DISASTER MITIGATION AND MANAGEMENT CENTRE UTTARAKHAND SECRETARIAT DEHRADUN

Geological note on road subsidence on Yamunotri NH 94 below Wariya village in Barkot tehsil of Uttarkashi district in Uttarakhand (India)

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DEPARTMENT OF DISASTER MANAGEMENT

Preface

Interplay of a number of geotechnical parameters and ground conditions decide the place and pace of slope instability and mass wastage. Geological / geotechnical investigations are therefore highly important for formulating a sound plan for restoration of landslides as also for initiating new developmental programs.

The present study focuses upon mass instability problem in a part of the Yamuna valley around Wariya village in Barkot tehsil of Uttarkashi district. The field investigations were undertaken by Shri Sushil Khanduri, Geologist at DMMC in compliance of the request to this regard from the office of the District Magistrate, Uttarkashi forwarded to DMMC through letter No. 350/13-24(2012-13) dated 16th August, 2012.

During the course of the investigations Dr. R. Rajesh Kumar, District Magistrate, Uttarkashi and Shri Devendra Singh Patwal, Disaster Management Officer, DDMA, Uttarkashi were present in the field on 19th August, 2012 along with other officials of various concerning departments. Assistance extended during the fieldwork by the district administration and other departments is highly appreciated.

1.0 Introduction

Evolutionary history of the terrain, geotectonic setup of the rocks, ongoing tectonic activities, high relative relief and concentrated seasonal precipitation together make the State of Uttarakhand prone to a number of natural hazards. Besides earthquakes the area is frequently devastated by landslides, cloudbursts, flash floods, floods, avalanches, droughts, lightening, cold waves and hailstorms.

Geological instability of the region together with high atmospheric precipitation is responsible widespread landslide occurrences in the region. The rocks of the region are characterized by multiple structural discontinuities and the relationship of these with surface slope often makes conditions favourable for landslides to occur. Once instability is introduced the hill slopes often become chronically prone to landslides. The problem of landslides is aggravated during the monsoon season due to i) enhanced pore water pressure, ii) increased weight of the rock mass and ii) reduced frictional forces.

Landslides cause massive loss of human lives, infrastructure, property and environment. In the year 1998 the State witnessed major landslides at Malpa and Okhimath that took toll of more than 350 human lives. Every year the state looses a number of human lives due to landslides (Fig. 1)

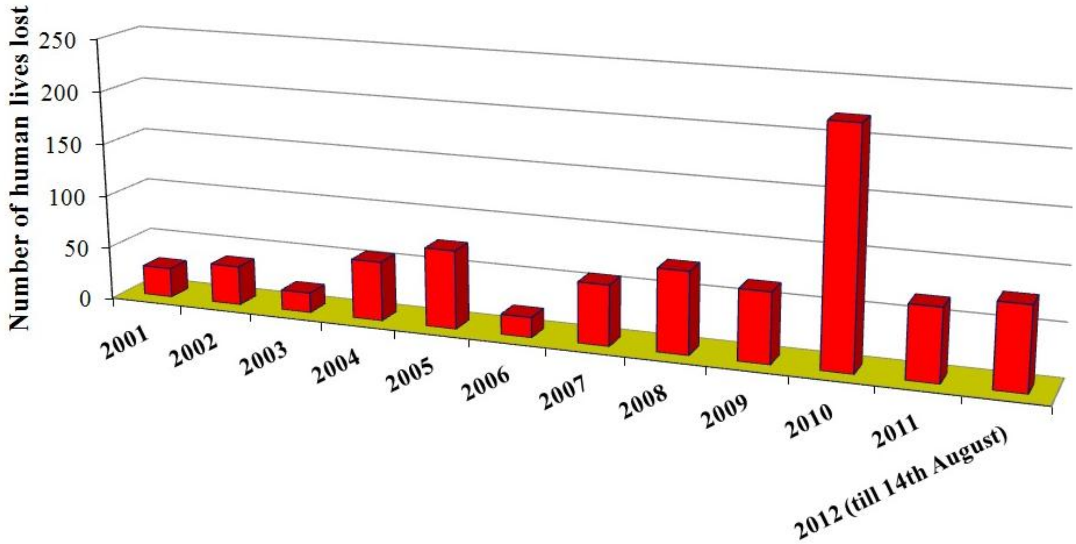

Fig. 1. Year wise loss of human lives due to landslides and flash floods in Uttarakhand.

