8.46	3.70	4.28	14.54	0.88	$6.1\ 4.4 \times 10^{-2}$
16.	Karamti	41.97	14.40	4.37	3.75	3.84	30.63	1.46	$4.8\ 4.4 \times 10^{-2}$
17.	Mayoselbe	44.90	14.40	8.42	3.34	4.31	10.58	1.01	$9.5\ 4.4 \times 10^{-2}$
18.	Saukakahuta	48.00	ND	5.90	ND	ND	9.10	ND	ND
19.	Tudunwada	26.70	17.28	8.80	3.30	5.24	6.20	2.10	$3.4\ 4.4 \times 10^{-1}$
20.	Gangpenton	55.20	17.28	7.33	9.16	1.89	10.67	0.57	$5.3\ 4.4 \times 10^{-2}$
21.	Hamdallahi	51.46	17.28	6.63	3.96	4.36	6.37	1.44	$2.3 \times 4.4 \times 10^{-2}$
22.	Garbachede	91.30	13.25	2.55	1.04	12.74	ND	4.50	ND
23.	Garin Yusufu	55.80	14.40	7.80	3.40	4.24	22.20	1.91	$8.6\ 4.4 \times 10^{-2}$
24.	Sansani	46.40	18.70	4.32	6.22	3.01	10.68	1.87	$1.8\ 4.4 \times 10^{-1}$
25.	Gangdole	42.54	17.28	7.68	2.02	8.55	28.32	19.7	$7.0\ 4.4 \times 10^{-1}$
26.	Dakka	103.20	14.40	5.85	4.77	3.02	ND	2.53	ND
27.	Tudunwada	59.20	10.51	6.20	6.88	1.53	ND	0.54	ND
28.	Bitako	55.70	14.40	2.97	2.59	5.56	32.10	2.93	9.1×10^{-2}
29.	Lakwati	61.67	11.23	2.60	4.81	2.33	ND	0.87	ND
30.	Monkin	37.36	11.23	9.50	9.66	1.16	ND	0.76	ND
31.	Yakoko	34.35	14.40	9.44	4.79	3.01	ND	0.59	ND
32.	Gov. Lodg. Zing	16.90	14.40	8.00	1.53	9.41	ND	3.20	ND
33.	Yonko	27.96	15.84	4.21	9.37	1.67	ND	0.56	ND
34.	Mararaba Kunini	54.00	14.40	5.28	ND	Nd	3.00	1.51	5.0×10^{-1}
35.	Tsoro Dangung	45.83	17.57	8.60	1.47	11.95	13.40	2.98	2.2×10^{-1}
36.	Jekadafari	42.00	14.40	3.00	6.80	2.12	ND	0.57	ND
37.	NTA Vill. Jalingo	42.00	20.16	6.56	7.93	2.54	28.44	1.23	4.3×10^{-2}
38.	Wuro Sambe	37.00	11.52	26.00	ND	ND	ND	ND	ND
39.	Sabongari Jalingo	49.00	14.40	5.27	4.67	3.08	37.73	1.14	3.0×10^{-2}
40.	Kantiyel	31.00	21.6	10.05	ND	ND	ND	ND	ND
41.	Tutare	30.00	21.6	4.92	0.69	31.30	26.58	15.7	5.9×10^{-1}
42.	Jauro Manu	45.87	10.08	6.87	1.33	7.58	26.13	3.6	1.4×10^{-1}
43.	Garin Shuaibu	23.86	11.52	8.26	2.04	5.65	ND	1.92	ND

BH: Borehole

ND: No data

Table 2: CLASSIFICATION OF SPECIFIC CAPACITIES IN THE STUDY AREA

Group	Specific Capacities Range (m^3/day/m)	Borehole performance
		Excellent performance
1	<31.30	BH 41
		Good performance
2	11.95-31.30	BH7, BH8, BH22, BH35
		Moderate performance
3	1.16-11.95	BH2, BH3, BH4, BH5, BH6, BH9, BH10, BH14, BH15, BH16, BH17, BH19, BH20, BH21, BH23, BH24, BH25, BH26, BH27, BH28, BH29, BH30, BH31, BH32, BH33, BH36, BH37, BH39, BH42, BH43,
		Poor performance
4	0.60-1.16	BH1, BH11, BH13

