

Landscape Processes in the Chure Range Central Nepal *

- Harka Gurung & Narendra Khanal **

Introduction

Nepal is predominantly a mountainous country with extreme elevation and steep slopes. Diverse physical and cultural processes operate that vary both in form and intensity from place to place. A better understanding of these processes and their influence on landscape change is essential for rational management of land resources and environment.

It was in this context that the mountain hazard mapping project was initiated in Nepal in 1979 with the support of UNESCO, United Nations University and HMG/Nepal. MAB, Nepal was designated the host agency. The Project was designed to be carried-out in three representative altitudinal belts: high (Khumbu), middle (Kakani) and low (Siwalik area) (Ives and Messerli, 1981).

The first phase work was completed in Kakani area, immediately north-west of Kathmandu. The areas of investigation were slope stability, mass wasting, channel behaviour and land use with mapping exercises in hazard and slope stability (Kienholz *et al.*, 1983). The second phase study was done in Khumbu area and dealt with slope processes, soil erosion and hazard mapping. The Khumbu work indicated that prevailing notions about serious deforestation and high erosion rate were over-estimated. (Ives, 1986).

Objectives

The present study deals with the Chure range focussing on four sample localities. It is a preliminary investigation with limited scope conducted during a short duration. The main areas of enquiry included

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geomorphology, hydrology and landscape dynamics in selected localities. The major objectives of the study were:

1. To identify various geomorphic processes;
2. To describe prevalent landforms;
3. To assess change in land use; and
4. To prepare geomorphic maps of the sample locations.

The principal purpose of the study was to provide a basis for a more detailed investigation in the future. The aspects covered have direct relevance to hazard mapping exercise as visualized by the UNESCO/UNU/MAB Nepal project design.

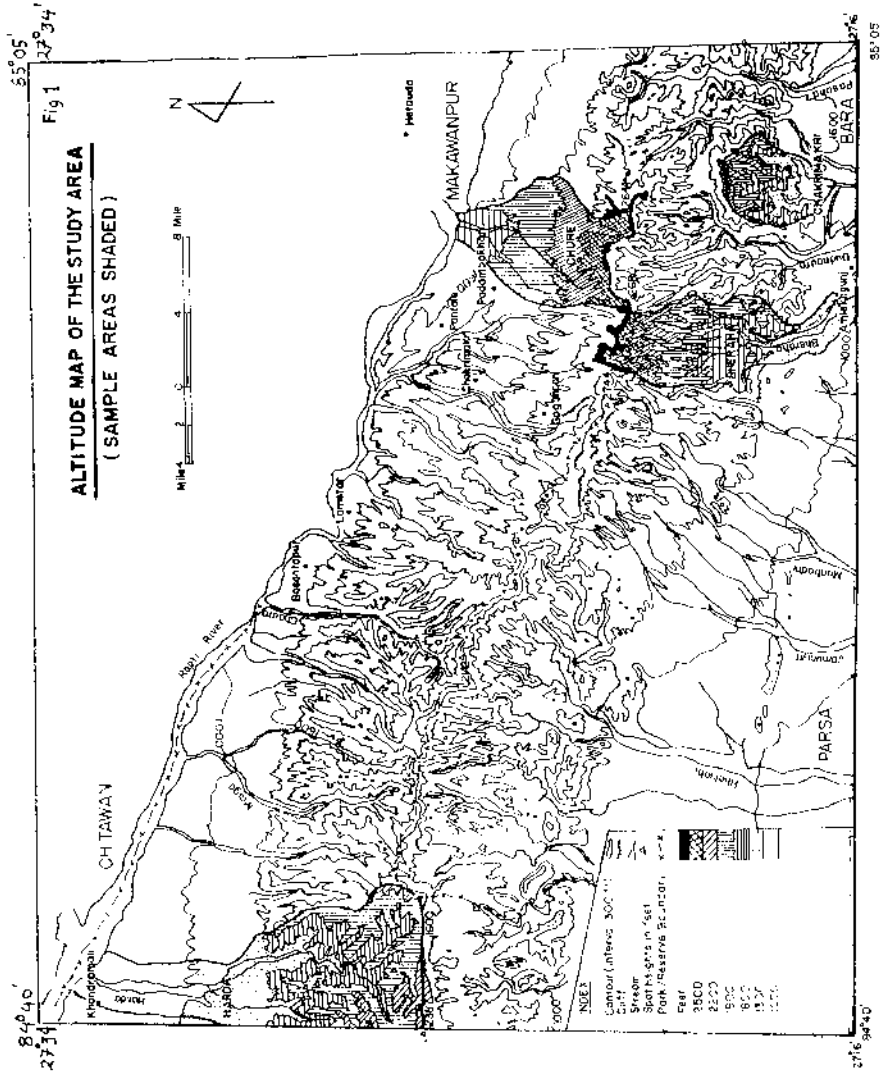
Study Area

The area chosen for the present study is located in Central Nepal along the Chure range between longitudes 84°40'E-85°05'E and latitudes 27°16'N - 27°34'N. The boundaries in the east (Pasa), north (Rapti) and west (Harda) are defined by streams. In the south, it traverses the tarai plain ranging from 900 to 1,000 feet in elevation. Important locations on the periphery of the study area are Hetauda (North-east), Amlekhganj (south-east) and Khandramali (north-west). The total area is 378 square miles (Fig. 1).

The Chure range within the study area extends for 28 miles flanked by dun valleys to the north and tarai plain to the south. The range also forms a boundary between the two northern (Chitwan, Makwanpur) and two southern (Parsa, Bara) administrative districts. Nearly 40 percent of the northern slope lies within the Chitwan National Park while over two-third of the southern slope falls within Parsa Wildlife Reserve. The aspects studied for the macro area were relief, drainage network and basin morphometry.

Further, four drainage basins were selected for more detailed investigation. Their selection was based on two locational aspects: slope orientation and in relation to Park/Reserve area. Thus, samples from the north-facing slope included Harda and Chure basins while those from the south-facing slope were Bheraha and Chakrimakri. Again, Harda and Bheraha were selected from within Park/Reserve area and Chure and Chakrimakri basins from unprotected areas. The latter two basins were also the focus for study in land use change.

Harda basin located on the western end of the study area is the largest of the sample locations with an area of 22.3 square miles. It is drained north by a perennial stream originating above 2,000 feet near the ridge-crest. A western tributary joins it at spot-height 1,008 feet. Harda stream debauches into the Rapti at the spot-height of 721 feet. The southern ridge divide is fairly regular with spot-heights of 2,387 feet in the west, 2,142 feet in the centre and 2,128 feet in the west. Thus, the basin has a relative relief of 1,666 feet. since the relocation of



population from Khandramali near Rapti, there are no settlements within the basin.

Chure basin is drained by two streams - Chure and Kukhreni - that are seasonal upstream of their junction at the spot-height 1,589 feet. The lowest point of the basin is less than 1,500 feet at the trijunction of the Churia, Karra and Rapti. The highest points are spot-heights of 2,660 feet in the south-east and 2,644 feet in the south-west. The relative relief of the basin is over 1,160 feet. The area of the basin is 10.4 square miles. The south-western part is traversed by a busy highway across the Chureghati (over 2,300 ft.). There are numerous settlements in the basin.

Bheraha basin has no perennial stream and covers an area of 8.0 square miles. The extreme spot-heights are 1090 feet in the south and 2,660 feet in the north with a range of 1,570 feet. There are no permanent settlements as the basin lies within Parsa Wildlife Reserve.

Chakrimakri south is the smallest of the sample basins with an area of 4.8 square miles. It is a compact amphitheatre on the south side of Bilpati ridge and drained by a seasonal stream. The extreme elevation zones range from 900 feet in the south to 2,300 feet in the north.

Methodology

The present study had a schedule of three months. Field work was carried-out during April-May 1987. However, procurement of aerial photographs and data interpretation took much more time than planned.

Field-work was preceded by data collection and map interpretation. Most of the information on terrain analysis were obtained from the Survey of India topographical maps (1: 63,360). These maps were based on vertical aerial photographs taken in March 1954 and surveyed on the ground during 1955-56. Altitude levels, drainage network and land use information were derived from these maps. Contour interval used for elevation was 300 feet for the macro area and 100 feet for sample localities. Maps of different slope categories were prepared based on these contour maps. Digital planimetre was used for calculating areas by elevation, slope categories and land use type. Kargl Reflecting Projector was used for map reduction.

In the case of the sample basins, 100 feet contours and drainage network were traced at a scale of 1: 63,360 and then enlarged with the help of reflecting projector. This was followed by area computation with the aid of computer as well as digital planimeter.

Aerial photographs of 1978 (1: 50,000) were interpreted to examine land use. Transfer of photographic data to topographic scale using river channels as control points revealed significant distortions in the 1978

photographs. Thus, the area under different land use were traced and calculated directly from the photographs. The percentage under different uses were then adjusted to the area of sample basin derived from topographic maps.

Field work was done on the basis of enlarged (1: 25,000) contour and drainage network maps as well as aerial photographs (1: 50,000). The latter was specifically used for ground verification of different geomorphic forms and land use. The field-work was carried-out for 25 days. On an average six days were spent in each sample basin. Harda basin could not be covered fully due to its extensive size and lack of support facilities (lack of habitation). The three eastern basins were investigated in more depth despite problems of access in certain highly dissected sections.

Geology, Climate and Vegetation

Geology

The present study area lies entirely in the Sub-Himalaya south of the Main Boundary Thrust. It is composed of Siwalik series dating from Mid-Miocene to lower Pleistocene period. The main strike is directed north-west to south-east as indicated by the general parallel alignment of the Chure Watershed and the Rapti-Karra Valley. Local faults are generally aligned north-south. The strata dips towards the north at varying angles. Strata sequence is normal with younger series overriding the older ones.

Folding and faulting in the Siwaliks is of early to middle Pleistocene age (Gansser, 1964). Folding is more pronounced in the older formations than in the younger beds due mainly to difference in lithology than tectonic forces. Generally, younger beds outcrop towards the north and older ones in the south. The later are less exposed due to extensive overlay of recent deposition. The lower elevations on both side of the Chure range are covered with colluvial and alluvial deposits. It is difficult to distinguish the bhavar alluvial from poorly consolidated Siwalik formations (LRMP, 1986 : Geology Report). The coarse clastics of the bhavar zone, derived from the Siwaliks, have beds dipping away from the hill.

