ESTIMATION OF FLOOD DISCHARGES IN BANGLADESH

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A THESIS SUBMITTED
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN ENGINEERING
(WATER RESOURCES)

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DHAKA. MAY, 1985.

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF WATER RESOURCES ENGINEERING

May 11,1985

WE HEREBY RECOMMEND THAT THE THESIS PREPARED BY

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ENTITLED ESTIMATION OF FLOOD DISCHARGES IN BANGLADESH.

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING (WATER RESOURCES).

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ABSTRACT

This thesis deals with the analysis of extreme value discharge data of Bangladesh. Yearly maximum discharge data having discharge record for a period of more than 10 years, which covers about 67% of all the existing discharge stations have been analysed and discussed in this thesis. The analysis has been done to find the possible coefficients and exponents of some general empirical formulas with the aim of arriving at some empirical relations for the estimation of flood discharges in Bangladesh, at places where no discharge station is available. Discharge data corresponding to different return periods have been calculated by using the double exponential distribution function.

The analysis shows coefficients and exponents like Dicken's formula in north-western region and Ryve's formula in north-eastern region may be used to roughly estimate the flood discharges. Relations between discharge per drainage area and drainage area have been obtained for south-eastern region and hydrologic area 17 of S.W.region Relations between discharge and drainage area at different return periods have also been developed for Sylhet hilly areas. An envelope curve (straight envelope) has been developed for Bangladesh.

The analysis also shows that the Horton formula, Lane formula and Davis and Wilson's formula are not applicable in Bangladesh. It was observed that the drainage area and few other flood producing parameters are not sufficient to describe the flood discharges in Bangladesh. A large number of flood producing parameters should be incorporated for any reasonable results.

ACKNOWLEDGEMENT

The author gratefully acknowledges his indebtedness to his supervisor Dr. Syed Mohib Uddin Ahmed, Associate Professor, Department of Water Resources Engineering, for his able guidence and warm inspiration at all stages of the study.

The author wishes to express his warm gratitude to other members of his thesis committee, Dr. A. Hannan, Professor and Head, Department of Water Resources Engineering, Dr. M.Shahjahan Professor, Department of Water Resource Engineering, Dr. S.K. Chowdhury, Associate Professor, Department of Water Resources Engineering and Mr. Lutfar Rasul Munsi, Chairman, BWDB, for their valuable comments, criticisms and suggestions regarding this study.

The author is indebted to all the officials of the Surface Water Hydrology, Directorate-II, BWDB for their help and co-operation in collecting the discharge data.

Finally the author wishes to thank Mr. Yusufjai, Mr. Abdul Ali and Mr. Md. Mafiz Uddin for their help in drafting and typing the report.

Md. Aminur Rahman

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NOTATIONS USED

NOTATIONS

A	Drainage/catchment area, sq.miles
A_1	Drainage/catchment area, acres
A_2	Area of catchments, intercepted by irrgation, sq.miles
A_3	Wooded area of the Watershed, sq.miles
B	Coefficient
C	Coefficient
C_{max}	A limiting runoff coefficient corresponding to a reccurance interval of 100 years
C_2	Coefficient
F	Coefficient connecting characteristics of basin
F_1	Frequency factor
F_2	Multiplicative correction factor
K	Coefficient
L	Stream length, miles
N	Coefficient, sample size
P	Maximum rainfall over the catchment in 24 hours, inches
Q	Flood discharge, cusec
Q_T	Flood discharge equalled or exceeded once in an average of T years, cusec.
$Q_{T\ max}$	Maximum flow at flood peak, cusec
R	Rainfall, inches
S_N	Standard deviation
T	Return period, years
U	Parameter

NOTATIONS

$\bar{X}$	Sample mean
Y_N	Theoretical quantity
σ_N	Theoretical quantity
β	Scalar parameter
θ	Apical angle of the tringles dividing the catchment area
a	Coefficient
b	Coefficient
b_1	Average width of the catchment, miles
d	Coefficient
i	Rainfall intensity, inch/hour
k	Shape factor of catchment, ratio
m	Exponent
n	Exponent
p	Probability of accedance
q	Flood discharge, cusec/sq. miles
q_T	Flood discharge equalled or exceeded in a return period of T years, cusec/sq. miles.
t	Duration of rainfall, minutes
v	Velocity of runoff, ft/sec.
x	Exponent, initial variate
y	Dimensionless reduced variate

CHAPTER ONE

INTRODUCTION

1.1. General

From time immemorial, rivers and flood plains played an important role in human civilization. The natural facilities viz. adequate quantity of water for drinking and irrigation purposes; ease of travel, trade etc. through waterways; and the fertile agricultural land of the flood plains have attracted people to settle themselves near rivers and flood plains. These resulted in the implementation of various structures and projects in the areas for modernization of human life.

Once civilization start in such places, man's life fall in tremendous hazard by occasional flooding of the flood plains. The uncontrolled flood discharges erode river banks, damage flood plains and various engineering works therein, and causes loss of life and other natural resources. Sometimes flood is so much severe that it destroys civilization. To check these losses man always attempted to control floods.

For the control of floods, its measurement is very much important. Of the measurable features, the flood height, area inundated, peak discharge, volume of flow are remarkable. The peak discharge can be estimated by various methods and the concepts of flood formula is one of such methods.

Flood flow formulas are usually used to estimate the peak flow corresponding to a given basin of small or moderate size. The formulas usually contain one or more parameters, the most common being the catchment area. Difficulties in the application of such relationships arise from the lack of knowledge of exact conditions under which they may be applied. More reliance can be placed, of course, on equations or relationships developed for the region under study.

Flood in Bangladesh is quite destructive. Millions of cusecs of flood water are carried in the country every year by the major three rivers and their numerous tributaries and distributaries. Flood flow varies here from place to place distinctly. There are about 135 flood measuring stations in the country.[7] But it often become necessary to estimate the flood discharges to plan, design, and implement projects at places where no recorded data are available or a short duration data are available. It is, therefore, necessary to find means of estimating flood discharges in such situations.

Long-duration flood data for large rivers are usually available since the flood damage caused by them have always been of great concern to the public. For small and moderate size watershed flood data are inadequate. In Bangladesh almost all discharge stations, with a few exceptions, have recorded flood data for a period of about 5 to 20 years. In such situations flood frequency method is not always sutuable since flood record of at least 50 years are needed to establish reliable result.[6] Difficulties are also encountered with the method of enveloping, which sometimes give too higher values for discharges and need a wide range of drainage areas. Empirical method may therefore be used for estimating flood discharges in Bangladesh for places where there is no or only a few flood data is available.

1.2. Causes of Floods.

It is evident that rainstorm is the principal cause of flood. As per discussion by Mead[12], the causes of floods can be summarized as follows :

1) Floods occur on a given drainage area when the following conditions are satisfied at the same time and flood intensity and duration increases as the conditions become more favourable to increased runoff :

A. When the rainfall on the drainage area is of :

a. great intensity
b. wide distribution
c. long duration.

B. When the surface of the drainage area is impervious from :

a. saturation by previous rainfall
b. frozen condition of ground
c. normal geological structures.

C. When retention is at a minimum on the drainage area from:

a. cool weather
b. absence of vegetation.
c. high humidity.

In addition to the above, floods sometimes result from or are augmented by ice and the failure of reservoir dams.

II) In the comparison of floods on different drainage areas other factors are important : Topography, geology, arrangement of tributaries, surface conditions, location relative to storm paths and sources of vapour, climatic conditions, temperatures, wind velocities etc.

The maximum floods on all streams are due to a storm or a series of storms that have covered the drainage areas so as to produce a synchronism in the discharge of the various tributaries whereby the maximum flood accumulates at the locality under consideration.

While analyzing the causes of floods in India in the catchments with fluvial geomorphology, Rudra[15] stated that all flood-prone areas are topographically dish-shaped. So rain falling on high lands naturally flow down and the rivers of the plain being characteristically shallow cannot accomodate these huge bulk of water and thus flood is caused. The sediment deposition at the river estuary, tidal in nature, due to flood protection embankments is also a cause of floods. The change of courses of rivers and their tributaries and deforestation in the catchments also increases possibility of floods.

1.3. Design Flood.

The principal extreme events in hydrology are floods and droughts. Roudkivi[13] stated that floods may be characterised by peak flow rate, flood elevation, flood volume and flood duration. But in designing a project, the design flood are usually considered. The selection of the design flood is, in principle, an assessment of the risk involved against the failure of a structure which has been designed to prevent any loss with floods equal to or less than that of the selected frequency. To define design flood Singh[18] first classified floods into the following catagories :

(i) Ordinary floods which are equaled or exceeded once or twice in the lifetime of the structure.

(ii) Maximum probable floods which are equalled or exceeded only on rare occasions which corresponds to 100 year frequency.

(iii) Maximum possible floods which would occur only when the most severe flood producing combinations of meteorological and hydrological conditions to which the drainage basin is most susceptible would arise.

Kuiper[8] also defined maximum possible flood in the same manner. The selection of one of the three classes as the design flood depend upon the damage or damage and calamity both caused by the occurance of flood. For damage the ordinary flood is taken as the design flood. But for both damage and calamity the flood between maximum probable and maximum possible flood is taken as the design flood.[18]

Usual practice is the use of empirical methods for the estimation of floods or design floods where a few or no hydrometeorological observations are available or observations of short duration are available. The empirical methods and relationships are based on the observed data and are applied for the estimation of floods in the places with similar meteorological and hydrological conditions as in the places of evolution. These empirical relationships are also, in principle, regional methods in that these relationships can be applied with reasonable confidence in the region from which the data has been collected.

1.4. Objectives of the Study.

In view of the facts discussed above, it is felt that there is a definite need to study the empirical flood flow relationships for estimating floods in Bangladesh.

The main objectives of this study were therefore chosen as:

(i) To examine the applicability of the general flood formulas[5], with drainage areas as parameter, and to fix up the coefficients and exponents associated with them.

(ii) To examine the applicability of the flood formulas involving frequency relations and to fix up the coefficients and exponent associated with them.

(iii) To examine the applicability of the flood formulas connected to rainfall intensity and to fix up the coefficients.

(iv) To develope an envelope curve for flood discharges in Bangladesh.

1.5. Statement of the problem.

In the present data based study, discharge data of about 56 stations with separate catchment areas have been considered. The stations near the offtake points of the rivers have been excluded from the study since their drainage areas, the most common parameter of the formulas, are either zero or very small in compared to discharges or not well defined. There are some stations near the international boundary whose full catchment area are not known (since a portion lies in India). These stations have also been excluded from the study. All the stations having an available discharge record for a duration of less than 10 years have not been also considered. The data have been analysed and tested on each of the four hydrological regions namely north-western, north-eastern, south-western and south-eastern rigion of Bangladesh and also on 31 hydrologic areas of Bangladesh.[9]

Applicability of the flood flow formulas in Bangladesh are being examined in this study. In doing so, several formulas of different catagories have been considered. The scatterings of the plotted points of recorded flood discharge against different parameters of the formulas have been examined. In most of the cases the scattering of the plotted points were too much. When the plotted points were not widely scattered, the coefficients and exponents of each formulas have been found out from the average lines through the points which were either straight or curved lines as per trend of the plotted points.

Since the rainfall parameter is not readily available, the rainfall formulas have not been used for all the regions under study. Only the north-eastern region of Bangladesh has been considered to study by the rainfall formulas because the rainfall parameter for this area has been readily available.[11]

All the data analysed in this study were obtained from Bangladesh Water Development Board and Master Plan Organization.[9] It is expected that this study will be of great help for the Engineers connected with different water resources projects.

CHAPTER TWO

REVIEW OF LITERATURE

2.1. Introduction

Numerous formulas have been proposed by various authors for different parts of the world for the estimation of flood discharges. Vershney[19] and some others[1,14,16,17] collected some of these which are listed in table - 1. The formulas have usually been developed for certain streams or for certain areas in which the streams are believed to possess common characteristics. These areas also need to be of similar climatic and other conditions. From table-1 it is seen that some of the formulas can be generalised by some common formulas [5]. In the following a brief description is made on the rational formula, the general flood flow formulas, estimationof peak floods from hydrogeologic conditions of watersheds in U.S.A. etc.

2.2. The Rational Formula

Probably the first logical attempt to estimate flood flow was made by a group of Irish engineers during the period 1842 to 1847[2]. The method, in brief was for drainage channels capable of crrying a certain percentage of recorded maximum daily rainfall. Consequently the empirical formula

$$Q = CiA_1 \qquad \ldots \qquad (2.1)$$

was evolved as the first flood flow formula [2,13] where i is the rainfall intensity in inch/hour, C is a runoff coefficient, and A_1 is the area of the catchment in acres. The foundation of today's so-called rational method was laid by Thomas James Mulvaney[2] in a paper published in 1851. He suggested that for the maximum discharge to occur "a combination of circumstances as to fall of rain and the peculiar character of the catchment" may be required.

The rational formula was later recommended by Emil Kuichling in 1889 and Lloyd-Davis in 1906 and it is at present known as kuichling formula in the United States and Lloyd-Davis formula in the United Kingdom after the names of the engineers who first introduced it in their respective countries[2]. In 1932 Gregory and Arnold[3] developed a general rational formula like eqn. (2.1) in which

$$i = \frac{KT^x}{t^n} \quad \ldots\ldots\ldots \quad (2.2)$$

Where K is a coefficient depending on geographic location, T is the recurrance interval in years for a rainfall intensity of i in inch/hour for a duration of t minute to be reached or exceeded, x, n are the exponents depending on geographic location, and t is the duration of rainfall intensity in minutes. In 1938 Bernard[3] gave a formula for the coefficient C in the general rational formula (eqn.2.1) as given by

$$C = C_{max} \left(\frac{T}{100} \right)^x \quad \ldots \quad (2.3)$$

where C_{max} is a limiting runoff coefficient corresponding to a recurrance internal of 100 years. He also prepared charts for values of C_{max}, n, K, and x for the humid central and eastern half of the United States. In Bangladesh the rational formula is sometimes used by the designers. Assuming the areas around the eastern U.S. Gulf Coast to be approximately comparable to Bangladesh the coefficients of the rational formula have been developed [4]. Assuming a return period, T, of 10 years C has been calculated as 0.463. Also the value of i has been given by

$$i = \frac{68.2}{t^{0.73}} \qquad \ldots \qquad (2.4)$$

While applied to Sarai Basin (A_1 = 27,500 acres) in Rangpur district, the rational formula with these coefficients gave a discharge value of 2980 cusecs which is comparable with a measured peak of 3065 cusec [4].

The rational formula is based on many assumptions. Although these assumptions cannot be readily satisfied under actual circumstances, its simplicity has won its popularity. The formula is called rational because of numerical consistency of units of various quantities involved. Later the formula was found popular for design of drainage systems in urban areas and airport. Though the rational formula is sometimes used to compute discharge for drainage areas of many square miles, Chow[3] made a comment that this formula should be limited to areas of less than 100 acres, possibly 200 acres at most.

2.3. The general Flood Flow Formulas

It can be observed from table-1 that some of flood flow formulas can be generalised by the following equations[5]:

$$Q = CA^{n} \qquad \ldots \qquad (2.5)$$

$$Q = CA^{m\bar{A}^{n}} \qquad \ldots \qquad (2.6)$$

$$Q = \frac{CA}{(a+bA)^{m}} + dA \qquad \ldots \qquad (2.7)$$

Where Q is the flood flow rate, A is the drainage area and C,a,b,d and n,m are coefficients and exponents respectively.

Many formulas have been developed by various authors with different values of the above coefficients and exponents for various parts of the world. Most of the formulas were developed by analysis of the flood data. In the Indo-Pak subcontinent many formulas have been used such as Dicken's formula with coefficient 825-2,500 and exponent 3/4; Ryve's formula with coefficient 450-2,700 and exponent 2/3; Inglis formula with coefficient 7,000, 1 and 4 and exponent 1/2; Bransby William's formula with coefficient 4,600 and exponent 0.52 etc, the values of the coefficients being in the FPS unit.

For different values of the coefficients and exponents of equations - (2.5), (2.6) and (2.7) smooth lines can be obtained when calculated Q is plotted against A on log-log paper. Hence plotting of Q against A obtained from field can show whether any coefficient and exponent of equations-(2.5), (2.6) and (2.7) is possible for Bangladesh or not.

2.4. Peak Floods From Hydrogeologic Conditions of Watersheds

A detailed investigation to develope empirical runoff formula based on hydrologic conditions and geologic formations of watersheds was made by George J. Halasi-Kun for New Jersey in U.S.A.[6] . The author found from investigation in Czechoslovakia and West Germany that in rural areas the 100-year peak runoff of smaller watersheds (in the range of 300 km^2 or less) has upto a 90%-95% dependance on permeability of the geologic subsurface and on rainfall intensity. Vetetative cover and the form of the watershed were the factors causing the remaining 5%-10% of the flood. Configuration of the terrain, elevation above sea level, and average yearly rainfall values has practically no influence on the 100-year flood flow. The runoff values gained from research conducted in Central Europe(as in fig.1) was adjusted for New Jersey on the basis of point rainfall intensity characterization and area covered by storm centre. The general runoff formula took the following form :

$$q_{100} = CA^{-0.43} \quad .... \quad (2.8)$$

where, q_{100}= 100- year peak flood flow in cusec/sq. miles, C= coefficient with a value from 100 to 2000 depending on geologic subsurface, peak point rainfall intensity, and average annual rainfall (Fig.2). The value of the exponent varies from 0.37 for slightly rolling plains to 0.48 for mountains. Actual flood data obtained from measuring stations was then applied (Fig.3). Local corrections of the runoff formula for the effect of lakes and swams, wooded areas, shape of watersheds, and urbanization were also made. For lake and swamp a multiplicative factor from 1.75 to 0.25 was suggested (lake and swamp area varied from 0.1% to 20% of the total drainage basin). For wooded areas the suggested correction is :

$$F_2 = 1 + 0.5 \left(0.5 - \frac{A_3}{A}\right) \qquad \ldots \qquad (2.9)$$

where F_2 = multiplicative correction factor, A_3 = wooded area of the watershed, A= area of the entire watershed.

2.5. Double Exponential Distribution Function.

The double exponential distribution function of the largest value in its cumulative form is defined as :

$$p = F(X) = \exp\left(-e^{-y}\right) \qquad \ldots \qquad (2.10)$$

and

$$y = \frac{x-U}{\beta} \qquad \ldots \qquad (2.11)$$

Where y is the dimensionless reduced variate, x is the initial variate. The quantity U is the mode or location parameter of the distribution, β is a scaler parameter which is analoguus to the standard deviation, σ, of normal distribution. The parameters U & β completely define the distribution.

Combining the above two equation, the distribution function may be written as $F(X) = \exp(-\exp(\frac{1}{\beta}(x-U)))$. It was introduced for extreme values by R.A. Fisher and I.H. Tippet.[21] This function is sometimes known in Hydrology as Gumbel Di distribution because of Gumbel's various studies using this distribution in the flood frequency analysis.

For the prediction equation of double exponential distribution function, it is necessary to compute the sample mean $\bar{X}_N$ and the standard deviation S_N of annual series of sample of size N. The estimatore of two parameters U & β are given by

$$U = \bar{X} - \frac{\bar{Y}_N}{\sigma_N} S_N \qquad \ldots \qquad (2.12)$$

$$\beta = \frac{S_N}{\sigma_N} \qquad \ldots \qquad (2.13)$$

where $\bar{Y}_N$ and σ_N are the theoritcal quantities which are function of sample size only. Gumbel provides a table of values (Table - 2) for $\bar{Y}_N$ and σ_N as function of sample size N. Therefore the prediction equation for discharge magnitude (Q_T) may be expressed by the following equation :

$$Q_T = U - \beta \ln (\ln (\frac{T}{T-1})) \qquad \ldots \qquad (2.14)$$

CHAPTER THREE

COLLECTION AND ANALYSIS OF DATA

3.1. Introduction

The availability of flood data and the frequency of its occurance are very much important for the present study, the Estimation of Flood Discharges in Bangladesh. Bangladesh Water Development Board is the only organization which collect discharge data on many rivers of Bangladesh. Officials of the Hydrology Directorate of BWDB collect these data from field at definite intervals. In the following a brief description is made on the collection of data from field, the equipments and techniques used in the collection and the methods used for processing of the data.

3.2. Collection of Data from Stations

Data are collected at the gauging stations at regular intervals of time. Different intervals are used for different stations and different season. The intervals are decided on the size and importance of the catchment and also on the fund available.

During early sixties, Hydrological Survey Program of FAO/UNDP recommended[10] to gauge the major rivers once in a week throughout the year and to gauge the other rivers once in a week during the monsoon season and once in a fortnight during the rest of the year. With this program 52 measurements were done for major stations and 39 observations in other stations in each year. The program was more or less followed till late sixties and from then gauging frequency started decreasing because of shortage of fund. Presently the major stations are gauged weekly during the monsoon season and fortnightly during the rest of the year while the other stations are gauged fortnightly during the monsoon and monthly during the rest of the year. But gauging frequency has been increased in certain cases for special requirement. For example at Hardinge Bridge the river is gauged daily from 1st. January to 31st. May and weekly during the rest of the year, and at Dalia the river is gauged weekly throughout the year.

3.3. Processing of Raw data.

The discharges obtained from the gauging stations at intervals mentioned earlier are processed by the Hydrology office, Dhaka to get the mean daily discharges. Presently the processing work is done partially by computer. With the observed discharges obtained from a station in a year, a rating curve is prepared as shown in figure-4. The mean daily discharges are then obtained from the rating curve against the corresponding daily stage as measured at the discharge stations. The mean daily discharges, the ten day mean, monthly mean etc. are then produced on an "index card" from which data were obtained for this study. One index card contains discharges for one hydrological year from 1st. April to 31st. March.

3.4. Availability of Processed Data

There are 155 discharge measuring stations in Bangladesh[7]. Discharge measurement were going on at only 84 stations in March, 1982 as reported in Water Supply Paper-2 of Hydrology Directorate of BWDB[7]. The location of these 84 stations are shown in Fig.5. An upto-date discharge record, i.e. upto Water year 1982-83 and for some stations upto water year 1983-84 are available. Discharge record for different stations are available for different duration ranging from less than 10 years to 20 years and for a few stations upto 50 years. Hence all the stations were not possible to include in this study for a correct representation. To approach an accurate representation, the study regions, the hydrologic areas and the suitability of data in respect of duration of records were considered. A brief discussions are made on these in the following:

3.4.1. Study Regions

Bangladesh had been divided into four hydrological regions according to hydrometeorological and geological conditions. These regions are north-eastern region, north-western region, south-eastern region and south-western region. The present study covers all the regions.

M.P.O[9] divided the whole Bangladesh into 31 small divisions each of which has been called a "Hydrologic Area". Each of the hydrologic areas consists of one or more discharge measuring stations and in tern one or more catchment areas with similar hydrometeorological conditions. The boundaries of these hydrologic areas with their area number and also the locations of the stations included in the present study are shown in Fig.6.

3.4.2. Inclusion of Data in the Present Study

Discharge data of 56 stations have been included in the present study. A map with the location of these stations is shown in fig.7. Also table-3 shows the regionwise index containing the M.P.O.'s hydrologic area number, BWDB number and name of stations and corresponding number and name of rivers alongwith period of record used, number of years of record, catchment area, recorded maximum of mean daily discharges, the average of annual maximum discharges and recorded maximum of mean daily discharges per unit catchment area. Stations having available discharge record for a period of less than 10 years have not been included in the present study. The annual maximum discharges of all the 56 stations for all the years available and used in the study are presented in table-4.

3.5. Accuracy of the Data

In river flow gauging, daily flows are computed from rating curve and daily water level. Rating curve developed on the basis of actual measurement depends upon number of gauging available, but more gauging means increased cost of flow computations. M.A. Matin, Director, BWDB did a study about the relation between percentage error of rating and frequency of gauging in Bangladesh[10]. He obtained a relation shown in fig.8 The figure shows that for number of observations from 51 to 34 in a year, the percentage error of rating increases very slowly from about 8% to 10%. But when number of observations drops below 34, the percentage of error drastically increases. In Bangladesh, 39 observations are made in a year for major stations whereas 20 observations are usually made for other stations with a few exceptions.

