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Landslide Hazard Zonation Mapping of Aragam Erin and Bandipora, District Bandipora, Kashmir, India

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Abstract

Landslide is frequently occurring geologic hazard that causes changes in landscape and social environment. They have caused extensive damage to homes, highways and other properties. The Kashmir Himalayan Mountainous Terrain (KHMT) are generally characterized by the steep slopes, high relative relief, weathered, fractured and folded rocks with un-favourable hydrological conditions. The objective of the investigation deals with the landslide vulnerability mapping of Aragam, Erin and Bandipora of District Bandipora, Kashmir with a purpose to divide the hilly areas into different zones according to their susceptibility to landslide and identification of vulnerable natural hazard zones. This involved the study of Slope Instability (SI) and various causative factors associated with litho-units, primary and secondary discontinuities, slope aspects, elevation, hydrological conditions, landuse and landcover followed by their superimposition to produce a landslide hazard zonation map of an area for identification and delineation of unstable hazard prone areas/slopes. The landslide hazard zonation mapping of Aragam, Erin and Bandipora was carried out by using Indian Standard guidelines laid down under IS: 14496 of Part-2 published in the year 1998. The Landslide Hazard Evaluation Factor (LHEF) ratings and the Total Estimated Hazard (TEHD) valueswere calculated for the purpose of preparation of landslide hazard zonation map of Aragam, Erin and Bandipora, revealed that the major part of the area falls under the category of Very Low Hazard Zone (VLHZ) 49.60% followed by Low Hazard Zone (LHZ) 39%, Moderate Hazard Zone (MHZ) 9.40% and High Hazard Zone (HHZ) 2%. No area falls under the category of Very High Hazard Zone (VHHZ). The result of this study provides landuse planners with the information necessary to choose relatively safe zones for expansion in hills, so that an in-build fragile nature of Kashmir Himalayan mountain ecosystem can be protected and restrict developmental works to areas presenting least threat to individuals and property.

Keywords: Kashmir Himalayan Mountainous Terrain (KHMT), Landslide Hazard Evaluation Factor (LHEF), Total Estimated Hazard (THED).

Introduction

The study area is located in the northeastern corner of the Kashmir Himalayas (Figure-1) and is sutiated in district Bandipura of Jammu and Kashmir State, between latitudes 34°21′00″ to 34°28′30″ N and longitudes of 74°37′30″ to 74°45′00″ E covered by Survey of India (SOI) Topographic map bearing reference no 43 J/11 (Scale 1:50000) with an elevation ranging from 1584 meters to 4008 meters (Hurmukh Mountain) above mean sea level. Bandipora, a district headquarter is located on the banks of the Wular Lake, lies to the north of Srinagar, approachable by means of 56-kilometers long Srinagar-Bandipora metallic road as well as by River Jhelum. The area is drained by Madumati River in the north and Erin River in the northeast whereas; the world famous Wular Lake occupies the south-western part of the study area respectively. The Madhumati River, flows in the north direction and has a total linear length of 40 kilometers whereas, the Erin River generally flows in the western direction has a total longitudinal distance of 28 kilometers. Both the rivers finally drains into the Wular Lake near Nusu Ghat Bandipura. The area is densely forested, vegetation is generally supported on dip slopes comprising mainly conifers and other plants including Cedrus Deodar (Deodar), Pinus Wallichina (Kail), Pinus longifolia (Chil) Ascsulous indica (Chestnut), Jaglans regia (Walnut)[1].

The method of land division into zones and their ranking according to the hazard vulnerability of potential slides is termed as zonation[2].

Geological setting of the Area: The Kashmir (Palaeozoic-Mesozoic Basin) an oval shaped depression spread over an area of ∼5200 square kilometers between Pir Panjal Range (PPR) in the northwest and Zanaskar Range (ZR) in the southeast rest over the metasedimentries of Salkhalas has been tectonically transported on the back of the panjal thrust as thrust sheets. The study area is located between the latitudes 34°21′00″ to 34°28′30″ N and longitudes of 74°37′30″ to 74°45′00″ E in district Bandipora, Kashmir. The Study area spreads over an area of ∼120 Square kilometers. The geological mapping carried out in the Aragam, Erin and Bandipora area revealed the following lithologies: Alluvium, Limestone, Zewan Formation and Panjal Volcanic Group[3,4]. The area under report exposes Panjal Volcanic Group on the north and north-eastern mountainous terrain whereas, the Zewan Formation and Limestone with Quaternary sediments, are restricted to gentle slopes and central part of the study area over which the maximum population of the area are inhabited. The regional geological succession of various lithounits exposed in the area covered is given below.

Table-1: Regional Geological Succession.