Landslide induced losses cannot be completely prevented but with proper planning both intensity of their impact and frequency of their occurrence can certainly be reduced.

It is therefore necessary to undertake appropriate geological / geotechnical investigations before starting all developmental initiatives and implement suggested mitigative measures for warding off the threat of landslides. In places where instability has already been introduced in the slope material remedial measures should be undertaken in the area after geological / geotechnical investigation of the area. This would greatly help in significantly reducing the magnitude of the recurring losses caused by landslides.

2.0 General geology, geomorphology and physiography of the study area

The area under present investigation lies in the upper part of Yamuna valley that exhibits characteristically distinct rugged mountainous topography of the Higher Himalayan terrain and is occupied by rocks of Central Crystallines. The valley slopes in the area are largely controlled by lithology and the same have been modified by structural configuration of the rocks and associated erosional processes that include freezing and thawing as also action of flowing water and glaciers.

The rocks exposed in the area are characterized by long, continuous and steep joints / shears and foliation planes. These features are observed to control rocky and precipitous valley slopes at many places.

The ground elevations in the study area generally vary from about 1,960 meters to 2,100 meters above mean sea level (msl). Mountain peaks as high as 3,500 meters in altitude are however also present in the surroundings. The hill slopes in the area are generally observed to comprise of rocky outcrops, rocky cliffs and mantle of colluviums. This area is observed to be prone to rock falls and debris flows that are attributed to structural configuration of the rocks, high relief, presence of overburden and high seasonal precipitation. Steep rocky cliffs at places show indications of small scale instability. Occasionally failures are also observed in the overburden.

The area has sub - tropical climate and experiences high monsoonal rainfall. The summers are pleasant while the winters are cold. Average summer temperature remains around 25° C while the winter temperature may even drop to 0° C. The rainfall pattern in the area shows high spatial variability that is largely controlled by slope aspect.

The area under investigation is located in the Higher Himalayan geotectonic block and lies to the north of Main Central Thrust (MCT) that brings the Central Crystalline rocks in juxtaposition with meta-sedimentary rocks of Lesser Himalaya along a NE dipping tectonic plane. The geological setup of area is given in Table 1.

Table 1: General tectonostratigraphy around the study area.

Tectonic Zone	**Lithology**
NORTH	
Central Crystalline	Augen gneiss, biotite gneiss, with inter - bedded bands of amphibolite, chlorite schist
---------------------- Main Central Thrust (MCT)	---------------------------------
Lesser Himalaya	Quartzite with / without penecontemporeneous mafic metavolcanics intruded by epidiorite.
SOUTH	

3.0 Seismicity

Uttarkashi district has a long and devastating history of disasters, particularly earthquakes. The district falls in Zone V and IV of the Seismic Zoning Map of India (Fig. 2).

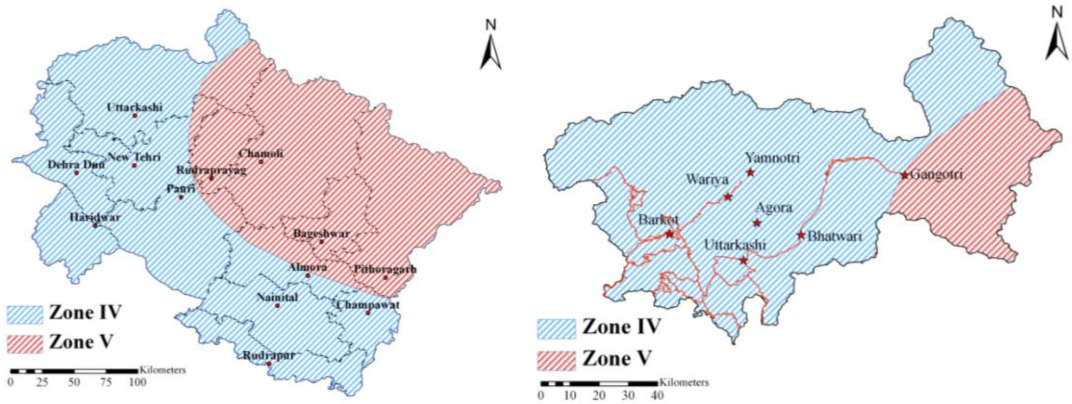

Fig. 2: Seismic Zoning Map Uttarakhand (left) and Uttarkashi (right).