3.6. Analysis of Data

The analysis of data for the present study includes plotting of data on suitable type of graph paper in which scattering of the plotted points is minimum. In the following a brief description is made on the analysis of data to examine the applicability of some formulas for different regions and hydrologic areas of Bangladesh.

For the formulas like equations- (2.5), (2.6) and (2.7) logarithmic plotting of Q against A have been done which are shown in fig. 9 to 12. From the trend of the plotted points it may be decided that whether any formula of the category of equations (2.5), (2.6) and (2.7) fits the data and which one fits best. Descharge per drainage area, q, were also plotted against A on log-log papers. Some of these which followed a definite trend are shown in fig. 13 and 14. Also the possibility of new coefficient and exponent can be seen from all these plottings.

To estimate flood discharges, q_T, in cusec/square miles at return period T years, Horton[5] found the formula -

$q_T = 4021.5A^{-0.5}T^{0.25}$. Plotting of q_T against A for particular return period can show whether this formula is applicable in Bangladesh or any new coefficient or exponent is possible. The discharges, q_T, for the present analysis were obtained as follows : The discharge equations were established for each station using the procedure mentioned in article 2.5. The equations are listed in table-5. From these equations, discharges of each station for return period of 2.33, 5, 10 and 20 years were obtained and are listed in table-6. From the values in table-6 discharges per drainage area (q_T) were obtained and plotted against drainage areas and are shown in figs. 15 to 18.

For the estimation of flood discharges, Q_T(cusec), at return period T years, Lane[19] developed the formula Q_T=KA(LogT + B) where K and B are the coefficients. From this equation it is seen that for a particular return period, if the plotting of Q_T against A can give a coefficient then it (the coefficient) may equal the quantity K(LogT + B). If two such plottings at two different return periods give two different coefficients then K and B can be equated which may be valid at those two return periods only. The Q_T values obtained from table-5 and 6 were plotted against A on log-log paper for return periods of 2.33, 5, 10 and 20 years and are shown in Figs. 19 to 23.

Davis and Wilson developed the formula $Q=KPA^{2/3}$ where P is the maximum rainfall over the catchment in 24 hours in inches. The authors found the values of the coefficient K 100 for undulating country and 200 for mountainous country. For the present study the rainfall parameter was taken from the available raingauge stations within the catchment. Matin[11] analysed the annual maximum daily rainfall data of the north-eastern region of Bangladesh. From his analysis the annual maximum daily rainfall for a return period of 20 years were taken as the parameter P since they constitute a more uniform set than the recorded maximum values. The parameter P is listed in Table-7. The values of K were calculated from $K=Q/PA^{2/3}$ (table-7) to see the variability of this coefficient.

An envelope curve for the rivers carrying very high discharges in comparison tothe size of their catchments was prepared for Bangladesh. The stations used in the analysis are listed in table-8 with their discharges, drainage areas etc. The modified Mayer's[19] formula $Q= C\sqrt{A}$ is usually used to express the straight envelope[20] while creager's[3,18,19] formula $Q=CA^{yA^d}$ is used to develope the curved envelope[20]. The coefficient and exponents can be determined on the basis of field data. For the present study the recorded maximum discharges were plotted against drainage areas on log-log paper and is presented in fig.24. The enveloping straight line was then drawn from where the coefficient and exponent were determined.

CHAPTER FOUR

DISCUSSION OF RESULTS

(1) Logarithmic plotting of recorded maximum discharge against drainage area in Fig.9 for north-western region of Bangladesh shows scatterings of the plotted points. So accurate relation is not possible in this situation. This may be due to the want of incorporation of more flood producing parameters.

Any way, a careful observation through fig.9 shows that the points are seperated into two rough but more or less distinct populations. One population roughly relates data of the northern part of north-western region, that means hydrologic areas 1 and 2, by the equation :

$$Q = 1,208.7A^{0.7574} \quad \ldots\ldots \quad (4.1).$$

which is comparable to Dicken's formula with coefficient 825-2500 and exponent 3/4 and used in north and central India.

The other population roughly relates the data of the southern part of north-western region, that means hydrologic areas 3, 4,5,6 and 7 by the equation:

$$Q = 200\ A^{0.7574} \quad \ldots\ldots \quad (4.2)$$

Whose exponent is comparable to Dicken's formula.

(2) Logarithmic plotting of recorded maximum discharges against drainage areas in Fig.10 for north-eastern region also shows scattering of the plotting positions. So in this case also accurate relation is not possible. This may be due to the lack of incorporation of flood producing parameters. Any way, a critical observation through the plotted points of fig.10 shows that the points are roughly separated into two populations. One population roughly relates the data of western part of north-eastern region (near the Brahmaputra river) that means hydrologic areas 8,9 and 10 by the equation:

$$Q = 1,548\ A^{0.62} \qquad \ldots\ldots \qquad (4.3)$$

which is comparable to Ryve's formula with coefficient 450 to 2,700 and exponent 2/3 and used in South India.

The other population roughly relates the data of the eastern part of the north-eastern region that means the hydrologic areas of 12,13,14,15 and 16 by the equati8n :

$$Q = 800\ A^{0.62} \qquad \ldots\ldots \qquad (4.4)$$

which is also comparable to the Ryve's formula.

(3) Logarithmic plotting of recorded maximum discharges against drainage areas as shown in figure - 11 and 12 for south - western and south - eastern region

respectively shows wide scattering of the plotted points. Hence, relation by such plotting is not possible for these regions. This may be due tothe fact that a large number of parameters need to be incorporated in these regions. However,by another way, a logarithmic plotting of recorded maximum discharges per drainage area against drainage area in fig. 13 for hydrologic area 17 shows the relation:

$$q = 30,636\ A^{-1.1455} \qquad \ldots\ldots \qquad (4.5)$$

where q is the recorded maximum discharge per drainage area. In a similar way, fig. 14 shows the relation :

$$q = 79,918.74\ A^{-1.1945} \qquad \ldots\ldots \qquad (4.6)$$

for south-eastern region.

(4). Logarithmic plotting of q_T (cusec/square miles) against drainage area in figs. 15 to 18 for different return periods shows wide scattering of the plotted points. Hence no conclusion could be drawn from these figures. This may be due to the fact that only a plotting of q_T against A is not sufficient to describe the coefficient and exponents of Horton formula. A number of parameters, which may be variable, need to be incorporated to find the coefficient and exponents.

(5) Logarithmic plotting of Q_T against A in figs. 19 to 22 for return periods of 2.33, 5, 10 and 20 years for different regions show wide scattering of the plotted points. Hence the values of K and B cannot be readily obtained from such plottings. Actually B is a constant for the region[19]. Hence to find the validity of Lane formula and to establish the values or K and B a number of flood producing parameters which also characterises the region need to be incorporated. However, the Logarithmic plotting of Q_T against A in Fig.23 for sylhet area comprising the hydrologic areas of 14,15 and 16 resulted the following relationships(unlike Lane formula) :

(i) $Q_{2.33} = 3.89 A^{1.4189}$ ..... (4.7)

(ii) $Q_5 = 8.81 A^{1.311}$ ..... (4.8)

(iii) $Q_{10} = 14.08 A^{1.2523}$ ..... (4.9)

(iv) $Q_{20} = 20.08 A^{1.2095}$ ..... (4.10)

(v) $Q_{50} = 29.04 A^{1.1669}$ ...... (4.11)

(vi) $Q_{100} = 36.522 A^{1.1414}$ ...... (4.12)

which may have only a local applicability.

(6) For Davis and Wilson's formula, it can be seen from table-7 that the calculated values of K for north-eastern

region of Bangladesh varies from 40 to 219. This wide variability of K is not comparable to the values of K=100 for undulating country and 200 for mountainous country as found by the authors. This creats a doubt about the direct applicability of Davis and Wilson's formula in the region. The cause may be the lack of incorporation of more parameters.

(7) Logarithmic plotting of recorded maximum discharges against drainage areas in Fig.24 for stations carrying large discharges in comparison to their catchment areas (table - 8) gives the following equation of straight envelope :

$$Q = 24{,}696 \quad A^{0.4127} \qquad \ldots\ldots \quad (4.13)$$

which is not comparable to any of the existing formula but only nearly coutgane's formula, $Q=20{,}000\sqrt{A}$, developed for Newzealand rivers. The excessively large co-efficient of 24,696 may be due to the following reasons : (i) the envelope curve represents the top line below which all the plotted discharges lie, (ii) in Bangladesh some rivers sometimes carry unusual discharges, may be, due to breaking of dam in the upstream country, India, or due to flashy character of the river etc.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The following conclusions can be drawn from the various analysis of flood discharges data presented in this study :

(1) Flood discharges can be roughly estimated by the equations :

(i) $Q = 1,208.7\ A^{0.7574}$ ...... (4.1)

in hydrologic areas of 1 and 2 and

(ii) $Q = 200\ A^{0.7574}$ .... (4.2)

in hydrologic areas of 3,4,5,6 and 7. But for a correct representation more flood producing parameters should be incorporated.

(2) Flood discharges can be roughly estimated by the equations :

(i) $Q = 1,548\ A^{0.62}$ ...... (4.3)

in hydrologic areas of 8, 9 and 10 and

(ii) $Q = 800\ A^{0.62}$ ...... (4.4)

in hydrologic areas of 12,13,14,15 and 16. But for a correct representation more flood producing parameters should be incorporated.

(3) Equation :

$$q = 30,636 \; A^{1.1455} \qquad \ldots\ldots \qquad (4.5)$$

gives the maximum flood discharge in hydrologic area 17 in cubic feet per second per square miles.

(4) Equation :

$$q = 79,918.74 \; A^{-1.1945} \qquad \ldots\ldots \qquad (4.6)$$

gives the maximum flood discharges in south-eastern region in cubic feet per second per square miles.

(5) Horton formula is not readily applicable in Bangladesh.

(6) Coefficients of Lane formula cannot be obtained only from discharge data.

(7) Equations :

(i) $Q_{2.33} = 3.89 \; A^{1.4189} \qquad \ldots\ldots \qquad (4.7)$

(ii) $Q_{5} = 8.81 \; A^{1.311} \qquad \ldots\ldots \qquad (4.8)$

(iii) $Q_{10} = 14.08 \; A^{1.2523} \qquad \ldots\ldots \qquad (4.9)$

(iv) $Q_{20} = 20.08 \; A^{1.2095} \qquad \ldots\ldots \qquad (4.10)$

(v) $Q_{50} = 29.04 \; A^{1.1669} \qquad \ldots\ldots \qquad (4.11)$

(vi) $Q_{100} = 36.522 \; A^{1.1414} \qquad \ldots\ldots \qquad (4.12)$

may have only a local applicability in the Sylhet area comprising the hydrologic areas of 14,15 and 16. The number in the suffix represents the return period in years.

(8) Davis and Wilson's formula is not readily applicable in north-eastern region of Bangladesh. More parameters should be incorporated to find the value of coefficient K.

(9) Equation :

$$Q = 24,696\ A^{0.4127} \qquad \ldots\ldots \qquad (4.13)$$

envelopes the major discharges of Bangladesh.

5.2. Recommendations for Future Study

The following recommendations are made for future study for the estimation of flood discharges in Bangladesh :

(i) Similar analysis of discharge data for all the stations of Bangladesh including the stations at the offtakes and also the stations whose drainage areas lies partly in India,

(ii) Study for the estimation of peak floods from hydrologic conditions of geologic surfaces of water-sheds and

(iii) Study for the estimation of flood discharges for the tidal areas of Bangladesh.

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APPENDIX - A

TABLES

TABLE - 1

EMPIRICAL FORMULAE

No	Author Author	Formula in metric unit	Formula in f.p.s.unit	Limitations
		INDIAN FORMULAE		
1.	Dicken Professional Paper on Indian Engg.Vol.II, 1865	$Q = CA^{3/4}$ Q in cumec, A in sq.Kms., C = 11.42 for areas with annual rainfall 600-1250 mm; max value of C = 35.	$Q = CA^{3/4}$ Q in cusec. A in sq.miles C = 825 = 2500 max.	Generally applicable for moderate size basins in North and Central India.
2.	Ryves	$Q = CA^{2/3}$ C = 6.8 within 80 km.of coast; 8.3 for areas between 80 and 2400 kms. from the the coast; 10.0 for limited area near the hills. Actual observed values are upto 40.	$Q = CA^{2/3}$ C = 450 to 2700	Derived from a study of river basins in South India.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s.unit	Limitations
3.	Craig Proc.of Inst. of C.E.Vol. L XXX 1884 - 85 pp. 201	$Q = 7.75\ Nb_1 \log_e(4.97\frac{L^2}{b_1})$ N = 0.12 to 0.18 b_1 = average width of strip in km. L = length of strip in km or $Q = 10\ CVi \log_e(\frac{4.97L^2}{b_1})$ where C = coefficient of discharge V = velocity in m/sec. i = rainfall in cms	$Q = 440\ Nb_1 \log_e(\frac{8L^2}{b_1})$ N = 0.12 to 0.18 b_1 & L in miles or $Q = 440\ CVi \log_e(\frac{8L}{b_1})$ V = velocity in ft/sec. i = rainfall in inches.	Area should be divided into a number of triangu lar strips before application;gives too low values in practice.
4.	Lillie Proc.of Inst. of C.E.Vol. CCXVII-1923-24pp. 295	$Q = 0.058\ VCa\Sigma(\theta L)$ $a = (1.1+\log 0.621L)$ $C = 2+ \frac{P}{38.1}$ P = annual rainfall in cm L = length of arm in km V = velocity of flow in m/sec. θ = apical angle of the triangles dividing the catchment area.	$Q = VCa\Sigma\theta L$ $a = (1.1+\log L)$ $C = 2+ P/15$ P in inches L in miles V= in ft/sec.	The catchment area has to be divided into a number of sectors of circles Formula gives too high values.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
5.	Inglis Tech.Paper No.30, Bombay P.W.D.1940	$Q = \frac{124\ A}{\sqrt{A+10.4}}$	$Q = \frac{7000\ A}{\sqrt{(A+4)}}$	Derived on the basi of rivers of Maharashtra.
6.	Ali Nawaz Jung Author's original note	$Q = C(0.386\ A)^{(0.925-1/14 \log 0.386A)}$ C = 49 to 60; max value = 86	$Q=C(A)^{(0.925-1/14.\log A)}$ C=1700 to 2100; maximum value= 3000	Lower values for south India and upper values for North India.
7.	Rhind Proc.Inst. of C.E. Vol. CLIV, 1902-3 PP. 292	$Q = 0.095\ \frac{C\ S Ra}{L} x (0.386\ A)^{p}$ S = average slope in m/km for 5 km above the site. Ra = greatest average rainfall in cms. P = index. L = greatest length of the catchment in km. C = a coefficient which varies as $\frac{Ra}{L}$	$Q = \frac{C\ S\ Ra\ A^{p}}{L}$ S = average slope of river in ft/mile for 3 miles above the site. Ra= greatest average annual rainfall in inches. L = in miles	Drived on the basis of data of some Indian rivers. Formula is not of much practical utility.

TABLE - 1 (Contd.)
EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
8.	Dredge and Burge U.S.G.S. water supply Paper No. 771	$Q = 19.5\ W.L^{1/3}$ or $= 19.5\ A/L^{2/3}$ W = average width of basin in km. L = length of basin in km.	$Q = 1300\ WL^{1/3}$ or $= 1300\ A/L^{2/3}$ W and L in miles	Based on Indian records but not useful.
9.	Hyderabad formula for Tunghbhadra	$Q = 49.6(0.386x\ A)^{(0.92-1/14 \log 0.386A)}$	$Q = 1,750x\ A^{(0.92-1/14 \log A)}$	Local Application
10.	Madras formula for Tunghbhadra. IV I.C.O.L.D. 1951	$Q = 56.7(0.386x\ A)^{(0.89-1/15 \log 0.386A)}$	$Q = 2,000x\ A^{(0.89-1/15 \log A)}$	Local Applicabilit
11.	Bransby William	$Q = 80\ A^{0.52}$	$Q = 4,600\ A^{0.52}$	For Western Indian catchments. $A \geqslant 25$ sq. km.
12.	Bourges	$Q = 19.6\ A/L^{2/3}$	$Q = 1300\ A/L^{2/3}$	

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s.unit	Limitations
		OTHER FORMULAE		
1.	Fanning. Treatise on Hydraulics and Water Supply pp.65 & "Hydrology and Water Sypply" by Fanning.	$Q = 2.64\ A^{4/3}$	$Q = 200\ A^{4/5}$	Based on data of New England Appalacian basins in America.
2.	U.S. Geological survey for columbia (Paper by Coutagne)	$Q = 25.2\ A^{0.476}$	$Q = 1400\ A^{0.476}$	A between 2500 and 60,000 sq.km.
3.	Ghamier-Proc.Inst. C.E.Vol CXXW Part IV 1897-78 pp.313	$Q = 3.5\ CR\ A^{3/4}$ R = in cms/hour C = 0.25 to 0.65	$Q = 640\ CR\ A^{3/4}$ R = greatest rainfall in inches/hour. C = 0.25 to 0.65	Applicable to small catchments.
4.	Murphy- U.S.G.C. Water Supply Paper 162, 1906.	$Q = (1325/(A+831) +0.164)\ A$	$Q = (46,790/(A+320) +15)\ A$	Mainly applicable to North-eastern U.S.A. and areas between 15 and 5000 sq.km.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
5.	Metcalf and Eddy Drainage and flood Control Engineering by Pickels pp.75.	$Q = 6.22\ A^{0.72}$	$Q = 440\ A^{0.72}$	Local application to water sheds over 500 sq.km.in area for American conditions.
6.	Burkli Ziegler-Trans.ASCE Vol. 77,1914 pp.616	$Q = 4.12\ A^{3/4}$	$Q = 296\ A^{3/4}$	Local application for American conditions.
7.	Possenti-Trans. AS.C.E. Vol.77, 1914 pp.616	$Q = 48.4\ \sqrt{A}$	$Q = 2{,}856\ \sqrt{A}$	Local application derived in U.S.A.
8.	Bremner-Drainage and Flood Control Engineering by Pickels pp.75	$Q = 26.4\ A/(2.42+\sqrt{A})$	$Q = 3{,}000\ A/(3+2\sqrt{A})$	For design of water way openings in C.B. & Q.R.R. in U.S.A. Applicable to small basins.
9.	Ganguilliet-Trans A.S.C.E. Vol.77, 1914 pp.615	$Q = 25\ A/(5+\sqrt{A})$	$Q = \frac{1{,}421\ A}{3.11+\sqrt{A}}$	Applicable to Swiss Strems.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
10.	Italian Formula Trans.A.S.C.E. Vol.77,1914, pp.615	$Q = \frac{32\,A}{0.5+\sqrt{A}}$	$Q = \frac{1,819\,A}{0.31+\sqrt{A}}$	For streams in Italy
		$Q = 45.7A/(0.5+\sqrt{A})$	$Q = 2,600A/(0.311+\sqrt{A})$	For small brooks in Italy.
11.	O'Cornell-Trans.A.S.C.E. Vol.77, 1914 pp.615	$Q = 9.53(A+0.0182)^{1/2}$	$Q = \sqrt{(458(640A+4.58)-45.8)}$	American origin - Local application
12.	Gramer-Trans. A.S.C.E.Vol.77 1914 pp.616	$Q = \frac{0.884\,A}{1+0.0985A^{1/2}}$	$Q = \frac{80.6\,A}{1+0.1347\,A^{1/3}}$	For Mohawak river U.S.A.
13.	Lanter Burg-Trans.A.S.C.E. Vol.77,1914 pp.616.	$Q = \frac{6710}{6000+A} + 0.085)A$	$Q = (\frac{615}{6+0.00259A} + 0.53)A$	American origin - local applicability.
14.	Coutgane (Newzealand).	$Q = 352\sqrt{A}$	$Q = 20,000\,\sqrt{A}$	For Newzealand rivers which are usually small.

TABLE - 1(Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
15.	Kuiching U.S.G.S. Water Supply Paper-771	$q = (\frac{1245}{A+440} + 0.022)$	$q = (\frac{44,000}{A+170} + 20)$	For occasional floods
		$q = (\frac{3,590}{A+960} + 0.061)$	$q = (\frac{1,27,000}{A + 370} + 7.4)$	For rare floods
		q = cumec/sq.km.	q = peak flood in cused per sq. mile	Areas upto 13,000 sq. km; mainly derived for Mohawak river in U.S.A.
16.	Cooley Drainage and Flood Control Engg. by Pickels pp.75	$Q = 0.015(145A+A^{2/3})$ for return period 5 to 10 years.	$Q = 200\ A + A^{2/3}$	For Mississippi Valley-local applicability.
17.	Fuller W.E. Trans. A.S.C.E. Vol.77, 1914 pp.564.	$Q_{av} = 0.013CA^{0.8} = C_1 A^{0.8}$ $Q = Q_{av}(1+ 0.8 \log T)$ $Q_{max}\ Q(1+2.5\ A^{-0.3})$ Q_{av} = yearly average flood	$Q_{av} = CA^{0.8}$	Constants derived on records of U.S.A. basins. If at least 10 years data is available it it applicable with sufficient reliability.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s.unit	Limitations
		Q = max.24 hr.flood for frequency once in T years. Q_{max} = maximum instantaneous flood discharge C varies from 0.026 to 2.27	$Q = Q_{av}(1+0.8 \log T)$ $Q_{max} = Q(1+2\ A^{-0.3})$ C varies from 2 to 210	
18.	Grunsky Trans A.S.C.E. Vol.85,1922 pp 66-136	$Q = \frac{13.6\ a.\ R.A.}{t^{1/2}}$ R = rainfall in cms. t = critical time in minutes $a = 60/(60+C_1\sqrt[3]{t})$ C_1 = 0.5 to 250.	$Q = \frac{3,200\ a.R.A.}{t^{1/2}}$ R = rainfall in inches C_1 = 0.5 to 250	Derived in California,not widely used.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s.unit	Limitations
19.	Myer Modified Trans.A.S.C.E. Vol.89,1926 pp. 985.	$Q = 176p\sqrt{A}$ p = a factor, depends on drainage factors and frequency of floods, usually unity.	$Q = 10,000\ p\sqrt{A}$	Based on long data of U.S.A. rivers. Wider applicability for first approximation.
20.	Horton, Trans. A.S.C.E. Vol. 77, 1914 pp. 665	$q = 114.1\,T^{0.25}/A^{-0.5}$ q = flood discharge in cumec/sq.km. equalled or exceeded in an average interval of T years.	$q = 4021.5T^{0.25}A^{-0.5}$ q = cusec/sq.mile	Constants variable & determinable on the basis of actual data. Hence not readily applicable.
21.	Lane, Trans, A.S.C.E. Vol.89,1926 pp. 1048.	$Q = k(\log T + B)A$ T = return period in years. B = a constant for the region.	$Q = k(\log T + B)\ A$	K and B determinable on the basis of actual data

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
22.	Pettis Major "A new theory of river flood flow" 1927. & The Engg. News Record. June 21, 1934.	$Q = C(pW)^{1.25}$ C varies from 0.195 for desert areas to 1.51 for humid areas. p = precipitation(100 year maximum) 1 day rainfall in cms. W = average width of the basin in km.	$Q = C(pW)^{1.25}$ C varies from 310 for humid areas to 40 in desert areas P in inches and W in miles.	Catchment between 2,600 to 26,000 sq. km.
23.	Switzer and Miller Floods Cornell Univ. Engg. Exp. Stn. Bulletin 13, Dec., 15, 1929.	$Q = P.C.\ W^{1.5}$ P = rainfall in cms. C = 0.436 usually.	$Q = P.C.W^{1.5}$ C = 80(usually) P = rainfall in inches.	For Miami Conservancy district

