

MODELING VARIATION IN SEASONAL WATER LEVELS OF BAUCHI TOWNSHIP RESERVOIR

¹Abdullahi IBRAHIM & O.I NDUBUBA²

¹Department of Civil Engineering,
Nigerian Defence Academy, Kaduna.

² Civil Engineering Programme,
ATBU Bauchi.

ABSTRACT

Inadequate of potable water and its likely poor quality have been man's age big problem. In Bauchi Township the main source of water supply is through Gubi dam, though the available water in the dam varies in quantity and quality due to seasonal changes. This research was carried out to establish the relationship between reservoir water level in Gubi dam and rainfall, temperature, evaporation, relative humidity and wind speed in Bauchi., using data from meteorological records in Bauchi and Gubi dam water supply from the period 1997 to 2003. The study was carried out using software package known as Polymath Polynomial, statistica and Mini-Tab R14, employing multiple regression analysis.. The result of the analysis gave high value of the multiple regressions coefficient R of 0.827377 for the dependent variable Y with the independent variable X close to 1. This shows that the relationship is positively significant between the dependent variable Y with the independent variable X. Similarly this high value of R also indicated that the dependent variable Y with the independent variable X are correlated

INTRODUCTION

Hydrological analysis and designs require information on flow rate at any point of interest along a stream. However, in most cases, this information may not be available in sufficient quantity due to lack of (inadequate of stream gauging or non-availability of records. Faced with these difficulties, engineers and planners resort to the use of mathematical approaches such as synthesis and simulation as tools to generate artificial flow data for use in design for water supply, structures sizes flood control measures e.t.c. (Mustafa and Yusuf 1997).

A mathematical model is simply a quantitative expression of a process or phenomenon one is observing, analyzing, or predicting (Gang,y and et al,2002). The developing nations with the advent of science and technology improved ways of making water available in appreciable quantities and of safe quality though, the rural communities are still having problem with acute shortage and poor quality of water caused by drought and pollution (Collins, 1983). Rainfall harvesting, spring water, direct intake from streams; ground water and impoundment of rivers are possible sources of water that can be developed for use in rural areas(Jasem AM,2002) (Faniran,1983) discussed that, for any locality most of these source are available for development.(Fair and et al 1971) in their findings concluded that the nature of the water source commonly determines the planning design and operation of the distribution work. Common sources of fresh water are: - rain water, surface water and ground water. (Hofkes, 1981) found out almost all surface water will require some treatment before it can be used for domestic purpose

THE STUDY AREA

Bauchi township is the study area and is located at 10° 04' N and 9° 09' E. It lies within the tropical climatic zone with marked wet and dry season. Fig.1 is the map of Bauchi State showing the study area.

THE GUBI DAM

The source of water in Gubi dam is mainly coming from three tributaries, namely Gubi River, Tagway river link with Shadawanka and Ran river. The function of the dam is to supply the state capital and its environs with potable water. A Temporary dam close to the site was constructed across one of the streams to provide water needed for the construction of the permanent dam. The embankment of the dam which has length of 3.86km and bottom earth-fill of 2,315, 000m³ with a reservoir area of 590 hectares. The catchments area is 17,900 hectares with total storage capacity of 38.4 x 10⁶m³, the expected yield from the reservoir is 90,000m³/d.(BSWB,1981) The cross sectional dimensions of the dam is shown in Fig. 2.

METHODOLOGY AND DATA COLLECTION

The method of analysis applied for this research work is regression analysis.

Regression analysis is often carried out to establish the relationship between two or more hydrological variables (Adeleye and et al, 2003). The general equation in n independent variables is

$$y = a_0 + a_1x_1 + a_2x_2 + \dots\dots\dots a_nx_n \quad (1)$$

The linear model in two independent variables with Y the dependent variables has the form

$$Y = a_0 + bx_1 + c_2x_2 \quad (2)$$

Constant a, b, and c can be determined by the method of least square and x₁ and x₂ are independent variables.