Formation	Age	Lithounits
Alluvium	Recent	Clay, silt, sand and gravel
Limestone	Triassic	Thickly bedded bluish grey limestone with inter-bedded papery shales
Zewan Formation	Permian	Pinkish to bluish grey fossiliferous limestone with subordinate shales
Panjal Volcanic Group	Permo-carboniferous	Thickly bedded basic lava flows in upper parts with thinly bedded andesitic lava flows in basal parts

Description of Lithounits: A brief description of the various lithounits exposed in the area are given below

Panjal Volcanic Group: The Panjal Volcanic Group comprising thickly bedded basic (Basaltic) lava flows in upper parts with thinly bedded andesitic (Andesitic) lava flows in basal parts. The basic flows frequently marked by the presence of vesicles filled with quartz, agate and epidote[5]. The lava flows are exposed in the areas to the northwest and northeast of Wular Lake, on the southern limb of easterly plunging Madmatti anticline. They unconformably overlie the Agglomeratic Slate and underlie unconformably the Zewan Formation[6].

Zewan Formation: The Zewan Formation comprises bluish grey to reddish grey, current bedded, fossiliferous limestone with interbedded subordinate carbonaceous shale and quartz arenite bands. The formation unconformable overlies the Panjal Volcanic Group and merges upwards imperceptibly into Triassic as seen in the Buth and Semthan area.

Limestone: The limestone at Naidahal conformably resting over the Panjal Volcanic Group as such belongs to Late Triassic geological age[7]. The limestone is dark grey to bluish grey in colour interbedded with thin shales and shally limestone layers. The general trend of the limestone bandsare N E-S W with northerly dips varying between 28 and 40 degrees.

Alluvium: The Quaternary alluvium mainly comprises terrigenious clay, silt, gravel and boulder in order of predominance is unconsolidated in nature and is susceptible to slide under conducive environment.

Structure Framework: The field relationship of lithological units and imprints of major and minor structures in the area indicate that the present structural framework is the outcome of fold deformations.

Folds: The area under study forms the southern limb of the easterly plunging Madmatti anticline. Thin limb is thrown into small anticlines and synclines, which at place are asymmetrical and occasionally even overturned. The core of the syncline preserves the Zewan Formation and Triassic limestone. A major NE-SW trending syncline is noted in the area northeast of Bandipora with Triassic exposed in the core while, Zewans and Panjal volcanic are well seen along the two limbs of the fold.

Fault: During the field study an inferred fault indicated by the sheared nature of contact between the Panjal Volcanic Group and the Zewan Formation has been noticed near Semthan Hamlet trending NNE- SSW and is parallel to the axial trace of fold.

Joint: Joints are developed all over the area, particularly in basalt and limestone. Several sets were recognized and classified as dip joints, strike joints and diagonal joints. The major joint sets usually trending NW-SE with dip ranging from 35°-70° due north and NE-SW direction dipping 65° towards south.

Methodology

Different methodologies are being practiced for Landslide Hazard Zonation Studies, both at macro and micro level zonation (smaller and larger scales)[8]. The author have adopted macro-level landslide hazard zonation as described by the BIS guidelines wherein six geo-environmental parameters have been considered for macro level landslide hazard zonation mapping[9]. These parameters include the study of i) slope angle, ii) lithology, iii) structure, iv) relative relief, v) landuse-landcover pattern and vi) hydrogeological condition (Table-2).

Table-2: BIS Guidelines (1998)[9].

Parameters/ Causative Factors	Landslide Hazard Evaluation Factor (LHEF)
Slope Morphometry	2
Lithology	2
Structure	2
Landuse-landcover	2
Hydrogeological condition	1
Relative relief	1
Total Estimated Hazard (TEH)	10

The Landslide Hazard Evaluation Factor (L.H.E.F.) rating and the Total Estimated Hazard (T.E.H.D.) value were calculated for the purpose of preparation of landslide hazard zonation map. Based on Total Estimated Hazard (TEH) value, the Bureau of Indian Standard has proposed the following classification of different types of hazard zones (Table-3).

Table-3: Classification of different types of Hazard Zones.

Total Estimated Hazard (TEH)	Hazard Zone
<3.5	Very Low Hazard Zone (VLHZ)
3.5 to 5	Low Hazard Zone (LHZ)
5.1 to 6	Moderate Hazard Zone (MHZ)
6.1 to 7.5	High Hazard Zone (HHZ)
>7.5	Very High Hazard Zone (VHHZ)

The Total Estimated Hazard (T.E.H.D) was computed by adding The Landslide Hazard Evaluation Factor (LHEF) ratings acquired for individual geo-environmental parameters zone wise by adding all values of causative factors as per the equation-1.

(TEHD) = (slope morphometry + lithology+ structure+landuse and landcover+hydrogeology+ relative relief) (1)

The resultant (TEHD) value indicates overall condition of an area. Based on Total Estimated Hazard (TEHD) value ranges, all slope/ zones in an area can be categorized into five categories of hazard zones (Table-3). The Very Low Hazard Zone (VLHZ) and the Low Hazard Zone (LHZ) are safe and suitable for planning and construction purposes in hills whereas, slopes falling in High Hazard Zone (HHZ) and Very High Hazard Zone (VHHZ) should be avoided. Instead of Very High Hazard Zone (VHHZ), areas/zones falling in Moderate Hazard Zone (MHZ) category are safe for construction purposes but with suitable mitigation techniques.

