CHAPTER - 6

MORPHOMETRIC ANALYSIS

The Khari river basin alongwith its major tributaries the Pur and Pat Nadi originate from the Central Kachchh Highland (Fig.1.3). The Khari river basin provides an interesting example of the control exercised by tectonism in its evolution during Quaternary. The Central Kachchh Highland forms the main water shed with numerous consequent streams draining the slopes with dendritic and radial pattern. Some of the streams cut steep resequent slopes of the central highland, especially Katrol hill range and empty their water through the Khari river into the plain of Banni.

A detailed morphometric analysis of the Khari river basin of Central Kachchh Highland was undertaken to appreciate the role of tectonism. The morphological units of the basin and the various erosional surfaces and tectono-erosional terraces have been described in earlier chapter. In addition to these parameters, morphological study of other related drainage basin morphometry like longitudinal stream profile, valley height and width ratio sinuosity index and mountain front analysis was undertaken.

Drainage basin morphometry consists of five stages namely, network delimitation, sampling measurement, variable definition and analysis. Although many authors advocate the use of field survey to identify the functioning drainage network; this is impossible for large drainage basins. The Khari river drainage network is not very large but the streams constituting the Khari basin remains mostly dry. However these function during monsoon which is also erratic in Kachchh. It is significant to note that the higher order river channels of the Khari basin show prominent cliffs (Plate 5.6a,5.7), broad courses and large pot-holes (Plate 5.6b) indicating tectonic activity in Recent times.

MORPHOMETRIC PARAMETERS

The network delimitation was deduced using 1:50,000 topographic maps. The river channels and the smallest streams marked by blue lines were only considered for the morphometric analysis. The contour crenulations mark the features of former morphogenic condition and fossil palaeohydrological element; hence not used to identify channels.

The stream ordering (Fig.6.1) was done following Strahler (1952). The smallest fingertip streams are considered as first order streams. At the junction of any two first order streams, a channel of second order

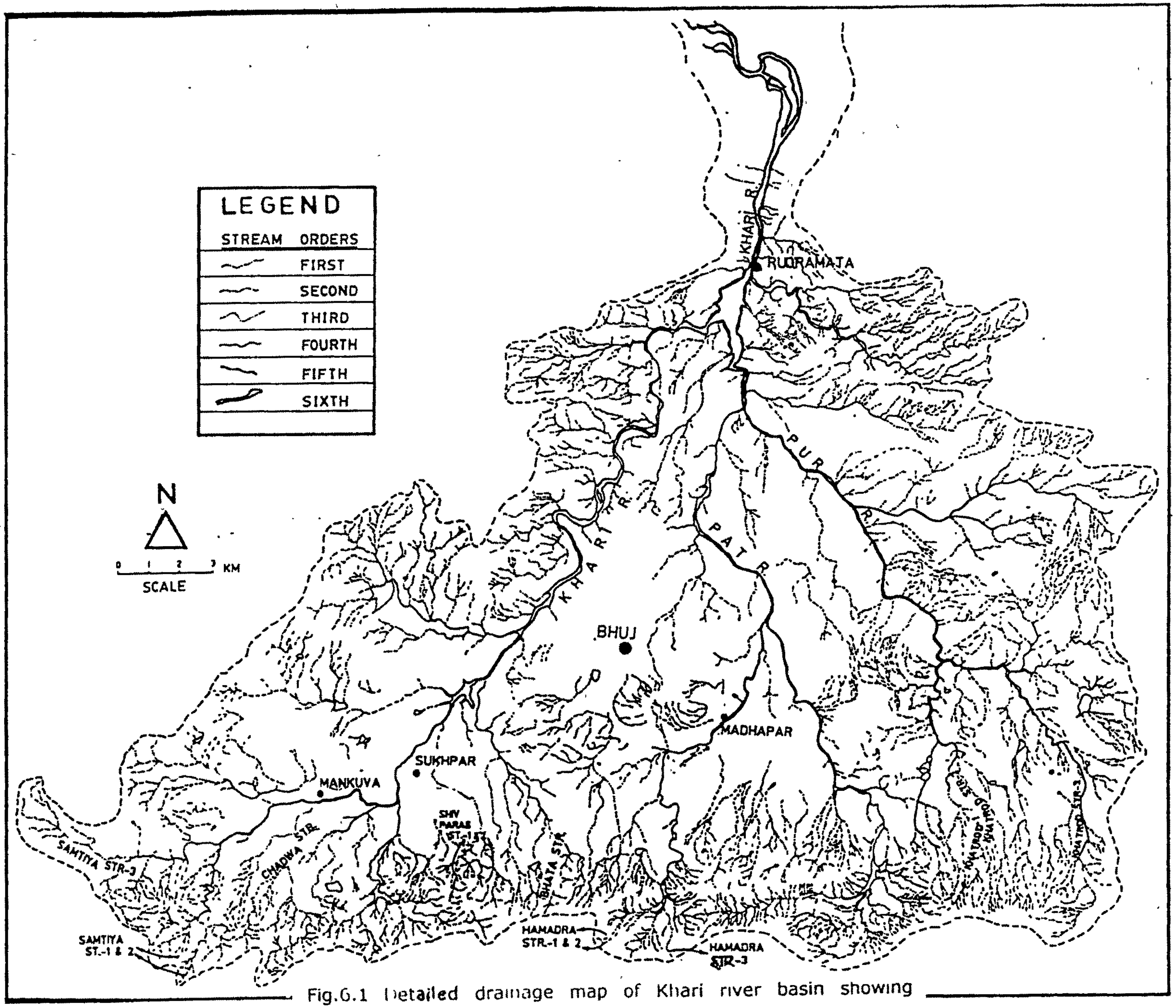


Fig.6.1 Detailed drainage map of Khari river basin showing streams of different orders.

stream is formed and extends down to the point where it joins another second order channel where upon a third order results, and so forth. The number of lower order streams in the Khari basin is obviously high than that of higher order streams (Fig.6.2a).

The variables utilized (Table 6.1a,b) for the present study are as under:

Total channel length: Total channel length of individual stream order is useful variable in calculating the other variables in the analysis. Symbol "L" is used for this unidimensional parameter.

Basin Length: Longest dimension of the basin, parallel to the principle drainage line is called basin length. The symbol used here is "Lb".

Basin Relief: It is the difference between the highest and the lowest basin altitudes. This is also a unidimensional parameter and symbol used here is "Hb".

Number of streams: Numbers of first to nth order of stream are useful parameter for deriving other variables such as bifurcation ratio.

Perimeter (P): Total length of the limit of the basin i.e. it is a linear distance along the drainage divide area in the basin of study.

Total Basin Area (A): It is nearly planimetric equivalent of the true area, as the difference is negligible except for very steep and small basins.

Relief Ratio (R=Hb/Lb): It is the ratio between the basin relief and the longest dimension of the basin parallel to the principle drainage line i.e. basin length (Schumm, 1956).

Drainage Density (Cd=Ct/A): It is the ratio of total channel segment lengths computed for all orders within a basin to the basin area as projected on the horizontal plane.

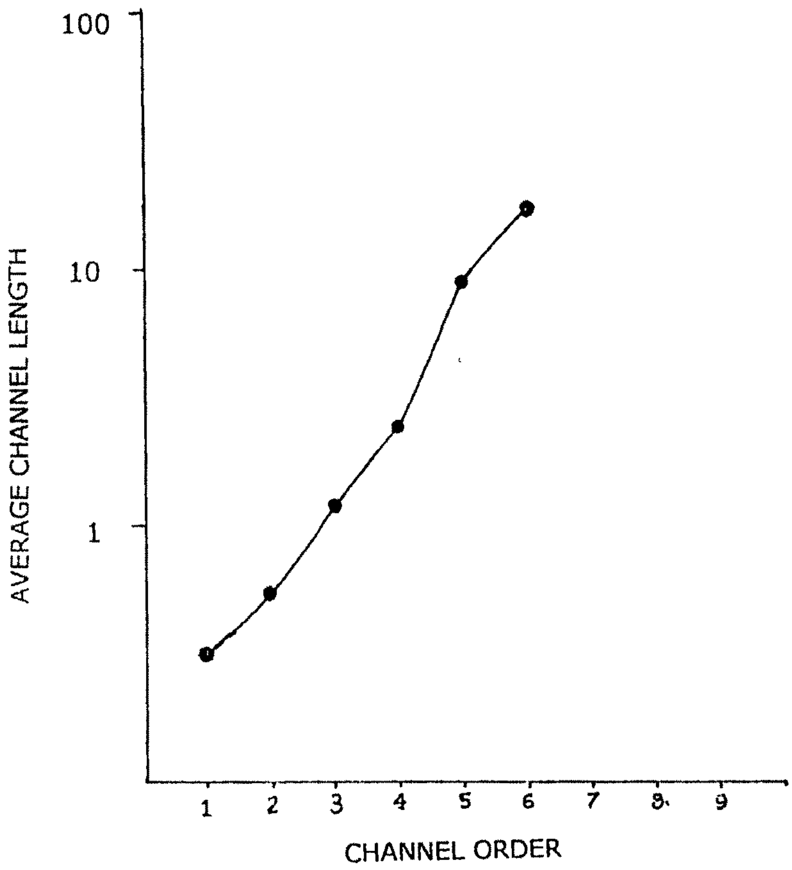


Fig.6.2b Graphical representation of the Log mean stream length Vs Order of streams.

