IS 14496-2 (1998): Guidelines for preparation of landslide - Hazard zonation maps in mountainous terrains, Part 2: Macro-zonation [CED 56: Hill Area Development Engineering]

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भारतीय मानक

पर्वतीय भूभाग में भू-स्खलन आपदा के समक्ष क्षेत्रीय मानचित्रों की तैयारी के लिए मार्गदर्शी सिद्धान्त

भाग 2 स्थूल क्षेत्रीय

Indian Standard

PREPARATION OF LANDSLIDE HAZARD ZONATION MAPS IN MOUNTAINOUS TERRAINS — GUIDELINES

PART 2 MACRO-ZONATION

ICS 07.040

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

March 1998 **Price Group 8**

FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hill Area Development Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

The mountainous terrains such as Himalaya are generally characterised by steep slopes, high relative relief, weathered, fractured and folded rocks with unfavourable hydrogeological conditions. The implementation of development schemes like road, dam, building construction, etc, often cause heavy environmental damages if the existing instabilities are not adequately accounted for.

A landslide hazard zonation (LHZ) map divides the land surface into zones of varying degrees of stability, based on the estimated significance of causative factors in inducing instability. If such multi-purpose terrain evaluation maps are used as a basis of preliminary planning of the development schemes, it will help to select geo-environmentally sound sites which may pose minimum hazards of instability. The LHZ maps are prepared based on the basic causative factors of slope instability. The LHZ maps are useful for the following purposes:

a) To identify and delineate unstable hazard-prone areas, so that environmental regeneration programmes can be initiated adopting suitable mitigation measures, and

b) To help planners to choose favourable locations for citing development schemes, such as, buildings, dam and road constructions. Even if the hazardous areas can not be avoided altogether, their recognition in the initial stages of planning may help to adopt suitable precautionary measures.

The Sectional Committee responsible for formulation of this standard decided to formulate this standard into three parts to cover different scales of mapping to cover different extents of details as required depending on the type and stage of various projects. This standard (Part 2) 'Macro-zonation', covers the scale of the order of 1 : 25 000 or 1 : 50 000; the other parts of the standard are as follows, which are under preparation:

Part 1 Mega-regional (covering a scale of 1 : 50 000 or more), and

Part 3 Micro-regional (covering a scale of 1 : 1 000 or 1 : 2 000).

In the formulation of this standard, assistance has been derived from Mountain Risk Enginerring Handbook.

The composition of technical committee responsible for the formulation of this standard is given at Annex B.

Indian Standard

PREPARATION OF LANDSLIDE HAZARD ZONATION MAPS IN MOUNTAINOUS TERRAINS — GUIDELINES

PART 2 MACRO-ZONATION

1 SCOPE

This standard (Part 2) covers guidelines for preparation of macro-zonation landslide hazard zonation (LHZ) map on scale of the order of 1:25 000 or 1 : 50 000.

NOTE — The map shall be prepared by superimposing the terrain evaluation maps in a particular seismic zone such as lithological map, structural map, slope morphometry map, relative relief map, land use and land cover map and hydrogeological condition map using landslide hazard evaluation factor (LHEF) rating scheme and calculating the total estimated hazard (TEHD). However, the limitations of the methodology are external factors, which are difficult to account for being not easily determinable with particular reference to landslides, such as flood-prone area, cyclone-prone area and snow avalanches, permafrost, etc.

2 REFERENCES

The following Indian Standards contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
7422	Symbols and abbreviations for use in geological maps, sections and subsurface exploratory logs :
(Part 1) : 1974	Part 1 Abbreviations
(Part 2) : 1974	Part 2 Igneous rocks
(Part 3) : 1974	Part 3 Sedimentary rocks
(Part 4) : 1985	Part 4 Metamorphic rocks
(Part 5) : 1992	Part 5 Line symbols for formation contacts and structural features

3 FACTORS CONSIDERED FOR MACRO-ZONATION LHZ MAPS

3.1 The primary factors that govern the selection parameters for macro-zonation LHZ mapping shall include the major causative factors of the slope instability, namely, lithology, structure, slope morphometry, relative relief, land use and land cover, and hydrogeological conditions. The stability of an area depends on the combined effect of the factors indicated above.

3.2 The smallest unit of study shall be slope facet. A slope facet is a part of hill slope which has more or less similar characters of slope, showing consistent slope direction and inclination. The slope facets are generally delimited by ridges, spurs, gullies and rivers.

4 LANDSLIDE HAZARD EVALUATION FACTOR (LHEF) RATING SCHEME

4.1 The LHEF rating scheme is a numerical system which is based on the major causative factors given in **3.1**. The maximum LHEF ratings for different categories are determined on the basis of their estimated significance in causing instability (*see* Table 1).

Table 1 Maximum LHEF Rating for Different Causative Factors for Macro-Zonation

(*Clause* 4.1)

Sl No.	Causative Factor	Maximum LHEF Rating
i)	Lithology	2
ii)	Structure	2
iii)	Slope morphometry	2
iv)	Relative relief	1
v)	Land use and land cover	2
vi)	Hydrogeological condition	1

4.2 A detailed LHEF rating scheme showing the ratings for a variety of sub-categories of individual causative factors, is given in Table 2, which is based on the criteria given in **4.2.1** to **4.2.6**.

4.2.1 *Lithology*

4.2.1.1 The erodibility or the response of rocks to the processes of weathering and erosion shall be the main criteria in awarding the ratings for the sub-categories of the lithology. The rock types such as unweathered quartzite, limestone and granite are generally hard and massive and more resistant to weathering. These form steep slopes. In comparison, terrigenous sedimentary rocks are more vulnerable to weathering and erosion.

Table 2 Landslide Hazard Evaluation Factor (LHEF) Rating Scheme

(*Clause* 4.2)

Contributory Factor (1)	Description (2)	Category (3)	Rating (4)	Remarks (5)
a) LITHOLOGY	i) Rock Type	*Type* 1		*Correction Factor for Weathering*
		Quartzite and limestone	0.2	i) *Highly weathered* — Rock discoloured, joints open with weathered products, rock fabric altered to a large extent — Correction factor C_1
		Granite and gabbro	0.3	
		Gneiss	0.4	
		Type 2		
		Well cemented terrigenous sedimentary rocks dominently sandstone with minor beds of clay stone	1.0	ii) *Moderately weathered* — Rock discoloured with fresh rock patches, weathering more around joint planes, but rock in-tact in nature — Correction factor C_2
		Poorly cemented terrigenous sedimentary rock dominently sand rock with minor clay shale beds	1.3	iii) *Slightly weathered* — Rock slightly discoloured along joint planes, which may be moderately tight to open, intact rock — Correction factor C_3
		Type 3		The correction factor for weathering to be multiplied with the fresh rock rating.
		Slate and phyllite	1.2	*For Rock Type* 1 $C_1 = 4$, $C_2 = 3$, $C_3 = 2$
		Schist	1.3	
		Shale with interbedded clayey and non-clayey rocks	1.8	*For Rock Type* 2 $C_1 = 1.5$, $C_2 = 1.25$, $C_3 = 1.0$
		Highly weathered shale, phyllite and schist	2.0	
	ii) Soil Type	Older well compacted alluvial fill material	0.8	
		Clayey soil with naturally formed surface	1.0	
		Sandy soil with naturally formed surface (Alluvial)	1.4	
		Debris comprising mostly rock pieces mixed with clayey/sandy soil (Colluvial)		
		—Older well compacted	1.2	
		—Younger loose material	2.0	