Preparation of Thematic Maps as per the BIS guidelines: In total six numbers of thematic maps namely Slope Morphometry Map, Structure Map, Lithology Map, Landuse-Landcover Map, hydrological and Relative Relief Map have been prepared for the purpose of macro-level landslide hazard zonation. The author used Google Earth imaginary, digital elevation model (D.E.M) 30m, Stereonet version 7.8.0. for stereo net plots and Global Mapper version (13.2) softwares for generation of various map attributes and layers. The Survey of India (SOI) Topographic map bearing reference no 43 J/11 (Scale 1:50000) were georeferenced and photo-enlarged for digitization of different layers and finally, the landslide hazard zonation map was prepared. The study area was divided into 512 zones covering hamlets, viz., Bod Buth, Bonakut, Buth, Lawaypora, Ajar, Semathan, Dardpora, Erin, Nusu, Guripora, Nasu Ghat, Sumlar, Salander, Mulekiuhom, Chattebande, Gurihagan, Aragam, Haungtanj, Jasan and Langanmarg. Based on the information gathered from Google Earth imaginary, digital elevation model (D.E.M.) 30m, topographic maps, available literature both published and unpublished, field observations the thematic maps were generated and are discussed as follows.

Slope Morphometry Map: The common force tending to generate movements on slopes is gravity. Generally, the steeper the slope, the greater is the likelihood that landslide will occur. Slope Morphometry Map defines slope categories based on frequency of occurrence of particular angle of slope[9]. The slope morphometry map (Figure-1) has been prepared zone wise by calculating tan ī (slope angle) of vertical interval (V) divided by horizontal distance (H) in the zone. As amount of slope inclination is considered the most important parameter inducing various degree of Slope Instability (SI), a Landslide Hazard Evaluation Factor (LHEF) value-2 has been assigned to this parameter. The rating assigned for its different sub-categories is given in Table-4.

Table-4: Slope Classification with Rating.

Sub-category	Rating
i. Very gentle slope ≤15^o	0.3
ii. Gentle slope >15^o to 25^o	0.6
iii. Moderately steep slope >25^o to 35^o	1.2
iv. Steep slope >35^o to 45^o	1.5
v. Very steep slope >45^o	2.0

As revealed from slope morphometry map of the total hilly area falls under the category of very gentle slope (38.55%) and the rest of area falls under the category of gentle slope (49.45%), Moderately steep slopes 9.15 and Steep slope 1.85 respectively.

Lithology and Structure: Basalt, limestone and shale are the main lithological units in the study area. These rock units (Figure-2) are grouped into Rock Type –1 category as per BIS guidelines and ratings were awarded as 0.3, 0.2 and 0.1 respectively. The response of these rock units to the weathering process is least (slight weathered). Based on the genesis (colluvial or alluvial) and age (older or younger) of the soil type, a ratings of 2.0 were awarded for older well compacted alluvial soil which is characterized by high shear strength in comparison to the younger colluvial soil, which is loose in nature and were awarded with a rating of 1.2. Discontinuities (primary and secondary) associated with in situ rocks have greater influence on stability of slopes. The in situ rock stability is mostly dependent on the type of relationship between the slope orientation and the attitude of major structural discontinuities like bedding plane, joint plane and foliation that sometimes present in combination trigger planer or wedge failure. Landslide Hazard Evaluation Factor (LHEF) value ‘2’ has been assigned to structure.

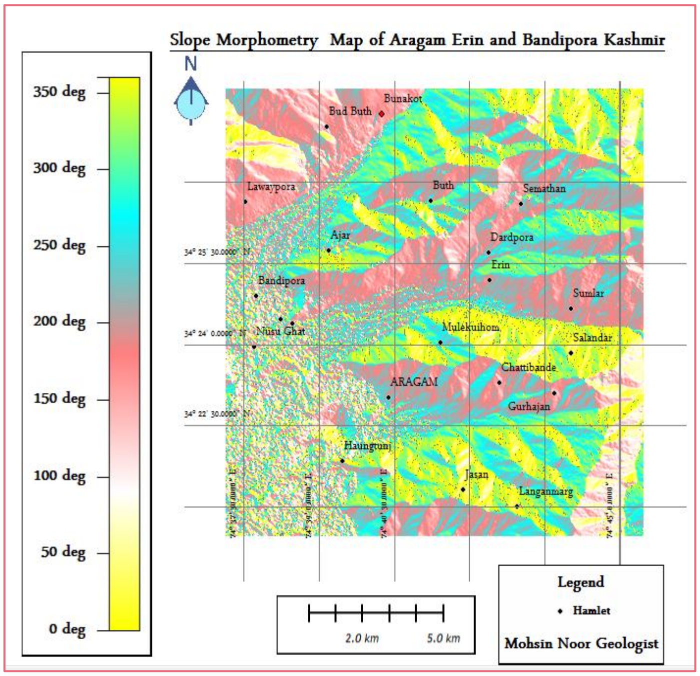

Figure-1: The slope morphometry map.

