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Response of Groundwater to Basin Variables in The Upper Kaduna Catchment

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Abstract - Groundwater componentis animportant contributor to total runoff within the Basement Complex rocksin Nigeria despite the dominance of regolithaquifer in the region. This paper examines the response of groundwater to basin variables in the Upper Kaduna Catchment, Nigeria.Data used in this study consists of hydro meteorological, geological and land usedata. The hydrometeorological data were obtained from the Hydro Meteorological Department of The Kaduna State Water Board, Kaduna, Nigeria,while morphometric, land use and geological data were obtained from maps. Groundwater components were derived using semi -logarithmichydrographic analysis. A total of 220 hydrographs were separated and 30 basin variables were also derived using various morphometric methods. Both descriptive and inferential methods were used in interpreting the data generated. The descriptive analyses include mean, standard deviation and graphs. The inferential methods used in this study are:moment product correlation, factor analysis, multiple regression and stepwise regression methods. Moment product correction was used to associate groundwater component and basin parameters, factor analysis was used to reduce the 30 basin variables into orthogonal factors;multiple regression was used to establish a relationship with basin variable and groundwater components, while stepwise regression was used to also establish a relationship and to also reduce the regression model to an orthogonal size. The 30 basin variables were reduced by factor analysis into 8 orthogonal variables (namely: length of mainstream, total rainfall, %younger granite, leminiscate ratio, savanna scrubland, % forest, basin scale, and % fadama) which altogether explained 84.3% of the variance. The results of the multiple regression showed that these 8 factors explained 86.0% of the groundwater pattern in the Upper KadunaCatchment. The result of the stepwise regression further showed that only 3 factors (namely: total rainfall, percentage of forest and percentage area underlain by younger granite explained 76.4% of the variance in groundwater. Two groundwater models were also generated to describe groundwater response in the catchment. The study recommends the use of the orthogonal factors in watershed management and further stressed the need for further study.

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Keywords : Groundwater, hydrograph, semi-lagarithmic separation, total rainfall, geology,land use.

I. Introduction

Studies of base flow and groundwater component of stream hydrograph have been documented for more than 100 years ago outside the tropics (Boussineq ,1904;Maillet 1905, Horton, 1933; Hall, 1968; Nothan and Mchon, 1990; Tallaksan, 1995; Smahtkin, 2001,etc). Pointing to the role of groundwater component is the experimental study of DeZeeuw (1966) where he reported that the response of drain ditches is deep enough to cut the water table. He discovered in this experiment that groundwater is generated via deep percolation of rainwater which results in water oozing out as stream along channel. Indeed, Sklash and Falvolden (1979),Abdul and Gilham, (1984), Gilham(1984) have also confirmed the role of groundwater to total runoff.

Groundwater and base flow can be influenced by several activities such as stream regulation, direct pumping , artificial diversion of water into or out a basin, or part of basin transfer, direct discharges into stream for mine dewatering activities, seasonal return flow from drainage or irrigation areas , artificial drainage of the floodplain , typically for agriculture or urban development which can enhance rapid runoff and reduced delayed drainage , changes land use , such as clearing,reforestation or changed in crop type, which can significantly alter evapotranspiration rates. Others are groundwater extraction sufficient to lower the water table and decrease or reverse the hydraulic gradienttowards the stream (Querna, 1997; Grifts and Glausen, 1997;Smakhtin, 2001; Singh, 2001; Quian, 2003; Neal, et al 2004; Bredie and Hostetler, 2005; Scanlon, 2005).Tiangi, (2003) examined the importance of basin scale on groundwater, he discovered that small or average sub basin size produces higher peak discharge , larger base flow and total runoff for floods, while similar effects on annual runoff was not discernable. Flugel (1995) also reported that interflow is also a dominant flow processes to groundwater recharge and river runoff.

Indeed, several published works have pointed to the fact that groundwater hasimportant contribution to total runoff (Christopherson, et al 1984; in Norway, Obradovic and Sklash 1986, in Canada, Hooper and Shoemaker 1986, in USA, bishop and Richard 1988 in Scotland). Also wells(1990)documented that 60% groundwater contribution to runoff. Others are Sklash and Falvolden (1969), Sklash,(1978), Dincer and (1970), Maitenence, et. al. (1979), Fritz, et al (1974).

Studies of groundwater within the basement complex in Africa have not been favoured in the past, in view of the misconception on water availability within crystalline geological formations. However, typical deep weathering profile comprising of indurated, mottled and pallid zones overlying weathered and un-weathered

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bedrock have been reported in Nigeria (Faniran, 1970;Faniran and Areola, 1978;Faniran and Ojo, 1990). For example, Faniran, (1968)and Thomas (1974) reported depth thicker than 30meters in south western Nigeria. Investigations from geophysical survey coupled with the increasing large numbers of rural communities being supported by hand pumps showed that a reasonable quantity of groundwater is found in the basement complex rocks in South Africa. Faniran and Jeje (1984) equally reported a similar geophysical data in the Dan Mangu area of Jos, Nigeria.

