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Landslide hazards in eastern Himalayas

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ABSTRACT

The Himalayas, with extreme variations in relief, are characterised by very steep slopes. harsh (i.e. cold and humid) climate, and a dynamic geotectonic setting. These characteristics appear responsible for widespread slope failures and mass movements, which are often accentuated by various human activities. The importance and severity of landslide phenomenon was not recognised until recently because of sparse habitation, remoteness of its occurrence, and limited sphere of influence of the individual slides. During the last few decades, increasing developmental activities, such as unplanned urbanisation, communication, dam construction, deforestation, and agriculture, have substantially affected the geo-environment and aggravated the landslide hazard in the eastern Himalayas.

Three sample areas: i) along the National Highway 31A (the East Sikkim District), ii) in the area of the Rammam Hydroelectric Project Stage II (the Darjeeling District), and iii) in the Kalimpong Municipal area (the Darjeeling District), all within the inner tectonic belt of the Lesser Himalaya, were investigated for preparing LHZ maps on 1:25,000 scale. Landslide hazard evaluation factors (LHEF) were rated for each of the major causative factors, namely lithology, structure, slope morphometry, relative relief, land use, and drainage density, and summed up to obtain the total estimated hazard (TEHD) values for each slope facet. The TEHD values from 0 to 10 were classified into five zones of increasing relative hazard.

INTRODUCTION

The Himalayan mountain terrain is unique in its morpho-tectonic environment. Elevated to the astounding height due to collision of the Indian plate with the Tibetan landmass, it exhibits extreme relative relief, the world's steepest slopes, a harsh (i.e. cold and humid) climate, and a dynamic geotectonic setting. It is still rising, resulting in neotectonic and seismic activities. These characteristics are responsible for numerous landslides of various types. The incidence of landslides appears to increase along the valley sides of streams of all orders, communication networks, and along zones of ingress of surface and subsurface water. Random construction of hutments and ploughing along slope crests also initiate slides.

Widespread slope failures and mass movements are believed to have been occurring ever since the formation of the lofty ranges, but the importance and severity of the phenomenon was not recognised until recently because of relatively sparse habitation. Landslides occur in remote and in accessible locations, and individual slides have limited spheres of influence. Unlike the gigantic rockslides in the Alps, Himalayan slides are smaller and shallower, but much more numerous, frequent, and repetitive. During the last few decades, excessive population growth and consequent anthropogenic interference, in the form of developmental activities like unplanned urbanisation, communication, dam construction, deforestation, and agriculture, have greatly aggravated the situation.

In the eastern Himalayas, landslide occurrences are frequent. The magnitude of damage caused annually is large. Most of the damage is caused during the later part of monsoon (August–September), when rainfall intensity may exceed 1 mm per minute.

LANDSLIDE HAZARDS

Amongst all types of natural disasters, landslides cause the highest property losses globally (Jahns 1978). Such losses have been estimated to exceed a billion dollars annually in the USA (Schuster 1978), Japan (personal communication, 1982, of Director, Japanese National Research Centre for Disaster Prevention, to Schuster and Fleming, quoted in Schuster and Fleming 1984), and Italy (Arnould and Frey 1978). Similar damages must be occurring in many other countries.

Most nations are developing landslide damage reduction programmes, e.g. the national programme for landslide control in Japan since 1940s (Japan Society of Landslide 1980), the ZERMOS (Zones Exposed to Risks of Movements of the Soil and Subsoil) plan in France (Humbert 1977). The procedures adopted follow mainly the following aspects:

- understanding geomorphological history of landslide-prone terrains,
- identifying and recording geomorphological characteristics of slopes,

- preparing landslide inventories in the form of reconnaissance and/or detailed landslide incidence maps,
- terrain analyses, and
- landslide hazard zonation mapping (Cooke and Doornkamp 1990).

Indian scenario

Mathur (1982) estimated the annual property losses due to landslides in India to be around 600 million US dollars. The landslides damaged mainly the highways and roads in the Himalayan region. Another sum of 350 million US dollars is lost on account of loss of man and vehicle time due to road blockage.