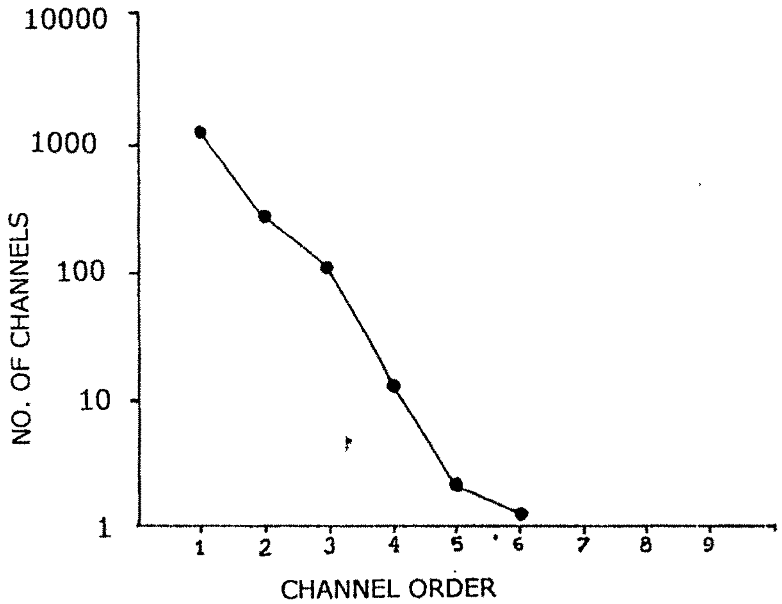


Fig.6.2a Graphical representation of Number of streams Vs order of streams.

TABLE (6.1a & b) Important morphometric parameters of the Khari River Basin.

(a)

MORPHOMETRIC PARAMETERS	RESULTS FOR THE BASIN STUDIED
BASIN LENGTH (Lb)	43.63 km
BASIN RELIEF (Hb)	330 m
PERIMRTER (P)	130.83 km
TOTAL BASIN AREA (A)	646.48 Sq.km
RELIEF RATIO (R= Hb/Lb)	5.958 m/km
DRAINAGE DENSITY (Cd = Ct/A)	2.297 km/sq.km
STREAM FREQUENCY (F = (N1+N2-1) / A)	3.34 STREAMS / sq.km.
ELONGATION RATIO (Se = A0.5 / L)	0.657
RUGGEDNESS NUMBER (RN = Cd*Hb / 1000)	0.597

(b)

ORDER	TOTAL NUMBER OF STREAMS	LENGTH (in km)	AVERAGE STREAM LENGTH (in km)
1ST	1618	834.25	0.56
2ND	415	320.00	0.77
3RD	105	194.00	1.85
4TH	20	86.00	4.3
5TH	3	28.50	9.5
6TH	1	22.50	22.5
TOTAL	2162	1485.25	

Stream Frequency (F=(N1+N2-1)/A): It is the number of streams per unit area.

Elongation Ratio (Se=A 0.5/L): The ratio between the diameter of a circle with the same area as the basin and the maximum length of the basin as measured for the relief ratio to indicate the shape of the basin (Schumm, 1956).

Ruggedness number (RN): This dimensionless number is the product of relief and the drainage density.

It is important to note that morphometric analyses in morphotectonic and/or tectono-geomorphic studies refer to the measurement on topographic maps of quantitative landform parameters, such as stream gradient, stream gradient index, pseudo-hypsometric integral (PHI), longitudinal stream profiles, valley floor width to valley height ratio, sinuosity index and mountain front sinuosity.

This study, utilized landform analyses that focuses on the response of the fluvial system to discrete tectonic perturbations created by localized uplift across fault zones that intersect stream channels. The theoretical basis for the morphometric analyses involves relative adjustments between local base level processes (tectonic uplift, stream down cutting, basin sedimentation and erosion) and fluvial systems crossing structurally controlled topographic mountain fronts (Bull, 1973, 1984; Bull and Mc Fadden, 1977).

The landforms of Central Kachchh Highland supposed to have evolved in different episodes in the geological history since the Late Mesozoic time. It is believed that the northward push of the Indian plate has caused the upliftment in the western marginal basins (Biswas, 1982,1987). However the role of Quaternary tectonic episodes in shaping up the landscape and the evolution of the drainage basins and networks in Kachchh Mainland remains to be dealt. It is with this background the morphometric analysis is done to identify the geomorphic indicators of uplift and subsidence.

Interpretation of drainage basin morphometric analysis is based on the results obtained after the quantitative data processing for each variable individually. Some variables are assessed, using the results of earlier variables. In the morphometric analysis of the Khari basin of Central Kachchh Highland the variables that are indicative of tectonic activities were analyzed to get a clear picture of episodic evolution of the basin. These variables/parameters are sensitive to rock resistance, climate and tectonic activities. Mathematical calculations of these parameters have been found useful in reconstructing the evolutionary model of the Khari river basin.

DESCRIPTION OF THE VARIABLES

The Khari river has been identified as a sixth order channel. Total channel length of all the stream orders indicate stream richness in the basin (Table 6.1b). The length and number of the lower order streams (Table 6. 1b) in the basin suggests moderate to high relief head-water area. However, the lesser number and lesser length of the higher order streams suggest small extent of the basin.

The cumulative length of channel segments increases with the channel order. The 'law of stream lengths' states that the mean length of channel segments of each of the successive orders of a basin forms approximately a direct geometric series. A plot of logarithms of mean stream lengths against their respective orders is illustrated in figure (Fig.6.2b).

The bifurcation ratio tends to be constant for a particular drainage basin and for drainage basins having a uniform climate, lithology and stages of development. The bifurcation ratio generally varies from a minimum of two in flat or rolling drainage basins to three to four in mountainous or hilly dissected drainage basins. The bifurcation ratio in the Khari river basin varies between 3-4, which indicates that it arises from hilly terrain and having high gradient. The bifurcation ratio for fourth and fifth order streams is usually around 6.66 (Table below) which is quite high. This could be related to a high degree of tectonic activity in the basin during Quaternary.

Bifurcation ratio computed for each consecutive set of orders

(N)TH ORDER / (N+1)TH ORDER	BIFURCATION RATIO
1ST / 2ND	3.898
2ND / 3RD	3.952
3RD / 4TH	5.250
4TH /5TH	6.666
5TH /6TH	3.000

The increase in the value of drainage density reduces the size of individual drainage units, such as the size of first and subsequent higher order streams. Factors affecting drainage density are the erodability of rock and climate. The drainage density is generally low in semi-arid and arid climates but comparatively high in humid terrain (Gardiner,1980); in case of Khari it is about 2.3 km drainage length/sq km indicating a moderate to high drainage density (Table 6.1a) (Horton, 1945). Since the area falls under semi-arid to arid climate as also revealed by other variables, the high drainage density is attributed to neotectonic activity .

The drainage frequency (F) is a measure of the texture of the drainage network. Melton(1958) related the frequency and drainage density by the equation F= 0.694 D2. The dimension less number F/D2 tends to approach a constant value of 0.694 even under diverse physiographic situations and size of drainage basins. Here this constant is 0.631 (Table 6.1a) pointing that the Khari drainage originated under diverse physiographic conditions.

In the case of ruggedness number, it is high when both the relative relief and the drainage density are high. Ruggedness number in the Khari basin is less than 1.00 (Table 6.1a), which suggests low relief and moderate to high density , a typical value of semi-arid and arid climatic condition (Gardiner,1980).

LONGITUDINAL STREAM PROFILE

The most commonly used technique to identify river response to tectonics is the analysis of the longitudinal profiles, which is a graph of the relationship between river elevation and river length. The least work profile is thought to be more common in humid regions (Bloom, 1978) and from this investigation it appears to be common in areas that have experienced high uplift and tilting.

