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Hydrological Assessment On The Dams Safety With Climate Change Condition

[1]May Thazin Maung, [2]Win Win Zin, [3]Tin Maung
Civil Engineering Department, Yangon Technological University, Myanmar
Email – [1]aprilmay.am87@gmail.com, [2]winwinzin@gmail.com, [3]tinmaung@gmail.com

Abstract: *More than 100 dams and reservoirs had been constructed in Myanmar mostly with inadequate hydrological information. Monitoring of completed dams for their safety and sustainability is vital to guarantee food security. The largest dam with maximum irrigated area in Myanmar, Thaphanseik dam with storage capacity of 3553 million m3 is selected. This study predicted station rainfall until year 2100 by using GCM models and also generated catchment rainfall to 2100 year periods with multiple correlation analysis. Monthly inflow of 2001 to 2100 were also predicted by considering recession curve equation for reservoir operation study which will highlight optimum use of water for irrigation. In this paper , we considered the climate change affect to do hydrological assessment of Thaphanseik dam safety and also simulate and optimize reservoir operation system for future period. Finally we would like to give optimized water release when unexpected storm will occur in that area*

Key Words: *GCM model, Correlation Analysis, Recession Equation,Rainfall Runoff Relation, Reservoir Operation.*

1. INTRODUCTION:

There is an increasing interest in dam break hydraulics and hydrology, having in mind potential of occurrence of extreme meteorological events due to rapidly chang-ing climate. Observations made in recent years warn that global climate change will have devastating impact (e.g. Intergovernmental Panel on Climate Change (IPCC) assessment reports). According to IPCC the decreasing ice volume in Arctic, increas-ing of melting of Greenland ice sheet and global rising of mean sea level are the most evident consequences of global warming. In many regions, changing precipitaion or melting snow and ice are altering hydrological systems, affecting water recources in terms of quantity and quality. Glaciers continue to shrink almost world-wide because of climate change, affecting runoff of water resources downstream. Climate change is causing permafrost warming and thawing in high latitude regions and in high-elevation regions (IPCC 2014).

2. CASE STUDY AREA:

The Thapanseik Reservoir Project is the main part of Mu river valley project. Its capacity is 2.8 million acre feet and water from the Mu river can fully be utilized. The government aims at undertaking agricultural activities in Anya regions without waiting for the rain water, increasing the income of the farmers, greening of the arid zone and rice sufficiency in the region.

Thapanseik Reservior with high water storage capacity suppilies water to Kindat diversion weir. It can irrigate over 500,000 acres of cultivable land all year round. It can also supply water to Budalin and Ayadaw Townships. The Thaphanseik Reservior will benefit about 530,000 acres of farmland and some 600,000 acres of crops. Moreover, three turbine engines will also generate 30 mega- watts. The multi- purpose project is 15 times bigger than Ngamoyeik Reservior, 10 times bigger than South Nawin Dam near Pyay and twice bigger than Inlay lake in Southern Shan State.

This paper considered the climate change affect to do hydrological assessment of Thaphanseik dam safety and also simulate and optimize reservoir operation system for future period. Finally we would like to give optimized water release when unexpected storm will occour in that area.

3. METHODS AND MATERIALS:

3.1 Data Avalibility

In this study, I selected seven rainfall stations data in and out of catchment area; Thapanseik dam, Kawlin, Wuntho, Katha, Pinlebu, Kanbalu and Kyunhla. Also collected daily and monthly rainfall and inflow data during the observed period of 2001 to 2015.

3.2 Global Climate Change Model (GCM)

Numerical models (General Circulation Models or GCMs), representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations . While simpler models have also been used to provide globally- or regionally-averaged estimates of the climate response, only GCMs, possibly in conjunction with nested regional models, have the potential to provide geographically and physically consistent estimates of regional climate change which are required in impact analysis, .

