

Disaster Prevention and Management

Disaster management strategy for avoiding landslide induced losses to the villages in the vicinity of the Himalayan township of Mussoorie in Uttarakhand (India)

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ISSN 0965-3562

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Published in association with the
Disaster Prevention and Limitation Unit,
University of Bradford



Certificate number 1965299

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Printed by Printha Group Ltd, Scirocco Close,
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378

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Abstract

Purpose – Many villages in the vicinity of the hill township of Mussoorie in the Indian Himalayas are witnessing signs of an impending disaster. These villages are witnessing active wastage that might take a heavy toll of human interest during the monsoon season and therefore the paper proposes examining this subject.

Design/methodology/approach – A detailed study was undertaken in the area of Mussoorie.

Findings – It is suggested that a series of prevention and mitigation measures (both structural and non-structural) with the involvement of the local community are required for ruling out the possibility of any mishap in the area.

Originality/value – This paper highlights the importance of having a disaster management strategies for the region and involving the community with these.

Keywords Landslides, India, Disasters, Management strategy

Paper type Research paper

Introduction

Natural disasters are common in the Himalayan state of Uttarakhand but their increased frequency and impact in the recent past has turned out to be a cause of concern for both the masses and the government alike. In the past earthquakes (1991 Uttarkashi and 1999 Chamoli), landslides (1998 Malpa and Okhimath, 2003 Uttarkashi), cloudbursts and flash floods (1971 Alaknanda, 2001 Burakedar and Khetgaon) have caused great damage to life and property in the various parts of the state.

The Himalayas owe their evolution to the subduction and eventual collision of the alien plates (Indian and Eurasian) that have resulted in the formation of the tectonically active Himalayan orogenic belt (Thakur, 1992) which is subject to modifications by natural processes. High relief and peculiar meteorological regime of the region add to the pace of the natural degradational processes. Unplanned and uncontrolled



anthropogenic interventions in this sensitive and fragile terrain, in the form of unplanned cutting of slope for construction, blasting of highly jointed rock mass for road construction and unplanned disposal of the slope cut debris material, further add to the vulnerability of the populations residing in this terrain and expose them to the risk of natural hazards.

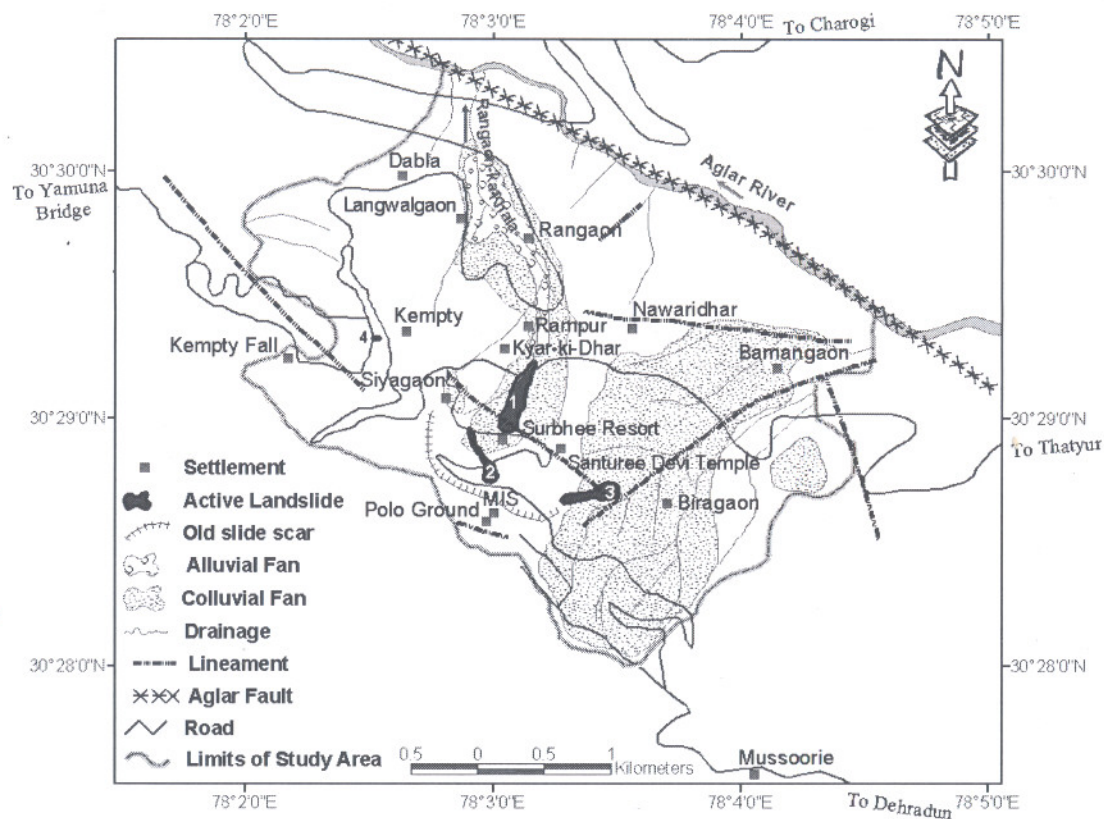
The present communication focuses on the mass wastage-related problem around the hill township of Mussoorie located in the Lesser Himalayas. Natural degradational processes together with unplanned disposal of the atmospheric precipitation and mounting anthropogenic pressure are observed to threaten the livelihood strategy of the masses and exposing them to the risk of natural disasters. The micro-watershed of Rangaon-ka-Kahala together with the surrounding area of Birgaon and Kempty housing the landslide zone was studied in detail and a detailed management plan for the same was prepared on the basis of the satellite image interpretation and field studies. The individual layers of the various geo-environmental parameters, such as faults, lineaments, landforms, drainage, landslides and the others, were integrated using ARC GIS 8.3 software (Figure 1). Rangaon, Rampur, Lagwalgaon and Dabla villages of Thatyur Block of Dhanolti Tehsil (district Tehri Garhwal) fall in Rangaon-ka-Khala micro-watershed (Figure 1).