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
24.	Boston Society. Journal of the Boston Society of Civil Engineers September, 1930. Dec., 1952 and Jan., 1942 Report of the Committee on floods.	$Q = (5.54\ P/T')A$ T' = Base period of hydrograph in hours p = rainfall in cms	$Q = (1290\ P/T')A$ P = rainfall in inches.	Wide applicability if some actual hydrograph and rainfall data are available.
25.	J.M. Baird & J.F.Mcillwraith. -IV I.C.O.L.D. world peak.	$Q = 3010A(277+A)^{0.78}$	$Q = 131{,}000A/(107+A)^{0.78}$	Maximum recorded flood flows throughout the world.
26.	Australia	$Q = \frac{5100A}{(277+A)^{0.9}}$	$Q = \frac{22{,}2000A}{(107+A)^{0.9}}$	Max. recorded worst cloud bursts in Australia.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
27.	Coutagne -France	$Q = (10 \text{ to } 70)\ A^{0.5}$		Mild rain, A between 3,000 and 160,000 sq.km.
		$Q_a = 150\ A^{0.5}$		Violent rain; A between 400 and 3,000 sq.km.
		$Q_m = 200\ A^{0.4}$		A between 30 and 10,000 sq.km.
		$Q_a = 54.6\ A^{0.4}$		River Garonne; A between 300 and 35,000 sq.km.
		$Q_m = 10.76\ A^{0.737}$		For dams of Massif Central France
28.	Bransby Williams, U.K.	$Q_m = 37.5\ A^{0.75}$	$Q_m = 2700\ A^{0.75}$	$A < 25$ sq.km.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s.unit	Limitations
29.	Fridrich (Germany)	$Q = 24.12\ A^{0.516}$ Mean flow		A from 15 to 200,000 sq.km.
30.	Whistler(Italy)	$Q_m = (1538/A(A+259)+0.054)A$		A between 1,000 to 12,000 sq.km.
	Pagliaro(Italy)	$Q_m = (2900/(A+90))\ A$		$A \leqslant 1,000$ sq.km.
	Scimemi(Italy)	$Q_m = (600/(A+10)+1)A$		$A \leqslant 1,000$ sq.km.
	Baratta(Italy)	$Q_m = (280/A + 2)\ A$		For mountain basin
	Giandotti(Italy)	$Q_m = (532.5/(A+16.2)+5)A$		For mountain basins
	Forti (Italy)	$Q_m = (1625/(A+125)+1)\ A$		$A \leqslant 1,000$ sq.km. max. rainfall 400 mm in 24 hrs.
	Forti (Italy)	$Q_m = (1175/(A+125)+0.5)\ A$		Max.rainfall 200 mm in 24 hours.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
31.	Creager	$Q_m = C_1 (0.386A)^{0.894(0.386A)^{-0.048}}$	$Q_m = 56^{0.894A^{-0.048}}$	
		C_1 = 130 usually	C = 100 usually	
32.	Hunter & Wilmot U.K.	$Q_m = 38.5\ A^{0.72}$	$Q_m = 2,700\ A^{0.72}$	$A \leqslant 25$ sq.km.
		$Q_m = 80\ A^{0.52}$	$Q_m = 4,600\ A^{0.52}$	$A > 25$ sq.km.
33.	Lazarevic R.H. (Morocco) Int. Symp. Leningrad, 1967			
	Central Rif.	$Q = 15.55\ A^{0.776}$		Rainfall 100 - 130cm
	Western Rif.	$Q = 9.68\ A^{0.793}$		80 - 100
	Eastern Rif	$Q = 7.58\ A^{0.808}$		60 - 80
	H. Atlas Sahara	$Q = 9.38\ A^{0.742}$		20 - 40

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
	Middle Atlas	$Q = 14.94\ A^{0.636}$		Rainfall 70 - 90
	"	$Q = 13.51\ A^{0.613}$		50 - 70
	" (Karst)	$Q = 13.41\ A^{0.587}$		40 - 70
34.	Besson	$Q_m = (P_m/P_r)\ Q_r$ Q_m = max. expected flood Q_r = observed max. flood P_m = Expected max. rainfall P_r = Rainfall that caused Q_r		Very rational. Applicable to all places where data is available.
35.	Jarvis C.S. Proc.ASCE 1924	$Q = C\sqrt{A}$ $C = 17.6$ to 176	$Q = C\sqrt{A}$ $Q = 1000$ to $10,000$	For large catchments in U.S.A.

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
36.	Davis & Wilson Irrigation Engg.	$Q = k P_{av} A^{2/3}$ P_{av} = in cms. k = 0.6 to 1.2	$Q = k P_{av} A^{2/3}$ k = 100 for undulating country = 200 for mountainous country P_{av} = Max. rainfall over the catchment in 24 hours in inches	
37.	Waitt F.W.F. Report of the Stornmater standards Committee of I.O.E. Australia	$Q = \frac{176\ A}{0.8+\sqrt{A}}$	$Q = \frac{10,000\ A}{0.5+\sqrt{A}}$	

TABLE - 1 (Contd.)

EMPIRICAL FORMULAE

No	Author	Formula in metric unit	Formula in f.p.s. unit	Limitations
38.	Iszkowski-zeitschrift oesterv des eichischer Ingenieur and Architckton verein Vol.XXXVIII Wien 1886	$Q = 3.171\ C_h\ mI.A$ C_h = coefficient of annual runoff-0.017 to 0.8 I = annual rainfall cms. m = a coefficient relating max. to average discharge - 1 to 10.		

Source : VERSHNEY, R.S., 1979, "Engineering Hydrology", Nem Chand & Bros.

TABLE – 2

VALUES OF $\overline{y}_N$ AND σ_N AS A FUNCTION OF SAMPLE SIZE, N.

N	$\overline{y}_N$	σ_N	N	$\overline{y}_N$	σ_N
8	0.48430	0.90430	46	0.54680	1.15380
9	0.49020	0.92880	47	0.54730	1.15570
10	0.49520	0.94970	48	0.54770	1.15740
11	0.49960	0.96760	49	0.54810	1.15900
12	0.50350	0.98330	50	0.54854	1.16066
13	0.50700	0.99720	51	0.54890	1.16230
14	0.51000	1.00950	52	0.54930	1.16380
15	0.51280	1.02050	53	0.54970	1.16530
16	0.51570	1.03160	54	0.55010	1.16670
17	0.51810	1.04110	55	0.55040	1.16810
18	0.52020	1.04930	56	0.55080	1.16960
19	0.52200	1.05660	57	0.55110	1.17080
20	0.52355	1.06283	58	0.55150	1.17210
21	0.52520	1.06960	59	0.55180	1.17340
22	0.52680	1.07540	60	0.55208	1.17467
23	0.52830	1.08110	62	0.55270	1.17700
24	0.52960	1.08640	64	0.55330	1.17930
25	0.53086	1.09145	66	0.55380	1.18140
26	0.53200	1.09610	68	0.55430	1.18340
27	0.53320	1.10040	70	0.55477	1.18536
28	0.53430	1.10470	72	0.55520	1.18730
29	0.53530	1.1!860	74	0.55570	1.18900
30	0.53622	1.11238	76	0.55610	1.19060
31	0.53710	1.11590	78	0.55650	1.19230
32	0.53800	1.11930	80	0.55688	1.19382
33	0.53880	1.12260	82	0.55720	1.19530
34	0.53960	1.12550	84	0.55760	1.19670
35	0.54034	1.12847	86	0.55800	1.19800
36	0.54100	1.13130	88	0.55830	1.19940
37	0.54180	1.13390	90	0.55860	1.20073
38	0.54240	1.13630	92	0.55890	1.20200
39	0.54300	1.13880	94	0.55920	1.20320
40	0.54362	1.14132	96	0.55952	1.20440
41	0.54420	1.14360	98	0.55980	1.20550
42	0.54480	1.14580	100	0.56002	1.20649
43	0.54530	1.14800	150	0.56461	1.22534
44	0.54580	1.14990	200	0.56715	1.23598
45	0.54630	1.15185	250	0.56878	1.23292

Source : RAUDKIVI, A.J., 1976, Hydrology; Pergamon Press.

TABLE - 3

INDEX OF DISCHARGE STATIONS

Sl. No	M.P.O's Hydrologic Area Number	BWDB No.& Name of Station	BWDB No.& Name of river	Period of record From	to	No.of years	Catchment area in sq.miles	Recorded max.flood discharges in cusec	Average of Annual max. flood discharges in cusec.	*** q in cuse per sq. mile
				North-Western Region						
1.	1	142.1 Bushir Bandar	57 Karotoa Atrai Gur - Gumani - Hura - sagar	**1964-65	1980-81	14	787	88,604	37,882	112.6
2.	"	142 Khansama	"	67-68	80-81	12	737	161,321	74,436	218.9
3.	"	140 Panchagarh	"	64-65	82-83	17	197	187,798	37,237	953.3
4.	"	285 Thakurgaon	105 Tangaon	64-65	82-83	15	103	17,968	8,856	174.4
5.	2	294 Kaunia	104 Tista	59-60	83-84	22	1320	327,584	173,211	248.2
6.	"	81 Pateswari	36 Dudh Kumar	68-69	82-83	14	1417	253,807+	125,065	179.1
7.	3	16.1 Malonchi	9 Boral	65-66	82-83	16	87	36,359	20,397	417.9
8.	4	155 Mohimagonj	59 Kahak	64-65	82-83	18	1204*	39,889	19,270	33.1
9.	"	312 Talora Rly. Bridge	120 Nagor	64-65	79-80	15	128	7,378	3,170	57.6

** Water year 1964-65 means 1st April, 1964 to 31st March, 1965.

*** Recorded maximum flood discharges per unit catchment area.

* Catchment area partly in Bangladesh.

+ Second highest discharge. The highest(8,15,430 cusec)is exceptionally higher than the lowest (9,990 cusec).

TABLE - 3 (Contd.)

INDEX OF DISCHARGE STATIONS

Sl. No.	M.P.O's Hydrologic Area Number	BWDB No.& Name of Station	BWDB No.& Name of river	Period of record From	To	No. of years	Catchment area in sq.miles	Recorded max.flood discharges in cusec	Average of Annual max. flood discharges in cusec.	q*** in cus per sq mile
10.	5	65 Bogra	28 Deonai-Charal-Kata Jamuneswari-Karotoa	1964-65	1982-83	18	220	9,743	3,377	44.3
11.	"	306 Gabtoli	115 Isamati	64-65	1977-78	12	59	3,954	1,538	67.0
12.	"	313 Nangoora R.B.	121 Nangoora	64-65	79-80	15	134	32,158	11,016	240.0
13.	"	66 Ullapara	28 Deonai-Cha-Charal-Kota Jamunesswari-Karotoa	64-65	82-83	18	2007*	1,01,664	34,782	50.7
14.	6	238 Rohanpur	89 Punarbhaba	66-67	82-83	16	938	26,934	17,339	28.7
15.	7	147 Atrai R.B	57,Karatoa-Atrai-Gur-Gumani-Hurasquar	60-61	82-83	19	2875*	28,664	18,122	10.0
16.	"	149.1 Gumani Rly.Bridge	"	64-65	80-81	16	984	55,422	23,984	56.3

*** Recorded maximum flood discharges per unit catchment area.

* Catchment area partly in Bangla desh.

* Water year 1964-65 means 1st April, 1964 to 31st. March, 1965

TABLE - 3 (Contd.)

INDEX OF DISCHARGE STATIONS

Sl. No	M.P.O's Hydrologic Area Number	BWDB No.& Name of Station	BWDB No.& Name of river	Period of record From	To	No.of years	Catchment area in sq.miles	Recorded max.flood discharges in cusec	Average of Annual max. flood discharges in cusec.	*** q in cu per s mile
17.	7	17.1 Boral Rly. Bridge	9 Boral	1964-65	1982-83	17	60	16,273	8,580	271.2
18.	"	83.1 Naldanga Rly.bridge	37 Fakirni-Barnai	65-66	82-83	15	214	5,401	4,015	25.2
19.	31	90 Hardinge Bridge	39 Ganges	34-35	83-84	49	3,50,100*	25,83,960	17,71,916	7.4
				North - Eastern Region						
20.	8	34 Nakuagaon	17 Bhogai-Kangsa	64-65	79-80	15	187 *	35,653	15,431	190.1
21.	"	314 Ghosegaon	122 Nitai	64-65	82-83	17	150 *	23,722	12,137	158.1
22.	"	263A Durgapur	99 Sameswari	66-67	80-81	14	915 *	64,600	45,983	70.6
23.	9	134A Bausi R.B	52 Jhenai	64-65	77-78	13	54	17,085	10,052	316.4
24.	"	134 Jokerchar	52 Jhenai	65-66	80-81	13	98	27,358	20,860	279.2
25.	"	228.5 Mymensingh	86 Old Brahmaputra	64-65	82-83	16	430	1,34,846	102,163	313.6
26.	"	9 Kaoraid	6 Banar	65-66	76-77	10	75	10,590	6,594	141.2
27.	"	14 Mirjapur	8 Bangshi	65-66	81-82	12	552	32,724	13,991	59.3

* Catchment area partly in Bangladesh. *** Recorded max.flood discharges per unit catchment area.

TABLE - 3 (Contd.)

INDEX OF DISCHARGE STATIONS

Sl. No.	M.P.O's Hydrologic Area Number	BWDB No.& Name of Station	BWDB No.& Name of river.	Period of record From	To	No.of years.	Catchment Area in sq.miles	Recorded max.flood discharges in cusec.	Average of Annual max. flood discharges in cusec.	q*** in cusec per s miles
28.	10	301 Kaliakoi-r	111 Turag	1965-66	1982-83	15	444	42,714	26,964	96.2
29.	"	14.5 Nayerhat	8 Bangshi	64-65	79-80	15	1,175	1,14,726	65,929	97.6
30.	"	302 Mirpur	111 Turag	63-64	82-83	18	410	56,481	35,451	137.8
31.	11	230.1 Bhairab Bazar	86 Old Brahmaputra	64-65	75-76	11	24,993*	5,08,320	223,096	20.3
32.	12	36 Jariajangail	17 Bhogai-Kangsa	64-65	82-83	17	686*	44,126	32,389	64.3
33.	14	192 Motigonj	73 Lungla	64-65	80-81	11	86*	4,095	4,213	47.6
34.	15	267 Sylhet	102 Surma-Meghna	64-65	81-82	14	1,080*	87,544	73,008	81.1
35.	16	201 Manu R.B.	77 Manu	64-65	81-82	16	390*	26,687	18,994	68.4
36.	"	67 Kamalganj	29 Dhalai	64-65	80-81	15	195*	11,684	7,672	59.9
37.	31	46.9L Bahadurabad	22 Brahmaputra-Jamuna	65-66	82-83	17	2,06,895*	32,15,830	23,09,243	15.5

* Catchment area partly in Bangladesh.

*** Recorded maximum flood discharges per unit catchment area.

TABLE - 3 (Comtd.)

INDEX OF DISCHARGE STATIONS

Sl. No	M.P.O's Hydrologic Area Number	BWDB No.& Name of Station	BWDB No.& Name of river.	Period of record From	To	No. of years.	Catchment Area in sq. miles	Recorded max.flood discharges in cusec.	Average of Annual max. flood discharges in cusec.	q*** in cusec per sq miles.
38.	31	91.9L Baruria Transit	39 Ganges	1966-67	1983-84	16	2,24,000*	39,88,900	30,65,143	17.8
39.	"	93.5L Mawa	39 Ganges	65-66	83-84	16	6,03,701*	39,18,300	30,72,865	6.5
				South-Western Region						
40.	17	101.5 Kamar-Khali Tr.	42 Gorai-Modhu-mati Baleshwar	62-63	81-82	17	362	2,80,988	1,96,766	776.2
[illegible]	"	171 Goraganj	65 Kumar (Jessore)	61-62	82-83	19	336	9,637	2,981	28.7
[illegible]	"	205 Kazipur	79 Mathabhanga	67-68	82-83	15	59	17,897	8,860	303.3
[illegible]	"	206 [illegible]oalia	79 Mathabhanga	67-68	82-83	19	230	14,861	8,060	[illegible]
[illegible]	"	208 [illegible]	79 Mathabhanga	66-67	82-83	16	646	14,438	9,326	22.3
[illegible]	18	[illegible]	25 Chitra	65-66	77-78	11	139	1,108	684	8.0
[illegible]	19	[illegible]	64 Kumar(Faridpur)	65-66	76-77	11	229	9,390	[illegible]	[illegible]

* [illegible] partly in Bangladesh.

*** [illegible] maximum flood discharges per unit catchment area.

TABLE - 3 (Contd.)

INDEX OF DISCHARGE STATIONS

Sl. No.	M.P.O's Hydrologic Area Number	BWDB No.& Name of Station	BWDB No.& Name of river.	Period of record From	To	No. of years	Catchment Area in sq. miles	Recorded max.flood discharges in cusec.	Average of Annual max. flood discharges in cusec.	q*** in cusec per s[q.] miles
47.	21	162 Jhikargacha	62 Kobadak	1965-66	1977-78	10	226	4,201	1,142	18.6
				South-Eastern Region						
48.	11	114 Jibanpur (Gumti branch)	43 Gumti-Burinadi	65-66	82-83	17	911	21,780	10,582	23.9
49.	25	110 Comilla	43 Gumti-Burinadi	65-66	82-83	17	874	25,769	15,848	29.5
50.	27	212 Parsuram	81 Muhuri	65-66	81-82	16	263	24,145	10,243	91.8
51.	"	119 Panchpukuria	44 Halda	65-66	82-83	17	315	20,580	12,035	65.3
52.	28	124 Thandachari	47 Isamati	65-66	82-83	14	60	41,655	12,645	694.2
53.	"	40 Ramu	19 Bhogai	65-66	82-83	17	186	28,770	14,226	154.7
54.	"	247 Bandarban	92 Sangu	65-66	82-83	15	895	79,778	46,855	89.1
55.	"	203 Lama	78 Matamuhuri	65-66	82-83	17	401	78,013	41,478	194.5

*** Recorded maximum flood discharges per unit catchment area.

TABLE - 4

ANNUAL MAXIMUM DISCHARGES IN CUSEC.

Water Year	142.1 Bushir-Bandar	142 Khansama	140 Pancha-garh	285 Thakurgaon
1964-65	35,265	-	17,968	7,272
65-66	32,758	-	14,544	3,812
66-67	42,360	-	51,044	6,178
67-68	-	66,384	27,463	17,968
68-69	88,604	1,32,022	57,539	-
69-70	44,478	94,957	24,463	9,213
70-71	39,536	75,895	16,485	8,578
71-72	- - -	- -	- -	- -
72-73	30,076	87,897	1,87,798	4,660
73-74	27,675	31,452	15,497	7,731
74-75	43,419	48,714	25,381	-
75-76	27,781	63,893	34,876	-
76-77	27,463	61,775	18,886	13,379
77-78	-	-	-	7,731
78-79	25,416	30,676	20,086	4,448
79-80	33,464	25,557	29,899	10,202
80-81	32,052	1,61,321	39,183	11,508
81-82	-	-	40,948	8,719
82-83	-	-	10,978	11,437
83-84	-	-	-	-

TABLE-4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	81 Pateswari	161 Malonchi	155 Mohimagonj	312 Talora R.B.
1964-65	-	-	19,592	7,378
65-66	-	13,132	9,566	2,446
66-67	-	36,359	19,309	2,107
67-68		35,159	12,002	2,676
68-69	8,15,430	23,580	15,779	3,989
69-70	83,308	20,792	17,897	3,145
70-71	1,64,851	18,356	25,981	3,117
71-72	-	-	-	-
72-73	1,49,642	13,202	11,790	2,489
73-74	35,053	25,275	39,889	4,766
74-75	57,892	22,274	39,536	4,518
75-76	40,948	24,463	24,887	2,676
76-77	2,53,807	24,675	25,381	3,336
77-78	28,558	14,473	19,980	3,166
78-79	14,049	26,016	18,391	575
79-80	39,536	11,296	20,121	1,168
80-81	23,263	-	4,413	-
81-82	9,990	17,191	5,401	-
82-83	34,559	102	16,944	-
83-84	-	-	-	-

TABLE- 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	65 Bogra	306 Gabtoli	313 Nangura R.B.	66 Ullapara
1964-65	2,828	-	32,158	98,840
65-66	2,898	812	17,756	1,01,664
66-67	1,747	469	15,532	74,130
67-68	1,419	544	4,695	22,486
68-69	4,836	1,338	8,190	25,487
69-70	4,342	1,119	9,178	23,792
70-71	4,695	1,899	9,531	37,418
71-72	-	-	-	-
72-73	1,949	854	6,389	20,686
73-74	9,743	3,954	12,179	4,589
74-75	4,942	2,499	12,496	52,597
75-76	2,139	1,977	4,624	15,285
76-77	3,742	1,758	7,590	25,769
77-78	2,708	1,239	10,590	27,463
78-79	2,916	-	6,001	15,814
79-80	1,709	-	8,331	18,709
80-81	4,589	-	-	27,816
81-82	1,532	-	-	20,827
82-83	2,062	-	-	12,708
83-84	-	-	-	-

TABLE – 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	238 Rohanpur	149.1 Gumani R.B	17.1 Boral R.B.	83.1 Naldanga R.B
1964–65	–	55,422	16,273	–
65–66	–	28,911	14,261	3,989
66–67	16,485	20,792	7,943	3,276
67–68	18,003	19,274	7,201	2,828
69–70	22,168	26,262	11,084	4,660
70–71	23,969	24,181	9,355	3,601
71–72	–	–	–	–
72–73	10,096	16,697	6,213	–
73–74	19,909	22,063	8,613	–
74–75	21,392	21,780	9,249	3,477
75–76	8,366	21,462	7,554	2,736
76–77	17,438	26,475	8,190	4,095
77–78	13,944	22,769	9,566	3,883
78–79	16,662	22,310	–	4,589
79–80	14,085	23,333	6,551	5,154
80–81	13,873	16,626	6,283	4,413
81–82	16,838	–	5,683	5,401
82–83	17,262	–	3,452	3,495
83–84	–	–	–	–

TABLE - 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	34 Nakuagaon	314 Ghosegaon	134A Bausi R.B.	134 Jokerchar
1964-65	8,225	8,507	8,684	-
65-66	16,838	-	5,154	19,768
66-67	9,955	8,260	6,707	19,380
67-68	13,979	9,990	11,790	21,286
68-69	24,957	12,673	9,355	20,086
69-70	5,083	21,780	9,708	22,168
70-71	12,743	14,897	12,885	26,863
71-72	-	-	-	-
72-73	15,567	9,778	13,485	16,768
73-74	10,872	10,590	14,402	16,167
74-75	35,653	10,696	17,085	27,358
75-76	20,580	12,885	6,813	24,181
76-77	11,790	6,848	4,624	17,579
77-78	15,885	7,660	9,990	-
78-79	7,943	9,778	-	-
79-80	21,392	12,214	-	14,579
80-81	-	8,119	-	24,992
81-82	-	23,722	-	-
83-84	-	17,932	-	-

TABLE - 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	228.5 Mymensingh	9 Kaoraid	14 Mirjapur	301 Kaliakoir
1964-65	99,899	-	-	-
65-66	1,14,019	10,590	15,356	18,886
66-67	1,23,197	4,413	13,555	31,382
67-68	1,05,900	5,083	11,084	26,475
68-69	99,193	7,519	13,202	33,853
69-70	97,781	5,895	15,779	-
70-71	1,14,725	8,649	-	42,714
71-72	-	-	-	-
72-73	-	-	13,273	35,265
73-74	-	4,942	8,507	30,570
74-75	1,34,846	7,166	10,872	38,124
75-76	1,08,018	6,425	4,660	20,968
76-77	1,13,313	5,260	12,990	17,968
77-78	1,25,315	-	-	23,898
78-79	97,781	-	-	15,391
79-80	92,839	-	32,724	16,556
80-81	1,17,902	-	-	35,653
81-82	2,686	-	15,885	-
82-83	87,191	-	-	16,768
83-84	-	-	-	-