Landslide hazards in India are being investigated since 1970s (e.g. Sinha et al. 1975; Chopra 1977; Chatterjee 1983; Mazumder 1983; Choubey and Litoria 1990; Gupta and Joshi 1990; Mehrotra et al. 1992, 1993, 1996; Pachauri and Pant 1992), and a few of them cover the eastern Himalayas. Mehrotra et al. (1996) have presented a landslide hazard zonation (LHZ) map of the East Sikkim District based on a landslide susceptibility index calculated in a semi-quantitative way by aggregating the landslide susceptibility values assigned to various terrain factors like lithology, structure, slope, land use, and drainage in relation to existing landslides. The data were collected from 1:50,000 topographical maps, satellite imageries, and field traverses.

PRESENT STUDIES

Present studies were carried out in the following places (Fig. 1):

- between Singtam (27°14' N:88°30' E) and Ranipal (27°17'30" N:88°36' E) along the National Highway 31A in the Rani Khola Valley within the East Sikkim District (45 km^2),
- around Lodhama (27°05'40" N : 88°07' E) in the Rammam Hydroelectric Project Stage II in the Darjeeling District (17 km^2), and
- within the Kalimpong Municipality (27°04' N: 88°28'E) in the Darjeeling District (9 km^2).

The LHZ map on 1:25,000 scale was prepared for the area between Singtam and Ranipul (Ghosh 1997), following the landslide hazard evaluation factor rating scheme proposed by the Bureau of Indian Standards. The Rammam Hydroelectric Project area was studied earlier in relation to the engineering work sites only (Bandyopadhyay 1994). The Kalimpong Municipality area is being studied currently on a larger scale (Adhya 1999).

LANDSLIDE HAZARD ZONATION MAPPING

Following the draft guidelines for preparation of macro-regional LHZ maps on 1:25,000 scale as proposed by the Bureau of Indian Standards in 1995, the area has been classified into 129 slope facets (Fig. 2). The major causative factors considered are lithology, structure, land use, relative relief, slope morphometry, and drainage density. Their maximum landslide hazard evaluation factor (LHEF) ratings are given in Table 1. A detailed LHEF rating scheme worked out for the area for all subcategories of individual causative factors is given in Table 2. The individual factors were

Table 1: Maximum LHEF rating for different causative factors for macro zonation

Contributory factor	Maximum LHEF rating
Lithology	2.0
Relationship of structural discontinuities with slope	2.0
Slope morphometry	2.0
Relative relief	1.0
Land use	2.0
Drainage density	1.0
Total	**10.0**