The normal equations are expressed as:

$$\sum y = \sum a + b \sum x_1 + c \sum x_2 \quad (3)$$

Multiply equation 3 by x₁ and x₂ respectively and summing

$$\sum yx_1 = a\sum x_1 + b \sum x_1^2 + \sum x_1x_2 \quad (4)$$

$$\sum yx_2 = a\sum x_2 + b \sum x_1 x_2 + c\sum x_2^2 \quad (5)$$

the multiple correlation coefficient is

$$R = (1-s_e^2 /s_y^2)^{1/2} \quad (6)$$

where Se = standard error of estimate given as

$$S_e^2 = \frac{1}{n-3} \sum (y_i - \hat{y}_i)^2 \quad (7)$$

where Y_i are the observed values and y_i are predicted by equation (2), S_y is the standard deviation of y. The form of equation (Mustafa and Yusuf, 1997) for standard error of estimate from equation (6) is

$$S_e^2 = S_y (1-R^2) \quad (8)$$

Multiple regression equation involving more than three variable is written as

$$\bar{y}_i = a + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + \dots\dots\dots b_mx_{mi} + e_i \quad (9)$$

The value of the estimation a, b₁, b₂,...b_m can be obtained by direct extension of the least square approaches. Assuming a sample of n observation (ie, I = 1,2,...n), it is again

necessary to minimize the sum of the squared deviation of the individual value Y_i about the predicted value \hat{y}_i

$$\sum_{i=1}^n (y_i - \hat{y}_i)^2 = \sum_{i=1}^n (y_i - a - b_1x_{1i} - b_2x_{2i} \dots \dots b_mx_{mi})^2 \tag{10}$$

When the normal equation involves only one or two independent variable (ie two or three equation) then solving these equation for a and b₁ or a and b₂ is usually relatively simple. For the equation involving many independent variable the used of computer is necessary. the normal equations are as follows

$$n_a + b_1 \sum x_{1i} + b_2 \sum x_{2i} \dots \dots b_m \sum x_{mi} = \sum y_i \tag{11}$$

$$a \sum x_{1i} + b_1 \sum x_{1i}^2 + b_2 \sum x_{1i}x_{2i} \dots \dots b_m \sum x_{1i}x_{mi} = \sum x_{1i}y_i \tag{12}$$

$$a \sum x_{2i} + b_1 \sum x_{1i}x_{2i} + b_2 \sum x_{2i}^2 + \dots \dots b_m \sum x_{2i}x_{mi} = \sum x_{2i}y_i \tag{13}$$

$$a \sum x_{mi} + b_1 \sum x_{1i}x_{mi} + b_2 \sum x_{2i}x_{mi} + b_m \sum x_{2i}m_i = \sum x_{mi}y_i \tag{14}$$

The multiple standard error of the estimate is given as:

$$Se = \sqrt{\frac{1}{n-m-1} \sum_{i=1}^n ie^2} \tag{15}$$

where n = no of samples, m = number of independent variable and e = error of estimate
 The mean of predicted value is the same as the mean of observed value. The discrepancy between the observed value Y_i and the predicted value \hat{y}_i is the residual ie $(Y_i - \hat{y}_i)$

3.0 RESULTS AND DISCUSSION

The result of the analysis obtained is expressed as:

$$\hat{y} = 559.7316015 - 0.006973x_5 - 0.125336x_4 - 77.71812089x_3 - 1.760586599x_2 - 0.060594074x_1 \dots \dots \tag{16}$$

where x_1 = temperature, x_2 = rainfall, x_3 = evaporation, x_4 = relative humidity, x_5 = wind speed and 559.7316015 is a constant. The values of x_1, x_2, x_3, x_4 and x_5 which can be substituted in equation (16) are shown in Table 4. Similarly any value of mean monthly temperature (x_1) mean monthly Rainfall(x_2), mean monthly Evaporation(x_3), mean monthly R/humidity (x_4) and mean monthly wind speed(x_5) measured at a given particular time can be substituted in the equation (16) to obtained the predicted change of water level in Bauchi township reservoir. Similarly, a regression analysis can be carried when two or more of the independent variable varies.

The standard deviation for x_1, x_2, x_3, x_4 and x_5 is shown in (Table 1), similarly R^2 value, standard error (y), variance, and sum of square is also shown in (Table 2).The R^2 which is known as multiple coefficient of determination is an estimate of the strength of the relationship
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variables. Similarly, the multiple correlation (R) obtained is statically significant with value
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independent variable combined., see (table3)

TABLE 1: Multiple Linear Regressions including a free parameter.