GCMs depict the climate using a three dimensional grid over the globe , typically having a horizontal resolution of between 250 and 600 km, 10 to 20 vertical layers in the atmosphere and sometimes as many as 30 layers in the oceans. Their resolution is thus quite coarse relative to the scale of exposure units in most impact assessments. Moreover, many physical processes, such as those related to clouds, also occur at smaller scales and cannot be properly modelled. Instead, their known properties must be averaged over the larger scale in a technique known as parameterization. This is one source of uncertainty in GCM-based simulations of future climate. Others relate to the simulation of various feedback mechanisms in models concerning, for example, water vapour and warming, clouds and radiation, ocean circulation and ice and snow albedo. For this reason, GCMs may simulate quite different responses to the same forcing, simply because of the way certain processes and feedbacks are modelled.

3.3 Watershed Delineation

HEC-GeoHMS, the GIS-based physical basin model preparation tool for HEC-HMS, was used to delineate the river basin using GIS capabilities in ESRI's ArcMap . Mathematical methods to describe the transfer and exchange of water between the meteorologic model and the physical model are explained in the section Technical Theory of Methods. The spatial distribution information was derived from GIS maps using HEC-GeoHMS, a HEC-HMS extension tool developed specifically to prepare a physical basin model for the program. A digital elevation map or DEM is used to assess the direction of water flow , subbasin centroids and lag time to calculate runoff. The river basin model is assigned properties taken from land coverage maps such as imperviousness, land use and subbasin area. Geospatial maps were thereafter formed as input to HEC-HMS modelling program.

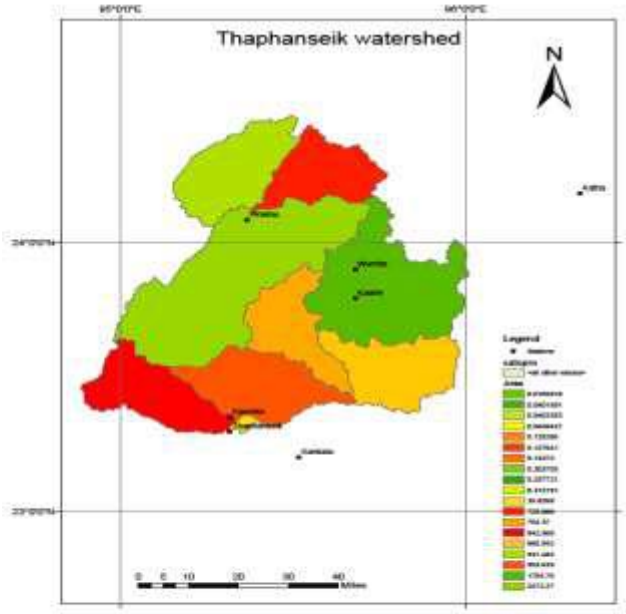

Fig 1. Watershed Delineation for study area

3.4 Recession Curve

Recession curve or master recession curve is a smoothed composite of the recessions of several observed hydrographs, drawn to represent the characteristic time graph of decreasing total runoff for a drainage area after passage of a peak flow. Curves of this type, designed to characterize the nature of a drainage area, may be constructed as a plot of flow (stage of discharge) versus time, or as a plot of flow versus flow at some fixed later interval; also, separate recession curves may be derived for surface runoff, groundwater runoff, and even for interflow. Although the exponential function of the recession is quite and old method, this function is still widely used and can be written in the following form (e.g. Nathan and McMahon 1990, Tallaksen 1995):

$$Q_t = Q_0 \exp(-t/\tau)$$

Where Q_t is the discharge at time t,Q_0 is the initial dis-charge and τ is a recession time scale, i.e. the mean residence time of the groundwater system, defined as the ratio of storage to flow; in some cases it is substituted by the recession constant, $k=1/\tau$.

