CS (AR) - 152

GEO-MORPHOLOGICAL CHARACTERISTICS OF PUNPUN BASIN OF GANGA RIVER SYSTEM

GANGA PLAINS REGIONAL CENTRE (PATNA)
NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667 (UP)
1993-94

PREFACE

Understanding and management of flood problems require clear understanding of geomorphological characteristics. Specially in ungauged basins the streamflow synthesis using geomorphological techniques is becoming popular. For synthesizing and understanding the hydrological behaviour of a basin, different geomorphological parameters can be employed. The Geomorphological properties are generally referred to the basin composition which represents the topographical and geometric properties of the basin.

In this report various important geomorphological parameters including linear, areal and relief aspects have been discussed and computed for Punpun basin of Ganga river system. This report entitled "**Geomorphological Studies of Punpun Sub-basin of Ganga Basin**" is a part of work programme of Ganga Plains Regional Centre of the institute. The study has been carried out by Shri A.K.Lohani, Scientist'B', Shri Manohar Arora, Senior Research Assistant, Shri Rahul Kumar Jaiswal, Senior Research Assistant under the guidance of Dr. K.K.S.Bhatia, Scientist 'F' & Head, Ganga Plains Regional Centre, Patna. Services of Shri A.K.Sivadas, Tech. Gr. III and Shri Santhosh M.B, Tech. Gr. III are also acknowledge herewith.

(S.M. Seth)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Geomorphology is the study of landforms, and in particular their nature, origin, processes of development, and material composition. The climatological and watershed characteristics has direct impact on hydrologic response of a basin. In spite of the fact that the hydrologic balance of a region is dynamic and everchanging, different approaches have been made to obtain relationships involving morphological, geological and climatic characteristics. The linking of the geomorphological parameters with the hydrological behaviour of a watershed acts as a tool in understanding its hydrological response.

For the purpose of hydrological studies, geomorphological characteristics are classified in three groups; (i) linear aspects of watershed, (ii) areal aspects of watershed and (iii) relief aspects of watershed.

The river Punpun is one of the important tributaries of the river Ganga, originating from Chottanagpur hills of Palamau district in Bihar. Since Ganga Plains Regional Center has taken up the task of making Punpun basin as Representative basin for micro studies, It becomes utmost important to Know the geomorphological characteristics of the basin. This report encompasses the methodology for the estimation of some of the important geomorphological parameters. Further some of the major and widely used geomorphological parameters of the Punpun basin have been evaluated.

1.0 INTRODUCTION

Understanding and successful management of the flood problems require an understanding of geomorphological characteristics of the basin. Apart from flood forecasting and flood control geomorphological characteristics also have application in the field of energy resources and engineering projects. Now a days streamflow synthesis from ungauged basins is gaining importance and the geomorphologic techniques have recently been advanced for hydrograph synthesis. Before taking up studies related with flood and hydrologic simulations using geomorphologic characteristics, the important geomorphological properties have to be quantified from the available topographical map of the basin. The linking of geomorphological parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of different basins. Various geomorphological parameters generally required for hydrological studies include linear, areal, and relief aspects of the basin. In this study some important geomorphological parameters have been evaluated for Punpun basin.

The river Punpun is one of the important right bank tributary of the river Ganga in Bihar. The upper most catchment lying in the districts of Palamau and Hazaribagh is hilly and mostly covered under forest. While the lower part of the catchment is mostly plain or having some uniform mild slope. The river system receives about 85% of its annual rainfall during the parameters required for hydrological studies are linear aspects, areal aspects, and relief aspects of the basin. In this study some important geomorphological parameters have been evaluated for Bagmati basin, typical in nature. These geomorphic parameters can be readily evaluated from the topographic maps of the watershed.

Bagmati is a river originating at Shivpuri range of hills in Nepal. The upper catchment of Bagmati river is hilly and forested while the lower one, to its confluence with the Kosi, is almost plain. It has been observed that the river Bagmati has been shifting its course constantly in the past within the measuring zone. Therefore, it is necessary to have a clear understanding of geomorphological characteristics of the Bagmati basin.

In this report various geomorphological characteristics representing the linear, areal and relief aspects are discussed in detail with a full description of various methods available for computation of such parameters. The study may be useful for any hydrological analysis for the basin.

2.0 DESCRIPTION OF THE STUDY AREA

The river Punpun originates from Chottanagar hills of Palamau district in Bihar at an elevation of 300m and at North latitude of 24°11' and east longitude of 84°9'. It joins the Ganga near Fatwa about 25 Km downstream of Patna covering a total distance of 232 Km. The river has a number of tributaries joining it mostly from its right bank. Important among them are the Batane, the Madar, the Mohar and the Dardha. All these rivers rises in the Chhotanagpur plateau and are rainfed. They flow only during monsoon and dry for the rest of the year. The river Punpun receives most of the discharge from its right bank tributaries. The contribution of left bank tributaries is very low in comparison to right bank tributaries. A line diagram showing its left as well as right bank tributaries is given in Fig 2.1.

The Punpun basin lies between longitude 84°10' E to 85°20' E and latitude 24°11'N to 25°N. It is located on the right bank of the Ganga and is bounded by the Sone river system on the west and Kilul-Harohar-Falgu river system on the east. On its northern side is the river Ganga and on its southern side, it is bounded by Chottanagpur hills.

The Punpun river system is roughly trapezoidal in shape. The length of the catchment is about 180 Km and average width in the upper and lower reaches of the river system is 60 Km. and 25 Km. respectively. The total catchment area of Punpun is about 8530 Sq.Km., which is 1% of the total area of Ganga