Stereo-net plot: Bedding planes, joints, shear zones and faults in rock masses are broadly named as structural discontinuities. In order to analyze the stability of individual rock blocks, it is necessary to understand the factors that control the shear strength of the discontinuities. However, to understand the Slope Instability (SI), Stereo-net plots were drawn to determine the mode of slope failures viz. wedge, planer or toppling (Figure-3). The field data so far collected on structural geology during the course of field study was plotted on stereo-net by using a software Stereo-net version 7.8.0. The results are useful to identify active mode of failures and determine potential failure zones on the slope.

Structural discontinuities: i. Joint (J1) Peak orientation – 54^0/ 68^0, ii. Joint (J1) Peak orientation – 248^0/ 63^0, iii. Joint (J1) Peak orientation – 121^0/ 84^0, iv. Slope Orientation – 92^0/35^0

Stereo-net plots drawn from the field data collected mainly on the structural properties of Basalt rock (Panjal Volcanic Group) of Sumlar Hamlet, Bandipora[10]. The hamlet had witnessed devastating mass wasting during the spring season of 2014. Subsequently, the hamlet was paid attention by the author in respect of data collection on structural geology for slope failure analysis.

The intersection of Joint J1 and Joint J3 trigger a wedge failure along the slope face with trend and plunge 136^0 and 68^0.

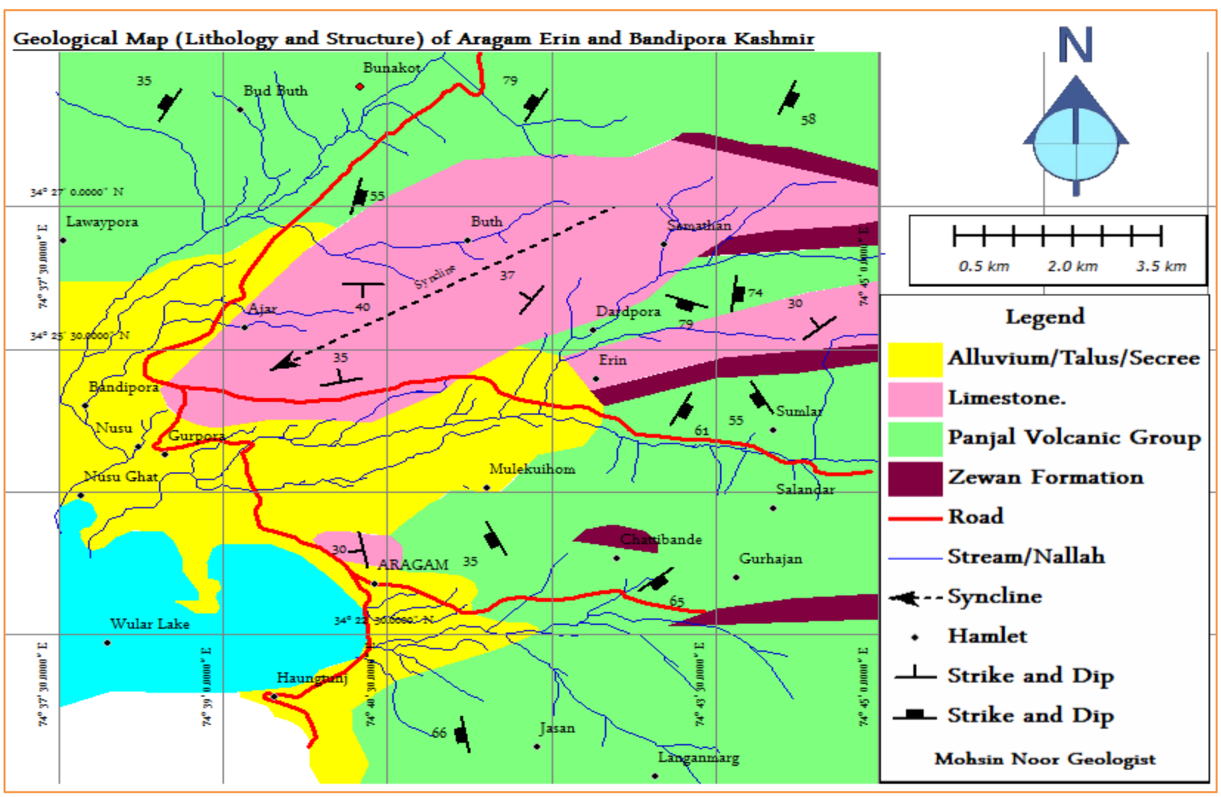

Figure-2: Geological Map (Lithological and Structural Map).