In view of the ephemeral nature of surface water, groundwater abstraction is often the only realistic and affordable means of providing water supply for much of Africa need (Adelana and MacDonald, 2008). It is pertinent to note that there is shortage of data on groundwater as little attention is being paid to systematic gathering of information about groundwater resources. Hence, investment is poorly targeted, expert are not consulted before projects are executed. indeed, groundwater is not understood in this part of the world, despite its potentiality towards achieving the Millennium Development Goals (MDGs) in Nigeria. Cobbing and Davies (2006) have identified the benefits of scientific approach to sustainable development of groundwater in Africa. This present study will attempt to fill some of these gaps.

II. Study Area

The Upper Kaduna Catchment (UKC) is located between latitudes 9^0 11` and longitude $6^o.0$ and $8^o.0$. Twenty river basins were selected for analysis within the catchment. The choice of the catchment is because of data availability and the fact that the study area is located within a drought prone area, where there is a seasonal water scarcity problem. It also has high rural population density with dispersed settlement pattern; the scattered nature of settlements has been a limitation to water resources development as surface water scheme will largely be unsuitable for such scattered dwellings. In addition some of the water projects of government have actually failed; hence, studies of water resources within the environment are crucial.

Rainfall in the catchment ranges between 1000mm around Ikara north East of Kaduna to 1500mm in Kagoro south of Kaduna. The higher rainfall in Kagoro is due to the orographic effects of the Jos Plateau. Vegetation in the southern part is classified as guinea savanna. Around Kaduna vegetation is largely *Isoberlina* savanna, which is intensively grazed with locust bean tree as dominant specie. Below latitude 10^0 North rainfallsare higher due to the orographic effect of Jos Plateau, situation similar to rain forest is found around Kagoro. Three relief patterns dominated the UKC landscape these are: gentle undulating landscape around Galma and Karami plains where slope is about 1-20; dissected landscape which stands above the plains where slope is greater than 5^o especially to the south east. The drainage pattern is purely dendritic, with river Kaduna as the principal drainage line. Geology is mainly pre Cambrian Basement Complex comprising undifferentiated metamorphic and igneous rocks. Rocks are gneiss, migmitite, volcanic, quartzite, porphyriticbiotite and granite rocks. Large expanse of weathered mantle is found. The soil is ferruginous in nature with compacted B-horizon, which is likely to promote higher overland flow.

The land use types are: intensively cultivated Sudan Savanna where groundnut formed a dominant crop found around Zaria, Saminaka and Ikara. There is also, rough Savanna landscape with extensive open grazing with some cultivation near Kaduna; and lastly, area of dry season farming around Kagoro. On the whole, all these land use types are likely to promote high surface runoff.

III. Materials and Methods

a) Data Base and Data Generation

The runoff and climatic data used in this study covers an 11 year period (1979-1989) for which data are available. These data were obtained from the Hydrological Department of the Kaduna State Water Board, Kaduna.

The morphometric parameters were extracted from Nigerian topographical map series (1:50,000) series (Table 1). Many researchers (e.g. Okechukwu, 1973; Anyadike and Phil-Eze, 1989), have adopted 1:50,000 map series in various studies. The sheets used in this study are: 100-103, 123-126, 144-147 and 165-168 covering the UKC and published by Northern Nigeria Survey (1966). Physiographic attributes of land use and geology such as the percentage are under each geological and land use types were extracted from the 1:500,000 Geological and Land use Maps prepared for the Kaduna State Agricultural Development Project (KADP) by AERMAP of Florence, Italy, 1987. A total of 30 basin variables given in Table 2 were examined in this study. Twenty sub-basins were selected within the Upper Kaduna Catchment for this study (Figure 1).

Table 1 : Derivation of Basin Morphometric parameters

s/n	Morphometric variables	Procedure of derivation
1.	Length of mainstream	Length of principal drainage line in km(Smith,1956)
2.	Total stream length	Length of all the tributaries and principal drainage line in km (Smith,1950)
3.	Maximum relief	Differences between the highest and lowest points on a basin(Strahler,1952)
4.	Basin Length	Length of the basin along the most distant point(Schumn,1963)
5.	Basin area	Calculated via graphical method (Anderson,1957)
6.	Total segment of 1^{st} order stream	Sum of all 1 basins (Horton,1952)
7.	Total segment of 2^{nd} order streams	Sum of all second order stream (Horton,1952)
8.	Bifurcation ratio	Ratio of lower order to a higher order (Strahler,1964)
9.	Relief ratio	Rh=H/L, H=horizontal distance L=length of the basin along the principal drainage line (Schumn,1950)
10.	Drainage density	(∑L)/L; ∑L; H=horizontal distance, L=length of the basin (Solokov,1969)
11.	Miller's circularity ratio	CR=A/AC;A=Area of the basin (Miller's,1953)
12.	Form factor	F=A/L2: A=Area of the basin, L=Length of the basin along (Horton,1932)
13.	Lemniscate ratio	K=L2/4A, L=length of the basin. A=basin area (Chorley, et al 1957)
14.	Total stream segments	∑L=sum of all the length (Horton,1932)
15.	Channel mean slope	Lm=H/L: H= change in slope, L=Length of the basin (Horton,1932)

Source : Selected references.