(1)	(2)	(3)		(4)
b) STRUCTURE	Relationship of Structural Discontinuity with Slope			
	i) *Relationship of parallelism between the slope and the discontinuity**	I	>30°	0.20
		II	21° - 30°	0.25
		III	11° - 20°	0.30
		IV	6° - 10°	0.40
		V	<5°	0.50
	Planar ($\alpha_j - \alpha_s$)			
	Wedge ($\alpha_i - \alpha_s$)			
	ii) *Relationship of dip of discontinuity* and inclination of slope*	I	>10°	0.3
		II	0° - 10°	0.5
		III	0°	0.7
		IV	0° – (-10°)	0.8
		V	> (-10°)	1.0
	Planar ($\beta_j - \beta_s$)			
	Wedge ($\beta_i - \beta_s$)			
	iii) *Dip of discontinuity**	I	<15°	0.20
		II	16° - 25°	0.25
		III	26° - 35°	0.30
	Planar - β_j	IV	36° - 45°	0.40
	Wedge - β_i	V	>45°	0.50
	Depth of soil cover		<5m	0.65
			6 - 10m	0.85
			11 - 15m	1.30
			16 - 20m	2.0
			>20m	1.20

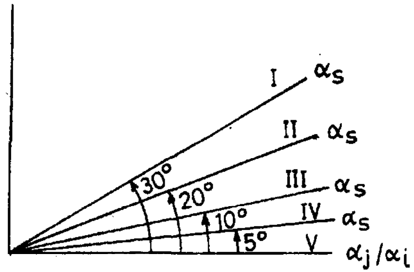
(5)

*Discontinuity refers to the planar discontinuity or the line of intersection of two planar discontinuities whichever is important from the point of view of instability.

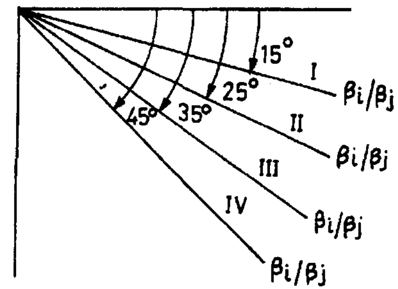
α_j = Dip direction of joint
α_i = Direction of line of intersection of two discontinuities
α_s = Direction of slope inclination

β_j = Dip of joint
β_i = Plunge of line intersection of two discontinuities
β_s = Inclination of slope
β_j/β_i = β_j or β_i

Category I = Very favourable
II = favourable
III = fair
IV = unfavourable
V = very unfavourable



PARALLELISM BETWEEN THE SLOPE AND THE DISCONTINUITY [$\alpha_j/\alpha_i - \alpha_s$]



DIP OF DISCONTINUITY [β_i/β_j]

RELATIONSHIP OF DIP OF DISCONTINUITY AND THE INCLINATION OF SLOPE [$\beta_j/\beta_i - \beta_s$]

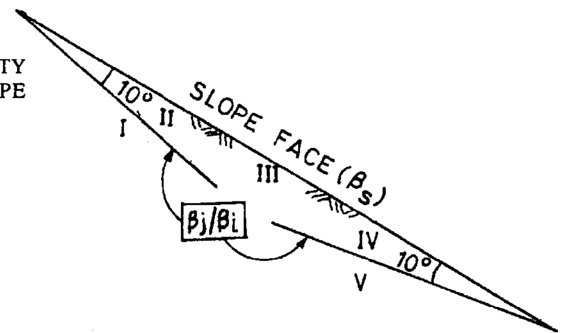


Table 2 — *Concluded*

(1)	(2)	(3)	(4)	(5)
c) SLOPE MORPHOMETRY	i) Escarpment/cliff	>45°	2.0	No. of contour lines of 20 m interval over 10 mm length (1 : 50 000) — Slope angle >25 — >45° 19 - 25 — 36° - 45° 13 - 18 — 26° - 35° 8 - 12 — 16° - 25 ≤7 ° — ≤15°
	ii) Steep slope	36° - 45°	1.7	
	iii) Moderately steep slope	26° - 35°	1.2	
	iv) Gentle slope	16° - 25°	0.8	
	v) Very gentle slope	≤15°	0.5	
d) RELATIVE RELIFF	i) Low	<100 m	0.3	NOTE — In regions of low seismic activity (1, 2 and 3 zones), the maximum rating for relative relief may be reduced to 0.5 and that of hydrogeological conditions be increased to 1.5 (Table 1). Accordingly the detailed ratings of these contributory factors (Table 2) may be multiplied by 0.5 and 1.5 respectively. For seismic zones 4 and 5, no corrections are required.
	ii) Medium	101 - 300 m	0.6	
	iii) High	>300 m	1.0	
e) LAND USE AND LAND COVER	i) Agricultural land/ populated flat land		0.6	
	ii) Thickly vegetated forest area		0.80	
	iii) Moderately vegetated area		1.2	
	iv) Sparsely vegetated area with lesser ground cover		1.5	
	v) Barren land		2.0	
f) HYDROGEOLOGICAL CONDITIONS				
	i) Flowing		1.0	
	ii) Dripping		0.8	
	iii) Wet		0.5	
	iv) Damp		0.2	
	v) Dry		0.0	

The phyllites and schists are generally more weathered close to the surface. Accordingly the LHEF ratings shall be awarded. A correction factor on the status of weathering of rocks shall also be incorporated.

4.2.1.2 In case of soil materials the genesis and age are the main considerations in awarding the ratings. The older alluvium is generally well compacted and has high strength whereas slide debris are generally loose and have low shearing resistance and erosion resistance.

4.2.2 *Structure*

4.2.2.1 Structure includes primary and secondary discontinuities in the rocks such as bedding planes, joints, foliations, faults and thrusts. The discontinuities in relation to the slope inclination direction has greater influence on the stability of slopes. In this connection the following three types of relations are important:

a) The extent of parallelism between the directions of discontinuity or the line of intersection of two discontinuities and the slope.
b) Steepness of the dip of discontinuity or plunge of the line of intersection of two discontinuities.
c) The difference in the dip of discontinuity or plunge of the line of intersection of two discontinuities to the inclination of the slope.

4.2.2.2 The LHEF ratings of the above three categories shall be assigned for various stability conditions. In case of soil, the inferred depth shall be considered for awarding the ratings.

4.2.3 *Slope Morphometry*

Slope morphometry map defines slope categories on the basis of frequency of occurrence of particular angles of slope. The slope morphometry map shall be prepared by dividing the larger topographical map into smaller units within which the contour lines have the same standard spacing, that is, the same number of contour lines per kilometre of horizontal distance. Five categories representing the slopes of escarpment/cliff, steep slope, moderately steep slope, gentle slope and very gentle slope shall be used.

4.2.4 *Relative Relief*

The relative relief map represents the local relief of maximum height between the ridge top to the valley floor measured in the slope direction within an individual facet. Three categories of slopes of relative relief shall be used for hazard evaluation purposes namely low, medium and high.