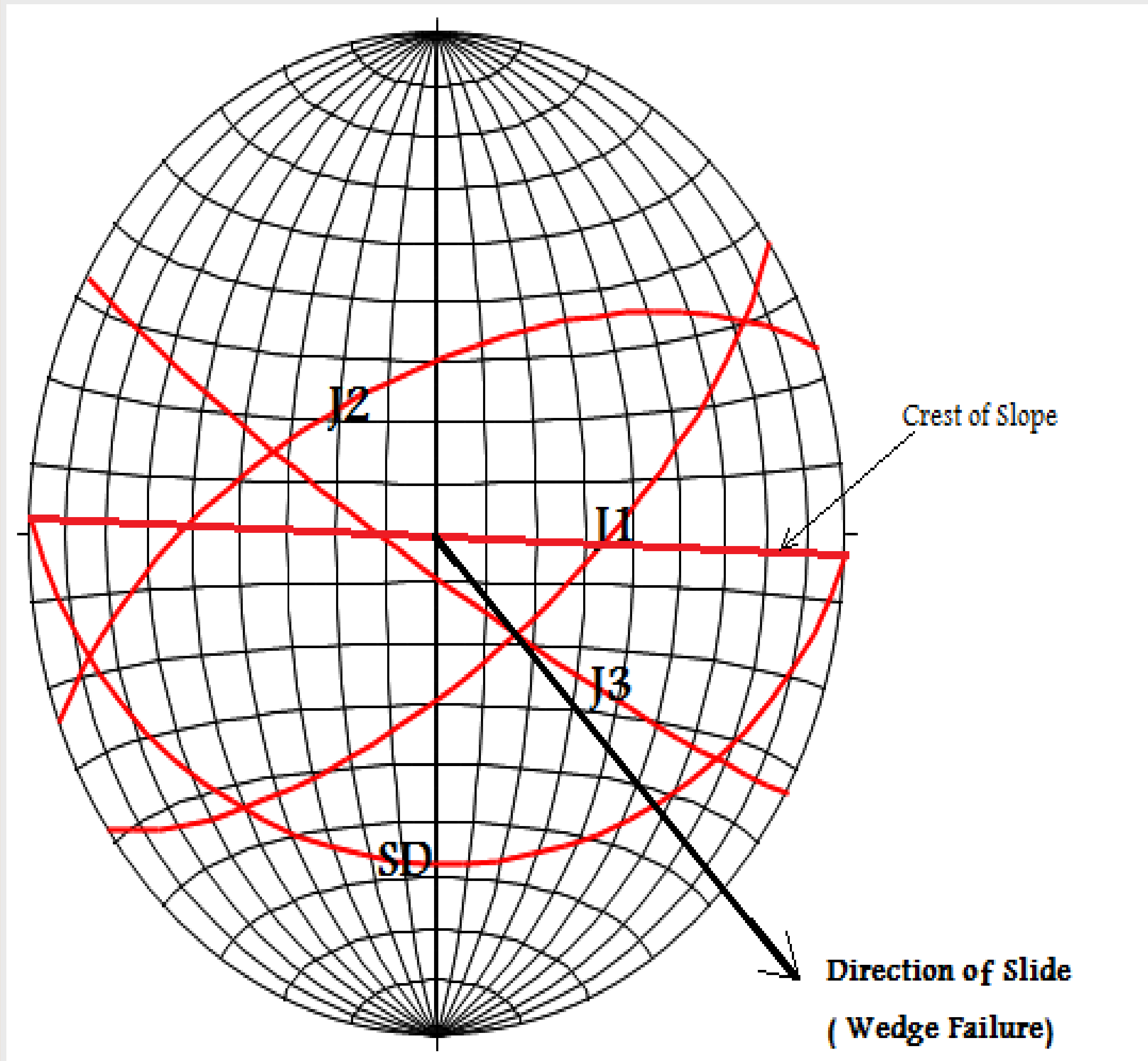

Figure-3: Direction of slide.

Landuse-Landcover Map: The landuse-landcover map of the study area has been prepared from the Survey of India (S.O.I) Topographic map bearing reference no 43 J/11 (Scale 1:50000). The BIS guideline considers 5 categories for the landuse-landcover map. Landuse-landcover map of the study area reveals that thickly vegetated forest area covers (26.63%) while as agricultural land/populated flat land area covers (21.40%), sparsely vegetated forest area covers (32.57%) moderately vegetated forest area covers (10.47%) and barren land cover (9.02%) respectively.

Relative Relief Map: The relative relief map (Figure-4) of the study area has been prepared from the Survey of India (S.O.I) Topographic map bearing reference no 43 J/11 (Scale 1:50000). The relative relief for each zone was calculated by subtracting the lowest contour value from the highest contour value in a zone. Finally, the base map was digitized on Global Mapper version (13.2) software for generation of relative relief map.

The relative relief values of the zones of the study area ranges from 1584 m to 3487m. About 28.10% of the total zones falls under the category of high relative relief followed by medium relative relief (44.90%) and low relative relief (27%).