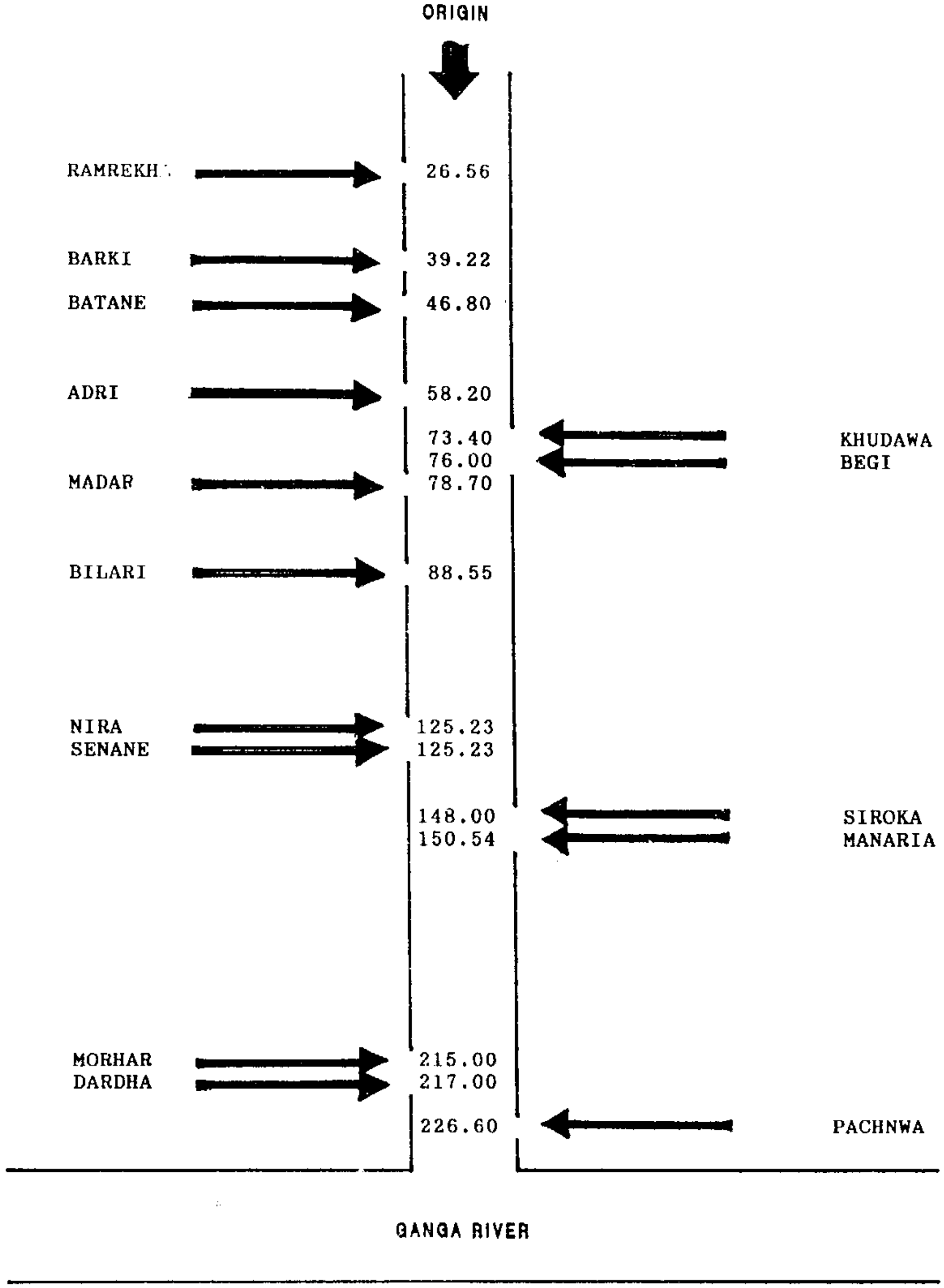

FIG 2.1. LINE DIAGRAM OF PUNPUN RIVER SYSTEM

basin in the country. The general drainage direction of the basin is from south-west to north-west. The entire catchment lies within the state of Bihar and is spread over the districts of Patna, Gaya, Aurangabad, Hazaribagh and Palamau. The district wise break up of its catchment area is shown in table 2.1

TABLE 2.1 DISTRICT WISE BREAK UP OF CATCHMENT AREA OF PUNPUN

Sl. No.	Name of the district	Sub-basin area in sq.km lying in the district	% of total catchment in the district
1.	Patna	960	11.25
2.	Gaya	3060	35.25
3.	Aurangabad	2310	27.08
4.	Hazaribagh	800	9.39
5.	Palamau	1400	16.41
	Total	8530	100.00

2.1 Topography

The upper most catchment of Punpun river lying in the districts of Palamau and Hazaribagh in Chottanagpur hills is mostly covered under forest. While the lower part of the catchment lying in the districts of Aurangabad, Gaya, Patna is mostly having some uniform mild slope. The land elevation varies from 300 m near origin of the river to about 50 m near its outfall into the river Ganga.

2.2 Soil And Geology Of The Basin

The geology of the basin varies from granite, gneiss, charnokitess in the hills to the recent alluvium in the plains. The broad soil groups are calcium and non calcium, recent and old alluvium and brown forest soils, red soil podzowe, lateritic soils with cover being very deep in plains and deep to shallow in hills.

2.3 Rainfall Distribution

The basin receives about 85% to 87% of its annual rainfall during the South-West monsoon period occurring from June to September. The average annual rainfall being 992 mm. The maximum value of 24 hours rainfall of 50 years frequency is 32 cm, which occurs in the upper catchment of the Morhar river, a tributary of Punpun. The rainfall in the remaining portion being between 24 cm to 28 cm.

2.4 Land Use

The land use pattern of the Punpun basin shows that out of the total area of 8500 sq. km. about 5,000 sq. km. is under agriculture, 2.500 sq. km. is under forest and the remaining area of 1000 sq. km. is under miscellaneous use. Thus the pie chart shows that 59% is agricultural area, 29% forest area and 12% miscellaneous area.

3.0 MEASUREMENT AND COMPUTATION OF GEOMORPHOLOGICAL PROPERTIES

In this section the methodology of measurement of various geomorphological characteristics which are of importance in hydrological studies for Punpun basin are presented.

3.1 Measurement and Counting of the Properties

3.1.1 Stream ordering

Earlier Horton's method of ordering of channels was used for all quantitative study of channel networks, but in the year 1952 Strahler proposed a method for ordering of channels which is still successfull in present day context. In the present study Strahler's system of stream ordering is used for the selected watershed (Fig 3.1). According to the Strahler's system of ordering, a stream which has no branches is designated as a 1st order stream. Where two first-order streams join, a channel segment of 2nd order is formed; where two 2nd order streams join, a channel segment of 3rd order is formed, and so forth. The trunk stream through which all discharge of water and sediment passes is designated as the stream segment of highest order.

It is found that the Punpun river is a sixth order stream. The number of streams of order one, two, three, four, five and six have been counted and their values are 671, 104, 28, 7, 2 and 1 respectively.

