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GEOMORPHOLOGY OF SABARMATI BASIN UPTO DHAROI

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PREFACE

The advanced knowledge of geomorphology of a basin is of importance. The different geomorphological parameters of a watershed can be employed in synthesizing and understanding its hydrological behavior. The geomorphological properties of channel network are generally referred to the basin composition which represents the topographical and geometrical properties of the basin. The linear, areal and relief aspects of the watershed are some of the important characteristics which are considered generally in the science of geomorphology and particularly in hydrological studies.

In this report an attempt has been made to present methodology to quantify various geomorphological parameters of Sabarmati basin upto Dharoi using modern measuring techniques for use in subsequent rainfall runoff modeling studies. This study has been carried out by Sri M K Jain, Scientist B, and assisted by sri U K Singh, R. A. ,in the Mountain Hydrology Division, National Institute of Hydrology, Roorkee.

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ABSTRACT

Geomorphology is a science which deals with the basin composition with respect to the topographical and geometric configurations of the basin. Climate and geomorphological characteristics affects basin response to a considerable extent. Thus linking of the geomorphological parameters with the hydrological behavior of the basin provides a powerful way to understand hydrological response of different basins particularly of the ungauged basins.

In this study various geomorphological characteristics covering linear, areal and relief aspects of the Sabarmati basin upto Dharoi are evaluated using modern measuring tools. The study may be useful at finding out effect of geomorphology on watershed runoff response and identifying those parameters which are more closely related to runoff in the region.

1.0 INTRODUCTION

The geomorphology describes the environment in which the hydrological processes operates. A strong mutual correlation exists between geomorphological variables and hydrological characteristics. such relationship can be applied to both surface and ground water regime. Thus the linking of geomorphological parameters with hydrological characteristics of the basin provides a simple way to understand the hydrological behavior of different basins and particularly of the ungauged basins.

Quantitative studies of geomorphological parameters is a prerequisite for taking up hydrological simulation studies by using these parameters. The geomorphological properties which are important to the hydrological simulation studies includes the linear, areal and relief aspects of the basin. Various measures have been suggested by many investigators to represent the linear, areal and relief aspects of the basin. The quantification of these measures is cumbersome and time taking if carried out manually . But the task becomes comparatively easy by using electronic digitizers and computers.

The sabarmati river is one of the important rivers of Gujarat State and has tremendous potential for supplying water for domestic,industrial and agricultural and other uses. It also has tremendous potential for generating hydroelectric power. This study is carried out to quantify various geomorphological parameters of the Sabarmati basin upto Dharoi for use in subsequent hydrological studies.

In this study various geomorphological aspects such as linear, areal and relief aspects of the Sabarmati basin upto Dharoi are evaluated. The catchment area have been delineated from the Survey of India toposheets in the scale of 1:2,50,000. The area is then further divided into various sub basins according to the gauging sites. The catchment areas of important gauging sites were marked on the map and the river system and catchment boundaries were digitized for each sub basin. The digitized information is used to quantify some of the important geomorphological properties of the basin with the help of electronic computers. Some of the derived geomorphological parameters will be used in another study for simulating rainfall runoff of the basin in conjunction with other conventional hydrological data.

2.0 METHODOLOGY

In this section a brief description of various geomorphological parameters which are of importance in hydrological studies is given. The methodology to quantify them is also stated.

2.1 Geomorphological Characteristics:

Systematic description of the geometry of a drainage basin and its stream channel system requires the measurements of (i) linear aspect of drainage network, (ii) areal aspect of drainage basin, and (iii) relief aspect of channel network and contributing ground slopes. Here, the first two categories of measurement are planimetric (i.e. treat properties projected upon a horizontal datum plane) and the third category treats the vertical inequalities of the drainage basis forms.

2.1.1 Ordering of the streams:

For all practical purposes, the quantitative study of channel networks used to begin with Horton's (1945) methods of ordering of channels . Later on, Strahler (1952) proposed a modification of Horton's ordering scheme. Strahler's method is now generally preferred due to its simplicity and greater freedom from subjective decisions. In this report, the Strahler's method will be employed. There are three steps in Strahler's ordering procedure.

i) Channels that originate at a source are defined to be first order streams;

ii) When two stream of order w joins, a stream of order (w+1) is created; and

iii) When two streams of different order joins, the channel segment immediately downstream has the higher order of the combining streams.

Fig. 1 shows the Sabarmati basin upto Dharoi. One sub-basin is also ordersd by Strahler's ordering method in the figure.

2.2 Linear Aspects

The linear aspects proposed by various investigators which are of importance in hydrological studies, are described below. The methodology used to quantify them is also stated.

