REGIONAL FLOOD FREQUENCY ANALYSIS OF TARABA CATCHMENT

BY

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DECLARATION

I hereby declare that this project was carried out solely by me under the guidance and supervision of Dr A.O. Ehigiator of the Civil Engineering Department, Federal University of Technology, Minna.

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CERTIFICATION

This project was approved by the Department of Civil Engineering, Federal University of Technology, Minna, Niger State.

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DEDICATION

This project is dedicated to my family who are always there for me

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I will like to really appreciate God for the gift of life and my family for the firm support. My sincere appreciation also goes to my project supervisor and all my lecturers at the Department of Civil Engineering, Federal University of Tecbnology, minna; who have really imparted knowledge in me.

ABSTRACT

Regional Flood Frequency Analysis was used to generate an equation to predict mean annual discharge at any point within the Taraba region by relating the length, L of a stream and the Area, A of the catchment. A 23 years annual mean discharge records for three rivers at four stations was used. The homogeneity of the records was checked using the double mass curve method by plotting a graph to show consistency in the discharge records and Benson Regression Analysis was used to generate superscript factors for L and A respectively that is only peculiar to the Taraba region.

The predicted annual mean discharge generated using the equation was subsequently compared with the Actual annual mean discharge and was found out to be 80% efficient.

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hydrologically similar gauged catchments is used to characterize the extreme flow regime for the ungauged catchments. To ascertain if catchments are hydrologically similar, then there is need for regionalization.

1.1.4 REGIONALIZATION

This is the process of identification of groups of catchments that are sufficiently similar to allow the combination of extreme flow information from sites within the region. A region here means a collection of catchments that can be considered to be similar in terms of hydrological response. These regions have to be homogenous with respect to the extreme flow characteristics.

1.1.5 HOMOGENEITY.

A homogenous record is one, which is drawn from the same population or statistical distribution (Bovee, 1982). The hypothesis for homogeneity implies that, frequency distribution for different sites are the same except for a site specific factor (index Flood). The hypothesis can only be proved through a homogeneity test. Among several methods for homogeneity test is the Double mass curve analysis method.

1.1.6 DOUBLE MASS CURVE ANALYSIS

This allow data from stream flow gauge to be compared with data from other stream flow gauges from the same general region, to detect non climatic changes in flow regime. In essence, compares data in the same region.

1.2 STATEMENT OF THE PROBLEM

Accurate data as far as flood prediction and estimation of discharge is concerned is the most important parameter as far as hydraulic structures are concerned. However, not every stream or river have a record of discharge especially in developing countries like Nigeria where so many circumstances lead to the non availability of such records. In spite of all these, more hydraulic structures like dams, culverts, bridges, irrigation schemes etc still has to be built to improve the life of people. These hydraulic structures need a basis for accurately estimating and predicting the discharge at any point of concern.

Based on the forgoing, this research work is intended to analyze and present a model that can be used to predict the discharge of a stream or river provided there are records of other streams in that same region, using a case study of Taraba region.

1.3 PURPOSE OF STUDY

The aim of the study is to use regional flood frequency analysis to predict the mean annual flood at any point within a region. Specifically the study seeks to:

- Check the consistency of the available records in the region.
- Come up with a simple equation that can be applicable anywhere in the region.
- Predict the mean annual discharge of any river within the catchment using the length and area of stream and catchment respectively.
- Come up with a procedure that can be adopted for other regions.

1.4 SIGNIFICANCE OF THE STUDY

Based on the reasons pointed out previously, so many factors lead to non availability of records for some streams. Some of these factors are inevitable and therefore need an alternative to be provided to predict the discharge of streams with ease so that the devastating effects of flood in the failure of hydraulic structures can be curtailed. The study can also go a long way in solving the problem of over design and under design in hydraulic structures.

1.5 SCOPE OF THE STUDY

As stated previously, Regional analysis consists of two major parts. The first is the development of the basic dimensional frequency curve representing the ratio of the flood of any frequency to the mean annual flood.

The second part is the development of relations between topographic characteristics of the drainage area and mean annual flood to enable the mean annual flood to be predicted at any point within the region.

