Hydrology of River Oyun and Hydropower Potential of Unilorin Dam, Ilorin, Kwara State, Nigeria

[1]Sule, B.F, [2]Salami, A.W, [2]Bilewu, S.O, [2]Adeleke, O.O and [3]Ajimotokan, H.A.

[1]National Centre for Hydropower Research & Development
[2]Department of Civil Engineering, and [3]Department of Mechanical Engineering,
P.M.B 1515, University of Ilorin, Ilorin, Nigeria
salami_wahab@unilorin.edu.ng

Abstract: The paper presents the hydrological analysis of Oyun River and estimation of hydropower potential of Unilorin dam. The study involves estimation of design floods from extreme rainfall through convolution with unit hydrograph ordinates obtained from soil conservation services method. The domestic & institutional water requirement, evaporation losses over reservoir area and reservoir sediment were also determined. The Oyun River flow at Unilorin dam was estimated from the extended flow obtained at upstream gauging station on the river dammed at Offa. The peak and low flows were fitted with Gumbel extreme value type I and III respectively and return period (recurrence interval) of peak flow (19.34 m^3/s) was obtained as 40 year, while low flow (0.0020 m^3/s) may reoccur annually. In order to determine available flow for power generation, sequent peak and flow duration analysis were carried out. The analysis revealed that the flow of 50%, 75%, and 90% reliability that is available for energy generation from Oyun River at Unilorin dam is 1.45 m^3/s, 0.70 m^3/s, and 0.45 m^3/s respectively, while the corresponding hydropower potential was obtained as 0.108 MW, 0.052 MW and 0.034 MW respectively. It is recommended to provide 3 units of turbine with 100 KW, 50 MW and 35 KW generating capacity respectively. Hence the total maximum energy potential of Unilorin dam is about 200 kilowatt.
[Sule, B.F, Salami, A.W, Bilewu, S.O, Adeleke, O.O and Ajimotokan, H.A. **Hydrology of River Oyun and Hydropower Potential of Unilorin Dam, Ilorin, Kwara State, Nigeria**. New York Science Journal 2011;4(1):69-78]. (ISSN: 1554-0200). http://www.sciencepub.net/newyork.

Keywords: Oyun River, hydrology, Water resources, Unilorin dam, Hydropower

1. Introduction

The estimated long term power demand of Nigeria was put at 25GW for the year 2010 to sustain industrial growth (Okpanefe and Owolabi, 2001). The Power Holding Company of Nigeria (PHCN) has an installed capacity of 6GW, but actual available output is less than 2.5GW. Of this, thermal plants provide 61%, while hydropower generation is about 31% (Olivia, 2008). The overall potential of hydropower generation of Nigeria is in excess of 11GW (Zarma, 2006). This mean that less than 20% of the hydropower potential of the country has been realized. The development of a mini hydro scheme at Unilorin Dam is thus a giant stride in the right direction.

Power is a very important infrastructure in the overall development of a nation. There is therefore, an ever increasing need for more power generation in all countries of the world. In true global perspective of power demand, most countries of the world are formulating methods and devices to explore the various possibilities of energy generation. From the criterion of mass generation, thermal, hydro and nuclear are most prominent. Other sources like solar currently have limited contribution. Among the disadvantages of hydropower projects is that it is capital intensive and have long gestation periods (Dandekhar, 1992). However, where there are existing storage facilities as at Unilorin Dam, both cost and gestation period is reduced.

The Unilorin Dam was commissioned in 2007 primarily for water supply, is located on the Oyun River. The Dam is a zoned earthfill embankment with an ogee-shaped concrete spillway. The intake for water supply and the low lift pumping station are located on the wing wall. The Dam parameters are shown in the table 1.

Table 1. Relevant Details of the Unilorin Dam

S/NO	ITEM	DETAILS
A	RESERVOIR	
1.	Catchment area	573 km^2
2.	Average Annual Yield (Catchment Runoff)	$50.53 \times 10^6\ m^3$
3.	Live storage	$1.54 \times 10^6\ m^3$
4.	Dead storage	$0.26 \times 10^6\ m^3$
5	Surface area @ elevation 294 m amsl	$0.696 \times 10^6\ m^2$
6	Reservoir capacity @ elevation 294 m amsl	$1.80\ 10^6\ m^3$
7.	Length of the river	48.30 km
8.	Fetch	6.10 km
B	DAM EMBANKMENT	
1.	Type	Zoned Earthfill

		embankment
2.	Crest Elevation	EL 296.50
3.	Crest length	178 m
4.	Top width	5 m
5.	Maximum height of embankment	10.30 m
6.	Maximum height of earth core	8.90 m
7	Maximum length of base	31.40 m
8	Base of the earth core	21.40 m
9	Upstream slope	1:3
10	Downstream slope	1:2
11	Upstream and downstream slope of earth core	1:1
	SPILLWAY	
1.	Type	Ogee-shaped concrete spillway
2.	Crest length	50 m
3.	Crest elevation	EL 294
D	Maximum height	7.70 m
1.	Maximum flood discharge	434.81 m^3/s
2.	Freeboard height	2.50 m

Source: Technical Report on Unilorin dam by CIWAT Engineering Consultants

2. Hydrology of Oyun River at Unilorin Dam

2.1 Estimation of design floods from extreme rainfall for catchment of Unilorin dam

In many parts of the world, rainfall and runoff data are seldom adequate to determine a unit hydrograph of a basin or watershed. This situation is common due to lack of gauging stations along most of the rivers and streams. Generally, basic stream flow and rainfall data are not available for planning and designing water management facilities and other hydraulic structures in undeveloped watershed. However, techniques have evolved that allow generation of synthetic unit hydrograph. This includes Snyder's method, Soil Conservation Service (SCS) Method, Gray's Method and Clark's Instantaneous Unit Hydrograph Method. This study applied US Soil Conservation Service methods to develop unit hydrographs and subsequently used to generate peak storm hydrographs of rainfall depth of various return intervals through convolution.