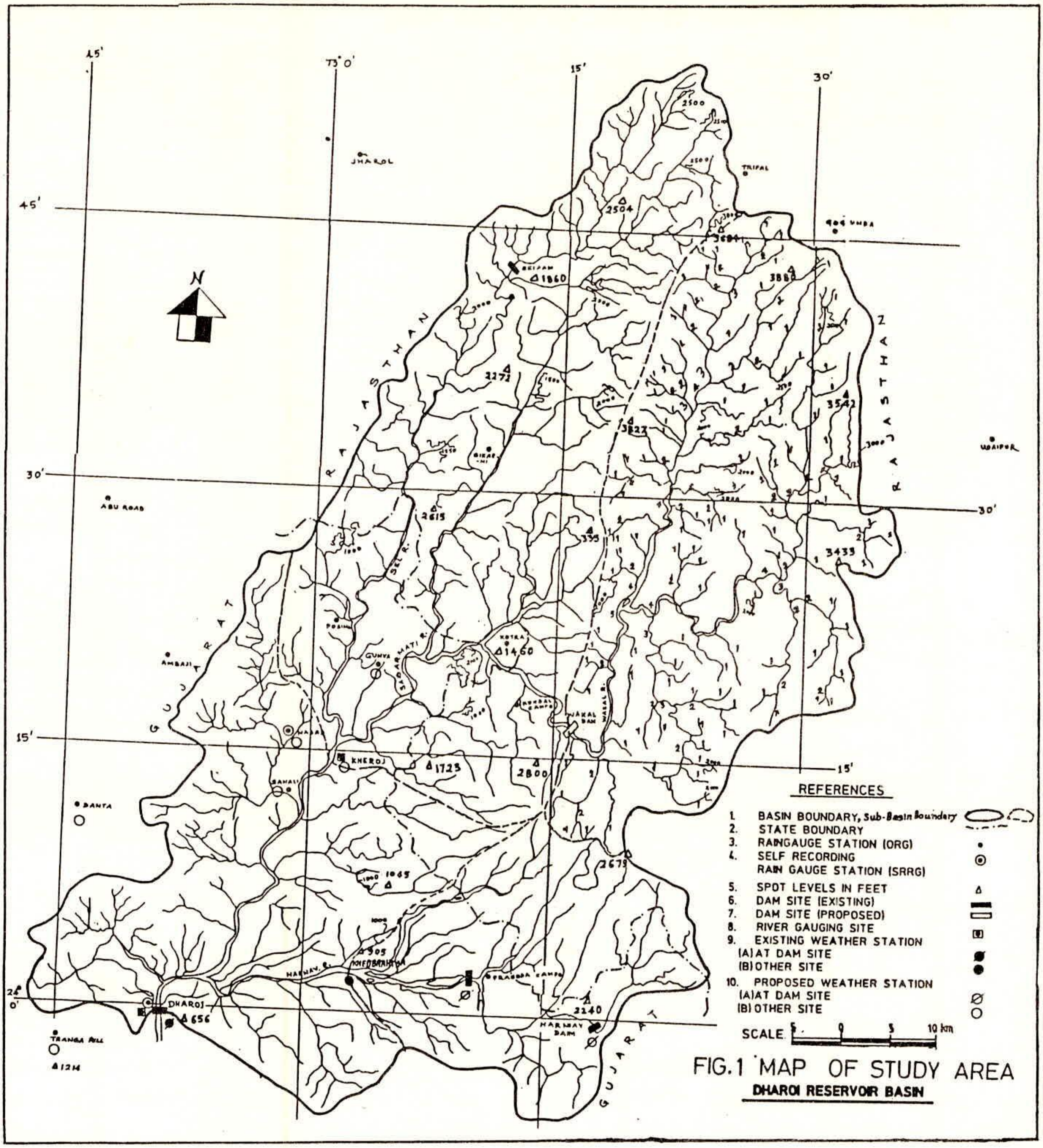

FIG.1 MAP OF STUDY AREA

DHAROI RESERVOIR BASIN

2.2.1 Number of streams of given order (N_w):

The quantity N_w represent total number of all streams, counted as the stream segments, having the order w to present in the watershed. Since a watershed of a given order can be modelled as a collection of elements of lower orders, the number of streams of each order is an important concept in hydrologic synthesis.

2.2.2 Bifurcation ratio (R_b):

The bifurcation ratio (R_b) for a given channel network can be obtained by determining the slope of the fitted regression of the plot of the logarithm of number of stream on ordinate versus order on abscissa. The regression coefficient b is identical with the logarithm of R_b . The R_b is a dimensionless quantity and shows only a small variation from region to region. The value of R_b varies normally between 3 to 5 and is a useful index for hydrograph shape for watersheds similar in other respect.

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

$$N_w = R_b^{k-w}$$

where k is the order of trunk segment

N_w is the number of segments of order w

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

or $$\log N_w = a - b_w$$

where

$$a = k \log R_b \quad \text{and}$$

$$b = \log R_b$$

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

For computing R_b a subroutine for linear regression REG based on least square approach is used. This value of R_b is used to compute the total number of streams of all order (N) in a given network.

$$N = \sum_{w=1}^{k} N_w = \frac{R_b^k - 1}{R_b - 1}$$

2.2.3 Length of the main channel (L):

This is the length along the longest water course from the outflow point of designated sub basin to the upper limit of the catchment boundary. For computing the length of the main channel (L), the data file was prepared by tracing the cursor of analog to digital converter along with the main channel. The coordinates of the closely spaced points were stored in a data file and distance between two points was obtained by

$$\text{Distance} = [(\Delta x)^2 + (\Delta y)^2]^{1/2}$$

For the length of the channel, distances of all the small segments were added using a subroutine LENGTH.

2.2.4 Stream lengths (L_w):

Stream length L_w is the total length of all streams of order w in a given drainage basin.

$$L_w = \sum_{i=1}^{N_w} L_i$$

Where L_i is the length of the i th segment of order w and N_w is the number of streams of order w . Stream lengths are employed in development of simplified geometric configurations required in hydraulic modeling of watershed response. The length of all streams of each order was calculated in the same way as of main channel length using the subroutine LENGTH.

2.2.5 Stream length ratio (R_L):

This is the ratio of mean stream segment length of order w to the mean stream segment length of order (w-1),

$$R_L = \frac{\bar{L}_w}{\bar{L}_{w-1}}$$

The value of R_L ranges normally between 1.5 to 3.5 in natural networks. The R_L is calculated by using Horton's law of stream lengths and stream numbers, or

$$L_w = \sum_{i=1}^{w} \sum_{j=1}^{N_i} L_{ij} = \bar{L}_1 R_b^{w-1} \frac{R_{Lb}^{w}-1}{R_{Lb}-1}$$

Here, L_i , $\bar{L}_1$ and R_b are known. The above equation is solved for R_{Lb} by using Newton-Rapson non-linear optimization technique. The R_L is calculated by

$$R_{Lb} = \frac{R_L}{R_b}$$

2.2.6 Length of overland flow, (L_o):

The length of over land flow can be defined as the length of flow of water over the ground before it becomes concentrated in defined stream channels. It can be measured as the length of flow path, projected to horizontal, of non channel flow from a point on the drainage divide to a point on the adjacent stream channel. Horton recommended using half the reciprocal of drainage density D for the average length of over land flow $\bar{L}_o$ for the entire watershed.

$$\bar{L}_o = \frac{1}{2D}$$

2.2.7 Length of channel between outlet and a point near to C.G, (L_c):

It 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. The centre of gravity is located by procedure described below,

For computing centre of gravity (x_g , y_g) of the basin, it is divided into small triangles and x_g and y_g coordinates of small triangles (x_c, y_c) are calculating using formulae:

$$x_c = \frac{1}{3} (x_1 + x_2 + x_3)$$

$$y_c = \frac{1}{3} (y_1 + y_2 + y_3)$$

Where (x_1,y_1), (x_2,y_2) and (x_3,y_3) are the coordinates of the three nodes of any triangle. If catchment is divided into n parts, the x coordinate of the centre of gravity of each part (x_{Gi}) is obtained by dividing sum of multiples of x_c and area of all respective triangles by the sum of areas of all the triangles. Similarly, the y - coordinates of the centre of gravity (y_{Gi}) are also obtained for each parts of the catchment. The x and y coordinates of centre of gravity of whole basin is calculated by

$$x_G = \frac{\sum_{i=1}^{n} x_{Gi} . Area_i}{\sum_{i=1}^{n} Area_i}$$

$$y_G = \frac{\sum_{i=1}^{n} y_{Gi} . Area_i}{\sum_{i=1}^{n} Area_i}$$

Where $Area_i$ represents the area of i th part of the catchment. Now a point nearest to the centre of gravity can be located on a channel segment taking the minimum of perpendicular distances from the centre of gravity to the different channel segments.