Multiple Linear Regression, including a free parameter						
	a5	a4	a3	a2	a1	a0
Coefficients	-0.006973	-0.125336	-77.71812089	-1.760586599		559.7316015
Std.dev.s	0.0008794	0.619878878	26.43849566	10.77900049		0.820554927
R², SE (y)	0.6845522	0.528468305				
95% conf. int.	0.0017235	1.214962601	51.81945149	21.12684097	0.046810382	1.608287656
Variance	0.2792787					
Sum of Squares	21.783742					
Model	$Y_Exp = a_5 * x_5 + a_4 * X_4 + a_3 * X_3 + a_2 * X_2 + a_1 * X_1 + a_0$					

TABLE 2: Summary output of Regression Statistics and ANOVA analysis

SUMMARY OUTPUT					
Regression Statistics					
Multiple R	0.827377				
R Square	0.684552				
Adjusted R Square	0.664331				
Standard Error	0.528468				
Observations	84				
ANOVA ANALYSIS					
	df	SS	MS	F	Significance F
Regression	5	47.27283	9.454567	33.85351	3.17873E-18
Residual	78	21.78374	0.279279		
Total	83	69.05658			

TABLE 3: Intercept, coefficients of regression equation and standard error of the variables X

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	559.7316	0.820555	682.1379	5E-149	558.0980021	561.3652	558.098002	561.3652
X Variable 1	-0.06059	0.023883	-2.53714	0.013171	-0.108141171	-0.01305	0.10814117	-0.01305
X Variable 2	-1.76059	10.779	-.16333	0.870677	-23.21992778	19.69875	23.2199278	19.69875
X Variable 3	-77.7181	26.4385	-2.93958	0.004322	-130.3531216	-25.0831	130.353122	-25.0831
X Variable 4	-0.12534	0.619879	-0.20219	0.840291	-1.359420027	1.108748	1.35942003	1.108748
X Variable 5	-0.00697	0.000879	-7.92993	1.29E-11	-0.008723846	-0.00522	0.00872385	-0.00522

TABLE 4: Data for the Modeling Analysis

Mean
monthly
draw.d/rise
(masl)
Y

S/No	Year/Month		Mean Monthly Temp. (°C) X ₁	Mean Monthly Rainfall (m) X ₂	Mean Monthly Evapo (m/d) R/X ₃	Mean Monthly R/Humidity X ₄	Mean Monthly Wind Speed (m/d) X ₅
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1997							
1	January	555.642	35.584	0.000	0.006	0.280	112.500
2	February	555.642	34.793	0.000	0.007	0.250	245.833
3	March	555.359	38.484	0.000	0.008	0.270	183.333
4	April	554.860	38.867	0.010	0.010	0.400	300.000
5	May	554.702	36.516	0.014	0.009	0.600	237.500
6	June	554.681	32.667	0.011	0.005	0.630	220.833
7	July	554.826	31.387	0.013	0.001	0.690	217.391
8	August	556.660	30.483	0.023	0.002	0.680	150.000
9	September	557.051	30.666	0.033	0.003	0.620	120.833
10	October	557.015	32.290	0.006	0.005	0.480	129.167
11	November	556.798	32.166	0.000	0.006	0.420	75.000
12	December	556.530	32.806	0.000	0.009	0.320	91.667
1998							
13	January	556.132	31.129	0.000	0.007	0.300	179.167
14	February	555.814	34.248	0.000	0.008	0.200	179.167
15	March	555.700	35.516	0.000	0.009	0.210	183.333
16	April	555.344	40.100	0.004	0.010	0.320	216.667
17	May	554.630	35.161	0.014	0.010	0.430	354.167
18	June	554.836	34.966	0.018	0.009	0.480	266.667
19	July	554.841	32.903	0.023	0.008	0.650	312.500
20	August	556.261	30.890	0.027	0.007	0.770	129.167
21	September	557.259	30.333	0.018	0.006	0.780	125.000
22	October	557.070	31.480	0.003	0.005	0.600	83.333
23	November	556.738	31.866	0.000	0.006	0.400	119.583
24	December	556.445	32.830	0.000	0.007	0.360	201.667
1999							
25	January	556.043	32.880	0.000	0.013	0.380	200.000
26	February	555.681	33.220	0.000	0.012	0.410	156.250
27	March	555.285	35.880	0.000	0.013	0.300	116.667
28	April	554.014	38.770	0.008	0.013	0.350	270.833
29	May	554.771	36.200	0.019	0.008	0.450	262.500
30	June	554.587	34.600	0.020	0.010	0.600	195.833
31	July	555.439	32.400	0.015	0.009	0.590	162.500
32	August	557.194	30.660	0.021	0.008	0.780	87.500
33	September	557.096	31.020	0.026	0.005	0.770	79.167
34	October	557.110	32.110	0.009	0.005	0.700	50.000
35	November	556.814	31.240	0.000	0.005	0.490	54.167
36	December	556.500	30.260	0.000	0.009	0.400	58.333