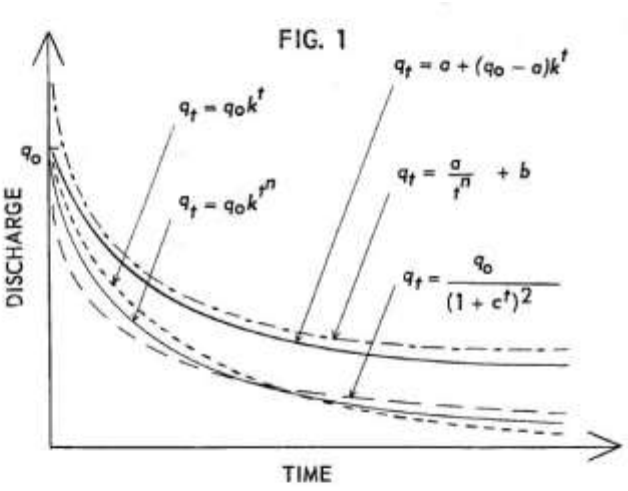

Fig 2. Recession curves and equations

3.5 Master Recession Analysis

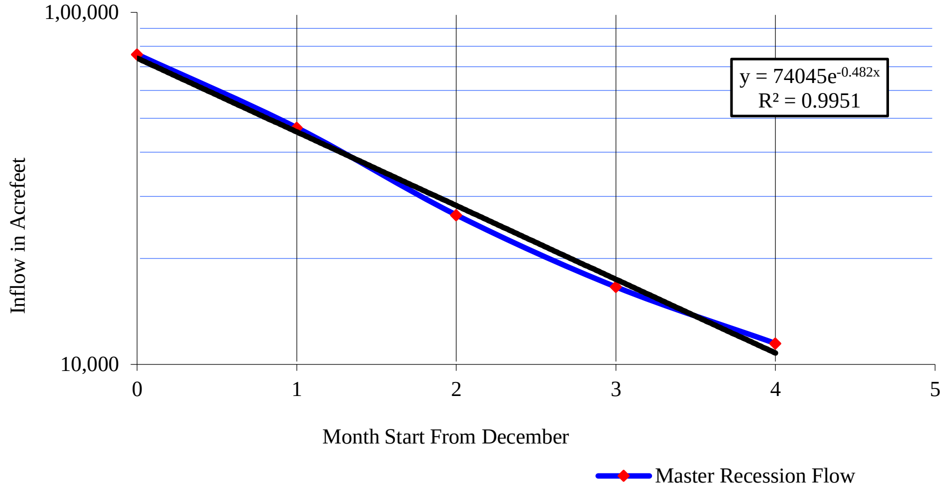

Fig.3 Master Recession Flow Analysis (2001 to 2008)

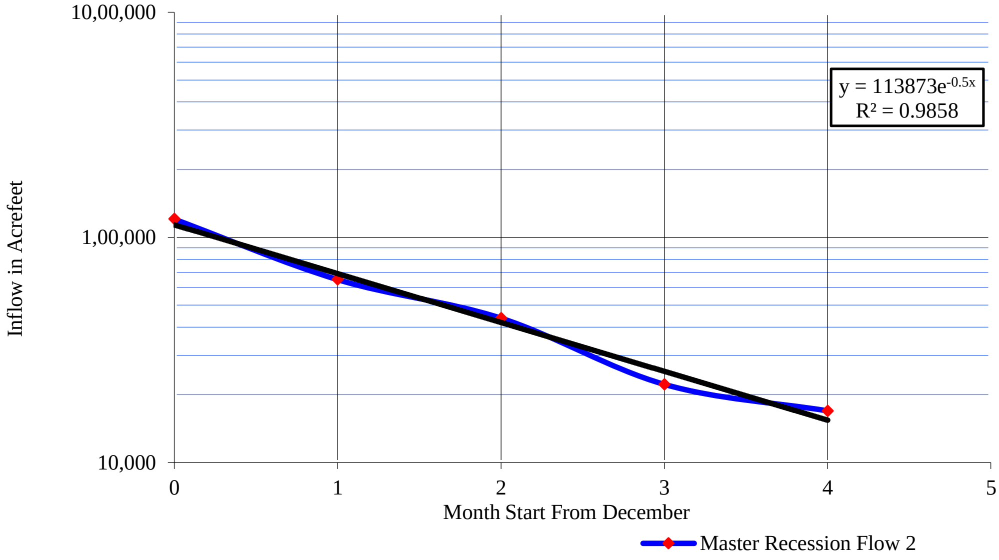

Fig.4 Master Recession Flow Analysis (2010 to 2015)

In master recession curve, we should take the base month especially dry month (nearly no baseflow) to draw the recession curve and how much correlate stream inflow with the time. Finally we can make recession equation and recession constant for study area .