3.1.2 Channel length

The following are five methods which may be used for

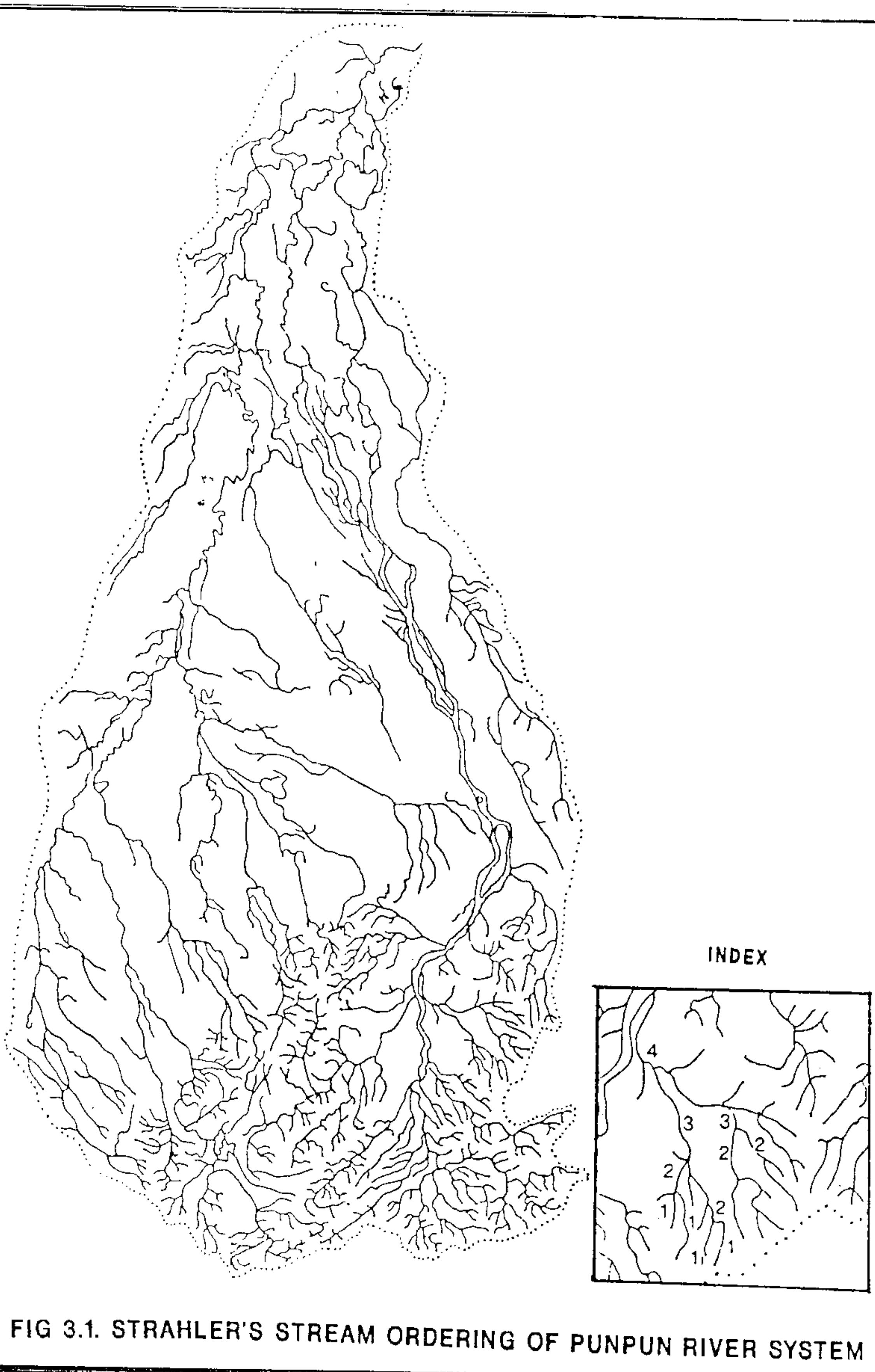

FIG 3.1. STRAHLER'S STREAM ORDERING OF PUNPUN RIVER SYSTEM

length measurement from topographic maps :

(i) Pair of dividers
(ii) Thread length
(iii) Edge of paper strip
(iv) Opisometer
(v) Analog to digital converter

The measurement of stream lengths in Punpun basin was done by thread length method.

3.1.3 Determination of C.G. of the basin

The centroid of the Punpun basin has been determined using a cardboard piece. The cardboard piece was cut in the shape of Punpun catchment. Then the C.G. was located on the catchment shape card board piece using point balance standard procedure. The card board piece marked with centre of gravity was superimposed over the catchment plan and by pressing a sharp edge pin over the centre of gravity of the card board piece it was marked on the catchment.

3.1.4 Drainage area

The Drainage area is probably the single most important characteristics for hydrologic design. It is hydrologically important because it directly affects the flood hydrograph and the magnitude of flood peaks. The larger the size of the basin, the greater is the amount of the rain intercepted and higher is the peak discharge. The drainage area can be defined as the collecting area from which water would go to a stream or river. The boundary of the area is determined by ridge separating water flowing in opposite directions.

The following methods may be used for the determination of the area of a drainage basin from the available toposheets of the basin.

(i) Estimation
(ii) Polar planimeter
(iii) Dot grid
(iv) Strip sub division
(v) Geometric sub division
(vi) Analog to digital converter.

The basin area of the Punpun river has been measured by dot grid method.

3.2 Evaluation of Geomorphic Parameters

Various geomorphic parameters can be broadly classified into three categories.

1. Linear aspects of channel
2. Areal aspects of the basin
3. Relief aspects of the catchment and channel network

3.2.1 Linear aspects of channel

Various parameters grouped under this category are listed below.

(a) Length of the main channel (L)
(b) Length of the channel between the outlet and a point nearer to C.G. (L_c).
(c) Stream lengths (L_u)
(d) Length of over land flow ($\bar{L}_o$)
(e) Basin perimeter (P)
(f) Stream length ratio (R_L)
(g) Bifurcation ratio (R_b)
(h) Wandering ratio (R_w)
(i) Fineness ratio
(j) Watershed eccentricity (r)

The methodology to quantify these parameters for Punpun basin is given below:

3.2.1.1 Length of the main channel (L)

This is defined as the length along the longest water course from the outflow point of designated basin to the upper limit to the catchment boundary. The length of the main channel of Punpun basin is 255 Km.

3.2.1.2 Length of channel between the outlet and a point nearer to C.G. (L_c) :

L_c is the length of the channel measured from the outlet of the catchment to a point on the stream nearest to the centroid of the basin. Its value for the Punpun basin is 180 Km.

3.2.1.3 Stream lengths (L_u)

Total channel length is the total sum of the lengths of channels of all the orders in the basin. If L_u is the total channel length of all streams of order w in a given basin then it can be expressed as

$$L_u = \overset{N_u}{\underset{i=1}{d}} L_i$$

Where L_i is the length of the ith segment of order u and N_u is the number of streams of order u. This parameter gives an idea of over land flow and channel flow in the basin. Channel storage varies with stream length as a simple power function. The stream lengths of one, two, three, four, five and six order has been obtained 1671.50, 548.75, 521.50, 165.25, 295.50, and 16.00 Km.

3.2.1.4 Length of overland flow (L_o)

Horton (1945) defined length of overland flow as the length of flow path, projected to the horizontal, of non channel flow from a point on the drainage divide to a point on the adjacent stream channel. The length of overland flow is one of the most important independent variables affecting both the hydrologic and physiographic development of drainage basins. Horton recommended using half the reciprocal of drainage density D for the average length of overland flow L_o for the entire watershed,

$$\bar{L}_o = \frac{1}{2D} \quad .....(3.1)$$

Where,

D = drainage density

Length of overland flow for Punpun basin is 1.326.

3.2.1.5 Basin perimeter (P)

Basin Perimeter is defined as the length of the watershed divide which surrounds the basin. It is measured along the divides between basins and may be used as an indicator of basin size and shape. The perimeter of Punpun basin is 487.25 Km.