The author has prepared long profiles for the main Khari river and its tributaries (Fig.6.3) and also for a few selected major streams (Fig.6.4 and 6.5) originating from the Katrol hill range. A sudden change in the gradient at 120 m to 100 m is observed which points to a transitional landsurface that separates the pre-Quaternary and Quaternary surfaces.

The long profiles of the Khari river and its major tributaries are highly concave upward (Fig 6.3-6.5), suggesting that the headwater area is tectonically very active.

STREAM GRADIENT, GRADIENT INDEX, PSEUDO-HYPSOMETRIC INTEGRAL

Analysis of long profile of the Khari river and its various tributaries is used to determine the stream gradient, stream gradient index and the pseudo-hypsometric integral (PHI). Gradient and gradient index are commonly used to measure river slope and can also be utilized to define relative difference in uplift (Merritts and Vincent, 1989) and erosion (Hack, 1973). The river sinuosity is generalized from the topographic maps and therefore map length will always be less than true length. Since slope is proportional to 1/length, slopes determined from topographic maps will be greater than true slopes. According to Rhea (1982), gradient or slope is the elevation change over a distance and is useful for comparing slope changes over similar nearby length.

Stream gradient, stream gradient index and pseudo-hypsometric integral are decisive parameters calculated from longitudinal stream profiles. Gradient or slope is the elevation change over a distance and is useful for comparing slope changes over similar nearby lengths. Gradient index is the elevation change over a logarithmically normalized distance

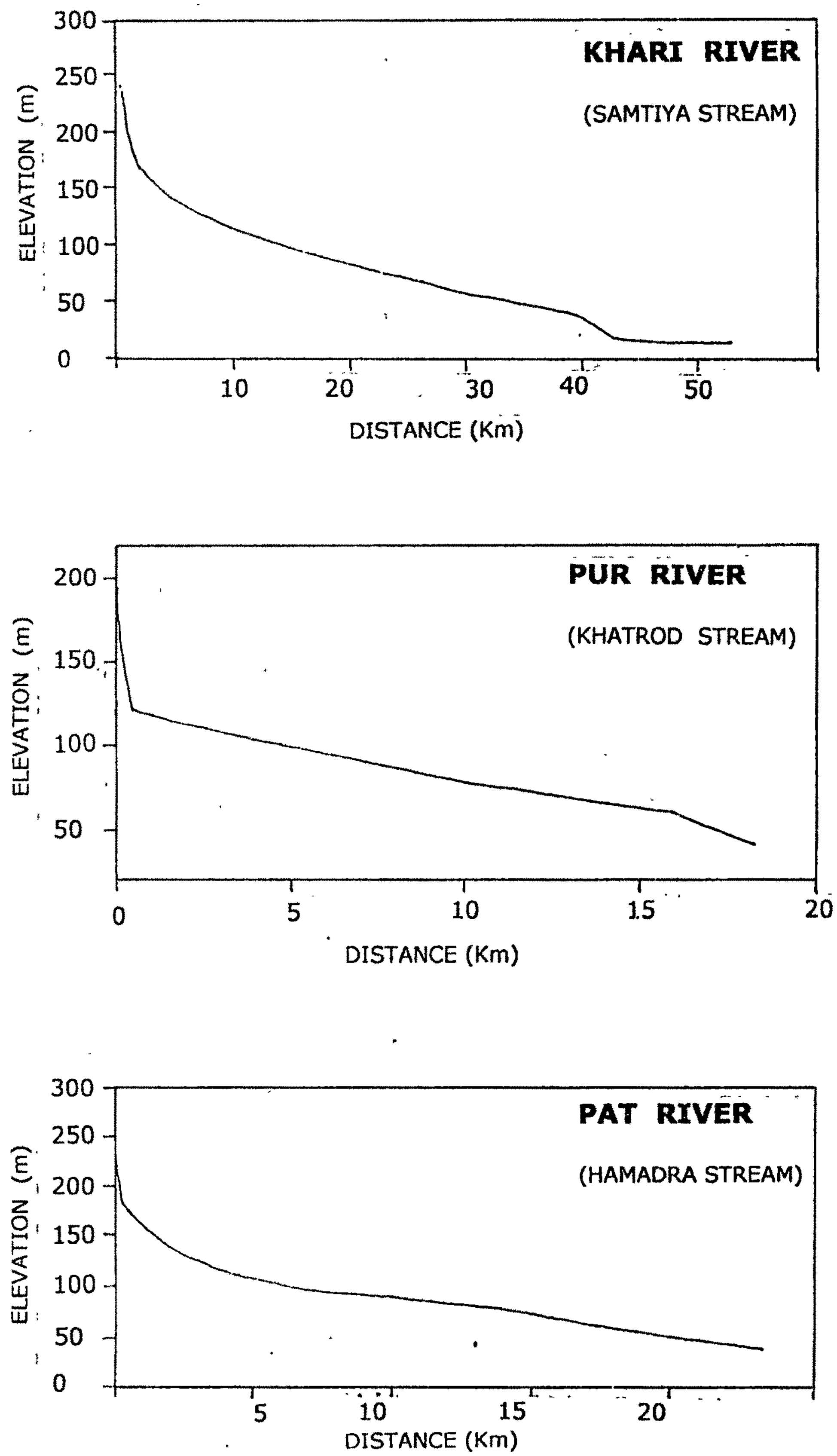


Fig.6.3 Longitudinal profiles of Khari river and its tributaries.

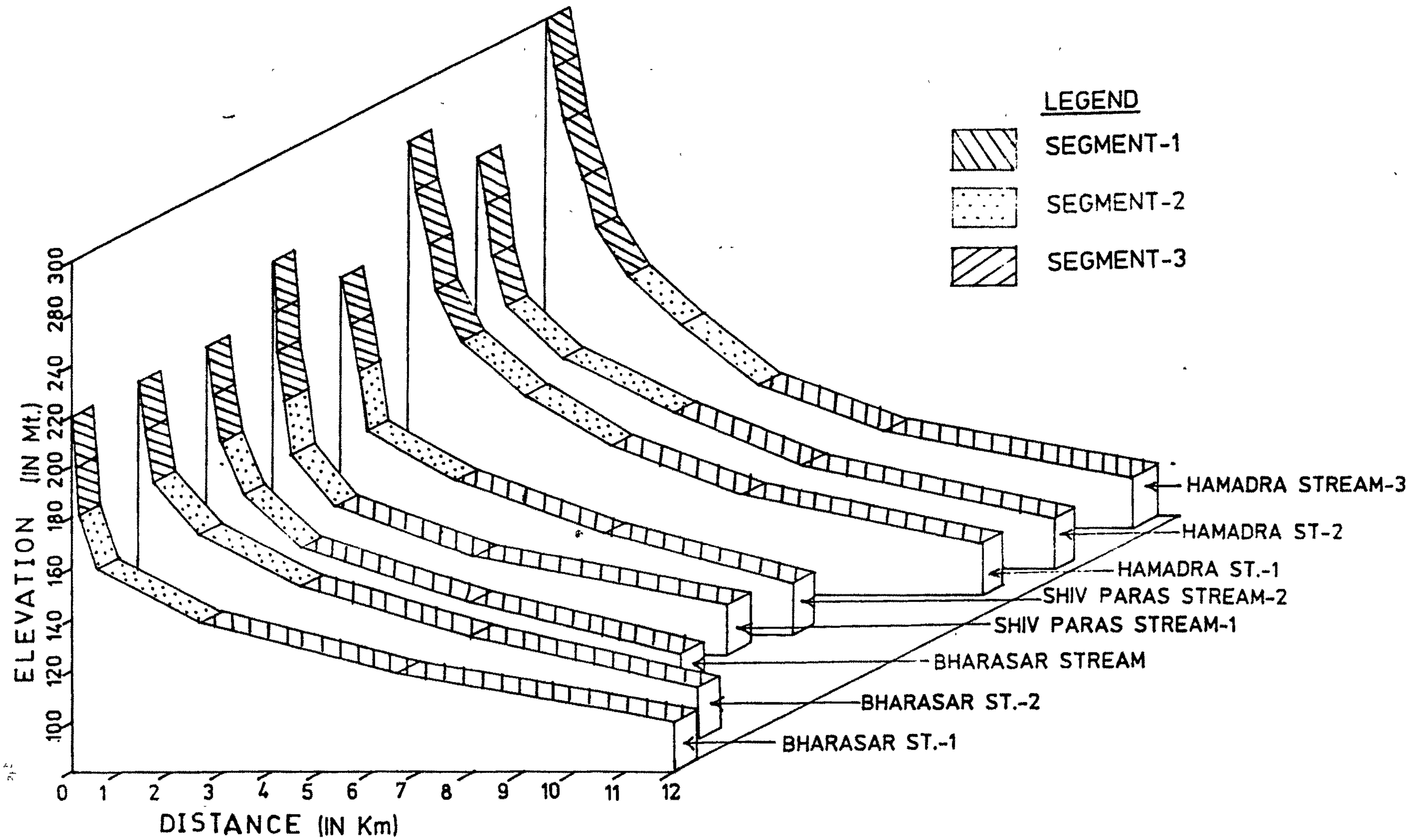


Fig.6.4 Longitudinal profiles of selected lower order streams . Note the change in the nature of profile in different segments.

