Landslide Hazard Zonation and Evaluation of Lunglei Town, Mizoram - Its Utility in Planning and Development

Pankaj Kumar* and C. D. Singh*

Abstract

With ever increasing need for sustainable development, particularly in unstable hilly areas like Lunglei, landslide hazard zonation maps help to identify and delineate hazard prone areas. A landslide hazard zonation map divides the land surface into zones of varying degrees of stability, based on causative factors inducing instability. Such maps help to identify geo-environmentally favourable sites for future developmental activities in hilly terrain.

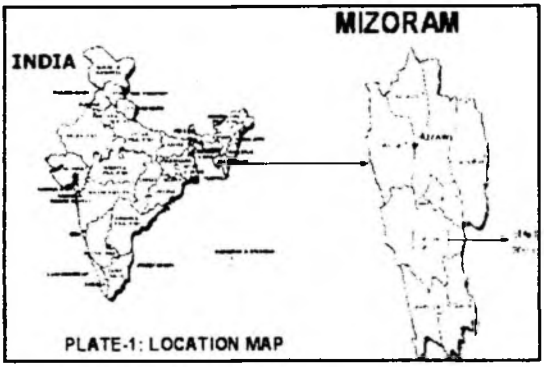
The landslide hazard zonation map of the area in and around Lunglei town has been prepared based on the modified BIS (2004) guideline. Facet map as well as different thematic maps has been prepared and sub-categories of each geo-environmental parameter have been awarded rating values according to their influence on slope stability. The facet map has been superimposed over the different thematic maps and the total estimated hazard for each facet has been calculated by adding the rating values of different sub-categories of each geo-environmental parameter.

Introduction

The state of Mizoram is located in the southern part of the northeastern India, bordered on the east by Myanmar and on the south by Bangladesh. It is a scenic country traversed by long N - S trending narrow anticlinal hills and synclinal valleys, draped by luxuriant forests resplendent with colourful orchids (Nandy, 2001). In spite of the fact that Mizoram is having strategic and economic importance, the state remains largely underdeveloped because of its inaccessibility. Now the state is undergoing all-round development such as, construction of road, hydroelectric projects, urban agglomerations etc. and such activities cause landslides in the region. Landslides account for considerable loss of life in the state and also cause damage to human settlements, civil structures, hydroelectric projects, communication routes and agriculture & forest lands, particularly during monsoon months. The region experiences very high (>2000mm annually) and continuous rainfall, which triggers landslides (Singh & Hazra, 2006). In addition northeast India falls in zone V of the seismic map of India.

Lunglei town, the fast growing second largest city of the state is located in the southern part (Fig.1). The mountainous terrain of Lunglei is characterized by steep slopes and high relief occupied by weathered, fractured and folded rocks with adverse? hydrogeological conditions. The situation worsens further due to human interferences, such as, deforestation, 'jhum' (shifting) cultivation and unplanned developmental activities on hill slopes. Lunglei town, the headquarters of Lunglei district, has experienced several devastating landslides in 1995. The planning, design and execution of developmental schemes, such as road, building construction etc., are often carried out hastily due to financial and time constraints. As a result, many projects have not taken into consideration of geological and geotechnical factors, thereby causing instability of hill slopes and a manifold increase in the incidences of landslide. With ever increasing need for development,

*Geological Survey of India, North Eastern Region, Shillong, e-mail: pankaj_gsi@rediffmail.com



systematic investigations of the terrain were taken up for Landslide Hazard Zonation, in order to identify and delineate different categories of hazard prone areas. Landslide hazard zonation maps are of great utility to planners and field engineers for identifying suitable areas to implement developmental schemes, as well as, for adopting appropriate remedial measures in unstable, hazard-prone areas. If, the hazardous areas have to be developed, suitable remedial measures have to taken to minimise the loss/damage.

Study area: The of study area covering 150 sq. km. falls in parts of the Survey of India (SOI) toposheet nos. 84B/9 & 13 (Fig. 1). The Lunglei town is situated in the centre of the area and connected to Aizwal city by NH-54. The area is characterized by a rugged and immature topography represented by open valleys and sharp ridges trending N-S to NNE to SSW direction.