IV. Hydrograph Separation

Altogether, 220 hydrographs were computed for the 20 sub basins for the 11 year of study. The h groundwater hydrographs were computed using graphical logarithmic method (Barnes, 1939; 1940; Linsley, 1982; Olu, 1995 and Smakhtin, 2001). A typical separated hydrograph of Kogun at Kagoro is presented in Fig 1.

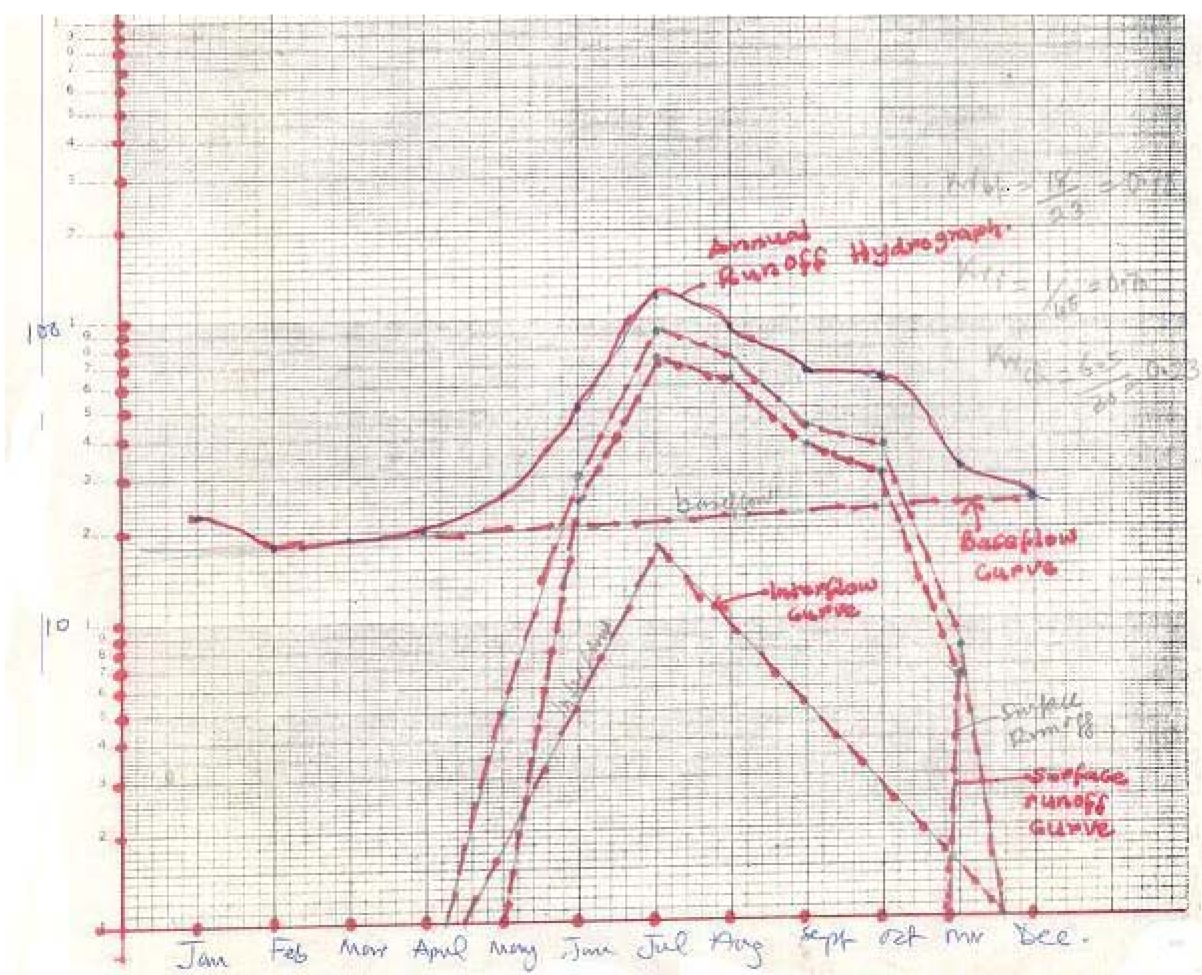

Fig.1 : A sample of separated hydrograph of Kogun at Kagoro (1989)

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V. Statistical Method

Correlation analysis was used to examine the types of associations existing among the thirty basin variables. Factor Analysis was adopted in other to overcome the problem of multicollinearity; hence, it was adopted to rewrite the 30 basins parameters to orthogonal factors.

The multiple regression method was used to establish a relationship between total runoff and the factor scores of the eight orthogonal factors derived from the result of factor analyses to predict runoff response to total runoff. In addition to the above, the linear regression model was also used to order the individual contribution of the 8 orthogonal factors to total runoff using the result of the stepwise multiple regression as input.