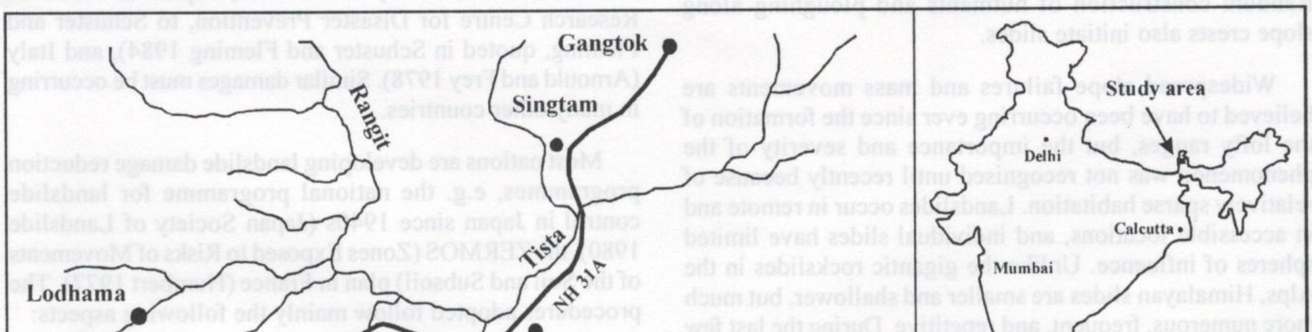

Fig. 1: Location of the study areas

Table 2: LHEF rating scheme

S. N.	Contributory factor	Description	Category	Rating
1.	Lithology	Rock type	Quartzite-phyllite intercalation	1.8
			Schists	1.3
			Quartzite	0.5
			Lingtse Gneiss	0.5
			Terrace	1.0
2.	Structure	i) Dip of discontinuity	<15°	0.20
			16°–25°	0.25
			26°–35°	0.30
			36°–45°	0.40
			>45°	0.50
		ii) Relationship between dip of discontinuity and inclination of slope	>10°	0.45
			0°–10°	0.75
			0°	1.05
			0°–(-10°)	1.20
			>(-10°)	1.50
			Over burden	2.0
3.	Slope morphometry	Escarpment	>45°	2.0
		Steep slope	30°–45°	1.7
		Moderately steep slope	20°–30°	1.0
		Gentle slope	10°–20°	0.5
		Very gentle slope	<10°	0.0
4.	Relative relief	Very low	≤ 100 m	0.1
		Low	100–200 m	0.3
		Medium	200–300 m	0.5
		High	300–500 m	0.7
		Very high	>500 m	1.0
5.	Land use	Barren land		2.0
		Depleted forest cover		1.3
		Dense forest cover		0.8
		Cultivated land (with or without human settlement)		0.6
6.	Drainage density		≤ 2.0	1.0
			2.0–4.0	0.8
			4.0–6.0	0.7
			6.0–8.0	0.5
			>8.0	0.3

mapped independently on 1:25,000 scale using the topographical maps, aerial photographs, existing geological maps, and field observations. Each of these maps was successively overlaid by the facet map to obtain the cumulative total estimated hazard (TEHD) value for each facet. Finally, the aggregate value of the TEHD for the entire area was classified into five classes (Table 3), and shown as the LHZ map (Fig. 3).

Rammam Hydroelectric Project area

Slope failures in this region occur along the Lodhama Valley, the northern sector being comparatively more affected. The valley crests are most unstable. Debris slides are more common than rock falls and soil flows (Fig. 4).

Table 3: LHZ on the basis of TEHD

Zone	TEHD value	Relative hazard level
I	≤3.5	Very low hazard (VLH)
II	3.5 – 5.0	Low hazard (LH)
III	5.0 – 6.5	Moderate hazard (MH)
IV	6.5 – 8.0	High hazard (HZ)
V	> 8.0	Very high hazard (VHZ)