Geology: Mizoram area is part of Tripura-Mizoram miogeosynclinal basin which, in turn, belongs to the broad Assam-Arakan geosynclinal basin. The area is occupied by repetitive succession of argillaceous and arenaceous sediments of Palaeogene-Neogene age. The Mizo fold belt is slightly arcuate in shape and convex westward. It comprises a series of N-S trending, longitudinally plunging, strongly folded anticlines and synclines arranged in en-echelon pattern (Ganguly, 1975). The anticlines are long, narrow and tight but the intervening synclines are broad and gentle. These are commonly dislocated by the numerous longitudinal faults and thrusts (Jokhan Ram and Venkatarman 1984).

Rocks of Middle Bhuban and Upper Bhuban Formation of Surma Group are exposed in the study area. The Middle Bhuban Formation is rich in shale and siltstone, with fine interbands of sandstone and it grades into the overlying Upper Bhuban Formation with increase in proportion of arenite. Shale is friable in nature and show high degree of weathering. Moderate to thick-bedded hard sandstone bands with intervening thin shale and siltstone layers characterise the upper Bhuban Formation. These sedimentary units show good primary structure (bedding) and the general strike of bedding is NNE-SSW to NNW-SSE, with gentle to moderate dip on either side. Two to three sets of joints have been noted in the area among which bedding joint is predominant. The geomorphology is controlled by lithology structure. The resistant sandstones form the ridges and scarps, where as the shale/ siltstones form the low-lying valleys. Cuestas and hogbacks are other important geomorphic features in the area.

Methodlogy

The Macro Level Landslide Hazard Zonation on 1:25000 scale has been carried out as per modified BIS (2004) guidelines. A total ten geo-environmental causative parameters have been considered to prepare the hazard zonation map of the area. Based on their influence on slope instability, the Landslide Hazard Evaluation Factor (LHEF) values have been assigned for these causative factors. As per guidelines, the slope morphometry, lithology, structure & landslide incidences, have been assigned a maximum LHEF value-2 and relative relief, landuse, landcover, hydrogeological condition, rainfall and slope erosion parameters have been assigned maximum LHEF value-1. This is a semi quantitative, super imposition methodology based on 14 points rating.

Thematic Maps

During the macro-level landslide hazard

zonation study on 1:25,000 scale of Lunglei area (Kumar, 2007) a total ten number of thematic maps namely Facet map, Slope morphometry map, Relative relief map, Lithological map, Structural map, Landcover map, Landuse map, Hydrogeological condition map, Landslide incidence map and Slope erosion map have been prepared. A brief description of each of these thematic maps is given below:

(i) Slope Facet Map: A slope facet is a part of hill slope, which has more or less similar characters of slope showing consistent slope direction and inclination (BIS, 1998). The slope facet map has been prepared with the help of Survey of India (SOI) toposheet nos. 84B/9 & 13 by delineating the polygonal map area having consistent slope direction as well as amount of inclination. These are separated carefully from one another marked by conspicuous change in contour configuration/pattern, ridges, spurs, gullies, nala/stream, rivers, etc. A total of 821 numbers of facets have been delineated in the area.

(ii) Slope Morphometry Map: Generally, the steeper the slope, the greater is the possibilities of landslide to occur but, there is no universal threshold value of slope at which slides take place. Many steep slopes on competent rock are more stable than comparatively gentle slopes on weak material (Bell, 1999). The slope Morphometry map has been prepared facet wise with the help of SOI toposheets. Out of total 821 facets, 82 facets (10%) fall within very gentle slope category, 453 facets (55.17%) fall within gentle slope category, 226 facets (27.52%) fall within moderately steep slope category, 19 facets (2.31%) fall within steep slope category and 41 facets (5%) fall within escarpment/ cliff category.

(iii) Lithological Map: The lithological map of the area has been prepared by compilation of available geological maps and unpublished systematic geological mapping reports of GSI and the data collected from the field. Major part of the area is occupied by sandstone and siltstone, which is slightly to moderately weathered. Shale is friable in nature and shows high degree of weathering. The soil cover in the area is sandy/clayey in nature and ranges in thickness from <5m to 15m.

(iv) Structural Map: The disposition of structural discontinuities in relation to slope inclination and direction has a great influence on the stability of slopes. The more the discontinuity or the line of intersection of two discontinuities tends to be parallel to the slope, the greater is the risk of failure. The structural map of the area has been prepared by the study of available systematic geological mapping reports of GSI and the data collected from the field. The primary structure is bedding, with a strike of NNE-SSW to NNW-SSE, with gentle to moderate dip on either side. Three sets of joints have been mapped in the area among which bedding joint is predominant.