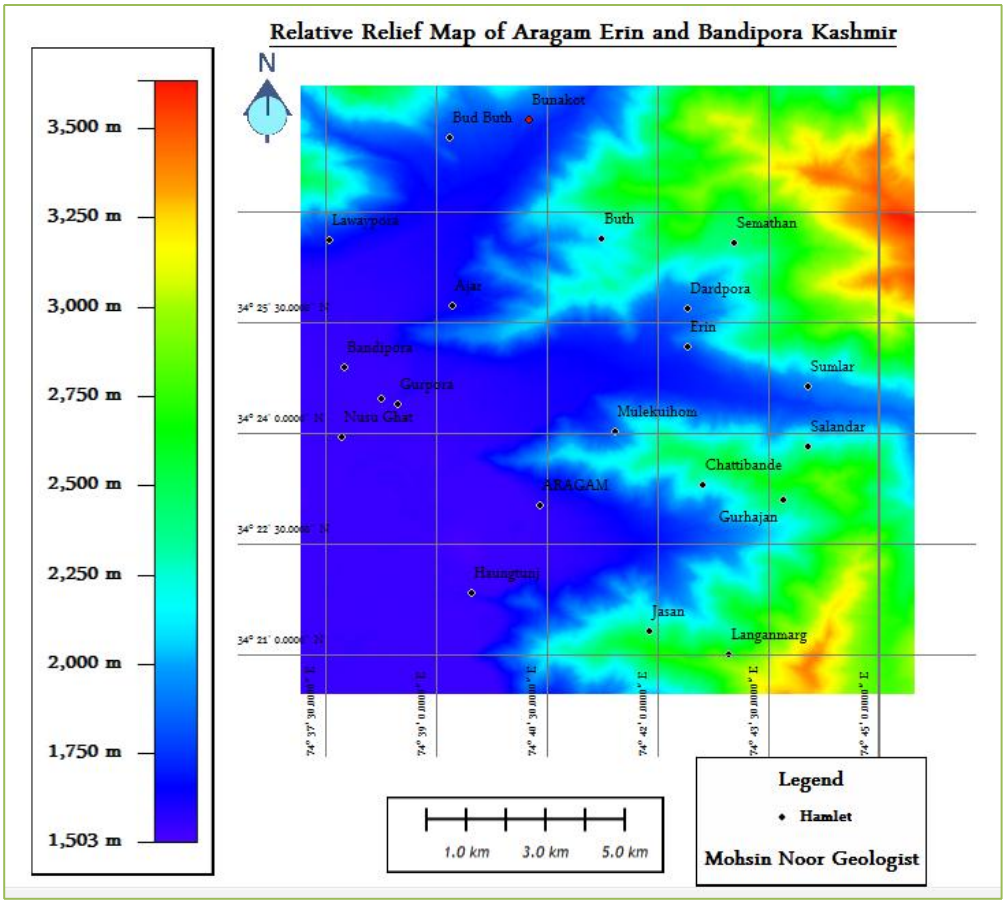

Figure-4: Relative relief map.

Hydrogeological / Drainage Map: From the hydrogeological point of view the area can be broadly divided into two sectors viz. the hills and adjoining pediplains. For the geo-environmental parameter hydrogeology, the Bureau of Indian Standard (BIS) has described the slope condition as dry, moist, dripping/flowing and awarded different ratings to these subcategories. The details with the rating of individual category are given in Table-5.

Table-5: Hydrogeological Condition with Rating.

Description	Rating
Dry	0.2
Wet	0.5
Flowing / Spring	1.0

The Hydrogeological map (Figure-5) of Aragan, Erin and Bandipora was prepared from the topographic map bearing reference no 43 J/11 (Scale 1:50000) Survey of India (S.O.I.) and data collected from the field.

Result and Discussion

The hazard vulnerability map of Aragam, Erin and Bandipora (Figure-6) has been prepared according to the Total Estimated Hazard (TEH) of each zone by superimposing zone map successively one by one over all thematic maps. The Total Estimated Hazard (TEH) values of individual zones was calculated after adding the Landslide Hazard Evaluation Factor (LHEF) values of all six geo-environmental parameter / causative factors encompassing the particular zone. Finally, each zone has been re-classified into various hazard zones. It is revealed from the landslide hazard zonation map of Aragam, Erin and Bandipora (Table-6) that the major part of the area falls under the category of Very Low Hazard Zone (VLHZ) 49.60% followed by Low Hazard Zone (LHZ) 39%, Moderate Hazard Zone (MHZ) 9.40% and High Hazard Zone (HHZ) 2%. No area falls under the category of Very High Hazard Zone (VHHZ). About 9.40% of the area is occupied by moderate hazard zone indicating a critical condition of slope stability, which may aggravate to high hazard zone category with deterioration of above described geo-environmental parameters/ causative factors individually or collectively with the passage of time. Furthermore, any alteration in the present condition in the geo-environmental parameters/causative factors may change the present status of landslide hazard zonation of a slope.