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2000							
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37	January	556.146	32.387	0.000	0.009	0.340	103.333
38	February	555.766	29.897	0.000	0.010	0.250	220.833
39	March	555.414	35.580	0.000	0.012	0.240	191.667
40	April	555.124	28.666	0.010	0.015	0.410	254.167
41	May	554.780	37.645	0.020	0.010	0.540	266.667
42	June	554.747	32.700	0.024	0.005	0.710	262.500
43	July	555.004	30.506	0.016	0.004	0.740	220.833
44	August	557.011	39.322	0.019	0.004	0.780	55.333
45	September	557.064	31.166	0.018	0.003	0.750	241.667
46	October	556.977	32.677	0.005	0.003	0.650	33.333
47	November	556.745	34.133	0.000	0.008	0.310	29.167
48	December	556.526	30.806	0.000	0.009	0.290	50.000
2001							
49	January	555.968	30.677	0.000	0.010	0.340	120.833
50	February	555.728	31.964	0.000	0.011	0.250	85.417
51	March	555.383	36.774	0.000	0.013	0.330	105.000
52	April	554.992	37.366	0.006	0.009	0.540	148.333
53	May	555.893	34.354	0.017	0.006	0.480	310.417
54	June	555.038	31.866	0.018	0.004	0.680	241.667
55	July	556.204	29.774	0.017	0.002	0.750	220.833
56	August	557.277	29.354	0.018	0.002	0.690	179.167
57	September	557.243	29.866	0.015	0.003	0.750	200.000
58	October	556.938	32.484	0.001	0.006	0.580	145.833
59	November	556.635	33.933	0.000	0.009	0.490	104.167
60	December	556.348	32.580	0.000	0.009	0.320	133.333
2002							
61	January	556.003	28.000	0.000	0.009	0.340	175.000
62	February	555.527	32.642	0.000	0.011	0.360	191.667
63	March	555.089	37.226	0.000	0.013	0.530	187.500
64	April	554.639	37.700	0.026	0.010	0.520	318.333
65	May	554.231	38.664	0.007	0.009	0.640	321.667
66	June	553.852	34.900	0.016	0.007	0.580	330.000
67	July	554.742	32.032	0.014	0.004	0.710	223.333
68	August	555.319	29.032	0.017	0.003	0.780	160.000
69	September	556.968	30.133	0.021	0.003	0.790	102.917
70	October	556.962	31.677	0.005	0.005	0.630	87.083
71	November	556.690	32.666	0.000	0.008	0.420	51.667
72	December	556.363	31.226	0.000	0.009	0.320	97.917
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
2003							
73	January	556.136	28.000	0.000	0.010	0.350	86.250
74	February	555.554	32.642	0.000	0.012	0.210	104.583
75	March	555.281	37.226	0.000	0.013	0.240	190.417
76	April	555.048	37.7	0.008	0.011	0.430	325.000
77	May	554.900	38.064	0.024	0.011	0.590	213.750
78	June	555.026	34.9	0.027	0.004	0.670	247.917
79	July	555.867	32.032	0.010	0.003	0.730	241.583
80	August	555.891	29.903	0.015	0.002	0.770	172.500

81	September	557.114	30.133	0.019	0.003	0.780	115.833
82	October	557.012	31.677	0.004	0.004	0.680	72.916
83	November	556.737	32.666	0.000	0.008	0.480	70.417
84	December	556.452	31.226	0.000	0.008	0.300	112.917

