

LANDSLIDE MAPPING AND MITIGATION ALONG ALAKNANDA BASIN OF GARHWAL HIMALAYA

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Abstract

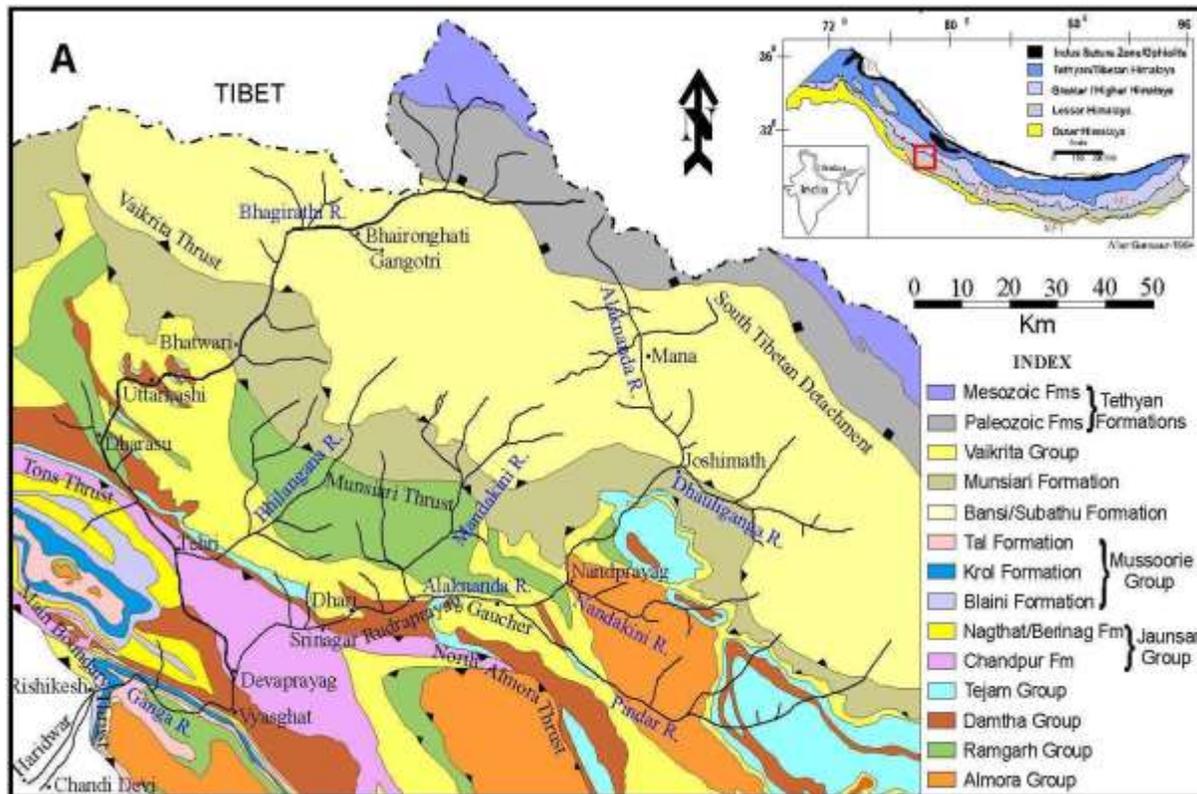
Landslide, the sudden fall of the loose and unconsolidated rock debris due to gravity also termed as falls, flows, creep, lahar, lateral spreads, slides etc. occur as a ground failure of river bluffs, cut and-fill failures that may accompany highway and building excavations, collapse of mine- waste piles, and slope failures associated with quarries and open-pit mines. Underwater landslides usually involve areas of low relief and small slope gradients in lakes and reservoirs or in offshore marine settings. Many factors contribute to slides, including geology, gravity, weather, groundwater, wave action, and human actions. Anthropogenic reasons viz. inappropriate drainage system, change in slope/land use pattern, deforestation, agricultural practices on steep slopes, cutting & deep excavations on slopes for buildings, roads, canals & mining, inappropriate disposal of debris after excavations are also responsible for landslides. Loading the top of the slopes, cutting in to sensitive slopes, placing fills on slopes, or changing the water condition on slope should be avoided or done very cautiously. Common engineering techniques for landslide prevention include provisions for surface and subsurface drainage, removal of unstable slope material, construction of retaining walls, or some combination of these. Landslide along Alaknanda basin in the areas of narendranagar, srinagar valley, kaliyasaur, hailing, hanuman chatti and joshimath takes place and mapping of it will help in formulating the mitigation plan for the landslide in these areas of Garhwal Himalaya. [1][4][6][9][12].