3.2.1.6 Stream length ratio (R_L)

Stream length ratio is the ratio of the mean stream segment of order u to the mean segment of order (u-1),

$$R_L = \frac{\bar{L}_u}{\bar{L}_{u-1}} \quad .....(3.2)$$

Normally the value of R_L ranges between 1.5 to 3.5 in natural networks. The value of stream length ratio for Punpun basin has been determined by taking the anti-logarithm of slope of regression plot of logarithm of average stream length versus stream order (Fig 3.2).

3.2.1.7 Bifurcation ratio (R_b)

The R_b computed using Horton's law of stream number which states, "The number of stream segments of each order form an inverse geometric sequence with order number" or

$$N_w = R_b^{k-w} \qquad .....(3.3)$$

Where,

k = order of trunk segment

N_w = number of segments of order w

$$\log N_w = (k-w) \log R_b$$

cr $$\log N_w = a - b_w \qquad .....(3.4)$$

Where,

$a = k \log R_b$ and

$b = \log R_b$

or $$R_b = \log^{-1}(b)$$

The value of bifurcation ratio varies normally between 3 and 5 and is used as an index of hydrograph shape for watersheds similar in other respects. The bifurcation ratio of Punpun basin has been determined by taking anti-logarithm of slope of the regression plot of logarithm of stream number versus stream order (Fig 3.3).