Table 5: A result of the modelling analysis for predicted value and residual

(a)	(b)	(c)	(d)	(e)	(f)
S/no	Yr/month	Y_Exp	Y_Exp calc	Y_Exp residual	Y_Exp residual ^2
	1997				
1.	Jan	555.642	556.2895349	0.64753486	0.419301395
2.	Feb	555.642	555.3337499	-0.308250063	0.095018101
3.	mar	555.359	555.465697	0.106696956	0.01138424
4.	April	554.86	554.4396121	-0.420387916	0.176726
5.	May	554.702	555.0635019	0.361501914	0.130683634
6.	Jun	554.681	555.7253449	1.044344883	1.090656234
7.	Jul	554.826	556.1267382	1.300738179	1.691919811
8.	Aug	556.66	556.5573751	-0.102624929	0.010531876
9.	Sep	557.051	556.6618676	-0.389132431	0.151424049
10.	Oct	557.015	556.4149969	-0.600003073	0.360003688
11.	Nov	556.798	556.7405931	-0.057406883	0.00329555
12.	Dec	556.53	556.3649699	-0.165030067	0.027234923
	1998				
13.	Jan	556.132	556.0143747	-0.117625265	0.013835703
14.	Feb	555.814	555.7601973	-0.053802703	0.002894731
15.	mar	555.7	555.5753422	-0.124657793	0.015539565
16.	April	555.344	554.9665871	-0.377412885	0.142440486
17.	May	554.63	554.2756543	-0.35434567	0.125560854
18.	Jun	554.836	554.9620336	0.126033571	0.015884461
19.	Jul	554.841	554.8150448	-0.025955159	0.00067367
20.	Aug	556.261	556.2710726	0.01007263	0.000101458
21.	Sep	557.259	556.4261909	-0.832809133	0.693571052
22.	Oct	557.07	556.7739289	-0.296071087	0.087658089
23.	Nov	556.738	556.4503922	-0.287607821	0.082718259
24.	Dec	556.445	555.7468872	-0.698112796	0.487361476
	1999				
25.	Jan	556.043	555.2866664	-0.756333632	0.572040563
26.	Feb	555.681	555.6450996	-	0.001288836
27.	mar	555.285	555.6960082	0.411008151	0.1689277
28.	April	554.014	554.4255105	0.411510451	0.169340852
29.	May	554.771	554.9960354	0.225035394	0.050640929

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32.	Aug	557.194	556.5071534	-0.686846645	0.471758314
33.	Sep	557.096	556.7690519	-0.326948101	0.106895061

34.	Oct	557.11	556.945095	-0.164905018	0.027193665
35.	Nov	556.814	557.0109204	0.196920369	0.038777632
36.	Dec	556.5	556.74166	0.241659994	0.058399553
	2000				
37.	Jan	556.146	556.3065029	0.160502856	0.025761167
38.	Feb	555.766	555.5715919	-0.194408096	0.037794508
39.	mar	555.414	555.2764351	-0.13756485	0.018924088
40.	April	555.124	554.9874906	-0.136509358	0.018634805
41.	May	554.78	554.7109426	-0.069057408	0.004768926
42.	Jun	554.747	555.3998787	0.652878723	0.426250627
43.	Jul	555.004	555.9114169	0.907416905	0.823405439
44.	Aug	557.011	556.5209879	-0.490012146	0.240111903
45.	Sep	557.064	555.7990889	-1.264911108	1.600000111
46.	Oct	556.977	557.1957057	0.218705744	0.047832203
47.	Nov	556.745	556.7993577	0.054357665	0.002954756
48.	Dec	556.526	556.7804702	0.25447021	0.064755088
	2001				
49.	Jan	555.968	556.2103697	0.242369717	0.05874308
50.	Feb	555.728	556.3129099	0.58490988	0.342119568
51.	mar	555.383	555.7194332	0.336433216	0.113187309
52.	April	554.992	555.6553805	0.663380539	0.440073739
53.	May	555.893	554.9289549	-0.964045118	0.929382989
54.	Jun	555.038	555.6877284	0.64972844	0.422147045
55.	Jul	556.204	556.1081941	-0.095805938	0.009178778
56.	Aug	557.277	556.42993	-0.847069956	0.71752751
57.	Sep	557.243	556.173695	-1.069305003	1.143413188
58.	Oct	556.938	556.2055756	-0.732424444	0.536445567
59.	Nov	556.635	556.1882084	-0.446791626	0.199622757
60.	Dec	556.348	556.0881191	-0.259880882	0.067538073
	2002				
61.	Jan	556.003	556.0725812	0.069581208	0.004841545
62.	Feb	555.527	555.5171383	-0.00986166	9.72523E-05
63.	mar	555.089	555.091689	0.00268904	7.23093E-06
64.	April	554.639	554.3392761	-0.299723891	0.089834411
65.	May	554.231	554.3537437	0.122743741	0.015066026
66.	Jun	553.852	554.6708233	0.818823337	0.670471658
67.	Jul	554.742	555.8087986	1.066798617	1.13805929
68.	Aug	555.319	556.4958769	1.176876938	1.385039327
69.	Sep	556.968	556.818918	-0.149082046	0.022225456
70.	Oct	556.962	556.7285612	-0.233438848	0.054493696
71.	Nov	556.69	556.7175654	0.02756536	0.000759849
72.	Dec	556.363	556.4171261	0.054126111	0.002929636
	2003				
73.	Jan	556.136	556.6124806	0.476480641	0.227033801
74.	Feb	555.554	556.0654742	0.511474193	0.26160585