Overview of the area

Mussoorie is a famous hill station located in the Lesser Himalayas at a distance of 26 kilometres from Dehradun, the capital of Uttaranchal state of India. The township is located between 1,820 and 2,100 metres above mean sea level and experiences appreciable rainfall (annual rainfall > 2,000 mm) most of which (~95 per cent of the total) is confined to the monsoons. It was during the British rule that Mussoorie developed into a township and its population in 1881 was just 3,106 (Atkinson, 1882). Increasing economic opportunities have led to the growth of population and infrastructure and the present population of the town is 29,329, excluding the floating population of tourists, students and others. This has resulted in the hitherto pristine hills witnessing rigorous cutting of hill slope for erecting new commercial/residential complexes, expansion of existing parking spaces to cope up with the mounting vehicular traffic, creation of educational and recreational facilities besides road cutting and widening. The vegetal cover is consequently being destroyed and the natural drainage system is being disrupted or disturbed even in the outskirts of Mussoorie town, thereby causing the problems of slope instability and bank erosion in the nearby villages.

The Mussoorie-Yamuna bridge road links the township of Mussoorie to Yamuna valley and passes through Kempty Fall which is a major tourist attraction around the town. Severe landsliding is observed in the vicinity of Kempty Fall along the Mussoorie-Yamuna bridge road that is taking toll of the agricultural and community forest land and threatens the livelihood strategy of the people and the existence of the habitations around. The vehicular traffic along Mussoorie-Yamuna bridge motor road together with other link roads (Kempty-Thatyur and Kempty-Charogi) also faces high risk of landslide hazard (Figure 1).

The geomorphic set-up of the area is defined by the highly dissected denudo – structural hills that have witnessed gravity transport with the villages of Rampur, Langwalgaon, Birgaon and Bamangaon being located on colluvial deposits. Rangaon



Note: 1, 2, 3 and 4 in the map refer to Surbhee Resort Slide, Siyagaon Slide, Devidhar – Biragaon Slide and Kempty Slide respectively

Figure 1.
Map of the study area
showing disposition of
landslides, landforms,
faults, lineaments and
drainages together with
road network and
habitations

village is located on an alluvial fan (Rangaon Fan) and immediately above the proximal end of this fan a major slide (Surbee Resort Slide) has developed (Figure 1 and Plates 1 and 2).