and is more useful for highlighting gradient changes. PHI is a numerical means to describe the overall change of the long profile (Fig.6.6). It reflects the relative amount of deformation and/or degradation that has occurred on each river. Comparisons between long profiles are more easily made using PHI because bias introduced by scale and vertical exaggeration in the figures is removed. The PHI values computed for different streams of Khari river basin are falling between 17 to 28. The lower values exhibited by Khatrod stream and Shiv Paras stream suggest high degree of degradation and head water area uplift along the Katrol Hill Fault. It also indicates that the active scarp faces (Fig. 6.5) are least affected by erosional activity implying little time elapsed after the development of the scarp. The PHI values in this case are 17 to 21 which are unusually low.

Stream gradient, gradient index and PHI are calculated for some selected streams of the Khari river basin (Table 6.2). They are Hamadra, ShivParas (Lakki), Bhata, Bharasar, Samtya, Khatrod and Chadwa streams. The base level for all these streams is nearly 100 m. The above variables are calculated for three different segments S_1,S_2 and S_3 (Table 6.3). S_1 being the highest elevated part of the stream, shows higher values of gradient for each stream. The S_2 segment falls between 120-160m elevation interval. The gradient values of the streams of this segment are below 10 m/km, except in Khatrod stream where it goes up to 22 m/km, which is due to exceptionally high fault scarps or cuesta cliffs, formed due to recent upliftment of that segment along the Katrol Hill Fault. The lowermost S_3 segment shows the lowest gradient values because it falls in the central rocky plain forming an Early Quaternary

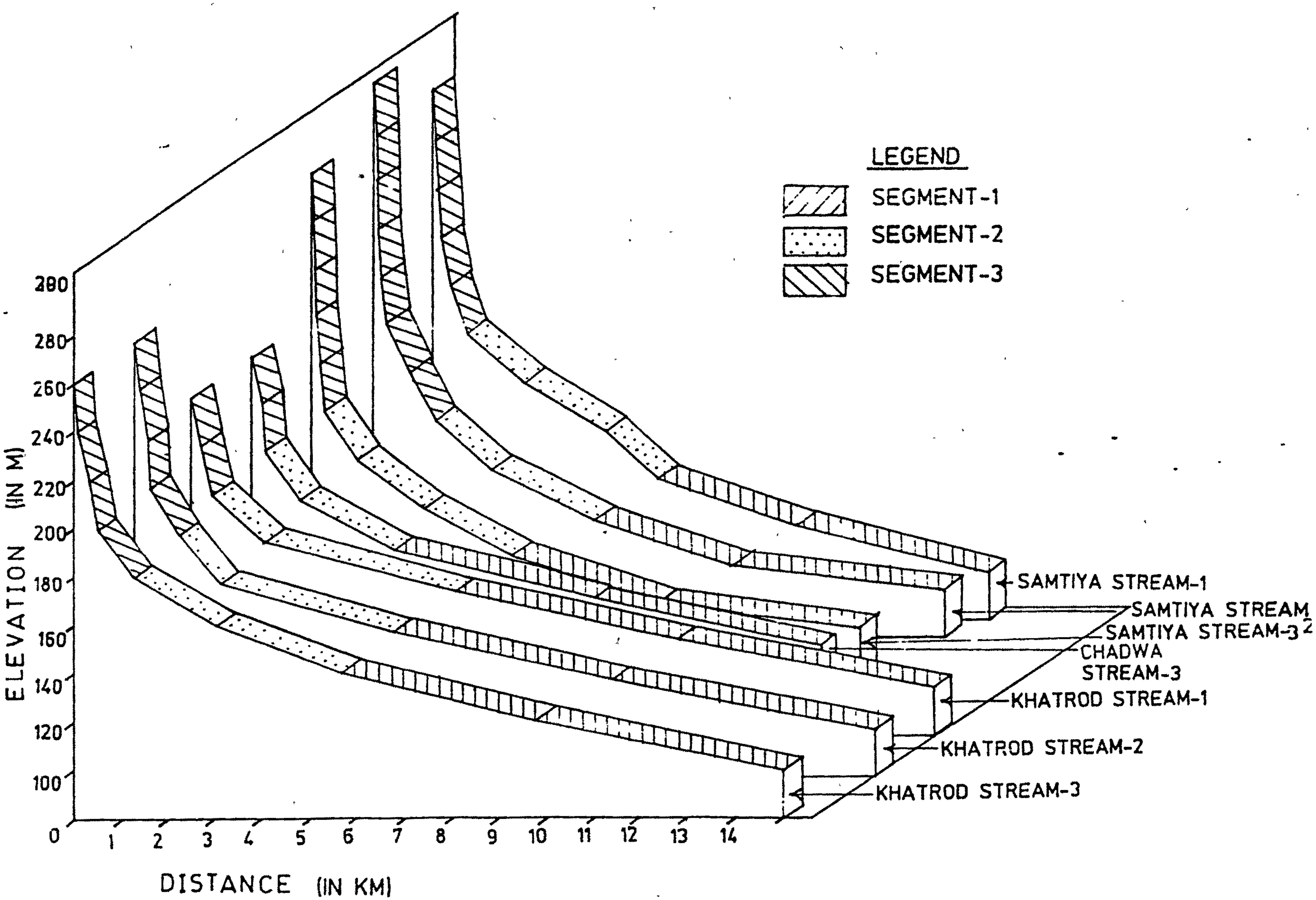
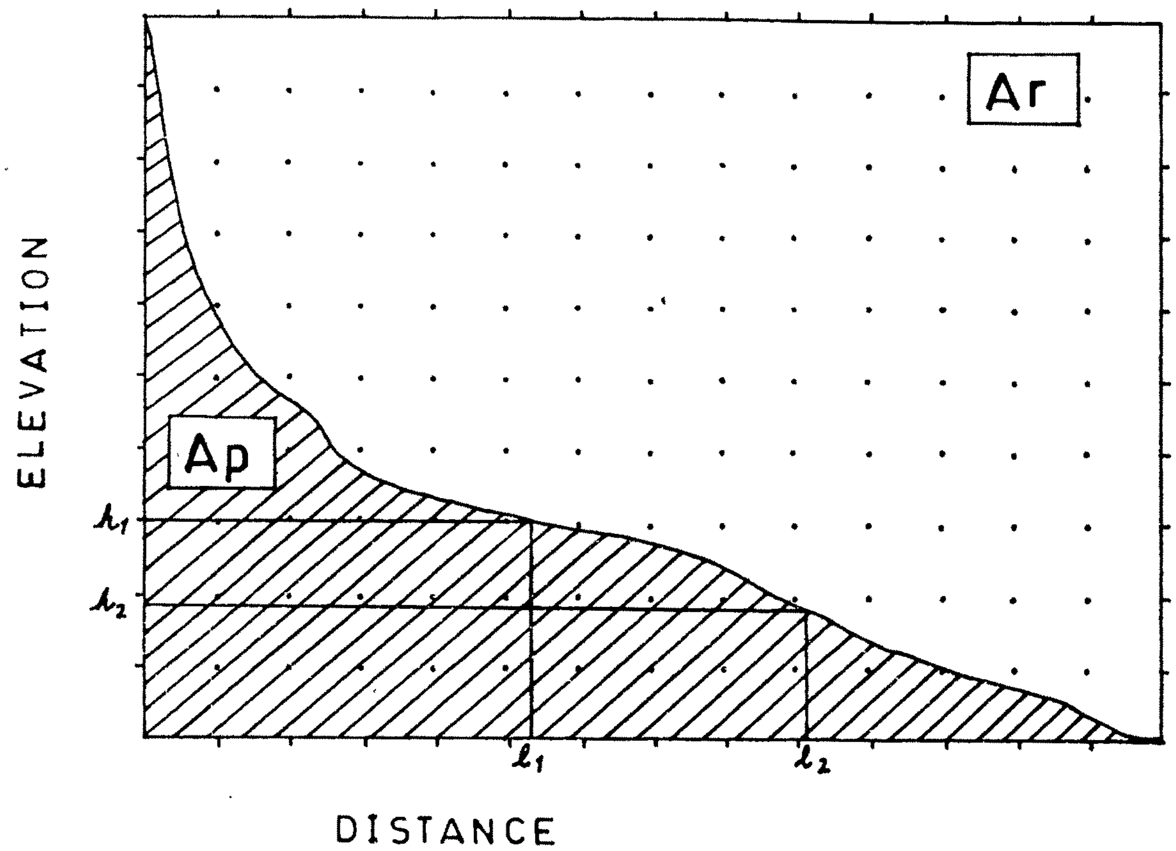


Fig.6.5 Longitudinal profiles of selected lower order streams . Note the change in the nature of profile in different segments.