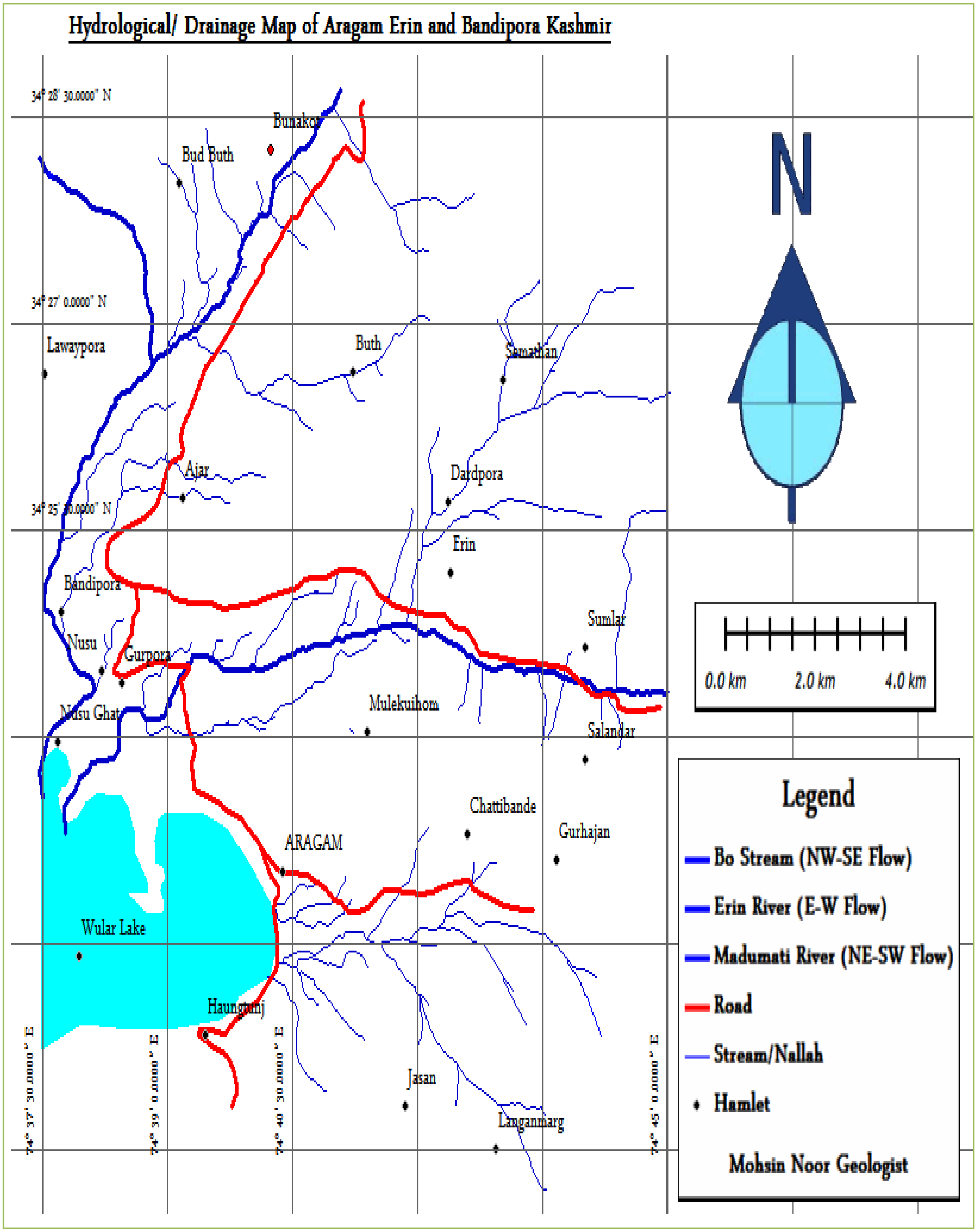

Figure-5: The Hydrogeological map of Aragan, Erin and Bandipora.