Subsequently the length of channel from the outlet to the nearest located point from C.G. is computed.

2.2.8 Watershed eccentricity (τ):

Watershed eccentricity is given by

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

where

τ = watershed eccentricity, a dimensionless factor

L_c = length from the watershed mouth to the centre of mass of the watershed

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

It is to be noted that if $L_c = W_L$, $\tau = 0$, and as either L_c or W_L increases, τ increases. Thus the lcwer the value of τ, the greater the compactness of the watershed concentrated near to the mouth and higher the peak flood. The τ is calculated using formula described earlier.

2.2.9 Basin perimeter (P):

Basin perimeter is defined as the length of the watershed divide which surrounds the basin. The perimeter P of the basin is obtained using the same procedure as for length. The sum of lengths of segments along the catchment boundary include the length between first and last digitized point provides the estimate for perimeter of the catchment. A subroutine PARAM is used to compute the perimeter P from digitized basin boundary points.

2.3 Areal Aspects:

Various areal aspects of the geomorphological characteristics which have been evaluated include:

2.3.1 Drainage area (A):

Drainage area represents the area enclosed within the boundary of the watershed divide. The drainage area A is probably the single most important characteristics for hydrologic design. It reflects the volume of water that can be generated from rainfall.

The catchment area is calculated using analog to digital converter. The data for calculating catchment area A, are obtained by tracing around the catchment boundary with the cursor of analog to digital converter. The coordinates of closely spaced points are stored in a data file along with the coordinate of a centrally located point as the last value. The centre point should be such that the lines joining each boundary point to it lie within the catchment. Some times a single centre point does not fulfill this condition. In such cases the catchment is divided in to two or more parts according to the shape of the catchment. Each part is then digitized separately and area of each part is later added to give total area. A subroutine AREA is used to calculate area using digitized data of the catchment, each digitized point along the boundary are joined with the centre point dividing the whole catchment into small triangles. Area of each triangle is computed using formula

$$A = \sqrt{s\,(s-a)(s-b)(s-c)}$$

where

a, b and c are the lengths of sides of triangle

$$\text{and } s = \frac{a+b+c}{2}$$

The areas of triangles are added for computing the drainage area of the basin . The area drained by individual channel segments was marked and their areas were measured by digital planimeter and were added separately to compute area drained by 1st, 2nd, 3rd, 4th and 5th order segments respectively.

2.3.2 Drainage density (D):

Drainage density is defined as the ratio of total length of channels of all orders in the basin to the drainage area of the basin. The drainage density is calculated using formula.

$$D = \frac{\sum_{i=1}^{w} \sum_{j=1}^{N_i} L_{ij}}{A_w}$$

2.3.3 Constant of channel maintenance (C):

Constant of channel maintenance is defined as the ratio between the area of drainage basin and total lengths of all channels expressed as sq.m per metre. It is equal to the reciprocal of drainage density. This parameter indicates the number of square meters of watershed surface required to maintain one linear metre of channel or,

$$C = \frac{A_w}{\sum_{i=1}^{w} \sum_{j=1}^{N_i} L_{ij}}$$

2.3.4 Stream frequency (F):

Stream frequency is defined as the number of streams per unit area. Melton (1956) analysed in detail the relationship between drainage density and stream frequency and gave following relation

$$F = 0.694\ D^2$$

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

$$F = \frac{N}{A}$$

where,

N is the total number of segments of all orders in the catchment area

A is the drainage area of basin

2.3.5 Circularity ratio (R_c):

Basin circularity ratio is defined as the ratio of the basin area to the area of a circle having circumference equal to the perimeter of the basin. As the basin shape approaches to a circle, the circularity ratio approaches to 1. It is computed as the ratio of basin area to the area of a circle having same perimeter as of the basin.

2.3.6 Elongation ratio (R_e):

It is defined as the ratio between the diameter of a circle with the same area as the basin and basin length. The value of R_e approaches to 1 as the shape of the basin approaches to circle. This ratio varies from 0.6 to 1 over a wide variety of. climatic and geologic regimes. Typical values are close to 1 for areas of very low relief and are between 0.6 and 0.9 for regions of strong relief and steep ground slope.

2.3.7 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

$$R_f = \frac{A}{L^2}$$

2.3.8 Unity shape factor (R_u):

The unity shape factor was introduced by smart and Surkan (1967) and can be defined as the basin length (L_b) to the square root of the basin area.

$$R_u = \frac{L_b}{\sqrt{A_w}}$$

2.3.9 Watershed shape factor (R_s):

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

$$R_s = \frac{L_c}{D_c}$$

2.4 Basin Relief Aspects:

The following aspects have been considered.

2.4.1 Total relief (H):

The basin relief or total relief is the maximum vertical distance between the lowest (outlet) and the highest (divide) points in the watershed. It has been defined in several ways. Schumm (1956) measured it along the longest dimension of the basin parallel to the principal drainage line. On the other hand, Maxwell (1960) measured relief along the basin diameter, an objectively defined axial line, whereas Strahler (1954, 1957) obtained it by determining the mean height of the entire watershed divide above the outlet. Relief is an indicative of the potential energy of a given watershed above a specified datum available to move water and sediment down slope. In this study relief is measured as the maximum vertical distance between the outlet and the highest (divide) point in the watershed.

2.4.2 Relief ratio (R_h):

The relief ratio is a dimensionless ratio and can be defined as the ratio between the relief and the distance over which the relief is measured. It measures the overall steepness of the watershed and can be related to its hydrological characteristics.

2.4.3 Relative relief (R_p):

Melton (1957) defined relative relief as the ratio of basin relief H to the length of the perimeter P. It is an indicator of general steepness of the basin from summit to mouth. It is computed using equation.

$$R_p = \frac{H}{P}$$

2.4.4 Ruggedness number (R_n):

Melton (1957) and Strahler (1958) defined a dimensionless number called Ruggedness number R_n as a product of relief H and drainage density D. The ruggedness number combines slope and length characteristics in one expression. The areas of low relief but high drainage density are as ruggedly textured as areas of higher relief having less dissection. The ruggedness number R_n is calculated as

$$R_n = HD$$

2.4.5 Taylor and Schwartz's slope (T_s):

Taylor and Schwartz (1938) described the slope of the main channel as parts per 10,000. Here the channel was treated as series of lengths (l) of approximately uniform slope (s), whose time of flow are considered to be proportional to ($1/\sqrt{s_i}$) . The average slope of channel is therefore computed by

$$L / \sqrt{T_s} = \sum_{i=1}^{n} (l_i / \sqrt{s_i})$$

where, T_s is the Taylor and Schwartz slope of the channel of the same length and time of flow as of actual length, n is the total number of segments of the main channel, l_i is the length of i th segment and s_i is the slope of the i th segment.