(v) Relative Relief Map: Oldham reported that high hill slopes in Assam and Meghalaya were much more affected by landslides in comparison to the low-lying hill slopes during Great Assam earthquakes in 1897. It has also been experienced in Meghalaya, Mizoram and eastern Himalayas that higher slopes are much more affected by landslides than moderate or low slopes. The relative relief map of the study area has been prepared with the help of the SOI toposheets. Out of total 821 facets 84 facets (10.23%) fall within low relative relief category, 513 facets (62.49%) fall within medium relative relief category, 224 facets (27.28%) fall within high relative relief category.

(vi) Landcover Map: Barren and sparsely vegetated areas show faster erosion and greater instability as compared to reserve or protected forests, which are thickly vegetated and generally less prone to mass wasting process (Anbalagan, 1992). The landcover map of the study area has been prepared with the help of field data and SOI toposheets. Out of total 821 facets, 406 facets (49.45%) fall within thickly vegetated/ forest area category, 298 facets (36.30%) fall within moderately vegetated area category and 117 facets (14.25%) fall within sparsely vegetated area category. In general, the western part of the mapped area is thickly vegetated, the central part of the mapped area is moderately vegetated, and area around Lunglei town is sparsely vegetated.

(vii) Landuse Map: It is felt that landuse patterns impart more influence on destabilisation of slope as evident from the high frequency of landslide incidences along the road cuts. Some slopes may become highly unstable as a result of human activity on them. The landuse map of the study area has been prepared with the help of data collected from field and SOI toposheets. Out of total 821 facets, 35 facets (4.26%) fall within moderately populated slope/ village road category, 120 facets (14.62%) fall within thickly populated slope category, 67 facets (8.16%) fall within major communication routes category, whereas large number of facets i. e. 599 facets (72.96%) do not fall within any landuse category.

(viii) Hydrogeological Map: For the purpose of quick appraisal, the nature of surface indication of groundwater such as damp, wet, dripping and flowing water conditions has been recorded as per guidelines. The Hydrogeological map of the area has been prepared from SOI toposheets and data collected from the field. Out of total 821 facets, 778 facets (94.76%) fall within dry category, 29 facets (3.53%) fall within wet category and 14 facets (1.71%) fall within flowing/ spring category.

(ix) Average Annual Rainfall: Landslides are triggered by rainfall, when threshold intensity is exceeded, so that pore water pressure increases to the critical value, resulting in landslide during or immediately after rainfall. The slope stability is also affected by the duration of the rainfall, the slope angle, the variation in shear strength and permeability of overburden and rock mass. It has been observed that larger, deeper slides are more likely to occur during long continuous wet periods, while shallow slides are most characteristics of short duration, high intensity rainfall (After Bell, 1999). As intensity of rainfall data is rarely available, average annual rainfall data is taken as an important parameter (Fig. 2).

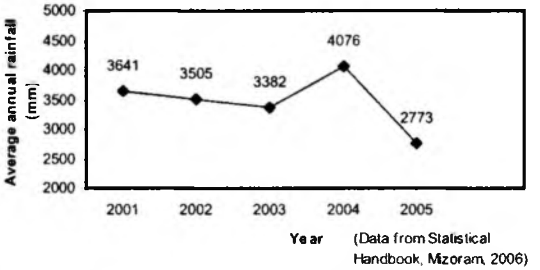


Fig. 2 : Average annual rainfall of Lunglei area, Mizoram

(x) Slope Erosion Map: Erosional aspect of hill slope is an important factor in determining its stability. It is observed that deep gully, toe erosion by nalas and rivers destabilize slope alarmingly. Slope erosion map has been prepared with the help of SOI toposheets and data collected from the field. Out of total 821 facets, 53 facets (6.46%) fall within deep gully erosion/rill erosion of hill slope category, 28 facets (3.41%) fall within severe toe erosion category and remaining 740 facets (90.13%) are not affected by slope erosion.