Table 2 : Basin Parameters

a. Morphometric variables	1.lenght of mainstream(km)
	2.total stream length(tsl)
	3. maximum relief (ts1)
	4.basin area (a)
	5. basin length (bl)
	6. total segment of 1st order (tsl)
	7.total segment of 2nd order basins (ts2)
	8. bifurcation ratio (rh)
	9. relief ratio (rh)
	10. drainage density (dd)
	11. circularity ratio (cr)
	12.form factor (Fa)
	13. leminiscate ratio (k)
	14.total stream segments (tss)
	15. basin order (bn)
b. Geological variables	16. percentage area of undifferentiated Basement Complex
	17. percentage area of volcanic rock (%vol)
	18. percentage area of porphyritic biotite (%pb)
	19. percentage area of undifferentiated granite (%ug)
	20. percentage area of younger granite (%yg)
	21. percentage area of quartzite (%qzt)
c. Land use variables	22. percentage area under forest (%for)
	23. percentage area under savannah (%sav)
	24. percentage area under fadama (%fad)
	25. percentage area under urban (%urb)
	26. percentage area under cultivation (%cut)
	27. percentage area under rock outcrop (%roc)
d. Hydrometeorological variables	28. dry season rainfall (dsr)
	29. wet season rainfall (wsr)
	30. total rainfall (tr)

Source : Authors computation

VI. Result and Discussion

a) Multivariate relationshipbetween groundwater and selected basin parameters.

According to Table 3 out of the thirty variables in this study only four basin variables significantly correlated with groundwater flow. These are drainage density, percentage of the basin on rock outcrop, wet season runoff and total rainfall. All these have positive relationshipwith groundwatercomponent implying that as these variables increases groundwater increases.

Table 3 : Moment product correlation between groundwater runoff and basin variables

S/N	Basin Variables	Correlation Coefficient
1	1.Lenght Of Mainstream(Km)	-0.07
2	2.Total Stream Length(Tsl)	-0.01
3	3. Maximum Relief (mrh)	-0.16
4	5. Basin Length (Bl)	-0.08
5	4.Basin Area (A)	-0.06
6	6. Total Segment Of 1st Order (Tsl)	0.00
7	7.Total Segment Of 2nd Order Basins (Ts2)	-0.02
8	8. Bifurcation Ratio (Rh)	-0.03
9	9. Relief Ratio (Rh)	-0.04
10	10. Drainage Density (Dd)	0.46*
11	11. Circularity Ratio (Cr)	-0.15
12	12.Form Factor (Fa)	-0.19
13	13. Leminiscate Ratio (K)	0.07
14	14.Total Stream Segments (Tss)	-0.17
15	15. Basin Order (Bn)	-0.09
16	16. Percentage Area of Undifferentiated Basement Complex	-0.29
17	17. Percentage Area Of Volcanic Rock (%Vol)	0.24
18	18. Percentage Area Of Porphyritic Biotite (%Pb)	-0.11
19	19. Percentage Area Of Undifferentiated Granite (%Ug)	-0.02
20	20. Percentage Area Of Younger Granite (%Yg)	0.48*
21	21. Percentage Area Of Quartzite (%Qzt)	-0.21
22	22. Percentage Area Under Forest (%For)	0.35
23	23. Percentage Area Under Savannah (%Sav)	0.11
24	24. Percentage Area Under *Fadama* (%Fad)	0.07
25	25. Percentage Area Under Urban (%Urb)	0.13
26	26. Percentage Area Under Cultivation (%Cut)	-0.02
27	27. Percentage Area Under Rock Outcrop (%Roc)	-0.38
28	28. Dry Season Rainfall ((Dsr)	0.68*
29	29. Wet Season Rainfall (Wsr)	0.31
30	30. Total Rainfall (Tr)	0.68*

Source: Authors computation

Note: values between 0.42 and 0.52 are significant at 95%; Values >0.52 are significant at 99%

Of all the fifteen variables drainage density is the only one that is significantly correlated with groundwater.This is excepted because high drainage density quite suggestshigher groundwater level, suggesting that spring lines are common in the UKC. The strong association between percentage of the basin on rock outcrops and groundwater is expected because areas of major rockoutcrops coincide with spring lines, particularly areas of younger granite rocks which doubles as the edge of the Jos plateau system but also forms the headwaters of river Kaduna the ring complex of UKC. The strongpositive relationship between total rainfall and wet season rainfall and groundwater is also expected since these two hydro metrological variables are the major sources of groundwaterrecharge in the UKC.

b) Factors controlling groundwater runoff

The results obtained above were further subjected to factor analysis method; in other to overcome multi co-linearity problems; eight factors emerged with a total explanation of 84.27% of the variance (Table 4).