[Keywords: Landslide, Alaknanda basin, Mitigation]

Introduction

The Himalayan orogenic belt has been a topic of interest for geoscientists from all over the world because it represents the southern border of the largest zone of active crustal deformation on the Earth, resulting from the continental collision between India and Asia this orogenic belt formed as a result of northward drift of the Indian plate after it split from the Gondwanaland since the Eocene, about 55 million years ago. The Himalayan kinematic evolution is largely controlled by major thrusts, bounding the various terrains that have been gradually scraped off the under thrusting Indian plate and accreted to the orogenic.

The Garhwal Himalaya geographically forms the central part of the Himalayan orogenic belt that runs in an actuate shape for a strike length of about 2400 km with width varying from 230 to 320 km and represents a classic example of collision-type mountain belt. The collision followed by continued northward convergence of India against Tibet resulting in crustal shortening accompanied by uplift and thrusting activity which led to the thrusting of Higher Himalayan Crystallines over the sediments of the Lesser Himalaya along the Main Central Thrust (MCT). Continued tectonic activity also produced nappes (e.g. Krol) in the Lesser Himalaya which was pushed due south along the Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT). Stacking of thrust slab caused differential loading and depressed the frontal part of the Indian plate in front of the advancing nappes, thus producing sag or a foreland basin in front of the rising Himalaya. [1][2][7][8].



Geological Map of the study area (Garhwal Himalaya, Extracted from Valdiya, 1980)