2.1.1 Soil Conservation Service (SCS) method

US Soil Conservation Service method was used to develop dimensionless unit hydrograph for many drainage areas of varying sizes and different geographical locations The peak discharge and the time to peak were determined in accordance to the standard method and the results are used to plot unit hydrographs, which was adopted in the establishment of storm hydrographs of desired return periods. The parameters used are estimated based on equations 1-4

Peak discharge:

The peak discharge can be obtained through the equation (1)

$$Q_p = \frac{0.208 * A * Q_d}{t_p} \qquad (1)$$

where

Q_p = peak discharge (m^3/s); A = watershed area (km^2);
Q_d= quantity of run off (mm) and
t_p = time to peak (hr)

Time to peak (t_p) and lag time (t_l)

$$t_p = \frac{t_r}{2} + t_l$$

$$t_p = \frac{t_c + 0.133 t_c}{1.7} \qquad (2)$$

$$t_l = 0.6 t_c \qquad (3)$$

$$t_c = 0.0195 \left(\frac{L^{0.77}}{S^{0.385}} \right) \qquad (4)$$

Where t_c = time of concentration (min) and t_r = rainfall duration (min), L = length of channel (m); S = slope of channel

The estimated values for both the peak discharge and time to peak were applied to the dimensionless hydrograph ratios in accordance to SCS and the points for the unit hydrograph were obtained (Raghunath, 2006) and used to develop the unit hydrograph curve.

2.1.2 Development of unit hydrograph

The watershed characteristics obtained from the topographic map of the River catchment under consideration in accordance to Ramirez (2000) and Arora (2004) are presented in Table 2.

Table 2 Parameters for the generation of unit hydrograph

River watershed	L (km)	t_L (hr)	t_r (hr)	t_c (hr)	t_p (hr)	q_p (m^3/s)	A (km^2)	S (%)
Oyun River	48.3	8.31	1.51	13.86	9.07	131.40	573.0	0.0022

The method of US Soil Conservation Service (SCS) for constructing synthetic unit hydrographs was based on a dimensionless hydrograph, which relates ratios of time to ratios of flow (Viessman et al, 1989 and Ramirez 2000). This method requires only the determination of the time to peak and the peak discharge. The calculated values for parameters t_p and q_p were applied to the SCS dimensionless unit hydrograph to obtain the corresponding unit hydrograph ordinates, the estimated unit hydrograph ordinates for Oyun River at Unilorin dam is presented in Table 3 based on the values of time to peak discharge (t_p) and peak discharge (q_p) for each river.

Table 3 Unit hydrograph ordinates for Oyun River based on US SCS method

t (hr)	Q (m^3/s)
0.00	0.00
4.54	56.50
9.07	131.40
13.61	86.72
18.14	42.05
22.68	20.37
27.21	9.85
31.75	4.73
36.28	2.37
40.82	1.18
45.35	0.53

2.1.3 Design floods hydrographs

The established unit hydrographs ordinates were used to develop the storm hydrographs due to actual rainfall event over the watershed. Peak storm hydrographs for selected return periods (10yr, 20yr, 50yr, 100yr and 200yr) were developed through convolution. The maximum 24-hr rainfall depths of the different recurrence interval for the catchment under consideration are 115.30 mm, 127.68 mm, 144.99 mm, 159.02 mm and 174.00 mm respectively (Olofintoye et al 2009). The storm hydrograph was derived from a multiperiod of rainfall excess called hydrograph convolution. It involves multiplying the unit hydrograph ordinates (U_n) by incremental rainfall excess (P_n), adding and lagging in a sequence to produce a resulting storm hydrograph. The SCS type II curve was used to divide the different rainfall data into successive equal short time events and the SCS Curve Number method was used to estimate the cumulative rainfall for storm depth. The incremental rainfall excess was obtained by subtracting sequentially, the rainfall excess from the previous time events. The equations that apply to the SCS Curve Number method are given in equation (5) and (6).

$$Q_d = \frac{(P^* - I_a)^2}{P^* + 0.8S} \; for \; P^* > 0.2S \qquad (5)$$

$$Q_d = 0 \; for \; P^* \leq 0.2S$$

Where I_a = initial abstraction I_a = 0.2S

$$S = \frac{25400}{CN} - 254 \qquad (6)$$

With the CN = 70 based on soil group A, lowest runoff potential, includes deep sands with very little silt and clay, also deep (Source: US SCS, 2000). It was also revealed that the catchment area is a rangeland, where one quarter is cultivated and one quarter are woodlands; all the catchment is in fair to good hydrological condition and the soils are moderately well drained. S is estimated as 108.86 mm, while I_a is 21.77 mm. This implies that any value of rainfall less than 21.77 mm is regarded as Zero. The unit hydrograph with the generated storm hydrographs of different return periods of 10, 20, 50, 100 and 200 year is presented in Figure 1.