The satellite imageries (IRS 1D LISS III False Colour Composite of October, 2002) reveal a prominent ridge valley topography of area with narrow valleys and deep gorges in the upper part. The valleys, however, widen gradually towards the lower part with slopes being generally moderate to steep. Dendritic drainage pattern is conspicuous in the area with the drainage texture being medium to coarse and most of the slides are observed to be developing along the drainage lines. Rangaon-ka-Khala drains into Aglar River that is the major stream of the area and follows NW-SE trend of the Aglar Fault (Figure 1).



Plate 1.
Field view of
Rangaon-ka-Khala
flowing through an
alluvial fan (Rangaon Fan)
and seen in the
background is Surbee
Resort Slide

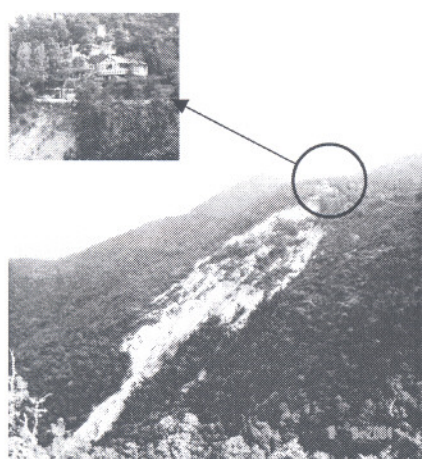


Plate 2.
Full view of the Surbee
Resort Slide. Inset is the
Surbee Resort situated
immediately above the
active scarp of the large
slide named after this
resort

The rocks exposed in the area belong to meta-sedimentaries of Lesser Himalaya that are mostly calcareous in nature together with subordinate variegated shales (Valdiya, 1980). These have witnessed many stages of tectonism that has rendered these highly folded, faulted, jointed, and fractured. Four joint sets trending NNE-SSW, ESE-WNW, NNW-SSE and NE-SW are prominent in the region. Together with these the area has many prominent lineaments delineated through the study of satellite imageries. These trend E-W (Aglar Fault), NW-SE, E-W, and NE-SW. The NW-SE trending lineament extending from the NE of Siyagaon to the SE of Santuree Devi Temple is very conspicuous. The steep slope (more than 45°) below Surbee Resort and Siyagaon village is the geomorphic expression of this lineament. Another major lineament mapped in the area trends NW-SE can be traced along the southern edge of the Polo Ground where the hill slope is steep with prominent zones of old rock fall. The creep observed on the northern (valley ward) edge of Polo Ground in upper reaches of MIS can also be attributed to this lineament. Sudden skewing of the distal part of large colluvial fan of Birgaon-Bamangaon area is due to E-W trending lineament that passes through the proximity of Rampur-Nawaridhar-Bamangaon villages (Figure 1).

The land use/land cover in the hill slope around Santuree Devi and Surbee Resort area is defined by open to dense forest cover (Plate 2). Terrace cultivation is dominantly practised around Siyagaon, while a few pockets of open scrub and sparse scrub are also noticed. Along Rangaon-ka-Khala terrace cultivation is being practised on the colluvial deposits on the upper slopes while the middle slopes support grasses. On both the banks of Rangaon-ka-Khala around Rangaon and to the upslope of Kempty-Charogi road crossing terrace cultivation is being practiced on the reworked fan surface (Plate 1). In the lower part of Rangaon-ka-Khala micro watershed down slope of the Kempty-Charogi road the agricultural fields of Langwalgaon, Rampur and Dabla villages occupying the lower slopes of Rangaon-ka-Khala are developed over the distal part of Rangaon Alluvial Fan.