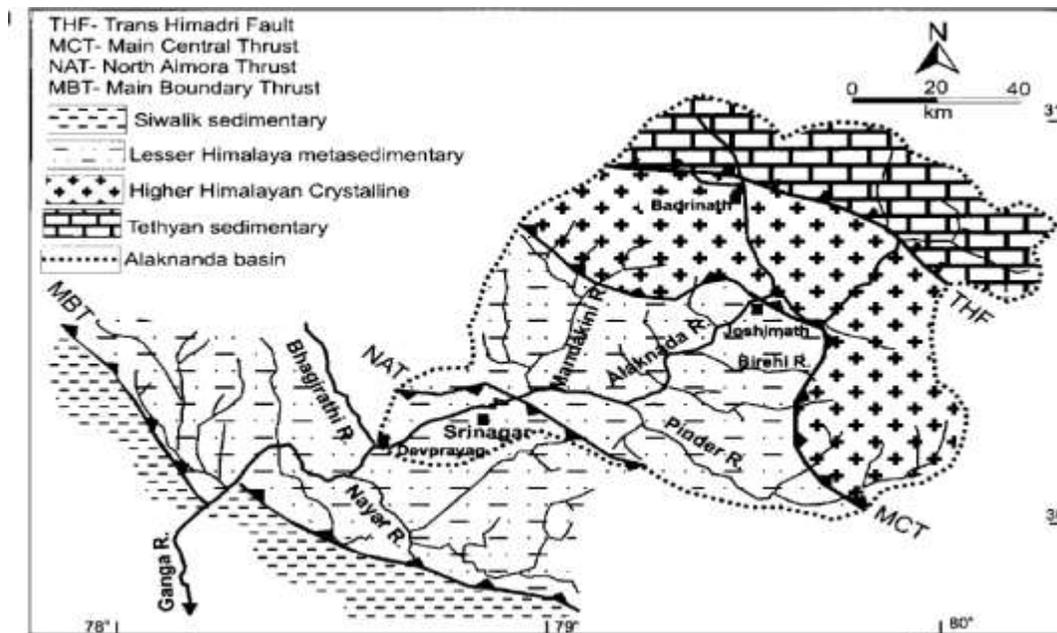
Geomorphology and Hydrogeology

The Alakhnanda River, after originating from the Bhagirath Kharak and Satopant glaciers, is joined by many tributary streams before meeting the Bhagirathi River at Devprayag to form the Ganga River. Along its course, the river traverses through the Tethyan sedimentary, higher Himalayan Crystallines and the lesser Himalayan meta-sedimentary rocks. In the present study, the Alakhnanda basin around Srinagar ($30^{\circ}12' - 30^{\circ}15'N$ and $78^{\circ}45' - 78^{\circ}50'E$). After emerging from a narrow valley in the upstream of Srinagar, the Alakhnanda River becomes a wide, highly sinuous meandering river which flows through a wide valley of ~ 8 km. [3]

The area shows a young mountainous topography wherein the snow covered high peaks and the deep narrow gorges present a picturesque awe inspiring landscape. The height above the m.s.l. rises from 510.87 m at Devprayag to 1906.25 m at Joshimath and to 3123.2 m at Badrinath. The height at the Mana pass, 8 km ahead of Badrinath, attains 3660 m mark. The climate is governed by the altitudes. Winters are marked by heavy snowfall and the temperature often comes down below zero degree mark. [2][7]

The Alakhnanda originated from beyond Mana pass. The river uptill its confluence with Dhauliganga at Vishnuprayag is known as Vishnu Ganga. There are two prominent streams joining the Alakhnanda from left side near Hanumanchatti and south of Pandukeshwar. The Dhauliganga is the most significant of all tributaries with considerable discharge. The Helang and Patal Ganga are nearly parallel streams with an unusual straight course, suggesting a structural control. The Birahi Ganga joins Alakhnanda River between Chamoli and Pipalkoti. It was on this river that the Gohana Lake once existed. [8]

The rivers in the Alakhnanda valley have strong erosional power because of steep gradient, cutting thereby deep V-shaped gorges. The valley widens beyond Pandukeshwar. River terraces are common at places where the valley is wide enough. The change in the river course has been observed at 205 km. there are several sites where the river has abandoned its original course and now flows in comparatively younger courses.



Generalized lithology and structure of the Alakhnanda basin (Modified after Ahmad et al.2000).

Demarcated areas of Landslide

Narendranagar: is around 14 km away from Rishikesh. At Narendranagar the rocks generally we found is of Krol formation. Krol formation consists of permo-carboniferous age which is thrust over the meta- sedimentaries of Early Proterozoic to Late Paleozoic. Krol formation basically consists of sedimentary rocks like crystalline Limestone, low grade metamorphosed rocks like Phyllites and Quartzites etc. which are thrust over the Lesser Himalaya. This Krol thrust and the Main Boundary Thrust are parallel to each other. In Some place we had seen some pulverized limestone having re-crystallized small cris-cross veins, vein let structure, secondary minerals in the veins like calcite. [4][5]

Due to over thrusting the fold limbs got vertical inclination and water precipitations act as a leaching between the joints of the two limbs of the fold. There was a significant feature of Landslide near the Narendranagar village. As the rock type of the area is of milky quartzite, phyllite, and slate i.e. flaky materials, this landslide may have caused due to heavy rains.

Srinagar valley (NAT & KT): Srinagar Valley is bounded by two major north dipping Thrusts which we known as the North Almora Thrust (NAT) and the Kirtinagar Thrust (KT). We see meandering in the Alakhnanda River between NAT and KT. We also see sand bars; point bars deposits in this river.