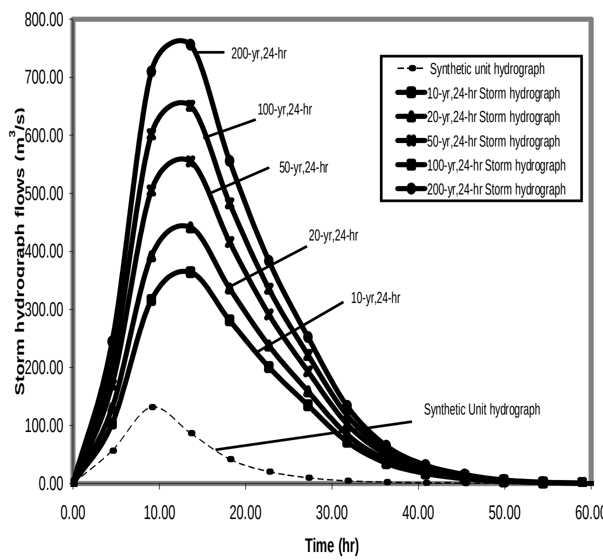

Figure 1 Unit hydrograph with generated storm hydrographs of different return periods for Oyun River at Unilorin dam

2.2 Water Resources of the Unilorin Dam

To decide on the hydropower potential of the dam, it is important to begin with an evaluation of the available water resource of the river. The energy potential of the scheme is directly proportional to the flow and head. To fairly select the most appropriate hydraulic equipment and estimate the Dam's potential, the water resource analysis must take into consideration the following:

a. The water to meet the primary responsibility of the Dam.
b. The evaporation losses over the reservoir area
c. The reservoir sediments which may have reduced the storage
d. The direct rainfall on the reservoir and
e. The inflow into the reservoir.

2.2.1 Water Supply

It is necessary to determine the amount of water needed to fulfill the primary mandate of the Dam which is water supply. It is assumed that the population making use of Unilorin dam is 30,000 people including academic activities. The per capital consumption recommended by the World Bank for urban areas is 120 l/d. This puts the total demand as

W = Population x Per Capital Consumption

30,000 x 0.12 = 3600 m^3/d or 108,000 m^3/month or 0.05 m^3/s

2.2.2 Evaporation Losses Over reservoir Area

Considerable quantity of stored water in a reservoir is lost due to evaporation, seepage and leakage. Of these, the most active is evaporation. The main factors which determine its rate include net radiation, water availability, wind velocity, atmospheric temperature and "reflexibility" of land surface (Fetter, 2007). Free water evaporation is measured by using shallow pans, called Class A pans. However, evaporation pan data cannot be directly applied to free water surfaces like reservoirs because of physical and climatological factors (Subramanya, 2002) thus the pan evaporation of Ilorin, obtained from the metrological Station at Ilorin airport has to be adjusted by multiplying it with the pan coefficient of 0.8. The adjusted values are shown in Table 4. In practice, the reservoir evaporation is taken as a product of monthly evaporation and reservoir surface area at ¾ maximum capacities. From data presented in Table1 and the topographical data used to establish the Elevation-Surface area-Capacity curve, the reservoir surface area corresponds to about 0.56 x 10^6 m^2. This value was used in the computation of the monthly evaporation losses shown in Table 4.

2.2.3 Reservoir Sediment

The storage capacity of the Unilorin Dam is expected to reduce with time based on the accumulation of sediments. However, a quick check using the Flemings equation and the Brune Curves for reservoir trap efficiency (Linsley, 1992). The sediment yield range of solids concentration is usually given for many rivers and streams in this region to be between 1.0 g/l to 2.0 g/l and higher values for areas further north (MRT). The same report gives a regional sediment rating curve that is sediment S per unit discharge as in equation (7)

$$S = e^{(-0.0124R + 11.81)} + 1.0 g/l \qquad (7)$$

where

R = annual rainfall in mm for the project area (1200 mm) and S was obtained as 1.0464 g/l. The total annual sediment inflow was obtained by multiplying the sedimentation rate with the catchment runoff given in Table 1 to obtain the annual sediment inflow as 52.88 x 10^6 kg.

Taking the value of consolidated sediment as 1500 kg/m^3, the sediment volume per year was obtained as 35.250 x 10^3 m^3.

Table 4 Mean Monthly Evaporation at Unilorin Dam Reservoir

Month	Mean Evaporation (mm)	Adjusted Mean Evaporation (mm)	Reservoir mean monthly Evaporation (m^3)
Jan.	316.20	252.96	141657.60
Feb.	276.64	221.31	123934.72
Mar.	253.58	202.86	113603.84
April	179.70	143.76	80505.60
May	124.93	99.94	55968.64
June	97.50	78.00	43680.00
July	88.66	70.93	39719.68
Aug.	84.32	67.46	37775.36
Sept.	75.00	60.00	33600.00
Oct.	98.58	78.86	44163.84
Nov.	177.00	141.60	79296.00
Dec.	249.55	199.64	111798.40
Total	2021.66	1617.328	905703.68

2.2.4 Reservoir Inflow

Monthly inflow data of Oyun River at Oyun Dam Offa is available from 1972 to 1981 (Salami and Ajenifuja, 2009). In modeling the monthly reservoir inflow, the Thomas – Fierring model based on a first order Markov model was adopted and the synthetic flow series were calculated using observed historical monthly stream flow sequences (Salami, 2007). The monthly flow parameters of the observed flow for Oyun River at Offa dam when the monthly inflows are described as first order autoregressive normal and loq-normal is presented in Table 5 and the model developed was used to extend the flow up to the year