3.0 DESCRIPTION OF STUDY AREA

3.1 Sabarmati Basin:

The sabarmati river is one of the four main rivers which travels the alluvial plains of Gujarat. It originates from the Aravalli hills, near the popular Shrine of Ambe Bhawani. It travels a length of 169 km in southern westly direction, wandering along jungle covered hills, over a bed shrewn with shingles and boulders before it enters Dharoi reservoir, 9.6 km north of Hadol. From here the river comes with plains of Gujarat and flows south, with a slight westerly trend,till it passes Ahmedabad and ultimately falls in Gulf of Combay.

3.2 The Study Area:

In the present study, the Sabarmati upto Dharoi dam site is selected. The study basin lies between $23^{\circ}53'$ to $24^{\circ}46'$ north latitude and $72^{\circ}43'$ to $73^{\circ}36'$ east longitude. The river sabarmati runs in a valley with the ground rising on both the sides. The drainage area is a fan shaped basin. The topography of the study area can be considered as hilly.The chief tributaries of the river Sabarmati upto Dharoi dam are sei,seri meeting at right and Wakal and Harnav from left side of the river.

The river sei rises from the south western spurts of the Aravalli hills and mostly flows in Rajasthan State. The river is formed by confluence of several nallah originating from the western slopes of Aravalli hills. The sei river meets Sabarmati after traversing a length of 102 km. The catchment area of the sei is hilly with steep slopes.

The river Wakal rise from the south western spurts of the Aravalli hills at North latitude $24^{\circ}46'$and east longitude $73^{\circ}23'$.The Wakal basin is hilly and covered with forests. The basin covers Sabarkantha district of Gujarat and parts of Udaipur District of Rajasthan.

The river Harnav rises from Aravalli hills near village Ghadvas at north latitude $24^{\circ}12'$and east longitude $73^{\circ}16'$. The catchment area is hilly in its upper reach and plain in lower reaches. After traversing a length of about 61 km, the Harnav river meets the Sabarmati. The main tributaries of the Harnav are Kaluri and Kusumba.

3.2.1 Climate and rainfall:

The climate of the area is tropical, semi arid and monsonic type characterized by three well defined seasons, viz monsoon, winter and summer. The south west monsoon comes in third week of June and last upto end of September. The winter season persist from Nov. to February. The summer season starts from March to May. The average annual rainfall of the basin is 603.7 mm.

3.2.2 Topography:

Topographically the whole basin can be classified as a hilly basin. The upper part of the catchment is characterized with steep slopes compared to the lower parts. The general elevation of the basin ranges between 160 m and 1183 m above mean sea level.

3.2.3 River network:

The catchment area is heavily dissected by stream network. The stream frequency is high in upper reaches compared to lower reaches.

3.2.4 Geology:

The geology of the area as evident from the geologic records belongs to the archeans, Marine jurassic, creliceous, basalt and recent to sub recent alluvium and marine and aeolian deposits.

3.2.5 Soils:

The soils of the basin can be classified into three broad groups viz. Calciorthids (gray brown soils), Natrargids, salargids, salorthids (saline and saline alkaline soils), Pelluderts, pellusterts, chromusterts (deep black soils). (Source: Agricultural Atlas of India)

4.0 ANALYSIS AND DISCUSSION OF RESULTS:

For evaluating various geomorphological parameters, the catchment boundary and its river system was traced from Survey of India toposheets No. 45 H, 45 D, 46 A, 46 E, in the scale of 1:2,50,000. The catchment area was further divided according to the gauging sites available in the basin. The various sites to which the geomorphological properties reported are: (1) Wakal dam site, (2) Kheroj gauging site, (3) Khedbrahma gauging site and (4) upto Dharoi dam. After marking various sub basins on the map, the ordering of the basin was done according to the Strahler's ordering system described earlier. It is observed that 3 sub basin namely Wakal, Kheroj and Dharoi are fifth order basins and the Harnav sub basin upto Khedbrahma is a fourth order basin. Fig.1.shows the map of the study area with various sub basins marked on it.

The contributing areas of each stream was marked on the map and measured using digital planimeter. The river network and catchment boundaries were digitized on Vax 11/780 computer system on calcomp 9100 digitizer. The digitized data were stored in a file as input to the program GEO.FOR for calculating various geomorphological parameters. After successful execution of the program we obtain some of the geomorphological parameters.

Table 1 shows the various linear measures for wakal, Kheroj,Khedbrahma and Dharoi gauging sites. It can be seen from the table that mean length of stream shows an increasing trend with increase in order. The number of streams are decreasing with increase in stream order for all the basins. Fig. 2 shows the variation of number of streams of different order with their order number on semi-log plot. The slope of the straight line is negative showing reduction in number of stream with increase in order. It follows the law of stream numbers. Fig. 3 shows the variation in mean stream length with different order of the stream. The plot shows increasing trend in mean length with increase in order and it follows the Horton's law of stream length.

Other linear measures evaluated include, basin perimeter, length of main channel, wandering ratio, fineness ratio, watershed eccentricity etc. It can be seen from the table that the Harnav upto Khedbrahma has very low watershed eccentricity indicates greater compactness of basin which in turn will result in sharp flood peak compared to other basins. There is little variation in wandering ratio and fineness ratios for all