Landslide scenario in the area

During the fieldwork undertaken in the area attempts were made to assess the past disaster events in the area through interaction with the village elders. It was revealed that a small slide scar had developed below the Surbee Resort in Panyara area after the 1991 Uttarkashi Earthquake. This slide scar activated and enlarged gradually and the incessant rains of 2003 monsoon transformed it into a large and active slide zone. The slide material comprises rock fragments of various sizes including large boulders along with debris material. This slide is causing the subsidence of Mussoorie-Yamuna bridge road that poses serious risk to the vehicular traffic around Surbee Resort where the road passes through the active scarp, besides threatening the infrastructure of the resort itself (Plate 2). The slide mass, transported downstream by Rangaon-ka-Khala, is causing severe damage to crop fields, together with community lands of Kyar-ki-Dhar, Nawaridhar, Rangaon, Rampur, Langwalgaon and Dabla villages. The Water mills (*gharats* in local parlance) of these villages were reportedly washed away during the monsoons of 2003. Rangaon village is the worst affected and suffered major loss of agricultural and community land, the *khaliyas* (granaries in local parlance), and houses. The cattle sheds (*channies* in local parlance) of Nawaridhar, Kyar-ki-Dhar and Rampur villages were also washed away during this event. The Kempty-Charogi and Kempty-Thatyur motor roads are also being badly damaged by the slide.

Siyagaon Slide is a translational debris rock slide developed below Mussoorie International School (MIS) with the slide debris being spread over the crop fields and community land of Siyagaon and causing damage to Mussoorie-Yamuna bridge motor road at three places (Plate 3). The slide material comprises rock fragments including large boulders of dolomite and limestone along with the debris material. Evidence of creeping movement were observed in the upper hill reaches at the junction of Polo Ground and MIS.

Devidhar-Biragaon Slide is a translational debris rock slide that has developed in the upslope of Biragaon and has an active scarp with the slide material fanning out into the agricultural fields and community lands of Biragaon village and adjacent area of Ghuttudhar (Plate 4). Santuree Devi-Biragaon motor road has been badly damaged by this slide.

During the fieldwork small slide scars were also observed to be initiating to the down slope of Kempty and upslope of Kempty Lake on Mussoorie-Yamuna bridge road (Plate 5).

Causative factors of the landslides

Both Surbee Resort and Siyagaon slides represent reactivation of a large old slide zone that extends from Siyagaon to the further east of MIS (Figure 1). The *in situ* rocks



Plate 3.
Field view of the Siyagaon
Slide damaging
agricultural fields of
Siyagaon along with the
Mussoorie-Kempty stretch
of the Mussoorie-Yamuna
Bridge motor road

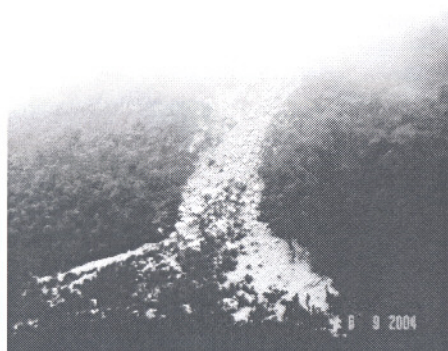


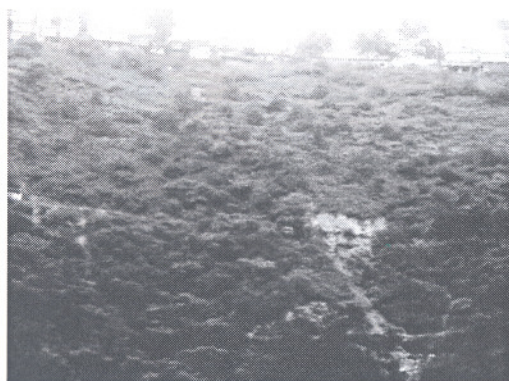
Plate 4.
Field view of
Devidhar-Biragaon Slide

exposed in the road cutting in this area are observed to be highly jointed and fractured dolomitic limestone with four distinct sets of joints. The joint set trending ESE-WNW with 60° - 70° dip towards north shows joint spacing of 4-6 cm and aperture of 3-5 mm. Other joint set trending NNW-SSE with dip of 70° towards east shows joint spacing of about 5 cm and joint aperture of the order of 1 mm. The third set of sub vertical joints trends NE-SW and has joint spacing of about 4 cm with an aperture of 2 mm. The NNE-SSW trending fourth joint set dips towards west at angles varying between 60° and 65° . These show joint spacing of about 10 cm and aperture of the order of 2 to 2.5 mm. Stereographic analysis of the joint set data shows that the intersection of the former three joint sets plunges at high angles (65 - 70°) towards NE that is also the direction of the slope in the area that is a major cause of rock failure. Apart from this the percolation of water through joints, fractures and cracks and consequent increase in pore water pressure as also the lubrication of joint planes that act as failure surfaces seem most likely reasons for triggering the Surbee Resort and Siyagaon slides. Field investigations reveal that rainwater collected over the Polo Ground and MIS is being disposed off in an unmanaged manner in the crown portion of the active slide scars. This concentrated discharge has a definite role to play in destabilising the slopes and triggering landslides.

