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# NATURAL HAZARDS IN THE TOWNSHIP OF NAINITAL, UTTARAKHAND IN INDIA

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*Abstract—* **Nainital, the Lesser Himalayan famous tourist destination of Uttarakhand has been repeatedly devastated by natural hazards since 1866 while habitation in the same started only after 1841. The area is seismically active and is falls in Zone IV of Earthquake Zoning Map of India. Tectonically active fragile mountains together with fast pace of urbanization enhanced vulnerability of the area. Apart from the rainfall is largely responsible for initiation of slope instability and landslides in the same region. An attempt has been made to enlist natural hazard events in tabular form along with their impacts since 1866 to present days. Some of the recent slope instability and landslides are also described in the same. The main focus of the paper is to lessons learnt from these natural hazards while preparing any future developmental plans within the township**

*Keywords—* **Tourist destination, Landslide, Earthquake, Damage, Trigger, Lessons learnt, Future plan, Kumaun Lesser Himalaya**

## I. INTRODUCTION

Landslides are one of the most threatening natural hazards in the world occurs in mountainous landscapes, particularly in the Himalayan belt which are accelerated by either due to inherent or external factors. Inherent factors indicate the inherent characteristic of hillslopes as geology, slope gradient, local relief, hydrological conditions, land use and land cover while external factors indicate the outside triggers as rainfall, earthquake and anthropogenic activities. Among these are accountable directly or indirectly for slope instability and landsliding. Furthermore, landslides are common in hilly areas which are controlled by drainages and structural discontinuities.

Though causing immense and recurring loss of human lives, infrastructure, property and natural resources and often looked upon as curse for the hilly areas, landsliding is an important landform building process that promotes soil formation "Khanduri (2018)". In the mountainous terrain, the fast pace of urbanisation modifies the landscapes coupled with change in weather regime pose a serious threat to slope instability and landslides. Landslides are not only affected the socio-economy but also the geo-environment. The study of landslides has drawn worldwide attention mainly due to increasing awareness of the socio-economic impacts of landslides "Aleotti and Chowdhury (1999)".

In the previous some years, mainly due to extreme precipitation events, slope instability and landslides have become a major cause of concern. The extreme weather events are catastrophic as they bring with them a lot of water. When this water runs down the hills is washes away whatever come in its way "Khanduri et. al. (2018)". Losses due to landslides and flash floods in Uttarakhand in 2010, 2012, 2013, 2016 and 2017 testify this fact (Table 1). Some of major incidences in these durations are: (i). Landslides in Uttarakhand during August and September, 2010 "Sati et. al. (2010)", (ii). Asi Ganga flash floods in August, 2012 "DMMC (2012)", (iii). Ukhimath debris flows in September, 2012 "DMMC (2012)", (iv). Kedarnath flash floods in June 2013 "Khanduri et. al. (2018); Rautela (2013)", (v). Bastari, Naulra and Didihat landslides/debris flows in July 2016 "Khanduri (2017)" and (vi). Mangti and Malpa flash floods in 2017 "Khanduri et. al. (2018)".

Table 1. Losses incurred in Uttarakhand due to landslides and flash floods of 2010, 2012, 2013, 2016 and 2017. Data source: State Emergency Operations Centre, Government of Uttarakhand.

| Sl. No. | Item | Year of occurrence | | | | |
|---|---|---|---|---|---|---|
| | | **2010** | **2012** | **2013** | **2016** | **2017** |
| 1. | Human lives lost | 220 | 176 | 225 | 119 | 84 |
| 2. | Human beings missing | 00 | 00 | 4,021 | 5 | 27 |
| 3. | Persons injured | 139 | 96 | 238 | 102 | 66 |
| 4. | Farm animals lost | 1,798 | 997 | 11,268 | 1,391 | 1,020 |
| 5. | Fully damaged houses | 1,215 | 285 | 2,295 | 252 | 101 |
| 6. | Severally damaged houses | 00 | 00 | 3,001 | 839 | 434 |
| 7. | Partially damaged houses | 10,672 | 743 | 11,938 | 2,684 | 1,067 |
| 8. | Loss of agriculture land (in hac.) | 240.9 | 40.3 | 1309 | 112.3 | 21 |