TABLE - 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	14.5 Nayerhat	230.1 Bhairab Bazar	114 Jibanpur (Gumti Br.)	36 Jariajangail
1964-65	75,895	4,34,190	-	27,075
65-66	69,894	4,27,130	10,378	31,876
66-67	87,544	5,08,320	12,779	34,771
67-68	56,480	4,48,310	9,107	34,876
68-69	95,310	4,69,490	10,166	33,253
69-70	61,422	20,968	11,578	-
70-71	1,14,726	28,381	6,354	30,182
71-72	-	-	-	-
72-73	59,657	24,992	5,789	35,653
73-74	84,367	24,392	9,496	26,087
74-75	96,722	42,007	9,002	44,126
75-76	33,464	25,875	12,885	31,558
76-77	34,382	-	21,780	27,358
77-78	47,302	-	11,120	31,876
78-79	38,830	-	18,886	30,076
79-80	32,935	-	11,155	36,288
80-81	-	-	7,413	29,511
81-82	-	-	6,989	29,334
82-83	-	-	5,013	36,712
83-84	-	-	-	-

TABLE - 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	263A Durgapur	192 Motiganj	267 Sylhet	201 Manu R.B
1964-65	-	2,097	75,595	18,780
65-66	-	505	57,504	-
66-67	44,831	-	82,839	16,344
67-68	40,948	-	71,800	10,767
68-69	58,951	-	69,506	26,687
69-70	44,125	-	74,998	14,402
70-71	44,831	1,638	73,989	23,263
71-72	-	-	-	-
72-73	64,600	-	63,399	15,391
73-74	32,970	1,370	79,199	22,168
74-75	57,186	1,338	74,998	19,592
75-76	30,252	621	80,837	17,968
76-77	48,361	2,097	87,544	20,862
77-78	39,536	4,095	64,246	21,568
78-79	44,125	2,146	-	20,474
79-80	51,397	1,980	-	16,979
80-81	39,571	2,845	-	17,862
81-82	-	-	65,658	20,792
82-83	-	-	-	-
83-84	-	-	-	-

TABLE – 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	67 Kamalganj	46.9L Bahadurabad	91.9L Baruria Transit	93.5L Mawa
1964–65	6,884	–	–	–
65–66	–	22,66,260	–	30,25,210
66–67	7,731	24,32,170	28,69,890	30,07,560
67–68	7,448	24,56,880	22,45,080	24,42,760
68–69	9,496	21,99,190	28,31,060	32,19,360
69–70	7,943	19,76,800	25,66,310	34,66,460
70–71	5,719	26,47,500	29,72,250	30,07,560
71–72	–	–	–	–
72–73	5,613	23,50,980	27,03,980	27,74,580
73–74	7,378	23,75,690	32,08,770	35,30,000
74–75	7,272	32,15,830	39,88,900	39,18,300
75–76	6,707	18,42,660	32,95,490	–
76–77	7,590	23,15,680	29,47,550	29,79,320
77–78	11,684	31,27,580	28,87,540	–
78–79	7,378	19,97,980	28,38,120	31,24,050
79–80	6,742	23,33,330	–	27,99,290
80–81	9,496	21,60,360	38,47,700	38,47,700
81–82	–	15,92,030	31,13,450	27,28,690
82–83	–	19,66,210	31,62,880	23,08,620
83–84	–	–	35,65,300	29,86,380

TABLE - 4 (Contd)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	205 Kazipur	206 Hatboalia	208 Darsana	54 Kaliganj
1964-65	-	-	-	-
65-66	-	-	-	822
66-67	-	-	5,436	-
67-68	9,355	8,684	10,872	487
68-69	6,107	6,389	6,566	1,108
69-70	10,202	10,202	12,284	939
70-71	5,189	6,495	8,613	964
71-72	-	-	-	-
72-73	4,130	4,024	4,201	317
73-74	7,413	6,813	9,002	547
74-75	8,472	8,613	9,249	533
75-76	8,825	7,342	8,790	340
76-77	10,696	8,543	11,190	554
77-78	7,307	6,954	9,999	907
78-79	12,214	11,578	12,179	-
79-80	3,989	4,448	5,577	-
80-81	17,897	11,155	14,438	-
81-82	6,001	4,801	8,507	-
82-83	15,108	14,861	12,320	-

TABLE - 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	162 Jhikargacha	169 Muzurdia	110 Comilla	212 Parsuram
1964-65	4,201	3,954	18,956	7,201
66-67	537	5,683	22,910	13,626
67-68	1,670	6,919	15,391	8,119
68-69	1,077	7,519	25,769	16,167
69-70	-	9,390	18,356	6,283
70-71	3,989	7,095	13,132	7,484
71-72	-	-	-	-
72-73	-	3,812	8,507	6,531
73-74	1,348	8,579	15,003	13,732
74-75	2,429	9,390	14,897	9,602
75-76	1,063	5,789	19,486	5,507
76-77	897	5,295	16,379	3,019
77-78	1,207	-	15,497	15,285
78-79	-	-	17,791	12,990
79-80	-	-	13,061	6,954
80-81	-	-	7,625	7,237
81-82	-	-	9,919	24,145
82-83	-	-	16,732	-
83-84	-	-	-	-

TABLE – 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	119.1 Panchpuku-ria	124 Thanda-chari	40 Ramua	27 Bandar-ban	203 Lama
1964-65	–	–	–	–	–
65-66	9,672	22,380	11,472	62,[illegible]	15,638
66-67	11,296	4,342	18,497	79,778	68,482
67-68	10,273	13,873	12,602	15,[illegible]	20,862
68-69	10,802	5,189	14,791	–	29,970
69-70	13,767	13,096	11,684	–	43,419
70-71	11,684	–	28,770	39,[illegible]	53,056
71-72	–	–	–	–	–
72-73	9,919	–	28,169	22,[illegible]	13,485
73-74	6,001	–	7,590	26,[illegible]	29,758
74-75	10,872	6,036	12,990	55,[illegible]	71,306
75-76	13,449	5,472	10,484	33,[illegible]	64,952
76-77	10,272	5,966	4,660	67,776	49,067
77-78	14,897	8,296	13,979	22,[illegible]	24,569
78-79	15,481	41,655	6,248	77,[illegible]	37,418
79-80	5,224	9,602	14,085	37,[illegible]	28,946
80-81	17,509	8,296	12,567	48,[illegible]	78,013
81-82	12,920	6,107	15,567	67,776	27,816
82-83	20,580	26,722	17,685	46,[illegible]	49,067
83-84	–	–	–	–	–

TABLE - 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water Year	294 Kaunia	147 Atrai R.B.	302 Mirpur	101.5 Kamarkhali Transit	171 Garaganj
1959-60	73,429	-	-	-	-
60-61	1,26,727	8,543	-	-	-
61-62	2,62,632	8,084	-	-	9,637
62-63	1,84,972	-	-	1,09,077	3,389
63-64	1,75,794	-	42,007	-	-
64-65	-	12,885	39,183	-	-
65-66	-	19,380	42,360	1,08,724	1,942
66-67	1,18,961	19,062	24,286	1,99,798	1,153
67-68	2,17,801	15,779	42,713	1,65,910	2,153
68-69	3,27,584	22,168	28,381	1,79,677	2,648
69-70	1,32,728	20,580	37,418	1,86,737	4,660
70-71	1,44,730	23,792	,-	1,94,150	2,457
71-72	-	-	-	-	-
72-73	2,20,625	10,872	31,170	1,52,849	1,490
73-74	2,17,801	-	36,006	2,05,799	1,818
74-75	1,79,677	20,968	56,481	2,80,988	1,889
75-76	1,96,974	15,497	26,969	2,26,626	3,424
76-77	1,65,910	28,664	24,569	2,33,686	2,298
77-78	2,15,683	18,180	32,970	2,27,332	3,707
78-79	1,10,842	17,015	25,345	2,23,096	2,054
79-80	1,75,088	20,580	35,229	2,32,627	5,330
80-81	1,33,434	23,086	55,774	2,08,976	2,107
81-82	1,94,150	20,050	30,676	2,08,976	3,004
82-83	84,014	18,497	26,581	-	1,472
83-84	1,51,084	-	-	-	-

TABLE – 4 (Contd.)

ANNUAL MAXIMUM DISCHARGE IN CUSEC

Water year	99 Gorai R.B.	90 Hardinge Bridge	Water year	99 Gorai R.B.	90 Hardinge Bridge
1934–35	–	16,44,980	1959–60	1,95,9[illegible]	18,60,310
35–36	–	15,53,200	60–61	1,45,7[illegible]	16,94,400
36–37	–	15,99,090	61–62	1,29,9[illegible]	25,83,940
37–38	–	13,90,820	62–63	1,18,9[illegible]	20,72,110
38–39	–	16,87,340	63–64	–	19,80,330
39–40	–	12,67,270	63–65	2,05,7[illegible]	17,29,700
40–41	–	13,80,230	65–66	1,68,3[illegible]	12,99,040
41–42	–	13,51,990	66–67	2,06,5[illegible]	14,79,070
42–43	–	15,77,910	67–68	2,42,8[illegible]	17,93,240
43–44	–	15,28,490	68–69	2,92,6[illegible]	15,95,560
44–45	–	15,28,490	69–70	2,66,8[illegible]	19,48,560
45–46	–	14,89,660	70–71	1,78,9[illegible]	17,19,100
46–47	–	17,33,230	71–72	–	–
47–48	1,63,792	18,07,360	72–73	1,77,9[illegible]	13,48,460
48–49	1,77,912	21,56,830	73–74	2,54,1[illegible]	17,89,100
49–50	1,70,852	18,56,780	74–75	2,98,6[illegible]	17,89,710
50–51	1,90,973	18,56,980	75–76	2,10,3[illegible]	18,03,830
51–52	1,27,080	14,89,660	76–77	2,33,7[illegible]	23,08,620
52–53	1,51,084	18,56,780	77–78	2,07,5[illegible]	18,03,830
53–54	1,75,794	17,96,770	78–79	2,45,6[illegible]	23,96,870
54–55	2,12,859	20,68,580	79–80	1,49,8[illegible]	13,02,570
55–56	–	21,28,590	80–81	2,31,9[illegible]	20,40,340
56–57	1,54,967	21,21,530	81–82	2,34,0[illegible]	16,90,870
57–58	1,29,904	16,30,860	82–83	2,40,7[illegible]	21,74,480
58–59	2,06,858	19,87,390	83–84	–	21,28,590

TABLE - 5

DISCHARGE - FREQUENCY RELATIONSHIPS FOR INDIVIDUAL STATIONS

M.P.O's hydrologic area No.	BWDB No.& name of station	Equation by double exponential distribution function (Q_T in cusec, T in years)
		North-Western Region
1	142.1 Bushir Bandar	$Q_T = 29,848 - 15,7$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	142 Khansama	$Q_T = 52,318 - 41,$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	140 Panchogarh	$Q_T = 16,849 - 39,$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	285 Thakurgaon	$Q_T = 6,986 - 3,6$[illegible] $\ln(\ln(\frac{T}{T-1}))$
2	294 Kaunia	$Q_T = 1,44,421 - 54,6$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	81 Pateswari	$Q_T = 34,792 - 73,5$[illegible] $\ln(\ln(\frac{T}{T-1}))$
3	16.1 Malonchi	$Q_T = 15,878 - 8,7$[illegible] $\ln(\ln(\frac{T}{T-1}))$
4.	1 55 Mohimaganj	$Q_T = 14,479 - 9,$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	312 Talora R.B	$Q_T = 2,363 - 1,7$[illegible] $\ln(\ln(\frac{T}{T-1}))$
5.	65 Bogra	$Q_T = 2,206 - 1,9$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	306 Gabtoli	$Q_T = 1,037 -$ [illegible] $\ln(\ln(\frac{T}{T-1}))$
	313 Nungoora R.B	$Q_T = 7,523 - 6,$[illegible] $\ln(\ln(\frac{T}{T-1}))$
	66 Ullapara	$Q_T = 20,667 - 27,$[illegible] $\ln(\ln(\frac{T}{T-1}))$
6	238 Rohanpur	$Q_T = 14,920 - 4,6$[illegible] $\ln(\ln(\frac{T}{T-1}))$

TABLE - 5 (Contd)

DISCHARGE - FREQUENCY RELATIONSHIPS FOR INDIVIDUAL STATIONS

M.P.O's Hydrologic area No	BWDB No.& name of station	Equation by double exponential distribution function (Q_T in cusec, T in years)
7	147 Atrai R.B.	$Q_T = 15,514 - 4,987 \ln(\ln(\frac{T}{T-1}))$
	149.1 Gumani R.B	$Q_T = 19,424 - 8,863 \ln(\ln(\frac{T}{T-1}))$
	17.1 Boral R.B.	$Q_T = 7,030 - 2,970 \ln(\ln(\frac{T}{T-1}))$
	83.1 Naldanga	$Q_T = 3,615 - 779 \ln(\ln(\frac{T}{T-1}))$
31	90 Hardinge Bridge	$Q_T = 1629465 - 259899 \ln(\ln(\frac{T}{T-1}))$

North-eastern Region

8	34 Nakuagaon	$Q_T = 11,510 - 7,446 \ln(\ln(\frac{T}{T-1}))$
	314 Ghosegaon	$Q_T = 9,706 - 4,692 \ln(\ln(\frac{T}{T-1}))$
9	134A Bausi R.B.	$Q_T = 8,145 - 3,762 \ln(\ln(\frac{T}{T-1}))$
	134 Jokerchar	$Q_T = 18,777 - 4,106 \ln(\ln(\frac{T}{T-1}))$
	228.5 Mymensingh	$Q_T = 87,432 - 28,564 \ln(\ln(\frac{T}{T-1}))$
	9 Kaoraid	$Q_T = 5,589 - 2,030 \ln(\ln(\frac{T}{T-1}))$
	14 Mirjapur	$Q_T = 10,548 - 6,837 \ln(\ln(\frac{T}{T-1}))$

TABLE - 5 (Contd)

DISCHARGE - FREQUENCY RELATIONSHIPS FOR INDIVIDUAL STATIONS

M.P.O's Hydrologic area No	BWDB No.& name of station	Equation by double exponential distribution function (Q_T in cusec, T in years)
10	301 Kaliakoir	$Q_T = 22,441 - 8,823 \ln(\ln(\frac{T}{T-1}))$
	14.5 Nayerhat	$Q_T = 52,852 - 25,501 \ln(\ln(\frac{T}{T-1}))$
	302 Mirpur	$Q_T = 30,627 - 9,274 \ln(\ln(\frac{T}{T-1}))$
11	230.1 Bhairab Bazar	$Q_T = 106,703 - 232,973 \ln(\ln(\frac{T}{T-1}))$
12	36 Jariajangoil	$Q_T = 30,173 - 4,277 \ln(\ln(\frac{T}{T-1}))$
8	263A Durgapur	$Q_T = 40,962 - 9,554 \ln(\ln(\frac{T}{T-1}))$
14	192 Motiganj	$Q_T = 1,366 - 1,039 \ln(\ln(\frac{T}{T-1}))$
15	267 Sylhet	$Q_T = 68,804 - 8,244 \ln(\ln(\frac{T}{T-1}))$
16	201 Manu R.B	$Q_T = 17,085 - 3,700 \ln(\ln(\frac{T}{T-1}))$
	67 Kamalgonj	$Q_T = 6,892 - 1,520 \ln(\ln(\frac{T}{T-1}))$
31	46.9L Bahadurabad	$Q_T = 2103,193 - 397703 \ln(\ln(\frac{T}{T-1}))$
	91.9L Baruria Transit	$Q_T = 2839696 - 437168 \ln(\ln(\frac{T}{T-1}))$
	93.5L Mawa	$Q_T = 2849544 - 433045 \ln(\ln(\frac{T}{T-1}))$

TABLE - 5 (Contd)

DISCHARGE - FREQUENCY RELATIONSHIPS FOR INDIVIDUAL STATIONS

M.P.O's Hydrologic area No	BWDB No.& name of station		Equation by double exponential distribution function (Q_T in cusec, T in years)
			South - Western region
17	101.5	Kamarkhali Transit	$Q_T = 1,74,731 - 42,532 \ln(\ln(\frac{T}{T-1}))$
	171	Ganagonj	$Q_T = 2,019 - 1,842 \ln(\ln(\frac{T}{T-1}))$
	205	Kazipur	$Q_T = 6,880 - 3,861 \ln(\ln(\frac{T}{T-1}))$
	206	Hatboalia	$Q_T = 6,576 - 2,895 \ln(\ln(\frac{T}{T-1}))$
	208	Darsana	$Q_T = 7,895 - 2,775 \ln(\ln(\frac{T}{T-1}))$
18	54	Kaligonj	$Q_T = 543 - 282 \ln(\ln(\frac{T}{T-1}))$
21	162	Jhikargacha	$Q_T = 1,169 - 1,359 \ln(\ln(\frac{T}{T-1}))$
19	169	Muzardia	$Q_T = 5,661 - 2,030 \ln(\ln(\frac{T}{T-1}))$
			South - eastern Region
11	114	Jibanpur	$Q_T = 8,402 - 4,207 \ln(\ln(\frac{T}{T-1}))$
25	110	Comilla	$Q_T = 13,500 - 4,531 \ln(\ln(\frac{T}{T-1}))$
27	212	Parsuram	$Q_T = 7,564 - 5,194 \ln(\ln(\frac{T}{T-1}))$
	119.1	Panchpukuria	$Q_T = 10,143 - 3,652 \ln(\ln(\frac{T}{T-1}))$

TABLE - 5 (Contd)

DISCHARGE - FREQUENCY RELATIONSHIPS FOR INDIVIDUAL STATIONS

M.P.O's Hydrologic area No	BWDB No.& name of station	Equation by double exponential distribution function (Q_T in cusec, T in years)
28	124 Thandachari	$Q_T = 7,236 - 10,606 \ln(\ln(\frac{T}{T-1}))$
	40 Ramu	$Q_T = 10,999 - 6,227 \ln(\ln(\frac{T}{T-1}))$
	247 Bandarban	$Q_T = 36,353 - 20,480 \ln(\ln(\frac{T}{T-1}))$
	203 Lama	$Q_T = 31,450 - 19,434 \ln(\ln(\frac{T}{T-1}))$

TABLE - 6

DISCHARGES IN CUSEC AT DIFFERENT RETURN PERIODS

M.P.O's hydrologic area No.	BWDB No.& name of station		T= 2.33 Yrs	T= 5 yrs.	T= 10 yrs	T= 20 yrs
		North-Western Region				
1	142.1	Bushir Bandar	38,962	53,475	65,297	76,636
	142	Khansama	76,518	115,054	146,441	176,549
	140	Panchagarh	39,618	75,876	105,407	133,739
	285	Thakurgaon	9,096	12,456	15,193	17,818
2	294	Kaunia	176,041	226,392	267,403	306,741
	81	Pateswari	77,333	145,075	200,250	253,175
3	16.1	Malonchi	20,948	29,020	35,596	41,903
4	155	Mohimaganj	19,808	28,292	35,203	41,832
	312	Talora R.B	3,274	4,724	5,905	7,035
5	65	Bogra	3,489	5,252	6,688	8,066
	306	Gabtoli	1,615	2,531	3,279	3,997
	313	Nungoora RB	11,464	17,739	22,850	27,753
	66	Ullapara	36,367	61,367	81,730	101,262
6	238	Rohanpur	17,634	21,957	25,478	28,855
7	147	Atrai R.B	18,404	22,999	26,742	30,331
	149.1	Gumani R.B	24,552	32,719	39,370	45,750

TABLE - 6(Contd)

DISCHARGES IN CUSEC AT DIFFERENT RETURN PERIODS

M.P.O's hydrologic area No.	BWDB No.& name of station	T=2.33 Yrs.	T= 5 Yrs.	T = 10 Yrs.	T = 20 Yrs
7	17.1 Boral R.B	8,748	11,485	13,714	15,852
	83.1 Naldanga R.B	4,066	4,783	5,368	5,928
31	90 Hardinge Bridge	17,79,840	2019,299	2214,334	2401,417
	North-eastern Region				
8	34 Nakuagaon	15,934	22,978	28,716	34,219
	314 Ghosegaon	12,421	16,744	20,265	23,642
9	134A Bausi R.B	10,322	13,788	16,610	19,318
	134 Jokerchar	21,153	24,937	28,019	30,974
	228.5 Mymensingh	103,959	130,277	151,712	172,273
	9 Kaoraid	6,763	8,634	10,157	11,618
	14 Mirjapur	14,504	20,804	25,934	30,856
10	301 Kaliakoir	27,545	35,674	42,294	48,645
	14.5 Nayerhat	67,606	91,102	110,239	128,595
	302 Mirpur	35,993	44,540	51,497	58,173
11	230.1 Bhairab Bazar	241,498	456,148	630,977	798,677
12	36 Jariajan-gail	32,648	36,588	39,798	42,876
8	263A Durgapur	46,490	55,292	62,462	69,339
14	192 Motiganj	1,967	2,923	3,703	4,450

TABLE - 6 (Contd)

DISCHARGES in CUSEC AT DIFFERENT RETURN PERIODS

M.P.O's hydrologic area No.	BWDB No.& name of station	T= 2.33 yrs.	T= 5 yrs.	T= 10 yrs.	T-20 yrs.
15	267 Sylhet	73,573	81,169	87,356	93,290
16	201 Manu R.B	19,226	22,636	23,413	28,076
	67 Kamalganj	7,772	9,172	10,313	11,407
31	49.6L Bahadurabad	2333,299	2699,718	2998,170	32,84,448
	91.9L Baruria Transit	3092,636	3495,421	3823,483	41,38,169
	93.5L Mawa	3100,416	3499,086	3824,550	41,35,773
	South-Western Region				
17	101.5 Kamarkhali Tr.	199,339	238,526	270,443	3,01,058
	171 Garaganj	3,085	4,781	6,163	7,489
	205 Kazipur	9,114	12,671	15,568	18,348
	206 Hatboalia	8,251	10,918	13,090	15,174
	208 Darsana	9,501	12,058	14,140	16,138
18	54 Kaliganj	7!6	965	1,177	1,380
21	162 Jhikargacha	1,955	3,207	4,226	5,204
19	169 Muzardia	6,835	8,706	10,229	11,691
	South-eastern Region				
11	114 Jibanpur (Gumti Br.)	10,838	14,712	17,870	20,898
25	110 Comilla	16,122	20,297	23,697	26,958
27	212 Parsuram	10,569	15,355	19,253	22,992

TABLE - 6 (Contd)

DISCHARGES IN CUSEC AT DIFFERENT RETURN PERIODS

M.P.O's hydrologic area No.	BWDB No.& name of station	T1 2.33 yrs.	T= 5 yrs.	T= 10 yrs.	T= 20 yrs
	1191 Panchpu-kuria	12,256	15,621	18,362	20,901
28	124 Thanda-chari	13,372	23,145	31,104	38,738
	40 Ramu	14,603	20, 340	25,013	29,496
	247 Bandarban	48,202	67,071	82,440	97,182
	203 Lama	42,695	60,600	75,184	89,173

TABLE - 7

DATA FOR DAVIS AND WILSON'S RAINFALL FORMULA

M.P.O's Hydrologic Area No.	No. and Name of Discharge Station	No. and name of Raingauge station	Drainage Area in sq. miles	Recorded max. Discharges in cusec.	Recorded max. daily rainfall in inches	Yearly max. daily rainfall (P) for 20-yrs. return period in inches	$PA^{2/3}$	$K = \frac{Q}{PA^{2/3}}$
8	34 Nakuagaon	R74 Nalitabari	187	35,653	10.64	10.104	330.41	108
	314 Ghosegaon	R74 Nalitabari	150	23,722	10.64	10.104	285.25	83
	263A Durgapur	R74 Nalitabari	915	64,600	10.64	10.104	952.30	68
9	134A Bausi R.B.	R67 Jamalpur	54	17,085	10.50	10.372	148.21	115
	134 Jokerchar	R13 Gopalpur	98	27,358	10.05	8.860	188.33	145
	228.5 Mymensingh	R73 Mymensingh	430	134,880	8.36	10.807	615.67	219
	9 Kaoraid	R5 Bhaluka	75	10,600	10.42	9.997	177.79	60
	14 Mirjapur	R2 Atia	552	32,724	8.32	7.530	506.70	65
10	301 Kaliakoir	R17 Joydebpur	444	41,714	7.46	9.150	532.53	78
	14.5 Nayerhat	R31 Savar	1175	1,14,726	9.70	9.910	1103.48	104
	302 Mirpur	R31 Savar	410	56,481	9.70	9.910	546.93	103

TABLE - 7 (Contd.)