2020. In order to estimate the river flow at the Unilorin dam which is the flowing River Oyun through the University Campus, the following procedure was adopted. Loucks et al (1981) indicated that, Middleton and Lawrence in 1976 stated that the method used to estimate flows depend on the characteristics of the watershed of the river basin. In humid regions where watersheds are generally homogeneous throughout the basin, the spatial distribution of monthly or seasonal rainfall does not significantly vary from one part of the river basin to another. In these situations, estimated flows Q_t^s at any site s can be based on the watershed areas A^s above those sites, and the stream flow $Q_t^{s'}$ and watershed area $A^{s'}$ above the nearest or most representative gage site s'. The equation is given as in equation (8).

$$Q_t^s = Q_t^{s'}\left(\frac{A^s}{A^{s'}}\right) \qquad (8)$$

where

Q_t^s = stream flow at ungauged site downstream (m^3/s)

$Q_t^{s'}$ = stream flow at gauged site upstream (m^3/s)

A^s = watershed area contributing to gage site s (km^2)

$A^{s'}$ = watershed area contributing to gage site s' (Km^2)

The technical report on Unilorin dam (CIWAT, 2007) revealed that the catchment area for Unilorin dam is 573 km^2 while that of Oyun dam at Offa is 106 km^2. Nurudeen, (1987) . Based on the catchment area and the extended flows for Oyun River at Oyun dam Offa, the river flows at Unilorin dam were estimated. The hydrograph of the estimated river flow at Unilorin dam is presented in Figure 2. While the relationship between the summary of statistics of the extended river flow (m^3/s) at Oyun dam Offa and that of the estimated river flow (m^3/s) at Unilorin dam are presented in Figures 3a – 3f for mean, standard deviation, coefficient of variation, minimum, maximum and skewness coefficient respectively.

Table 5 Statistics of monthly flow (Mm^3) for Oyun River at Offa dam (1972-1981) and model parameter

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	0.30	0.73	1.69	1.88	1.72	2.06	1.99	1.33	3.69	2.10	1.21	0.83
Median	0.04	0.35	1.26	1.42	1.15	1.54	1.06	1.50	3.75	1.84	0.82	0.45
S.D	0.54	0.835	1.34	1.33	1.44	1.63	2.58	0.84	1.35	1.08	1.10	0.94
C.V	1.81	1.14	0.80	0.71	0.84	0.79	1.29	0.63	0.37	0.51	0.91	1.14
Min	0.00	0.02	0.43	0.63	0.64	0.88	0.84	0.13	1.32	0.88	0.03	0.01
Max	1.56	2.68	5.07	5.14	5.44	6.53	9.25	2.33	6.67	3.87	3.19	2.94
Skew	1.95	1.72	1.99	1.84	2.24	2.74	3.04	-0.43	0.73	0.66	1.29	1.71
Correl, r	$R_{1,2}$	$r_{2,3}$	$r_{3,4}$	$r_{4,5}$	$r_{5,6}$	$r_{6,7}$	$R_{7,8}$	$r_{8,9}$	$r_{9,10}$	$r_{10,11}$	$r_{11,12}$	$r_{12,1}$
	0.21	0.19	0.98	0.84	0.96	0.94	-0.40	0.51	0.19	0.73	0.97	0.13
Slope, b	b1	B2	b3	b4	B5	B6	B7	b8	b9	b10	b11	b12
	0.32	0.31	0.97	0.91	1.09	1.49	-0.13	0.82	0.15	0.74	0.82	0.08

Monthly inflows as first order autoregressive loq-normal, where $x_i = \ln q_i$ the parameters $U_{x,i}$; $S_{x,i}$; $r_{x,i}$ and $b_{x,i}$ are determined as follows

$U_{x,i}$	-2.66	-1.15	0.03	0.23	0.01	0.24	-0.29	-0.06	1.18	0.51	-0.41	-1.02
$S_{x,i}$	1.21	0.91	0.70	0.64	0.73	0.70	0.99	0.58	0.36	0.43	0.78	0.91
$r_{x,i}$	0.36	0.27	0.98	0.87	0.97	0.96	-1.11	0.55	0.20	0.75	0.98	0.19
$b_{x,i}$	0.47	0.20	0.76	0.79	1.11	0.91	-1.58	0.32	0.13	1.02	1.57	0.22

C.V = Coefficient of Variation, $U_{x,i}$=Mean of natural logarithms of the monthly flows

S.D = Standard deviation, $S_{x,i}$= Standard deviation of natural logarithms of the monthly flows

b = slope of regression equation, $r_{x,i}$= Correlation coefficient of natural logarithms of monthly flows