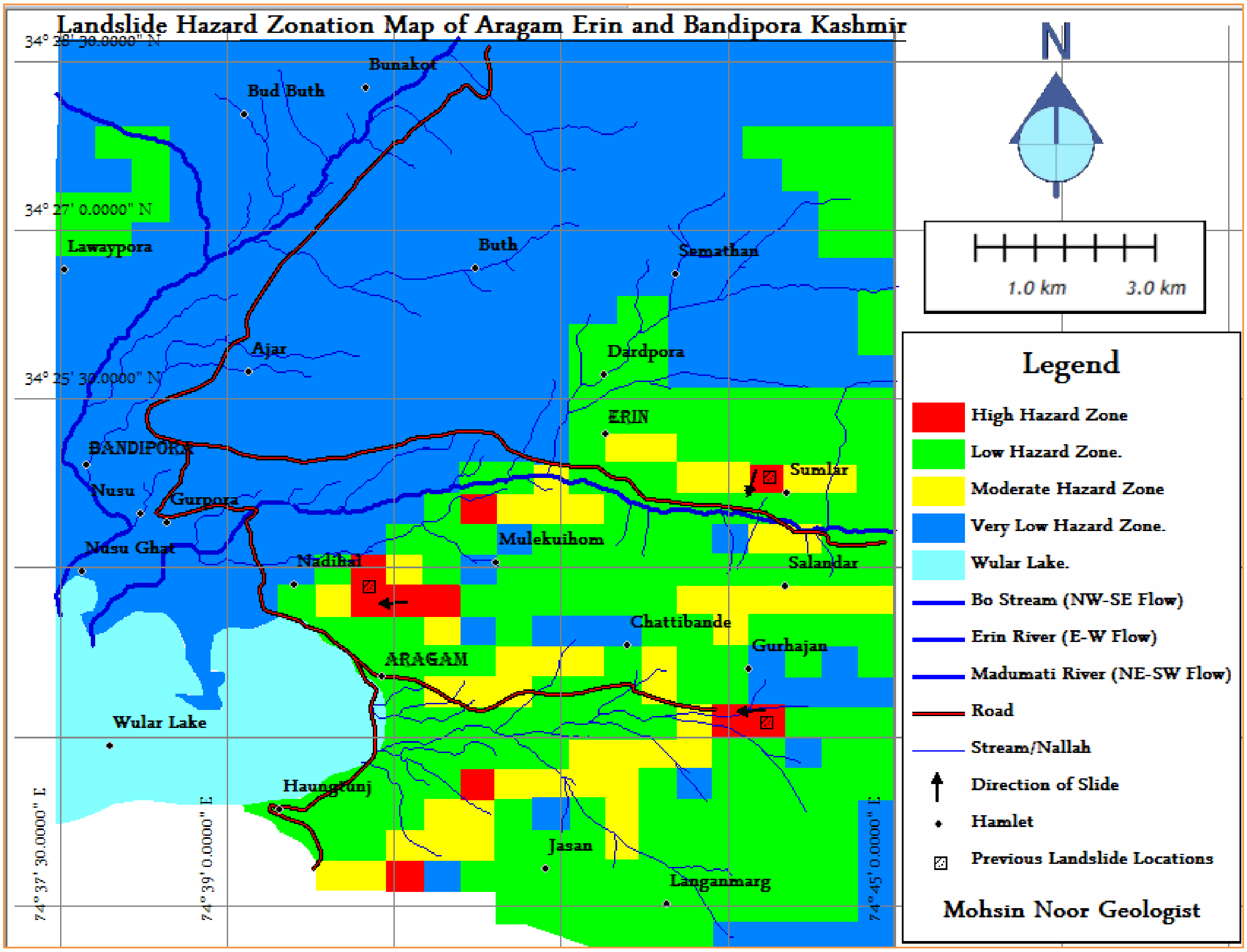

Figure-6: Landslide Hazard Zonation Map of Aragam, Erin and Bandipora.

Table-6: Statistics of the landslide hazard zonation

Zone Categorization	Total Number of Zone	Percentage (%) of Zone
Very Low Hazard Zone	254	49.60
Low Hazard Zone	200	39
Moderate Hazard Zone	48	9.40
High Hazard Zone	10	2
Very High Hazard Zone	0	0

Conclusion

The Kashmir Himalayan Mountainous Terrain (K.H.M.T.) represents one of the world's most fragile ecosystems, where developmental works are of utmost importance for overall well being of human race. The result of this study provides land use planners with the information necessary to choose relatively safe zones for expansion in hills so that an in-build fragile nature of Kashmir Himalayan mountainous ecosystem can be protected and restrict developmental works to the areas presenting threat to individuals and property. Macro-level landslide hazard zonation has its own limitations due to some constraints like small scale of mapping and inaccessibility of the terrain. It is of great importance to undertake micro-level landslide hazard and risk zonation on large scale before planning any developmental work in the moderate and high hazard zones.

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References

1. Singh, I. and Raina, C.B. (1980). Report on petrological, volcanological and stratigraphical studies of the Panjal Volcanics in the area west of Wular Lake and northeast of Bandipura, Baramulla district, J & K. Geological Survey of India report.
2. David J. Varnes (1984). Landslide Hazard Zonation: A review of principles and practices. UNESCO. ISBN 92-3-101895-7.
3. Mohsin Noor (2015-2016). Landslide Hazard Zonation Mapping of Parts of Bandipora District, Kashmir. Directorate of Geology and Mining, Srinagar. Unpublished Report.
4. Mohsin Noor (2016-2017). Landslide Hazard Zonation Mapping of Parts of Bandipora District, Kashmir. Directorate of Geology and Mining, Srinagar. Unpublished Report.
5. Pareek, H.S. (1973). Geological setting, petrography and petrochemistry of Darla trap and its comparative study with Mandi and Panjal trap. *Jour. Geol. Soc. Ind*., 14(4), 255-368.
6. Raina, B.K. & Razdan, M.L. (1971). Progress report on the Geological Mapping around Gangabal Lake, Ganderbal and Bandipora tehsils, Srinagar and -Baramulla districts, J&K State. Geological Survey of India, Unpublished Report.
7. Mohsin Noor et. al. (2019). Limestone deposits of Saderkote Bandipora Kashmir. *International Journal of Scientific Research in Engineering and Management*, 3(7), 1-4.
8. Bell, F. G. (1999). Geological hazards. E & FNSPON, London, pp-115-180.
9. Bureau of Indian Standard (1998). Preparation of Landslide Hazard Zonation maps in mountainous terrains. Guidelines, part-2 Macrozonation: ICS 07.040.54496, Part-2.
10. Khursheed Ahmad Mir and Mohsin Noor (2014). Interim site inspection report of an affected landslide area at village Sumlar, Bandipora. Directorate of Geology and Mining, Srinagar. Unpublished Report.