The state of Uttarakhand has not witnessed major seismic activity since its creation in 2000, the region was devastated by Mw~7.6 Garhwal Earthquake in 1803 "Rajendran et. al. (2013)"; Dasgupta and Mukhopadhyay (2014)" and its being

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located in the Seismic Gap of 1905 Kangara Mw~7.8 "Middlemiss (1910); Ambraseys and Bilham (2000)" and 1934 Bihar–Nepal Mw~8.2 "Dunn et. al. (1939); Bilham (1995)" earthquakes enhances seismic risk in the region "Rautela et. al. (2011); Jayangondaperumal et. al. (2018)". Nainital has so far not witnessed a major seismic activity. Previous landslide incidences around the town indicate high probability of landslides being triggered if a major seismic activity affects the area "Rautela et. al. (2019)".

Natural hazards in the form of landslide and earthquake have been recognised as being the dilemma of the township of Nainital. In the past, many scholars studied the problem of slope instability in and around the township in appreciable detail "Srivastava (1968); Ashraf (1978); Jaitley (1980); Valdiya (1988); Pant and Kandpal (1989) and Sharma (1998)". Subsequently Zonation of landslide hazard studies have been carried out in the township by various researchers "Sharma (2006); Anbalagan et. al. (2008); Rautela and Khanduri (2011)". Recently "Gupta et. al. (2015); Mohit Kumar et. al. (2017) and Yhokha Akano et. al. (2018)" also studied the problem of slope instability in the same region.

Landuse/land cover studies also carried out in the area between the years 2005 and 2010, it has been shown that on an average 35,602 $m^2$ of the forested area of Nainital had been encroached every year by various anthropogenic interventions "Rautela et. al. (2014)".

In view of earthquake vulnerability, total of 2,865 buildings of Nainital were surveyed using the rapid visual screening (RVS) technique. Of all the surveyed buildings about 14 percent fall in category 5 damages class while another 22 percent fall in category 4 damage class in case of damage reaching intensity VIII on MSK scale "DMMC (2010)".

Evolutionary history of the area indicates that heavy precipitation is one of the most common causes of landslide initiation in the area. Geologically, fragile mountains coupled with fast developments enhanced vulnerability of the area. Identification of hazard prone areas and regulation of developmental initiatives in these is the key to disaster risk reduction "Khanduri (2017)". In order to provides information about slope instability and related damages since 1866 to present days together with brief description of some recent significant slope instability and landslides within the township.

## II. STUDY AREA

The study area is located in Kumaun Lesser Himalaya and is falls in Zone IV of Earthquake Zoning Map of India (IS 1893, Part 1, 2002). The area is surrounded by a number of hills as Naina peak, Sher-ka-Danda, Deopatha and Ayarpatha respectively have altitude of 2612, 2402, 2435 and 2352 meters above mean sea level. Naini lake the heart of township has elevation of 1935 meters. Fed by the discharge of the Naini lake, Balia nala is the major drainage system of the area. Another lake named as Khurpatal to the southwest of the Naini lake has elevation of 1570 meters above msl (Fig. 1).