4.2.5 *Land Use and Land Cover*

The nature of land cover is an indirect indication of the stability of hill slopes. Forest cover in general smoothers the action of climatic agents on the slope and protects them from the effects of weathering and erosion. A well spread root system increases the shearing resistance of the slope material. The barren and sparsely vegetated areas show faster erosion and greater instability. Agriculture in general is practiced in low to very low slopes though moderately steep slopes are also used at some places. However, the agricultural lands represent areas of repeated artificial water charging for cultivation purpose and as such may be considered stable. Based on the criteria of intensity of vegetation cover, the ratings shall be awarded. In thickly populated areas, smaller facets shall be taken.

4.2.6 *Hydrogeological Conditions*

Since the groundwater in hilly terrain is generally channelized along structural discontinuities of rocks, it does not have uniform flow pattern. The observational evaluation of the groundwater on hill slopes is not possible over large areas. Therefore for purposes of quick appraisal the nature of surface indications of water such as damp, wet, dripping and flowing shall be used for rating purposes. The studies shall be carried out soon after the monsoon season. The self-draining slope materials are likely to be dry.

4.3 Other Factors

A 100 m to 200 m strip on either side of major faults, thrusts and intra thrust zones shall be awarded an extra rating of 1.0 to consider higher landslide susceptibility depending upon intensity of fracturing.

5 PROCEDURE FOR MACRO-ZONATION LHZ MAPPING

5.1 The macro-zonation LHZ mapping technique is an approach showing the probabilities of landslide hazards of a watershed area preferably on scales 1 : 25 000 or 50 000. The LHZ mapping shall comprise mainly two components a) desk study, and b) field investigations. The scope of the desk study shall consist of identifying the important parameters with the help of aerial photographs, satellite imageries and toposheets. The study shall involve the preparation of various types of pre-field maps on 1 : 50 000 scale, such as lithological map, structural map, slope morphometry map, relative relief map, rock outcrop and soil cover map, land use and land cover map and hydrogeological map. The already available geological maps/aerial photographs/satellite imageries shall be studied to understand the geological setting of the study area as well as the adjoining areas. The information collected from the desk study helps to plan and execute the field investigations systematically. During field study a more detailed lithological and structural maps shall be prepared. The details of other maps prepared during the desk study could be verified in the field and modified wherever necessary. The field studies shall be carried out to collect the required data facet-wise for estimating the total hazard of the facets. The general procedures of LHZ mapping technique has been outlined in the form of a flow chart (*see* Fig. 1).

5.2 The total estimated hazard (TEHD) indicates the net probabilities of instability and shall be calculated facet-wise, since the adjoining facets may have entirely different stability conditions. The TEHD of an individual facet is obtained by adding the ratings of the individual causative factors of lithology, structure slope morphometry, relative relief, land use and land cover and hydrogeological conditions obtained from LHEF rating scheme.

5.3 The macro-zonation LHZ map of an area is prepared on the basis of TEHD of facets, calculated using the LHEF rating schemes as per the method given in Annex A by following the categories shown in the Table 3.

Table 3 Landslide Hazard Zonation on the Basis of Total Estimated Hazard (TEHD)
(*Clause* 5.3)

Zone	TEHD Value	Description of Zone
I	< 3.5	Very low hazard (VLH) zone
II	3.5 to 5.0	Low hazard (LH) zone
III	5.1 to 6.0	Moderate hazard (MH) zone
IV	6.1 to 7.5	High hazard (HH) zone
V	> 7.5	Very high hazard (VHH) zone

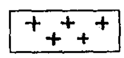
6 PRESENTATION OF RESULTS

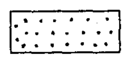
6.1 The results shall have to be presented in the form of maps. The terrain evaluation maps shall be prepared in the first stage showing the nature of facet-wise distribution of parameters. The terrain evaluation maps shall be superimposed and TEHD calculated for individual facets. A macro-zonation LHZ map shall be prepared based on the facet-wise distribution of TEHD values.

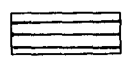
6.2 Symbols for Lithological and Structural Maps

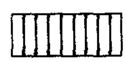
The symbols and abbreviations given in IS 7422 (Part 1), IS 7422 (Part 2), IS 7422 (Part 3), IS 7422 (Part 4) and IS 7422 (Part 5) shall be used for the lithological and structural maps.

6.3 Suggested Symbols for Slope Morphometry Map


Very gentle slope, ≤ 15°


Gentle slope, 16° to 25°


Moderately steep slope, 26° to 35°


Steep slope, 36° to 45°


Escarpment/Cliff > 45°

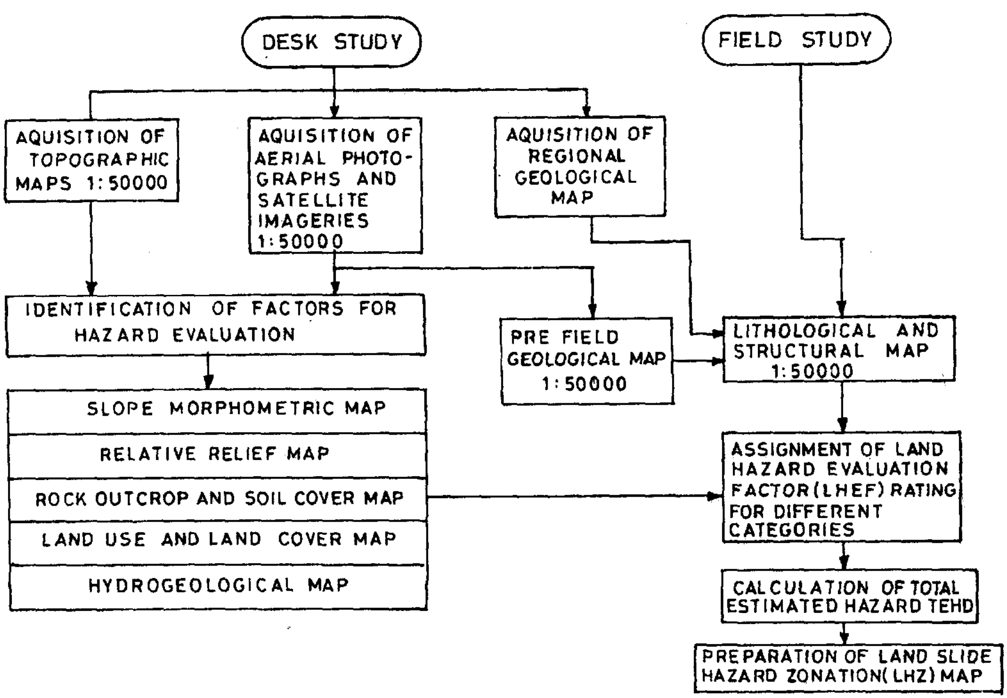


FIG. 1 PROCEDURE FOR MACRO ZONATION LANDSLIDE HAZARD ZONATION (LHZ) MAPPING

6.4 Suggested Symbols for Relative Relief Map

Low relief

Moderate relief

High relief

6.5 Suggested Symbols for Land Use and Land Cover

Agricultural land/populated flat land

Thickly vegetated forest area

Moderately vegetated forest area

Sparsely vegetated area with lesser ground cover

Barren land

6.6 Suggested Symbols for Hydrogeological Conditions

Dry

Damp

Wet

Dripping

Flowing

6.7 Suggested Symbols for LHZ Maps

Very low hazard (VLH)

Low hazard (LH)

Moderate hazard (MH)

High hazard (HH)

Very high hazard (VHH)

7 INTERPRETATION OF MACRO-ZONATION LHZ MAP

7.1 The VLH and LH zones are generally safer for development schemes. The MH zones may contain some local pockets of unstable slopes. Detailed geotechnical investigations shall have to be carried out to identify these pockets so as to adopt proper remedial measures. The HH and VHH zones mostly consist of unstable slopes, which may be active specially in case of VHH zones. Detailed geotechnical appraisals of unstable slope shall be carried out by mapping the slopes on 1 : 1 000 or 1 : 2 000 scales in order to evaluate the nature of instabilities, so that proper precautionary measures could be adopted during construction as well as for evolving appropriate mitigation measures to protect the geo-environmental stability of the area.