3.2.1.8 Wandering ratio (R_w)

It is defined as the ratio of the main stream length tc

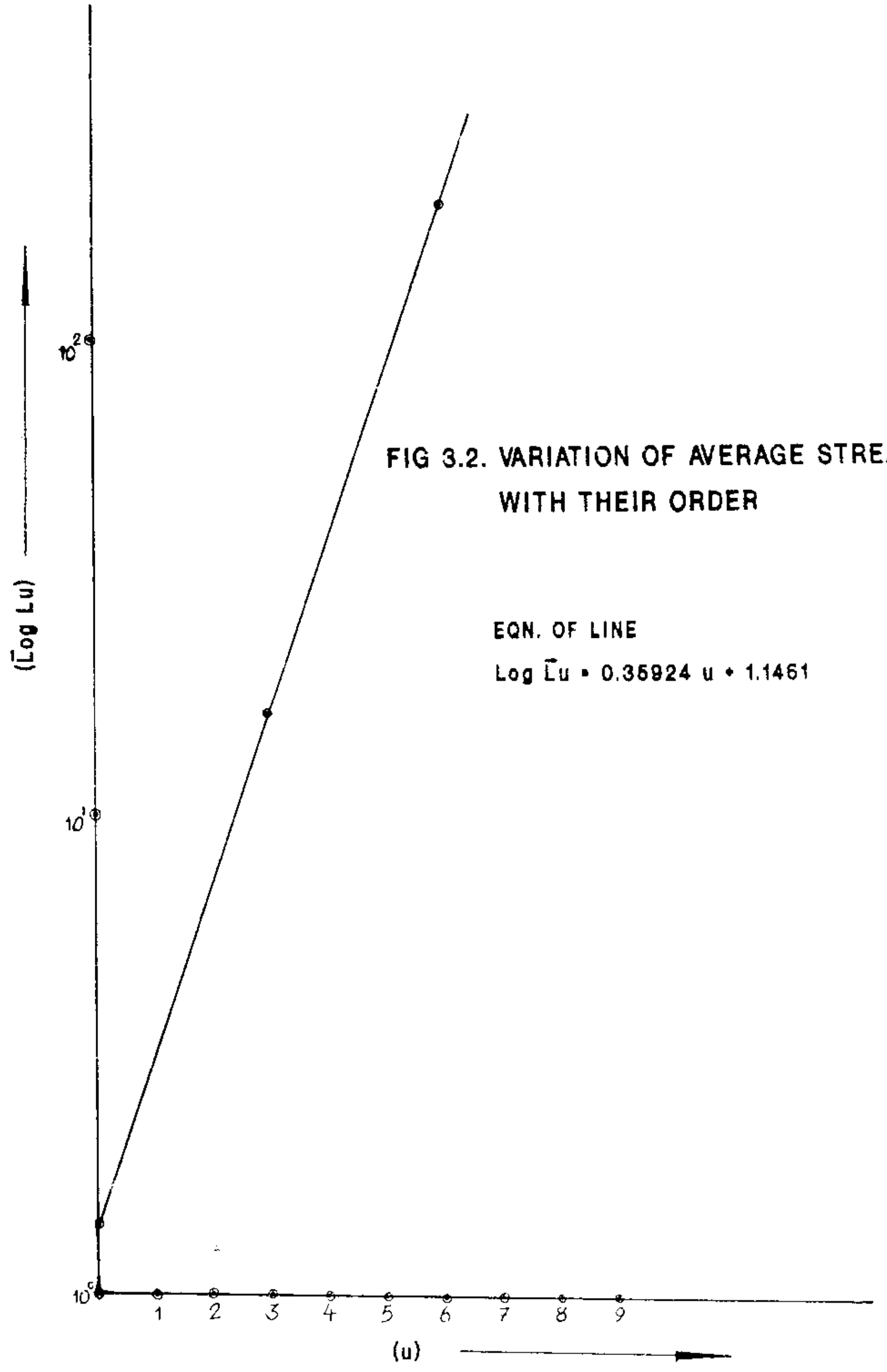

FIG 3.2. VARIATION OF AVERAGE STREAM LENGTHS WITH THEIR ORDER

EQN. OF LINE

$\text{Log } \bar{L}u = 0.35924\,u + 1.1461$

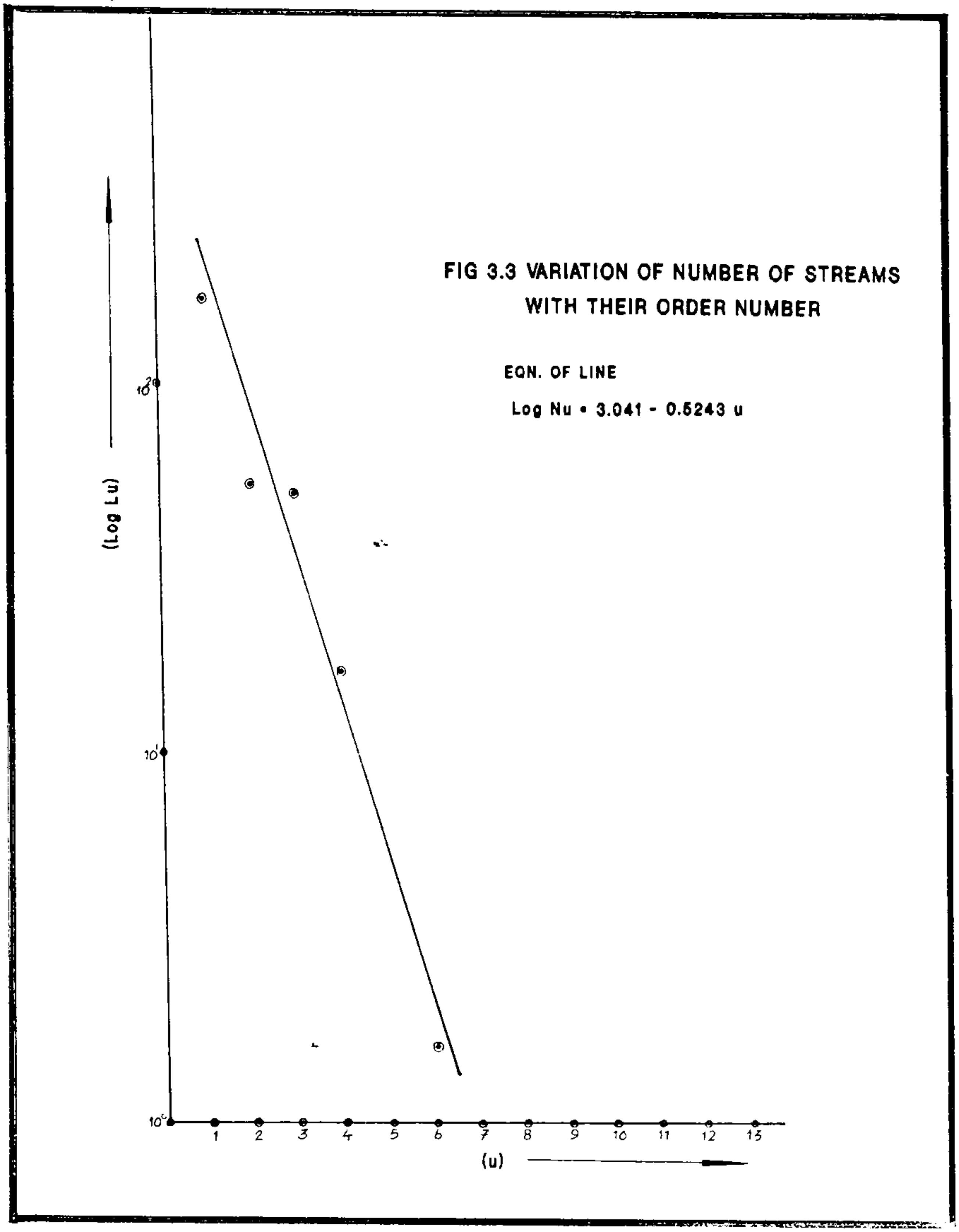

FIG 3.3 VARIATION OF NUMBER OF STREAMS WITH THEIR ORDER NUMBER
EQN. OF LINE
Log Nu = 3.041 - 0.5243 u
(Log Lu)
(u)
10^2
10^1
10^0
1
2
3
4
5
6
7
8
9
10
11
12
13

the valley length. Valley length is the straight line distance between outlet of the basin and the farthest point on the ridge (Fig 3.4). The value of Wandering ratio for Punpun basin has been obtained as 1.34.

3.2.1.9 Fineness ratio

Fineness ratio may be defined as the ratio of channel length to the length of the basin perimeter, which is a measure of topographic fineness. The value of Fineness ratio has been computed for Punpun basin and it's value is 0.52.

3.2.1.10 Watershed eccentricity (τ)

The watershed eccentricity is computed by the following equation :

$$\tau = \frac{\sqrt{|(L_c^2 - W_L^2)|}}{W_L} \quad .....(3.5)$$

Where

τ = watershed eccentricity, a dimensionless factor

L_c = length from the watershed mouth to the centre of mass of the watershed in the same unit, and

W_L = the width of the watershed at the center of mass and perpendicular to L_c.

The measurement for L_c and W_L are shown diagramatically into fig 3.5 it is also to be noted that if $L_c = W$, $\tau = 0$, and as either L_c or W get large, τ increase. Thus the lower the value of τ, the greater the compactness of the watershed concentrated near the mouth and the higher the flood peak. The watershed eccentricity obtained for Punpun basin is 2.509.