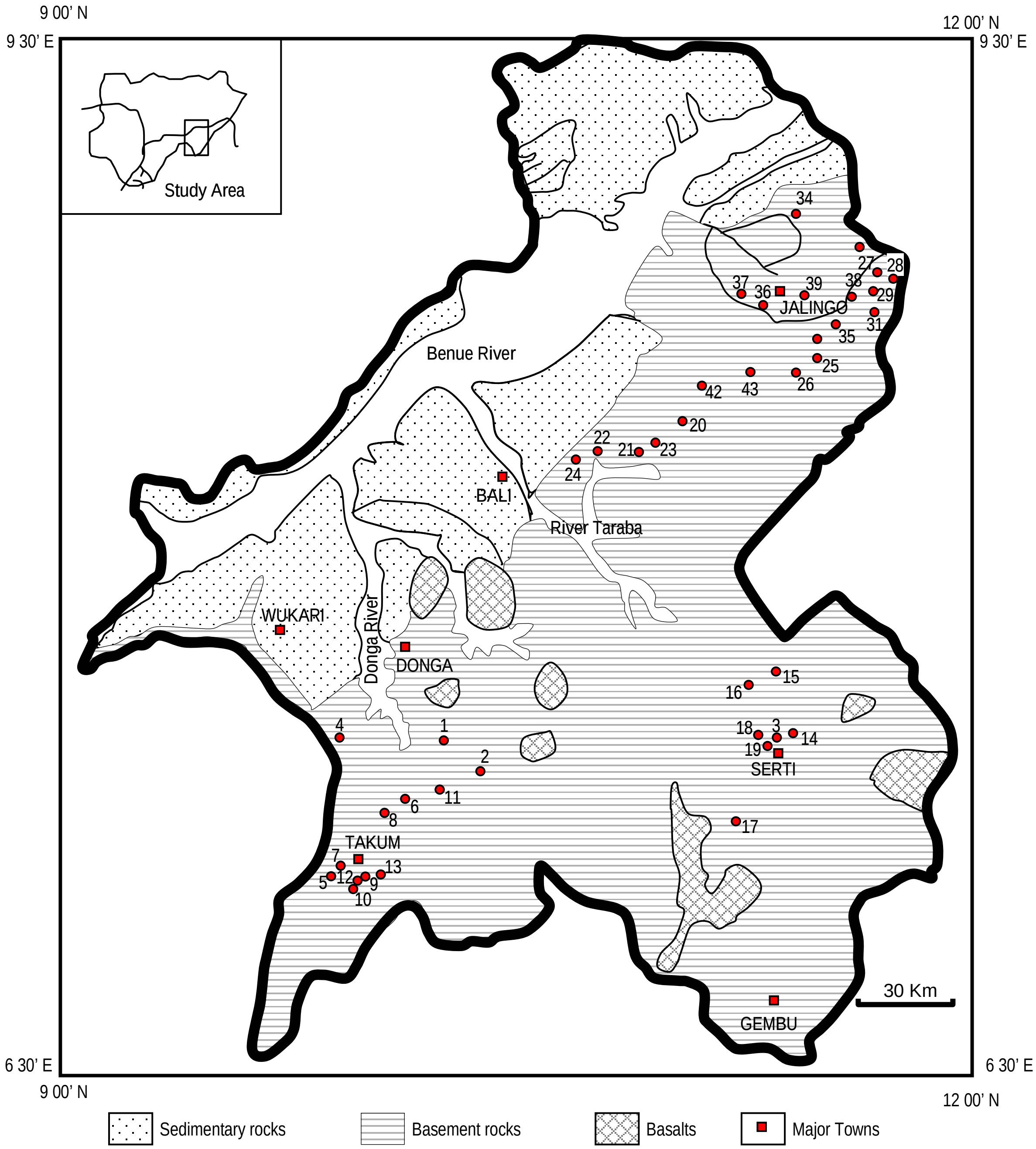

FIG. 1: BOREHOLE LOCATION MAP AND DRAINAGES OF THE STUDY AREA. MODIFIED FROM BADAFASH CONSULTING ENGINEEERS (1991)