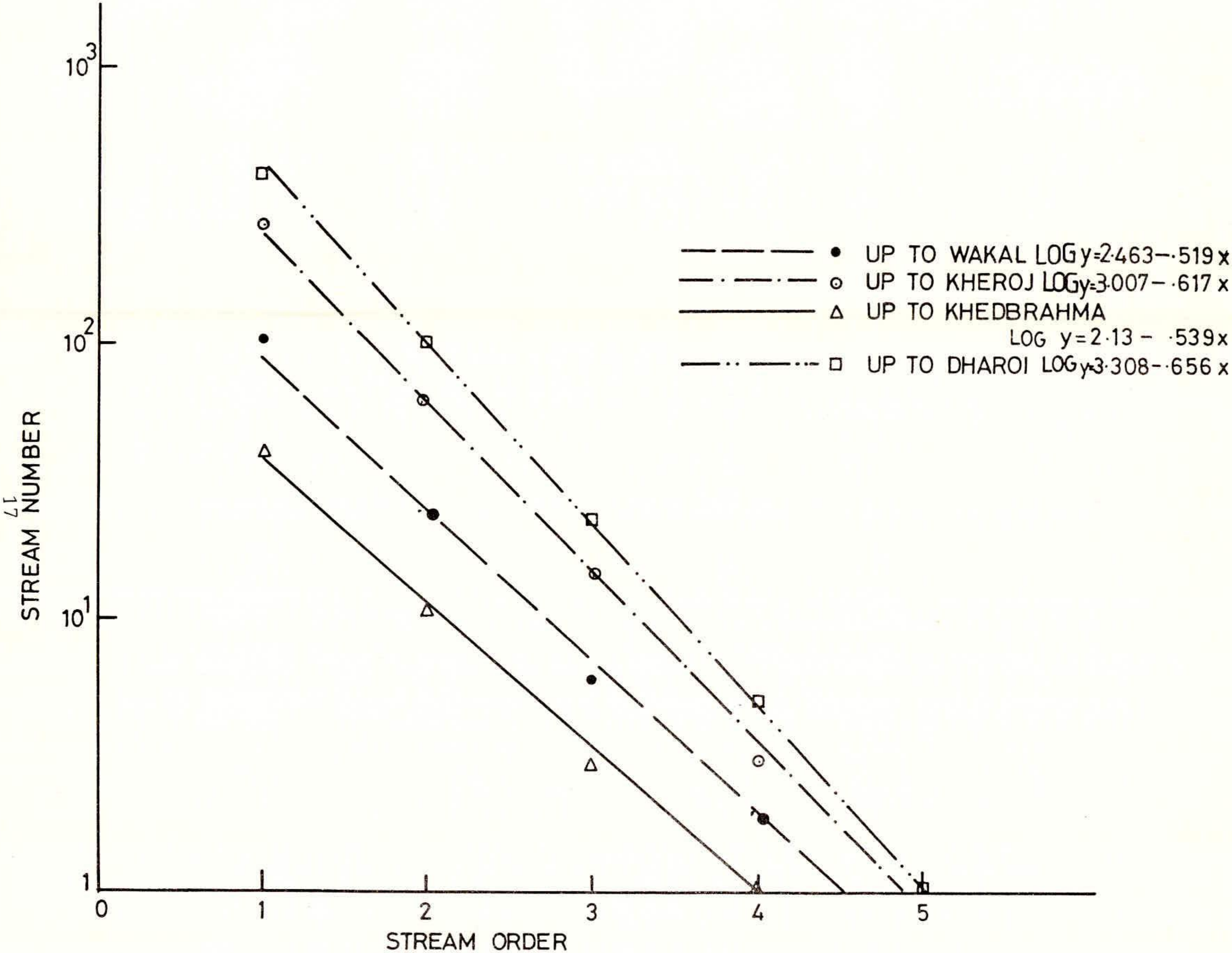

FIG. 2 SEMI LOG PLOT OF STREAM ORDER Vs STREAM NUMBER

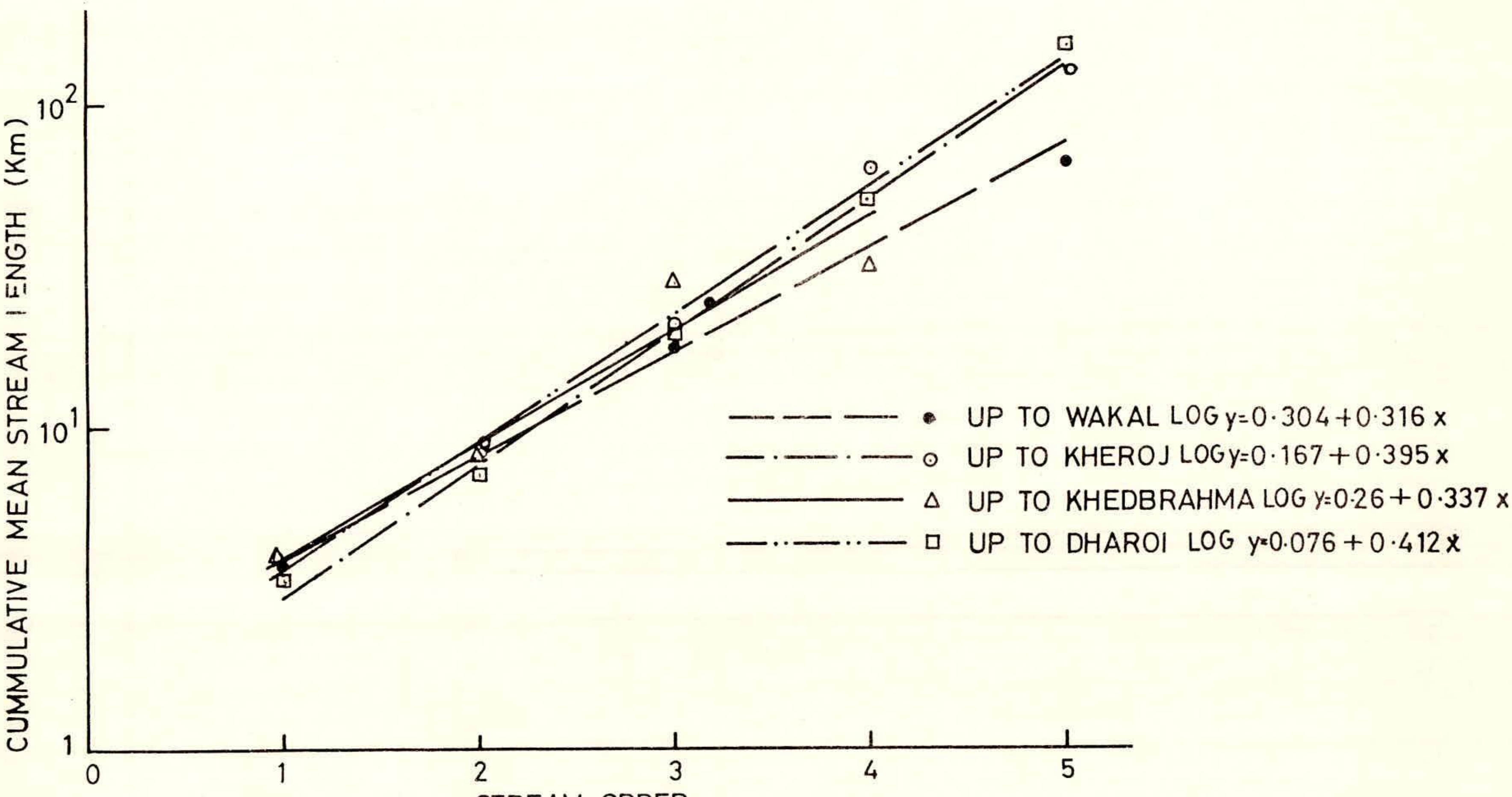

FIG. 3 SEMI LOG PLOT OF STREAM ORDER Vs CUMMULATIVE MEAN STREAM LENGTH

the basins.