75.	mar	555.281	555.1076957	-0.173304325	0.030034389
76.	April	555.048	554.2580385	-0.789961494	0.624039162
77.	May	554.9	554.9635269	0.063526882	0.004035665
78.	Jun	555.026	555.4457116	0.419711641	0.176157861
79.	Jul	555.867	555.7637916	-0.103208415	0.010651977
80.	Aug	555.891	556.4384272	0.547427236	0.299676579
81.	Sep	557.114	556.7336267	-0.380373279	0.144683831
82.	Oct	557.012	556.9005623	-0.11143771	0.012418363
83.	Nov	556.737	556.5792978	-0.157702176	0.024869976
84.	Dec	556.452	556.3927531	0.059246949	0.003510201

CONCLUSION

The method of regression analysis can be used to establish the relationship between dependent variable Y and independent variable X with the method above, the Model equation obtained is $\hat{y} = 559.7316015 - 0.006973 x_1 - 0.125336x_2 + 77.71812089x_3 - 1.760586599x_4 + 0.060594074x_5$, where x_1 = Temperature, x_2 = Rainfall, x_3 = Evaporation, x_4 = R/humidity, x_5 = wind speed and 559.7316015 is constant. These models equation can be used to predict the future reservoir water level in Gubi dam using the equation above by substituting the parameters x_1, x_2, x_3, x_4 and x_5 under the giving condition. The model equation is tested to compare the observed value and expected value as shown in table 5.

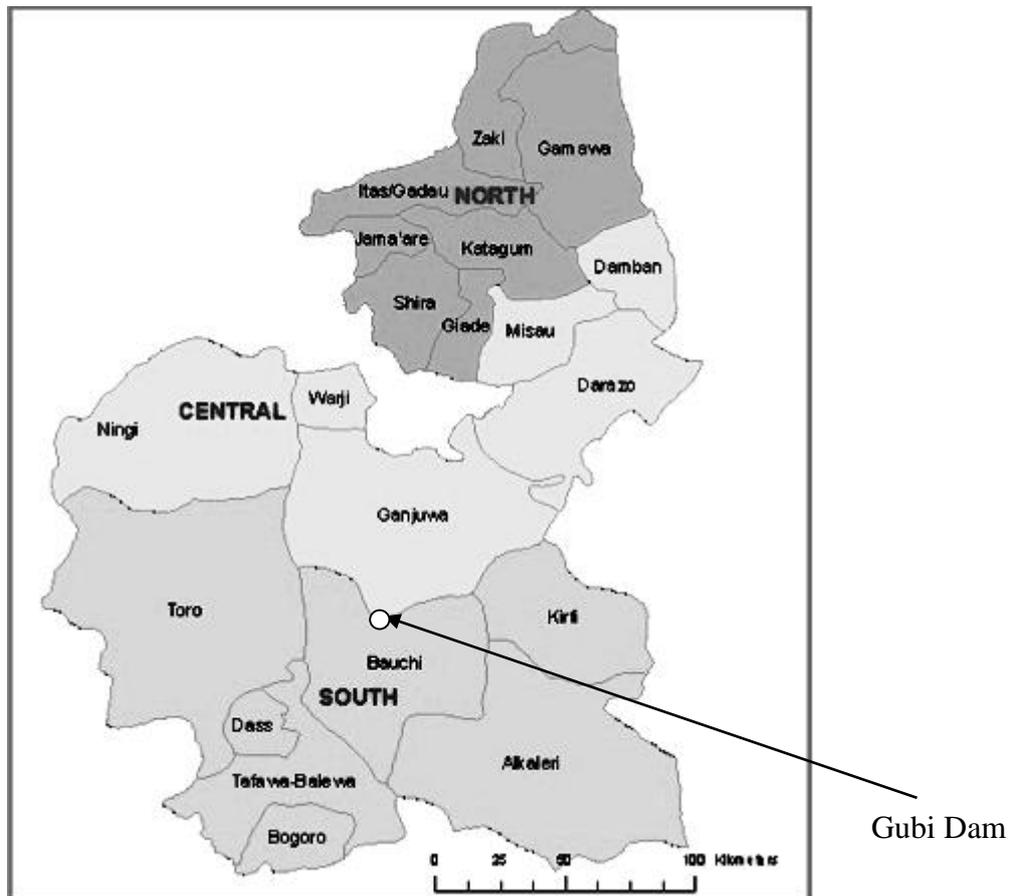


Fig. 1 Map of Bauchi State

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