8 RISK RATING

The risk to civil engineering structures shall be assessed on the basis of hazard rating, modes of failure (for example, boulder jumping, debris flow, toe erosion, chocked drainage system, meandering of gullies, etc) and type of damage to life and properties.

9 REVISION OF MACRO-ZONATION LHZ MAP

The map shall be revised from time to time specially after every major earthquake (> 5 on Richter's Scale), and major flood, cyclone, developmental activity, mining activity and cloud burst event when the watershed area would have been affected by new landslides.

ANNEX A

(*Clause* 5.3)

DETAILED METHOD FOR PREPARATION OF LANDSLIDE HAZARD ZONATION MAP

A-1 PREPARATION OF THE SLOPE FACET MAPS

Obtain the topographical map of the study area (*see* Fig. 2) and divide it into smaller segments of slope facets (*see* Fig. 3).

A-2 PREPARATION OF PRE-FIELD MAPS

On the slope facet map, a number of the pre-field maps are prepared so that these can be carried to the field, verified and modified wherever required. The geological data from the already available regional scale maps are collected and transferred on the facet map. The slope morphometric map and the relative relief map shall be prepared from the topographical maps. The available information regarding land use and land cover from the topographical maps shall also be transferred to a slope facet map. If aerial photographs or satellite imageries of the area are available, more accurate data on land use and land cover can be obtained. The wet patches on the slopes shall be identified using satellite imageries or aerial photographs and the same shall be transferred on a slope facet map for field validation.

A-3 PREPARATION OF FACTORIAL MAPS

The pre-field maps are carried to the field and they are validated facet-wise. While working on one bank of the river, the facets on the other side are also carefully observed. Using Table 2, individual factorial maps namely lithological map (*see* Fig. 4), structural map (*see* Fig. 5), slope morphometric map (*see* Fig. 6), relative relief map (*see* Fig. 7), land use and land cover map (*see* Fig. 8) and hydrogeological map (*see* Fig. 9) are prepared. For awarding ratings on structures, the observed structural discontinuities are plotted on stereonet and the preferred orientation as well as possible types of failures are also obtained. Moreover the visual stability conditions may be noted for comparison after analysis.

A-4 PREPARATION OF LANDSLIDE HAZARD ZONATION (LHZ) MAP

The LHZ map is prepared (*see* Fig. 10 and **6.2** to **6.7** for symbols) by calculating the total estimated hazard (TEHD) by adding the ratings of all the causative factors within a facet using Table 3. Major roads, important towns and villages shall also be shown on the final LHZ map for the purpose of regional planning.