The later hear is the main point of concern as far as this study is concerned. The study shall limit itself to finding a suitable equation for flood prediction within the region using the area and length of the catchment and river respectively.

1.6 STUDY AREA

The study area is the taraba state region, the records used where gotten from four stations located at different parts of the state. The areas include: river taraba at bali station, river donga at donga and gindin dorowa stations, river bantaji at suntai station.

1.6.1 RELIEF AND DRAINAGE

The state may be divided into three topographic regions. The first is the extensive fadama swamps of the muri plains which is west of the river benue, covering mostly ibi and Karin lamido local government areas. The second is the undulating lowland of the muri plains is another topographic plain. This is broken down intermittently by high hills such as the kungana, fali and bali hills which developed on both sedimentary and crystalline rocks.

The third is the mambila plateau topographic region which has some uniqueness. The topographic region has some of the largest and highest mountains in Nigeria, with peaks reaching over 1840m. The chabal Hendu for example is over 200m above sea level. The mambilla plateau forms the water shed from which the major drainage systems in Taraba state take their source. Rivers benue, Donga and Taraba are the dominant drainage systems which flows across the muri plains to drain the entire state. They form extensive flood plains in the central part of the state together with minor ones, such as the lamorde and the mayo randewo.

1.6.2 CLIMATE

Like most part of northern Nigeria, taraba state has a wet and dry climate. The wet seasons last on an average, from April to October. Mean annual rainfall varies between 1058mm in the north around Jalingo and zing, to over 1300mm in the south around Serti and Takum. The wettest months are august and September. The dry seasons last from November to March. The driest months are December and January with relative humidity dropping to about 15%. The minimum temperature ranges between 150 C to 230 .The mambilla plateau has climatic characteristics typical of the temperate climate. Temperatures are low throughout the year and the rainy season last from February to November with mean annual rainfall of over 1850mm.

1.6.3 VEGETATION

Rainfall distribution and topography are the most important factors influencing the pattern of vegetation in Taraba state. The vegetation may be classified into three broad types: the northern Guinea, the southern guinea and the mountain grass land and the forest vegetation. The boundary between the northern Guinea and southern Guinea correspond fairly closely with the 1400mm mean annual rainfall isohyets, while the mountain forest and the grass land vegetation occur mainly on the mambila plateau. Most of the lowland and the area are

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Floods are associated with the phenomenon of an unusual high stage of river, resulting from excessive rainfall. The water overflows the river banks and spread to the inundate adjoining the land. Floods are caused by a variety of factors which are both natural and man made; infact floods have historically killed more people than any other form of natural disaster. Because of this fact, human beings have made several attempts to manage flood using the variety of methods with varying decrees of success.

However, what ever these methods are, solving the problem lies in being able to estimate the discharge when there is a likely occurrence. The reasons for such occurrence is equally important and what to put in place or measures to take to reduce or remove the risk on life and properties. To predict such estimate of discharge, flood frequency Analysis has to be considered.

1.1.1 FLOOD FREQUENCY ANALYSIS.

This make use of observe data in the *past* to predict future flood events along with their probabilities or return periods. It is based on the assumption that, combination of numerous factors which produce floods is a matter of pure chance and therefore is subject to analysis according to mathematical theory of probability. To provide useful answers, it must be based on adequate and accurate data.

1.1.2 SELECTION OF DATA.

The data is merely a sample of the total population of floods that have occurred and may be expected to occur in future. If samples are too small, predictions about the future flood may not be reliable.

However, there are situations where there is no data at available, that is when the site is ungauged, certain measures have to be taken to estimate flood in such occasions or situations. Regional Flood Frequency Analysis is one of the approaches used.

1.1.3 REGIONAL FLOOD FREQUENCY ANALYSIS

This is used to provide a frame work for characterization of extreme extrapolations beyond the range of available data. This means it can be used for either gauged or ungauged locations. For gauged locations, the aim is to augment the available but limited at site information for estimating flow discharge. For ungauged locations, information from made up of the ferruginous tropical soils which develop on crystalline acid rocks and sandy parent material.

Envelope curves for extreme flood events in the United States were introduced by Crippen (1982). But the concept of robust flood frequency models was introduced by Kuczera (1982), who found that regionalized estimates which combine both site and regional information were preferable for longer record length.