Adopted Recession Equation

$$Q_t = Q_0 * e^{-0.4997t} \qquad (1)$$

Where Q_t is reservoir inflow in ac-ft at month t,
Q_0 is reservoir inflow in ac-ft at initial time
0.4997 is recession constant, and
t is time in month starting from intial

3.6 Area-Capacity Curve

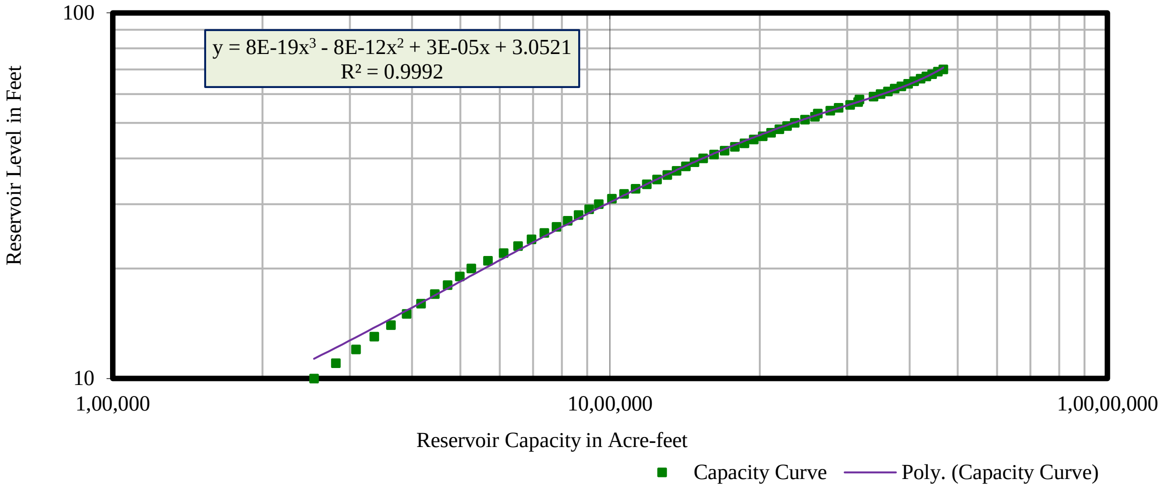

Fig.5 Capacity and Reservior Level Curve

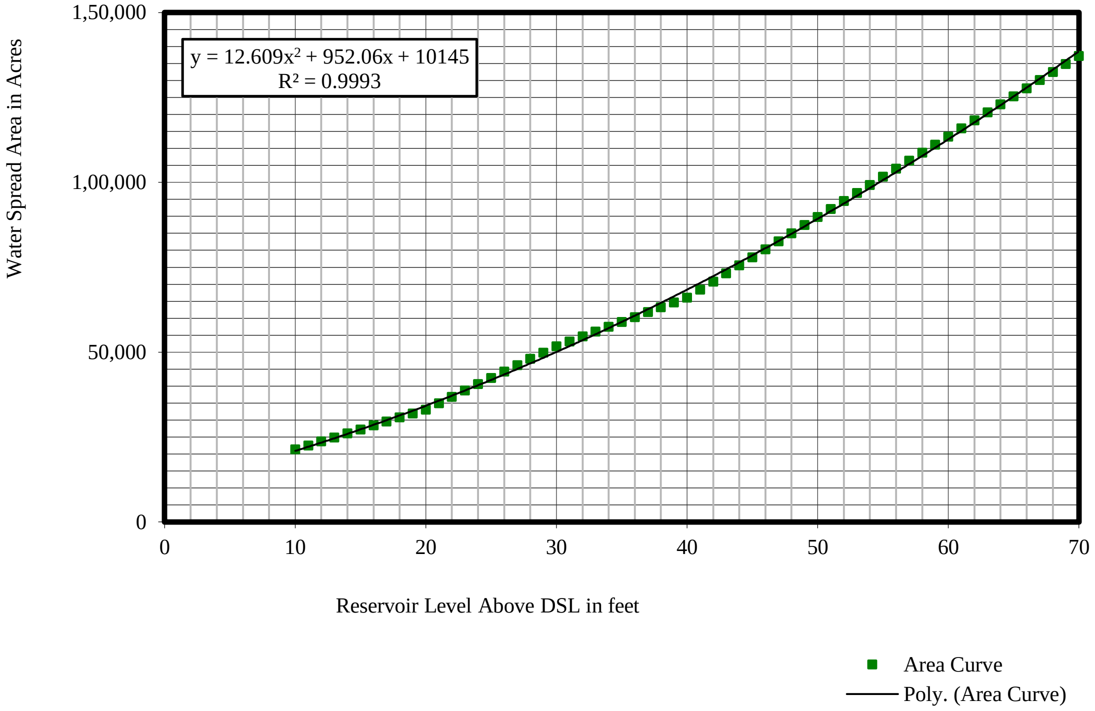

Fig.6 Reservior Level and Water Spread Area Curve

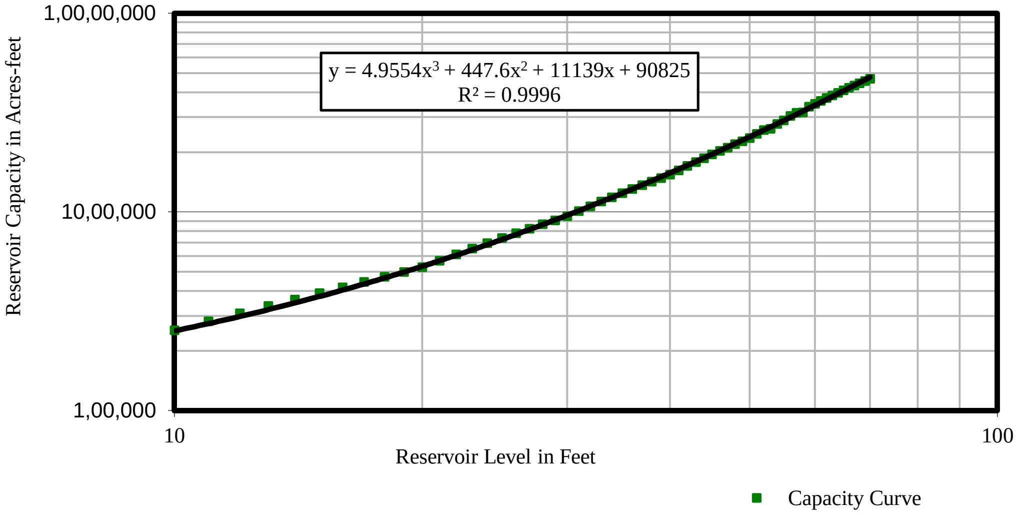

Fig.7 Reservior Level and Capacity Curve

3.7 Reservoir Operation Study

Reservoir operation is an important element in water resources planning and management. It consists of several control variables that defines the operation strategies for guiding a sequence of releases to meet a large number of demands from stakeholders with different objectives, such as flood control, hydropower generation and allocation of water to different users. A major difficulty in the operation of reservoirs is the often conflicting and unequal objectives. Therefore, it is necessary to optimise reservoir operation in determining balanced solutions between the conflicting objective.

3.8 Flood Frequency Analysis

Derived flood frequency analysis allows the estimation of design floods with hydrological modeling for poorly observed basins considering change and taking into account flood protection measures. There are several possible choices regarding precipitation input, discharge output and consequently the calibration of the model. The objective of this study is to compare different calibration strategies for a hydrological model considering various types of rainfall input and runoff output data sets and to propose the most suitable approach. Event based and continuous, observed hourly rainfall data as well as disaggregated daily rainfall and stochastically generated daily rainfall data are used as input for the model. As output, longer daily continuous flow time series as well as probability distributions of annual maximum peak flow series are employed. The investigations are carried out with the hydrological model HEC-HMS (Hydrologic Engineering Center's Hydrologic Modeling System). The results show that (I) the same type of precipitation input data should be used for calibration and application of the hydrological model, (II) a model calibrated using a small sample of extreme values works quite well for the simulation of continuous time series with moderate length but not vice versa, and (III) the best performance with small uncertainty is obtained when stochastic precipitation data and the observed probability distribution of peak flows are used for model calibration. This outcome suggests to calibrate a hydrological model directly on probability distributions of observed peak flows using stochastic rainfall as input if its purpose is the application for derived flood frequency analysis.