(xi) Landslide Incidence Map: As landslide affected slope indicates highly unstable slope condition. Hence, inventory of existing landslide incidences has been made and locations of individual slides are plotted. A total of twenty-two landslides have been noted in the area (Kumar, 2007). Landslide incidences map has been prepared with the help of data collected from the field. Out of total 821 facets, 12 facets (1.46%) fall within dormant landslide category, 22 facets (2.68%) fall within one active landslide category, 8 facets (0.97%) fall within more than one slide or one very large active slide category and remaining 779 facets (94.89%) are not affected by landslide.

(xii) Landslide hazard zonation map: The Landslide Hazard Zonation Map (Fig. 3.) has been prepared according to Total Estimated Hazard (TEHD) of each facet by superimposing the slope facet map successively one by one over all thematic maps (Kumar, 2007). The TEHD of the facet is calculated after adding the LHEF values of all ten geo-environmental parameters encompassing the particular facet. This is a semi quantitative, super imposition methodology based on 14 points rating scheme. The facet wise data of LHEF value has been recorded in tabular form as follows:

On the basis of TEHD value, the entire mapped area has been divided into five types of hazard zone namely Very Low Hazard Zone (VLHZ), Low Hazard Zone (LHZ), Moderate Hazard Zone (MHZ), High Hazard Zone (HHZ) and Very High Hazard Zone (VHHZ) as suggested by modified BIS guidelines.

Out of total 821 facets; 89 facets (10.84%) falls in the very low hazard zone, 650 facets (79.17%/) falls in low hazard zone, 57 facets (6.94%) falls in moderate hazard zone,

20 facets (2.44%) falls in high hazard zone and 5 facets (0.61 %) falls in very high hazard zone (Kumar, 2007).

Conclusions

The Macro-level Landslide Hazard Zonation of the Lunglei area gives an overall picture of stability condition of hill slopes. As Lunglei is the second largest city of Mizoram and is

Facet wise LHEF and TEHD Rating (Format Only)

Facet No.	Slope Morphometr	Relative Relief	Structure	Lithology	Landcover	Landuse	Hydrogeolo-gical Condition	Landslide Incidence	Rainfall	Slope erosion	TEHD	Zone
27	0.8	0.6	1.0	0.6	0.4	-	0.2	-	0.6	-	4.85	VLHZ
21	1.2	0.6	1.0	1.25	0.4	-	0.2	-	0.6	-	5.63	LHZ
-	-	-	-	-	-	-	-	-	-	-	-	-

The number of facets and their percentage falling in different hazard zone are given below:-

Zone	Number of Facets	Percentage (%)
I. Very Low Hazard Zone (VLHZ)	89	10.84
II. Low Hazard Zone (LHZ)	650	79.17
III. Moderate Hazard Zone (MHZ)	57	6.94
IV. High Hazard Zone (HHZ)	20	2.44
V. Very High Hazard Zone (VHHZ)	5	0.61