Table 1 : Geomorphological Parameters based on linear aspect of the Basin (lengths are in km.)

Name of Parameters	Symbol	value upto			
		Wakal	Kheroj	Khedbrahma	Dharoi
1. Basin Perimeter	P	193.75	268.75	100.00	388.75
2. Length of main channel	L	81.25	117.50	53.75	165.00
3. Length of main channel between outlet and a point near C.G.	L_c	33.75	25.00	25.00	62.50
4. Wandering Ratio		1.394	1.441	1.493	1.437
5. Fineness Ratio		0.419	0.437	0.537	0.424
6. Watershed Eccentricity	τ	0.640	0.720	0.391	0.818
7. Total length of channel					
	L_1	408.00	977.75	148.50	1457.5
	L_2	153.50	312.75	47.00	503.75
	L_3	49.75	153.25	61.00	270.50
	L_4	50.75	128.25	2.75	156.00
	L_5	23.00	64.25	nil	102.00
8. Total length of all orders	L_u	685.00	1636.25	259.25	2490.00
9. Mean length of channels					
	$\bar{L}_1$	3.743	3.662	3.622	3.502
	$\bar{L}_2$	5.904	5.044	4.273	4.844
	$\bar{L}_3$	8.292	12.771	20.333	11.761
	$\bar{L}_4$	25.375	42.750	2.750	31.200
	$\bar{L}_5$	23.000	64.250	nil	102.250
10. No. of streams of various orders	N_1	109	267	41	416
	N_2	26	62	11	104
	N_3	06	12	03	23
	N_4	02	03	01	05
	N_5	01	01	nil	01
11. Total No. of streams of all orders	N_u	144	345	56	549
12. Bifurcation Ratio:	R_b	3.3027	4.1383	3.4694	4.5250
13. Stream length Ratio	R_L	1.6324	1.9665	1.9632	2.3203

The various areal aspects evaluated for different sub basins are listed in table 2. The catchment area of Wakal, Kheroj, Khedbrahma and Dharoi are 1482.5, 3334.4, 685.3 and 5198.2 sq.km respectively. The catchment area is the single most important geomorphological parameters used extensively in various hydrological studies. It gives a clear idea of volume of runoff expected out of the catchment. Table also give the mean drainage areas drained by different order streams for all the four sub-basins. It shows that there is increasing trend in mean drainage area of different order streams with increase in order number. It can be seen from the table that Harnav upto Khedbrahma is a circular basin. The other measures which have been computed include drainage density, constant of channel maintenance, form factor,elongation ratio etc are given in table 2 for all the four basins. Fig. 4 shows the variation of mean drainage area of different order stream with order number. It can be seen from the plot that the drainage network follows the Schumm's law of drainage areas.

The various relief measure evaluated are listed in table 3. Relief studies clearly reveals that the basin in steep in higher altitude regions. The variation in average slope of the channels is very small which is indicative of overall homogeneity of the basin. Other relief measures evaluated include basin relief, relief ratio, ruggedness number, Taylor and Schwartz's slope etc.Fig.5 ,shows the profile of the main channel of Wakal river, Fig.6 shows the profile of the main channel of the Harnav and fig.7 shows the main channel profile of Sei river upto Kheroj and fig 8 shows the main channel profile of sabarmati river upto Dharoi.

Table 2 : Geomorphological Parameters based on areal aspect of the Basin (areas are in sq. km.)

Name of Parameters		Symbol	value upto			
			Wakal	Kheroj	Khedbrahma	Dharoi
1.	Total Drainage Area	A	1482.50	3334.40	685.30	5198.20
2.	Drainage Density	D	0.4621	0.4907	0.3783	0.4790
3.	Constant of channel Maintenance	C	2.1640	2.0379	2.6434	2.0877
4.	Circularity Ratio	R_c	0.4964	0.5803	0.8615	0.4324
5.	Elongation Ratio	R_e	0.7457	0.7993	0.8204	0.7088
6.	Watershed shape factor		1.6401	1.7270	1.8201	1.8502
7.	Unity shape factor		1.5128	1.4114	1.3752	1.5916
8.	Channel segment frequency		0.0971	0.1035	0.0817	0.1056
9.	Form factor	R_f	0.437	0.502	0.395	0.529
10.	Drainage area of various order	A_1	722.3	1650.7	397.5	2650.5
		A_2	902.6	1798.1	466.3	3050.4
		A_3	888.1	1890.6	658.8	3309.0
		A_4	1298.7	2174.3	685.3	3316.2
		A_5	1482.5	334.4	nil	5198.2
11.	Mean drainage area of various orders	$\bar{A}_1$	6.627	6.182	9.695	6.371
		$\bar{A}_2$	34.715	29.001	42.390	29.330
		$\bar{A}_3$	148.017	157.550	219.300	143.869
		$\bar{A}_4$	649.350	724.767	685.300	663.240
		$\bar{A}_5$	1482.500	3334.400	nil	5198.200

Table 3 : Geomorphological Parameters based on relief aspect of the Basin

Name of Parameters		Symbol	value upto			
			Wakal	Kheroj	Khedbrahma	Dharoi
1.	Basin Relief	H	833.00 m	943.00 m	532.20 m	1023.00 m
2.	Relief ratio	R_h	14.300	11.568	15.061	8.915
3.	Relative Relief	R_p	4.299	3.588	5.322	2.631
4.	Ruggedness Number	R_n	0.385	0.463	0.201	0.490
5.	Taylor & Schwartz slope	T_s	0.00458	0.00378	0.00947	0.00284