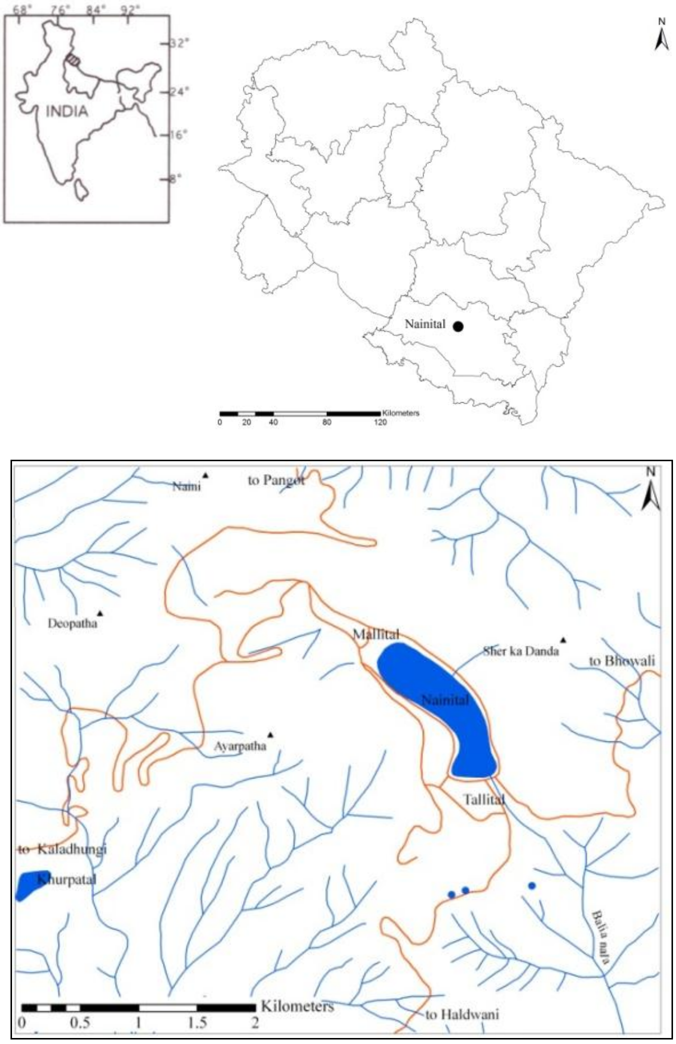



Fig. 1. Map showing study area

The first habitations grew up in the periphery of Nainital lake in 1842 and its population was just 10,054 till 1880. The township of Nainital, presently the district headquarters and previously the summer capital of the United Province during the British rule. The area has a population of 41,461; males constitute 52 percent of the population and females 48 percent "Census of India (2011)". It can be approached by Ramnagar - Nainital, Haldwani - Nainital and Bhowali - Nainital roads. Situated at a distance of 35 kilometers Kathgodam is the nearest railway station which is last terminus of the North East Railways. Situated at a distance of 70 kilometers, Pantnagar is the nearest airport.

The Nainital region has tropical climate with pleasant summers and cold winters. Average summer temperature is around 25° C while the winter temperature might even drop to

0° C. During the winters the township often experiences snowfall. The precipitation during the monsoon season is generally heavy. The present study is based on the data collected from secondary sources.

## III. THE FRAGILE MOUNTAIN LANDSCAPE

The Lesser Himalayan township of Nainital is situated in close proximity of Main Boundary Thrust (MBT) in the south that has thrust over Sub-Himalaya. The detailed account of the geological and structural set up of the same has been given by many researchers "Middlemiss (1890); Holland (1897); Heim and Ganser (1939); Auden (1942); Nautiyal (1949); Hukku and Jaitely (1965); Valdiya (1988); Sharma (1998) and Jiang et. al. (2002)". Besides MBT, other major Faults in this area are Nainital lake Fault "Middlemiss (1890)" and Manora Fault "Valdiya (1988)". Nainital lake Fault has been described to develop during 40-50 ka "Singhvi et. al. (1994)" with a movement rate of 6cm per year "Kotliya et. al. (2009)". The same indicates ongoing neotectonic activities along this Fault plane. The imprints of geological structure and lithology are seen in the form of strike ridges, fault scrap, anticlinal hills and synclinal valleys.

The area comprises of Baliana, Krol, and Tal Groups of Lesser Himalaya, with Krol Formation accounting for its major portion. Baliana Group is observed to comprise of Blaini and Infra Krol Formations. To the west of the lake most exposures are of calcareous rocks and these have been subject to erosion by the action of water. Apart from the region exhibits traces of a number of lineaments along Balia nala, Hanumangarhi, Golf Course, Lands End, IDH Colony and all these areas fall in the zone of maximum landslide hazards risk (Fig. 2).