$b_{x,i}$= Slope of regression equation of natural logarithms of the flows

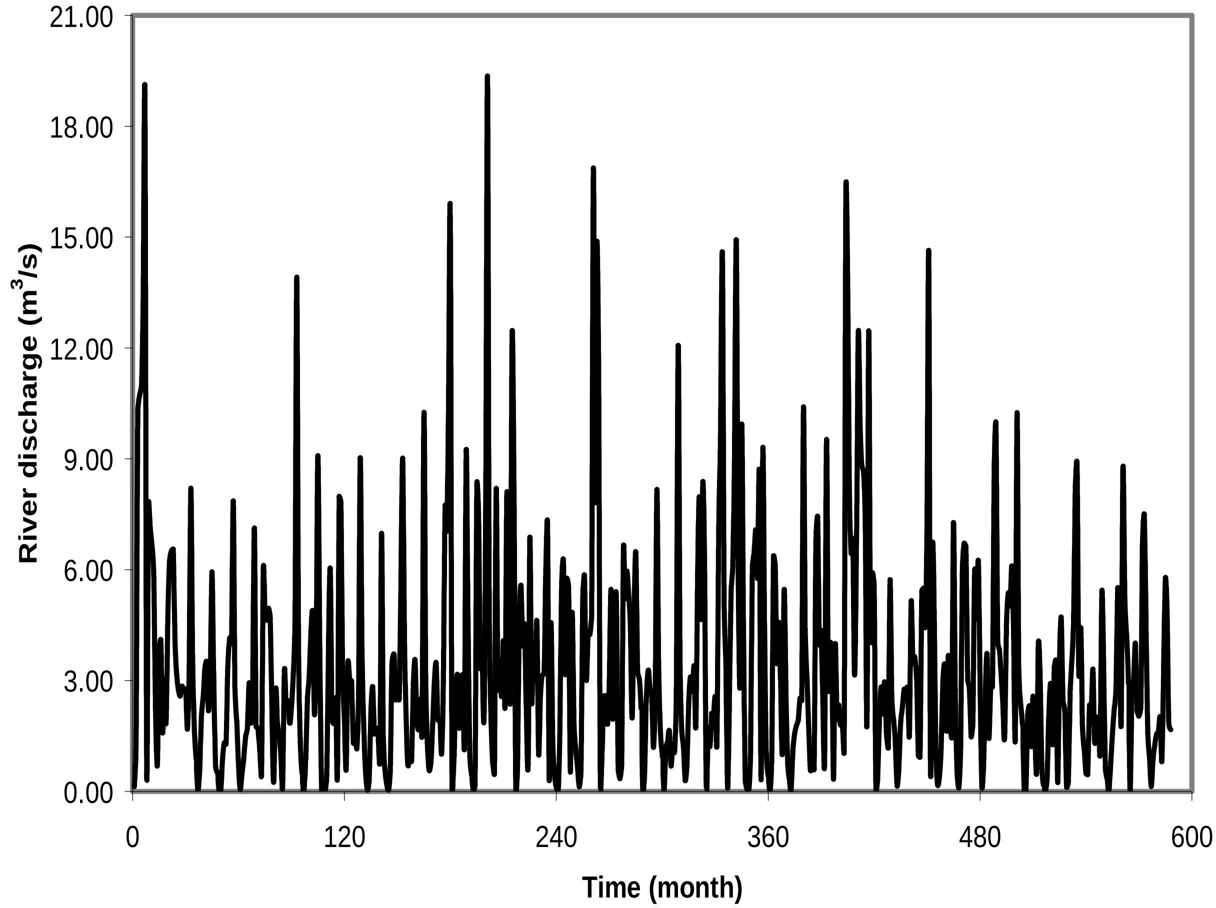

Fig. 2 Variation of estimated Oyun River flow at Unilorin Dam

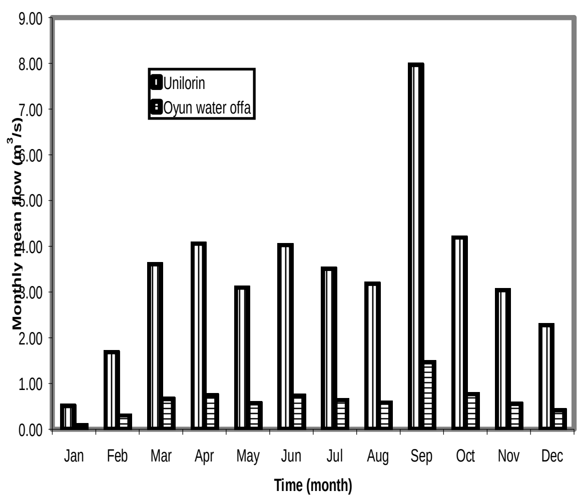

Fig. 3a Comparison between monthly mean flow at Unilorin dam and Oyun dam Offa

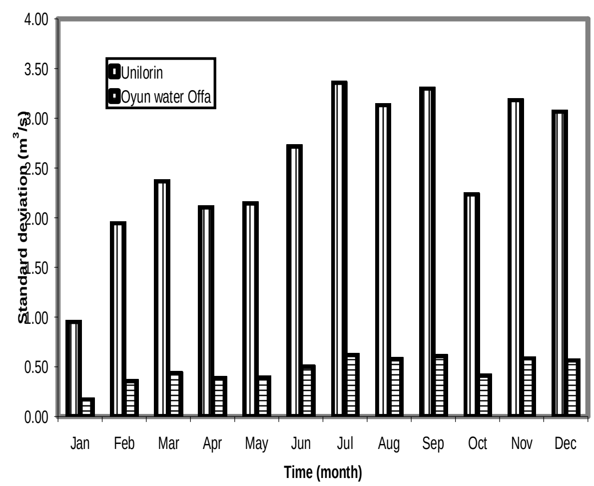

Fig. 3b Comparison between the standard deviation of flow at Unilorin dam and Oyun dam Offa

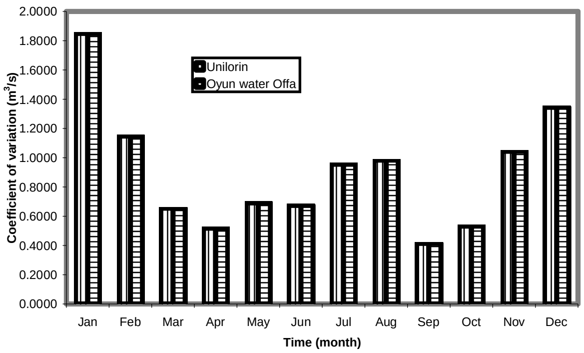

Fig. 3c Comparison between Coefficient of Variation of flow at Unilorin dam and Oyun dam Offa