DATA FOR DAVIS AND WILSON'S RAINFALL FORMULA

M.P.O's Hydro-logic Area No.	No. and Name of Discharge Station.	No. and name of Raingauge Station.	Drai-nage Area in sq. miles	Recorded max. Dis-charges in cusec.	Recorded max. dai-ly rain-fall in inches	Yearly max daily rain-fall (P) for 20 yrs. return per-iod in incs.	$PA^{2/3}$	$K = \frac{Q}{PA^{2/3}}$
12.	36 Jariajangail	R 68 Jariajangail	686	44,126	13.41	14.275	1110.34	40
14.	192 Motiganj	R126 Srimangal	86	28,452	7.96	8.606	167.67	170
15.	267 Sylhet	R128 Sylyet	1080	87,544	14.32	13.170	1386.34	63
16.	201 Manu R.B.	R114 Kamalganj	390	26,687	7.30	7.516	401.20	67
	67 Kamalganj	R114 Kamalganj	195	11,684	7.30	7.516	252.74	46

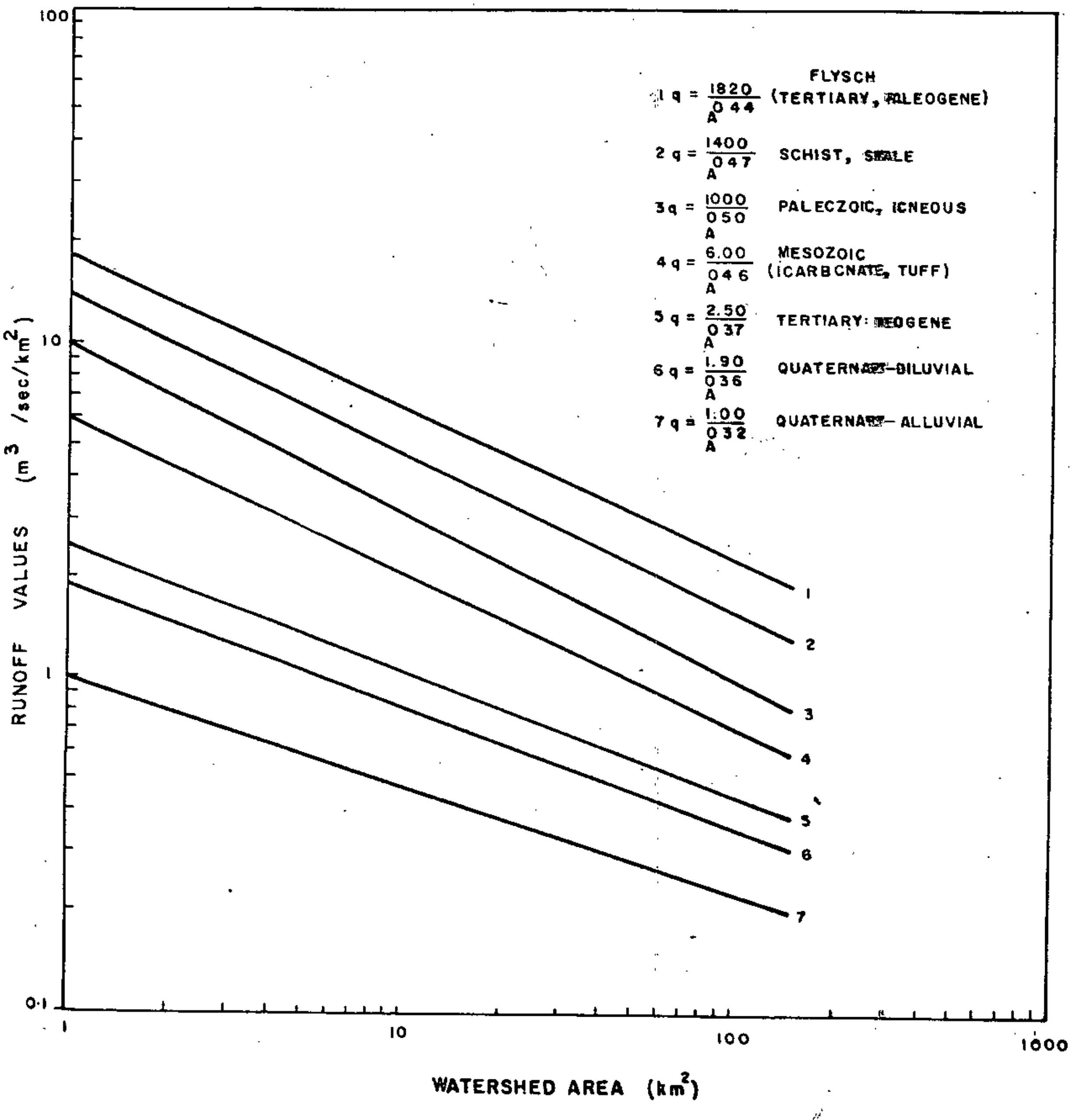
TABLE - 8

INDEX FOR STATIONS (WITH HIGHER DISCHARGES)
USED FOR ENVELOPE CURVE

M.P.O's Hydrologic area Number	BWDB No.& name of Station	BWDB No.& name of river	Drainage area in sq.miles	Recorded max.discharges in cusec
1	140 Panchagarh	57 Karatoa-Atrai	197	187,798
2	228.5 Mymensingh	86 Old Brahmaputra	430	134,846
11	230.1 Bhairab Bazar	86 Old Brahmaputra	24993	508,320
17	101.5 Kamarkhali Transit	42 Gorai-Madhumati-Baleswar	362	280,988
31	90 Hardinge Bridge	39 Ganges	350,100	2583,960
	91.9L Baruria Transit	39 Ganges	224,000	3988,900
	93.5L Mawa	39 Ganges	603,701	3918,300
	46.9L Bahadurabad	22 Brahmaputra Jamuna	206,895	3215,830

APPENDIX B

FIGURES



Figure—1 Peak runoff expected once in 100 years in Central Europe.

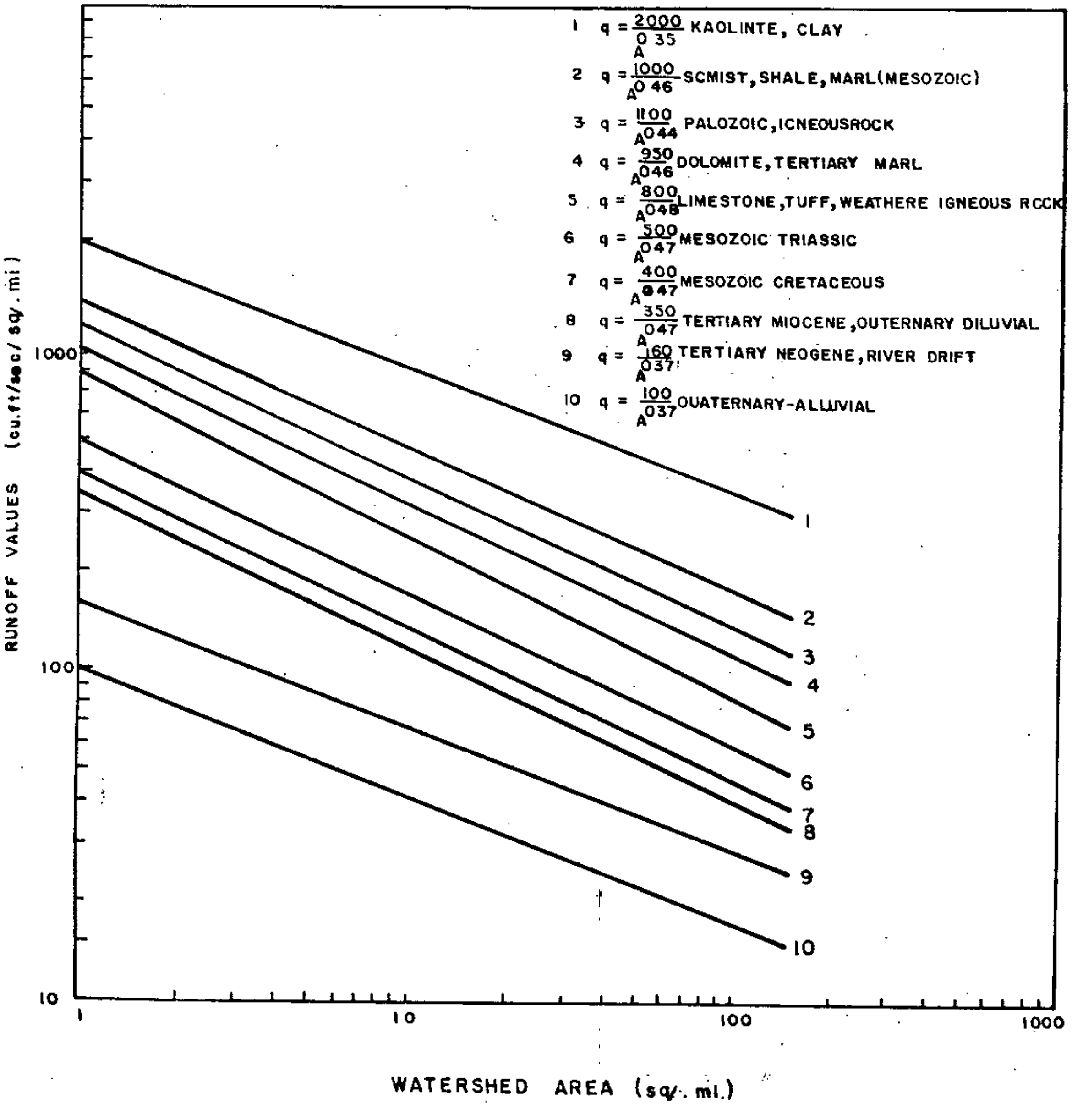


Figure-2 Peck runoff expected once in 100 years in New Jersey, U.S.A.

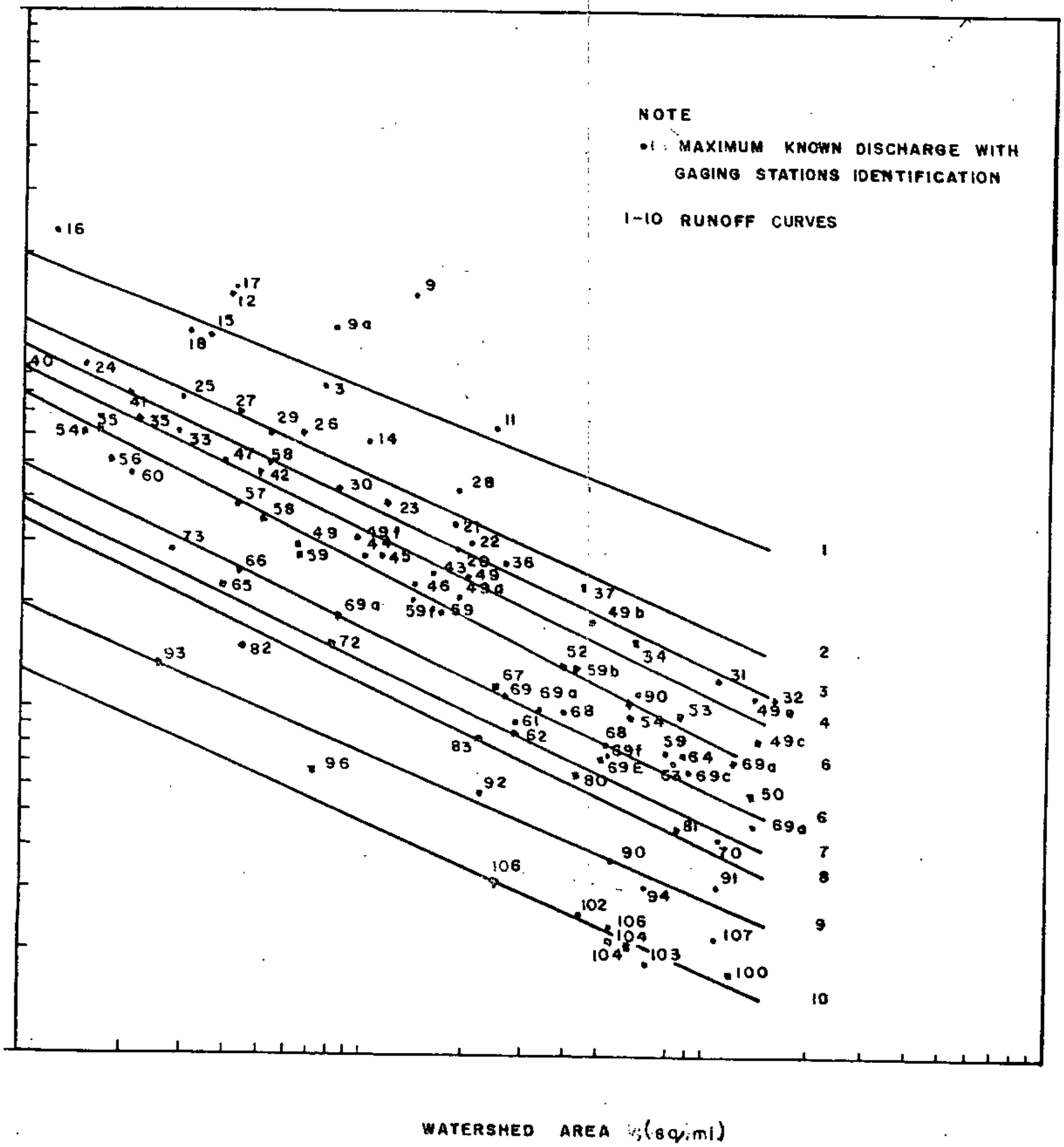
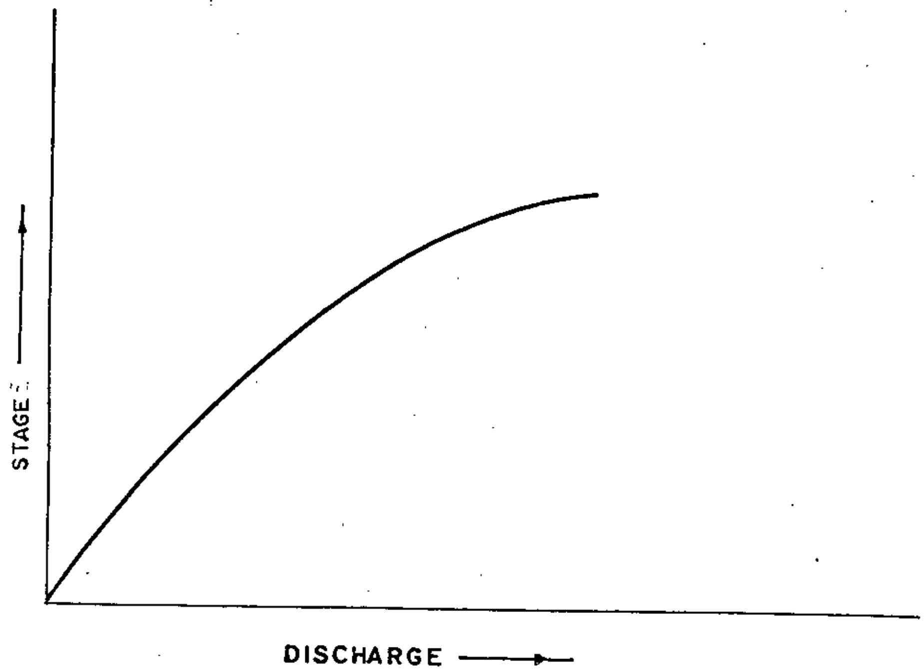
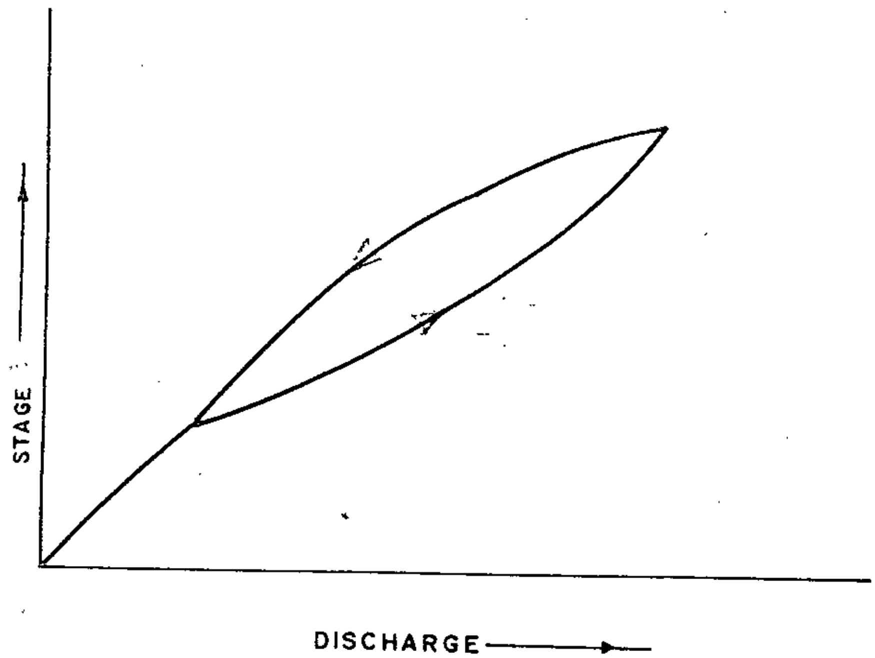


Figure — 3 Runoff coefficient curves and maximum known flood in NEW Jersey 1897 - 1972.



a Rating Curve



b LOOP Rating Curve

Fig -4 Rating Curves.

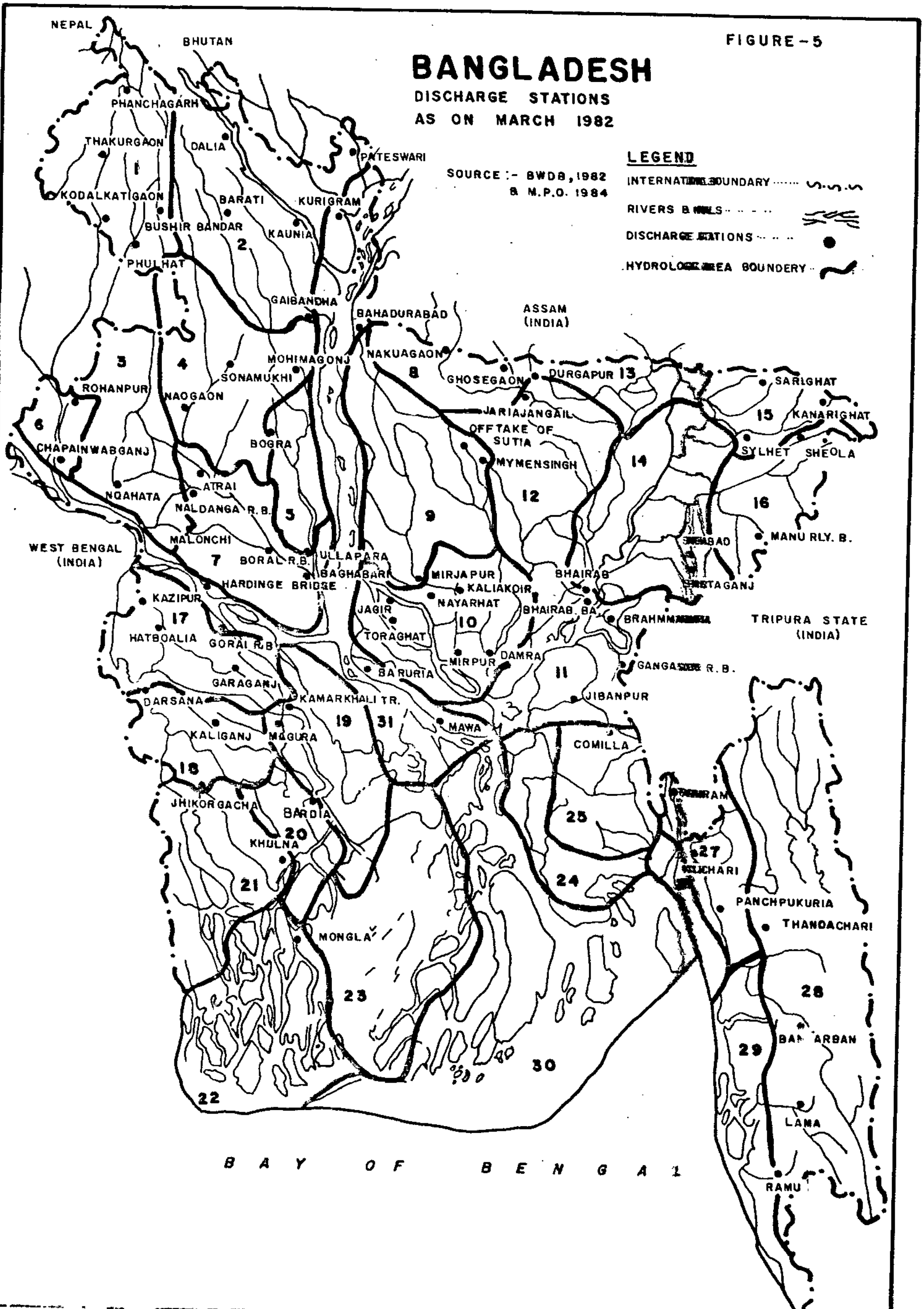


FIGURE-5
BANGLADESH
DISCHARGE STATIONS
AS ON MARCH 1982
SOURCE :- BWDB, 1982
& M.P.O. 1984
LEGEND
NEPAL
BHUTAN
ASSAM (INDIA)
WEST BENGAL (INDIA)
TRIPURA STATE (INDIA)
BAY OF BENGAL
PHANCHAGARH
THAKURGAON
DALIA
PATESWARI
KODALKATIGAON
BARATI
KURIGRAM
BUSHIR BANDAR
KAUNIA
PHULHAT
GAIBANDHA
BAHADURABAD
MOHIMAGONJ
NAKUAGAON
SONAMUKHI
ROHANPUR
NAOGAON
GHOSEGAON
DURGAPUR
SARIGHAT
JARIAJANGAIL
KANARIGHAT
OFFTAKE OF SUTIA
MYMENSINGH
SYLHET
SHEOLA
BOGRA
CHAPAINWABGANJ
NOAHATA
ATRAI
NALDANGA R.B.
MANU RLY. B.
MALONCHI
BORAL R.B.
ULLAPARA
BAGHABARI
MIRJAPUR
KALIAKOIR
BHAIRAB
HARDINGE BRIDGE
NAYARHAT
KAZIPUR
JAGIR
BHAIRAB. BA.
HATBOALIA
TORAGHAT
GORAI R.B.
MIRPUR
DAMRA
BARURIA
GARAGANJ
KAMARKHALI TR.
JIBANPUR
DARSANA
MAWA
KALIGANJ
MAGURA
COMILLA
JHIKORGACHA
BARDIA
KHULNA
PANCHPUKURIA
MONGLA
THANDACHARI
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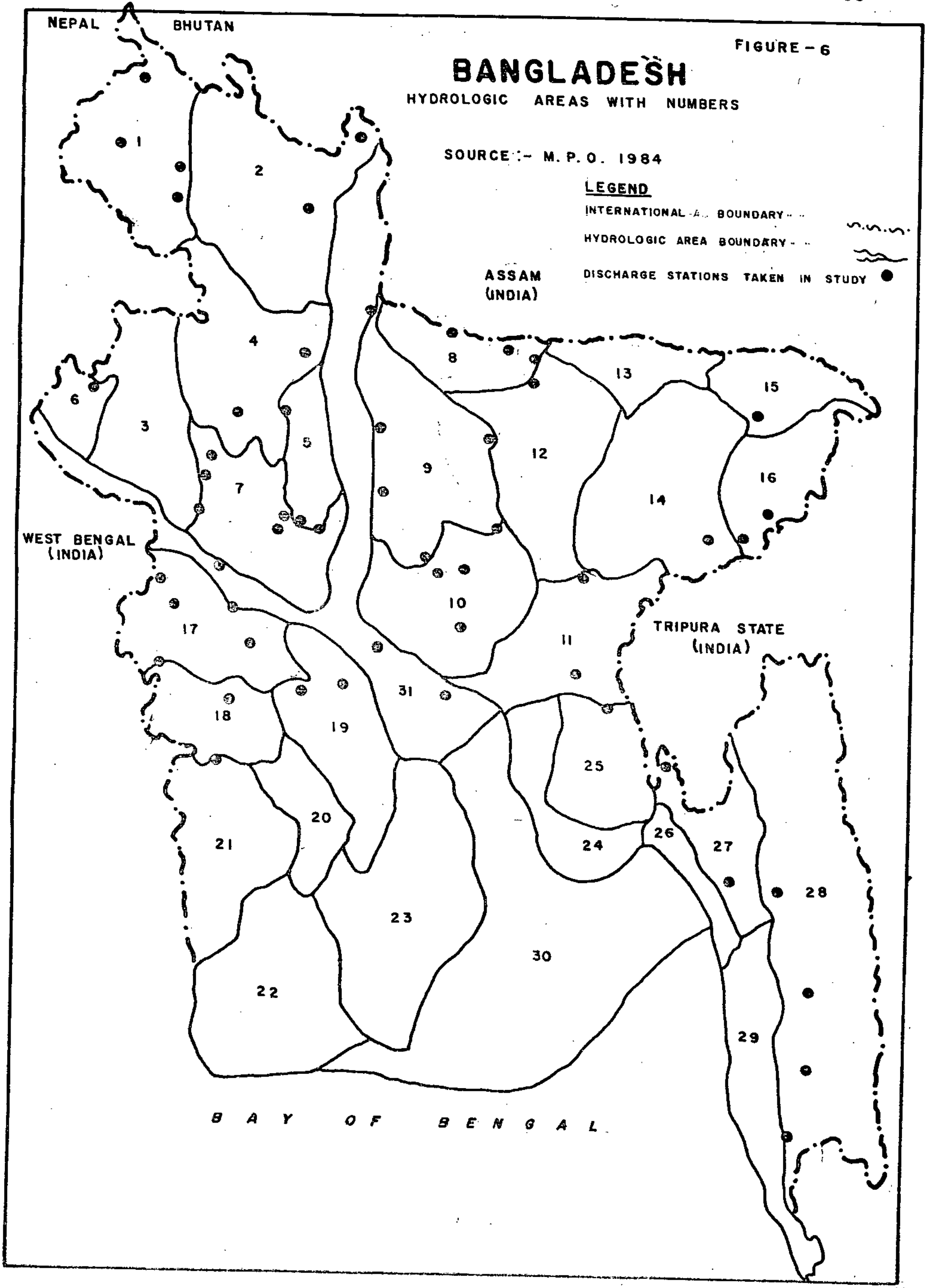