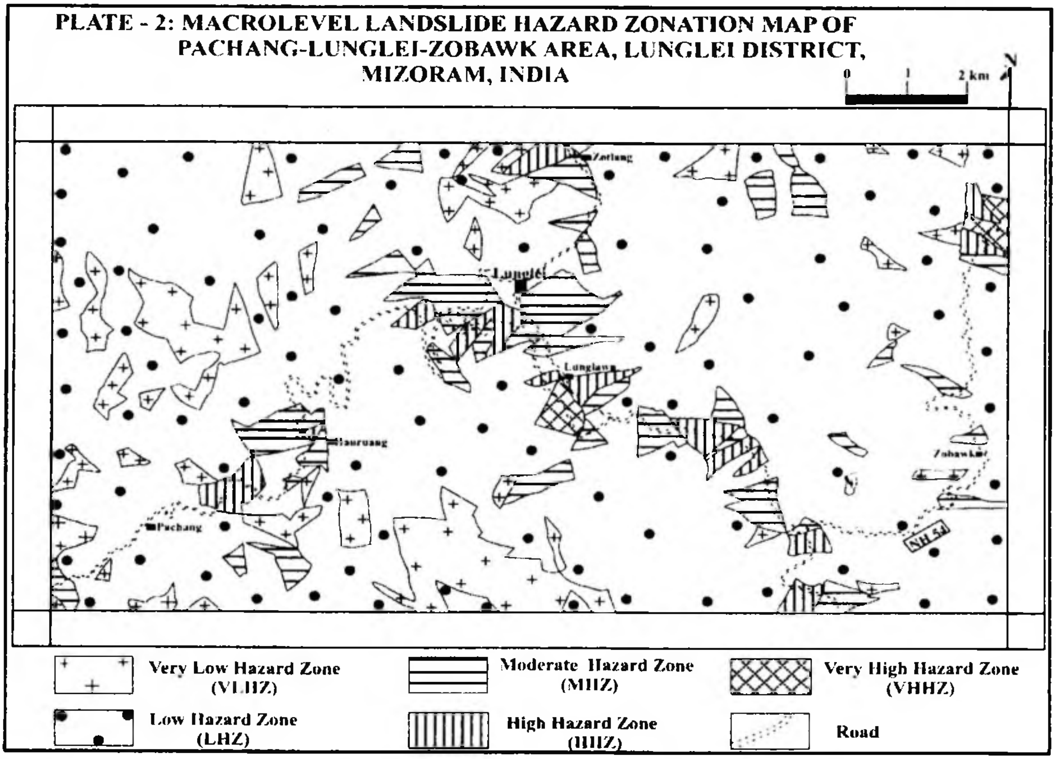


Fig. 3: Macrolevel landslide hazard zonation map of Pachang-Lunglei-Zomawk Area, Lunglei District, Mizoram, India

growing, this zonation map will serve as the base map for the planning of any future developmental scheme. Systematic urban planning should taken into account the slope instability factor of the hill slopes identified through successive meso & micro-level landslide hazard zonation studies. On the basis of macro-level landslide hazard zonation of Lunglei area, following conclusions has been drawn:

i) Out of total 821 facets; 89 facets (10.84%) fall in the very low hazard zone, 650 facets (79.17 %/) fall in low hazard zone, 57 facets (6.94%) fall in moderate hazard zone, 20 facets (2.44%) fall in high hazard zone and 5 facets (0.61 %) fall in very high hazard zone.

ii) The human settlements in the studied area fall in the very high or high hazard zone due to large scale modification of original slope and change in landuse and landcover pattern of the area during or after developmental activities.

iii) The moderate hazard zone areas mainly occur in close association with high and very high hazard zone areas.

iv) The very low and low hazard zone areas are widely distributed in the study area and mostly occupy valley floor or gentle slope areas.

v) As Lunglei is a landslide prone area affected by landslides in past, landslide hazard zonation map of Lunglei area is of great help for planners and field engineers for selecting suitable areas to implement development schemes in future, as well as, for adopting appropriate mitigation measures in unstable hazard-prone areas.

On the basis of the conclusions of the macro-level landslide hazard zonation of Lunglei area, following recommendations is given:

i) The very high hazard zone area and high hazard zone area should be avoided for any future developmental activities as these areas are much prone to landslide. Detailed slope stability studies of populated areas falling in very high and high hazard zone must be carried out and appropriate slope protective measures should be provided.

ii) Moderate hazard zone areas may be taken up for developmental activities only after detailed evaluation of slopes. For this purpose, priority should be given to those facet areas which occur in close association with very low and low hazard zone.

iii) Very low and low hazard zone is most suitable for future developmental activities.

iv) As deforestation is one of the major causes for slope erosion in the area, afforestation of the barren and sparsely vegetated hill slopes should be taken up immediately to protect the natural slopes.

v) Jhum cultivation which is widely practiced in the area must be stopped immediately, especially in the vicinity of populated hill slopes and along NH – 54 road benches.

vi) Construction of multistoried concrete buildings on the distressed hill slopes must be discontinued forthwith. Lined contour and linked chute drains should be constructed on the thickly populated hill slopes for disposal of wastewater away from the hill slope.

Acknowledgements

The authors express sincere thanks to Shri B. K. Mohanty, the Dy. Director General, GSI, NER, Shillong for his encouragement and kind permission to publish the work. The authors are grateful to Shri E. Ramalingam, Director, LHZP, GSI, Shillong, Shri E. Balasubramanian, Director, EGD-I, GSI, Shillong, Shri R. Dharuman, Director, EGD-II, GSI, Shillong and Shri P. V. S. Rawat, Geologist (Sr.), GSI, Shillong for their constructive comments and suggestion, which helped to improve the manuscript.

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