Conventionally, the Siwaliks are divided into three sub-groups (Lower, Middle and Upper) although lithological differences between the first two are not clear in all places. The Lower Siwalik is composed of fine to medium-grained grey sandstones interbedded with nodular shales, siltstone and some clay. The sandstone is compact and hard. A basin in the lower Siwalik is represented by Chakrimakri where the defiles are narrow and relief is high.

The Middle Siwalik is composed of soft sandstone with bands of hard calcareous sandstone and clay. This group is more friable due to poor

cementation. It occurs at certain depths in Bheraha basin and part of Chure basin. Where they are exposed, the relief is moderate to open with an undulating surface, particularly south of Hetauda. The profile near Hetauda had a succession of reddish soil with gravel up to 2.90 metres below surface, then 1.45 metres of grey soil gravel, and finally sandstone with silt and clay below 7 metres.

The Upper Siwalik is composed of unconsolidated conglomerates, clays and sandstones. The conglomerate pebbles are derived from sandstone, limestone, quartzite, phyllite, shale and slate. A sample profile in Bheraha included gravels and reddish sandy soil upto 5-10 metres below surface, another 2-5 metres of yellowish sandy silt, then 2-3 meters of black and grey soil, and finally gravels and yellowish soil below it. The Upper Siwalik is more prone to surface erosion and slides yielding high relief. On the higher Chure range, they exhibit a steeper relief on the south side.

Climate

The study area lies in the humid tropical climatic zone (Nayava, 1975). The lower elevations including the foothills and the dun below 1,640 feet have very hot summers. Temperature fluctuations range 20°C to 40°C in summer and 4°C to 24°C in winter. The higher elevations on the Chure range have mesothermal climate with a summer maximum of 25°C.

Hetauda (1,529 ft) near the Chure basin exemplifies the temperature regime through the year for part of the study area. Mean maximum and minimum temperatures show a distinct seasonal pattern. April to August are the hottest months with the maximum reaching 33°C. The temperature level decreases during September-December but rises steadily after January. The lowest mean maximum during January approach 19° centigrade. Range between maximum and minimum mean temperature is wide during November-April, coinciding with the dry period. The range is narrow during July and October. Mean minimum recorded in 1984 was highest during August (23°C) and lowest during January (5.4°C).

The average of monthly precipitation for 15 years (1971-85) recorded annual precipitation to be 2170.72 mm for Amlekhganj and 2254.29 mm for Hetauda. More than 80 percent of rainfall was during the months of June-September associated with the summer monsoon. The proportion of summer monsoon to total precipitation was 83.6 percent in Amlekhganj and 81.2 percent in Hetauda.

Pre-monsoon precipitation (March-May) accounted for 9.3 percent of the total rainfall in Amlekhganj and 12.8 percent in Hetauda. The share of post-monsoon rain during October was 4.8 percent in Amlekhganj and 3.3 percent in Hetauda and that of winter rain (November-February) due to westerly disturbances 2.3 percent at the former and 2.7 percent at the latter station. Thus the southern side of Chure range has higher share of precipitation for the monsoon and post-monsoon period (Fig. 8).

Amlekhganj also has a higher range of fluctuation in annual precipitation (1976 mm) than Hetauda (1129 mm). The deviation of annual precipitation was as follows:

Station	Mean (mm)	Standard (mm)
Amlekhganj	2170.72	543.21
Hetauda	2254.29	345.05

Mean maximum precipitation within 24 hours during 1971-85 was 175 mm with a minimum deviation of 55.87 mm. For Hetauda, the mean maximum was 171 mm and standard deviation 58.10 mm. The minimum intensity was 1.29 mm/hr at Amlekhganj and 7.23 mm/hr at Hetauda.

The mean rainy days was 91 for Amlekhganj and 122 for Hetauda. The mean days with more than 100 mm precipitation came to 3.33 per yr in Amlekhganj and 2.22 per yr in Hetauda. Although Hetauda (2254.29 mm) had higher volume of annual precipitation than Amlekhganj (2170.72 mm), intensity and total number of days of precipitation was much higher at the latter location. Thus, the effect of the summer monsoon was more pronounced on the south side of the Chure range.

Vegetation

Natural vegetation is fairly extensive in the present study area. A large part of the area falls under Chitawan National Park and Parsa Wildlife Reserve and are designated as protected forest. The main area of encroachment lies between Bhundrung and Chure streams on the gentler north slope of the range. Chakrimakri basin is unprotected but the rugged relief makes it less accessible for forest clearance.

The natural vegetation extant in the study area can be classified by habitat. The main species colonizing the riverine and new alluvial beds are Zizyphus jujuba, Acacia catechu, Dalbergia siisoo and Salamalia malabarica. Shorea robusta is the dominant species at lower elevations. It also grows on higher elevations but are relatively smaller in size. Pinus roxburghii is common on drier and steeper slopes. Dendrocalamus hamitonii are found in shady slopes along with Musa superba roxburghii. Cycas Sp. is a common variety as secondary forest growth. Eulaliopsis occurs widely on steep slopes.

Hydrography

Drainage Network

Numerous streams in the study area were examined as to their stream order, bifurcation ratio, channel profile and average channel slope. Of the 30 streams selected, 21 were in the fourth order. There were only four in the fifth order—Bhaluahi, Doharam, Dudhaura and Harda — and of these, all except Harda, drained south. The bifurcation ratio between the first and second order streams was 4.95. This ratio was higher on the northern side (5.21) of the Chure range than on the southern side (4.75). The bifurcation ratio between the second and third order streams was 4.76 and was also higher to the north (4.83) than to the south (4.71).

Of the 25 streams chosen for comparison of channel profile, 14 were from the north side and 11 from the south side slope (Figs. 2 & 3). The average channel length was 6.72 miles on the north and 9.28 miles on the south side. The average channel slope was 3.51 percent in the north compared to 3.06 percent in the south. However, the same was more pronounced on the south (19.16 %) as against the north (14.55 %) within 0.6 miles of the water divide. The basic characteristic of the south-flowing streams is a rapid initial fall and then extended length lower down in the plain (Fig. 3).

Of the four sample basins, only Harda has one stream of the fifth order (Table 2). The fourth order streams number 4 in Harda, one each in Bheraha, Chure and Chakrimakri. The bifurcation ratio between first and second order streams was 4.3 in Chure, 4.5 in Harda, 5.1 in Bherah and 6 in Chakrimakri. Thus, basins on the northern slope have a lower ratio. This locational pattern is not apparent in the bifurcation ratio between second and third order streams : high (5.3) for Chure and Bheraha.

The average length of first order streams ranges from 0.17 mile in Bheraha to 0.37 mile in Chure basin. It is 0.24 and 0.35 mile respectively for Harda and Chakrimakri. Standard deviation varies from 0.12 in Bheraha to 0.26 in Chure. The average length of second order is higher for Chure and lower for Bheraha (Table 2). Drainage density per square mile is 3.04 miles in Chakrimakri, 4.20 miles in Bheraha, 4.73 miles in Chure and 5.74 miles in Harda. Harda and Bheraha have a higher relief ruggedness and stream frequency. Geological structure seems to be an important factor of basin form and relief ruggedness.

Discharge

Most of the streams in the sample basins are seasonal. Water flow is pronounced during the monsoon from June to September and flood occurrence lasts about 2 to 4 hours. Harda is the largest perennial stream on the north-slope of the range. Its water discharge at mid-point near Ratmate was only 6.43 ft³/sec at the time of field survey in early

Fig. 2

CHANNEL PROFILE (NORTH FACING SLOPE CHITAWAN & MAKWANPUR)

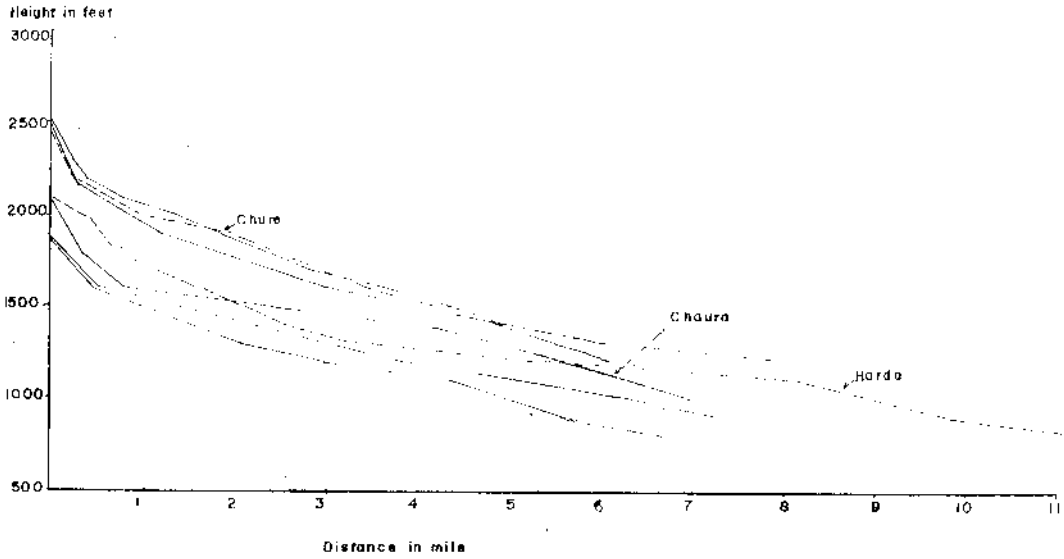
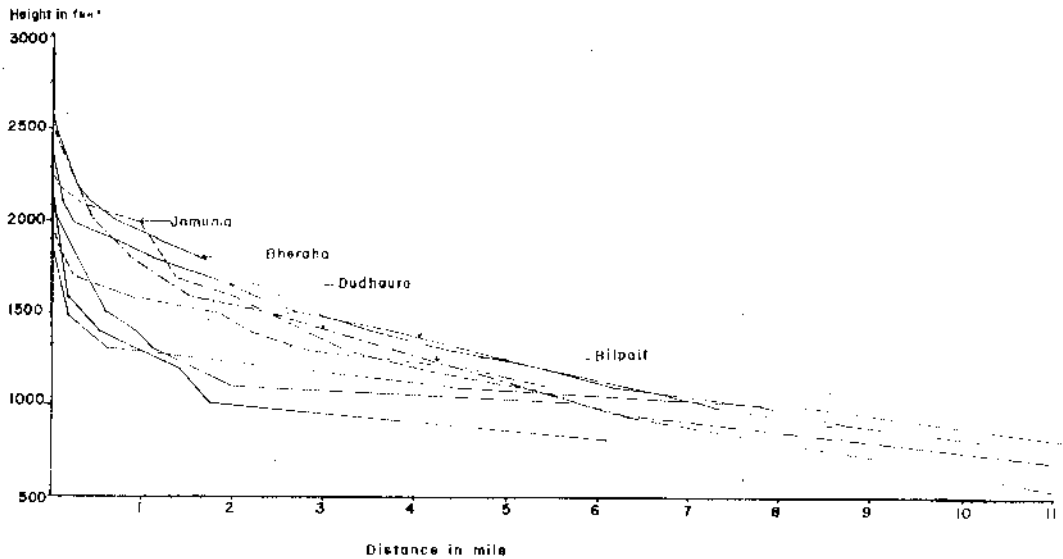


Fig. 3

CHANNEL PROFILE (SOUTH FACING SLOPE PARSA)



April. The well-forested upper section has stream flow but it disappears downstream. Opposite is the case in Chure basin where the stream bed is dry in the deforested upper section and the water resurfaces lower down.