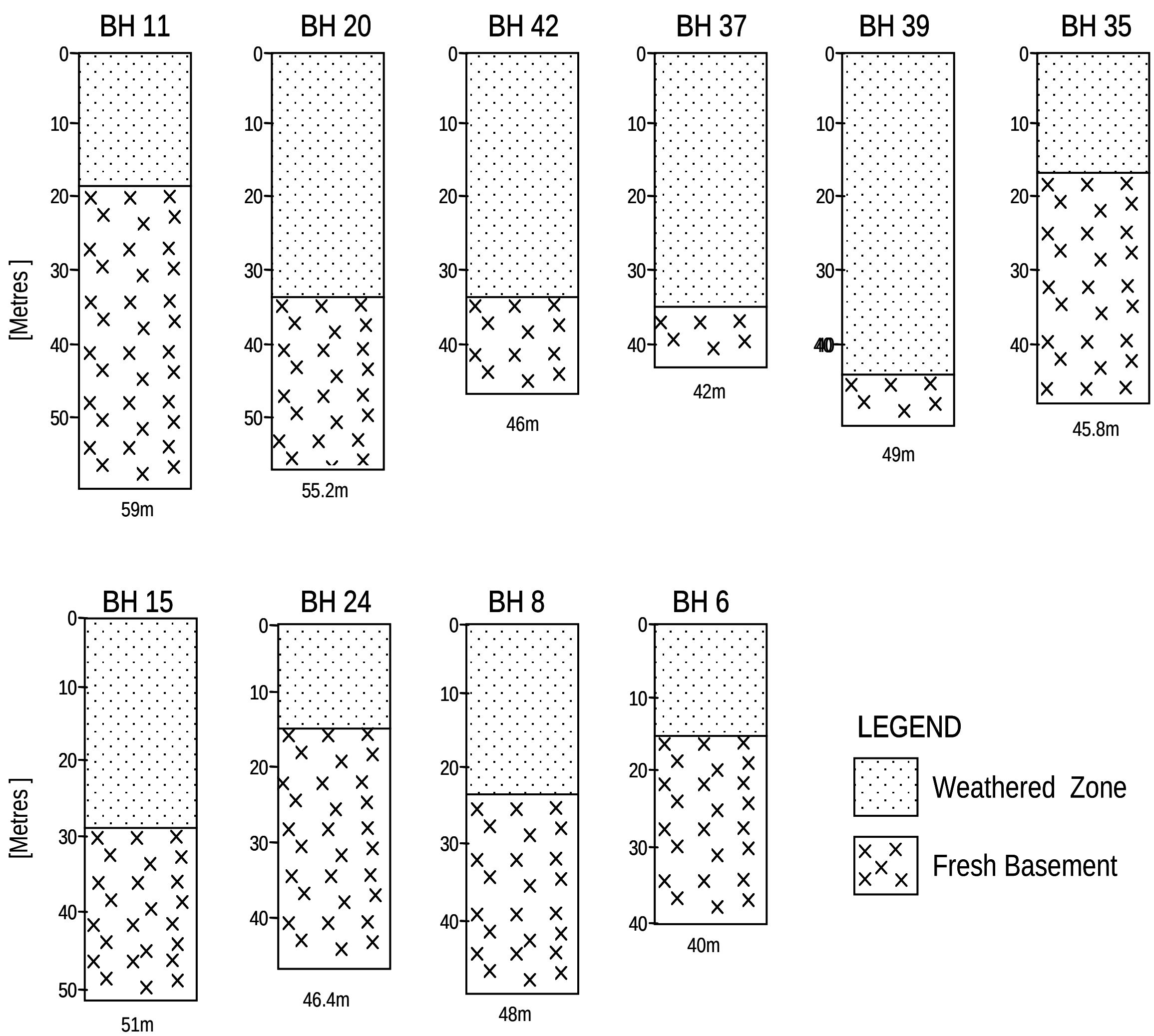

FIG. 2: LITHOLOGIC SECTION OF SOME HAND PUMP BOREHOLES IN THE BASEMENT AREAS

CONCLUSION

On the basis of borehole lithologic logs, weathered and fractured aquifer units were delineated in the area. The hydraulic properties of the basement aquifers indicate negligible to high transmissivity and moderate specific capacity values as revealed by most boreholes. This suggests boreholes of good performance for rural water supply. The aquifers have a total reserve of 281.8 x $10^6 m^3$ which is at present under exploited. The present population of the area is 1.4 x 10^6 and groundwater reserve is 281.8 x $10^6 m^3$. The recoverable reserve per capita amounts to $201.3 m^3$ per annum. With the projected population of 2.6 x 10^6 in the next 25 years at the growth rate of 2.5%, the recoverable reserve per capita is about $108.4 m^3$. The basement aquifers therefore when fully developed can sustain domestic, agricultural and industrial needs of the ever increasing population of the area. It is therefore recommended that borehole field should be designed in densely populated areas and infiltration galleries be constructed along perennial streams in order to meet the urgent water demand of the people.