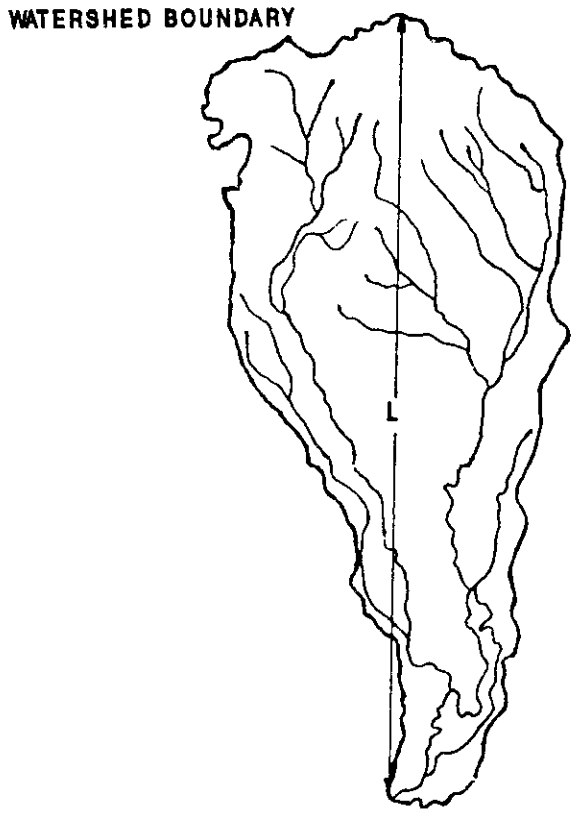

FIG 3.4. VALLEY/BASIN LENGTH FOR WANDERING RATIO

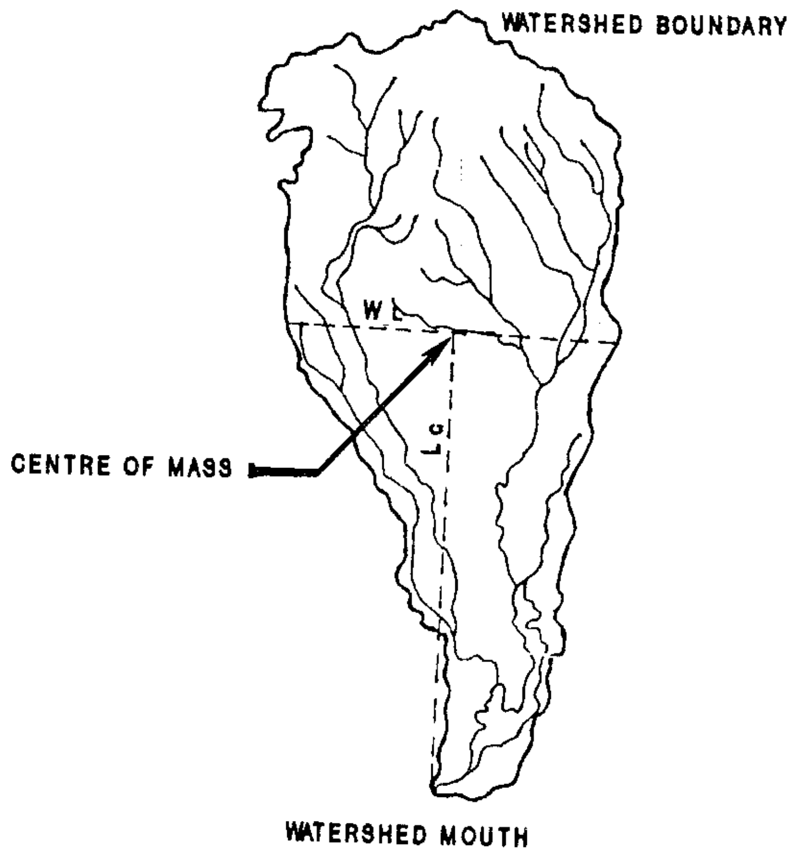

FIG 3.5 WATERSHED ECCENTRICITY

3.2.2 Areal aspects of the basin

The geomorphological parameters which are governed by the area of the drainage basin are classed as areal aspects of the basin. Various areal parameters which has been computed here includes :

(a) Drainage area (A)
(b) Drainage density (D)
(c) Constant of channel maintenance (C)
(d) Channel segment frequency (F)
(e) Circularity ratio (R_c)
(f) Elongation ratio (R_e)
(g) Watershed shape factor (R_s)
(h) Unit shape factor (R_u)
(i) Form factor (R_f)

3.2.2.1 Drainage area (A)

This has been described in section 4.1.4 of this report.

3.2.2.2 Drainage density (D)

Drainage density is defined as the ratio of the total length of channels of all orders in the basin to the area of the basin. The unit chosen for the drainage density is km/sq. km.

$$D = \frac{L_u}{A} \qquad .....(3.6)$$

where,

L_u is the sum of stream length of all orders,

A is the area of the basin

It should be measured on the topomaps of large scales (1:50,000) so that first order streams can also be taken into account. Drainage density is textural measure of a basin which is generally independent of basin size. It is considered to be a function of climate, lithology, and stage of development. Numerically this ratio expresses the number of kilometers of channel maintained by a square kilometer of drainage area. It's value for Punpun basin has been obtained as 0.377.

3.2.2.3 Constant of channel maintenance (C)

It is defined as the ratio between the area of a drainage basin and the total length of all the channels expressed in square feet per foot or square meters per meter. It is virtually the reciprocal of drainage density and for Punpun basin it is 2.653.

3.2.2.4 Channel segment frequency (F)

Channel segment frequency or stream frequency is defined as the number of streams per unit area in a drainage basin.

Stream frequency F is computed as the number of streams per unit area or,

$$F = \frac{N}{A} \qquad \text{.....(3.8)}$$

Where,

N = total number of segments of all order in the catchment area

A = drainage area of basin

The value of channel segment frequency for Punpun basin is 0.0953.

3.2.2.5 Circularity ratio (R_c)

The ratio of the basin area to the area of a circle having circumference equal to the perimeter of the basin is the circulatory ratio.

$$R_c = \frac{4\pi A}{P^2} = 12.566 \frac{A}{P^2} \qquad \ldots.(3.9)$$

The value of this ratio approaches unity as the shape of a drainage basin approaches circle. For Punpun basin the value of R_c is 0.451.

3.2.2.6 Elongation ratio (R_e)

It may be defined as the ratio of diameter of a circle of the same area as the basin to the the maximum basin length. This parameter is evaluated for all the watersheds to assess whether the shape of the basin approaches a circle. It can be computed by the following expression :

$$R_e = \frac{\sqrt{(4A/\pi)}}{L_b} \qquad \ldots..(3.10)$$

The value of elongation ratio approaches unity as the shape of drainage basin approaches a circle. The value of elongation ratio for Punpun basin is 0.5486.

3.2.2.7 Watershed shape factor (R_s)

Wu et al (1964) has defined the watershed shape factor as the ratio of main stream length L_c to the diameter D_c of a circle having the same area as of watershed.

$$R_s = \frac{L_c}{D_c} \qquad .....(3.11)$$

For Punpun basin the value of R_s is 1.7267

3.2.2.8 **Unity shape factor (R_u)**

It is defined as the ratio of the basin length (L_b) to the square root of the basin area.

$$R_u = \frac{L_b}{\sqrt{A_w}} \qquad .....(3.12)$$

The value of R_u for Punpun basin is 1.9480.

3.2.2.9 **Form factor (R_f)**

Horton defined form factor, R_f, as the ratio of basin area A, to the square of basin length L. The R_f is a dimensionless parameter and is computed as

$$R_f = \frac{A}{L^2} \qquad .....(3.13)$$

For Punpun basin the value of form factor is 0.1312

3.2.3 **Relief aspects of catchments and channel networks**

Variables involving relief aspects of the basin are the most significant parameters in hydrological studies of the watershed. These aspects are the functions of the elevation or elevation difference at various points in a catchment or along the channels. Various parameters involving the relief aspects to clearly understand the kind of relationship that exists between the sediment yield and the relief features, are as follows:

(a) Watershed relief (H)
(b) Relief ratio (R_r)
(c) Relative relief (R_R)
(d) Ruggedness number (R_N)

3.2.3.1 Watershed relief (H)

The difference in elevation between the remotest point in the divide line and the discharge point of the watershed is known as watershed relief. The elevation difference between the remotest point and the discharge point is obtained from the available contour maps. The value of H for Punpun basin is 250 m.

3.2.3.2 Relief ratio (R_r)

Relief ratio is a dimensionless ratio and can be defined as the total watershed relief(H) divided by the maximum length of the watershed.

$$R_r = \frac{H}{L_b} \quad \text{.....(3.14)}$$

The value of relief ratio for Punpun basin is 0.00132.

3.2.3.3 Relative relief (R_R)

Relative relief is defined as the ratio of the maximum watershed relief to the perimeter of the watershed. It is computed from the following equation

$$R_R = \frac{H}{P} \quad .....(3.15)$$

Relative relief is an indicator of the general steepness of a basin form summit to the outlet. For Punpun basin the value of relative relief is 0.0005

4.2.3.4 Ruggedness number (R_N)

Ruggedness number is (a dimensionless term advanced by Strahler) defined as the product of drainage density and maximum basin relief. Any change in either of the factors will obviously have a telling effect on the slope, steepness and ultimately on the erosion. It is computed from the following equation

$$R_N = \frac{H.D}{1000} \quad .....(3.16)$$

Where,

R_N = Ruggedness number,

H = watershed relief in m,

D = drainage density in Km^{-1}

The value of R_N for Punpun basin is obtained as 0.0943.