Table - 2

Drainage Network

1. Number of streams by order

a) Macro-level (a.1) (Total number of streams within the study area)

	<u>Northernside</u>	<u>Southernside</u>
First order	1301	1282
Second order	252	269
Third order	53	57
Fourth order	12	16
Fifth order	1	3

(a.2) Number and order of stream in 30 major watersheds

	<u>Northernside</u>	<u>Southernside</u>
First order	1058	1253
Second order	203	264
Third order	42	56
Fourth order	12	16
Fifth order	1	3

(a.3) Average Bifurcation Ratio (B)

B1 :2	5.21	4.75
B2 :3	4.83	4.71
B3 :4	3.5	3.5

b) Micro level (Four drainage basins)

b.1 Number and order of streams

	<u>Harada</u>	<u>Chure</u>	<u>Bheraha</u>	<u>Chakrimakri</u>
First order	312	69	107	24
Second order	69	16	21	4
Third order	16	3	4	1
Fourth order	4	1	1	-
Fifth order	1	-	-	-
Total :	402	89	133	29

b.2 Bifurcation Ratio (B)

	<u>Harda</u>	<u>Chure</u>	<u>Bheraha</u>	<u>Chakrimakri</u>
B1 : 2	4.5	4.3	5.1	6
B2 : 3	4.3	5.3	5.3	4
B3 : 4	4.0	3.0	4	-
B4 : 5	4.0	-	-	-

2. Stream length (in miles)

2.a Length of streams by orders

<u>First order</u>				
Total length	74.99	25.46	18.11	8.45
Mean length	.74	.37	.17	.35
Standard deviation	.13	.26	.12	.25
<u>Second order</u>				
Total length	23.17	10.04	6.88	2.35
Mean length	.34	.63	.33	.59
Standard deviation	.24	.43	.34	.46
<u>Third order</u>				
Total length	13.82	5.51	9.7	3.53
Mean length	.86	1.84	2.43	-
Standard deviation	.57	.33	1.24	-
<u>Fourth order</u>				
Total length	7.62	1.13	2.93	-
Mean length	1.91	-	-	-
Standard deviation	1.35	-	-	-
<u>Fifth order</u>				
Total length	8.22	-	-	-
2.b Total length	127.82	42.14	37.62	14.33

The area by broad altitudinal levels is as follows :

<u>Altitude Level (in feet)</u>	<u>Area (in %)</u>
2,200 and more	2.15
1,600 - 2,200	24.75
1,000 - 1,600	42.07
Below 1,000	31.03

In the case of Bheraha, water appears on the surface only in the middle section of the stream for a stretch of less than one mile. Further down stream it is lost in the bhavar gravel. There is less seepage in Chakrimakri basin in the Lower Siwalik.

Valleyforms in the Upper Siwalik is much broader indicating easier lateral erosion. In the Upper Siwalik, dun and bhavar areas, more than 20 percent of stream bed materials are composed of gravels, cobbles and a few boulders of 50 cm diameter. In some places, there are concretionary bedloads of more than 2 metres diameter. In contrast, areas in Lower and Middle Siwalik have bed materials that are mostly sand with sandstone that rarely exceed one metre in diameter.

No records of water and sediment discharge are available for the study area. However, numerous recent landslides and mass of weathered material on hill slopes indicate a very high rate of sediment discharge in these basins. The active channel-widening process, channels choked with fresh materials and wide floodplains downstream are further evidence of large-scale sediment transportation from the area.

Table - 3

	<u>Harda</u>	<u>Chure</u>	<u>Bheraha</u>	<u>Chakrimakri</u>
1. Drainage order	5	4	4	3
2. Area in sq. miles (A)	22.27	10.04	7.96	4.76
3. Basin length in miles (L_B)	9.28	3.88	5.27	2.47
4. Basin width in miles (W_B)	2.40	2.59	1.51	1.93
5. Basin perimeter in miles (B_P)	25.63	14.65	14.26	8.40
6. Basin Diameter in miles (B_D)	9.6	5.10	5.45	3.10
7. Basin elevation in ft.				
a) Maximum elevation	2387	2660	2750	2350
b) Minimum elevation	721	1405	1090	900
c) Differences in elevation	1666	1255	1660	1450
d) Average elevation	1450.6	1961.15	1734.29	1445.5
8. Average Slope (Tanp)				
a) Total area	12.20	11.43	22.57	22.35
b) Upper part of the catchment	14.39	19.50	23.53	26.14
9. Relief ratio (H/L_B)	0.03	0.06	0.06	0.11
10. Basin shape				
a) Shape in Dimensionless unit (LB/A^2)	3.87	1.50	3.49	1.28
b) Elongation ratio	.57	.92	.60	1.00
c) Rotundity	2.04	1.18	2.74	1.00
d) Compactness ratio	1.53	1.30	1.43	1.09

11. Altitude and Area in feet and Sq. miles

<u>Altitude</u>	<u>Area</u>			
	<u>Harda</u>	<u>Chure</u>	<u>Bheraha</u>	<u>Chakrimakri</u>
1000 below	2.73	-	-	.96
1000 - 1500	9.34	.45	2.31	1.91
1500 - 2000	8.82	5.92	4.05	1.62
2000 - 2500	1.38	3.47	1.47	.27
2500 above	-	.20	1.13	-
Drainage Density (Miles/ sq. miles)	5.74	4.20	4.37	3.01
Stream Frequency (EN / A)	18.05	8.86	16.71	6.09
Ruggedness number (DXH)	1.81	1.00	1.49	.82

Source : Topographic maps

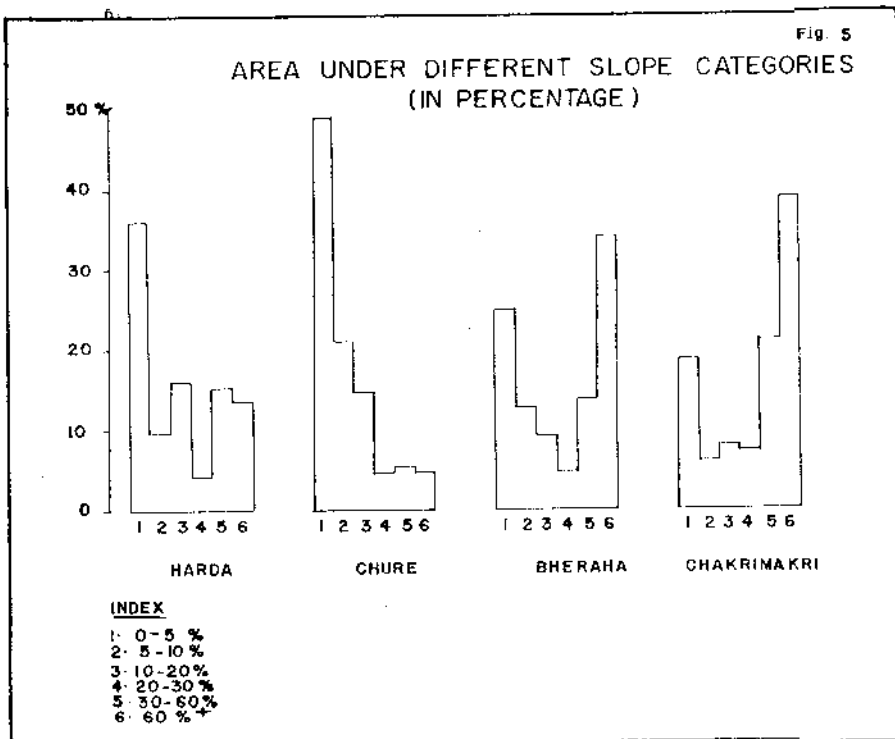
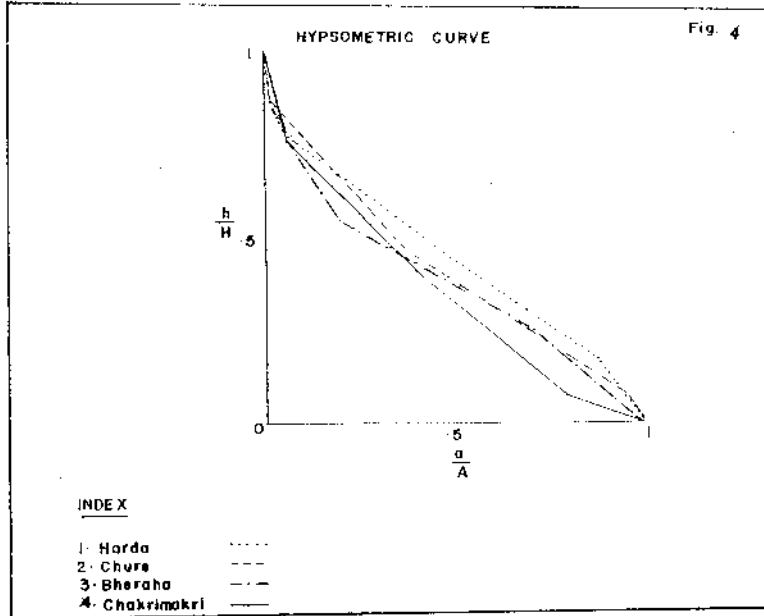
Geomorphology**Basin Morphometry**

The elevation base of the study area commences at 900 feet in the south-west, 1,000 feet in the south-east, 1,432 feet in the north-east and 721 feet in the north-west. The central area is traversed by the Chure range that reach elevations of 2,387 feet in the west, 2,142 feet in the center and 2,744 feet in the east. Relative relief is more pronounced in the east (Fig. 1). The Chure range has an average width of 7.8 miles. It is comparatively broad south of the drainage divide owing to occurrence of subsidiary ranges mainly on the Lower and Middle Siwaliks.