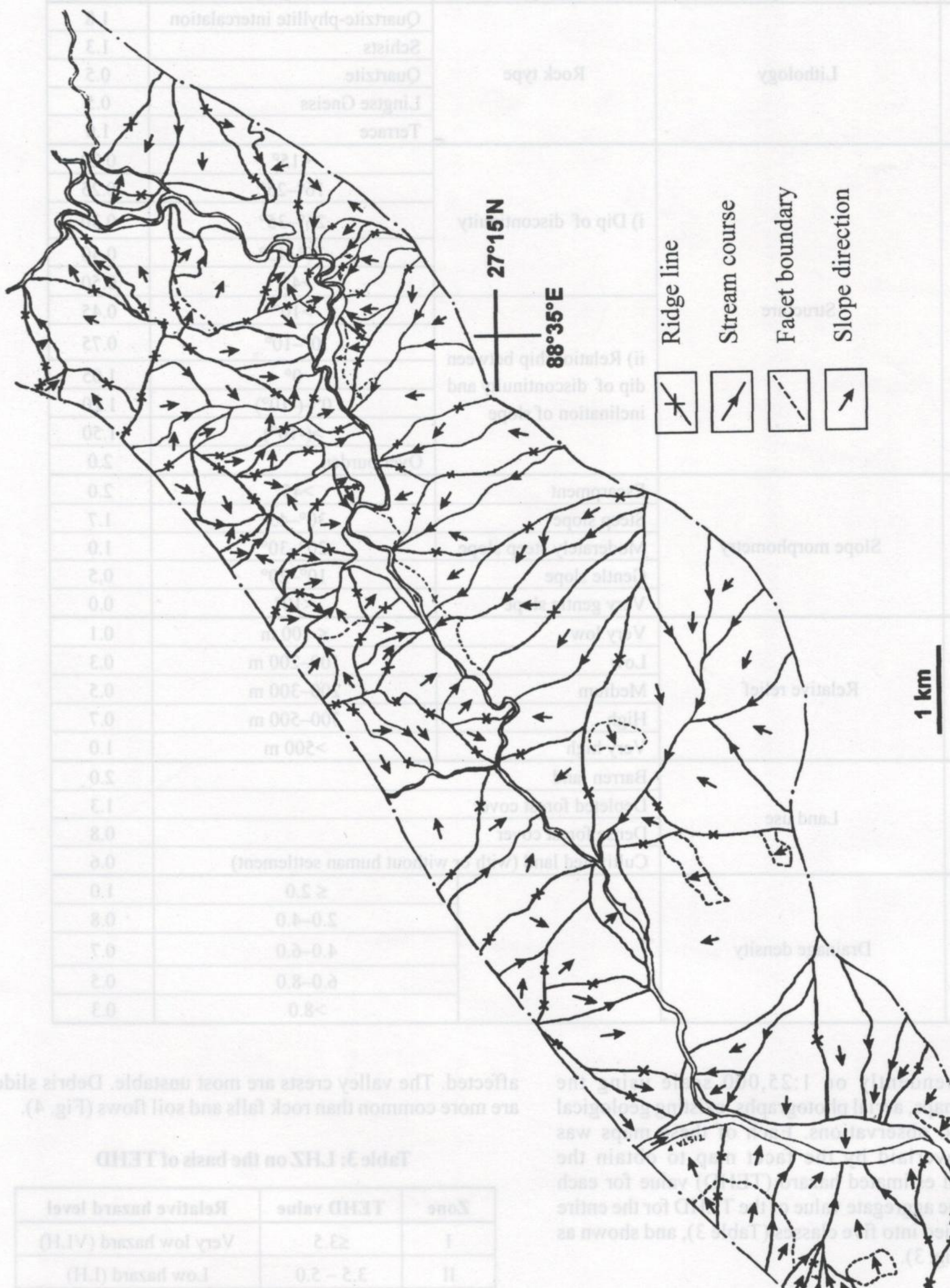

Fig. 2: Facet map of the Singtam–Ranipul area

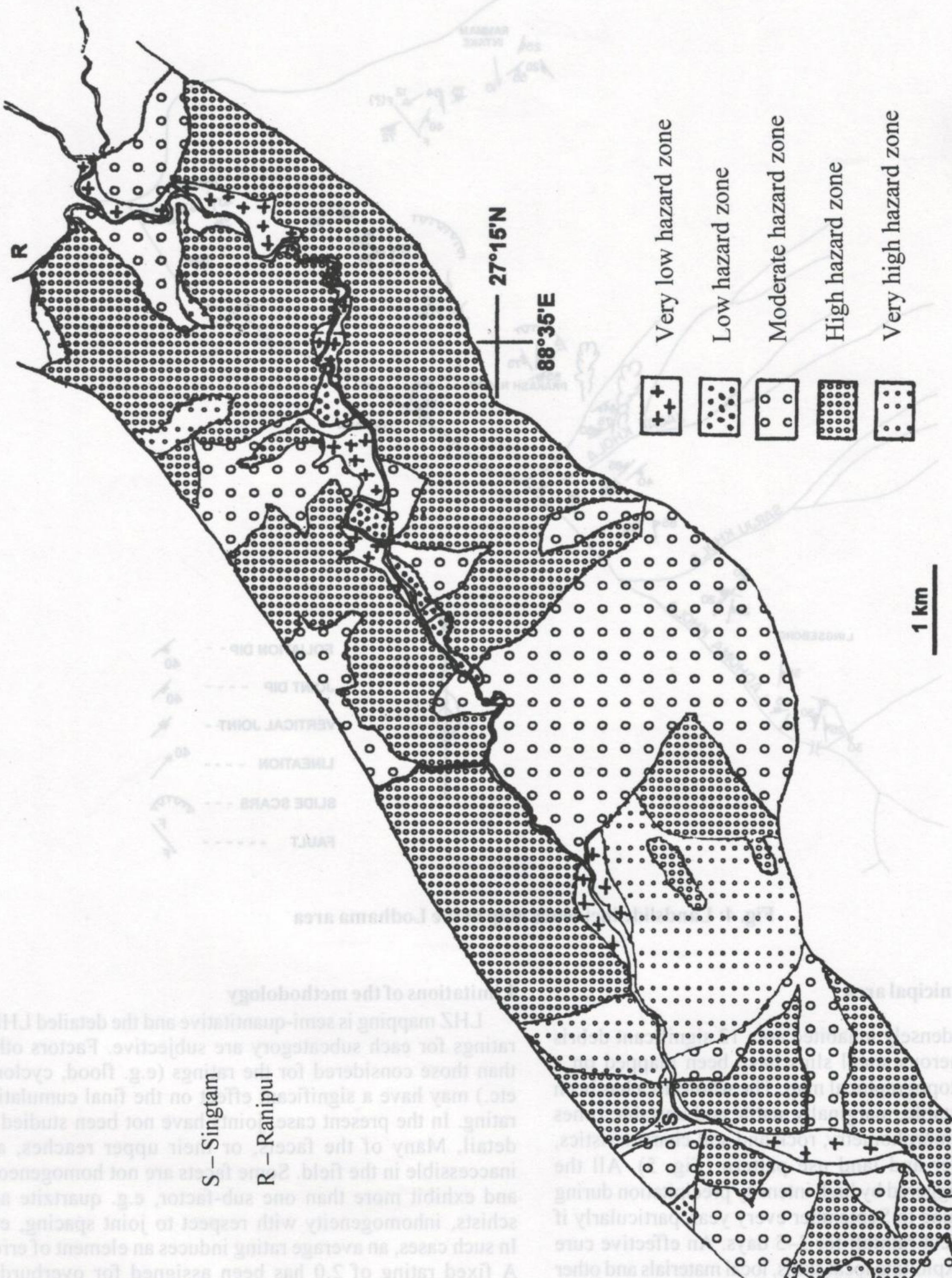

Fig. 3: Landslide hazard zonation in the Singtam-Ranipul area

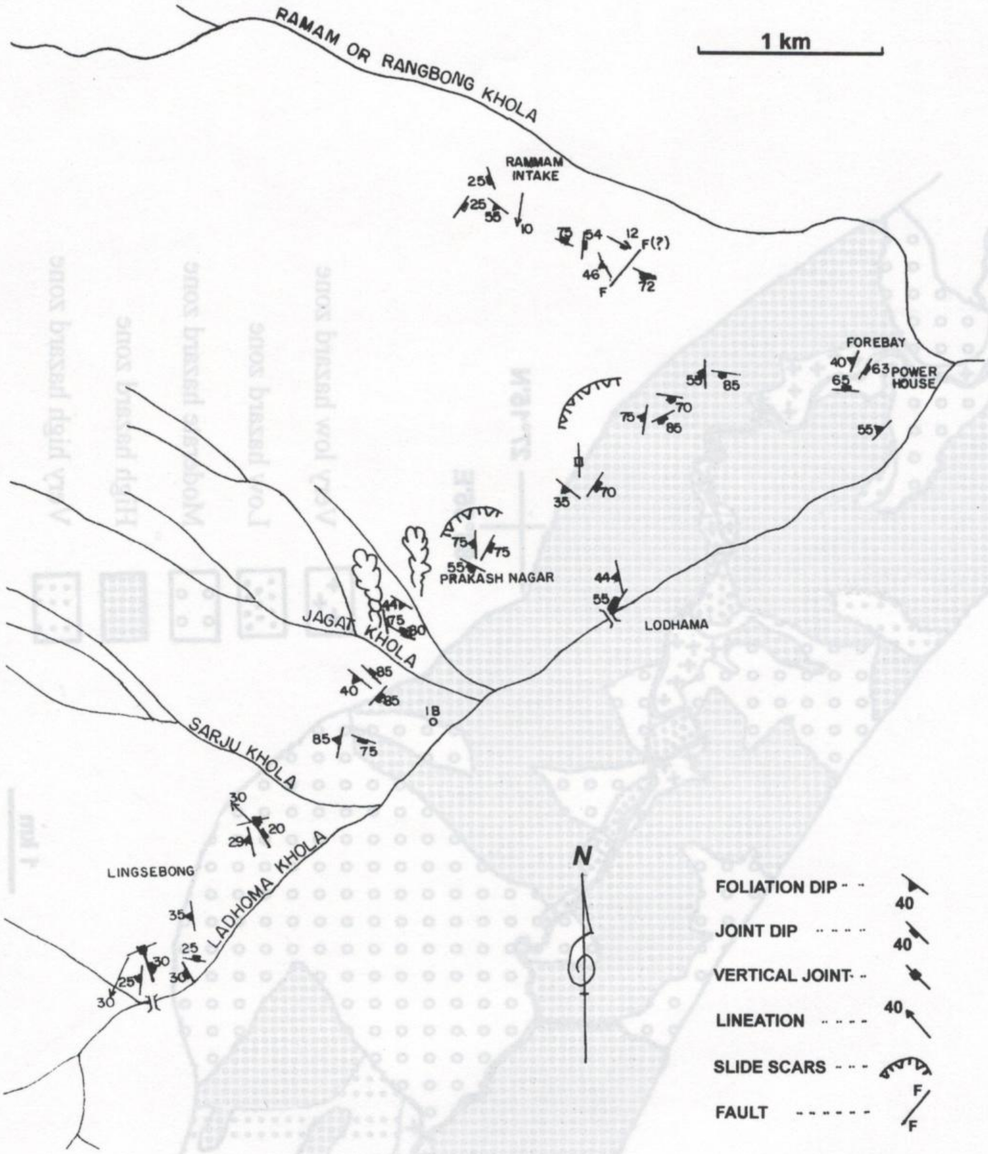

Fig. 4: Landslide incidence map of the Lodhama area

Kalimpong Municipal area

Within this densely inhabited area 12 significant debris slides and numerous small slips have been mapped on a 1:25,000 scale topographical map. The whole area has been classified into stable, marginally stable and unstable zones based on slope morphometry, rock and soil characteristics, vegetation cover and land use pattern (Fig. 5). All the landslides are triggered by high intensity precipitation during the months of June to September every year, particularly if there is antecedent rainfall for 3–5 days. An effective cure lies in usefully exploiting local skills, local materials and other local resources to their fullest potential. Cost effective innovative control measures such as anchored drum, retaining wall, horizontal drains, catch water drains, geogrids and afforestation are necessary to control slope failure.

Limitations of the methodology

LHZ mapping is semi-quantitative and the detailed LHEF ratings for each subcategory are subjective. Factors other than those considered for the ratings (e.g. flood, cyclone, etc.) may have a significant effect on the final cumulative rating. In the present case, joints have not been studied in detail. Many of the facets, or their upper reaches, are inaccessible in the field. Some facets are not homogeneous and exhibit more than one sub-factor, e.g. quartzite and schists, inhomogeneity with respect to joint spacing, etc. In such cases, an average rating induces an element of error. A fixed rating of 2.0 has been assigned for overburden irrespective of its thickness. LHZ mapping on 1:25,000 scale is not adequate for inhabited areas and sites for developmental works, for which micro-regional zonation on scales of 1:2,500 or larger is recommended.