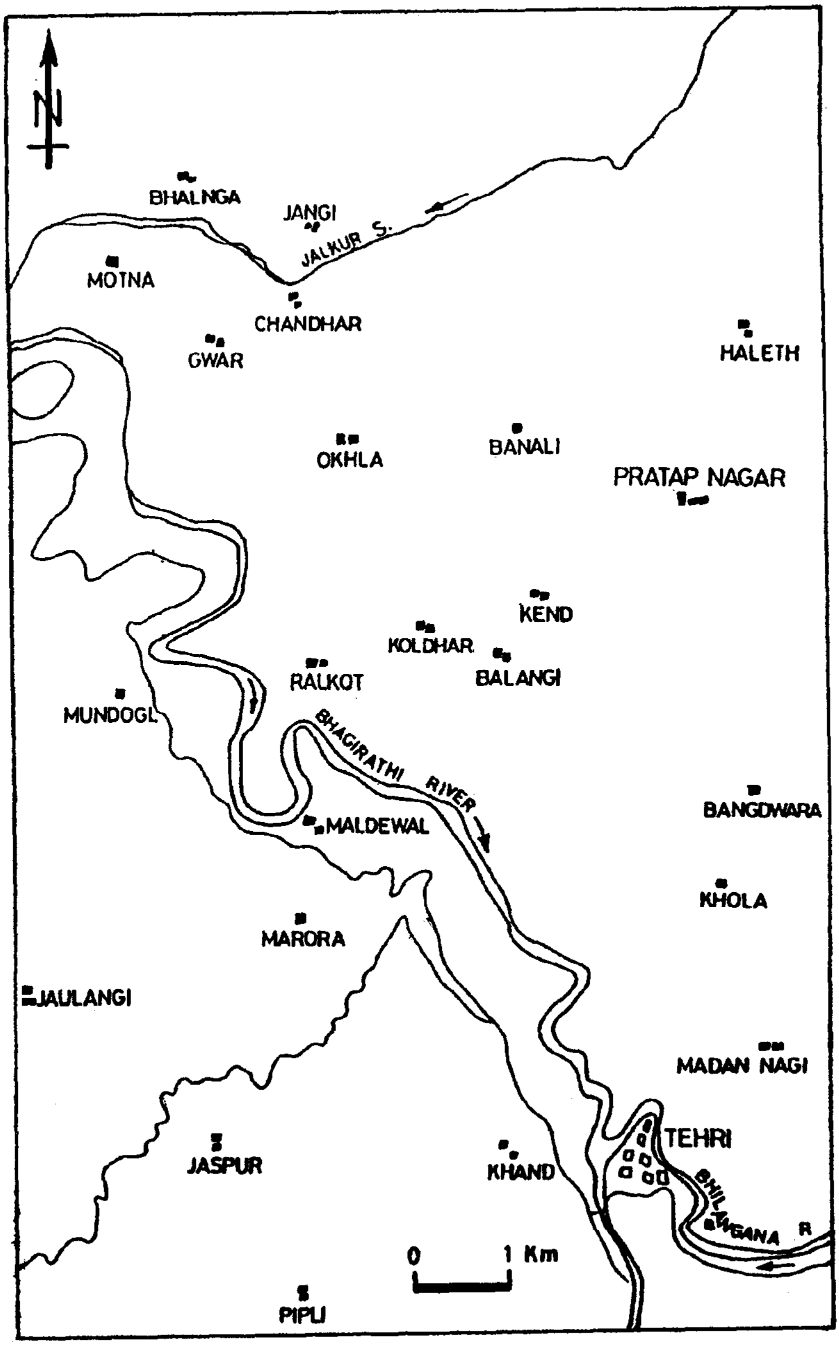


FIG. 2 A TYPICAL LOCATION MAP OF THE STUDY AREA

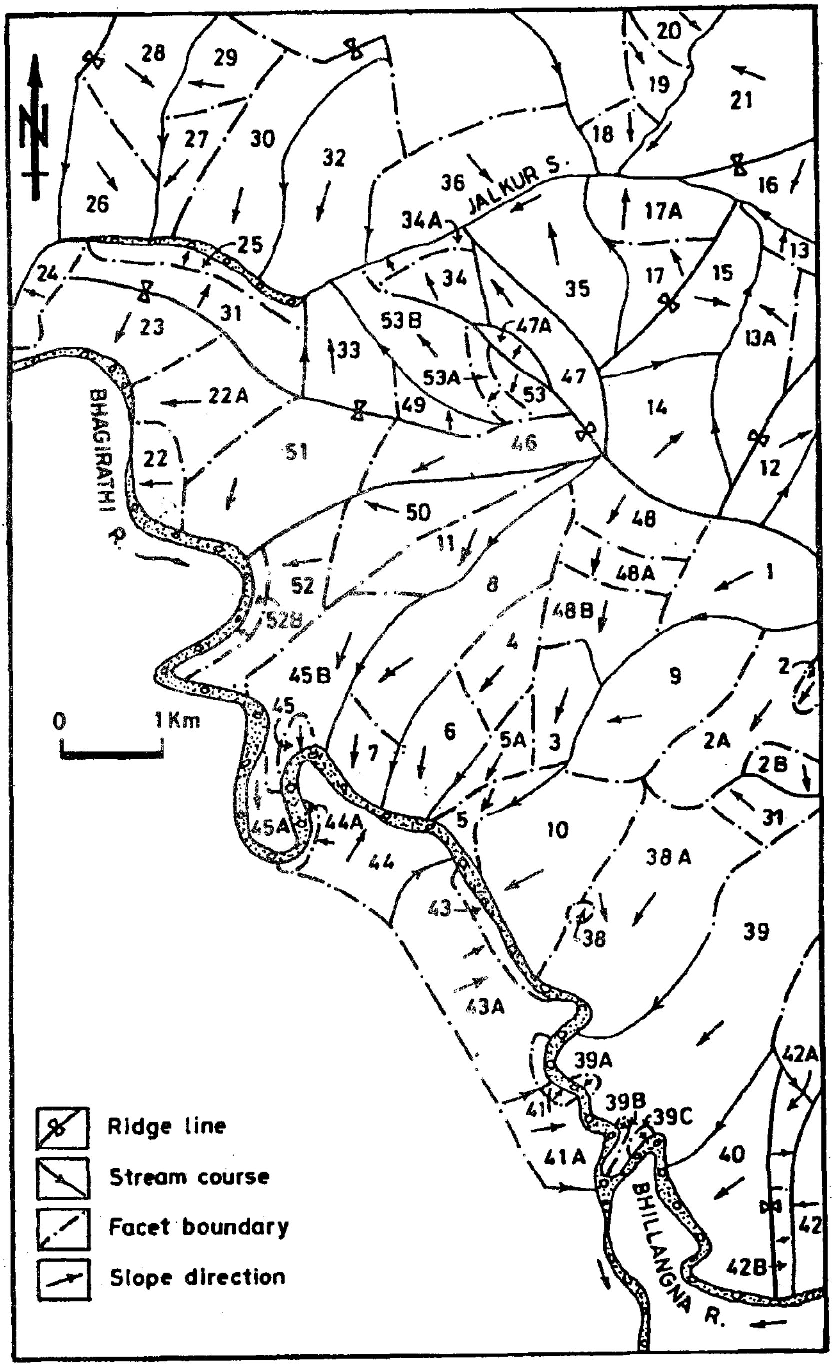


FIG. 3 A TYPICAL SLOPE FACET MAP

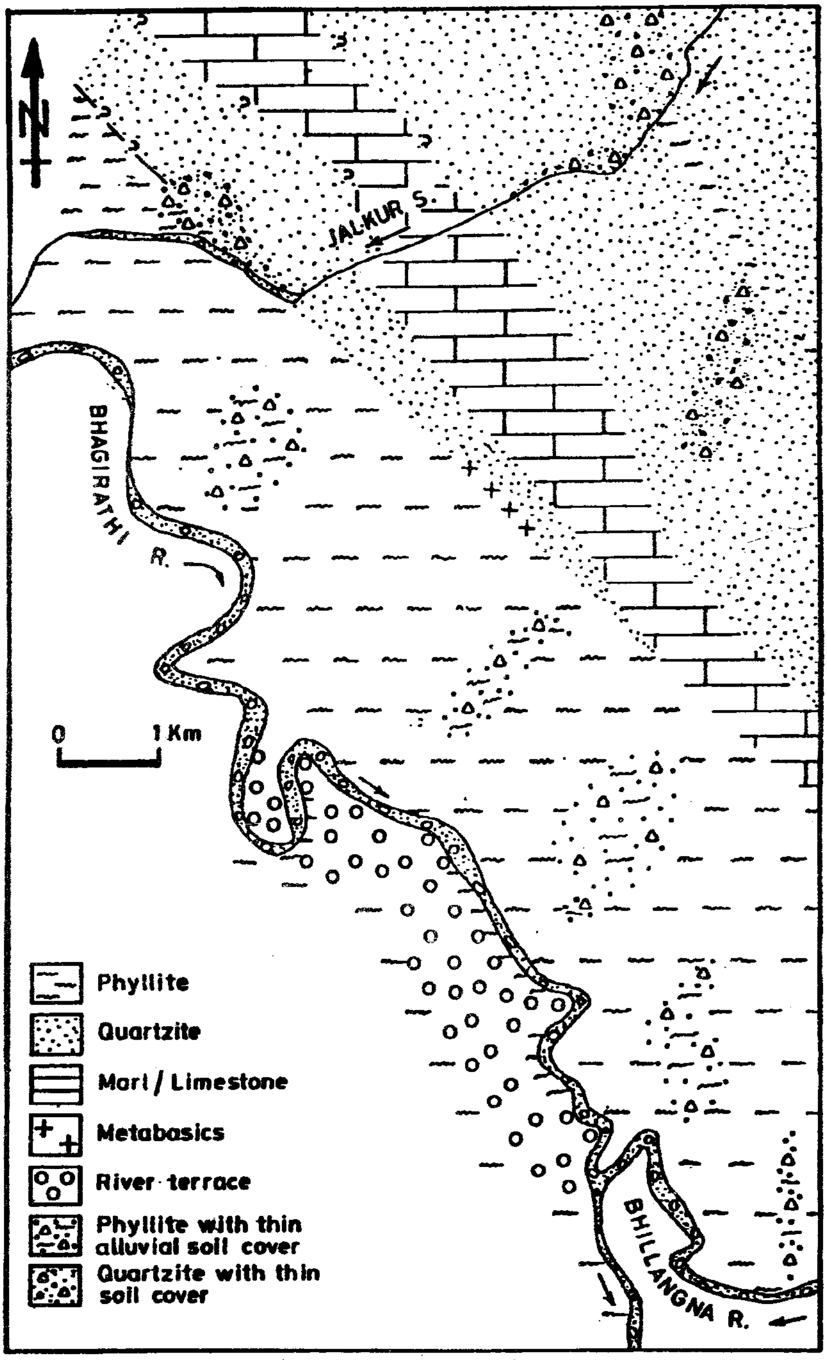


FIG. 4 A TYPICAL LITHOLOGICAL MAP

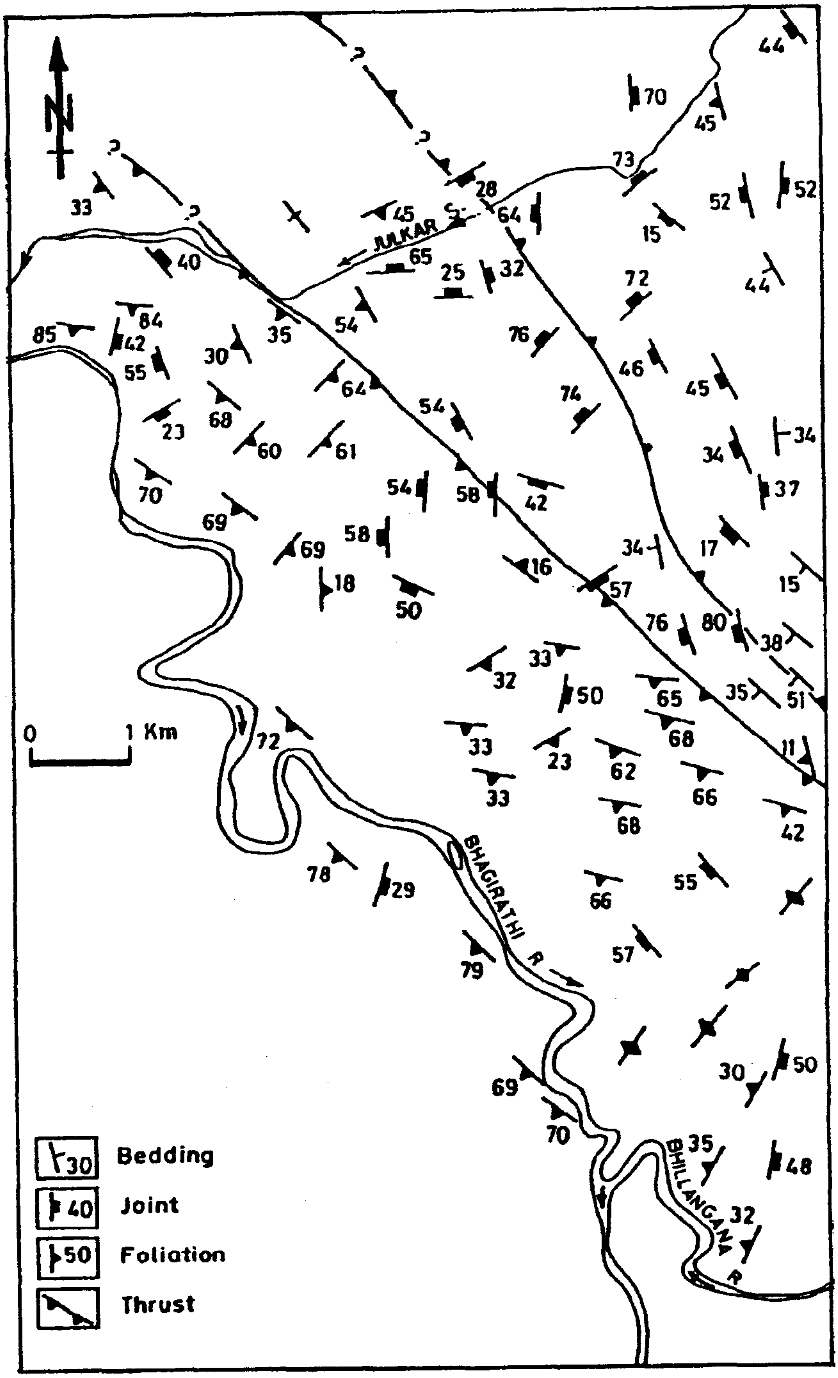


FIG. 5 A TYPICAL STRUCTURAL MAP