I. Factor I is tagged basin length of mainstream. This factor has the highest contribution to groundwater component. 9 other areal variables equally loaded positively high on this factor. This factor is **an index of basin magnitude.**

II. Factor II (total rainfall) contributes 14.6% explanation. It is referred to as total rainfall.Only 2 variables loaded highly on this factor. These are wetseason rainfall is equally highly loaded in the factor this is expected since these rainfall indices are mainly responsible for groundwater recharge on the UKC. This factor is **an index of basin rainfall.**

III. Factor III (undifferentiated basement complex) this factor contributed 10.4% to the variance. Four factors loaded highly on this factor: relief ratio,%rock outcrop, % younger granite, and % undifferentiated basement complex which has the highest loading. This factor is **an index of basin geology**.

IV. Factor IV (circularity ratio) contributed 9.4 % to the explanation of the variance. It has strong loadings on the three shape attributes namely: circularity ratio, form factor and lemniscates ratio. It is **an index of basin shape.**

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V. Factor V (percentage of the basin on savanna scrubland. Savannah scrubland covers about 80% of the total Land use of the UKC. The percentage area of undifferentiated granite is also a dominant rock of the basement complex family. This factor explains 7.12% of the variance. It is **an index of water repellence.**

VI. Factor VI (percentage of the basin on forest). This factor contributed 6.81% explanation. Two variables strongly load on this factor (percentage on forest and percentage area on quartzite) this pattern of loading suggest high water seepage. Hence, this factor is **an index of water ingress**.

VII. Factor VII (basin slope). This factor contributed 6.4% to the explanation. It has high loadings on 3 variables namely: namely basin relief, bifurcation relief, and basin scale. It is **an index of basin scale**

VIII. Factor VIII (percentage of the basin on *fadama*). *Fadama*refers to wetlands which are normally found in the flood plains. This factor contributed 5.92% explanation to the variance. The percentage area cultivated is equally highly loaded on this factor. This is expected because extensive *fadama*land in the study area, are extensively cultivated for dry season farming. This factor is **an index of basin agriculture**.

Table 4 : Factor scores, eigen values and percentages contributions of basin variables

S. no.	Basin variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
1	lm	0.96*	-0.02	0.02	-0.20	0.04	0.04	0.03	0.04
2	tsl	0.95*	0.07	0.10	0.06	0.12	0.25	-0.01	0.03
3	mrh	0.46	-0.31	0.35	-0.07	-0.10	-0.41	0.53	-0.02
4	bl	0.90*	-0.08	0.04	-0.37	0.01	0.03	0.00	0.06
5	A	0.96*	0.02	0.02	0.00	0.12	0.15	-0..09	0.06
6	ts1	0.92*	0.06	-0.04	0.10	0.13	0.30	0.06	0.08
7	ts2	0.90*	0.03	-0.02	0.12	0.16	0.34	0.04	0.02
8	br	-0.15	0.21	-0.36	-0.13	-0.08	0.01	0.35	-0.35
9	rh	-0.02	-0.17	0.65	-0.01	-0.15	-0.11	-0.05	-0.06
10	dd	0.00	-0.15	-0.20	0.40	-0.18	-0.24	0.28	-0.23
11	cr	-0.08	-0.14	0.18	0.91*	0.01	0.18	-0.19	0.04
12	fa	-0.02	-0.15	-0.01	0.89*	0.21	0.18	-0.10	0.21
13	K	0.10	-0.01	-0.09	**0.91***	-0.01	0.13	0.01	-0.06
14	tss	0.79*	-0.19	-0.06	0.20	0.18	0.17	0.32	-0.08
15	bn	0.48	-0.07	0.14	-0.20	0.02	0.03	**0.71***	-0.18
16	%cut	-0.08	-0.37	-0.39	0.14	-0.11	-0.03	-0.06	-0.75*
17	%sav	0.09	0.12	-0.10	0.06	**0.90***	0.04	-0.02	-0.12
18	%for	0.34	-0.03	-0.14	-0.06	0.06	**0.79***	0.07	-0.04
19	%urb	0.75*	0.23	-0.11	-0.09	-0.08	-0.24	-0.09	0.09
20	%roc	-0.04	0.37	0.74	0.09	-0.03	-0.10	0.16	0.13
21	%fad	-0.01	0.06	-0.24	0.11	-0.06	-0.02	-0.06	**0.91***
22	%vol	-0.27	0.59	0.30	-0.04	-0.19	0.10	0.45	0.15
23	%yg	0.11	-0.06	**0.89***	0.08	-0.13	-0.02	-0.14	-0.11
24	%ug	0.22	-0.11	-0.09	0.01	0.89*	0.21	0.04	0.17
25	%pb	0.75	0.17	-0.04	-0.09	-0.11	-0.34	-0.02	-0.09
26	%qzt	0.35	-0.06	0.02	0.41	0.36	0.72*	-0.03	0.05
27	%ubc	-0.07	-0.35	-0.80*	-0.06	-0.19	-0.13	-0.23	-0.08
28	wsr	0.23	0.92*	-0.05	-0.12	-0.07	-0.03	0.09	0.16
29	dsr	-0.34	0.47	-0.10	-0.14	0.17	0.15	0.70*	0.12
30	tr	0.18	**0.94***	-0.06	-0.13	-0.05	-0.01	0.08	0.16
GW_o		-0.06	0.81	0.25	-0.09	0.28	-0.07	0.13	-0.17
Factor Defining Variable		Length of mainstream	Total rainfall	Younger granite	Lemniscates ratio	% savanna	% forest	Basin order	% fadama
Factor Description		Index of basin magnitude	Index of basin rainfall	Index of basin geology	Index of basin shape	Index of water repellence	Index of porosity	Index of basin scale	Index of basin agric.
Total Eigen Value		7.88	1.53	3.21	2.92	2.21	2.11	1.99	1.81
% Variance		25.13	11.59	10.35	9.12	7.12	6.81	6.11	5.92
% Cumulative Variance		25.13	10.02	50.37	59.78	66.9	73.71	80.12	86.01