ACKNOWLEDGEMENT

The authors are grateful to Comprehensive Engineering Services, Yola for assistance provided during the fieldwork aspect of this research work.

REFERENCES

Achyara, G. (2004). The role of economic analysis in groundwater management in semi-arid regions the case of Nigeria. Hydrogeology Journal, 12, 33-39.

Adelana, S.M. A and MacDonald, A.M. (2008). Groundwater research issues in Africa. In: Adelana, S.M.A. & MacDonald, A.M. (eds) Applied Groundwater Studies in Africa. IAH Selected papers on hydrogeology. 13 CRC Press Balkema, Leiden, The Netherlands.

Babatola, J.O. (1997). Rural Water Supply: Issues, Problems and Prospects. Water Resources Journal of NAH, 8 (1), 19-25.

Badafash, B.C.E. (1991). Consulting Engineers, Ibadan.

Carter, J.D., Barber, W. and Tait, E.A. (1963). The geology of parts of Adamawa, Bauchi and Bornu Provinces in Northeastern Nigeria. Bull. No. 30, Geol. Surv. Of Nigeria, 108.

Census, (1991). Population of the Federal Republic of Nigeria. Taraba State Statistical Table. National Population Commission final results of population census of Nigeria.

Chilton, P.J. and Foster, S.S.D. (1995). Hydrogeological Characterization and water-supply potential of basement aquifers in tropical Africa. Hydrogeology Journal, 3, 36-49.

Dike, E.F.C. (1994). Geology and hydrogeology of Misau and Environs Water Resources, 4 (1 & 2), 57-63.

Du Preez, J.W and Barber, W. (1965). The Distribution and Chemical quality of groundwater in Northern Nigeria. Bull. 36. Geological Survey of Nigeria, 93

Foster, S.S.D., Tuinhof A, & Garduno, H. (2008), Groundwater in Subsahara Africa – A Strategic Overview of development issues. In Adelana, S.M.A. & MacDonald, A.M.(eds) Applied Groundwater Studies in Africa. IAH Selected Papers on Hydrogeology. 13, CRC Press/Balkenia, Leiden, The Netherlands.

Ghislain, de M, (1986). Quantitative Hydrology for Engineers. Academic Press, New York.

Grant, N.K. (1971). A compilation of radiometric age from Nigeria. Journal of Mining Geology, 6, 37-54.

Jacob, C.E. and Cooper, H.H. (1946). A Generalized graphical method for evaluating formation constants and summarizing well field history. Trans. Amer. Geophysical Union, 27, 526-534.

MacDonald, A.M., Cobbing, J. & Davies J. [2005 (a)]. Developing Groundwater for rural development supply in Nigeria. British Geological Survey Commissioned Report CR/05/219N

MacDonald, A.M., Kenip, S.J. & Davies, J. [2005 (b)]. Transmissivity Variations in mudstones. Groundwater, 43, 259-269.

Macleod, W.N., Turner, D.C. and Wright, E.P. (1971). The Geology of the Jos Plateau, Geol. Surv. Nigeria, Bull. No. 32, 18.

McCurry, P. (1976). A Generalized review of the Geology of the Precambrain to Lower Paleozoic Rocks, Northern Nigeria: In Kogbe, C.A. (ed), Geology of Nigeria Elizabethan Press, Lagos, 13-38.

Offodile, M.E. (2002). Groundwater study and development in Nigeria Mecon. Services Ltd., Jos, Nigeria.

Srinivasa, R.Y., Reddy, T.V.K. and Nayudu, P.T. (2000). Groundwater targeting in a hard rock-terrian using fracture pattern modeling, Niva River Basin, Andr. Pradesh, India. Hydrogeology Journal, 8 (5) 494-502.

Todd, DE.K. (1980). Groundwater Hydrology, 2nd (ed.) J. Wiley, New York, 535.

Turner, D.C. (1964). Notes on Fieldwork on the basement rocks of 1:250,000 sheets 7 & 8. Geol. Surv. Of Nig. Report. No. 5503.

Wright, E.P. & Burgess, W.G (eds). (1992). The hydrogeology of crystalline basement aquifers in Africa. Geological Society, London. Special Publications 66

2/9/2009