Two Thrust activated in this regions. Due to the gravity flow in the Srinagar valley of Alakhnanda River. River course is high in the monsoon time and the river cliff is cutting through the water flow. After emerging from a narrow valley in the upstream of Srinagar, the Alakhnanda River becomes a wide, highly sinuous meandering river which flows through a wide valley of ~8 km. the Gently sloping northern flank with high concentration of young stream. Due to high sinuosity and two faults in this region triggering the landslide and also meandering river cutting the river cliff and the landslide occur. [5][6][13].

Lithologically, the area is dominated by low-grade upper Proterozoic phyllites which merge with the flaggy quartzites towards north. The phyllites, which are tightly folded and fractured, are intercalated with sills and dykes of metabasics. Contact between the phyllites and flaggy quartzite is marked by southerly dipping NAT, which is characterized by a wide shear zone around Srinagar. NAT becomes vertical or even north-dipping at places.

Kaliyasaur landslide: One of the most anomalies landslides of the Himalaya is Kaliyasaur landslide. This landslide had blocked the national highway repeatedly till 15 year. This Landslide is caused due to Kaliyasaur fault i.e. tectonic movement.

In the rock formation there is feldspar is more that is kaolinization process is occurring and due to the process the fracture occurred in the rock. And landslide is starting from the fractured rock and Kaliyasaur Fault the fault gauge material made there. Also it is a sheared zone.

Hailang: Near Hailang village, we had seen exposure of Main Central Thrust (MCT). The Main Central Thrust (MCT) is a major intracontinental thrust in the Himalayas which plays central role in any discussion on the geodynamic evolution of the Himalayas. It is responsible for a significant proportion of the shortening consequent upon the India-Asia collision. However, identification and location of MCT has always been problematic in all the sectors of the Himalayas.

Chamoli Earthquake, 1999 in this zone triggering landslide near Hailang Village. Due to Main Central Thrust, many landslides occur in this faulted area. Rock type of this area is Dolomite which cause landslide in this region.

In the Alakhnanda valley, the Main Central Thrust (MCT) separates the Central Crystalline from the underlying meta-sedimentaries of the Garhwal Group [2]. Besides the MCT there are several faults present in the area. The area is composed of dolomites, slates and quartzites belonging to Garhwal Group and gneiss, schists and metabasics belonging to Central Crystalline Group of high grade metamorphics. These rocks are highly weathered and sheared. Slate units are generally thinly bedded while quartzites for the most part are thickly bedded and highly jointed. Locally, the jointed rock mass are filled by gauge materials as a result of shearing. The gneisses are hard and massive but at few locations these are observed as loose boulders. Average inclination of the beds is about 30° towards the NE, however, local variations are also observed due to multiple folds.

Hanuman Chatti: The landslides along Chamoli to Badrinath section of the Rishikesh – Badrinath National Highway are mostly debris slides, debris flows, rock slides and rock falls. Landslide masses are mainly composed of boulders, rock fragments and soil. Debris flows are mostly confined along lines of natural drainage. Where rock slides have occurred, they are predominantly planar failures along discontinuity that dipping downslope. In such cases sliding takes place as the rock blocks slide along the discontinuity surfaces. Landslides along the road occur on slopes that vary from 35° to sub vertical. Most of the landslides have fractured and jointed rocks in the main scarp below the crown below which are debris accumulation that extend to the road level and below.

Near Hanuman Chatti area, the hill slope is vertical or nearly vertical so the high grade of steepness and river tributary with high intense rainfall. The debris flow of the rock which draws down with water and sliding take place.

Joshimath: Here Landslide occurs due to the high intense water fall in upstream river of Alakhnanda Basin. In Rainy season water comes down with high volume in short term period and erodes the big rock to convert in to boulder. This boulder is rolled down with water force and also in tributary of this Basin. All the fragments of the rock slump down with water and occurring as a landslide. The River carrying incredible large amount of sediments, generated by widespread and frequently devastating landslide, rock fall and slumping. [2]

Mitigation

Prevention of large, natural landslides is nearly impossible, but common sense and good engineering practice can do much to minimize the hazard.