The area by broad altitudinal levels is as follows :

<u>Altitude level (in feet)</u>	<u>Area (in %)</u>
2,200 and more	2.15
1,600 - 2,200	24.75
1,000 - 1,600	42.07
Below 1,000	31.03

Land over 2,200 feet is limited and confined mostly along the drainage divide. It is to be noted that the south aspect of the drainage divide is more steep then the northern one. On the other hand, land within 1,600 - 2,000 feet are more extensive on the north side. About three-quarter of the land surface is below 1,600 feet and it includes both the dun and tarai extension.



Land surface with slopes exceeding 60 percent and above is characteristic of the main water divide and its subsidiary ranges. On the main Chure range, this slope zone forms an emphatic chain with only minor gaps. It also occurs on a secondary ridge south of the main range, particularly on the Lower Siwalik in the south-east. This secondary ridge is less apparent in the drainage basin of Jamunia and Manbodhi streams. The very steep slope category (more than 60 %) also appears on a third minor ridge in the latitude of Bhikhnathori in the south-west.

Land surface with steep slope (30-60%) is closely juxtaposed to those with very steep slopes referred above. It is more pronounced in the east and on the northern dip slope in the west. The rest of the land has a moderate slope (less than 30 %). The existence of this slope category closer to the main watershed is striking in the Upper Siwalik series in the north-west.

A closer examination of the sample basins reveals significant differences in local morphometry. Among the four, Harda is the largest in terms of area and order of streams. Chure and Bheraha have both fourth order streams but the former is larger in area. Chakrimakri with a third order stream has the smallest area. Thus, of the sample basins, those on the north slope cover a larger area. The basin shape of Harda and Bheraha are elongated while that of Chure and Chakrimakri are more rounded

Table - 4a

Slope Categoriesa. Frequency distribution in percent

<u>Slope categories</u>	<u>Harda</u>	<u>Churia</u>	<u>Bheraha</u>	<u>Chakrimakri</u>
Less than 1%	6.38	.14	.09	.14
1 - 3%	1.60	2.99	1.15	.14
3 - 5%	2.12	6.13	2.21	.14
5 - 10%	5.99	11.54	5.04	2.95
10 - 15%	11.10	15.10	5.40	3.51
15 - 20%	12.51	12.39	7.17	6.18
20 - 30%	16.15	14.10	8.67	11.52
30 - 40%	16.85	8.55	12.48	17.42
40 - 60%	15.51	12.96	20.18	24.02
More than 60%	17.74	16.10	37.61	33.99

The mean basin elevation and their standard deviations are as follows:

	<u>Basin</u>	<u>Mean Basin Elevation</u> (Feet)	<u>Standard Deviation</u> (Feet)
1.	Harda	1,450.6	348.5
2.	Chure	1,961.5	287.2
3.	Bheraha	1,734.3	326.3
4.	Chakrimakri	1,445.5	438.7

There is an inverse relationship between the mean basin elevation and standard deviation seen in the contrast between Chakrimakri (high standard deviation) and Chure (high mean basin elevation). The former basin has high ridges and deep gorges while the latter has extensive areas of terraces.

The distribution of area in relation to the relative elevation indicates that Harda and Chakrimakri have comparatively higher percentage of older erosional landforms (Fig. 4). In the lower reaches, Chakrimakri stream has concavity while Harda and Chure have convexity in their hypsometric curve.

Measurement of average slope based on the grid method provide much higher values for basins on the south slope. These range from 11.43 degrees for Chure and 12.20 degrees for Harda to 22.35 degrees for Chakrimakri and 22.57 degrees for Bheraha. Frequency distribution and area under different slope categories also shows the southern basins to be more rugged. Frequency distribution of slope categories in Bheraha and Chakrimakri are twice that of Chure and Harda (Table 4a).

The sample basins diverge widely in terms of area under various slope categories (Table 4b). Very steep (over 60 %) slopes exceed more than a third of the area of southern basins, Chakrimakri and Bheraha (Fig. 5). In Chakrimakri, it accounts for 38.9 percent of the basin area. Another 21.2 percent has a slope range of 30 to 60 percent. Very gentle slope, less than 5 percent slope, is confined to the south-east. In Bheraha, over a third of land surface has very steep and another 14 percent has steep slopes. About a quarter of the basin has very gentle slope not exceeding 5 percent slope. The conspicuous features of the basin are level terraces that incline south with a gentle slope.

The northern basins have a high proportion of very gently sloping land (Fig. 5). Land under this slope category is nearly half of the basin in Chure and over one-third in Harda (Table 4b). Area under gentle

Table 4b

a. Area (in percent)	Slope Categories			
	Harda	Churia	Bheraha	Chakrimakri
Very Gentle Less than 5%	36.26	49.19	24.84	18.99
Gentle 5 - 10%	9.96	21.05	12.66	5.65
Moderate				
10 - 20%	16.09	14.91	9.28	7.85
20 - 30%	8.47	4.48	4.85	7.43
Steep				
30 - 60%	15.49	5.43	13.95	21.18
Very Steep				
More than 60%	13.73	4.94	34.42	38.90
	100.00	100.00	100.00	100.00

solpe is one-fifth in Chure and 10 percent in Harda. In Chure, very steep slopes cover less than 5 percent area of the basin in scattered patches on the higher ridge. Harda has 13.7 percent as very steep and 15.7 percent as steep land, mainly along the interfluves.

Erosional Processes

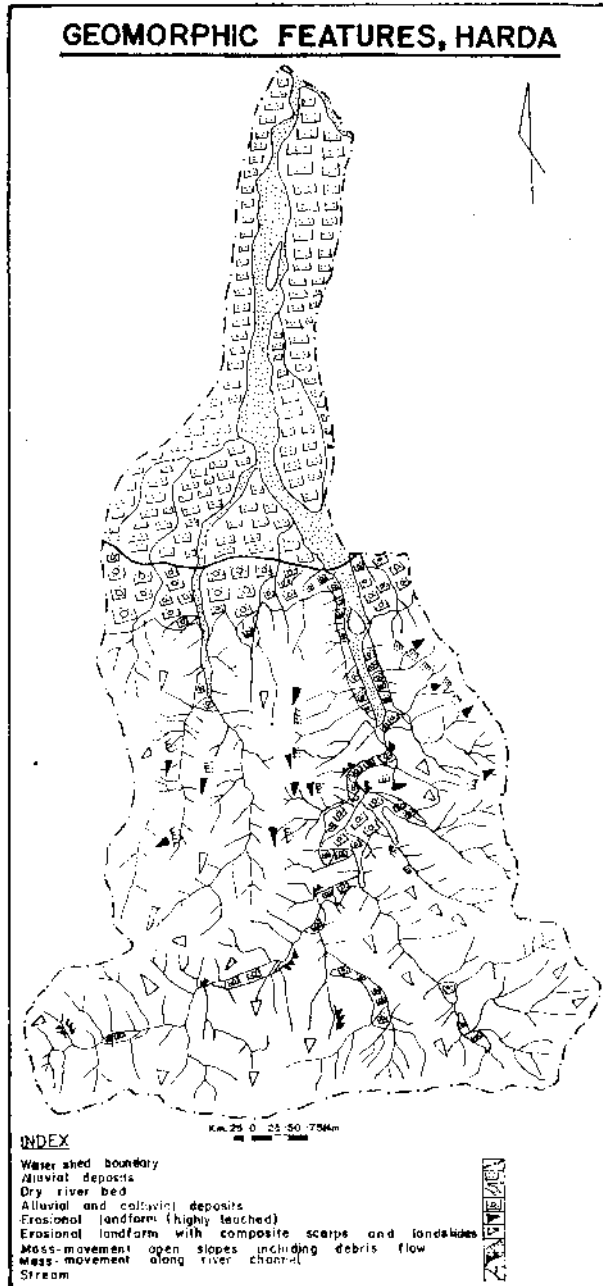
Gravity flow due to high relief is an important geomorphic process in the study area. Since the area lies in tropical humid climate zone, fluvial erosion and chemical weathering are also prominent. Wind is another agent of erosion observed in the area. The main processes have been identified as mass-wasting, surface erosion and fluvial action.