2.2 HOMOGENEITY

The performance of any regional estimation method strongly depends on the grouping of sites into homogenous regions even though regional estimation of flood quantiles at site of interest is an important step. Geographical contiguous regions have been used for a long time in the hydrology, but have been criticized for being of arbitrary character. In fact the geographical proximity does not guarantee hydrological similarity, but in a multidimensional space of catchments related characteristics or statistical characteristics.

A significant contribution to solving the delineation issue is the region of influence approach, developed by Burn (1990). Zrinji and Burn (1993, 1994) replaced the some what subjective choice of threshold with a statistical test in which sites are successively added, until the hypothesis of complete homogeneity is rejected by the test An advantage of the region of influence method is that in estimation of a regional curve, each site can be weighted according to its proximity to the site of interest.

Cadavis (1990) proposed another method for delineating homogenous regions based on canonical correlations. The approach is mathematically different from the region of influence approach method, but it is based on the same concept of neighborhood. Group of sites with similar floods response were visually identified in a space of two hydrological conical variables and then subsequently interpreted in a space of two physiographical conical variables. The flood and catchments variables must be carefully selected and weighted. An ungauged (or gauged) site can be assigned to a region based on catchments characteristics alone. The problem with this method is that the pattern of recognition is based on a subjective visual judgment, and that there is no guarantee that a pattern can be found. Canonical catchments variables were also used by Burn and Boorman (1990) for decimating between clusters.

Nathan and McMahon (1990) used clusters analysis to group sites into homogenous regions. Their work is notable for the emphasis and thorough discussions on the selections and weighing of attrite variables, an issue which should investigate much more.

The fact is, the selection and weighing of variables is one of the problems where no strict mathematical solutions are available, but use of common sense can lead to quite acceptable results. It is important to design simulation experiments so as to take adequately into account the regional heterogeneity always encountered in practice. Some regional estimation methods are sensitive to heterogeneity while others are the more robust to the violation of the basic assumptions.

It is however pertinent to note that heterogeneity sometimes can be as a result of certain reasons that no mathematical simulations can correct. These reasons include: changes in hydrological environment as a result of various human and natural activities like movement of gauge, change in observers, change in channel configuration at gauge site; installation of hydraulic structures like dams, irrigation schemes and so on; sudden change in hydrological parameters from catastrophic natural events (e.g. wild fires, landslides, earthquakes or large floods).

In view of all these factors, sometimes a simple check using the most convenient method based on the peculiarity of the data is the key, except if there are discrepancies then other methods can be used to correct it.

2.3 TRENDS IN FLOOD FREQUENCY ANALYSIS

Todd (1957) discussed the basic principle of frequency analysis of stream flow data and outlined computational procedures. Construction of probability papers for the exponential bounded exponential and log Pearson (3) distribution was discussed by Burkhadts and Parkshish (1976).

Linsley (1986) discussed the accuracy of flow estimates. The gap between research and practice in flood research and strategies to close them were discussed by Pilgrim (1986). One of Pilgrim's conclusions was that, inadequate attention was given by researchers to problems which are important to practitioners. Klemes (1987) was more categorized in his criticism, he stated that the term flood is being used merely as the number employed, at worst it is a pretentious game draining resources from both hydrology and engineering research; and a cheap opportunity to satisfy needs of academics to publish papers and supply easy topics for graduate students who know little beyond elementary statistics probability theory and computer programming

Although Klemes claims can be arguable, but the fact remains that, the classical approach to flood frequency analysis is hampered by lack of sufficient data. Regional analysis can to some extent compensate for the lack of temporal data, but introduced a spatial dimension which is not well understood. Classical flood frequency analysis, be it at site or regional, has been criticized for lacking balance and putting too much emphasis on mathematical rigor while completely neglecting the understanding of the physical factors that cause floods events. Again Klemes (1993) critically discussed this aspect by stating that "if more light is to be shed on the probability of hydrological extremes, then it will have to come from more information on the physics of the phenomenon involved, not from more mathematics". This is a fact which is difficult to argue against.