STREAM GRADIENT	=	$\frac{h_1 - h_2}{l_2 - l_1}$
GRADIENT INDEX	=	$\frac{h_1 - h_2}{l_n l_2 - l_n l_1}$
PHI	=	Ap / Ar (in%)

Fig. 6.6 Graphical representation of Pseudo Hypsometric Integral (PHI) .

TABLE: 6.2 Table showing important quantitative land form parameters computed on the basis of length and elevation data measured form the topographic maps for some of the selected streams.

SELECTED STREAMS	LENGTH (IN KM.)	ELEVATION (IN M.)	AVERAGE GRADIENT (M / KM)	AVERAGE GRADIENT INDEX	PSEUDO-HYPSOMETRIC INTEGRAL (%)
HAMADRA STREAM-1	11.5	263	13.9	150.8	21.38
HAMADRA STREAM-2	11.0	245	12.17	131.98	24.32
HAMADRA STREAM-3	11.5	286	15.65	169.6	20.43
BHATA STREAM	9.5	229	12.63	122.73	23.22
SHIV PARAS STREAM-1	9.0	242	15.55	146.71	18.97
SHIV PARAS STREAM-2	9.0	226	13.33	125.75	28.74
BHARASAR STREAM-1	11.0	220	10.9	115.2	22.88
BHARASAR STREAM-2	11.0	220	10.9	115.2	25.57
SAMTIYA STREAM-1	15.0	265	25.79	142.0	22.91
SAMTIYA STREAM-2	15.65	270	30.94	47.23	21.2
SAMTIYA STREAM-3	15.65	226	33.58	34.77	27.36
CHADWA STREAM	12.0	210	39.75	23.71	24.3
KHATROD STREAM-1	11.2	262	127.19	36.24	18.75
KHATROD STREAM-2	11.5	335	63.17	163.22	17.78
KHATROD STREAM-3	11.65	285	52.33	142.57	21.36

TABLE: 6.3 Values of stream gradient and stream gradient index f for selected segments.

SELECTED STREAMS	SELECTED PROMINENT SEGMENTS	GRADIENT	GRADIENT INDEX
HAMADRA STREAM-1	S1	40	251.2
	S2	10	96.39
	S3	04	15.32
	MEAN	18.0	120.98
HAMADRA STREAM-2	S1	45.7	329.1
	S2	8.4	70.19
	S3	04	15.32
	MEAN	19.36	138.20
HAMADRA STREAM-3	S1	48	301.5
	S2	10	96.39
	S3	04	15.32
	MEAN	20.66	137.73
SHIV PARAS STREAM-1	S1	228.5	175
	S2	8.85	40.5
	S3	3.33	56.78
	MEAN	80.25	90.76
SHIV PARAS STREAM-2	S1	120	199.3
	S2	9	46.33
	S3	3.33	56.78
	MEAN	44.11	100.8
BHATA STREAM	S1	80	480
	S2	8.42	46.22
	S3	5	84.2
	MEAN	31.14	203.47
BHARASAR STREAM-1	S1	120	199.3
	S2	6.66	35.9
	S3	4.44	87.53
	MEAN	43.7	107.57
BHARASAR STREAM-2	S1	48	619
	S2	7.62	55.86
	S3	4.44	87.53
	MEAN	20.02	254.13

Table 6.3 continued

SELECTED STREAMS	SELECTED PROMINENT SEGMENTS	GRADIENT	GRADIENT INDEX
SAMTIYA STREAM-1	S1	64	358.5
	S2	9.09	26.52
	S3	4.28	40.97
	MEAN	25.79	141.9
SAMTIYA STREAM-2	S1	80	80
	S2	8.88	23.46
	S3	3.94	38.25
	MEAN	30.94	47.23
SAMTIYA STREAM-3	S1	88.88	50.1
	S2	7.92	15.98
	S3	3.94	38.25
	MEAN	33.58	34.77
CHADWA STREAM	S1	100	24.91
	S2	14.81	17.37
	S3	4.44	28.85
	MEAN	39.75	23.71
KHATROD STREAM-1	S1	355.55	53.63
	S2	19.27	17.21
	S3	6.74	37.9
	MEAN	127.18	36.24
KHATROD STREAM-2	S1	160	417.13
	S2	22.85	33.22
	S3	6.66	39.32
	MEAN	63.17	163.22
KHATROD STREAM-3	S1	133.33	347.6
	S2	13.55	26.06
	S3	10.13	55.07
	MEAN	52.33	142.9

landsurface.

The gradient index values of each segment of the streams have obvious similarity except in the Khatrod streams where each value is quite high. Such highly variable gradient indices are typical in areas experiencing an intermediate to high rate of uplift (Rhea,1993). It is in conformity with the field observations around Katrol hill where the tectonic uplift is indicated by fault scarps, triangular and narrow fans, fault breccias and synclinal troughs.

VALLEY CROSS-SECTIONS

Valley incision is another measure that can be used to define relative uplift (Bull and McFadden, 1977; Ouchi, 1985). Cross-valley profiles are constructed from topographic maps. Valley floor width is estimated from the distance between abrupt slope increases adjacent to the river and valley height is estimated from the elevation between the river and the average elevation of the most pronounced slope decreases on either side of the river. A high valley-floor width to valley-height ratio (seen in a broad valley) is associated with a tectonic quiescence because lateral erosion has had time to occur. Conversely, a low valley-floor width to valley- height ratio (seen in a steep narrow valley) is associated with recent tectonic movement (Mayer, 1985). A steep and narrow valley profile may have many generative causes, but could be an indication of recent uplift.

Measurement of valley floor width-valley height ratio is also one of the useful parameters to define relative uplift. It is defined by the following formula.

$$Vf = Vfw / \left[\frac{(E_{ld} - E_{sc}) + E_{rd} - E_{sc})}{2} \right]$$

Vf- valley floor width- valley height ratio; Vfw- widht of valley floor; E_{ld}- altitude of left divide; E_{rd} - altitude of right divide; E_{sc} - altitude of stream channel.

As already stated earlier, high ratio is associated with a tectonic pause; morphological expression of which is a broad valley, while low Vf is seen in steep, narrow valley and is associated with recent tectonic movement. The streams of the Khari river basin show very low Vf ratio near their source in the hilly region (Fig.6.7), while a few kilometers away from the source, the ratio is quite high due to the broad valley morphology. At places it becomes very low, as valley incision is quite high for a particular part of the area, indicating periodic tectonic activity during the Quaternary.

Valley cross sections are prepared for the Samtiya and Hamadra streams and the main Khari channel (Fig.6.7) at varying distances from the source. The Vf values computed with the help of the above stated formula are combined with the longitudinal stream profiles (Fig.6.8). These values increase towards upstream side suggesting localized uplift as the streams approach the mountain fronts. The higher values around 12 at about 20 km from the source in Khari river suggest broad valley floor and lateral cutting of the streams.

RIVER SINUOSITY PARAMETERS

The sinuosity parameters have been used to understand the role of tectonism (Rhea,1993). Leopold, et.al.(1960) and Leopold and Langbein (1966) have described procedures for defining the sinuosity of channels.