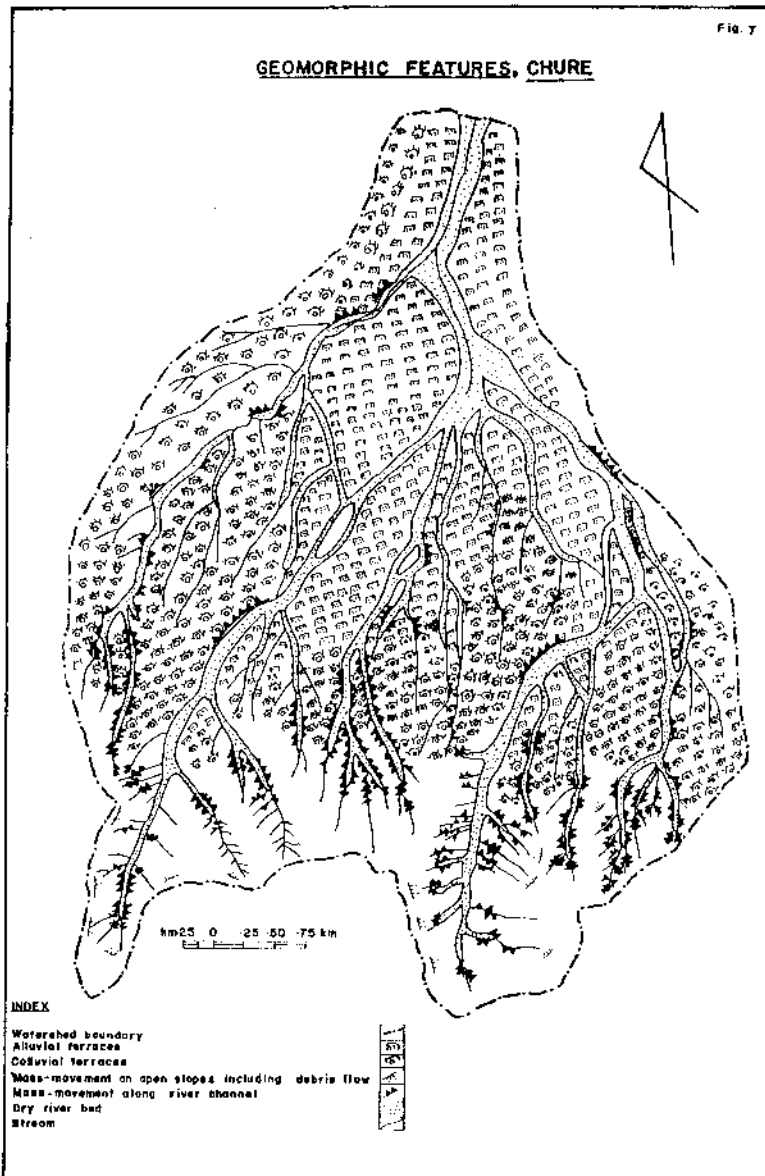
Mass-wasting. Structural scarps due to wrench-faulting are prominent in the sample basins on the south slope. Materials move downslope from these exposed faces. Further, materials composed of pebble, cobble, boulder and sandy silt of the Upper Siwalik are more liable to dislodgement and gravity flow. The process is accelerated by wind action during the dry period and by direct run-off during the monsoon. Besides landslides, too numerous to plot on the map, there also occur slumps on certain hill solpes particularly in the Middle Siwalik series. Immense volume of fresh materials, too large to be transported by the streams even in high flood in the sample basins, indicate a high rate of mass-wasting. Similarly, mass-wasting on open slopes with debris flow is common in all the basins (Fig. 6-9)

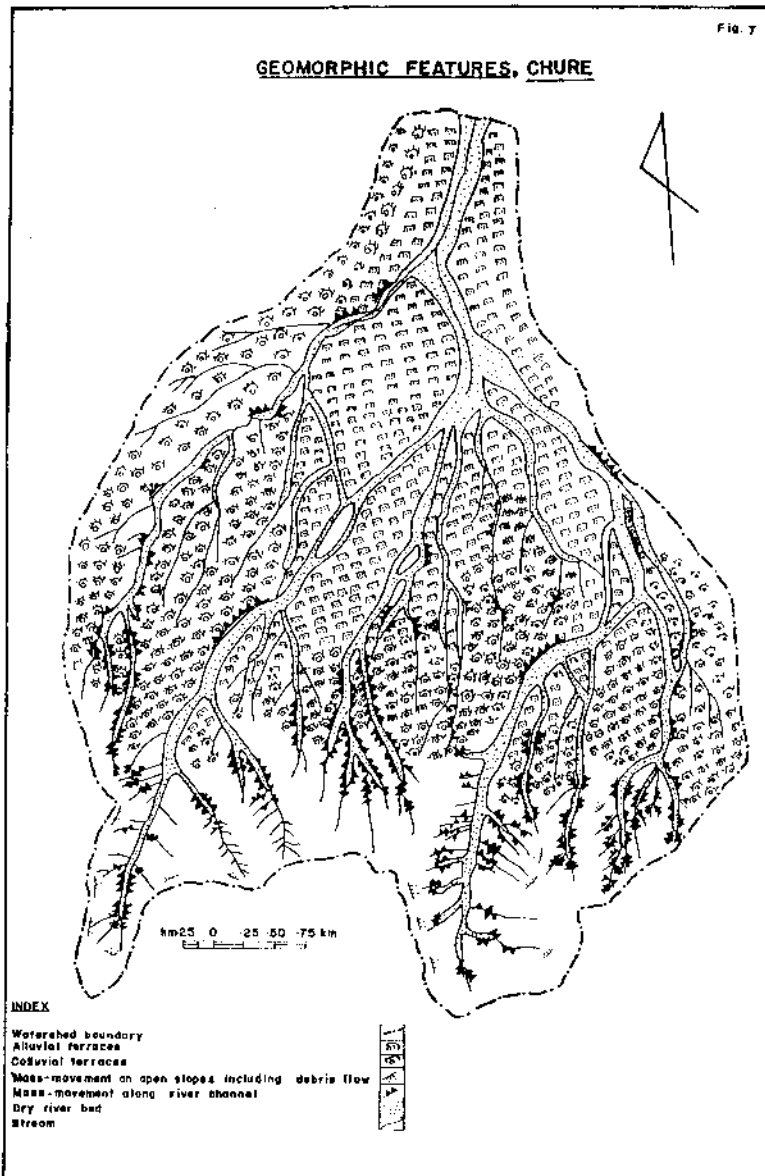
Surface erosion. Structural weakness, tropical weathering and torrential rainfall all contribute to much surface erosion in the sample basins. In numerous localities, the drainage divide is less than 2 to 3 meters wide due to rapid erosion and headward extension of channels. Indirect method was used to assess the rate of surface erosion. Cycus Sp. (Thakal) is one of dominant plant species in the area and its age was estimated with the aid of local informants. Observation of Thakal roots in relation to soil depth indicated the rate of surface erosion to range from 2.11 cm to 4.23 cm/yr. Similarly, the root exposure of mature trees in the Lower Siwalik indicated an average surface erosion rate of 2.50 metres for 75 to 100 years. The minimum rate of surface erosion in the above Siwalik series is estimated to be 2 cm/yr .

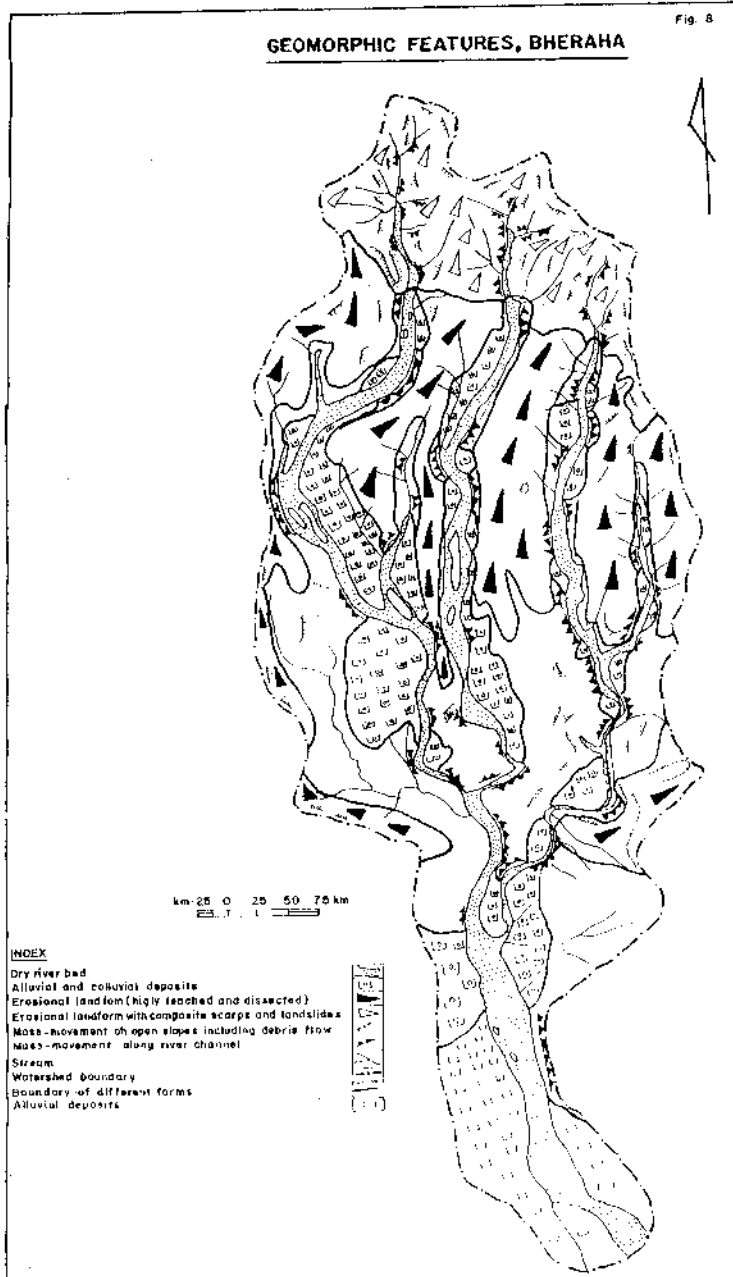
Fluvial action. Lateral corrasion and headward cutting by streams are active processes in the sample basins. Most of the land slips and slides were located near stream banks. In the Chure basin, 40 to 60 landslides were observed along the first order streams. Their average width was about 18 meters. Lateral and headward fluvial erosion were found to be major causes of such slides. Headward erosion and gullying seemed particularly active about 100-200 ft. below the drainage divide. In Harda, landslides are located mainly in the steep fault zone in the south. Though less in number, the landslides are comparatively larger than in other basins. Some of these have become stabilized as indicated by recent vegetation growth. (Figure 12 and 13)