Regionalization, in particular the identification of the physical or meteorological catchments that causes similarity in flood response, is a step in the right direction that can cover for a lot of flood frequency analysis problems.

CHAPTER TWO

LITERATURE REVIEW

2.1 REGIONAL FLOOD FREQUENCY ANALYSIS

It has long been recognized that many annual flood are too short to allow for a reliable estimation of extreme events.

Regional flood frequency analysis calls for assumptions, test and methods of some what ad-hoc nature. It is generally difficult to assess or compare the performance of the regional estimation methods, because the degree to which implied assumptions are valid is hard to measure or quantify in practice. Over the years the most widely used method are the index flood method, the regression region distribution and the envelope curves for extreme flood events.

The index flood method (Dalrymple 1960, Nerc 1975, Arch 1989, Maldnet, 1993, Wallis and Wood 1985; Landwehr et al 1989, Potter and Lethmaier 1990 among others) is the regionalization technique with the longest history in hydrology. The technique assumes that the distributions of flood of all the sites within a homogenous region are the same except for a scale or index parameter. The mean of the at-site recorded value is the index flood parameter most commonly used. Cunnane (1988) assessed that the index flood method with a regional wake by distribution is the best available regional procedure, while Potter and Lettenmaier (1990) found that better results could be obtained with regional GEV distribution.

The regression region distribution procedure is another technique that relates hydrological statistics (e.g. flood mean, standard deviation, quantiles) to physiographic basin characteristics and meteorological variables affecting the flood process. Mainly used for ungauged catchments or sites. Cox regression model was used by smith and Kar (1986) for flood frequency analysis. This model allowed incorporation of time varying exogenous information into flood frequency analysis.

The record augmentation procedure (Hisch 1979, 1982, Tasker 1983, Vogel and Stedinger 1985; Vogel and Krol, 1991) employed when floods at short recover site are highly cross related with floods at a near by sites with longer records. The general idea is to improve the estimates of at-site lower order moments such as the mean and variance, by transferring information from site with longer records.

CHAPTER THREE

METHODOLOGY

3.1 HOMOGENEITY

The double mass curve analysis principle was used based on the description by P.J Rami (1994) stating that as long as relationship remains constant, the double mass curve will appear as a straight line, a deviation denotes the timing of change. This principle was used to check the regional hydrologic homogeneity of flood discharge records between the four gauging stations Suntai, Gindin Dorowa, Donga and Bali respectively.

3.2 PRINCIPLES OF DOUBLE MASS CURVE ANALYSIS

A certain number of stations with reliable data in the region were selected (suntai, Gindin Dorowa, Donga, Bali)

One of the station (suntai) is denoted X which is the station chosen to be considered in relation to the remaining stations.

The cumulative addition of annual discharge at station X starting with the latest year is computed. Similarly the average of the annual discharge at the four stations (suntai, Gindin Dorowa, Donga and Bali) is computed for every year and its cumulative added, starting with the latest year also.

A double mass curve of the base station versus other stations was plotted as presented in figure. Fig. 4.1. Table 3.1 shows the records of the stations.

3.3 REGRESSION ANALYSIS FOR MEAN MAXIMUM DISCHARGE.

Benson (1962) method of determining discharge Q from Area A and main channel Length L of the form $Q = a A^{b} L^{c}$ was used. Table 3.2 shows the mean maximum annual discharge with the length and Area.

By Regression Analysis:

Log Q = log a + b Log A + cLog L

Error E = Log Q - Log a - b Log A - cLog L

:EE2 = :E(Log Q - Log a - b Log A - cLog L)

o E2/0 Log a = 0

-2 :E(Log Q - Log a - b Log A - cLog L) = 0

:ELog Q - :ELog a - b :ELog A - c :ELog L = 0

:ELog Q = n Log a + b :ELog A + c :ELog L ----------- 1

oE2/0 Log a= -2 Log A:E (Log Q -Log a- b LogA-c Log L) = 0

L Log Q LogA= Log aLLogA + b *L* (Log A) 2+ c *L* Log 1. Log A ------- 2

BE2/Be = -2 Log L *L* (Log Q-Log a- b LogA-c Log L) = 0

L Log Q Log L = Log a *L* Log Q + b *L* Log A Log L + c *L* (Log L) ^{2} ------- 3