For example, loading the top of the slopes, cutting in to sensitive slopes, placing fills on slopes, or changing the water condition on slope should be avoided or done very cautiously.

Common engineering techniques for landslide prevention include provisions for surface and subsurface drainage, removal of unstable slope material, construction of retaining walls, or some combination of these.

Drainage control is usually an effective way to stabilize a slope. The basic idea is to keep water from running across or infiltration the slope. Surface water may be diverted around the slope by a series of gutters. This practice is common for road cuts. The amount of water infiltrating a slope may also be controlled by covering the slope with an impermeable layer such as soil cement, asphalt, or even plastic.

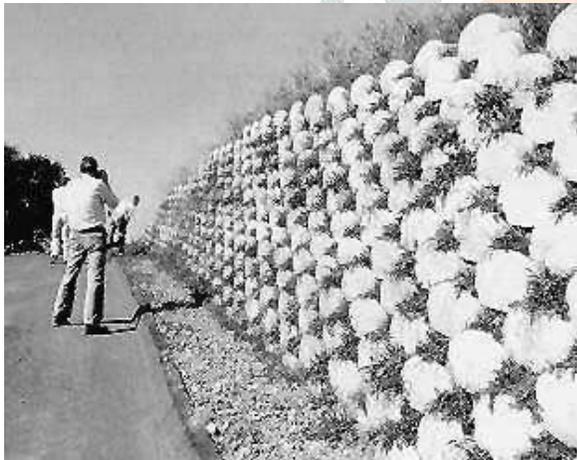
Groundwater may be inhibited from entering a slope by excavating a cutoff trench. the trench is filled with gravel or crushed rock and placed in a position to intercept and divert groundwater away from a potentially unstable slope.

Grading slope is another way to increase slope stability. Two common techniques are reducing the gradient of a slope by a single cut and fill operation, and benching. In the first case, material from the upper part of the slope is removed and placed near the base. The overall gradient is thus reduced and material is removed from an area where it contributes to the driving force, and placed at the toe of the slope, where it increases the resisting force. This method is not practical on very steep, high slopes. As an alternative, the benches are designed with surface drains to divert runoff. The benches do reduce the slope and, in addition, are good collection sites for falling rock and small slides.

Retaining walls constructed from concrete cribbing, gabions (stone-filled wire baskets) or piles (long concrete steel or wooden beams driven into the ground) are designed to provide support at the base of a slope. They should be keyed in well below the base of the slope, backfilled with permeable gravel or crushed rock, and provided with drain holes to reduce the chances of water pressure building up in the slope.



Retaining wall for prevent the landslide along the Road



Gabions (stone-filled wire baskets) to prevent the landslide along the Road

A less common method of increasing slope stability involves insertion of heavy bolts (rock bolts) through holes drilled through potentially unstable rocks into stable rocks.

After movement of a slide has begun, the best way to stop it is to attack the process that started the slide. In most cases, the cause of the slide is an increase in water pressure, and in such cases, an effective drainage program must be initiated. This may include surface drains at the head of the slide to keep additional surface water from infiltrating and subsurface drain pipes or wells to remove water and lower the water pressure. Draining will tend to increase the resisting force of the slope material and therefore stabilize the slope. [9][14][6].

When slope materials are fine-grained and relatively impermeable, drainage is difficult at best and will probably be ineffective. In this situation, common correction methods include reducing the slope angle and constructing artificial barriers such as retaining walls.

Drainage corrections: The most important triggering mechanism for mass movements is the water infiltrating into the overburden during heavy rains and consequent increase in pore pressure within the overburden. Hence the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels both micro and macro in vulnerable slopes.

Proper landuse measures: Adopt effective land-use regulations and building codes based on scientific research. Through land-use planning, discourage new construction or development in identified hazard areas without first implementing appropriate remedial measures.[10]

Structural measures: Adopt remedial techniques (i.e., buttresses, shear keys, sub-drains, soil reinforcement, retaining walls, etc.) of existing landslides that are in close proximity to public structures (Rogers, 1992 for examples).