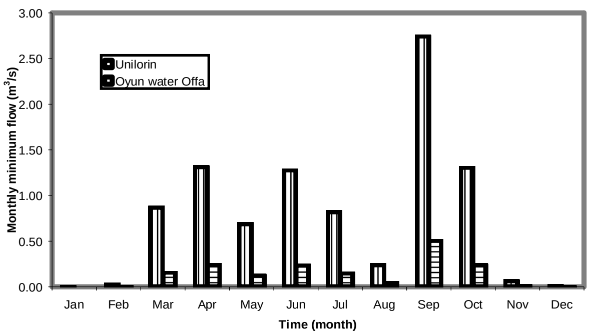

Fig. 3d Comparison between monthly minimum flow at Unilorin dam and Oyun dam Offa

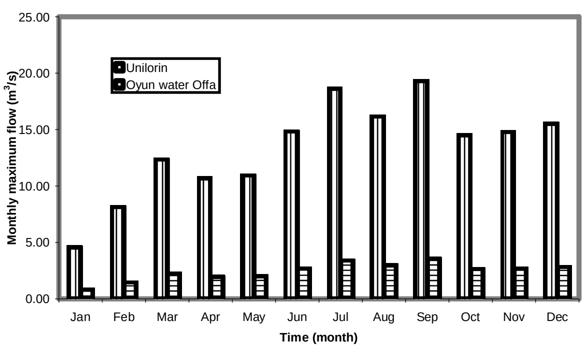

Fig. 3e Comparison between monthly maximum flow at Unilorin dam and Oyun dam Offa

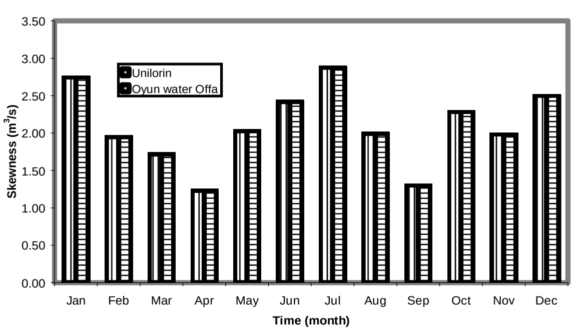

Fig. 3f Comparison between skewness of flow at Unilorin dam and Oyun dam Offa

2.3 Probability distribution analysis

2.3.1 Fitting of the probability function

The Gumbel extreme value type 1 (EV1) probability distribution function was used in fitting the low and high flow rate in order to predict values for various return periods. The probability functions obtained for low and high reservoir outflow rate are presented in equation (9) and (10) respectively.

Reservoir outflow rate

Low values

$$Q_T = 0.26 + 0.39(0.78y_T - 0.45)$$
$$y_T = -\ln(-\ln(p)) \qquad (9)$$

High values

$$Q_T = 9.62 + 3.98(0.78y_T - 0.45)$$
$$y_T = -\ln(-\ln(1-p)) \qquad (10)$$

In order to show how best the Gumbel probability distribution function fits the low and high values of the stream flow, the observed and predicted values were plotted. The relationships between the observed and predicted values of the high and low reservoir outflow rate are presented in Figures 4 and 5 respectively. In addition, statistical goodness of fit tests such as probability plot correlation coefficient (ppcc) and coefficient of determination were determined. The results are presented in Table 6; the result shows that the Gumbel probability distribution function can be adequately used to predict both low and high values of reservoir outflow rate and tail race water level. Based on this fact, values of the variables for different return periods are predicted and presented in Table 7.

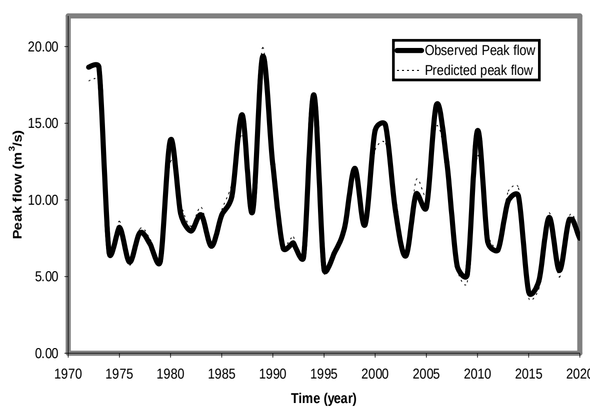

Figure 4 Comparison of observed and predicted peak flow

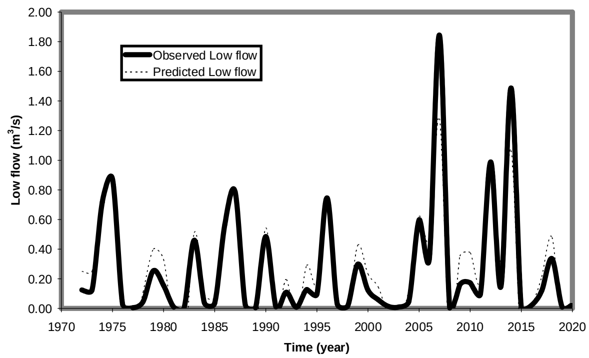

Figure 5 Comparison of observed and predicted low flow

Table 6 Value of statistical goodness of fit tests

Statistical Tests	Low flow	Peak flow
Correlation coefficient (r)	0.91	0.99
Coefficient of determination (R^2)	0.83	0.97

Table 7 Low and Peak flow of various return periods

Return Period	Low flow (m^3/s)	Peak flow (m^3/s)
2	0.20	9.37
5	0.00	12.88
10	0.00	15.21
50		20.33
100		22.49
200		24.65
500		27.50

3.3.2 Estimation of return period for low and peak flows

The analysis of the historical data revealed that the lowest and the peak reservoir inflow rates are $0.0020m^3/s$ and $19.34m^3/s$ respectively. However, it is necessary to determine the return periods of the historical low and peak flows using the Gumbel probability distribution function developed. The results are presented in Table 8

Table 8 Return periods for low and peak flows

Parameter	Oyun River flows at Unilorin dam (m^3/s)	
	Low flow	High flow
	0.0020	19.34
Return period (yr)	1.37	41.28

This means that low flow will be expected almost annually while flooding may occur on the average of every 40 years. The outcome helps to ascertain the pattern of dry and wet season recession of runoff and what flood risks are expected.