The three systems equations called normal equations are as follows:

L Log Q = n Log a + b *L* Log A + c *L* Log L

LLog Q LogA=Log a E Log A + bL(LogA) ^{2} + c *L* Log 1. Log A

L Log Q Log L = Log a *L* Log Q + b *L* Log A Log L + c *L* (Log L) ^{2}

The values for *L* Log Q, *L* Log A, *L* Log Q Log A, *L* Log Q Log L, *L* (Log A) ^{2}

L (Log L) ^{2}, *L* Log 1. Log A are computed in table 4.2.

The value for a, b, c are computed simultaneously using system equations and subsequently using the Length of the River and Area of the catchment to compute the predicted mean maximum discharge.

Table 3.1 Annual Mean Discharge Records of the Four (4) stations

YEAR	ANNUAL Q (m 3/s) suntai	ANNUAL Q (m 3/s) bali	ANNUAL Q (m3/s) G/Dorowa	ANNUAL Q (m3/s) Donga
1961	450	2125	1840	1645
1962	750	1642	740	1548
1963	850	2830	2380	2272
1964	900	2220	1780	1580
1965	508	2467	2000	1730
1967	632	1860	1840	1560
1968	950	2550	2300	1750
1969	910	2700	2500	2150
1970	619	2000	2100	1680
1971	600	1372	1280	1350
1972	630	2100	1760	1760
1973	640	2150	1800	1720
1974	562	2010	1850	1910
1975	646	1798	1500	1475
1976	856	1789	1700	1690
1977	378	1737	1760	1700
1978	407	1500	1750	2010
1979	800	1957	1790	1670
1980	745	2350	2170	2100
1981	960	767	2500	2400
1982	530	1897	2000	1740
1983	520	1415	1550	1600
1984	600	1398	1800	1490

Table 3.2 Mean Maximum Annual Discharge with Area and Length of the Rivers

River	Station	Drainage Area, A(km)	Drainage Length, L(km)	Mean Annual Max Discharge, Q(m3/s)
Bantaji	Suntai	5815	185	659.67
Taraba	Bali	10850	192	1998.42
Donga	GlDorowa	20390	305	2004
Donga	Donga	11909	257	1745.63

