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Application of Statistical Model of Water Level Variation in Reservoir Bauchi Township

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Abstract

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 continuous record 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 sequences for use in design regarding water supply, structures sizes flood control measures e.t.c. The water resources planners and designers will therefore continue to employ modeling techniques to simulate hydrologic processes and catchment behavior Mustafa and Yusuf (1997). The source of a water supply for the study area is through Gubi dam. During rainy season the reservoir level begin to increase up to a maximum value of 557.37m especially from the period of September to November, while at the period of December to around June draw down to minimum of 553m.The analysis of result was obtained by Least square method and moving average method of order 3 to forecast the future drawdown/rise up of water level in the reservoir and the future equation for water drawdown/rise up of reservoir. In the analysis of result, the regression equation is obtained to be equal to Water level(Y) = 556 + 0.00228 Month(X). In the trend analysis the equation was obtained as Yt = 555.774 + 2.43E-03*t with the graph plotted for the trend. The seasonality was removed living behind the trend line equation as seen from the graph.

These equations can be used to determine the reservoir water level at any time t (month). In the second analysis by the average method of order 3, the result in the first forecast that is in 1998 the forecasted drawdown/rise up is 556.734 while upper and lower values are 554.944 and 558.524 respectively. The analysis was forecasted using average method of order 3 for the period of 30years that is from 1997 to 2027.

Introduction

With world population growing rapidly the water reservoir of the world are becoming one of the most important assets. Water is essential for human consumption and sanitation, for the production of many industrial goods and for the production of food and fibre. Water is an important means of transport in many part of the world and a significant factor in recreation. Water is unequally distributed about the earth and its availability at any place varies greatly with time. The total supplies of fresh water on earth far exceed human demand. Most of mankind lives in areas, which receives an abundance of annual rainfall. The provision of water to urban areas requires major capital investment in storage, treatment, and supply networks. Furthermore the per capita consumption of water has generally tended to increase rather than decrease, although this can be expected to be largely a function of life style and population density Jasem (2002). 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 10^0 04' N and 9^0 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, Tagwaye 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, 000m^3 with a reservoir area of 590 hectares. The catchments area is 17,900 hectares with total storage capacity of 38.4 x 106m^3, the expected yield from the reservoir is 90,000m^3/d.(BSWB,1981) The cross sectional dimensions of the dam is shown in Fig. 2 below

Figure 1. Map of Bauchi state

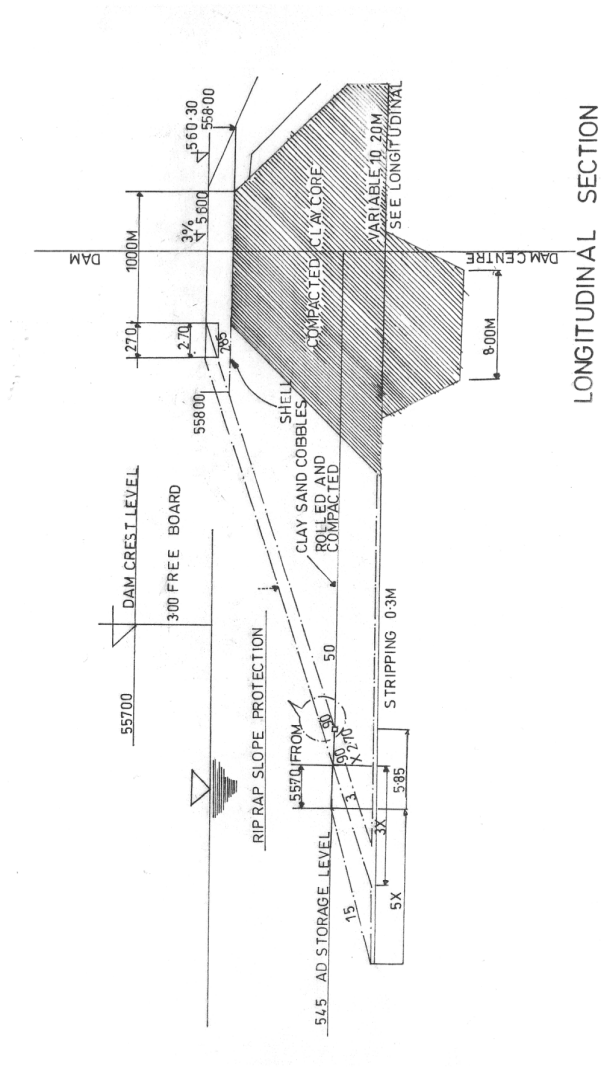

Figure 2. Cross-section of Gubi dam

The dam start with temporary construction, which was constructed across one of the streams at the permanent dam site to provide water needed for the construction of the permanent dam. In the temporary dam about 500 million gallons of water which is equivalent to $2.27\times10^4 m^3$ was impounded while construction of the permanent dam was going on, it was decided to make use of the temporary dam to supplement the water supply to the town. Consequently in take arrangements were made, a treatment plant and pumping mains were provided. Thus the scheme with a capacity of 6,820m^3/day was put in operation on 30th may, 1980 by His Excellency the Governor of Bauchi, Alhaji Abubakar Tatari Ali.