4.0 RESULTS AND DISCUSSION

The stream ordering of the Punpun basin, which falls in Survey of India toposheets no. 72 C,D,and G basin has been done using Strahler's ordering scheme. It is observed that the Punpun river is a sixth order stream.

The length of the main channel of the basin is 255 Km and the length of the channel between the outlet and a point near to center of gravity (C.G) is 180 Km. The streams of different order were counted and total lengths of streams of each order were measured and presented in table 4.1. It is observed from the table that the mean lengths which have been computed as the ratio of the total length of specific order of streams and the total number of streams of that order, are 2.49, 5.276, 18.625, 23.607,147.75 and 16.00 km for order one, two, three, four, five and six respectively. The number of streams falling under different order are 671,104,28,7,2, and 1 respectively. Total length of streams of all orders, basin perimeter, watershed eccentricity etc. have also been computed for the Punpun basin and these values are presented in Table 4.1. On a semilog paper number of stream of different orders with their order number were plotted. Negative slope of the straight line indicates that the number of streams of a particular order decrease with the increase in stream order and it follows the law of stream numbers. Which indicates that the number of streams of any given order are fewer than the immediate lower order but more in +numbers than the next higher order. However, in general, the average length of a particular order stream increases as the

TABLE 4.1: GEOMORPHOLOGICAL PARAMETERS BASED ON LINEAR ASPECTS OF THE BASIN (LENGTHS ARE IN KM).

Name of Parameters	Symbol	Value
1. Length of the main channel	L	255.00
2. Length of the channel between the outlet and a point near to C.G	L_c	180.00
3. Total length of channels of		
Order 1	L_1	1671.50
Order 2	L_2	548.75
Order 3	L_3	521.50
Order 4	L_4	165.25
Order 5	L_5	295.50
Order 6	L_6	16.00
4. Total length of streams of all orders	L_u	3218.50
5. Total number of channels of		
Order 1	n_1	671
Order 2	n_2	104
Order 3	n_3	28
Order 4	n_4	7
Order 5	n_5	2
Order 6	n_6	1
6. Total number of streams of all orders	n_u	813
7. Mean length of streams of		
Order 1	L_1	2.49
Order 2	L_2	5.276
Order 3	L_3	18.625
Order 4	L_4	23.607
Order 5	L_5	147.75
Order 6	L_6	16.00
8. Length of overland flow	L_o	1.326
9. Basin perimeter	P	487.25
10. Wandering ratio	R_w	1.34
11. Fineness ratio		0.52
12. Watershed eccentricity	τ	2.509
13. Bifurcation ratio	R_b	3.344
14. Stream length ratio	R_L	2.286

order of the stream increases which means that the mean length of a stream of a given order is greater than that of immediate lower order but less than that of the next higher order. The values of bifurcation ratio and stream length ratio are computed by finding out the anti-logarithms of slopes of the regression plots of log N_u versus u and Log L_u versus u respectively. The value of bifurcation ratio of the basin is 3.344. Bifurcation ratio is a non dimensional parameter which reflects the hydrological characteristics particularly effecting the time of peak.

Geomorphological parameters based on areal aspects have been evaluated for Punpun basin are presented in table 4.2. It is found that the drainage area of the selected basin is 8530.00 sq. km. The basin drainage area is considered to be one of the important geomorphological characteristic and has been used frequently in various hydrological studies. The values of various non dimensional areal measures e.g. elongation ratio, circularity ratio, constant of channel maintenance, drainage density, form factor and stream frequency are also computed. These non dimensional areal parameters are the governing factors for the peak and shape of the basin response hydrograph and these can be used in the modelling of hydrological response without considering the runoff records. Values of these non dimensional parameters are also presented in table 4.2

Under relief aspects of the basin some of the important parameters have been computed and presented in table 4.3. The Punpun river basin has a total relief of 250 m. Various

TABLE 4.2: GEOMORPHOLOGICAL PARAMETERS BASED ON AREAL ASPECTS OF THE BASIN (AREAS ARE IN SQ.KM.)

Name of parameters	Symbol	Value
1. Drainage area	A	8530.00
2. Drainage density	D	0.377
3. Constant of channel maintenance	C	2.653
4. Channel segment frequency	F	0.0953
5. Circulatory ratio	R_c	0.451
6. Elongation ratio	R_e	0.5486
7. Watershed shape factor	R_s	1.7267
8. Unity shape factor	R_u	1.9480
9. Form factor	R_f	0.1312

non dimensional relief measures e.g. relief ratio, relative relief, ruggedness number and average overland slope of the Punpun basin are also presented in table 4.3. The relief parameters have significant importance particularly in the modelling of mountainous catchment where velocity of flow are considerably high. Overland flow and stream flow process in the basin is also governed by them.

TABLE 4.3: GEOMORPHOLOGICAL PARAMETERS BASED ON RELIEF ASPECTS OF THE BASIN.

Name of parameters	Symbol	Value
1. Basin relief	H	250.0000 m
2. Relief ratio	R_r	0.00132
3. Relative relief	R_R	0.0005
4. Ruggedness number	R_N	0.0943
5. Average overland slope	S_a	%

6.0 CONCLUSION

In this report various geomorphological properties covering linear, areal, and relief aspects of Punpun sub-basin of Ganga river basin have been discussed and computed. It is observed that the main Punpun stream is a sixth order stream and the main channel is 255.00 km. long. Total relief of the basin was computed as 250 meters, which shows that basin is not very steep. The value of drainage density is 0.377 which is less thereby increasing the value of Constant of channel maintenance. The shape parameters such as circulatory ratio, elongation ratio, watershed shape factor and unity shape factor indicates that the basin does not have evenly distributed area. Various non dimensional geomorphological parameters of the basin were also computed. The geomorphological parameters, thus estimated, may be utilized for regional unit hydrograph studies, flood frequency analysis, instantaneous unit hydrograph study, simulation models. These parameters may also be utilized for the development of empirical formula.

7.0 REFERENCES

1. Broscoe, A.J. (1959), 'Quantitative analysis of longitudinal stream profiles of small watersheds', Project NR 389-042, Tech. Rept. 18, Columbia University, Department of Geology, ONR, Geography Branch, New York.

2. Chow, V.T. (1962), 'Hydrologic determination of waterway areas for the design of drainage structures in small drainage basins', Engineering Experiment Station Bulletin, no. 462, University of Illinois, Urbana.

3. Dingman, S.L. (1978), 'Drainage density and streamflow: a closer look', Water Resources Research 14(6), pp. 1183-1187.

4. Duru, G.H. (1976), 'Discharge prediction, present and former, from channel dimensions', Journal of Hydrology 30, pp. 219-245.

5. Gupta, V.K., E. Waymire, and C.T. Wang (1980), 'A representation of an instantaneous unit hydrograph from geomorphology' , Water Resources Research 16(5):855-862.