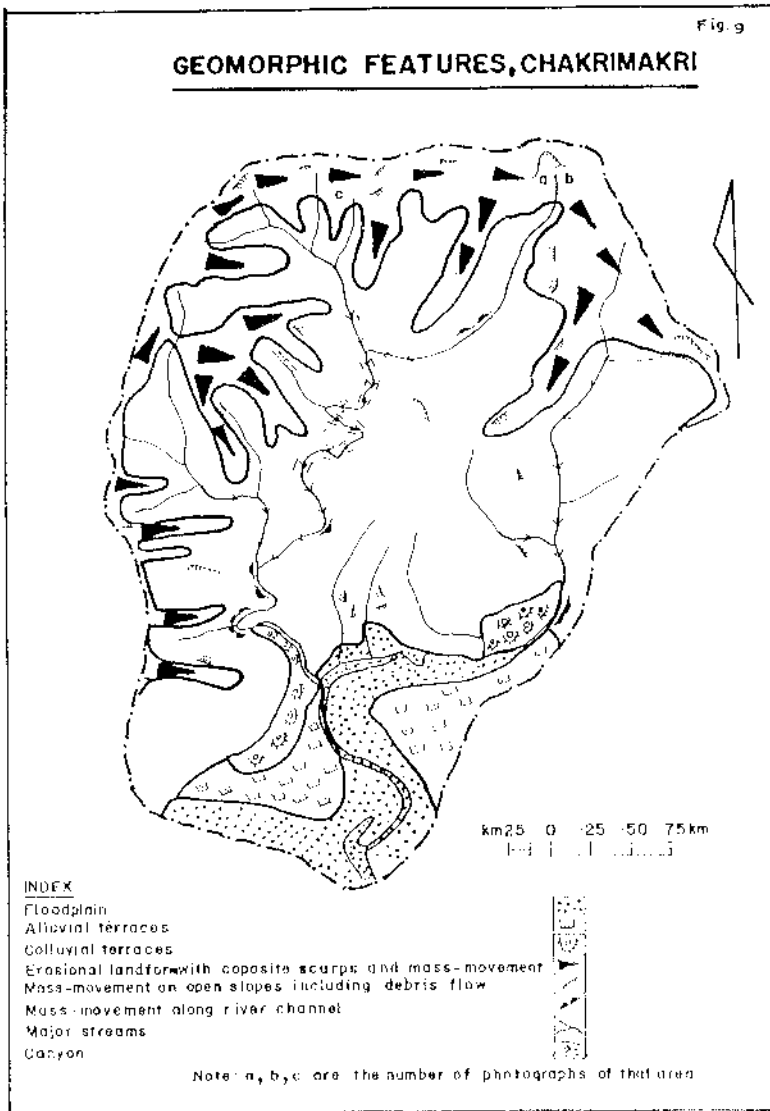
Fig. 6

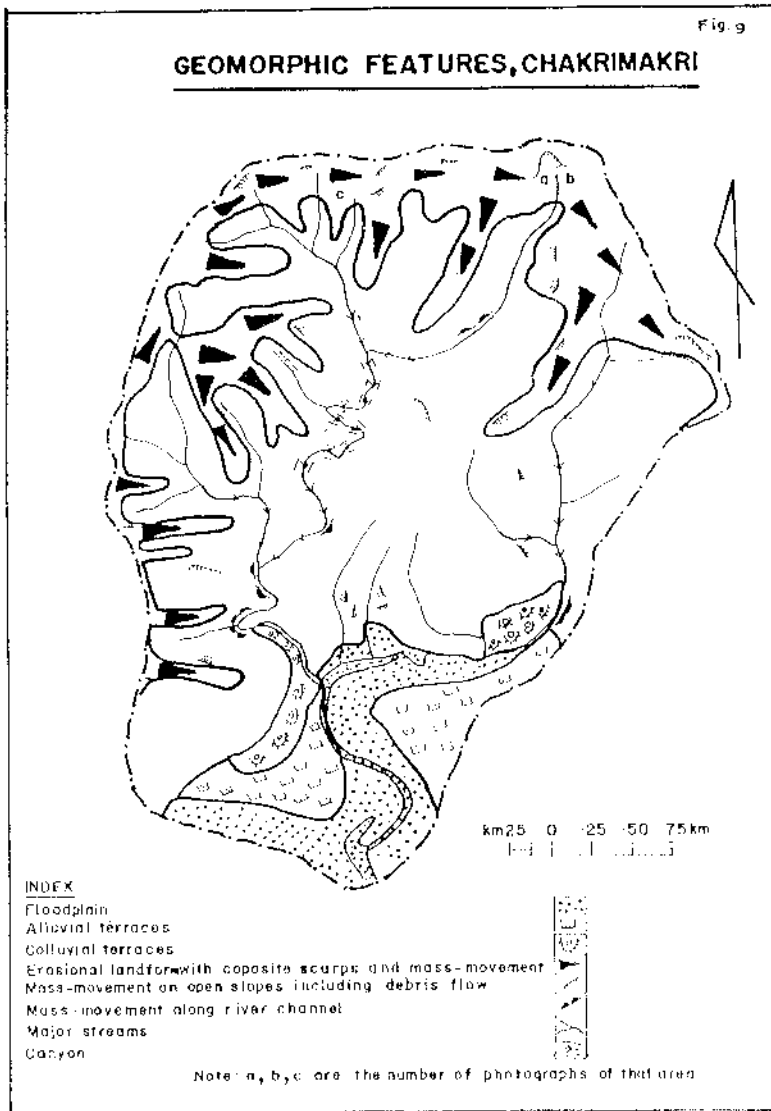


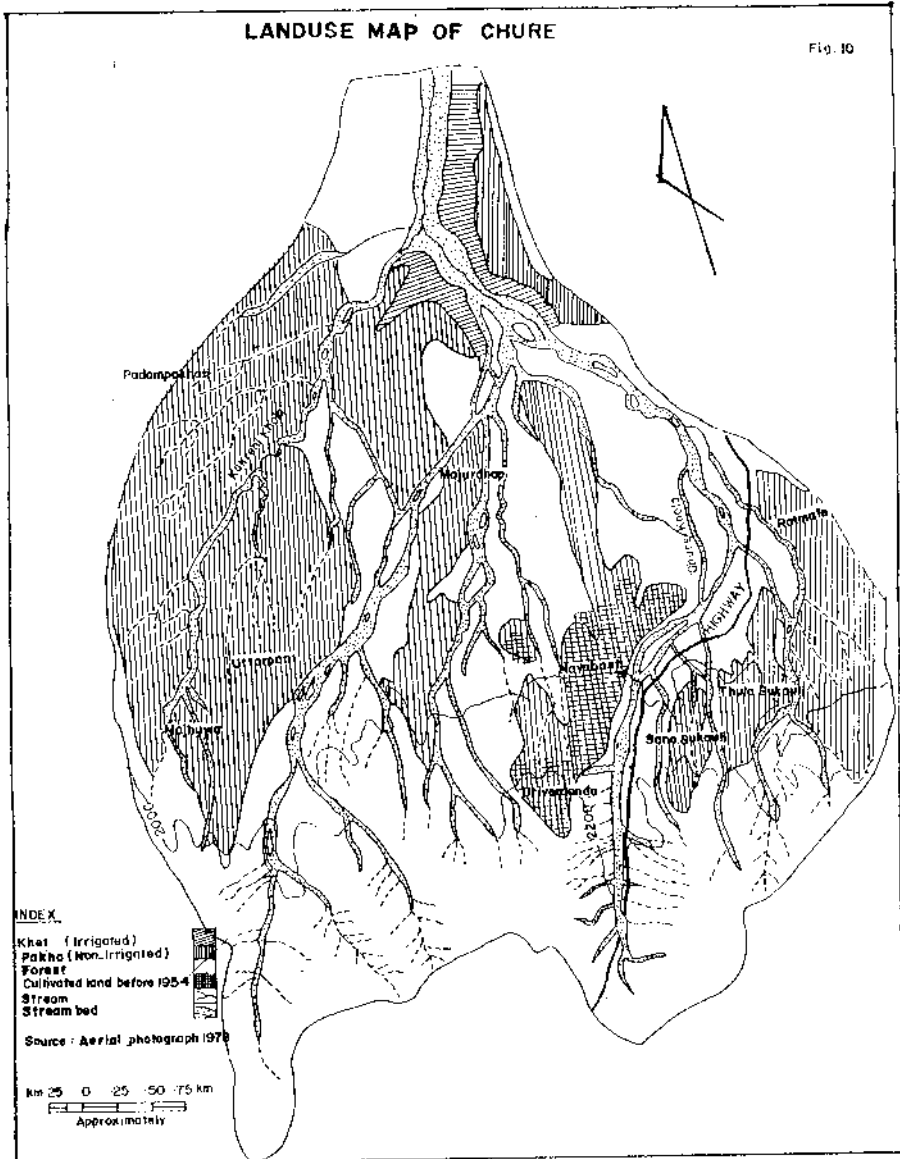


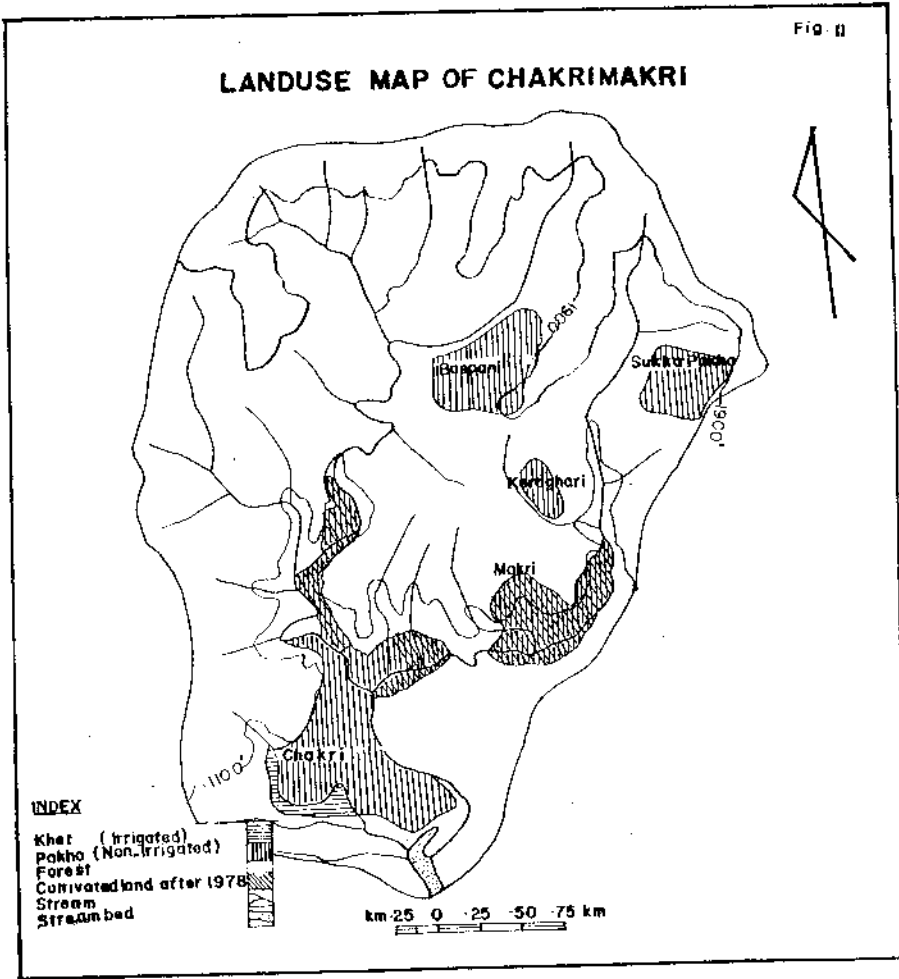














Fallen trees from eroded bank, Harda



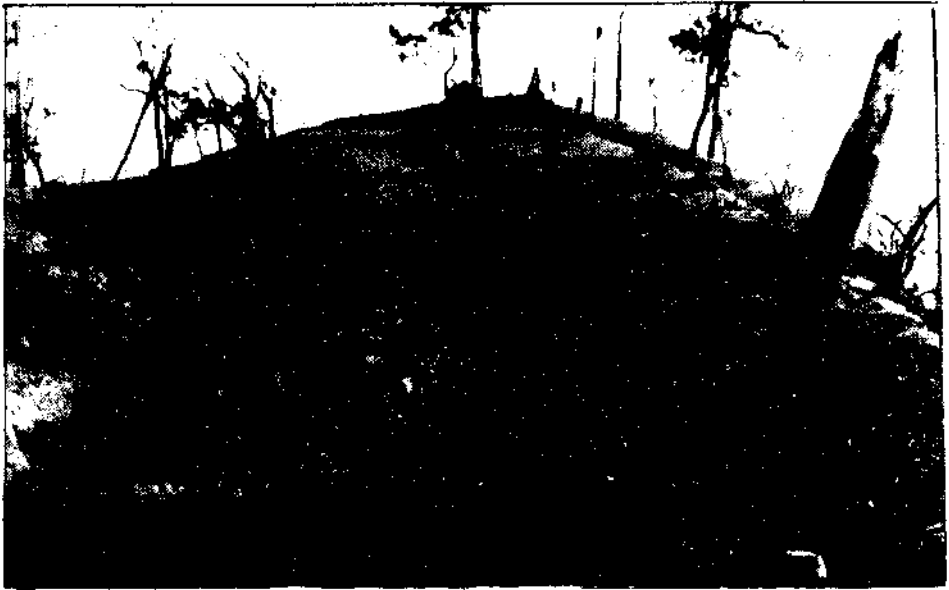
Headward erosion and bank slumping, Chure



Extraction of boulders and pebbles for construction, Chure



New land clearing, Chakrimakri



Clearing on a gently-sloping ridge, Chakrimakri

The two basins on the south side exhibit different aspects in surface erosion. In Chakrimakri, stream channels are very much determined by the bedrock. The channels are in the form of narrow gorges and have steep descent with some waterfalls of 10-15 metres in height. Landslides are rare along the stream channels. However, they are quite common on the higher open solpes that are in the fault zone. (Photographs.....)

In Bheraha basin, 56 landslides were recorded along the Panga tributary. Severe gulying has shaped highly dissected ridges. At places high benches correspond to the level of these sharp ridge. Elsewhere, the remnant of old land surface are retained in the form of columnar needles, similar to inselbergs.

Depositional Forms

For most streams in the study area, velocity of running water decreases within a short distance downstream of the drainage divide (Figs. 2 and 3). This is due both to the change in slope gradient and seepage of water into permeable materials deposited in the river bed. This loss in water velocity contributes to further deposition of materials that are transported downstream during storm periods. In the middle section of the catchment, lateral cutting and deposition takes place simultaneously. In the lower section, depositional process is dominant with channel beds approaching the level of enclosing banks. The principal depositional forms in the sample basins, therefore, are colluvial and alluvial terraces and flood plains.

Terraces. Alluvial and colluvial terraces are significant depositional features in all sample basins except in Chakrimakri (Figs. 6-9). Alluvial and colluvial forms may be distinguished by the finer matrix in the former and latter's proximity to the source area. Older alluvial terraces have vegetal growth and better humus formation. In Harda, both types of terraces have vegetation cover. In Chure basin, colluvial terraces are extensive at the intermediate elevation. These are interspersed with linear extensions of alluvial deposits along the stream banks. In Bheraha, they are prominent along the central axis as linear benches. Colluvials constitute mainly gravels, pebbles, cobbles while the alluvials have a mixture of gravel, sand and silt.

Flood plain. Most of the stream channels in the sample basins have extensive flood plains of gravel, sand and pebbles in their lower reaches. Compared to the narrow defiles in the upper catchment area, the flood plain width is considerable in all basins.

<u>Catchment Area</u>	<u>Flood Plain Width (in m.)</u>			
	<u>Harda</u>	<u>Chure</u>	<u>Bheraha</u>	<u>Chakrimakri</u>
1. Upper	10	5	5	5
2. Middle	20	30	80	10
3. Lower	130	146	183	36
Ratio of 1 to 3	1:13	1:29	1:37	1:7

It is apparent that flood plain width is minimal in the Lower Siwalik series in Chakrimakri basin. In Bheraha, the flood plain width is 50-80 metres in the north (Upper Siwalik) and narrows down to 20-50 metres in the south (Lower Siwalik) and then broadens considerably on reaching the bhavar zone. Thus, it has a high ratio of 1:37 in width between the upper and lower sections. The high ratio between upper and lower flood plain width in Chure in contrast to Harda is mainly due to the exposed land surface and greater sediment discharge in the former basin. The bed materials near the Lower Siwalik is greyish sandy silt. In the Upper Siwalik, it is mostly pebbles, cobbles and boulders. Those in the bhavar and lower section are mostly derived from the more friable Upper Siwalik.

Settlement and Land Use

Settlement

According to local informants, the study area had no human settlement until 1923. It was about the same time that Amlekhganj in the foothills was established as a new settlement for emancipated slaves. Three decades later in 1954, the place had a population of 712 (Statistics Dept. 1957). On the north-side, Chure had a population of 340 and Hetauda only 189, in 1954. Since the initiation of malaria control in 1955 in the area, there has been increasing migration through forest clearance. The main area of settlement has been the north slope between Chure and Bhundrung streams. Further west are settlements of Jametar and Basantpur.

The steeper southern slope has very few settlements. Those in Bheraha and Chakrimakri basin actually represent step migration from the Chure basin. Initially, settlers in Chure basin used the southern slope for animal grazing for about nine months (October-June). In due course, suitable land was cleared for permanent settlement. There are about 180 households in Chakrimakri basin but none have land registration certificate. In Bheraha basin, the occupied lands are within the wildlife reserve boundary.