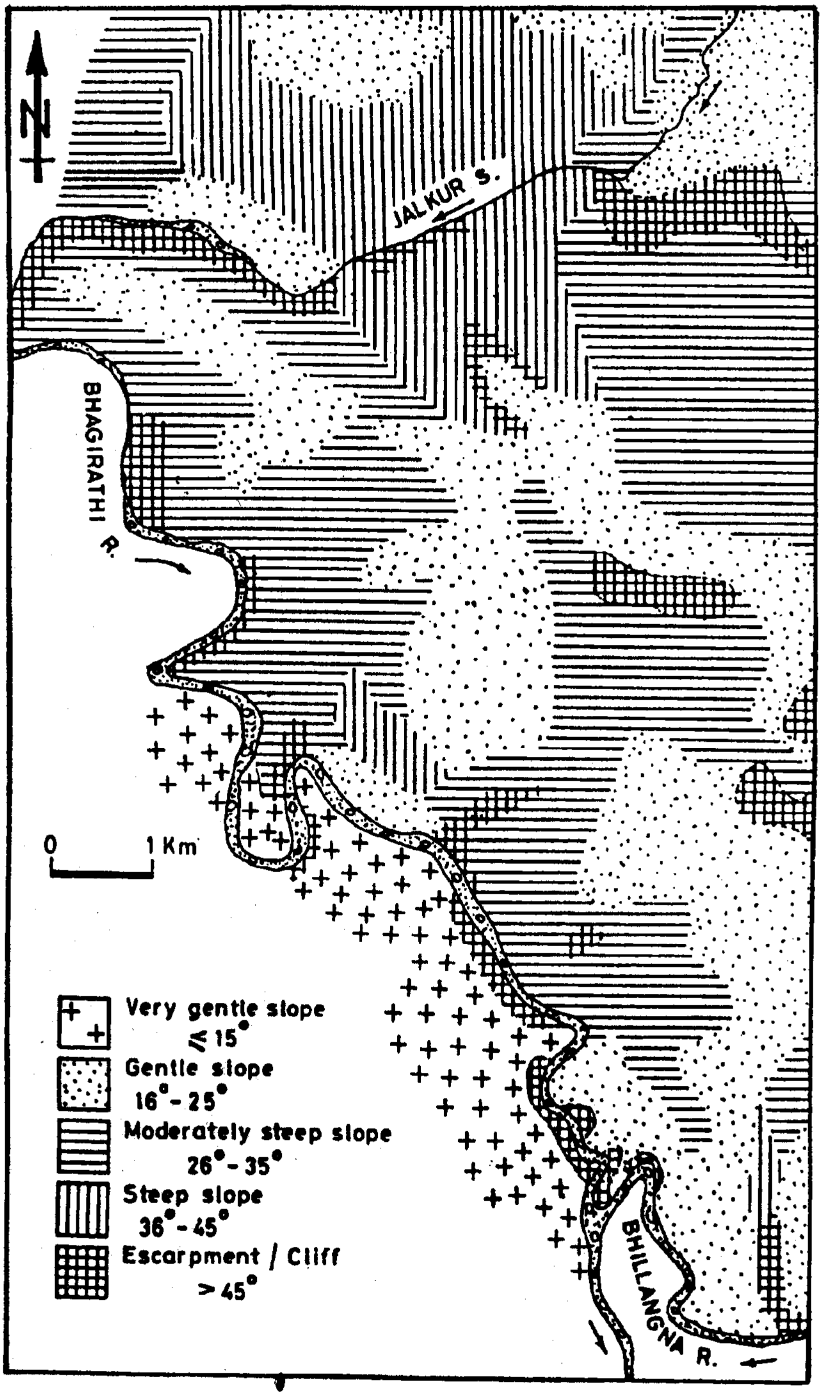


FIG. 6 A TYPICAL SLOPE MORPHOMETRY MAP

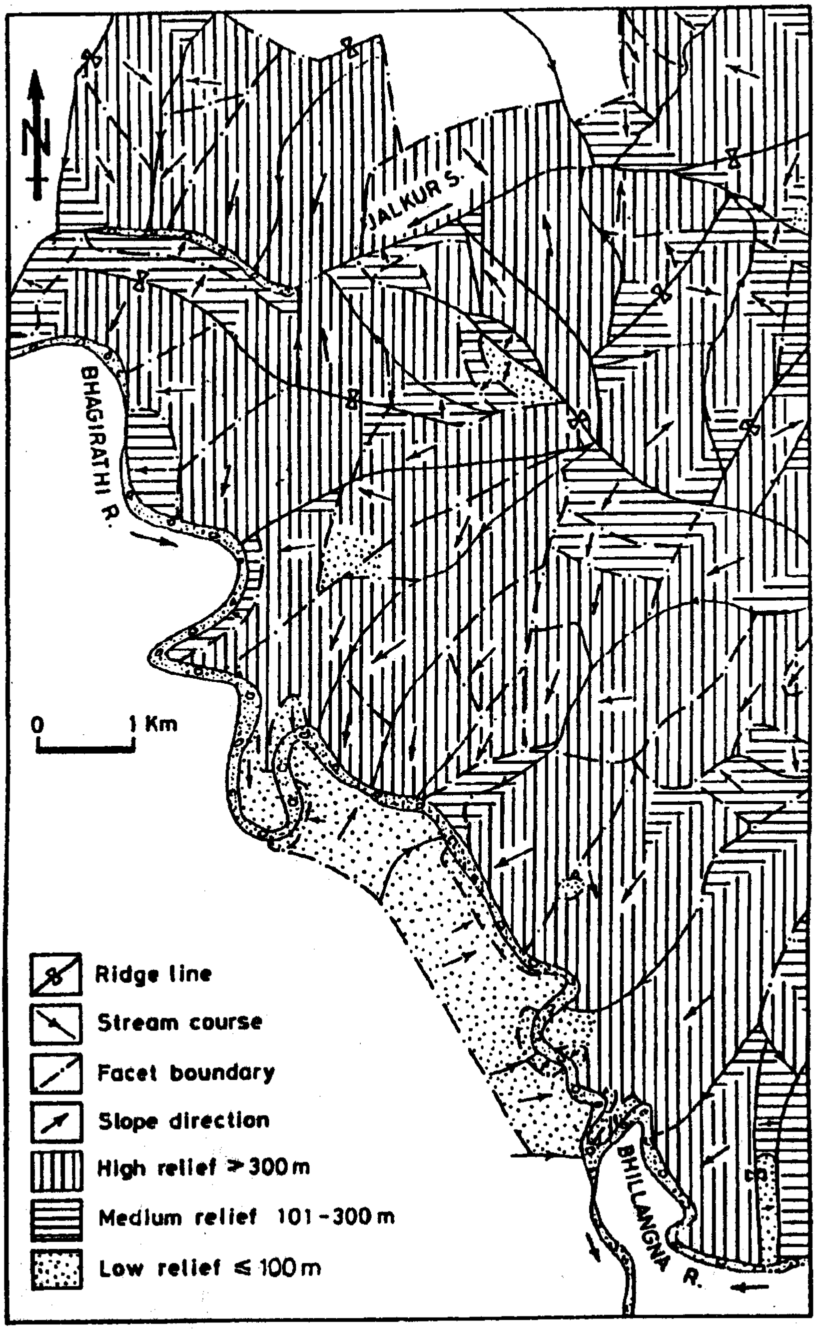


FIG. 7 A TYPICAL RELATIVE RELIEF MAP

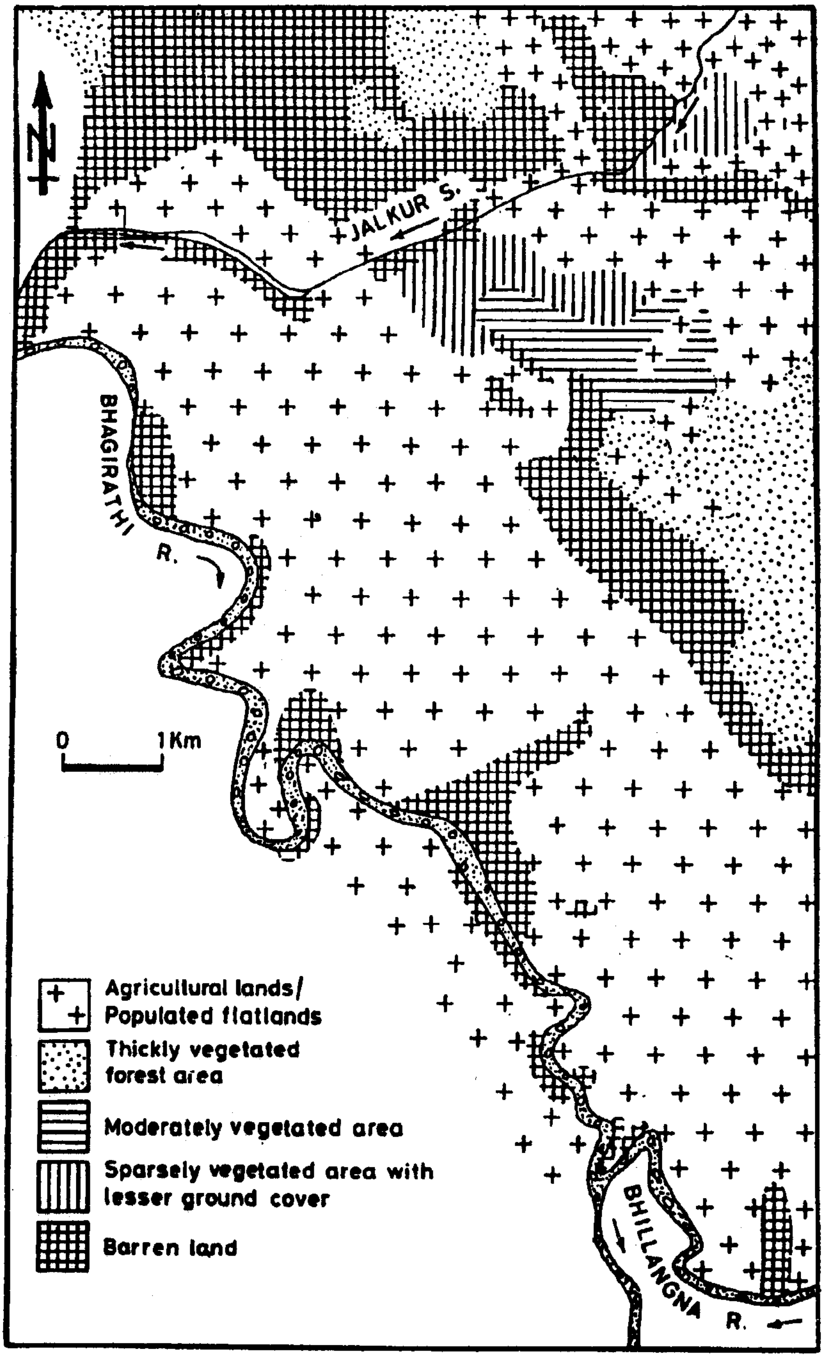


FIG. 8 A TYPICAL LAND USE AND LAND COVER MAP

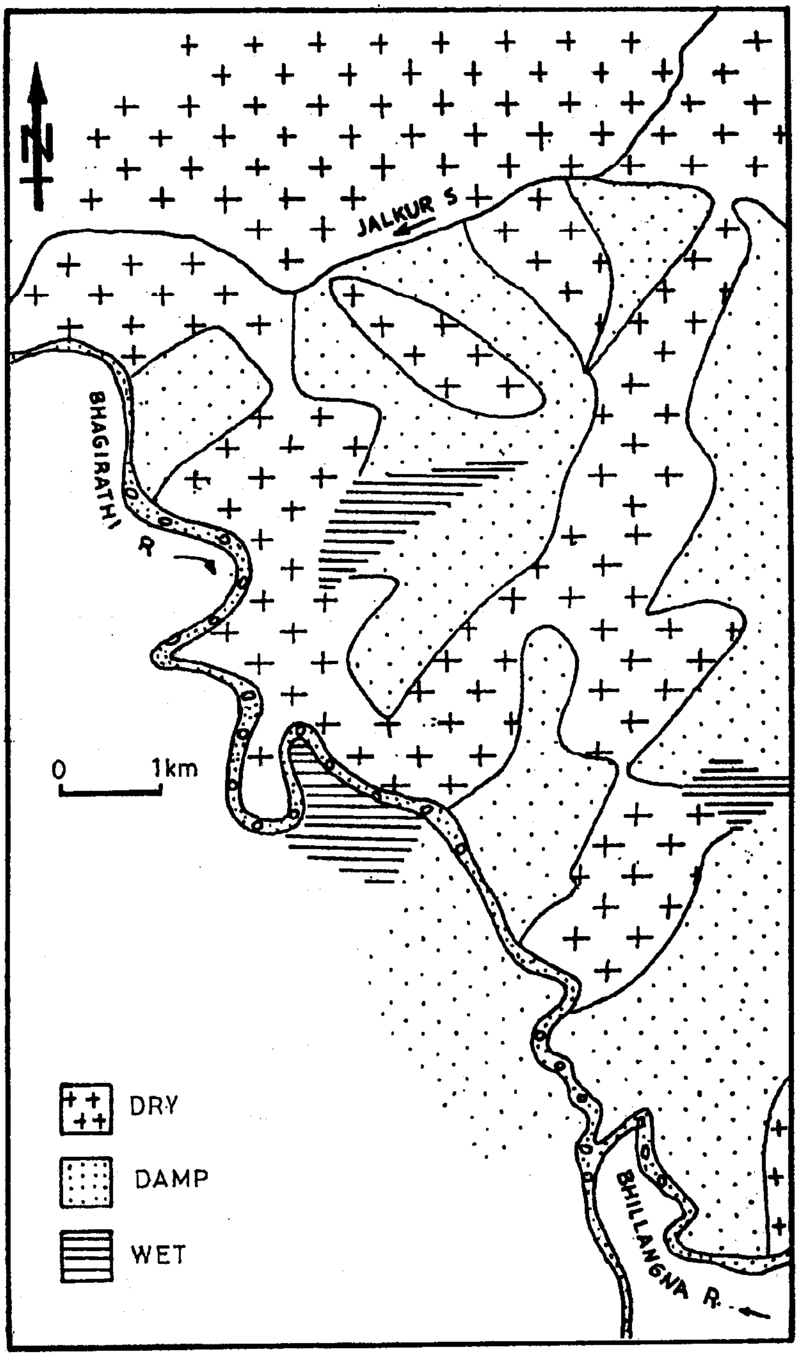


FIG. 9 A TYPICAL HYDROGEOLOGICAL MAP