Source: Authors computation

c) Relationship between groundwater and runoff factors.

The result of the regression analysis eight response factors contributed 84.3% to the response of groundwater. Thisis presented in Table 5.

Table 5 : Multiple Regression Model Summary of Groundwater and Basin Variables

Variable		Regression coefficient	Standard error	t-test	Sig level	R^2 %
Intercept		32.681		30.36	.000	
1.	Length Of Mainstream	-.563		-.51	.620	
2.	Total Rainfall	-3.491		-3.16	.009	
3.	% Younger Granite	-3.363		3.04	.011	
4.	Lemniscates ratio	-1.359		.244		84.3
5.	%Savanna Scrubland	6.504		5.67	.000	
6.	% Forest	.797		.72	.486	
7.	Basin Scale	.0067		.06	.952	
8.	% Fadama	2.003		1.81	0.97	

Source : Author's computation

This relationship can be described in eqation3

$$GWR_O = 32.681 - 0.56lm - 0.3.491tr + 3.363\%yg - 1.359k + 6.504\%sav + 0.797\%for + .07\%bn + 2.003\%fad .... \text{(eq. 1)}$$

$$(R^2 = 84.3\%;\ SE = 4.81)$$

Further analysis using stepwise regression method showed that only three basinfactors are most important in the explanation of groundwater response in the UKC. This presented in Table 6. These factors are total rainfall (49%), percentage forest (14.2%) and % granite (12.2%). These factors contributed 76.4%. This is presented in equation 2.

Table 6 : Stepwise regression model summary of groundwater and basin variables

Variable		Regression coefficient	Standard error	t-test	Sig level	R^2 Explained	R^2 Cumulative Explained
Intercept		32.681	1.96	29.8	.00	-	-
1.	Total Rainfall	6.504	1.13	5.76	.00	49	49
2.	Percentage Forest	-3.49	1.13	-3.14	.007	14.2	63.2
3.	% Younger granite	2.982	1.13	2.98	.009	12.2	76.4

Source : Authors computation.

VII. Discussion of Result

Length of mainstream is an areal index of the basin. Basin lengthis indicative of basin size. Large basins will have long mainstreams. Further, large basins will have high base flow contribution to runoff hydrograph, all things working well (Ward, 1990). The dominance of total rainfall in groundwater response in the study is expected, in view of the fact that both dry season rainfall and wet season rainfall are the most significant mode of groundwater recharge in the Kaduna catchment. More importantly, Ledger, (1964; 1969) also underscored the dominance of rainfall events to runoff response with examples from parts of West Africa. In Nigeria, Ogunkoya, (1984) reported that dry season rainfall has a strong impact on basin response to runoff in a south-western Nigerian study. Also, Todd (1980), Ward (1980), and Querer, (1997) established strong relationships between rainfall and groundwater recharge. The nature of basin geology in the UKC is also indicative of the pattern of response to basin parameters. Two major geological types are most common: these are undifferentiated basement complex rocks and younger granite rocks. In many parts of the UKC these 2 main rocks have formed rock outcrops, which has in turned became springs and head water for many streams, examples are Kagoro hill, Assob falls, Kufena Hill, and the ring complex massif surrounding the Jos plateau. This suggests that basement complex rocks, younger granite, and rock outcrops play significant role in the nature of groundwater response. Ogunkoya, et al (1984), Adejuwon, et. al. (1983) and Anyadike and Phil-Eze (1989) have all reported the role of basin geology in runoff response studies in Nigeria. Basin shape in the Upper Kaduna catchment range from elongated to circular. The shape of the basin will determine the response of groundwater. The elongated basins generally have high groundwater response. This is expected in view of the fact that elongated basins are normally large basins and therefore they tend to release more base flow, since they are matured and have eroded into their saprolite to the water table, hence they yield more base flow into the runoff hydrograph.

The impact of forest on groundwater has been pointed out. For example groundwater recharge has been found to be related toland use and land cover (Sanion, 2005; Querer, 1997, Garcia, et al. 1995). Dry season rainfall remain the major recharge term in the six month of dry season ; hence it is crucial to the response of base flow otherwise known as dry weather flow. A similar relationship was reported for southwest Nigeria by Ogunkoya,et.al. (1984).

a) Spatial pattern of groundwater response.