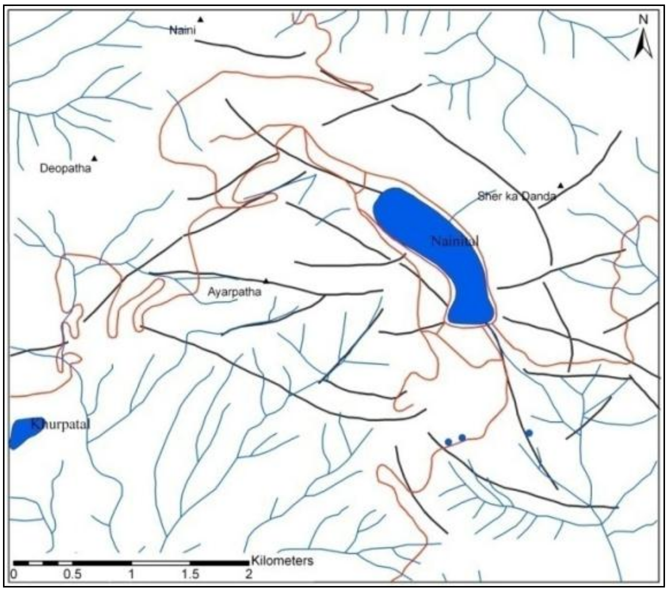



Fig. 2. Map depicting lineaments around Nainital "Rautela and Khanduri (2011)"

## IV. NATURAL HAZARD OCCURRENCE FROM 1866 TO PRESENT DAYS

The Lesser Himalaya is sandwiched between two major tectonic blocks as Main Central Thrust (MCT) and Main Boundary Thrust (MBT) where mass movements and slope instability is highest rather than Higher Himalaya and Sub-Himalaya. Located in the same terrain the township of Nainital is vulnerable to slope instability and landslides. Inhabited hillslopes of the same region has witnessed mass movements in 1866, 1867, 1880, 1893, 1898, 1924, 1989 and 1998 "Oldham (1880); Atkinson (1986); Middlemiss (1898); Rautela (2005)". Disastrous landslides of 1880 and 1893 resulted death of 151 and 28 persons respectively "Atkinson (1986); Clay (1928)". The region exhibits traces of a number of lineaments and continuing tectonic movements along these planes also makes the area prone to earthquakes. The area however falls in Zone IV of Earthquake Zoning Map of India and there exist records of ground fissures and cracks being observed in the township during earthquake events in 1877, 1889 and 1934. Cracks were reported in East Laggan house and Laidlow Hall building after the earthquakes of 1889 and 1934 respectively "Coulson (1939)". The same region has witnessed a number of natural hazards in the form of landslide and earthquake, since the British time to present days as is listed in Table 2.

Table 2. Natural hazards incurred in the township of Nainital since 1866 to present days "Thakur (1997); Sharma (2006); Bhandari and Wankhade (2015); Gupta et. al. (2015); DEOC; DMMC)

| **Sl. No.** | **Year of occurrence** | **unstable location** | **Damages** | **External force or trigger** |
|---|---|---|---|---|
| 1 | 1866 | Northeastern end of the town | Landslide scar developed | |
| 2 | 6 July, 1867 | Sher-Ka-Danda | The development of a 1.25km long crack on the slate-marl succession of Sher-Ka-Danda was observed | Rainfall |
| 3 | 1869 | Northeastern end of the town | Loss of vegetation and scanty human settlements. | Rainfall |
| 4 | 3 November, 1877 | East Laggan House | Cracks developed | Earthquake |
| 5* | 18 September, 1880 | Sher-Ka-Danda | 151 persons were killed. Old Victoria Hotel, some buildings, and the Naina devi temple were buried under the debris | Rainfall |
| 6 | 1882 | Balia Nala, Tallital | Affected cart approach road to Nainital | Rainfall |
| 7 | 1889 | East Laggan House | Destroyed the revetment wall | Earthquake |
| 8 | 30 July, 1893 | East Laggan | Portion of hill fell in Naini Lake | Rainfall |
| 9 | 19 October, | Northtwest | The fall of rocks and | Rainfall |