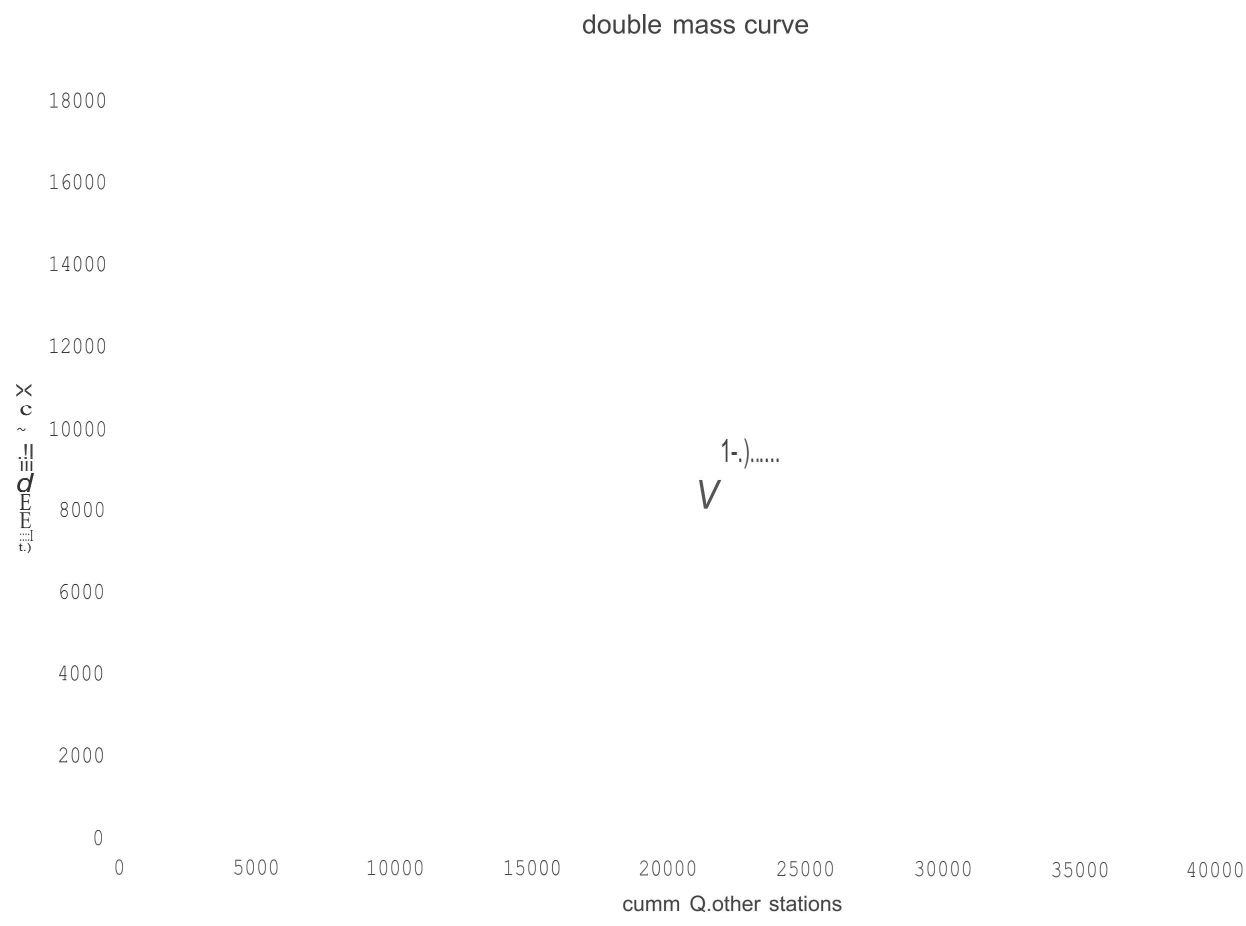
CHAPTER FOUR

RESULTS AND DISCUSSION.

4.1 HOMOGENEITY

The principle of double mass curve as stated previously was followed and the subsequent cumulative discharge is presented as shown in Table 4.1. while graph of the cumulative discharge of the four stations as abscissa and the cumulative discharge of station X (Suntai) as the ordinate was plotted as shown in the graph (fig 4.1).

Fig 4.1 Double Mass Curve Graph



The straight line obtained from the double mass curve in the graph plotted shows or indicate that the discharge records considered is consistent. This indicates some accuracy in the four stations. This is the condition or criteria showing consistency as far as double mass curve analysis is concerned.

Table 4.1 Annual Mean Discharge Cumulative of the four and Station X

Year	Annual cumm. Q (m3/s) Suntai(X)	Mean Annual cumm. Q(m3/s) of fourstations
1961	450	1515
1962	1200	2935
1963	2050	5018
1964	2950	6638
1965	3458	8314.25
1966	4128	9899.25
1967	4760	11404
1968	5710	13291.5
1969	6620	15356.25
1970	7299	16956.25
1971	7939	19257.25
1972	78469	20757.25
1973	9109	22334.75
1974	9671	23917.75
1975	10317	25272.5
1976	11175	26781.25
1977	11551	28175
1978	11958	29591.75
1979	12758	31146
1980	13503	32987.25
1981	14463	34894
1982	14993	36435.75
1983	15413	37682
1984	16013	39004

4.2 REGRESSION ANALYSIS

Using the system equations derived previously i.e.