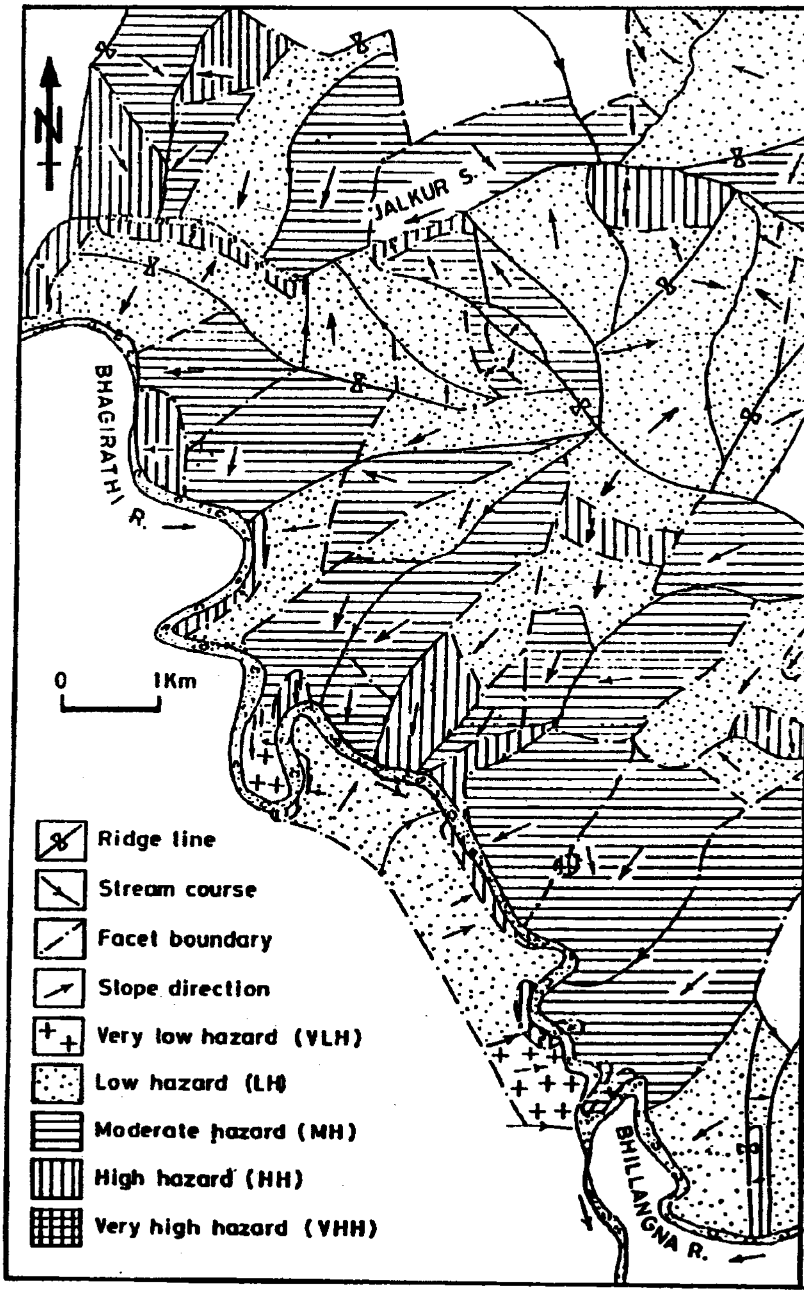


FIG. 10 LANDSLIDE HAZARD ZONATION MAP

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Hill Area Development Engineering Sectional Committee, CED 56

Chairman	*Representing*
DR GOPAL RANJAN	University of Roorkee, Roorkee
Members	
SHRI SHEIKH NAZIR AHMED	Public Works Department, Jammu & Kashmir
PROF A. K. CHAKRABORTY	Indian Institute of Remote Sensing, Dehra Dun
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This Indian Standard has been developed from Doc : No. CED 56 (5493).

Amendments Issued Since Publication

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Printed at Printograph, New Delhi, Ph : 5726847