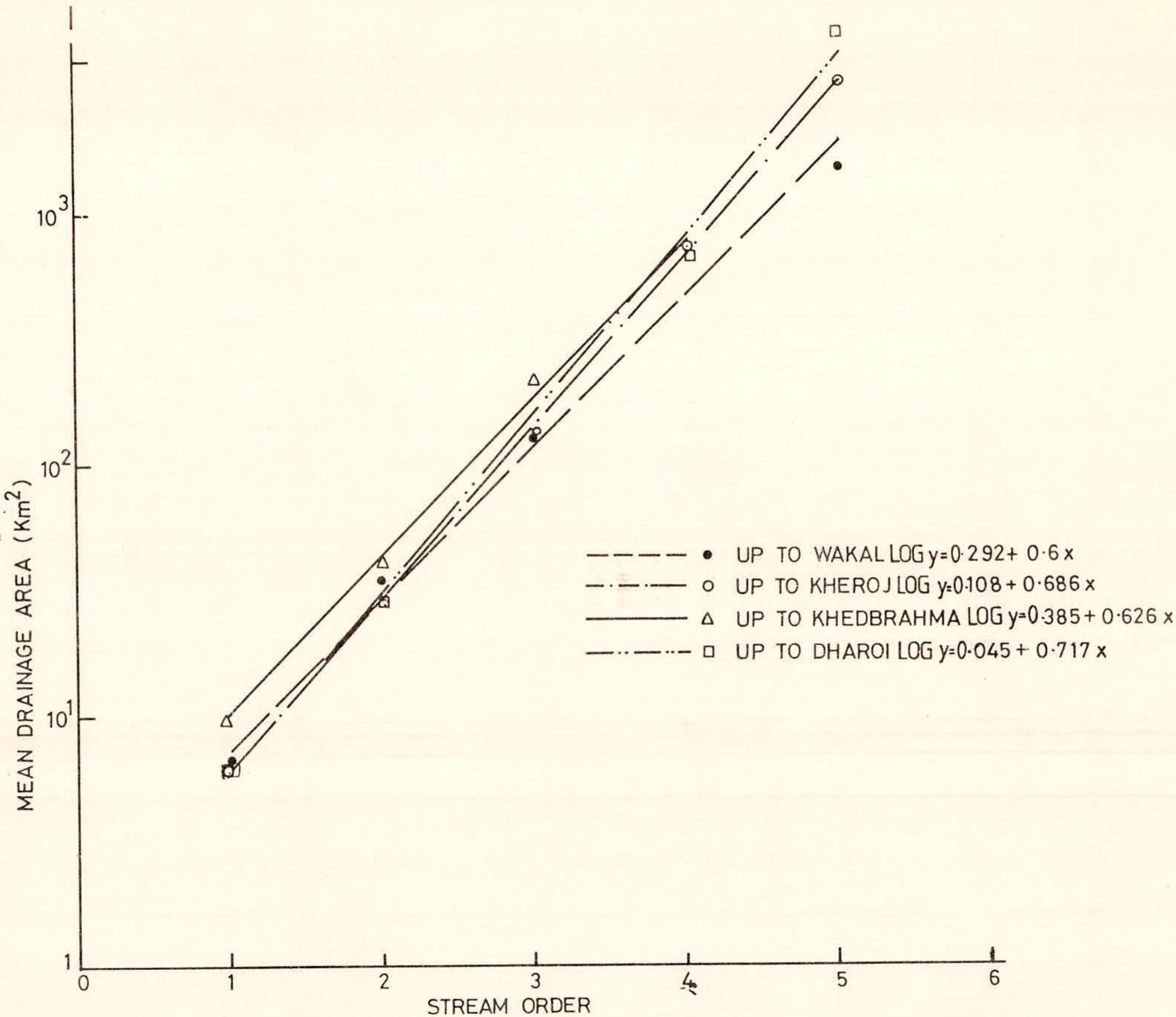

FIG. 4 SEMI LOG PLOT OF STREAM ORDER Vs MEAN DRAINAGE AREA

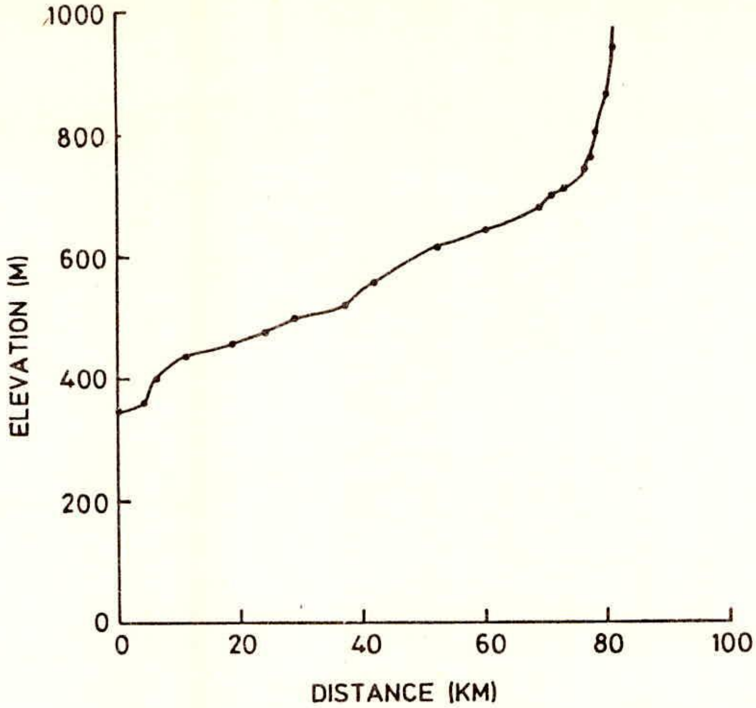

FIG. 5 - MAIN CHANNEL PROFILE OF WAKAL RIVER
(UP TO WAKAL)

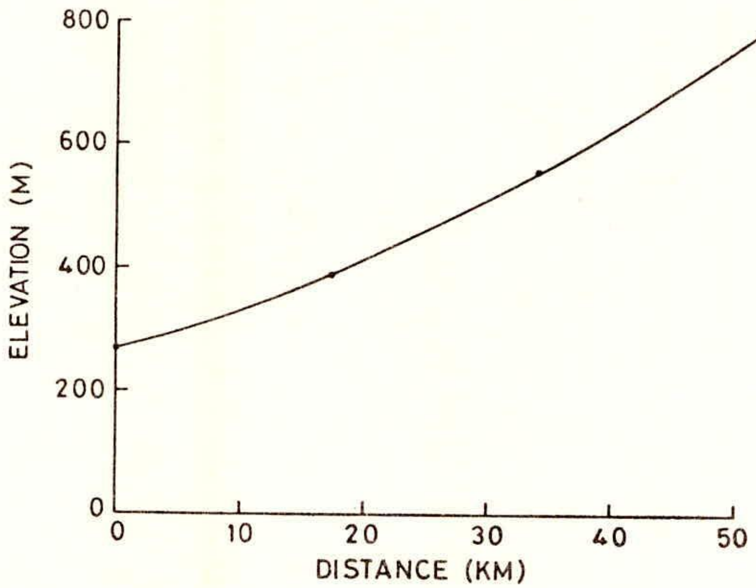

FIG.6-MAIN CHANNEL PROFILE OF HARNAV RIVER
(UP TO KHEDBRAHMA)