FIGURE - 6
BANGLADESH
HYDROLOGIC AREAS WITH NUMBERS
SOURCE :- M. P. O. 1984
LEGEND
INTERNATIONAL BOUNDARY
HYDROLOGIC AREA BOUNDARY
DISCHARGE STATIONS TAKEN IN STUDY
NEPAL
BHUTAN
ASSAM (INDIA)
WEST BENGAL (INDIA)
TRIPURA STATE (INDIA)
BAY OF BENGAL
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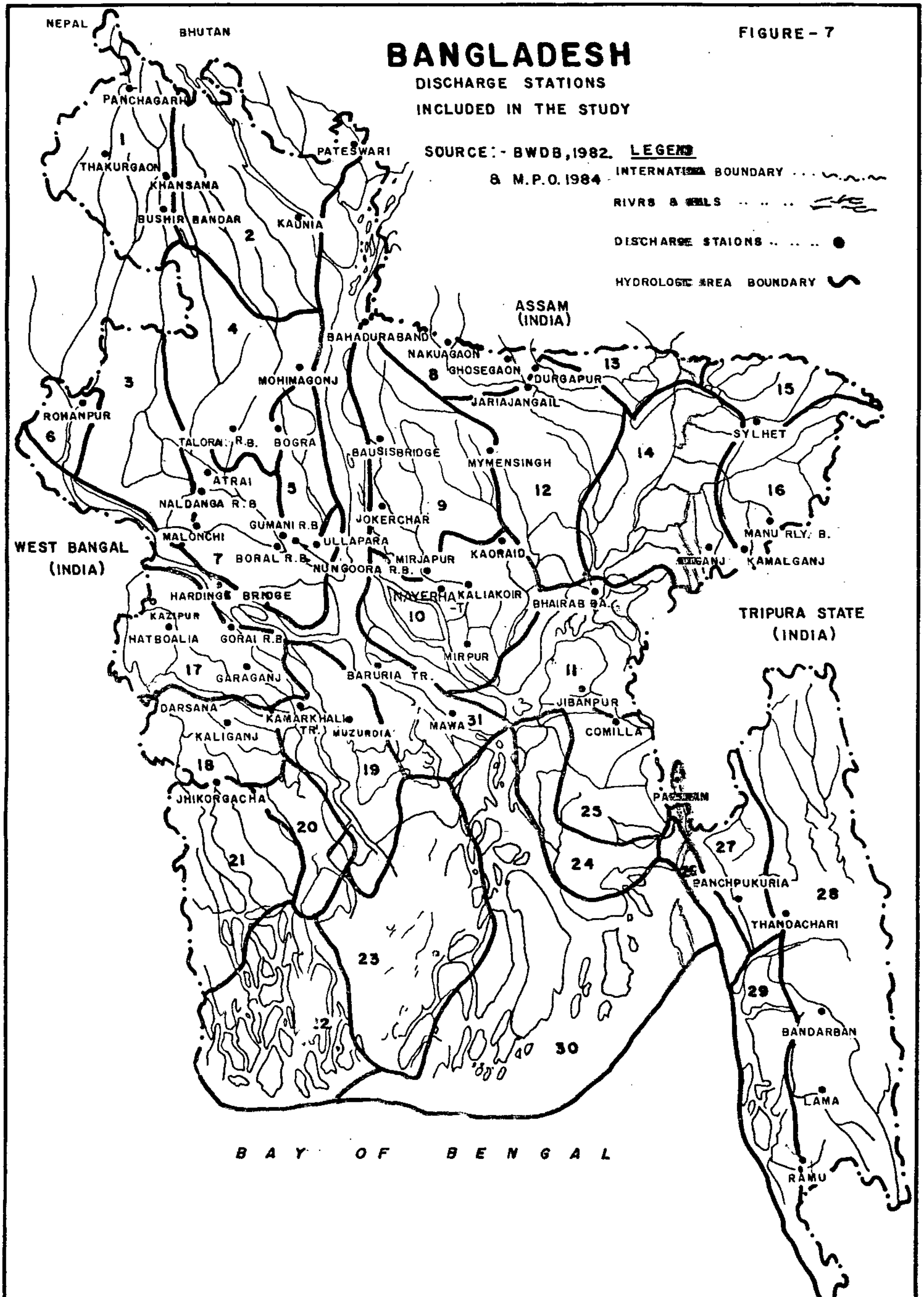
FIGURE-7
BANGLADESH
DISCHARGE STATIONS
INCLUDED IN THE STUDY
SOURCE:- BWDB,1982.
& M.P.O.1984
LEGEND
INTERNATIONAL BOUNDARY
RIVRS & BEELS
DISCHARGE STAIONS
HYDROLOGIC AREA BOUNDARY
NEPAL
BHUTAN
ASSAM
(INDIA)
WEST BANGAL
(INDIA)
TRIPURA STATE
(INDIA)
BAY OF BENGAL
PANCHAGARH
THAKURGAON
KHANSAMA
BUSHIR BANDAR
KAUNIA
PATESWARI
BAHADURABAND
NAKUAGAON
GHOSEGAON
DURGAPUR
JARIAJANGAIL
MOHIMAGONJ
ROHANPUR
TALORA R.B.
BOGRA
BAUSISBRIDGE
MYMENSINGH
SYLHET
ATRAI
NALDANGA R.B
JOKERCHAR
GUMANI R.B
ULLAPARA
MALONCHI
BORAL R.B.
NUNGOORA R.B.
MIRJAPUR
KAORAID
MANU RLY. B.
KAMALGANJ
HARDINGE BRIDGE
NAYERHAT
KALIAKOIR
BHAIRAB BA.
KAZIPUR
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GORAI R.B.
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JIBANPUR
DARSANA
KAMARKHALI TR.
MUZURDIA
MAWA
COMILLA
KALIGANJ
JHIKORGACHA
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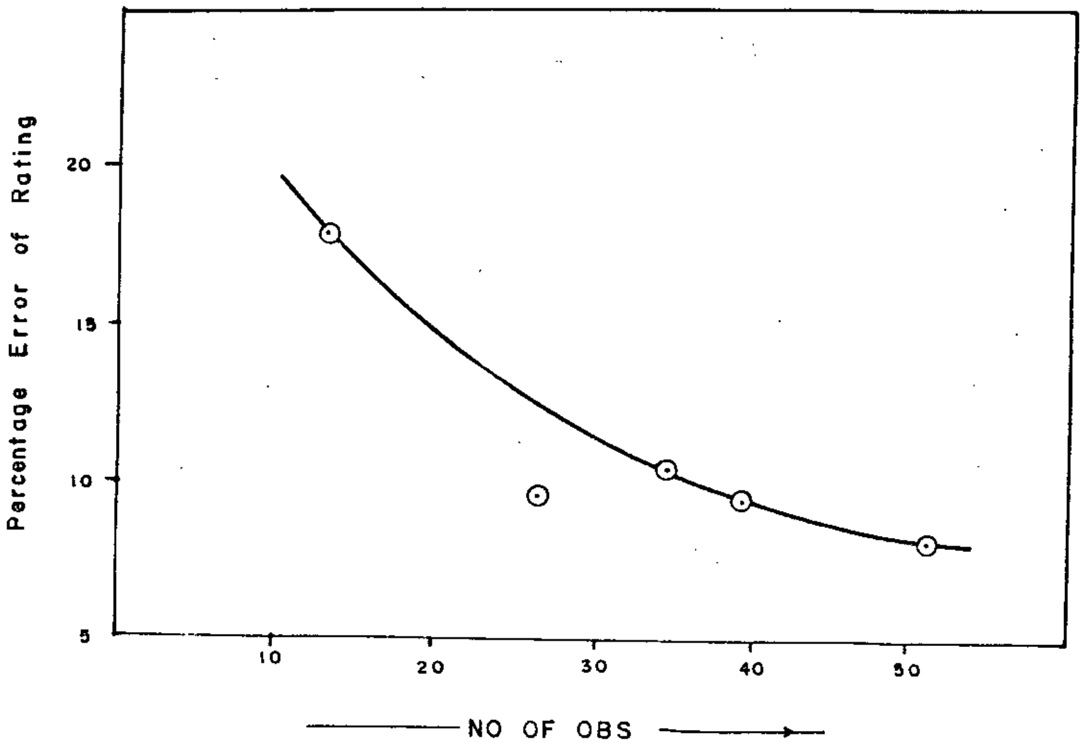


Fig. 8 Variation of Percentage Error of Rating with Number of Gaugings

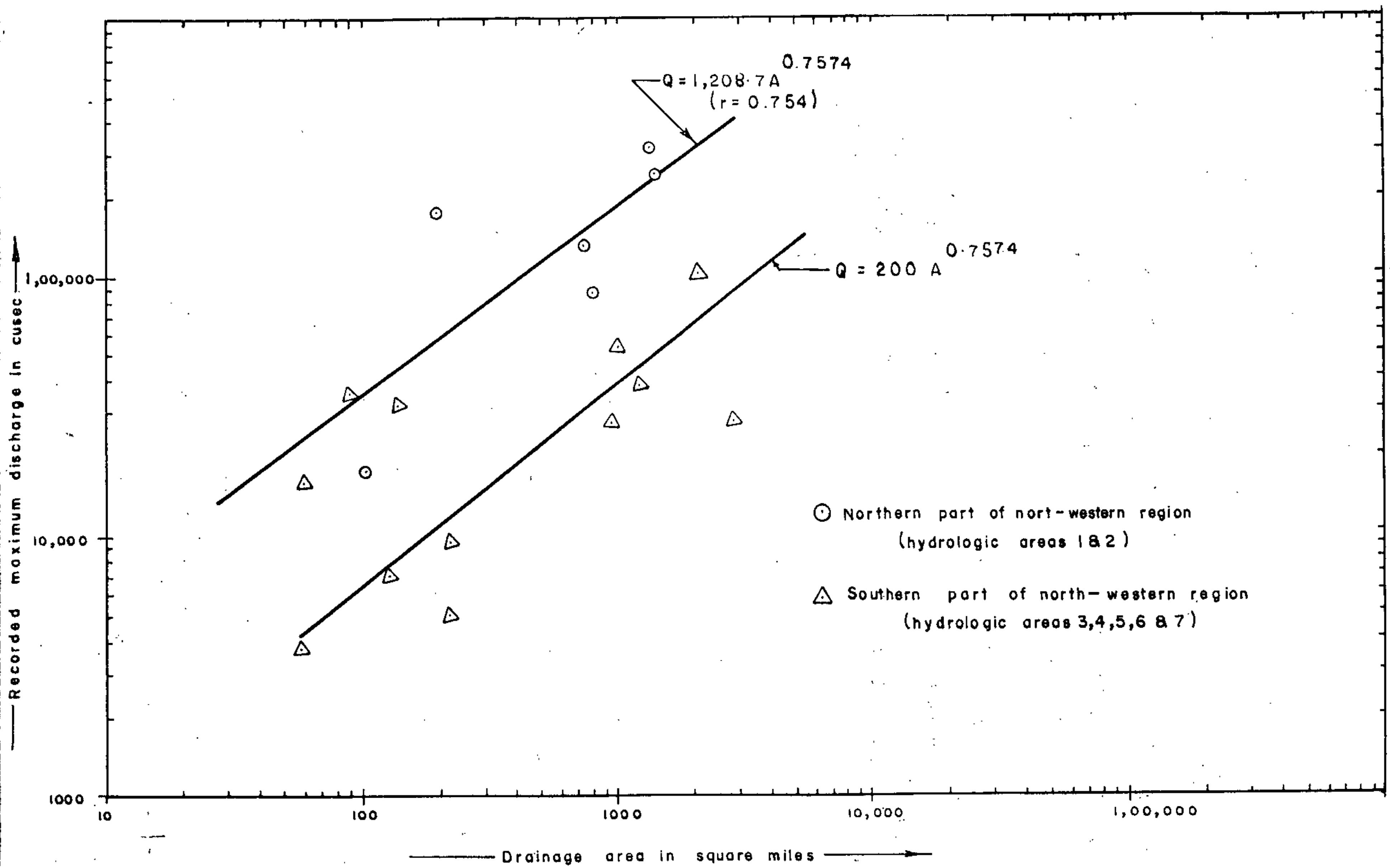


Fig. 9 Recorded maximum discharge against drainage area for north-western region.

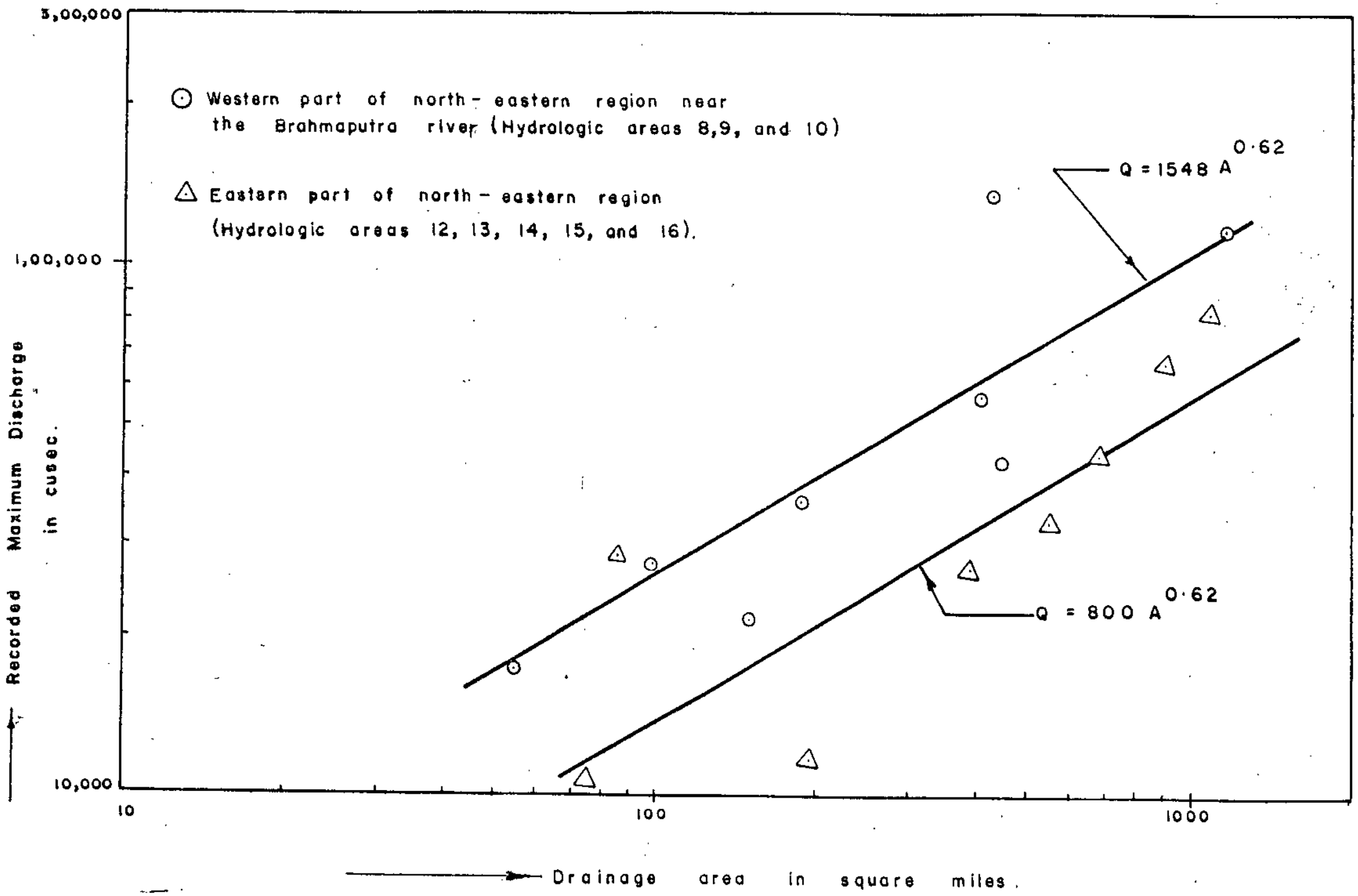


Fig- 10 Recorded maximum dincharge against drainage area for north eastern region.

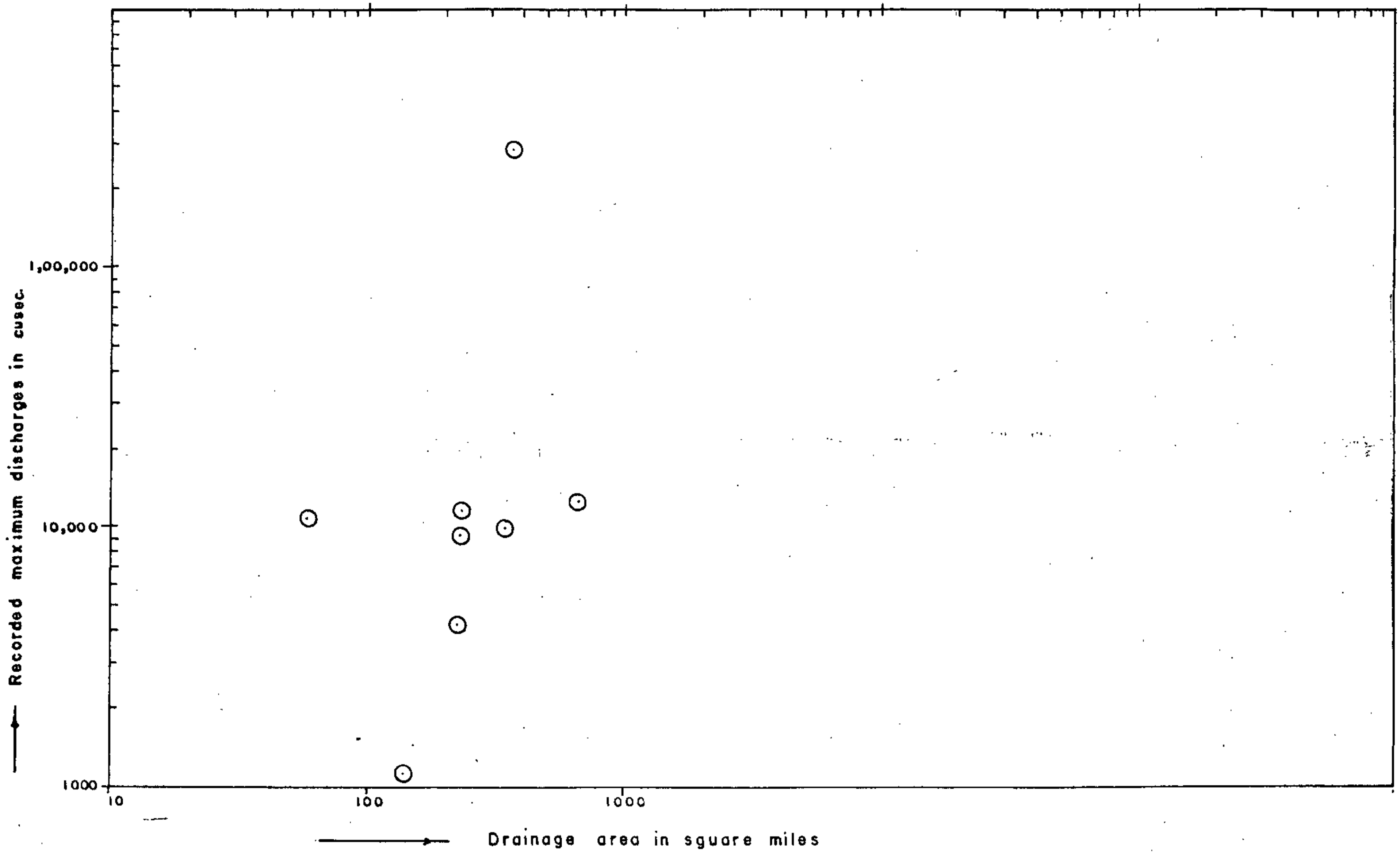
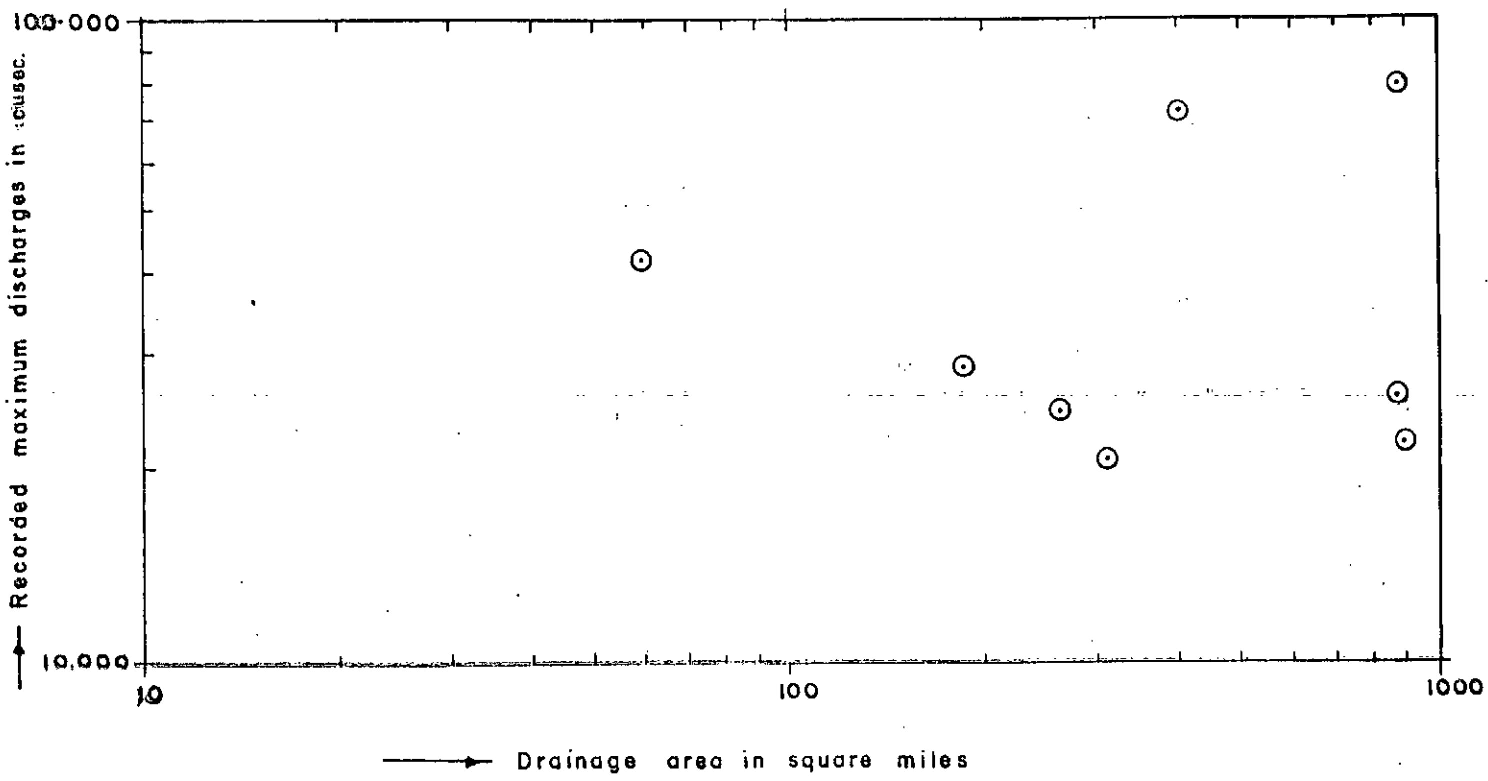