Earthquake of 1803 had devastated the old township of Uttarkashi, then known as Barahat. This was followed by 20th October 1991 Uttarkashi Earthquake. Official information indicates that population of about 3,07,000 in 1,294 villages was effected by this earthquake and 768 persons lost their lives while 5,066 were injured. In addition to this the earthquake claimed 3,096 cattle and as many as 42,400 houses were damaged.

This 6.6 magnitude earthquake had its epicenter at Agora, to the north of Uttarkashi town. Besides causing massive loss of infrastructure and property this earthquake triggered a number of rock slides besides introducing numerous ground fissures. The earthquake also brought forth changes in spring discharge besides those in hot spring chemistry (GSI, 1992).

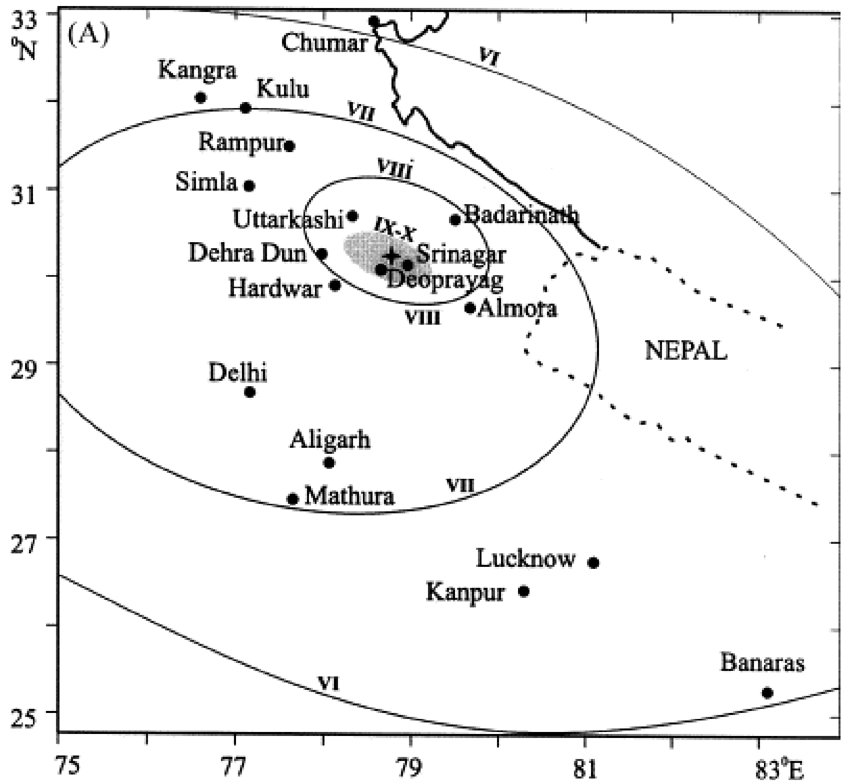

Fig. 3: Seismic Intensity Map of Uttarkashi Earthquake of 1991.

The epicentral tract of 1991 earthquake occupying an area of 20 sq km around Maneri in Bhagirathi valley recorded an intensity of IX – X on MSK - 64 Scale (Fig. 3). The main shock was followed by a series of over 2,000 aftershocks over a period of two months.

4.0 Ground subsidence on Yamunotri NH (NH 94) around Wariya village in Hanumanchatti area

4.1 Introduction

The area under present investigation is located on the Yamunotri National Highway (NH 94) at a distance of 41 kilometers from Barkot and 1 kilometer from Hanumanchatti. Wariya village is located above this area. The area is drained by Yamuna river that follows southwesterly flow direction at this location.

Geological traverses during the course of the investigations were taken along the road section, around the Wariya village and further upslope to examine the geological setup and instability of the slope. Numerous trees of atish (*Alnus napelensis*) were observed just below the affected road area which is indicative of old slide material. Site observations were carried out on 19th August, 2012 and traverses were taken around the site and upslope to examine the geological setup.

4.2 Geology of the study area

The area under investigation is located on the left bank of Yamuna river and is occupied by outcrops as well as overburden. Yamuna is the major drainage system of the area that generally flows in southwestwardly direction.

In situ rocks were not observed at the site of investigation and around the village. The area was observed to be occupied by thick overburden material. Thickness of the overburden was observed to be around 6.0 meters. The overburden material was observed to comprise of top soil, hill wash and debris that consists of brown and grayish, fine grained silty matrix with fragments of gneisses.