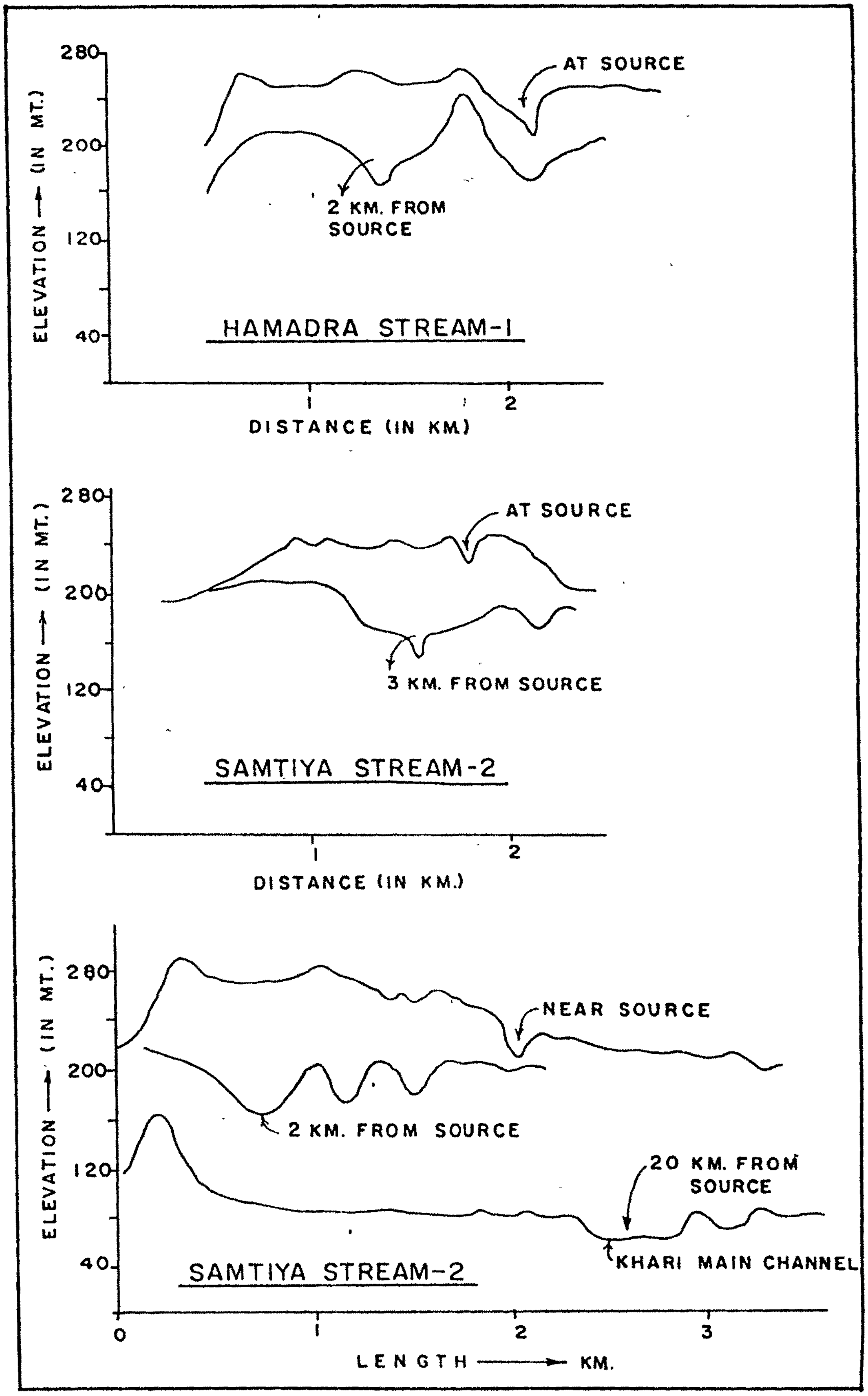


Fig.6.7 Valley cross sections of various streams at different distances from the source.

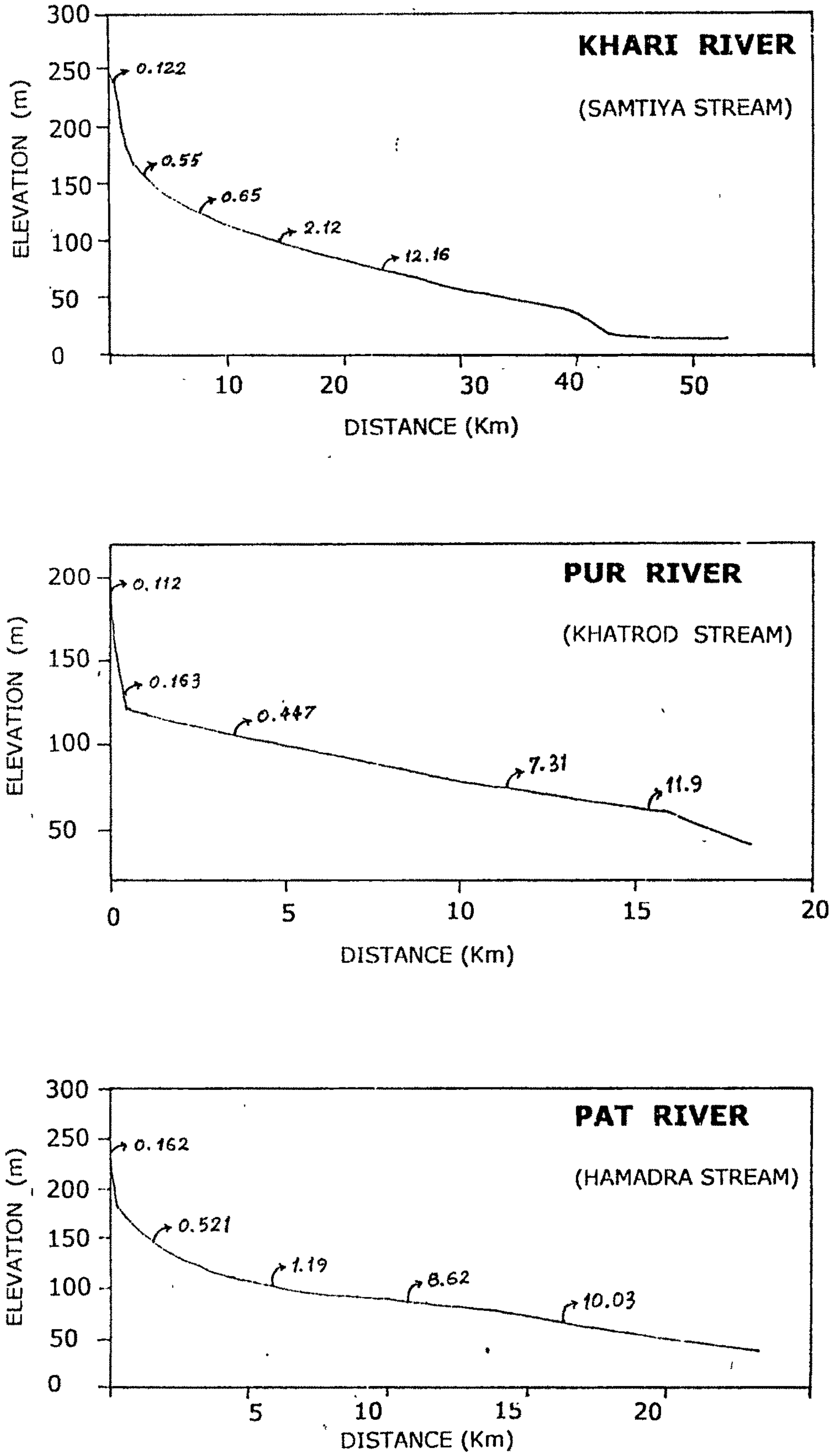


Fig. 6.8 Vf values plotted on the longitudinal profiles of the various rivers.

Mueller (1968) included the role of topographic factor in the computation of sinuosity indices. Hydraulic Sinuosity Index is also computed to show the role of climate, but the topographic index is extremely important as it includes all the factors which can lead to the modification of slope and topography. The indices of sinuosity are calculated as follows.

(1) Channel Index (CI) = CL/AL

where, CL is Channel Length and AL is Air Length (Straight Length).

(2) Valley Index (VI) = VL/AL; where VL=Valley Length.

(3) Standard Sinuosity Index (SSI) = CI/VI.

(4) Hydraulic Sinuosity Index (HSI) = CI-VI/CI-1X100.

(5) Topographic Sinuosity Index (TSI) = VI-1/CI-1X100.

Friend and Sinha (1988) suggested simpler method of measuring sinuosity by modifying the procedure proposed by Leopold and Wolman (1957). This is done by dividing the river channel into segments and determining the sinuosity parameter for each segment.

P = Lcmax/Lr.

Where P is the sinuosity parameter, Lr is length of the channel segment along a straight line and Lc_{max} is the mid-channel length.