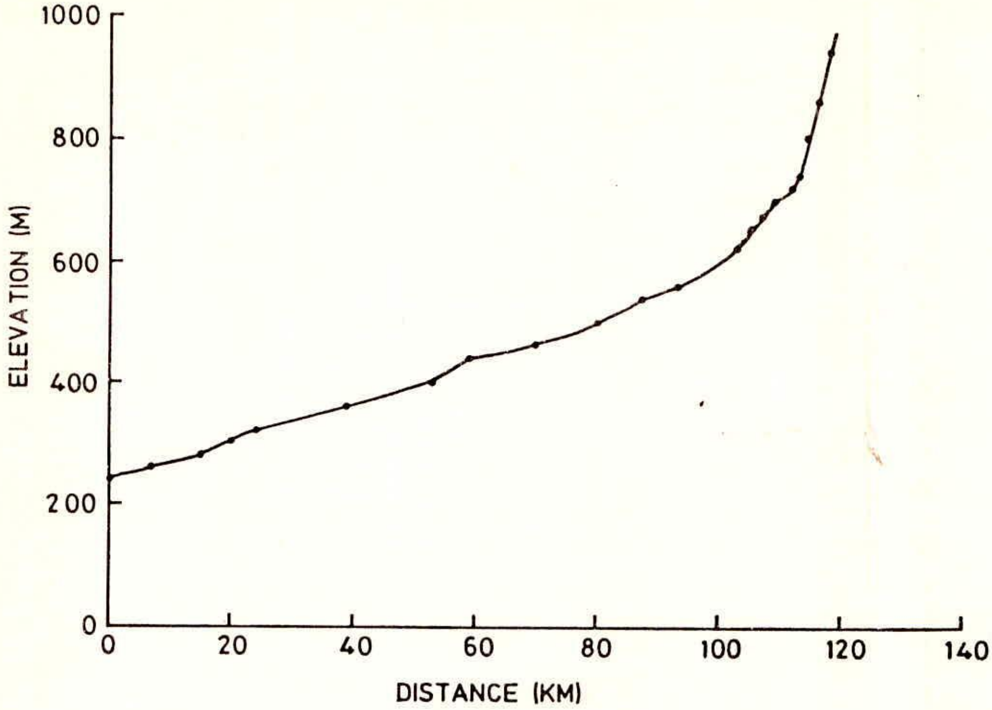

FIG. 7 MAIN CHANEL PROFILE OF SEI RIVER (UP TO KHEROJ)

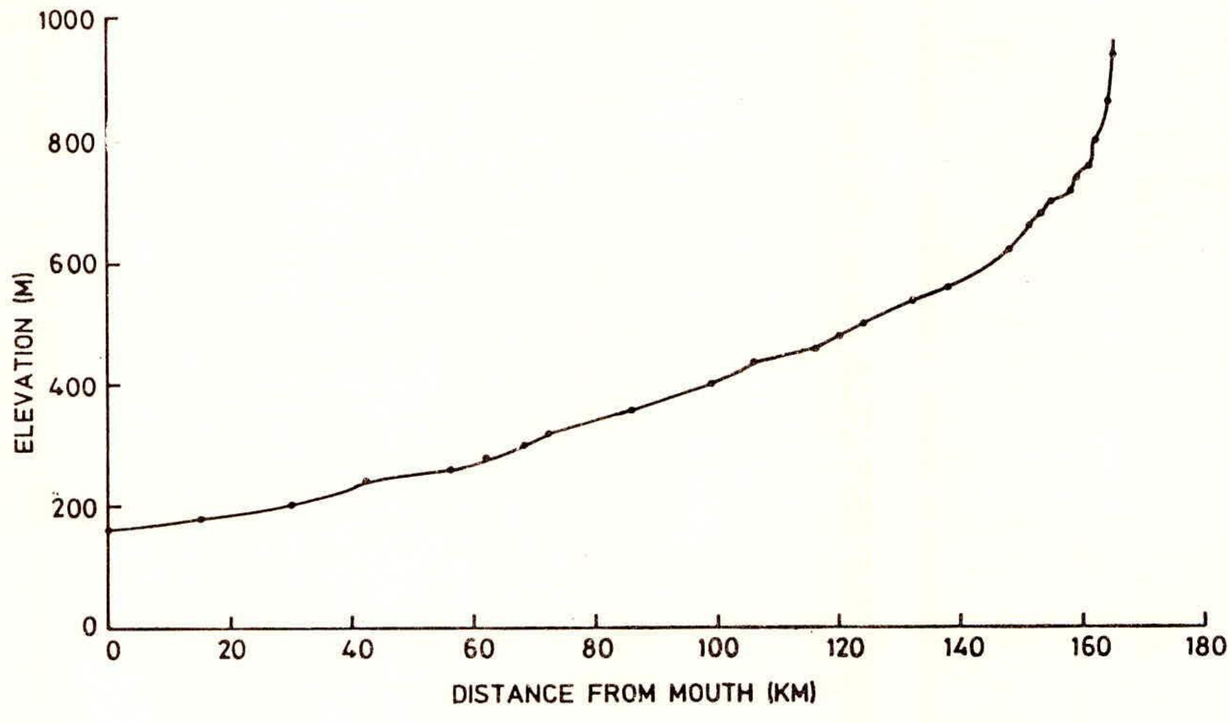

FIG. 8 MAIN CHANNEL PROFILE OF SABARMATI RIVER (UP TO DHAROI)

5.0 SUMMARY AND CONCLUDING REMARKS

This report describes various geomorphological parameters covering linear, areal and relief aspects of the Sabarmati basin upto Dharoi along with a methodology to evaluate these parameters. For evaluating various geomorphological parameters , the basin is divided into various sub-basins according to gauge/discharge observation sites. The sites for which these parameters evaluated are Wakal, Kheroj, Khedbrahma and Dharoi. On the basis of the study following conclusions can be made.

Since the watershed studied comprise of one large basin (Sabarmati upto Dharoi) and three of its sub basins, one can infer that there is very less variation in drainage density for various sub basins except for Khedbrahma which is having lowest drainage density, because of this, the constant of channel maintenance is high for Khedbrahma compared to the rest of the basin.The shape parameters such as circularity ratio, elongation ratio, watershed shape factor and unity shape factor indicates that Khedbrahma sub basin has most evenly distributed area compared to other basins which are of elongated shape. the relief measures indicates that the basin is steep in its upper reaches compared to the lower parts. The variation in average slope of channels is very small which indicate the overall homogeneity of the basin.

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