Devidhar-Biragaon debris rock slide is developed in an area that has witnessed rock fall in the past as evident by the presence of huge boulders with weathering surfaces and lichen growth. Large volume of water enters the crown portion of the slide during rainy season, as the surface runoff of MIS is drained into a small scupper across the road downslope, and drains further downslope through steep slope of large old rock fall zone to the immediate upslope of Biragaon. Previously the surface runoff used to get dissipated all through the hill slope but the slope modifications for infrastructure creation at MIS and consequent channelisation of the water has altered the natural mechanism of draining out the surface runoff through the multiple channels. This has augmented the pore water pressure and has ultimately caused slope failure in the form of debris rock slide.

The rocks in the area are disposed at critical spatial orientations that facilitate active mass wasting in the region. Overloading of this critical mass with heavy

Plate 5.
Field view of Kempty
Slide Zone. Seen in the
ridge are commercial cum
residential complexes of
Kempty



structures (MIS and Surbee Resort) and changing the subsurface water regime by unmanaged wastewater disposal add to the slope instability.

The perceived risk

During the previous monsoon seasons the area has witnessed losses (Table I) and the loss of agricultural land, pastures and community forest together with water resources adversely affect the life support strategy of the masses. If timely mitigation measures are not initiated the ongoing mass wastage in the area can lead to devastation during the coming monsoons.

It is observed that the flow lobe of the Surbee Resort Slide emerges from the proximal part of Rangaon Fan along Rangaon-ka-Khala and fans out further down slope, thereby posing a threat to the houses of Rangaon during incessant rains. Huge volumes of debris are presently being discharged into Rangaon-ka-Khala. In the vicinity of the Rangaon village Rangaon-ka-Khala flows through a narrow gorge and the material emanating out of the gorge fans out and poses threat to the habitations at Rangaon (Plate 6). Six families, with a population of 45 residing on the right bank of Rangaon-ka-Khala in Rangaon are at high risk though the entire Rangaon village is vulnerable to bank erosion during rainy season (Plate 6). The majority of these fall into the category of infants and women, which further enhances their vulnerability.

Slope cutting for road construction and widening has altered the slope angle at many places around Kemptoy on Mussoorie-Yamuna bridge road. Heavy concentrated precipitation during the previous monsoons initiated development of small slide scarps in this area. In the event of incessant rains the enlargement and the head ward shift of these slide scarps might pose a serious threat to commercial cum residential complexes

Village name	Families affected	Land affected (in hectares)	Watermills washed away	Cattle sheds affected
Rangaon	17	2.260	3	6
Nawaridhar	2	0.205	1	0
Langwalgaon	10	1.547	2	0
Dabla Matela	3	0.210	3	0
Biragaon	6	0.756	0	3

Table I.
Summary of the losses
incurred by the villages
in the vicinity of
Mussoorie



Plate 6.
View of the Rangaon
village that is vulnerable
to flash flood and debris
flow during rainy season.
Rangaon-ka-Khala is seen
in the background

of Kempty while the Kempty Lake might witness debris flow slide with the downslope expansion of the toe portion of these slides (Plate 5). This might jeopardise the very existence of the recreational facilities created around the Kempty Lake.

Disaster management strategy for the area

Although human interests are at stake at a number of villages in the area, human population is at risk in Rangaon village. In order to minimise the risk posed to the habitations of Rangaon village there is an urgent need of undertaking structural mitigation works, such as construction of check dams at every 25 m interval across the Rangaon-ka-Khala stretch in the down slope of Surbee Resort Slide and upslope of Rangaon village. This measure would minimise the pace of toe erosion of Rangaon-ka-Khala and the consequent loss of the agricultural and community lands of Nawaridhar, Kyar-ki-Dhar, Rampur, Rangaon, Langwalgaon and Dabla villages. For further ensuring the safety of the habitations in Rangaon village from flash floods and debris flow during the rainy season, construction of spurs/protection walls need to be taken up along the right bank of the stream between Kyar-ki-Dhar and Rangaon villages.