The impacts of the runoff underlying factors differ from one basin to the other(Table7; Fig 2(a-h)). Factor I (basin size) dominate the explanation of groundwater in Galma at Ribako and Gubunchi, Assob at Assob,Karami at Kauru. These basins are all large in all. The impact is least in Jamana at soba. Total rainfall dominates explanation in Assob at Assob the wettest basin, Kogun at Kagoro these are wet basin they receive the highest rainfall. This factor is of least dominant in Kahugu at Ikara a basin with the least rainfall. Factor III (%UBC) has its strongest influence in Galma at Gubunchi and Assob and of least impact in Tubo at Kaduna. Factor IV which is tagged circularity ratio dominate in Kogun at Ugwan Rimi, and least in Galma at Kuzuntu. Factor (% savanna dominated in Shaho at Kachia, and Chalwe at Zango Kataf. percentage of forest dominatedChalwe a t Zango Kataf. dry season rainfall is strong in Dorogoin at Kwoi, Kogun at Kagoro, Kogun at Ugwan Rimi (See : table 7). Factor 8 is dominant in Kachia at Kachia and Tubo at Lagos road it is least in Soba at Zango Kataf.

Table 7 : Factor scores depicting spatial pattern of basin variables

Sub Basins	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII	Factor VIII
	Length of mainstream	Total rainfall	% younger granite	Leminiscate ratio	% savanna	% forest	Basin order	% fadama
1.Galma at Ribako	2.87	0.79	-0.84	-0.16	-1.66	0.09	0.41	-.59
2. Karami at Saminaka	-0.22	-0.91	0	-0.41	-0.01	0.99	0.52	-0.2
3. Jamana at Soba	-0.79	-0.91	-0.84	0.46	-0.32	-0.42	1.03	0.36
4. Kogun at Kagoro	-0.54	0.92	-0.44	0.71	0.12	0.37	1.05	0.52
5. Kogun at Ugwan Rimi	-0.66	0.75	0.74	1.28	-1.13	0.44	-1.28	-0.43
6. Shika at Kano Road	-0.41	-0.7	0.51	-1.26	0.09	-0.87	0.79	0.37
7. Shaho at Kachia	-0.34	0.12	0.03	1.47	1.46	-1.80	0.07	-2.65
8. Kachia at Kachia	0.05	-0.04	-1.35	0.75	1.21	0.22	-0.52	2.18
9. Tubo at Kaduna Road	2.14	-0.81	2.72	1.24	1.16	-0.22	0.09	1.17
10. Galma at Gubunchi	0.60	-0.51	-1.33	-0.56	0.67	-1.49	-2.13	-1.20
11.Kwassau at Zonkwa	-0.53	0.86	-0.54	0.19	0.55	0.51	0.32	0.85
12. Chalwe at Zango Kataf	-0.2	-0.96	0.16	-0.8	1.46	2.46	-0.23	-1.64
13. Gurara at Galan	-0.24	0.42	-1.06	0.57	0.41	0.09	0.13	0.32
14. Assob at Assob	0.75	2.78	1.62	-1.49	-1.41	-0.14	-0.16	0.04
15. Dorogoin at Kwoi	-0.78	-0.02	0.38	0.61	0.42	-1.20	1.43	-0.09
16. Galma at Kuzuntu	-0.14	-0.4	0.16	-2.34	0.20	-1.32	-0.39	0.66
17. Kogun at Jagindi	-0.04	0.88	-0.19	0.34	-1.47	1.08	-0.33	0.07
18. Kahugu at Ikara	-0.57	-1.29	0.43	-0.21	-0.47	0.58	0.85	0.03
19. Kudan at Hunkuyi	-0.70	-1.29	0.65	0.19	-2.01	0.09	-1.77	0.06
20. Karami at Kauru	1.29	0.29	-0.81	-0.87	-0.31	0.43	0.99	-0.81

Source : Authors computation.