The salient features of the scheme are:

(a) **The temporary dam:** this as mentioned earlier was only intended for construction purposes. The life span of the dam is only three years, but all

the facilities provided can easily be removed to another dam when the main dam is ultimately commissioned.

(b) **Intake works and pumping Mains:** considering the nature of the temporary dam, the intake structure has been provided on pontoons. A total of five pumps have been installed. Four pumps working at a time discharging 340m^3/h and the fifth pump as a stand by.

About three kilometer length of 300mm diameter AC raw water pumping main conveys the water to the treatment plants for purification with a 169KVA generating supplying power to the intake pumps.

(c) **Water treatment plant:** The raw water is purified in four units of the treatment plant with each unit designed to treat 85m^3/h. the raw water is mixed with chemical and then passed to a function chamber where sedimentation takes place. From this stage, the clear water is pumped for filtration. The filter media is sand of size 1.15mm thick and supported on a nozzle plate. The filtered water is disinfected with calcium hypo-chlorite solution and stored in a 1250m^3 capacity reservoir. The purified water is then pumped to the town to distribution. The power station of the treatment plant consist of two 653 KVA generator sets.

Surface Water

The source of a water supply for the study area is through Gubi dam. During rainy season the reservoir level begin to increase up to a maximum value of 557.37m especially from the period of September to November, while at the period of December to around June draw down to minimum of 553m

Reservoir

The basic purpose of impounding reservoir is to hold runoff during period of high runoff, and release it during period of low runoff; the specific functions of reservoir are hydroelectric flood control, irrigation, water supply and recreation. Many large reservoirs are multipurpose.

The use of reservoir for temporarily storing stream flow often results in a net loss of total stream flow due to evaporation and seepage. While these losses may not be desired the benefits derived from regulation of water supplies from flood water storage, from hydroelectric power and from any recreational activities at the reservoir site may offset the hydrologic losses and the cost of reservoir storage capacity can be divided among three(3) major uses:-

(i) The active storage used stream flow regulation and for water supply.

(ii) The dead storage required for sediment collection, recreational development hydropower production.

(iii) The flood storage capacity reservoir to reduce potential downstream flood damage in the design of storage reservoir to serve as a water supply system for any community, it has been further recommended that judgment be based on the equalizing or operating storage which can be read from a demand curve during 12 and 24 hours respectively. The total amount storage is desirably equal to the sum of the component requirement which include domestic, industrial and commercial, public uses fire demand losses e.t.c Augustine (1997).

Methodology and Data Collection

Bauchi Township being the study area, the main source of water supply is through surface water, which is obtained from Gubi dam. The main source of water in the dam is mainly coming from three tributaries that is Gubi river Tagwaye river link with shadawanka and Ran River.

The source of any water supply on the use of reliable data-over a length of time is very vital. Data collection has been carried out to provide a suitable data base for the hydrological Analysis of water level variation in reservoir in Bauchi township water supply source. These include:

(1) Discharge record of Gubi dam.

(2) Data on important design features of the dam embankment and reservoir

(3) Climatologically data of Bauchi township

Discharge Records of Gubi Dam

Daily water level recording from Gubi dam reservoir obtained from Bauchi state water board showed the level of water for the period of 1997 to 2003. According to the information, the dam was established and operated in 1981 and has been the main source of water supply to the people of Bauchi township but no record of daily reservoir level since then until 1997. Where records are been kept. The values of draw down and rise in the reservoir are calculated from the daily reservoir level record as shown in Appendix. 1 There is a rise in reservoir from period of May-Sept

Method of Analysis

Trend Analysis

In time series analysis the hydrologic data is plotted against time, this plot will revealed the characteristic of the data such as trend seasonally or cyclic component and various component.

Estimator of trend can be achieved in one of the following ways:

1. **The Method of least square:** This can be used to find the equation of an appropriate trend line on trend curve.

2. **Free hand method:** This consists of fitting the trend line or curve by simply looking the trend line or curve by simply looking at the graph.
3. **Moving average method:** This is carried out by using moving average of appropriate order. Cyclical, seasonal and irregular path may be eliminated, those living only trend movement.
4. **Method of semi-average:** This consists of separating the data into two part (preferable equal) and averaging the data in each part. This gives two parts that can be joint to give trend line.