Fig. 11 Recorded maximum discharge against drainage area for south-western region



Fig· 12. Recorded maximum discharge against drainage area for south-eastern region

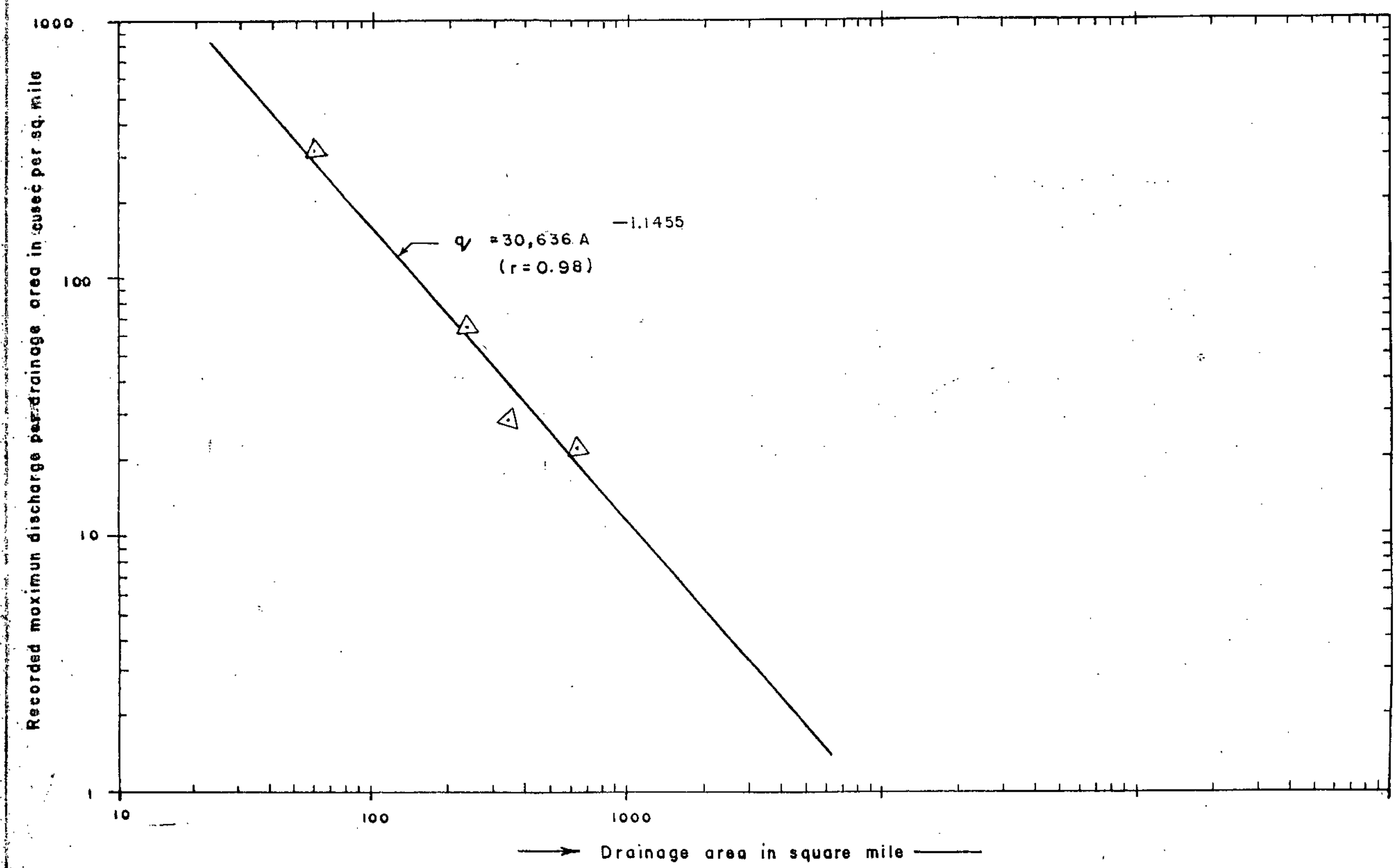


Fig. 13 Discharge Relation for Hydrologic area 17 in south-western Region

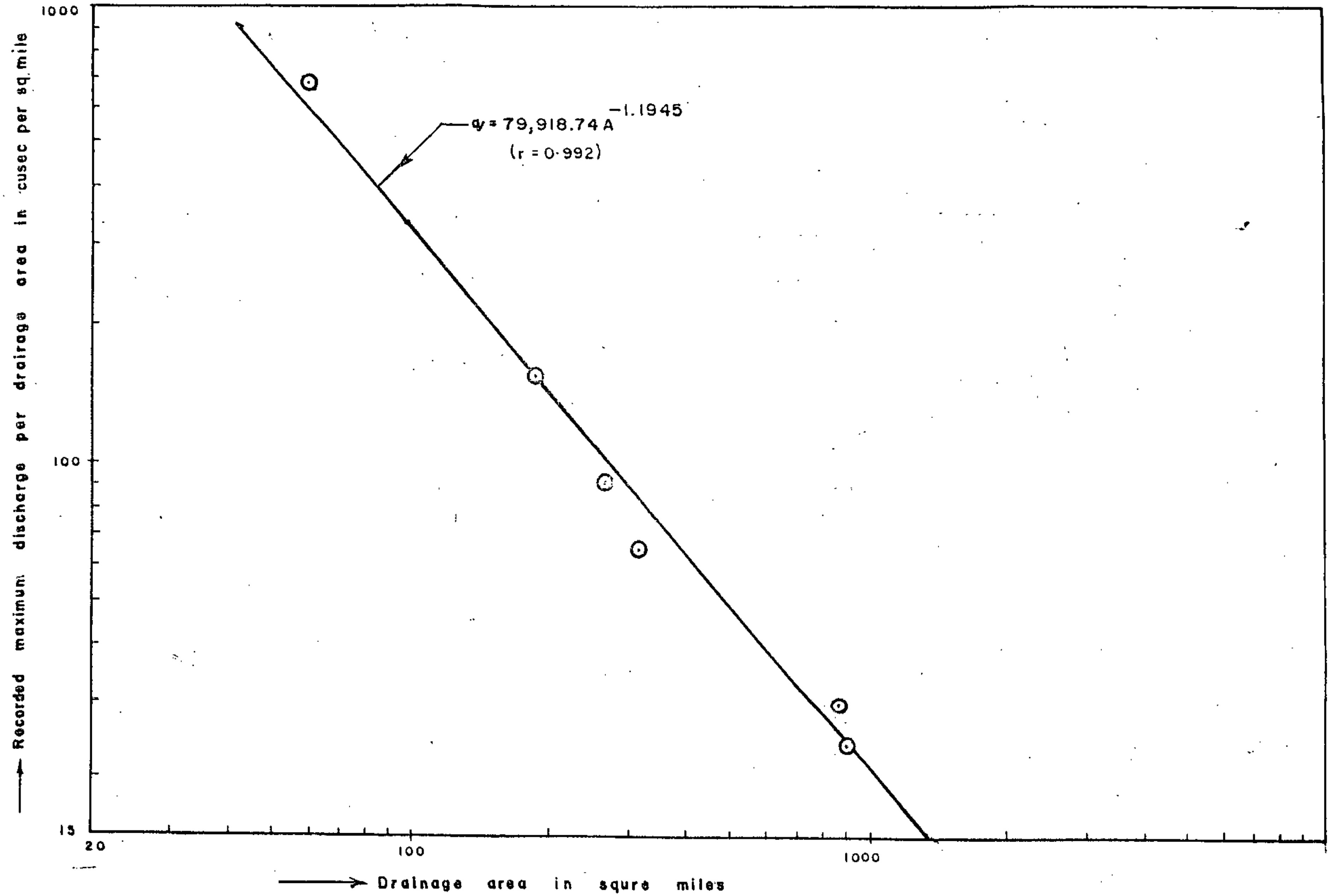


Fig-14 Discharge relations for south - eastern region.

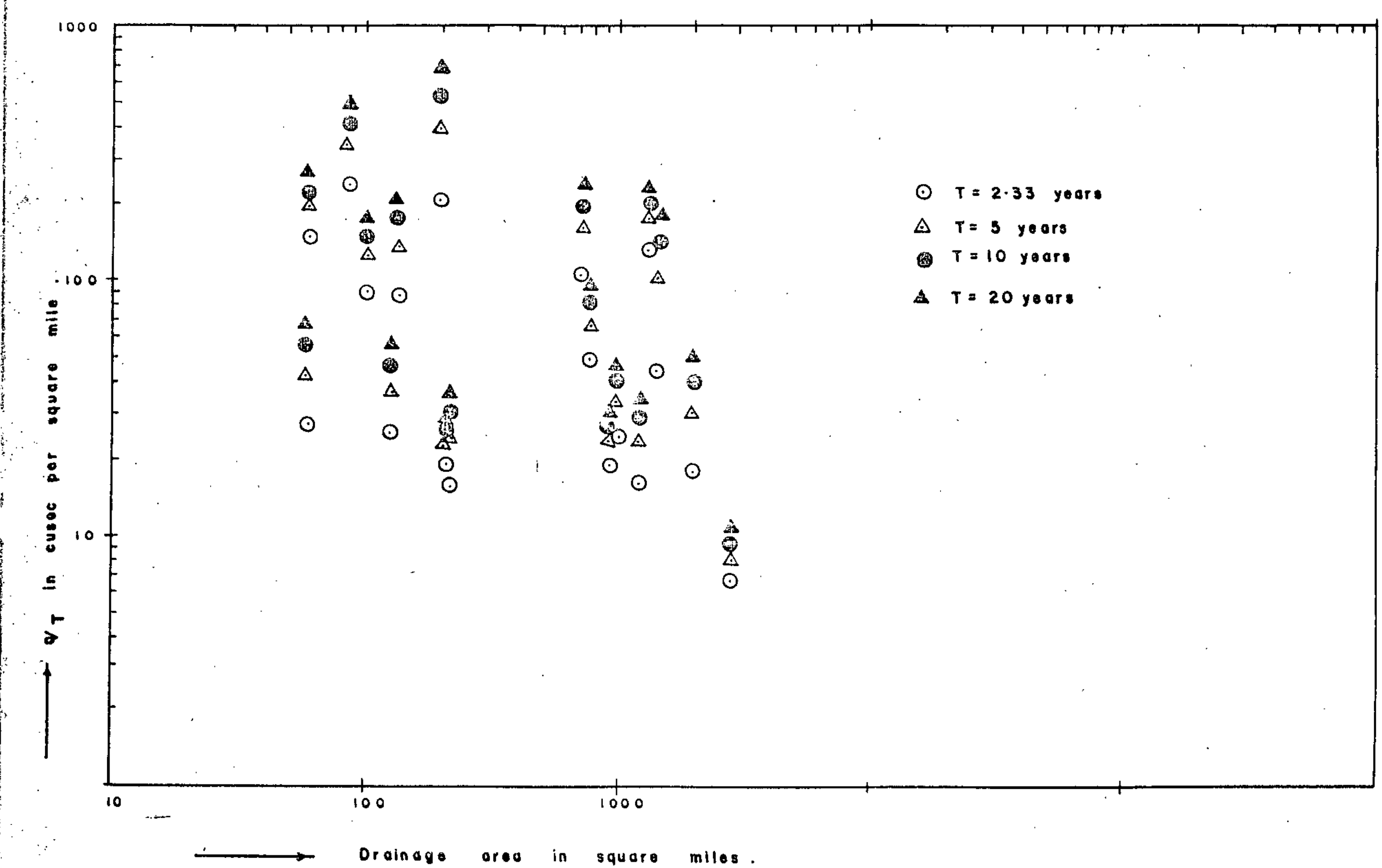


Fig- 15 Q/T against drainage area for north – western region.

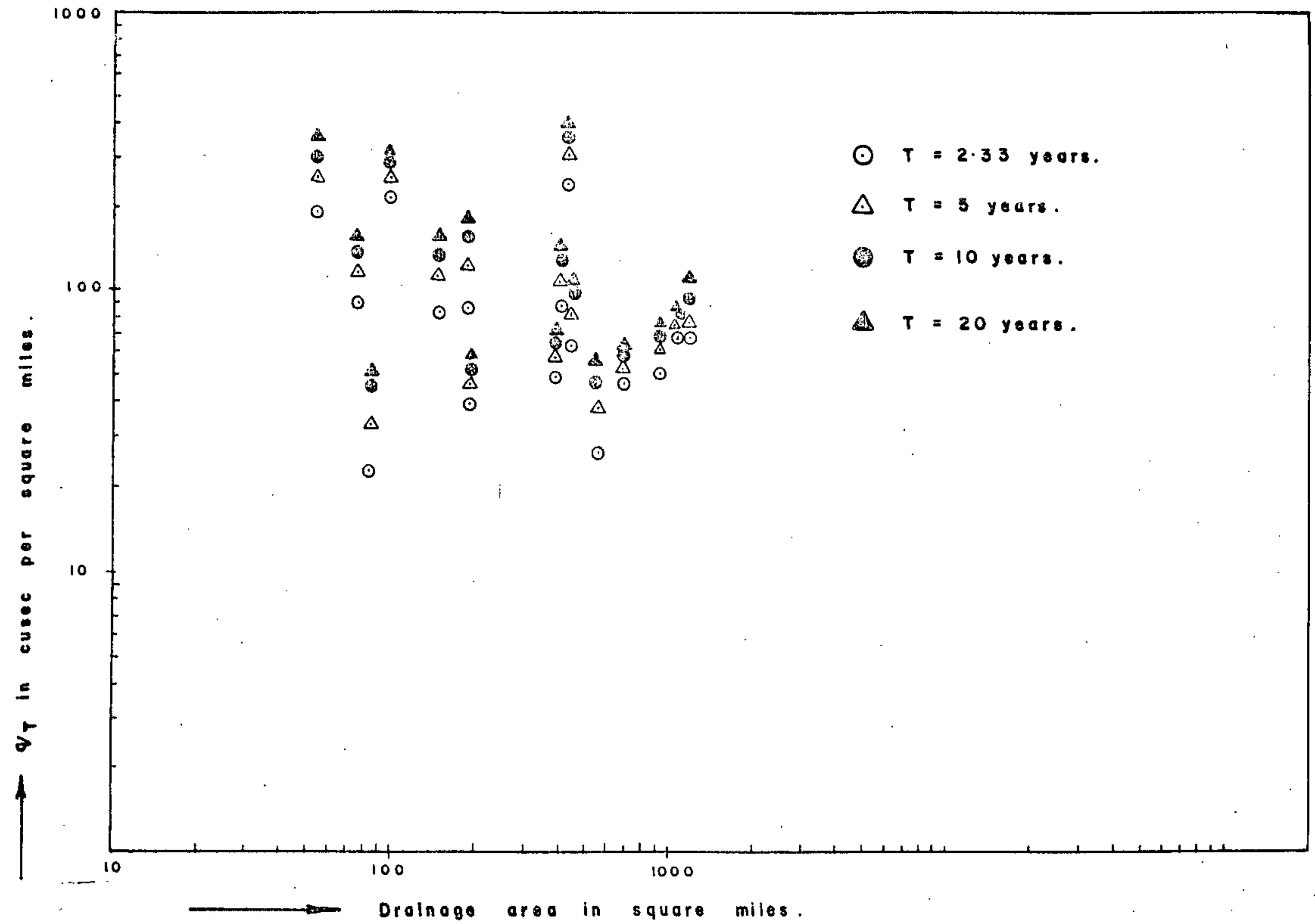


Fig- 16 q_T against drainage area for north eastern region.

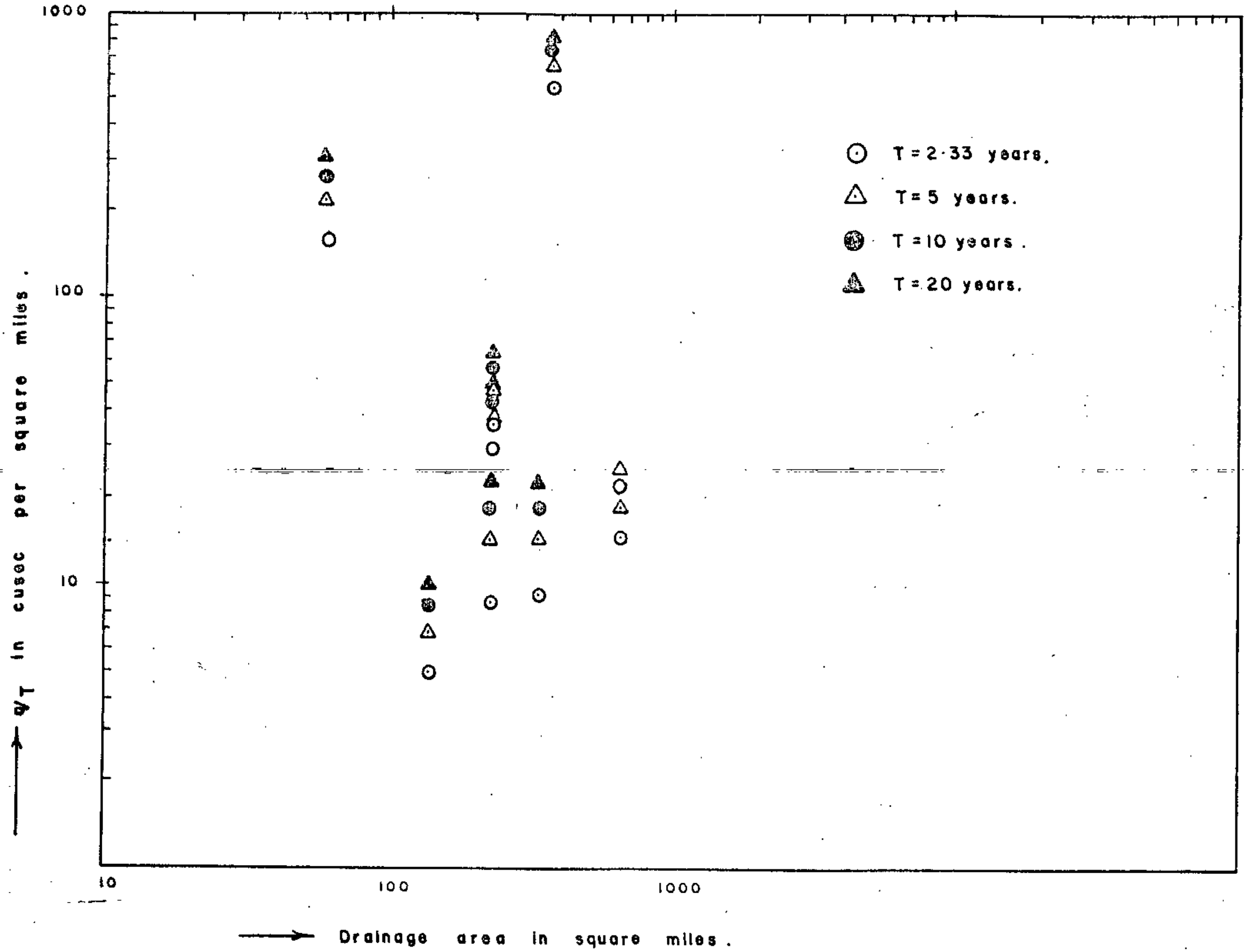


Fig-17 $q/_T$ against drainage area for south-western region.

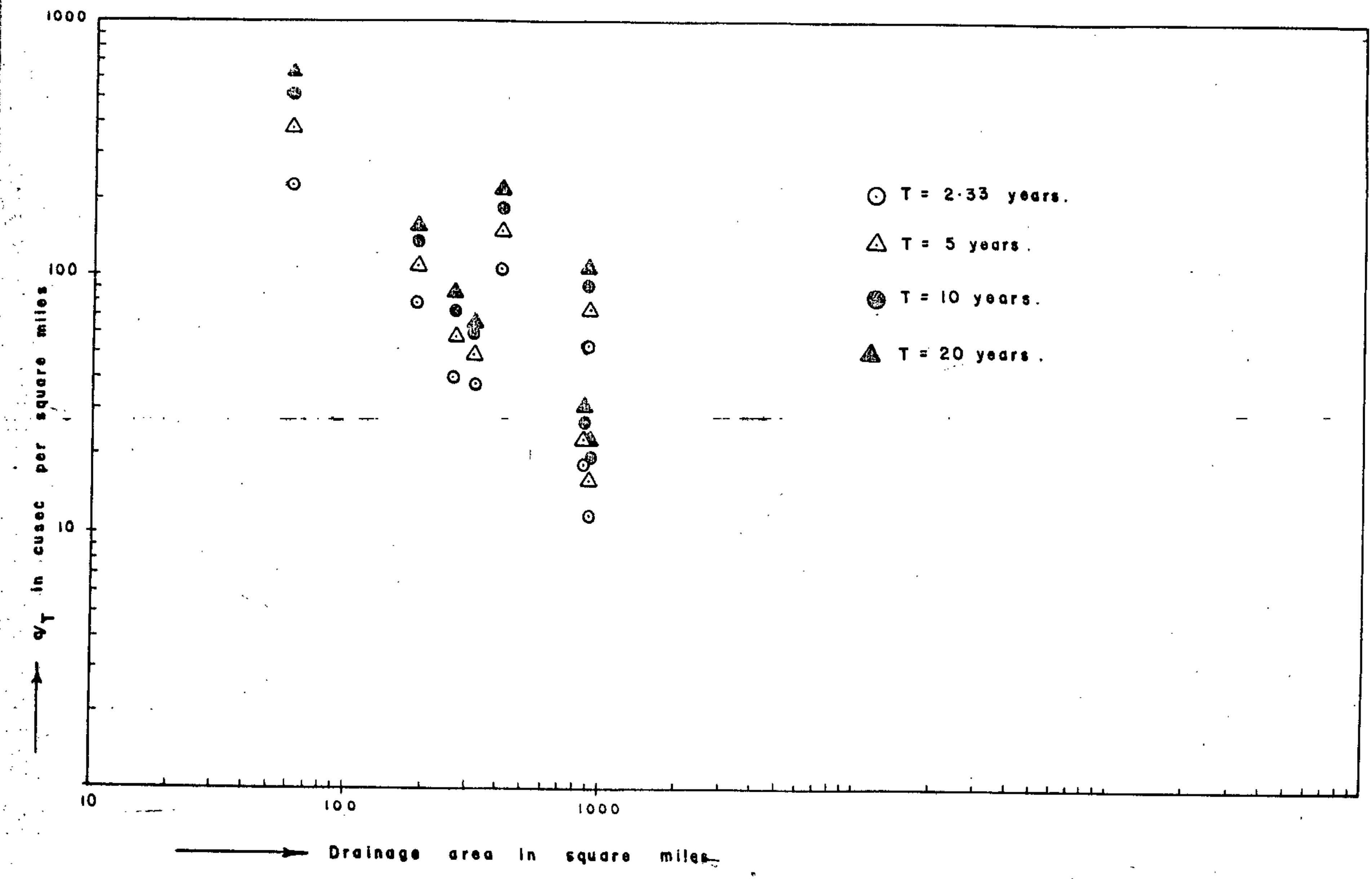


Fig-18 $q/_T$ against drainage area for south-eastern region.