2.4 Available Flow for Power Generation

It is not economically feasible to harness the entire runoff of a river during flood as this will require a huge storage. In this case, the storage is defined and fixed and the firm yield for power generation is dependent on overflow and some other quantity available from the reservoir without infringing on the water supply requirement.

2.4.1 Sequent – Peak Analysis

The Sequent – Peak method computes the cumulative sum of the inflows minus the reservoir releases over the time interval chosen for analysis. The analysis assumes that the time interval includes the critical period which is the time period over which the flows have reached a minimum causing the greater drawdown of the reservoir. The other assumption is that the total release over time interval of analysis does not exceed the total reservoir inflow (Mays and Tung, 1992). In this case, the Sequent – Peak method is implemented using equation (11)

$$S_t = W_t - I_t - R_t + E_t + S_{t-1}, \text{ if positive.} \qquad (11)$$
$$S_t = o, \text{ otherwise.}$$

where S_t = Storage at time t
W_t = Water Supply demand; I_t = Inflow;
R_t = Direct Rainfall on Rainfall
E_t = Evaporation from reservoir; and
S_{t-1}, = Previous Storage

The maximum value of S_t is the required active reservoir storage capacity for the flow sequence and the considered releases. Table 9 shows the computation of storage required at Unilorin dam to meet the specified obligations using the Sequent – Peak method. Data for water demand, inflow and evaporation have been established in previous paragraphs.

From Table (9), S_t = 396,687.04 m^3. The storage capacity of the Unilorin Dam reservoir is 1.80 x $10^6 m^3$. The estimated sediments yield in the reservoir has been established as 35250 m^3. The storage required to meet water demand obligation for the dam as established above leaves a balance of 1800000 – 35250 – 396687 = 1368063 m^3 for other uses. The Sequent – Peak analysis was done on a monthly basis. This amount of water for other uses translates to 0.53 m^3/s. A quick check using the estimated flow data for Unilorin dam for a flow duration curve method is presented in the following section.

Table 9. Computations of Sequent – Peak Method for Unilorin Dam

Month	Water Supply m^3	Minimum Reservoir Inflow m^3	Evaporation Losses m^3	Initial Storage m^3	Required Storage m^3
January	108,000.00	5,356.80	141,657.60	0	244,300.80
February	108,000.00	79,548.48	123,934.72	244,300.80	396,687.04
March	108,000.00	2,335,296.96	113,603.84	396,687.04	0.00
April	108,000.00	3,524,774.40	80,505.60	0.00	0.00
May	108,000.00	1,851,310.08	55,968.64	0.00	0.00
June	108,000.00	3,432,905.28	43,680.00	0.00	0.00
July	108,000.00	2,203,251.84	39,719.68	0.00	0.00
August	108,000.00	647,369.28	37,775.36	0.00	0.00
September	108,000.00	7,356,493.44	33,600.00	0.00	0.00
October	108,000.00	3,506,829.12	44,163.84	0.00	0.00
November	108,000.00	178,649.28	79,296.00	0.00	8,646.72
December	108,000.00	22,230.72	111,798.40	8,646.72	206,214.40

Storage required based on minimum river flow = 396,687.04 m^3

2.4.2 Flow duration curve for Oyun River flow at Unilorin dam

The flow duration analysis was carried out in accordance to method established by Oregon State University in 2002 to 2005, which can be referenced at http://water.oregonstate.edu/streamflow/. The method involves establishment of relationship between discharge and percent of time that the indicated discharge is equaled or exceeded (exceedence probability). The flow duration curve obtained is presented in Figure 6, the 50%, 60%, 75%, and 90% dependable flow for the Oyun River at Unilorin dam are obtained as $2.60 m^3/s$, $2.00 m^3/s$, $1.20 m^3/s$ and $0.50 m^3/s$ respectively. Hence the estimated reservoir yield of $0.53 m^3/s$ based on minimum flow corresponds to 90% reliable flow.

2.5 Hydropower Potential of Unilorin Dam

2.5.1 Equation required for estimation of hydro-electric energy

The hydropower potential of the dam was estimated from the equation below:

$P = 9.81 \times Q \times H \times E_t \times E_g$

where P = Power (KW); H = Net Head = 10 m; E_t = Turbine efficiency = 80%

E_g = Generator Efficiency = 95%; Water supply requirement = 0.05 m^3/s . The estimation of the energy potential is presented in Table 10.