Here, method 1 and 3 are applied for the analysis. Using the data by the application of MINI TAB R14 the result was obtained as follows:

Regression Analysis: Water level(Y) versus Month(X)

The regression equation is
Water level(Y) = 556 + 0.00228 Month(X)

Predictor	Coef	SE Coef	T	P
Constant	555.781	0.201	2766.49	0.000
Month(X)	0.002284	0.004124	0.55	0.581

S = 0.9160 R-Sq = 0.4% R-Sq (adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.2574	0.2574	0.31	0.581
Residual Error	82	68.7992	0.8390		
Total	83	69.056			

Trend Analysis

Data Water level(y)
Length 84.0000
NMissing 0

Fitted Trend Equation

Yt = 555.774 + 2.43E-03*t

Accuracy Measures

MAPE: 0.141148
MAD: 0.784562

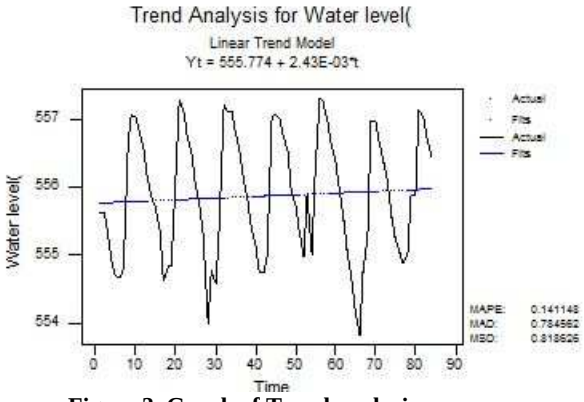

Figure 3. Graph of Trend analysis

Moving average

Data Water level(Y)
Length 84.0000
NMissing 0

Moving Average
Length: 3

Accuracy Measures
MAPE: 0.135833
MAD: 0.755370
MSD: 0.833941

Row	Period	Forecast	Lower	Upper
1	1998	556.734	554.944	558.524
2	1999	556.734	554.944	558.524
3	2000	556.734	554.944	558.524
4	2001	556.734	554.944	558.524
5	2002	556.734	554.944	558.524
6	2003	556.734	554.944	558.524
7	2004	556.734	554.944	558.524

Row	Period	Forecast	Lower	Upper
8	2005	556.734	554.944	558.524
9	2006	556.734	554.944	558.524
10	2007	556.734	554.944	558.524
11	2008	556.734	554.944	558.524
12	2009	556.734	554.944	558.524
13	2010	556.734	554.944	558.524
14	2011	556.734	554.944	558.524
15	2012	556.734	554.944	558.524
16	2013	556.734	554.944	558.524
17	2014	556.734	554.944	558.524
18	2015	556.734	554.944	558.524
19	2016	556.734	554.944	558.524
20	2017	556.734	554.944	558.524
21	2018	556.734	554.944	558.524
22	2019	556.734	554.944	558.524
23	2020	556.734	554.944	558.524
24	2021	556.734	554.944	558.524

25	2022	556.734	554.944	558.524
26	2023	556.734	554.944	558.524
27	2024	556.734	554.944	558.524
28	2025	556.734	554.944	558.524
29	2026	556.734	554.944	558.524
30	2027	556.734	554.944	558.524

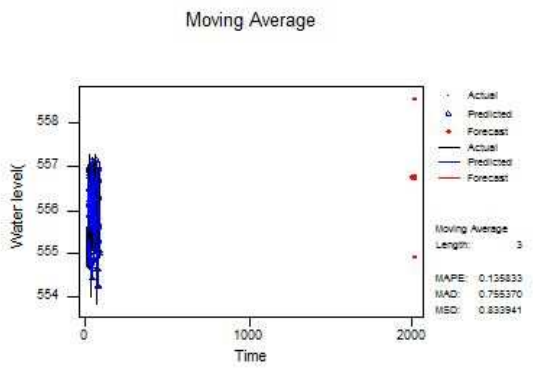

Figure 4. Graph of moving Average of order 3

Reference

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Table 1: Data for the Modelling Analysis

S/No	Year/Month	Mean monthly draw.d/rise (masl)	Mean Monthly Temp. (^oC) 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
(a)	**(b)**	(c)	(d)	(e)	(f)	(g)	(h)
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
(a)	**(b)**	(c)	(d)	(e)	(f)	(g)	(h)
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

2000							
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
(a)	**(b)**	(c)	(d)	(e)	(f)	(g)	(h)
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
(a)	**(b)**	(c)	(d)	(e)	(f)	(g)	(h)
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)(2003)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
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