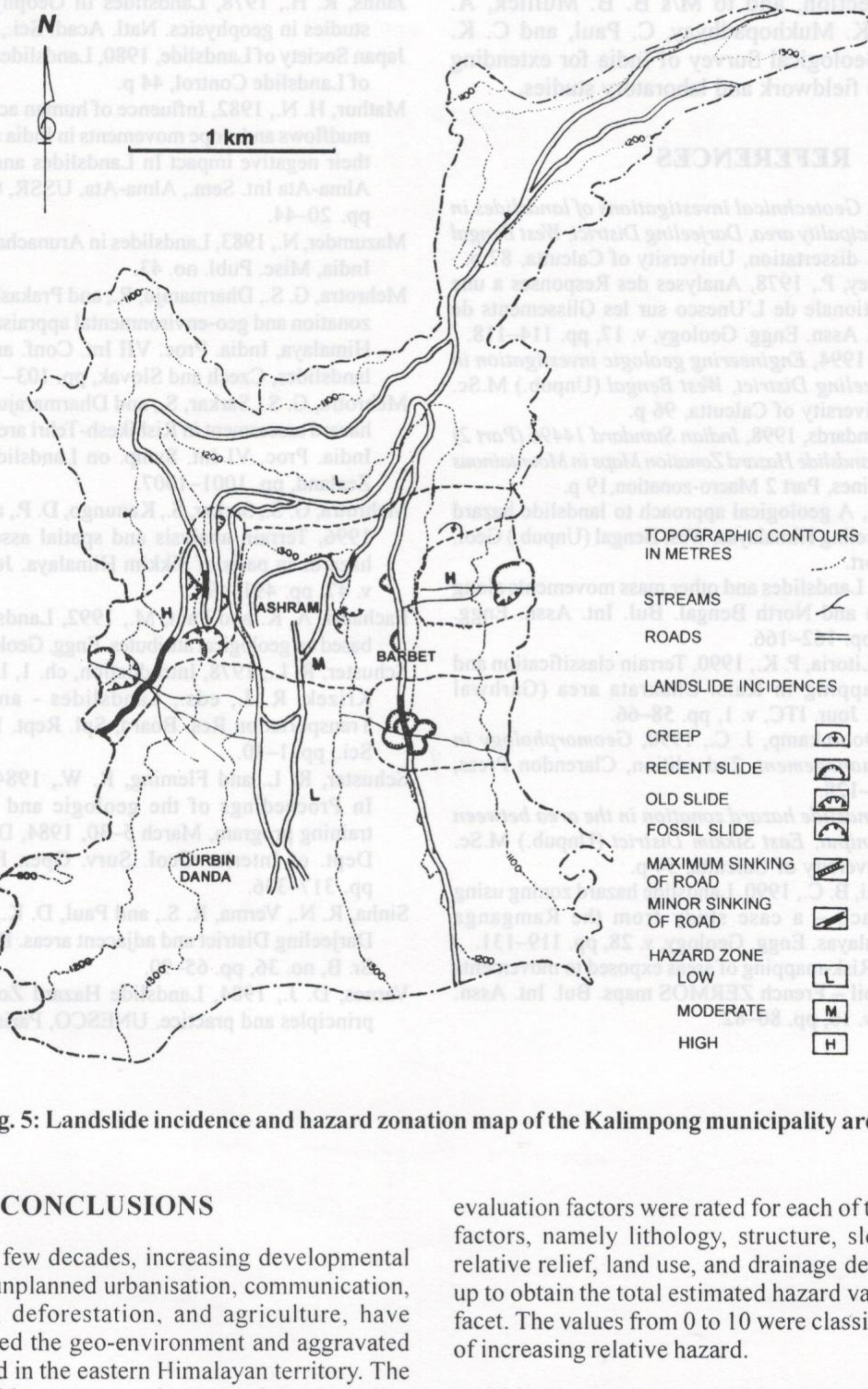

Fig. 5: Landslide incidence and hazard zonation map of the Kalimpong municipality area

CONCLUSIONS

During the last few decades, increasing developmental activities, such as unplanned urbanisation, communication, dam construction, deforestation, and agriculture, have substantially affected the geo-environment and aggravated the landslide hazard in the eastern Himalayan territory. The incidence of landslides appears to increase along the valley sides of streams of all orders, communication networks, and along zones of ingress of surface and subsurface water. Random construction of hutments and ploughing along slope crests also initiate slides.

Three sample areas from the inner tectonic belt of the Lesser Himalaya were investigated for preparing LHZ maps on 1:25,000 scale following methods after Varnes (1984) and Bureau of Indian Standards (1998). Landslide hazard evaluation factors were rated for each of the major causative factors, namely lithology, structure, slope morphometry, relative relief, land use, and drainage density, and summed up to obtain the total estimated hazard values for each slope facet. The values from 0 to 10 were classified into five zones of increasing relative hazard.

If further development of the region is to be sustainable, immediate steps must be undertaken to prepare LHZ maps at different scales, from regional to local, so that disasters due to landslides and debris flows may be better managed.

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