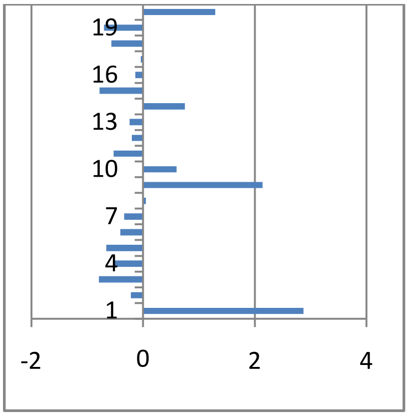

Fig.2 (a) Lenght of mainstream

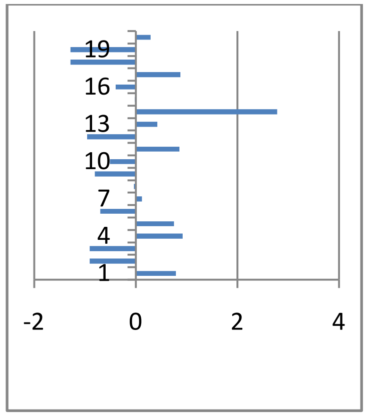

Fig. 2 (b): Total Rainfall

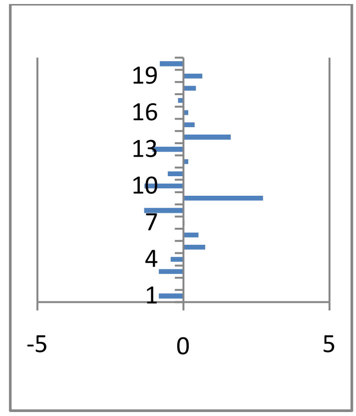

Fig.2 (c) % younger granite

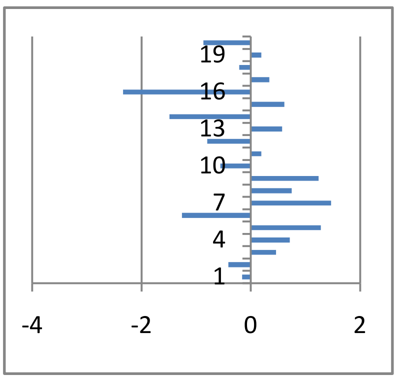

Fig. 2(d): Leminiscate ratio

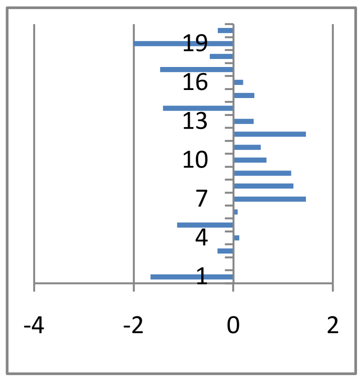

Fig. 2(e) % Savanna

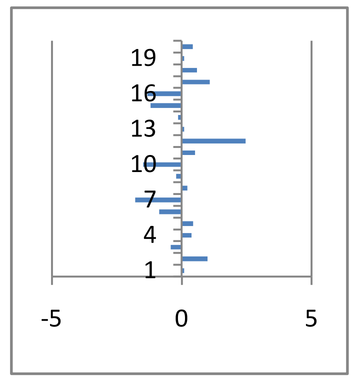

Fig. 2 (f): % Forest

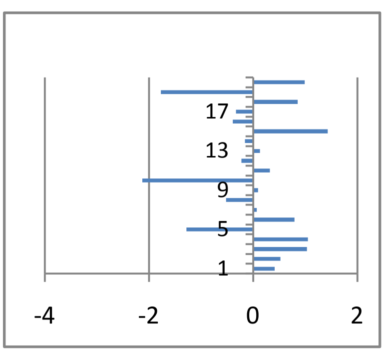

Fig. 2 (g) : Basin scale

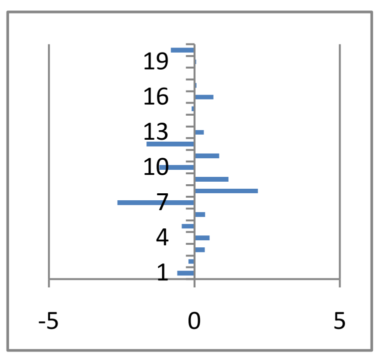

Fig.2 (h): % *Fadama*

Key for sub basins

1.	*Galma at Ribako*	*11.*	*Kwassauat Zonkwa*
2.	*Karami at Saminaka*	*12*	*Chalwe at Zango Kataf*
3.	*Jamana at Soba*	*13*	*Gurara at Gatan*
4.	*Kogun at Kagoro*	*14*	*Assob at Assob*
5.	*Kogun at Ugwan Rimi*	*15*	*Dorogoin at Dorogoin*
6.	*Shika at Kano Rd.*	*16*	*Galma at Kuzuntu*
7.	*Shaho at Kachia*	*17*	*Kogun at Jagindi*
8	*Kachia at Kachia*	*18*	*Kahugu at Ikara*
9	*Tubo at Lagos Rd.*	*19*	*Kudan at Hunkuyi*
10.	*Galma at Gubunchi*	*20*	*Karami at Kauru*

Fig. 2 : (a-h) Spatial patterns of loadings of basin factor scores of groundwater components in the Upper Kaduna Catchment

VIII. Conclusion

The results of the 220 separated hydrographs showed that Groundwater is major contributor to total runoff hydrograph in the basement complex; this is because deep regolith aquifers have been discovered in many parts of the basement complex sometimes as basin of decomposition. Despite the relevance of groundwater to rural water supply in the basement complex rocks few works are available on the response of groundwater to basin parameters particularly in northern Nigeria. The 30drainage basins variables considered in this study were reduced to only eight defining factors with a total explanation of 84.3% explanation. This implies the other 22 variables explained 15.7%. This confirms that there is high level of redundancy in the equation. Implying that groundwater in the UKC is largelyby these factors. Further analysis by stepwise regression analysis showed that only three of these eight factors, namely: total rainfall, percentage of forest and dry season rain fall were most relevant, as they explained 76.4% of the variance. However, a lot still has to be done in the understanding of the response patterns of groundwater to basin variable in Nigeria.

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