The population composition of Ratmate village panchayat of Chure basin provide some information on ethnicity and settlement pattern (Table 5).

Of the total 809 households in the six settlements, three-quarter is Tamang that originate in central and eastern hill. Hill Brahmin and Chhetri households are 9.8 percent and Magar from Central hill 7.5 percent. Chepang from nearby hill constitutes 5.8 percent. The rest are Newar traders and Kami occupational caste. In terms of locational distribution, Tamang, Magar and Chepang tribal people are mostly in the higher elevation only with unirrigated land. On the other hand, Brahmin and Chhetri caste groups are located mainly near irrigated lowlands. The Newars are also mostly in the lower settlements. The spill-over migrants from Chure to Chakrimakri are mostly Tamang from the upper settlements.

Table - 5

Village	Household Composition by Ethnic Caste Groups						Total
	Brahmin and Chhetri	Tamang	Mager	Chepang	Newar	Kami	
1. Uttarpani	15	235	-	-	-	-	250
2. Driverdanda	-	-	35	20	-	-	55
3. Nayabasti	-	120	25	20	-	-	165
4. Majurdhap	60	20	-	-	7	5	92
5. Sano Sukauli	-	40	-	7	-	-	47
6. Thulo Sukauli	4	192	-	-	4	-	200
	79	607	60	47	11	5	809
	(9.8%)	(75.0%)	(7.5%)	(5.8%)	(1.4%)	(0.62%)	(100.0%)

Resource use and Perception

Human activities that directly influence the landscape process in the area are related to use of natural resources. Forest clearance for agricultural settlement is the dominant activity. Slope categories with agricultural land range up to 20 degrees on the northern side and over 30 degrees in the South in Chakrimakri area. Dip slopes are preferred sites including subdued ridge locations. Animal grazing in forest areas is a common activity. Periodic firing of forest land is associated with this later activity. All fuel requirements and fodder for animals are extracted from forests near the settlement. Construction materials for houses are mostly derived from forest. Particularly important are bamboo as structures and Thakal leaves and thatch grass for roofing.

Road access has facilitated commercial use of local resources. Round timber from forests are cut on contract basis for supply to urban areas. After each rainy season, the flood plain is strewn with uprooted trees (jarna) and these are also collected on contract basis for fuelwood. Sabai grass from steep hill slopes are collected for industrial use. Collection of gravels and sand from stream beds for construction purposes is another activity near the highway.

Extraction of natural resources for domestic and commercial purposes have direct influence on landscape processes, particularly in depletion of vegetation cover. But the magnitude of such activities in accelerating natural degradation processes is unknown.

Most of the inhabitants in the study area are migrants from the hills. Their experience of natural processes in the Chure range is not long. The main problems faced in the area are topsoil erosion, lateral stream-cutting and seasonal flooding. Except for flooding in the lower catchment area, the people are familiar with other erosion processes from their hill experience. Owing to linguistic similarity of the settlers with those in Kakani area, (Johnson Olson and Manandhar 1982) the vocabulary relating to physical environment are also the same.

People perceive hazards from natural processes and also the negative effects of deforestation. But they are under compulsion to struggle for

survival in a hostile environment (Gurung, 1982). In a few places, there are check-dams to control erosion and embankment lining for flood control. But these local efforts are negligible in comparison to the scale of natural process of degradation. The marginalised households in the area have neither the necessary social mechanism nor economic resource to combat the problems.

Land Use

Most of the land in the study area is marginal from the point of view of agricultural settlement due to steep slope, poor soil and lack of water supply. Further, an extensive part in the west and south fall under park and reserve jurisdiction with restriction on human activity. Agricultural land is confined to a 24-mile stretch in the north-east and pockets of clearing in the south-east. Those on the north-east are on lower footslopes, alluvial terraces and valley fans while those in the south-east are steeply sloping terraces. The rest of the area is designated as forest land with wide variations in vegetation cover. The species are mostly tropical mixed hardwoods. The lower reaches of the stream channels are choked with gravel, pebble and sand that account for a sizable area.