| | | | | |
|---|---|---|---|---|
| | 1893 | of the town | trees into the lake is reported to have raised a wave that swamped the Mall on the opposite side | |
| 10* | 17 August, 1898 | Kailakhan, Balia Nala | 28 persons were killed. Depositing 5.5 million tons of debris into the Balia nala, burying a brewery settlement | Rainfall |
| 11* | 1924 | Charta Hill, Mallital | 4 persons were killed | Rainfall |
| 12 | 1934 | Laidlaw Hall | Cracks developed in building | Earthquake |
| 13 | 1963 | Mallital | Damages to road and houses | Rainfall |
| 14 | 11 March, 1988 | Naini Peak, Mallital | Massive mass movement from Naini peak overwhelmed many areas of Mallital | Rainfall |
| 15 | 4 & 6 July, 1998 | Naini Peak, Mallital | Massive mass movement from Naini peak overwhelmed many areas of Mallital | Rainfall |
| 16 | 17 August, 1998 | Ayarpatha | Damaged the road, part of a building and the debris material affected a portion of the lake | Rainfall |
| 17 | 24 September, 1998 | Near Mall, Mallital | Road filled with debris | Rainfall |
| 18 | 2008 | SW of Golf Course, Rajbhawan, Nainital | Subsidence | Old site of a lake |
| 19 | 12 August, 2014 | Rais Hotel colony locality | 20 meters RCC stretch of GIC-Krishanapur and 360 $m^2$ retaining wall were damaged | Rainfall |
| 20 | 6 July, 2015 | Cement House, near Mall road | Woodland Hydel colony, a house and Mall Road filled with debris | Rainfall |
| 21 | 18 and 25 August, 2018 | Mall road | Around 110 meters of the lower Mall road between Grand Hotel and HDFC Bank was collapsed | Rainfall |
| 22 | 10 September, 2018 | Balia nala | Rains Hotel colony and Harinagar areas, about 17 families as being marked unsafe and sifted | Rainfall |
| "*" Fatal landslides | | | | |

## V. ANALYSIS OF EXTERNAL FORCE OR TRIGGER

Based on secondary sources, total of 22 natural hazards in the form of landslide and earthquake have been observed in the area. Of these, 19 numbers are landslide and only 3 numbers earthquake. Out of total incidences, 18 numbers are caused by rainfall and 3 numbers by earthquakes while only 1 number by other. Most of the landslides listed in Table 2 are usually found to trigger during monsoon season from July to September. Fig. 3 indicates that the slope destabilisation and damages incurred largely (82 percent) by rainfall whereas earthquake and other factors account for only 14 percent and 4 percent of total incidences respectively.