Uncontrolled percolation of water into the slide zones is observed to be causing slope destabilisation in the area, therefore lined drains need to be constructed in the upslope portion of the Surbee Resort. This would restrict the head-ward shift of this slide and its further enlargement. The percolation of water in Siyagaon Slide zone and also in the area adjacent to the left flank of Surbee Resort Slide needs to be minimised by creating a proper drainage network in the upslope area around MIS and for this the cemented pipes of the Polo Ground should be connected to vertical lined drains or catch pipes. Similarly the horizontal drains with proper lining need to be constructed in MIS area and should be connected to the catch pipes or vertical lined drains to be laid in a radial pattern down slope up to the stream bed. The vertical lined drains or catch pipes should not be allowed to terminate in between as is happening presently. The radial pattern of vertical lined drains would facilitate the disposal and dissipation of surface runoff and minimise percolation of water into the valley slopes and consequently avoid slope failure to a great extent.

The Devidhar-Biragaon Slide can be controlled by minimising the percolation of water into crown portion of this zone through the construction of horizontal lined drains in the upslope area and connecting these to the vertical drains laid in a radial fashion along the slope up to the stream bed level. The vertical drains of MIS terminating into a small scupper across the road in the upslope of this slide zone should also be connected to catch pipes to be laid down slope up to the stream bed. This would check the head-ward shift of the slide zone.

In order to reduce the risk to the vehicular traffic along 100m stretch of the Mussoorie-Yamuna bridge motor road around Surbee Resort protection work needs to be taken up immediately. This would not however solve the problem permanently as all such structures would have to be erected over the active scarp of Surbee Resort Slide. Alternate route alignment through the crop fields of Siyagaon is a better, viable and cost effective option. This alternative of realignment of the road would not however avoid the Siyagaon Slide for which retaining wall with weep holes needs to be constructed at the hillside where the Siyagaon Slide was triggered.

The preventive measures such as shifting public utility buildings and buildings of mass occupancy to a safer location are also required as the head-ward expansion of the Surbee Resort Slide might cause subsidence of the Surbee Resort in the near future.

In order to cope with the impact of heavy rains and subsequent flash floods and debris flow during the rainy season an emergency evacuation plan needs to be prepared for Rangaon village as an essential component of preparedness. Facilitating creation of disaster intervention teams (DITs) in Rangaon, Nawaridhar, Kyar-ki-Dhar, Rampur, Langwalgaon and Dabla villages from among the masses could be the first step in this direction. Initiatives can then be directed towards human resource development of the DIT members through focused trainings on Search and Rescue and Medical First Aid and the like. The DITs at the same time have to be equipped with essential equipments like solar lights, first aid boxes and efficient communication systems. Besides bringing forth mass awareness regarding the disasters and preparing them mentally for temporary evacuation. The DIT members would be responsible for raising alarm in the event of heavy rains and facilitate temporary evacuation of the severe hazard prone Rangaon village. The DIT members would also be bringing forth unanimity amongst the fellow villagers of Nawaridhar, Kyar-ki-Dhar, Rampur, Langwalgaon and Dabla villages for not approaching their crop fields close to Rangaon-ka-Khala during heavy rains. Attempts would also be made to persuade the fellow villagers to prevent their children from attempting to cross Rangaon-ka-Khala at the time of heavy rains. The DITs are thus expected to act as the first responders in the event of flash flood and debris slide in the area.

Other urgently required non-structural mitigation measures include a complete ban on quarrying along hill slopes with active slide zones (as near Rampur village on Kempty-Charogi road) and the introduction of restricted blasting for road construction and or road widening in this area.

Kempty Fall is a major tourist attraction and revenue earner and the protection of the area can be ensured by constructing retaining walls to control the smaller slides developing on the upslope of Kempty Lake. A proper drainage system also needs to be introduced for the disposal of the household wastewater of Kempty.

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