Afforestation: The forestation programme should be properly planned so the little slope modification is done in the process. Bounding of any sort using boulders etc. has to be avoided. The selection of suitable plant species should be such that can with stand the existing stress conditions of the terrain.

Preparedness

Before landslide: Develop landslide-specific planning. Learn about landslide risk in your area. Contact local officials or departments of natural resources, and university departments of geology. Landslides occur where they have before, and in identifiable hazard locations. Ask for information on landslides in your area, specific information on areas vulnerable to landslides, and request a professional referral for a very detailed site analysis of your property, and corrective measures you can take, if necessary. (a) Develop an evacuation plan. You should know where to go if you have to leave. (b) Discuss landslides and debris flow with your family. Everyone should know what to do in case all family members are not together. Discussing disaster ahead of time helps reduce fear and lets everyone know how to respond during a landslide or debris flow.

During landslide: 1. Stay alert and awake. Many debris-flow fatalities occur when people are sleeping. Listen to early warning of intense rainfall. Be aware that intense, short bursts of rain may be particularly dangerous, especially after longer periods of heavy rainfall and damp weather.

2. If you are in areas susceptible to landslides and debris flows, consider leaving if it is safe to do so. Remember that driving during an intense storm can be hazardous. If you remain at home, move to a second story if possible. Staying out of the path of a landslide or debris flow saves lives. [11][10]

3. Listen for any unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing or falling mud or debris may precede larger landslides. Moving debris can flow quickly and sometimes without warning.

4. If you are near a stream or channel, be alert for any sudden increase or decrease in water flow and for a change from clear to muddy water. Such changes may indicate landslide activity upstream, so be prepared to move quickly. Don't delay! Save yourself, not your belongings.

5. Especially alert when driving. Embankments along roadsides are particularly susceptible to landslides. Watch the road for collapsed pavement, mud, fallen rocks, and other indications of possible debris flows.

After landslide: Stay away from the slide area. There may be danger of additional slides. 1. Check for injured and trapped persons near the slide, without entering the direct slide area. Direct rescuers to their locations.

2. Help a neighbour who may require special assistance - infants, elderly people, and people with disabilities. Elderly people and people with disabilities may require additional assistance. People who care for them or who have large families may need additional assistance in emergency situations.

3. Listen to local radio or television stations for the latest emergency information.

4. Watch for flooding, which may occur after a landslide or debris flow. Floods sometimes follow landslides and debris flows because they may both be started by the same event.

5. Look for and report broken utility lines to appropriate authorities. Reporting potential hazards will get the utilities turned off as quickly as possible, preventing further hazard and injury.
6. Check the building foundation, chimney, and surrounding land for damage. Damage to foundations, chimneys, or surrounding land may help you assess the safety of the area.
7. Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding.
8. Seek the advice of a geotechnical expert for evaluating landslide hazards or designing corrective techniques to reduce landslide risk. A professional will be able to advise you of the best ways to prevent or reduce landslide risk, without creating further hazard.

Discussion

There is a high landslide risk along the Alakhnanda valley. Given the high volume of traffic using the highway there is a need to identify and map these landslides so that in depth study can be carried out for appropriate solutions to minimize their impact. This also calls for a detailed geomorphological mapping of source zones, probable path of transportation of slided debris and the accumulation zone on a large scale using high resolution remote sensing data and field investigations. Upon completion of the mapping, the hazards and the risk elements must be identified and risks assessed. This will provide relevant data to mitigate landslide hazards. [1]

In this study it has been possible to confirm some of the earlier observations in respect to the relationship of the landslides with active faults and other features. In addition, it is found that an active microearthquake zone may have some bearing to the mass wasting processes over a period of time, although more data is needed to prove this. The study provides an example of relationship of landslides with geological and geomorphological factors. The higher landslide susceptibility areas could be the source areas of soil erosion and high sediment yield. [5]

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