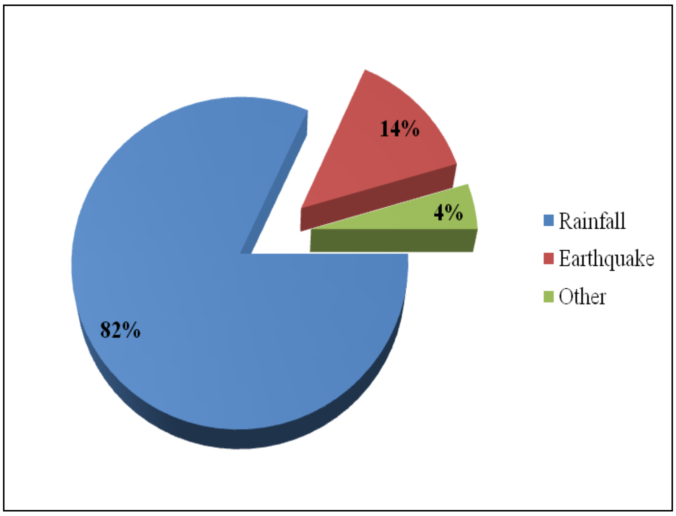



Fig. 3. Trigger percent of slope destabilization and related damages in the area

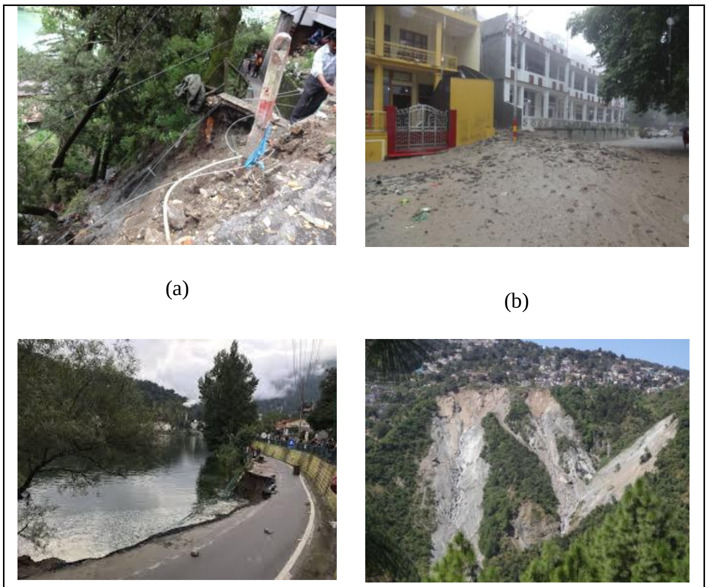
## VI. SOME RECENT SIGNIFICANT SOCIO-ECONOMIC SLOPE INSTABILITY IN THE TOWNSHIP

In the Lesser Himalayan township of Nainital, mass movement is often triggered by heavy precipitation during monsoon, destabilization of the toe of the slope materials by developmental initiatives and hill slopes undercutting by streams. Furthermore, fast pace of urbanisation is deduced to be the causative factor for the slope instability. This is reflected overloading of unstable slopes by heavy structures, construction on old landslide mass, change the course of natural streams, ill maintenance of artificial drainages, inadequate waste water management, indiscriminate hill cutting and change in landuse aggravated the problem. Some of the recent slope instability are described in the sections below.

### *A.* Cement house debris flows

As reported by District Emergency Operation Centre (DEOC), the township of Nainital received unusually heavy rainfall amounting to 388 mm within 6 hours in the evening of 6 July, 2015. The same resulted heavy discharge along the drainages and a debris flow got initiated from around Cement House that is on the upslope of Everest and India hotels on the Mall Road (Fig. 4a). Water along with debris entered in the residential colony, guest house, office and officers residence of

Uttarakhand Power Corporation Limited (UPCL) and also entered City congress President house just below woodland hydel colony. Besides, debris generated from these landslides accumulated on the Mall road (Fig. 4b).



(a) (b)

(c) (d)

Fig. 4. Slope instability and landslide in the area around Nainital; (a) slope failure with uprooted trees at Cement house (b) huge amount of debris accumulated between Everest and India hotels (c) collapsed portion of Lower Mall road between Grand Hotel and HDFC Bank and (d) Rais Hotel colony and Harinagar areas pose treat by Balia nala landslide

### *B.* Lower Mall road collapse

The increased water level of Naini lake during monsoon contributes to slope instability on the Mall road. Around 115 meters Lower Mall road between Grand Hotel and HDFC Bank was collapsed on 18 August 2018 and again 25 August 2018, it resulted vehicular traffic in the Mall road was disrupted (Fig. 4c). Failure portion was observed to be exposed with slope wash materials whereas trees were observed on either side of the collapsed portion. The Mall road is located on southwest facing slope and it has been reported by many researchers that the same slope is creeping towards the lake "Hukku et. al. (1974); Valdiya (1988); Rautela et. al. (2014); Yhokha Akano et. al. (2018)".