6. Hack, J.T. (1957), 'Studies of longitudinal stream profiles in Virgina and Maryland', U.s. Geol. Surv., Profess. Paper 294-B.

7. Harlin, J.M. (1984), 'Watershed morphometry and time to hydrograph peak', Journal of Hydrology 67, pp. 141-154.

8. Horton, R.E. (1932), 'Drainage basin characteristics', Trans. Am. Geophys. union, vol. 13, pp. 350-361.

9. Horton, R.E. (1945), 'Erosional development of streams and their drainage basins: hydro-physical approach to quantitative morphology', Bull : Geol. Soc. Am., Vol. 56, pp. 275-370.

10. Kinnison, H.B., and B.R. Colby (1945), 'Flood formulas based on drainage basin characteristics', Transactions of the American Society of Civil Engineers 110, pp. 849-876.

11. Leopold, L.B. and J.P. Miller (1956), 'Ephemeral streams: hydraulic factors and their relation to the drainage net' U.S. Geol. Surv. Profess. Paper 282-A.

12. Linsley, R.K., M.A. Kohler and J.L.H. Paulhus (1975), 'Hydrology for Engineers'. New Delhi : McGraw Hill Series in water resources and environmental engineering.

13. Maxwell, J.C.(1955), 'The bifurcation ratio in Hortan's law of stream numbers', Trans. Am. Geophys. Union, 36:520

14. Maxwell, J.C. (1960), 'Quantitative geomorphology of the San Dimas Experimental Forest, California' , Project NR 389-042, Tech. Rept. 19, Columbia University, Department of Geology, ONR Geography Branch, New York.

15. Melton, M.A.(1959), 'A derivation of Strahler's channel-ordering system', Jour. of Geology 67(3) : 345-346.

16. Melton, M.A. (1957), 'An analysis of relations among elements of climate, surface properties, and geomorphology', Project NR 389-042, Tech. Rept. 11, Columbia University, Department of Geology, ONR, Geography branch, New York.

17. Miller, V.C. (1953), 'A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee', Project NR 389-042, Tech. Rept. 3, Columbia University, Department of Geology, ONR, Geography Branch, New York.

18. Mimikou, M. (1983), 'A study of drainage basin linearity and nonlinearity', Journal of Hydrology 64, pp. 113-134.

19. Morisawa, M.E. (1957), 'Accuracy of determinations of stream lengths from topographic maps', Trans. Am. Geophys. Union 38: 86-88.

20. Morisawa, M.E.(1958), 'Measurement of drainage basin outline form', Jour. of Geology 66: 587-591.

21. Morisawa, M.E.(1962), 'Quantitative geomorphology of some watersheds in the Appalachian plateau', Geological Soc. Am. Bull. 73: 1025-1046.

22. Mosley, M.P. (1981), 'Delimitation of New Zealand Hydrologic regions', Journal of Hydrology 49, pp. 173-192.

23. National Institute of Hydrology, technical report on 'Geomorphological Characteristics of Western Ghat Region Part I - Upper Krishana Basin', TR-63,1988-89.

24. National Institute of Hydrology, technical report on 'Geomorphology of Kolar Sub-basin for Hydrological Studies', TR-99, 1990-91.

25. National Institute of Hydrology, technical report on 'Geomorphology of Sabarmati basin up to Dharoi', TR-138, 1992-93.

26. National Institute of Hydrology, technical report on 'Geomorphological studies of Bagmati basin of Kosi river system', TR-173,1992-93.

27. Nash, J.E. (1960), 'A unit hydrograph study, with

particular reference to British catchments', Proceedings of the Institution of Civil Engineers 17, pp. 249-282, London.

28. Rastogi, R.A. and T.C. Sharma.(1976), 'Quantitative analysis of drainage basin characteristics', Jour. Soil and Water Cons. in India 26(1-4) : 18-25.

29. Rodriguez- Iturbe, I. (1982), 'The coupling of climate and geomorphology in rainfall runoff analysis', edited by V.P.Singh, 431-448, Water Resources Publications, Littleton, Colo.

30. Rodriguez-Iturbe, I., and J.B. Valdes (1979), 'Ten geomorphologic structure of hydrologic response', Water Resources Research 15(6: 1409-1429.

31. Scheidegger, A.E. (1966a), 'Statistical description of river networks', Water Resources Research 2: 785-790.

32. Scheidegger, A.E. (1966b), 'Stochastic branching processes and the law of stream orders', Water Resources Research 2:199-293.

33. Scheidegger, A.E. (1965), 'The algebra of stream order numbers', U.S. Geol. Soc., Prof. Pap. 525-B, pp. 187-189.

34. Schumm, S.A. (1954 a), 'Evolution of drainage systems and slopes in Badlands at perth Amboy', New Jersey, Department of Geology, Technical Report No. 8, Columbia University, New York.

35. Schumm, S.A. (1954 b), 'The relation of drainage basin relief to sediment loss', International Association of Scientific Hydrology Publication 36, 1:216-219.

36. Schumm, S.A. (1956), 'Evolution of drainage systems and slopes in badlands at Perth Amboy', New Jersey, Bull. Geol. Soc. Am. , Vol, 67, pp. 597-646.

37. Strahler, A.N. (1952), 'Dynamic basis of geomorphology', Bull. Geol. Soc. Am., Vol. 63, pp. 923-938.

38. Strahler, A.N. (1952), 'Hypsometric (area-altitude) analysis of erosional topography', Bull. Geol. Soc. Am., Vol. 63 : 1117-1143.

39. Strahler, A.N. (1957), 'Quantitative analysis of watershed geomorphology', Trans, Am. Geophys. Union, Vol. 38, pp. 913-920.

40. Taylor, A.B., and H.E. Schwarz (1952), 'United hydrograph lag and peak flow related to basin characteristics', Transactions of the American Geophysical Union 33, pp. 235-246.

41. Thomas, D.M., and M.A. Benson (1970), 'Generalization of streamflow characteristics from drainage-basin characteristics', Geological Survey Water Supply Paper 1975, U.S. Department of the Interior, Washington, D.C.

42. Tyagi,N.K., B. Raghunath and V.Lakshman,(1970), 'Study of Watershed Characteristics affecting the hydrologic performance', Jour. Soil and Water Cons.

43. Wang, C.T., V.K. Gupta, and E. Waymire (1981), 'A Geomorphologic synthesis of nonlinearity in surface runoff', Water Resources Research 17 (3), pp. 545-554.

44. Varshney, R.S. 1977. 'Engineering Hydrology'., Roorkee (India) Nem Chand and Brothers Publication.

DIRECTOR	:	Dr. S. M. SETH
HEAD & TECHNICAL CO-ORDINATOR	:	Dr. K. K. S. BHATIA
STUDY GROUP	:	ANIL KUMAR LOHANI
	:	MANOHAR ARORA
	:	RAHUL KUMAR JAISWAL
ASSISTANCE	:	A. K. SIVADAS
		SANTHOSH M. B.