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4. METHODOLOGY:

. Data Generation, Rainfall Runoff Transformation and Reservior Operation

- To evaluate the available data to obtain monthly and seasonal catchment rainfall
- To analyze the available data to obtain seasonal rainfalls and seasonal reservoir inflows of 4 significant seasons namely DD, DW, WW and WD
- Using the 15 years monthly and seasonal catchment rainfall, to generate to get 100-year monthly and seasonal catchment rainfall with statistical program
- To generate to get monthly and seasonal reservoir inflow for 100 years using statistical program
- To check critical statistical parameters of the above analyses to observe accuracy and acceptability of the generated rainfall and runoff data.
- Monthly/seasonal rainfall to monthly/seasonal runoff transformation
- Adoption of generated monthly runoff
- Reservoir operation study for Thaphanseik Dam

B. Flood Analysis and Spillway Assessment

- To evaluate catchment rainfalls for the above storms.
- Also to analyze to obtain inflow hydrographs during the above storms.
- To produce catchment representative Unit Hydrograph using the above inflow hydrographs and corresponding rainfalls
- To get rainfall Intensity-Duration-Frequency (IDF) curve for the project area or the catchment using long term rainfall from a representative station and regional storm studies.
- Use hourly design rainfalls to produce design floods of 10, 50, 100, 1000 and 10,000 years (PMF) return periods.
- To route the above design floods through Thaphanseik reservoir with existing outlet structures to observe the outcome.
- If the existing structures are found not adequate to contain the design floods specifically the PMF, propose appropriate solution including spillway modification and additional spillway.

5. RESULTS AND DISCUSSIONS:

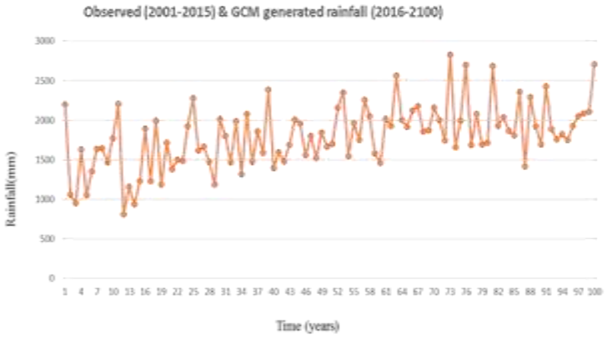

Fig 8. Pinlebu Station rainfall generated by MIROC-ESM

In rainfall generation by using GCM model for pinlebu rainfall station, MIROC-ESM model is used to generate rainfall for 100 years. In the result, there gave root mean square value, RMSE of 130 and correlation coefficient,R^2 of 0.3163 before bias correction. After making bias correction for these generated rainfall , these values were about 126 and o.3483. This parameters have poor correlation coefficient but this value is best result compare with parameter generated by other GCM, so this can be suitably used for future generation.

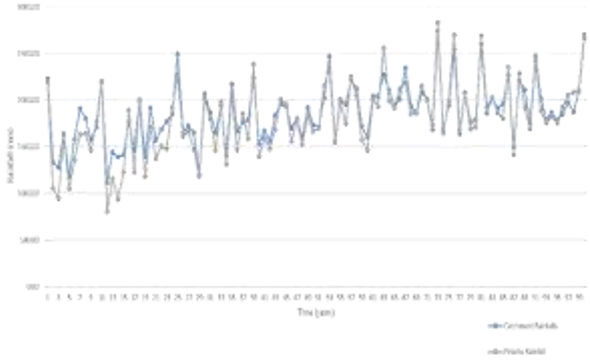

Fig 9. Pinlebu Station rainfall generated Catchment rainfall

To generate catchment rainfall data from pinlebu station rainfall, multiple linear correlation analysis is used with calculating correlation factor, R^2 between these. The R^2value of above 0.5 give good correlation between these two parameter so that there may be a little poor correlation in some months March, April, August, October and December. For that months, base flow and recession theory is applied to get relevant good runoff generation.