### *C.* Balia Nala landslides

Nainital again faced serious slope stability problem when Rais Hotel colony and Harinagar areas pose treat by Balia nala landslides during monsoon of the year 2018 (Fig. 4d). In these areas there exist a number of structures that are located over crown of landslides and these are therefore endangered during coming monsoons. Naini lake Fault is dissected by Main Boundary Thrust (MBT) which is passes through the Balia nala area that has witnessed many small and large slope failures in the past. On 12 September, 2014 in the Rais Hotel colony locality had been affected by a landslide due to continuous rainfall. About 20m RCC stretch of GIC-Krishanapur and 360 $m^2$ retaining walls on the slope were damaged in the same "Gupta et. al. (2015)". The area is composed of mainly shales and slates and relative affects of the fault have made the rocks fragile. Additionally, the instability is governed by the toe erosion together with overloading by constructions in the same localities.

## VII. DISCUSSION AND CONSCLUSION

The township of Nainital, situated in the Kumaun division of Uttarakhand state, is one of the popular hill station and famous tourist destination where people routinely gather in large numbers. In the past, the same area has witnessed mass movements in 1866, 1867, 1880, 1893, 1898, 1924, 1989 and 1998 while recently in 2008, 2014, 2015 and 2018. These inflicted heavy loss of life, infrastructure, property and geo-environment. The area also falls in Zone IV of Seismic Zonation Map of India and had suffered an earthquake in 1877, 1889 and 1934 which caused loosening of rock masses and partially damaged human settlements.

Geologically, the area is occupied by rocks of Lesser Himalaya. It mainly consists of limestone/dolomitic limestone, slate and quartzite. The rocks in this area are found highly deformed, degraded and dissected by structural discontinuities. Apart from the region exhibits traces of a number of lineaments along Balia nala, Hanumangarhi, Golf Course, Lands End, IDH Colony and all these areas fall in the zone of maximum landslide hazards risk.

Geomorphological study of the area indicates that the surface slopes consist mostly of old landslide materials which are mostly unconsolidated and loose in nature. Due to morphological setting of the area, the streams have high sinuosity and hence, higher erosive capacity, especially when these are loaded with sediments. High relief of the area promoted high surface runoff and enhanced pore water pressure together with reduced frictional forces promoted mass wastage in the area. The geo-hydrological condition of the hill slopes is an important parameter influencing the stability of the slopes as water reduces the shearing strength of the slope forming materials causing instability. It is therefore recommended that both surface and subsurface drainage measures should therefore be planned and executed in the same region (Khanduri, 2017).

Evolutionary history of the area indicates that heavy precipitation through the streams is largely responsible for initiation of slope instability and landslides. Management of drainage networks alone significantly improves the stability of the slide "Adhikiri (2001)". In order to control the flow of water of the natural and artificial streams/drainages in and around the township, the channel bed is required to be turned into a series of cascades. This would protect the banks and surrounding areas in the streams from being eroded.

Civil constructions should only be carried out at respectable distance from streams. Constructions should also be avoided in the vicinity of vulnerable slopes as also over low cohesive mass. In view of earthquake vulnerability, it is highly recommended that following the building code while construct the building in the township.

In view of the instability of the hill slopes around Naini peak, Sher-ka-Danda, Ayarpaha, Harinagar- Rais Hotel colony locality, Kailakhan and Golf course areas should be disallowed for any type of human activities. Particularly in Harinagar and Rais Hotel colony areas there exist structures located over the crowns of active landslides that are continuously threatened by toe erosion by Balia nala. Inhabitants of these areas are required to be sifted immediately to safer place. Besides, there should be monitored the movements of critical slopes with the help of state of art techniques which could provide timely warning in case any abnormal movement is noticed along the same.

It is a well known fact that vegetation cover minimizes soil erosion, gully formation, and inhibiting landslides which increase general slope stability. Apart from the use of vegetation to manage erosion and protect slopes is relatively inexpensive "Vasistha et. al. (2011)". Therefore well adapted aforestation programmed, combined with its protection leading to survival of plants should be taken up in the slopes, particularly in critical slopes.

Insurance is one means of protection against the natural hazards for fixed property "Friedman (1972)". In view of slope instability and earthquake vulnerability of the township of Nainital, local inhabitants are advised to take insurance for insuring property losses due to the weather hazards and earthquake.

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