$\sum \text{Log } Q = n \log + b \sum \log A + c \sum \log A$

$\sum \text{Log } Q \log A = \log a \sum \log A + b \sum (\log A)^2 + c \sum \log L .\log A$

$\sum \text{Log } Q \log L = \log a \sum \log Q + b \sum \log A \log L + c \sum (\log L)^2$

The values were computed as shown in Table 4.2 below with the values of L, A and Q gotten from Table 3.2

Table 4.2

Station	Log Q	Log A	Log L	Log Q Log A	Log Q Log A	Log A log L	(log)2	(Log N)
Suntai	2.8193	3.7645	2.2672	10.613	6.3919	8.5348	5.1402	14.1718
Bali	3.3007	4.0354	2.2833	13.319	7.5365	9.214	5.2135	16.2845
Dorowa	3.3019	4.3074	2.4843	14.229	9.2029	10.706	6.1717	18.5709
Donga	3.242	4.0759	2.4099	13.214	7.8129	9.8225	5.8076	16.613
Z	12.664	16.185	9.447	51.376	29.944	38.277	22.333	65.6402

$N = 4$ i.e. the number of stations

The corresponding equations are:

$\text{Log } a + 16.185b + 9.447c = 12.664$

$16.185 \log a + 65.6402b + 38.2771c = 51.3757$

$12.6639 \log a + 38.2771b + 22.333c = 38.2771$

The value for a, b and c was solved using Gaussian elimination method as shown in table 4.3

Table 4.3 Gaussian Elimination Table

	Log a	b	c	M
0.2471	4	16.1851	9.447	12.6639
	16.1851	65.6402	38.2771	51.3757
0.7824	12.6639	38.2771	22.333	29.944
0.00265		-0.0346	-0.0113	0.0310
		-13.0798	-7.6150	-10.252
			0.0089	-0.0038

From backward equation, we have the following

$0.0089c = -0.0038$

$-13.0798b \; -7.615c = -10.252$

12.6639 log a + 38.2771 b + 22.333c = 29.9442

Therefore

c= *-0.0038/0.0089* = -0.427

b= 10.252 + (7.6150 x 0.427)1l3.0798 = 1.032

Log a= 29.9442-(38.2771 x 1.031) + (22.33 x *0.427)/12.6639=0.00434*

Therefore

a=1.01

The mean annual maximum discharge $Q=a A^{b} L^{c}$

The equation now becomes $Q= 1.101 A^{1.032} L^{-0.427}$ which can be written as

$Q = AL^{-0.4}$ for the regional estimation of the mean annual maximum discharge.

Subsequently the predicted mean annual discharge is computed by putting in the values of L and A for each of the station and comparing it with the actual mean annual maximum discharge as shown in Table 4.4

Table 4.4 Comparism of the Predicted and Actual Mean annual discharge

Station	Area, A of catch. (km")	Length of River (km)	Mean max. Q (mvs)	Predicted Q (mvs)
Suntai	5815	185	659.67	863.l8
Bali	10850	192	1998.42	1709.88
GlDorowa	20390	305	2004	2492
Donga	11909	257	1745.63	1532.38

The comparism shows that the closeness of the predicted data obtained from the regression analysis and the observed data varies among the four stations when compared. It has a range of 12% - 31% error. The efficiency on the other hand ranges from 69% - 88% with an average of 80% efficiency and 20% error respectively.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The straight line obtained from the double mass curve in the graph plotted shows or indicate that the discharge records considered is consistent.

However based on the comparism of the actual mean maximum discharge and the predicted mean annual discharge as shown in the table 4.4, shows that the closeness of the predicted data obtained from the regression analysis and the observed data varies among the four stations when compared. It has a range of 12% - 31% error. The efficiency on the other hand ranges from 69010 - 88% with an average of 80% efficiency and 20% error respectively.

It can therefore be said that, there is a degree of accuracy in the result obtained and the regression equation obtain for the prediction.

The degree of error can be attributed to the fact that though rivers are of the same catchment area, but some are far apart from each other despite sharing the same source. Another reason is the slight variation in the climatic condition.

However it is important to point out that the degree of efficiency is attributed to the fact that the rivers lie in the same climatic region even though the stations are a little far from each other.

Based on the discussion above, it is pertinent to say that this report has been able to present a method of checking the consistency of discharge records for streams and the prediction of mean annual discharge for streams using the area of the catchment and length of stream. The prediction is 80% efficient.

5.3 RECOMMEDATION

The report is recommended for any catchment that satisfy the criteria for consistency and homogeneity both mathematically and physiographical, to predict mean annual discharge for streams. The report is strongly recommended for ungauged catchment sites that have incomplete records or no records at all, as long as records of other streams in that region are known.

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