Various sinuosity indices are calculated for different segments of the Khari river basin (Fig.6.9 Table 6.4). The main channel of the Khari in its higher reaches have cent percent topographic sinuosity values while it starts decreasing immediately after it enters into the rocky, flat landsurface around Bhuj where hydraulic sinuosity index starts rising. Again at the segment 12, 14, 16 and 18 (Fig.6.9) the TSI values dominate

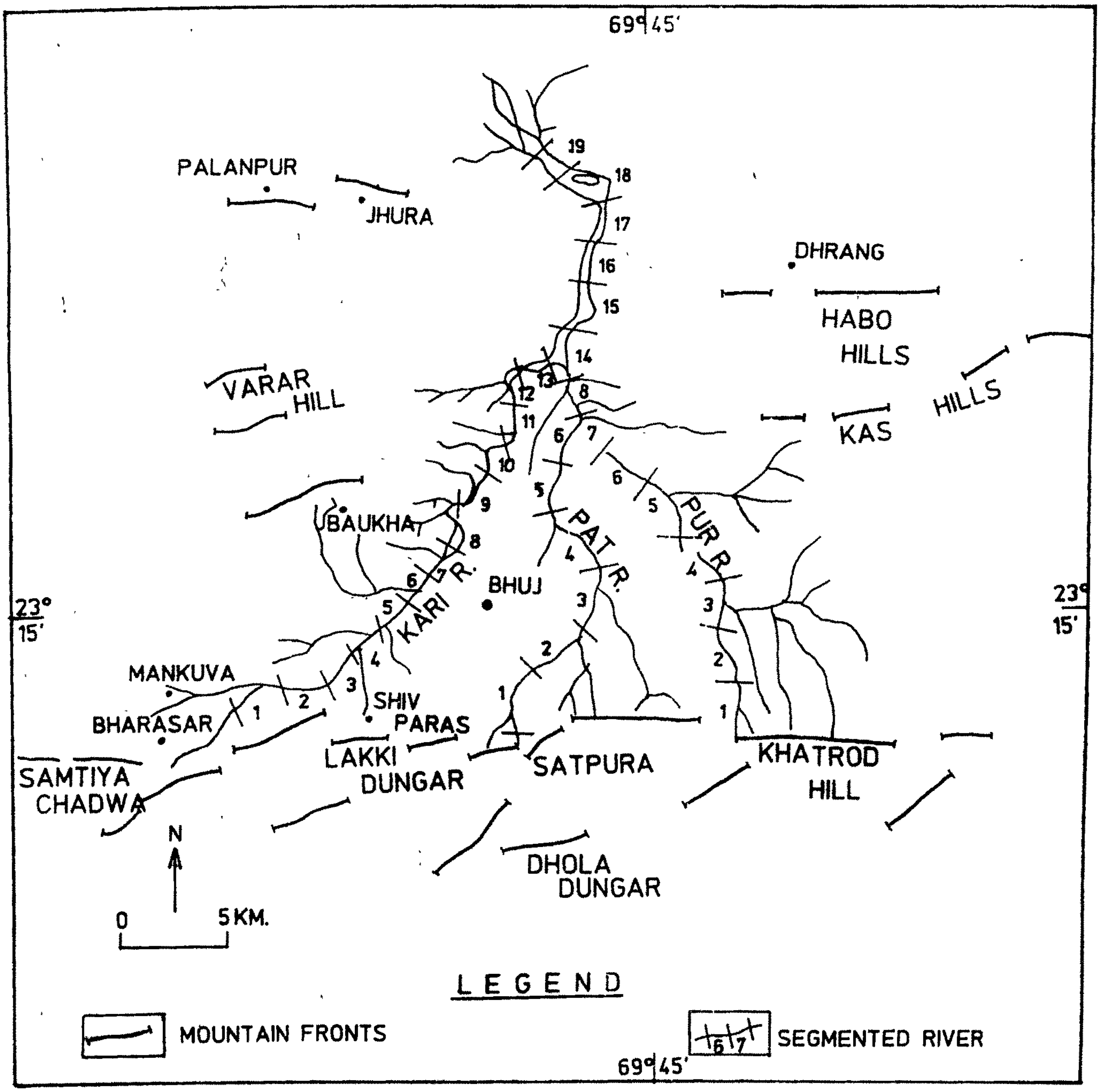


Fig. 6.9 Map showing trends of mountain fronts for which mountain front sinuosities have been caculated. The segments used for calculation of river sinuosity are also shown.

Table: 6.4 Table showing values of Channel Index (CI), valley Index (VI), Standard Sinuosity Index (SSI), Hydraulic Sinuosity Index (HSI) and Topographic Sinuosity Index (TSI) are computed for various segments of Khari river main channel and its tributaries.

NAME OF RIVER	SEGMENT NUMBERS	CHANNEL INDEX	VALLEY INDEX	S.S.I.	H.S.I. (in %)	T. S. I. (In %)
KHARI	1	1.08	1.08	1.00	0.00	100
	2	1.21	1.21	1.00	0.00	100
	3	1.06	1.06	1.00	0.00	100
	4	1.13	1.13	1.00	0.00	100
	5	1.11	1.11	1.00	0.00	100
	6	1.02	1.02	1.00	0.00	100
	7	1.05	1.04	1.00	20.0	80.0
	8	1.13	1.11	1.01	15.38	84.61
	9	1.12	1.11	1.00	8.33	91.66
	10	1.275	1.25	1.02	9.09	90.91
	11	1.5	1.42	1.04	14.2	85.8
	12	1.5	1.5	1.0	0.00	100.0
	13	1.5	1.5	1.04	14.2	85.8
	14	1.14	1.14	1.00	.0.00	100.0
	15	2.0	1.5	1.33	50.0	50.0
	16	1.06	1.06	1.00	0.00	100.0
	17	1.07	1.02	1.04	71.43	28.57
	18	3.65	3.65	1.00	0.00	100.0
	19	1.13	1.04	1.3	88.7	11.3
PUR	1	1.08	1.06	1.01	33.34	66.66
	2	1.11	1.11	1.00	0.00	100.0
	3	1.27	1.25	1.02	9.09	90.91
	4	1.04	1.02	1.01	50.0	50.0
	5	1.07	1.02	1.04	71.43	28.57
	6	1.11	1.11	1.00	0.00	100.0
	7	1.25	1.25	1.00	0.00	100.0
	8	1.25	1.25	1.00	0.00	100.0
PAT	1	1.04	1.04	1.00	0.00	100.0
	2	1.14	1.14	1.00	0.00	100.0
	3	1.02	1.02	1.00	0.00	100.0
	4	1.04	1.04	1.00	0.00	100.0
	5	1.14	1.08	1.05	42.85	57.15
	6	1.04	1.02	1.01	50.0	50.0

over the HSI. This suggests that the Khari river is tectonically controlled in its upper reaches while in the lower part it has been shaped both by tectonism and hydraulic actions. This inference is based on the high TSI and almost nil HSI values obtained from some of the lower segments.

The tributaries of Khari- the Pur and the pat river have the same kind of values (Table 6.4). The Pat river maintains very high values of TSI even after entering the flat rocky ground. The results of sinuosity parameters of the Khari river basin suggest that they are controlled dominantly by tectonism. The evolution of the Khari river basin in the later phase of tectonism is indicated by the sinuosity indices.

MOUNTAIN FRONT SINUOSITY

Study of the mountain fronts is useful in the general assessment of the degree of tectonic activities experienced by the area. Broadly speaking, a straight mountain front is indicative of an active fault or fold while wavy, pedimented fronts are generally considered to be representative of tectonic pause (Bull and McFadden, 1977). The degree of tectonic activity and erosional modification of tectonic structures can be measured by mountain front sinuosity index. It is the ratio of the length along the edge of the mountain-piedmont junction (Lmf) to the overall length of the mountain front (Ls) as shown in the equation.

$$S = Lmf/Ls$$

The value of S is high in the tectonically inactive areas while it is near to 1.0 in the most active fault zones where nearly vertical uplifts have taken place. The large scale topographic maps (1:50,000) are used here for the calculation of the mountain front sinuosity index (MFS) of different mountain fronts.

The values of mountain fronts sinuosity calculated for different mountain fronts of the area are given in the table (Table 6.5). The mountain fronts choosen here are related to E-W trending major faults i.e. Kachchh Mainland Fault (KMF) and Katrol Hill Fault(KHF) and many transverse faults displacing the Katrol Hill Fault (Fig.6.9). Most of the values fall in class-1 in the range between 1.0 to 1.6 of Bull (1978) suggesting that the area has experienced active tectonism.