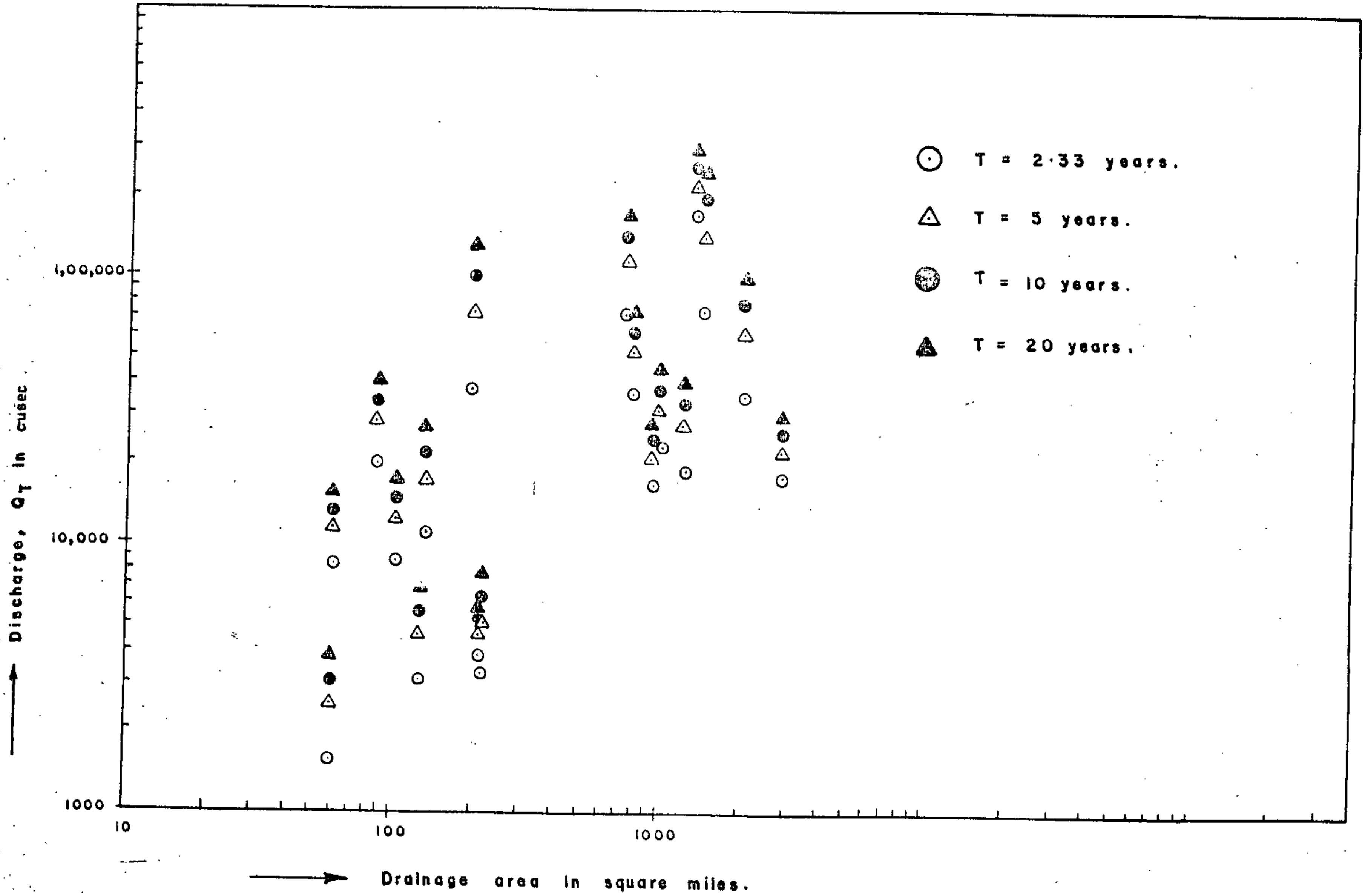


Fig-19 Q_T against drainage area for north-western region

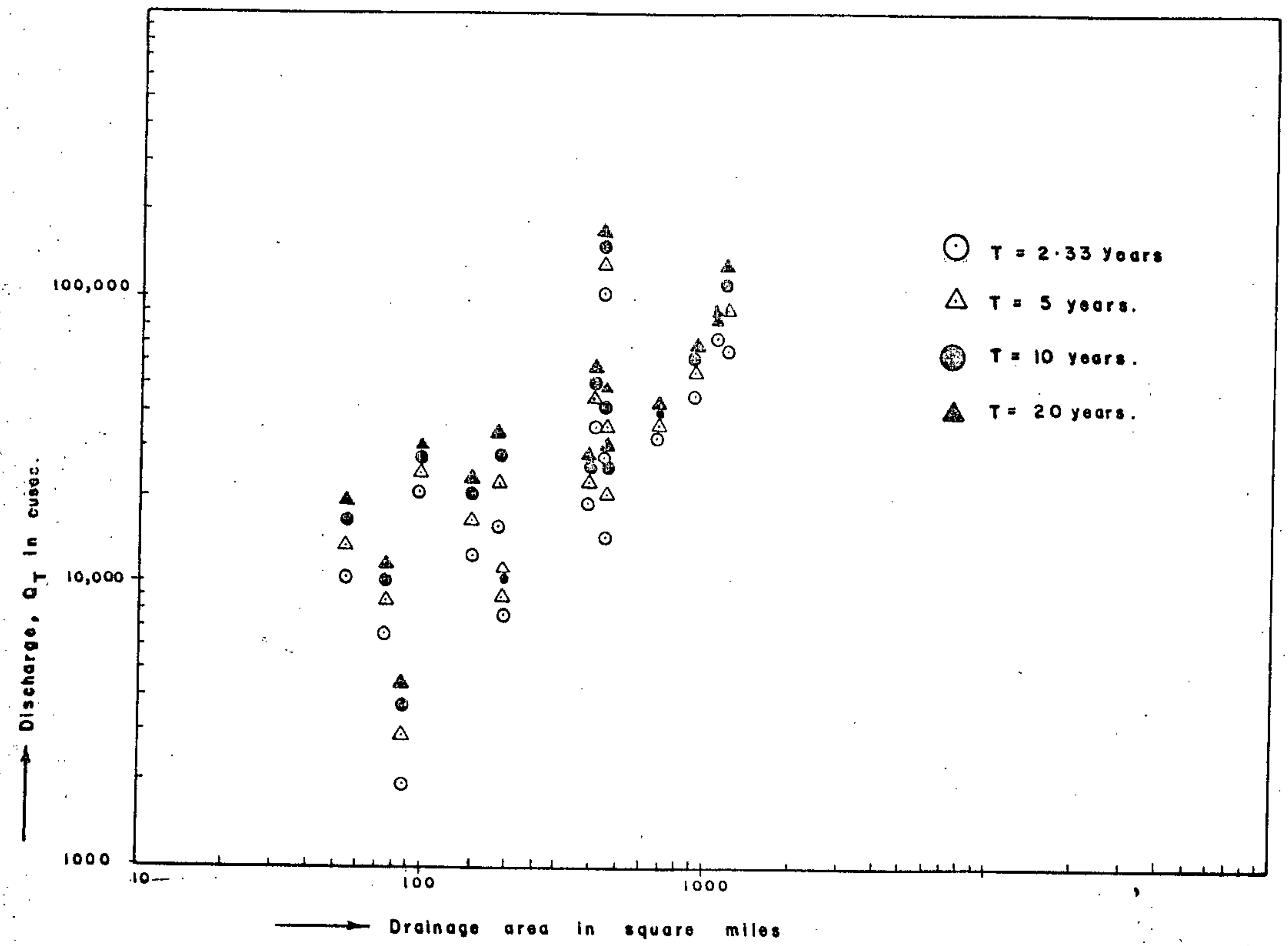
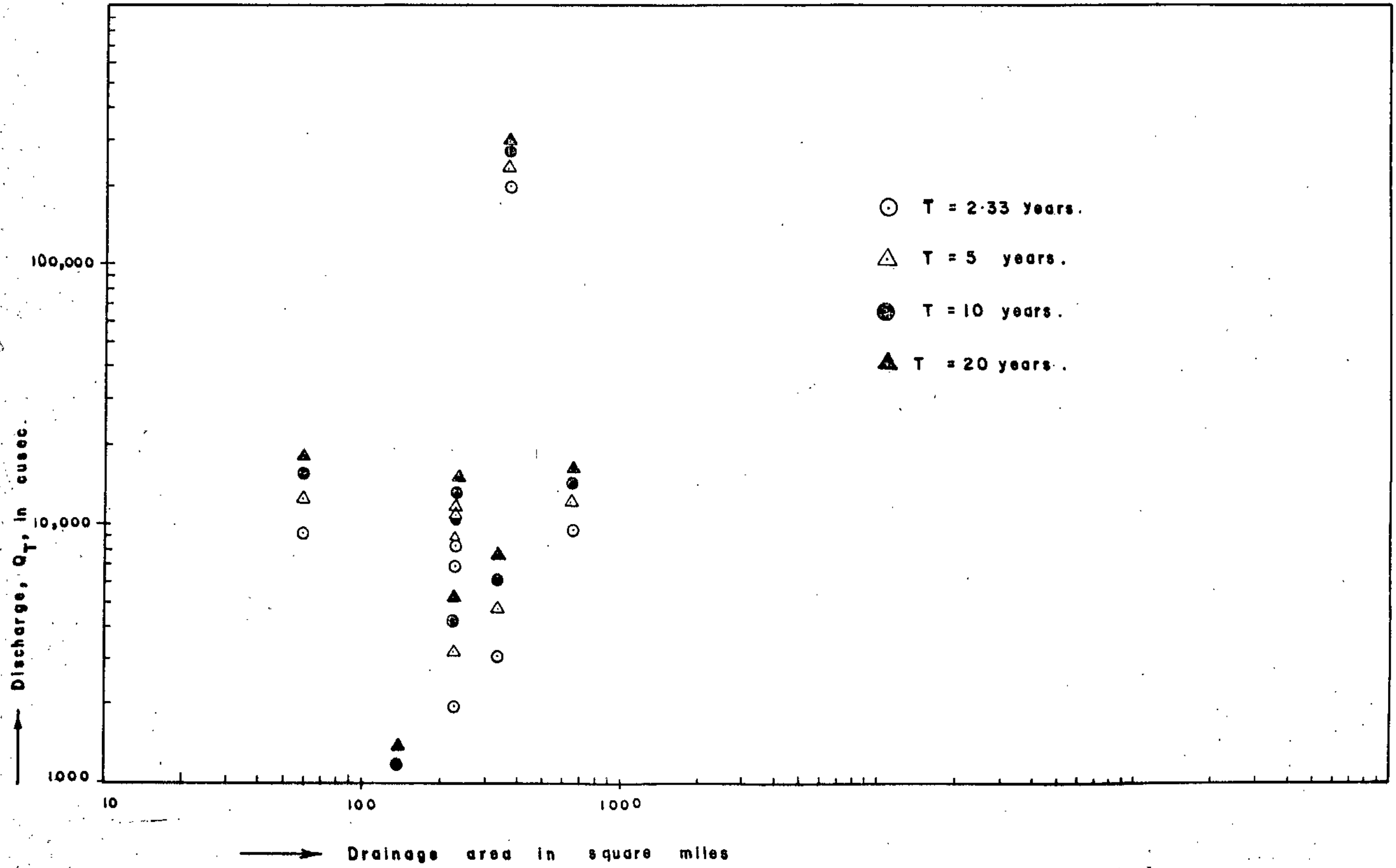


Fig – 20 Q_T against drainage area for north-eastern region.



Fig—21 Q_T against drainage area for south—western region.

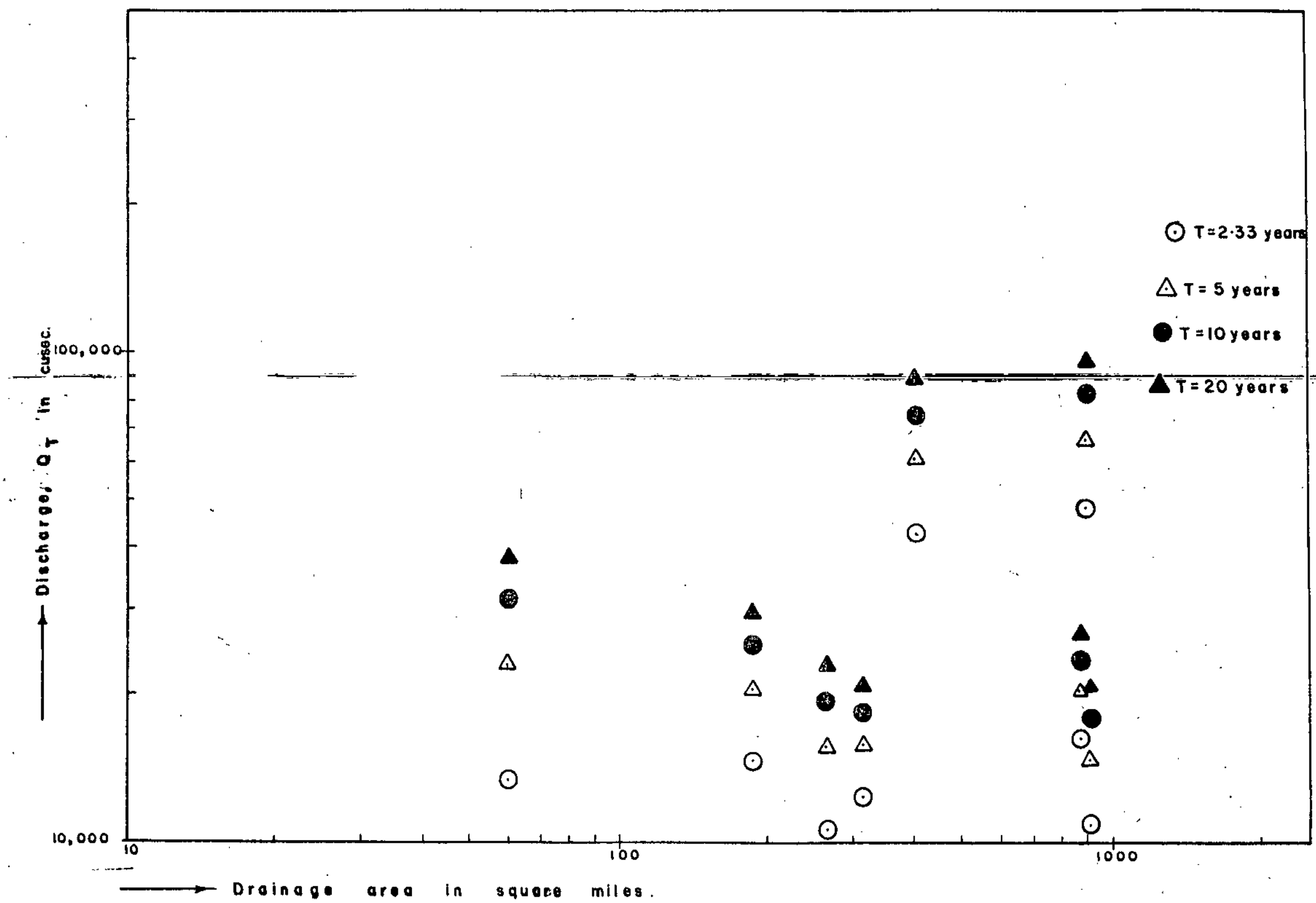


Fig- 22 Q_T against drainage area for south-eastern region.

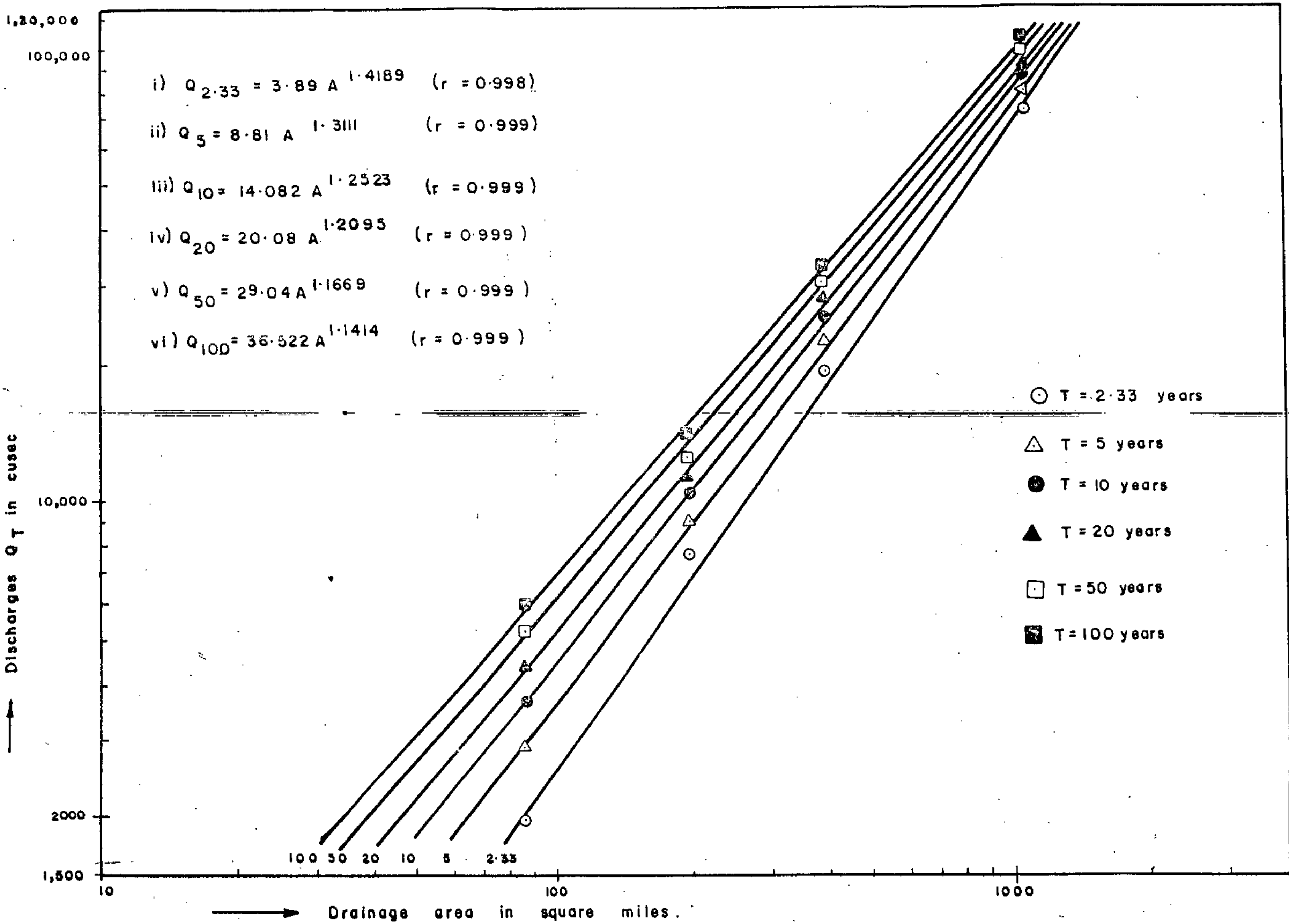


Fig – 23 Discharge relations for different return periods for hydrologic areas 14, 15 and 16 (sylhet area).

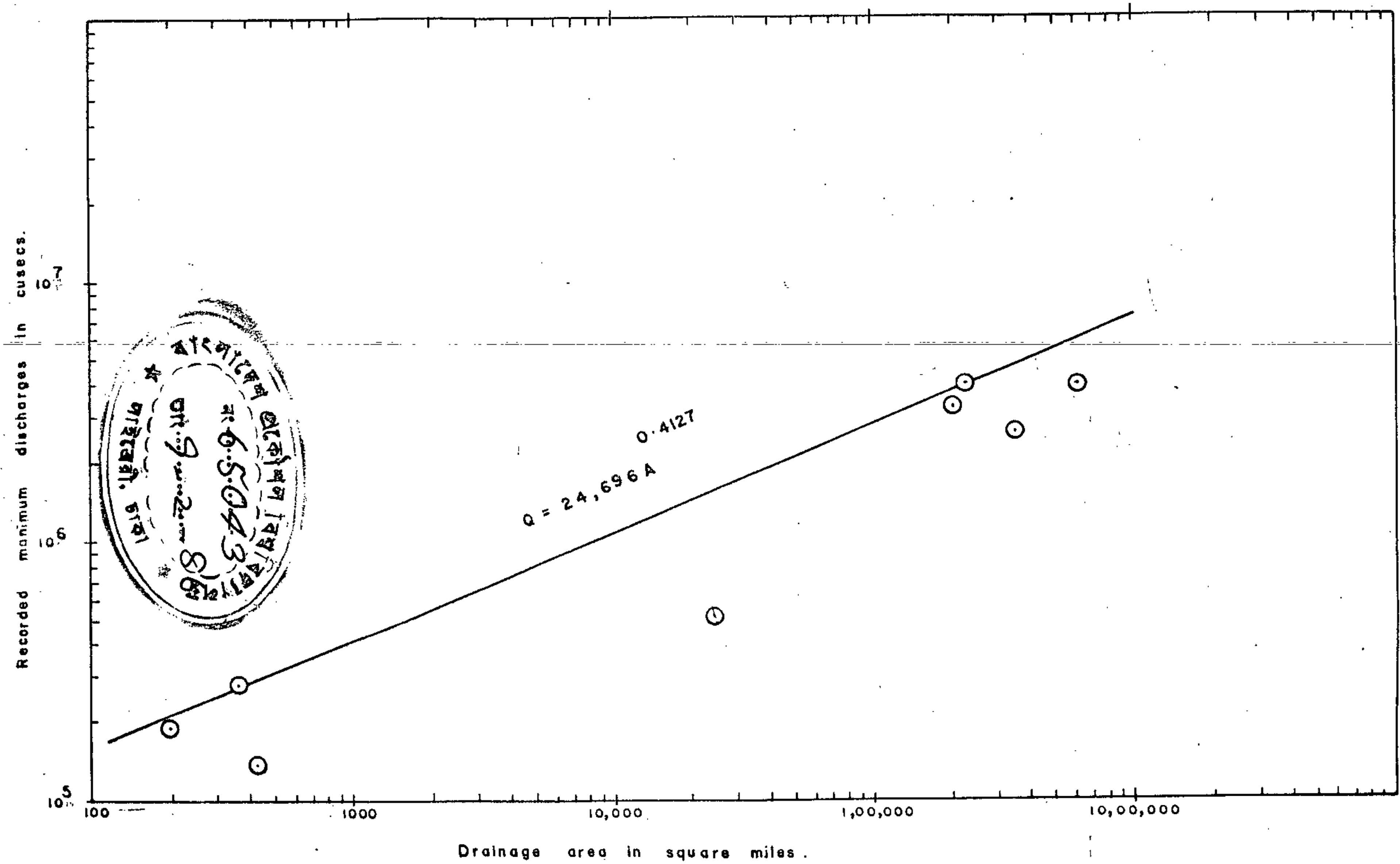


Fig — 24 Envelope curve for higher discharges in Bangladesh.