Among the four sample basins, Harda and Bheraha lie within protected area. The settlements of Khandramali and Harda were relocated elsewhere after the establishment of the Chitawan National Park. However, seasonal grass cutting is still allowed and there are evidences of human encroachment through firing. In Bheraha basin, within the Parsa Wildlife Reserve, there still exist some cattle sheds and the area is used for grazing by the people of Padampokhari to the south.

Comparison of land use over time shows considerable expansion of cultivated area in and around Chure basin. Until 1954, the settled areas were limited to the northern side of the Chure range. These were Gaganpani and Chakrimakri (north) east of Makri Khola, Bhauridanda, Pantale and Padampokhari east of Chakri Khola and Chure-Nayanbasti in Chure basin. There were no cultivated land in Bheraha and Chakrimakri (south) basins. In fact, place-names such as Chakrimakri and Padampokhari south of the range may be attributed to migrants from those earlier settlements in the north.

In Chure basin, there has been considerable expansion of cultivated land. Once confined to a single ridge due west of Chure Khola, cropland now cover all uplands and terraces as far high as 2,200 feet. Once a forested area, the entire sub-basin of Kukhreni Khola now is cropland. The rolling land surface immediately east of the highway has similarly been cleared for cropland. Chakrimakri basin represents an area of recent occupation. New land reclaimed for cultivation are steep slopes near the valley bottom. (Figs. 14, 15 and 16).

The distribution of land use by types is as follows in the two basins outside the protected area :

Table -6

Landuse in Chure and Chakrimakri

(In a sq. mile)

<u>Landuse</u>	<u>Chure</u>	<u>Chakrimakri</u>
1. Irrigated (khet)	.18 (1.79)	.03 (0.63)
2. Un-irrigated (pakho)	3.95(39.34)	.64 (13.45)
3. Dry river bed	.94 (9.36)	.01 (0.21)
4. Forest land	4.97(49.50)	4.08 (85.71)
Total :	10.04(100.00)	4.76 (100.00)

Note : Percentage is given in parenthesis.

Source : Aerial photographs 1978/79 and field verification, 1987.

The total area covered by Chure is more than twice that of Chakrimakri. Forest land constitutes 85.7 percent of land in Chakrimakri and 49.5 percent in Chure. However, the forests are in Chakrimakri, there is much recent clearing of forests for cropland. The remaining forest land are located on steeper slopes and on higher ground (Figs. 10 and 11).

Agricultural land accounts for 41.1 percent of Chure basin and 14.1 percent of Chakrimakri basin. There are two categories of agricultural land : irrigated (khet) and unirrigated (pakho). The irrigated land are located in the lower catchment area and are well terraced. Direct precipitation, springs and stream channels are sources of irrigation. The major crops are summer paddy, winter wheat and spring paddy of improved variety. Of the total agricultural land in Chure, only 4.4 percent is irrigated land. Irrigated land in this basin is confined to the lower section of the Chure stream (Fig. 10). Irrigated land in Chakrimakri similarly constitute only 4.5 percent of the agricultural land. It is found in the extreme south-west of the basin (Figs. 11 and 14).

Unirrigated land is fairly extensive in both basins. Such land varies from well-terraced to unterraced depending on slope declivity and soil texture. Soils on such land is reddish on the north side Chure and grey sandy-silt on the south side (Chakrimakri). Unirrigated fields on the north side are found on slopes with less than 20 degrees while it exceeds 30 degrees in the south. The major crops on dry fields are summer maize, millet and mustard during winter.

Dry stream beds constitute 9.4 percent of Chure basin and 0.2 percent of Chakrimakri basin. These are virtual wasteland except for collection of construction boulder. The south side of the range including Chakrimakri has considerable area that can be described as badland with intense dissection and leaching.

Conclusion

1. The Chure range is formed by materials deposited from Pliocene to Miocene period brought from the Himalaya. These were later thrust upward by the penetration of northern edge of the Indian plate into the Asian plate. The materials fall in Siwalik system grouped into upper, middle and lower formations. The Upper Siwalik is composed of conglomerates, clays and sandstones. The Middle Siwalik is composed of soft sandstones with bands of hard calcareous sandstone and the Lower Siwalik is composed of medium to fine-grained compact sandstones interbedded with minor siltstones, shales and clays.
2. The average maximum temperature exceeds 36°C in summer and 18°C in winter. Temperature fluctuates between 20°C to 40°C in summer and between 4°C to 24°C in winter. The annual precipitation of this area is between 1500-3200 mm and more than 80 % precipitation occurs from June to September.

Sal (Shorea robusta) is the dominant species in the study area. Pine (Pinus roxburghii), saj (Terminalia tomentosa) and shisoo (Dalbergia sissoo roxb) are the major species on south facing slopes.

Thakal (Cycus sp.), babioo (Eulaliopsis binata) and bamboo (Dendroclamus hamiltonii) are other vegetation components.

3. Most of the rivers fall in the fourth order. The bifurcation ratio in this area is a high 4.95. The average channel slope is 3.29 %. The channel slopes on the southern side is comparatively higher (19.16 %) on the upper section of the catchment. The average length of the first order streams ranges from .17 to .37 miles and the average length of second order streams ranges from .33 to .63 miles. The average length of third order streams is .86 miles in Harda, 1.84 in Chure and 3.53 miles in Chakrimakri. Drainage density in the four sample locations ranges from 3.04 miles/sq. mile in Chakrimakri area to 5.74 miles/sq. mile in Harda. Both stream frequency, relief ruggedness is higher in Harda and Bheraha than in Chure and Chakrimakri area. The texture of topography of Harda and Bheraha is coarse to medium whereas Chakrimakri has coarse topography. The geological structure and basin shape seem major controlling factors in relief ruggedness.

Most of the rivers in the study region are seasonal. Water is available only from June to September and the flood in the streams remains only 2 to 4 hrs in the summer. Both the surface runoff and sediment discharge from the hillslopes are very high.

4. The elevation of the study area ranges from 720 ft. near Harda to 2750 near Bheraha. The elevation of the Chure range from the

adjoining plain is higher in the west than in the east. The width of the Chure is from 5 to 10 miles with an average of 7.69 miles. Only a small portion (2.15 %) of the total studied area is above 2,200 ft. The basin shape of Harda and Bheraha is elongated and more rounded for Chure and Chakrimakri. The average slope of Harda and Chure on the northern side is comparatively lower than that of Bheraha and Chakrimakri located in southern side. Both the frequency and area under steep slope to very steep slope is higher on the south side than on the north side.

Mass-wasting, hillslopes slumping, surface erosion, and vertical as well as lateral cutting of the rivers are the major geomorphic processes in the area. However, landslides are common along the river banks and fault scarp on the southern side. Surface erosion is the dominant process on the hillslopes specifically in Chakrimakri and Chure. Very high rate of surface erosion (2.11 cm to 4.23 cm per year) is estimated in these areas. River corrosion is another important erosion process. About 40-60 landslides are located within half an mile distances along some river banks. The main reason for the initiation of these landslides is the headward as well as lateral cutting of the streams.

In the middle part of the catchment where the height of the bank is higher than the channel bed, both deposition and lateral cutting by streams occur. In the lower part of the catchment, where the channel bed is at the same height as the bank, deposition is the main process. On the northern side, there are extensive terraces of alluvial and colluvial deposits produced by erosional as well as depositional processes.

5. The process of change in land use in the Chure range is not very old. Increasing population migration from hills and mountains after malaria control was the main factor of change in land use. Harda and Bheraha basins are within the protected areas, still human activities such as grazing in Bheraha and bamboo cutting and babio (*Eulaliopsis binate*) collection in Harda continues. Irrigated khet land is located in the lower part of the catchment areas. The proportion of irrigated terraces to the total area is very low. The major crops on khet land consist of summer paddy, wheat and winter paddy. Maize, millet, wheat, mustard and beans are the major crops on nonirrigated pakho. More than half of the total land is forest land. However, the density of forest is very low near human settlement. There are no specific areas for animal grazing and all the accessible hill slopes have been used for grazing. There is quite a large area of widely leached, dissected and barren surfaces on the southern side of the Chure range. The area occupied by dry river beds ranges from .22 percent in Chakrimakri area to 9.36 percent in Chure area.

6. Tamang, Magar and Chepang are the major ethnic groups in the upper part of the catchment area. Brahmin, Chhetri and Newar are in lower part of the catchment. More than 75 percent of the total households in Chure area are Tamang. The major resource use activities in these areas include frequent forest fire, collection of fodder fuelwood, and timber, grazing, forest clearance for agricultural land and removal of gravels from the river beds. The experience of the people regarding geomorphic processes and damages in the area is recent. Most of the vocabulary relating to physical environment used in the hills are also used in this area. People do have knowledge of geomorphic processes and damages based on their experience from the hills but their efforts to mitigate seems very limited.
7. There are significant change in land use in the two settled sample sites. In Chure area, land under cultivation changed from .26 sq. miles in 1954 to 4.13 sq. miles in 1979. In Chakrimakri area new field terraces have been created from forest land. In a few cases, irrigated khet land has been converted into dry pakho land due to decreasing water table and increasing flood events, specifically in Chure area.
8. The present study in the Chure area is based on a short period of field work. One of the main objectives of this study was to identify the major geomorphological process that are responsible for the transformations of landscape. There is need for a more in-depth study of geology, geomorphology, hydrology, forestry, and socio-economic aspects of the area. The following are the aspects recommended for further investigation.
 - (a) Mass-movement on open slopes and along the river banks by measuring the volume of materials that are deposited on the foot of the slopes. Another important aspect is the retreating rate of the cliff both on landslide head of walls and stream banks. In order to quantify this process, regular monitoring is necessary.
 - (b) The rate of surface erosion and denudation processes need to be studied by monitoring hillslope lowering and sediment discharge from the catchment area. Similarly, sites for monitoring water and sediment (both suspended and bed load materials) are necessary to obtain data on water and sediment discharge.
 - (c) The ratio of precipitation and runoff need to be calculated to develop mathematical models for run-off and sediment discharge.
 - (d) Vegetative growth and succession are other important aspects that influence geomorphic processes. Thus vegetative change and indicative successional processes have to be examined in sample transects.

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- (e) Socio-economic condition and perception of the people in mitigating the natural hazards is another aspect. In-depth study on the change in population and use of resources is necessary for full understanding of human impact on natural processes.
- (f) The duration of investigation for the above aspects should be at least one year. Financial provisions for necessary scientific equipments are essential for conducting the study.

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