Centre Crystalline rocks comprising of gneisses were however observed to be exposed on the right bank of Yamuna river as also along the road section. These rocks were observed to be medium to course grained, grey, slightly to moderately weathered, moderately jointed, medium to thickly foliated and dipping towards northeast at moderate to moderately steep angles. At places the rock mass was observed to have slumped due to fractures and jointed nature of the rocks as also due to the presence of subsurface water / seepage.

4.3 Structural discontinuities

The rocks exposed around the area were observed to be traversed by numerous joints that comprise important structural discontinuities affecting the strength of rock mass and stability of slopes. The Central Crystalline rocks exposed in the area were generally observed to strike E - W to NW - SE and dip towards N to NE at angles varying between 20º to 35º. The rocks were observed to be well jointed and the details of the prominent joints observed in the field are recorded in Table 2.

Table 2: Details of the joint pattern observed in the field.

Joint sets	Dip amount	Dip direction	Strike trend	Remark
I	20° - 35°	000 - 040°	E - W to 130° – 310°	Foliation
II	65° - 75°	135° - 145°	NE – SW to 055° - 235°	Prominent joint
III	55° - 75°	220° - 235°	035° - 215° to 50° - 230°	Prominent joint

5.0 Reconnaissance geological - geotechnical assessment

The landslide zone at Wariya was observed to exhibit very steep slope and gneisses were observed to constitute the bedrock. The rocks were observed to have well develop foliation planes together with prominent jointing / cleavage. The foliations were generally observed to dip at angles varying between 20°– 35° towards N to NE. The foliations were thus observed to dip upstream with moderately steep dip amounts.

Two major springs were observed around the village. Effects of subsurface water are highly pronounced along the discontinuities. The same may however be highly irregular with depth. The rocks below the overburden mass were observed to be highly weathered. Presence of groundwater is thus attributed to intense rock weathering.

Old slide material was also observed in the area which provides favourable conditions for groundwater accumulation and enhanced pore water pressure during heavy rains.

Relative relief in the area was observed to be moderately high. The slopes in the area were observed to be steeper than 45° in the northwestern direction and consists of Central Crystalline gneisses.

The Yamuna river was observed to effect the stability of the slopes in the area. Toe erosion by Yamuna river was observed to induce landsliding along relatively steep slopes that consist of moderately jointed and fractured rock mass.

Presence of weak rock mass, overburden and old slide material in the area have together induced favourable conditions for enhanced pore water pressure and loading of this mass by construction has in turn generated soil creep and slope failure.

Evidences of soil creep and built up of stresses were observed in the agricultural land upslope of the road and below the village. Stress built up in the soil mantle was observed to be released by the creation of tension cracks. These cracks were observed to be up to 30 cm wide and up to 1.0 meter deep. Ground subsidence of around 2.0 – 4.0 meters was observed within the slide zone in its crown just below village.

Debris flows were observed in the entire stretch below the village and the road. The area under investigation was thus observed to be in an unstable state. Accelerated erosion and increased instability of hill slope are however attributed to indiscriminate excavation of the hill slope for construction of road. It is worth noting that the unconsolidated debris material on the slope below Wariya village is in a critical condition and the incisive stream-bed erosion poses grave threat of mass movement in the area.

Undercutting of slopes for reconstruction of the damaged road would remove the lateral support of the upslope material that might lead to slope failure and the same might pose a risk even for the village.

6.0 Conclusion and recommendations

Wariya village faces serious slope stability problem and a stretch of the NH 94 has already subsided during the current monsoons (year 2012). As discussed in the previous sections the area has a history of mass instability and interplay of many processes has rendered the area highly vulnerable.

In view of the risk posed to the settlement special care needs to be taken while excavating the hill slope for reconstructing the road. So far as possible excavation should be minimized and the slope material should not be disturbed.

Enhanced pore water pressure during heavy rains facilitates slope instability. It is therefore required that excess water be drained out from the slope material. Provision of valley ward slanting perforated pipes can be made for this.

At the same time provision of safe disposal of rainwater away from landslide and subsidence zone is required to be made by creating a network of lined drains.

In view of the landslide threat local population is advised to stay away from subsidence and landslide affected areas. The households living in the zone of subsidence are at the same time required to be shifted to alternate safer locations.