Table I. Monthly Correlation between Pinlebu Station Rainfall and Observed Catchment Rainfall

Month	Linear Equation	R^2
January	Y = 1.4501X + 0.6977	0.6148
February	Y = 1.4082X – 0.4559	0.8931
March	Y = 0.4245X + 5.5076	0.0844

April	$Y = 0.5477X + 9.766$	0.2674
May	$Y = 1.0685X - 1.2624$	0.9129
June	$Y = 0.9021X + 51.82$	0.3498
July	$Y = 0.4809X + 92.165$	0.5834
August	$Y = 0.6804X + 121.48$	0.256
September	$Y = 0.5355X + 113.71$	0.4874
October	$Y = 0.5876X + 83.432$	0.1671
November	$Y = 1.5417X - 2.435$	0.831
December	$Y = -1.0763X + 115.58$	0.0041

Table II. Monthly Correlation between Catchment Rainfall and Runoff

Month	Linear Equation	R^2
January	$Y = Q_0(-\ln(0.4997))$	1
February	$Y = Q_0(-\ln(0.4997))$	1
March	$Y = Q_0(-\ln(0.4997))$	1
April	$Y = Q_0(-\ln(0.4997))+(0.949X+20.809)$	0.542
May	$Y = 2E\text{-}05X^3-0.0047X^2+0.9288X+30$	0.965
June	$Y = 0.0001X^3-0.0409X^2+5.7937X-20$	0.958
July	$Y = 00038X^3+2.6795X^2+13.471$	0.943
August	$Y = 0.0754X^{1.721}$	0.820
September	$Y = 0.0065X^2+0.7829X+531.68$	0.889
October	$Y = 0.0228X^2+0.0734X+380.48$	0.856
November	$Y = 52.767+5.2363X+0.057(\exp(-0.4997))$	0.821
December	$Y = Q_0(-\ln(0.4997))$	1

In generation of runoff from catchment rainfalls, recession curve s used in dry months (Jan, Feb, Mar, Nov and Dec) because these months have poor correlation of base flow conditions. In April, there may be increase rainfall so recession plus linear correlation effect should be considered. For other months only linear correlation equation can be used to get better values.

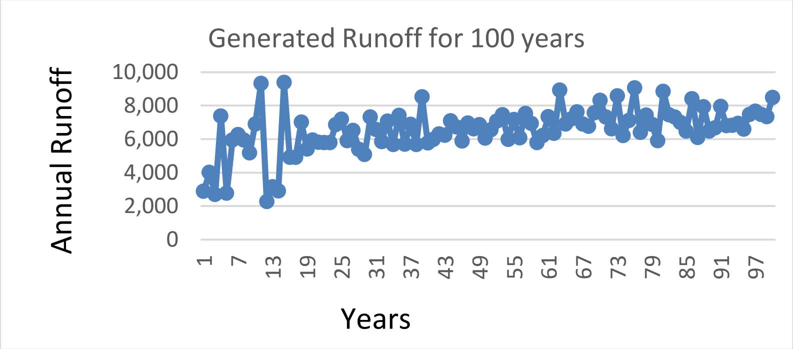

Fig 10. Generated runoff from catchment rainfall generation

7. CONCLUSIONS AND RECOMMENDATIONS:

According to the result from analysis showed the good correlation among Pinlebu rainfall to Catchment rainfalls and Catchment rainfalls to Runoff but there has poor correlate in some wet period with multiple correlation analysis.

Also checked Thaphanseik Dam rainfall and inflow data with time by master recession curve in poor linear correlation conditions as baseflow condition when there is little rainfall with increase inflow in dry months. Master recession curve is plotted with December flow as assumption of no flow condition that showed best R^2 value of about 0.99 and recession constant of 0.4997.

The multiple linear regressed operation rule will also prove useful for operation of reservoirs constructed in areas . As such the operation rules using the principle of multiple regression will be of much use not only under flood conditions but also under normal situations.

In simulation of rainfalls and inflows, there was given reliable results for future period with observed data. This can be reasonably applied for reservoir operation and flood study with design hydrograph.

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