Mountain fronts associated with KMF trend E-W direction and show moderate values of MFS falling in class-2 which indicates moderate to slightly active tectonism along the KMF during Quaternary. The fronts running along the KHF show low to moderate MFS values. Chadwa Dungar, Dhola Dungar and Satpura Dungar exhibit similar MFS values (1.6) and probably have suffered uniform tectonic disturbances., some of the segments of Katrol hill range formed due to the transverse shifting show unusually low values of MFS, for example the Khatrod hill scarp show only 1.08 to 1.11 MFS values. This suggests high degree of tectonic activity during Recent time.

It is interesting to note that the values of MFS associated with the transverse faults (i.e. NE-SW, NW-SE, NNW-SSE, NNE-SSW, N-S and WNW-ESE) are unusually low. The lowest values (i.e. 1.04 and 1.08) are exhibited by the hills near ShivParas and that to the east of Chadwa respectively, where the ENE-WSW and NE-SW faults displace the major KHF as well as the domes associated with it. The other mountain fronts trending in various directions with MFS values between 1.1 to 1.27 suggest the activeness of transverse faults. At places the values indicate

Table: 6.5 Mountain front sinuosity of various mountain fronts of the Khari river basin.

MOUNTAIN FRONTS	TRENDS	SINUOUS LENGTH (IN KM)	STRAIGTH LENGTH (IN KM)	MOUNTAIN FRONT SINUOSITY	TECTONIC ACTIVITY CLASS (after Bull,1977)
PALANPUR	E-W	9.0	4.5	2.0	Class-2
JHURA	E-W	4.0	2.5	1.6	Class-1
DHRANG	E-W	10.0	5.2	1.9	Class-2
LAKHARA	E-W	6.0	3.45	1.7	Class-2
KAS HILL	E-W	7.5	4.5	1.6	Class-1
KAS HILL	NE-SW	7.5	6.3	1.19	Class-1
BAUKHA	ENE-WSW	7.0	5.5	1.27	Class-1
SAMATY DUNGAR	E-W	3.75	2.75	1.36	Class-1
CHADWA DUNGAR	E-W	5.0	3.0	1.66	Class-2
DHOLA DUNGAR	E-W	5.5	4.0	1.37	Class-1
SATPURA DUNGAR	E-W	7.5	4.5	1.66	Class-2
KHATROD HILL	E-W	9.5	8.8	1.07	Class-1
WEST OF KHATROD HILLS	NE-SW	3.5	2.75	1.27	Class-1
SATPURA DUNGAR	NE-SW	1.5	1.0	1.5	Class-1
SHIV PARAS SCARP	ENE-WSW	1.25	1.2	1.04	Class-1
LAKKI DUNGAR	NE-SW	1.0	0.9	1.11	Class-1
BHARASAR - MANDVI ROAD SCARP	WNW-ESE	1.0	0.9	1.11	Class-1
EAST OF CHADWA	NE-SW	2.5	2.3	1.08	Class-1

that these have been more active than the Katrol Hill Fault. Overall, the MFS values indicate that the Khari river basin has been tectonically evolved during Quaternary.

LINEAMENT ANALYSIS

Lineament in a broad sense is the assessment of the influence of structural set up on major geomorphic features of the area. The lineament map based on the drainage network generally indicate the prominent fracture directions except a major or regional lineament. In other words, such maps indicate prominently the effects of younger tectonic events rather than those which took place in distant past and are represented by larger geomorphic texture. The lineament map and its rosette (Fig. 6.10) prepared on the basis of drainage network of the Khari river basin suggest the prominent fracture directions along the transverse faults. Majority of the groups of lineaments fall between 0-40^0 NE and 0-30^0 NW (Table 6.6). This suggests that youngest phase of tectonic activity in the basin took place along N-S, NE-SW, NW-SE.

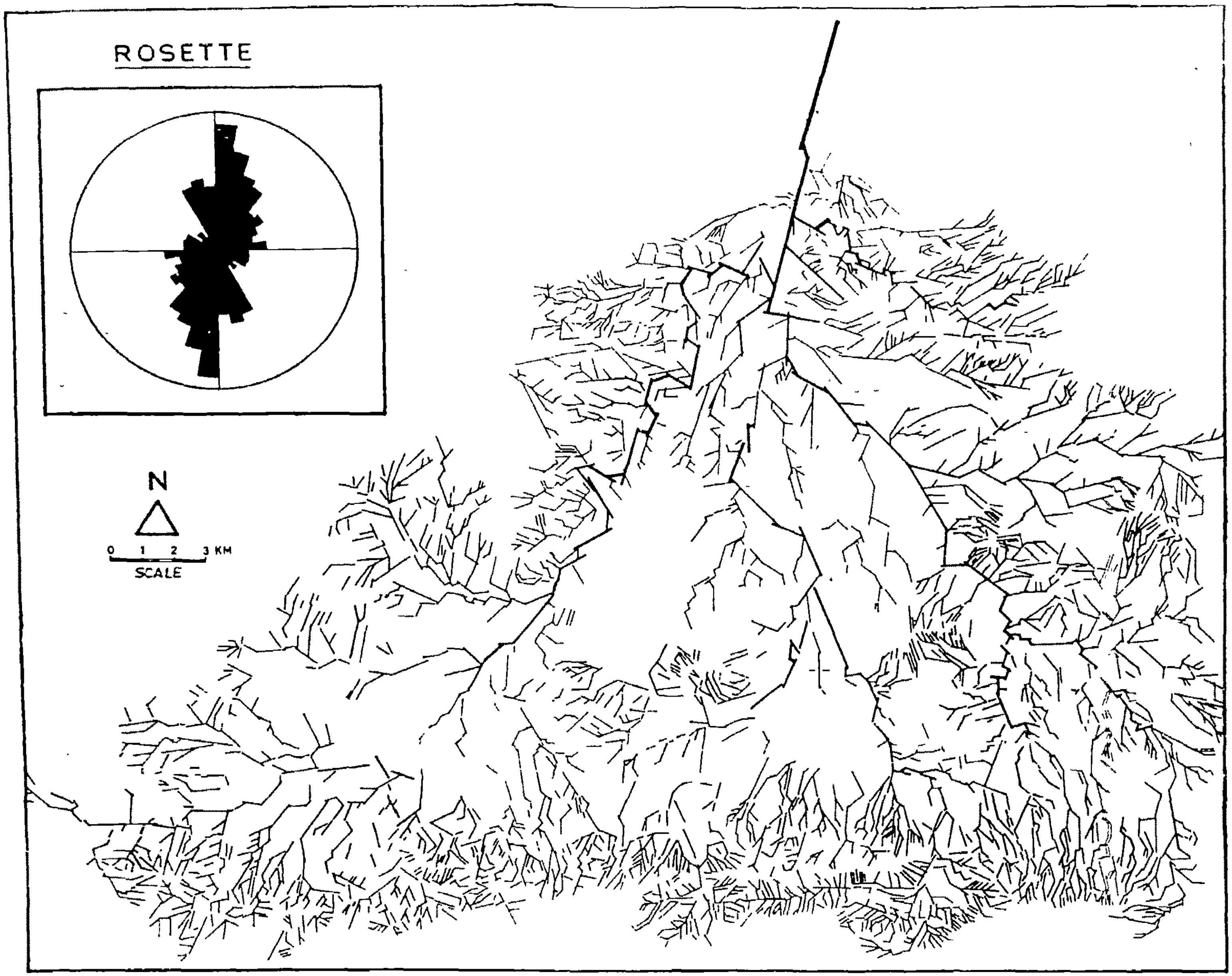


Fig. 6.10 Lineament map of the study area prepared on the basis of drainage.
Inset - Rose diagram of the lineaments.

TABLE: 6.6 Data showing total number, total length and average length for each azimuth class of lineament orientation based on drainage.

AZIMUTH CLASS	TOTAL NUMBER	TOTAL LENGTH (IN KM)	AVERAGE LENGTH (in km)
0 - 10 NE	262	110.333	0.42
10 - 20 NE	206	86.666	0.42
20 - 30 NE	167	80.91	0.48
30 - 40 NE	150	75.833	0.51
40 - 50 NE	97	45.666	0.47
50 - 60 NE	112	42.583	0.38
60 - 70 NE	89	45.416	0.51
70 - 80 NE	74	38.833	0.52
80 - 90 NE	105	59.166	0.56
0 - 10 NW	133	56.416	0.42
10 - 20 NW	152	62.833	0.41
20 - 30 NW	141	62.00	0.43
30 - 40 NW	40	19.666	0.49
40 - 50 NW	49	31.00	0.63
50 - 60 NW	41	23.5	0.57
60 - 70 NW	64	32.83	0.51
70 - 80 NW	68	43.083	0.63
80 - 90 NW	66	32.25	0.49