Table 10. Estimated energy potential

Reliability (%)	Flow (m^3/s)	Available flow (m^3/s)	Net head (m)	Turbine efficiency (%)	Generator efficiency (%)	Power (KW)
50	2.6	1.45	10	80	95	108
75	1.2	0.70	10	80	95	52
90	0.5	0.45	10	80	95	34

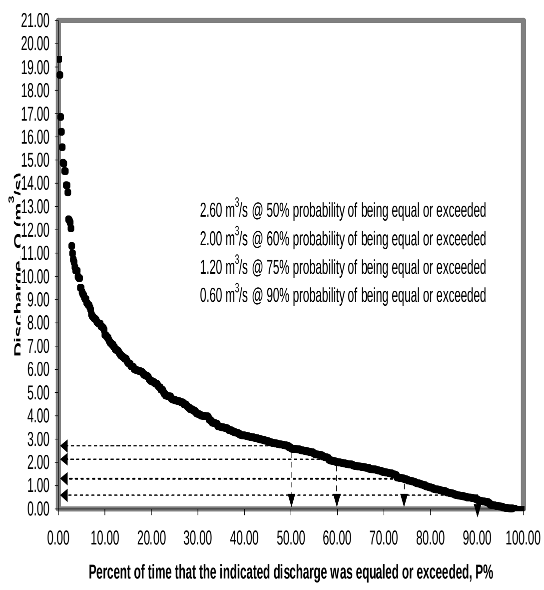

Fig. 6 Flow Duration Curve for Oyun River at Unilorin Dam

3.0 Conclusions

The Oyun River at Unilorin dam is ungaged, but there are inflow data at Oyun Dam in Offa, spanning from 1972 to 1981. This data was extended to year 2020 by modeling the inflow and the river flow at the Unilorin dam. These estimates were based on the procedural steps by Loucks et al (1981). The flow duration curve was established in accordance to the procedure developed by Oregon State University. For 50% reliability, the available flow for energy generation was obtained as $1.45m^3/s$ and the corresponding hydropower potential of the dam is estimated as 108 KW. While for the 75% and 90% reliability, the available flow is $0.70m^3/s$, and $0.45m^3/s$ respectively and their corresponding hydropower potential is estimated as 52 KW and 34 KW. Three units will be provided and their operation depends on the available flow into the dam.

Acknowledgements:

Authors are grateful to the National Centre for Hydropower Research and Development (NACHRED), University of Ilorin, Ilorin, Nigeria for financial support to carry out this work.

Corresponding Author:
Dr. A.W Salami Department of Civil Engineering,
Main Campus, University of Ilorin P.M.B 1515,
Ilorin, Nigeria
E-mail: salami_wahab@unilorin.edu.ng

References

1. Okpanefe, P. E., Owolabi, S. Small Hydropower in Nigeria, 2001 TCDC Training Workshop on Small Hydropower Programme. 2001.
2. Olivia, P. International Consulting Limited. Nigeria: Electric Power Sector Report 2008.
3. Zarma, H. I. Hydropower Resources in Nigeria, Country Paper presented at 2nd Hydropower for Today Conference, International Centre on Hydropower, Hangzhou, China. 2006.
4. Dandekar, M. M. Sharma. Water Power Engineering, Vikas, Publishing House. 1992.
5. Raghunath H.M. Hydrology: Principles, Analysis and Design. New Age International (P) Limited, Publishers, New Delhi. 2nd edition. 2006.
6. Remirez, J.A. Prediction and Modeling of Flood Hydrology and Hydraulics. Chapter 11 of Inland Flood Hazards: Human, Riparian and Aquatic Communities. Edited by Ellen Wohl; Cambridge University Press. 2000
7. Arora K.R. Irrigation, water power and water Resources Engineering. Standard Publishers Distributions, 1705-B, NAI SARAK, Delhi, 2004; 79-106.
8. Viessman W, Knapp J.W and Lewis G.L. Introduction to Hydrology, Harper and Row Publishers, New York, 1989; 149 – 355.
9. Olofintoye, O.O, Sule, B.F and Salami, A.W. Best-fit Probability Distribution model for peak daily rainfall of selected Cities in Nigeria. New York Science Journal, 2009;2(3), 1-12. ISSN 1554-020. (http://www.sciencepub.netyork, sciencepub@gmail.com).
10. SCS. Soil Conservation Service. Design of Hydrograph. US Department of agriculture, Washington, DC. 2002.
11. Fetter, C. W. Applied Hydrogeology, CBS Publishers. (2007).
12. Subramanya, K. Engineering Hydrology, second Edition, Tata McGraw Hill. 2002.
13. Linsley, R. K., Franzini J. B., Freyberg D. L., Tchbanoglous G. Water Resources Engineering, fourth Edition, McGraw Hill. 1992.
14. Salami, A.W and Ajenifuja, K.S. Potential of University of Ilorin Dam for Hydropower generation. Technical Report presented to Department of Civil Engineering, University of Ilorin. (2009).
15. Salami, A.W. Operational performance of water management models for a hydropower system under reservoir inflow forecasts. A Ph.D. Thesis report presented to the Post graduate School, University of Ilorin, Ilorin, Nigeria. 2007
16. Loucks, D.P. Stedinger, J.R and Haith, H.A. Water Resource System Planning and Analysis. Prentice Hall, Englewood Cliffs, New Jersey. 1981
17. Technical report on Unilorin dam prepared by CIWAT Engineering Consultants. Plot A5/2870 Maitama District, P.O. Box 11261, Garki, Abuja. 2007.
18. Nurudeen, U.A. Hydrological Modelling of River Oyun Basin, Kwara State. M.Eng Thesis, Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria. 1987.
19. Mays, L. W., Tung, Y. K. *Hydrosystems Engineering and Management*, McGraw Hill. 1992.
20. Oregon State University, 2002 – 2005. Streamflow Evaluations for watershed Restoration Planning and Design. http://water.oregonstate.edu/streamflow/

11/29/2010