Article

Massive Dharali Disaster in the Bhagirathi Valley, Garhwal Himalaya

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Introduction

The Garhwal Himalaya has a well-documented history of frequent and spatially clustered geomorphic hazards. The present study area—Dharali—is historically associated with high-magnitude glacial and paraglacial debris flow events, which have exhibited catastrophic geomorphic impacts on valley floors, river terraces, and human settlements. The Garhwal Himalaya has witnessed several catastrophic geomorphic events triggered by a combination of glacial, fluvial, and slope processes. Prominent examples include: The great Bhagirathi catastrophe of 1750; Gohna Tal Outburst, Birahi Ganga Source (26 August 1894); Alaknanda Flood due to breach of Birahi Tal (20 July 1970); Kanodia Gad cloud burst 1978 in Bhagirathi valley; Phata–Byung Landslide, Rudraprayag District (15 July 2001); Phata–Byung Landslide, Rudraprayag District (15 July 2001); Ukhimath Cloudburst (4 September 2012); Kedarnath Disaster (16–17 June 2013); Raunthi Gad (Rishi Ganga) hanging Glacier Collapse (February 2021); Maldevta–Song–Baldi River Flash Flood (August 2022); Dharali flash flood in BHairathi valley (5 August 2025).

Study Area

Dharali is a mountain village situated at the confluence of the Bhagirathi River and its third-order tributary, the Kheerganga, in Uttarkashi district, Uttarakhand. The Dharali lies roughly between 31.00–31.12° N latitude and 78.70–78.82° E longitude within the Higher Himalaya, extending from the headwaters north of Srikantha peak to the confluence at Dharali. The Kheerganga originates on the northern slope of Srikantha Peak (6,133 m) and debouches into the Bhagirathi at Dharali at 2,650m. The average basin elevation is ~4,100 m, and the source area remains snow-covered year-round. The climate is temperate to subalpine; based on the nearby Harsil station, annual precipitation is on the order of ~800–900 mm (with August (240mm) the wettest month) and driest month November (5mm), while lower-elevation Uttarkashi town records ~1,900 mm. The warmest month (with the highest average high temperature) is June (32.8°C). The month with the lowest average high temperature is January (15.9°C).

According to the 2011 Census**,** Dharali village recorded a total population of 505 individuals accommodated in 137 households. The areal extent of the settlement is approximately 3.27 km², yielding an average population density of 178 persons/km²**.** Males constitute 52% of the total population, while females account for 48%**,** with a corresponding sex ratio of 899 females per 1,000 males. In terms of social composition, Scheduled Tribes (STs) comprise 87% and Scheduled Castes (SCs) 9% of the total population. The overall literacy rate is 71%**.**

The Kheerganga catchment falls within the glaciated zone**,** which comprises **five** cirque-type glaciers**,** three small, debris-covered slope glaciers**,** and one prominent valley glacier. The northern face of the Srikantha Peak is characterized by steep, jointed quartzite cliffs. In the cirque glacial surface there are transverse, longitudinal and diagonal crevasses**.** The glacio-geomorphic assemblage includes well-developed lateral and terminal moraine ridges, numerous avalanche chutes, and a wide array of erosional and depositional landforms associated with active and relict glacial processes. The valley flanks are also characterized by talus cones, avalanche chutes, active landslide scars, and a thick cover of coarse detritus composed of angular to sub-angular rock fragments embedded in a silt–sand matrix. Downstream of the glaciated sector, the Kheerganga incises a deep, high-gradient V-shaped valley. At its confluence with the Bhagirathi River, the stream has developed a prominent debris-fan (alluvial/debris fan) formed by the deposition of coarse colluvial and fluvial materials.

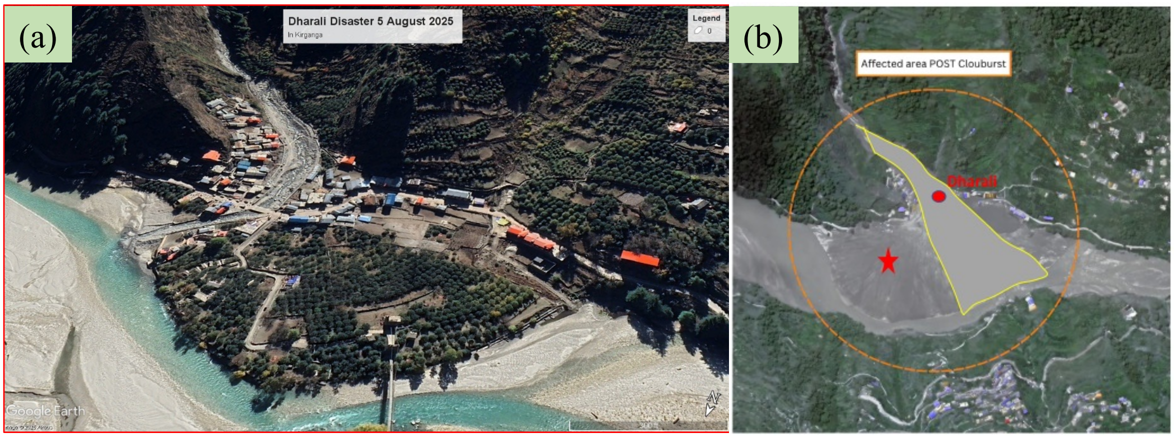

Fig. 1: Dharali Village (a) before August 5, 2025 (b) after August 5, 2025; Google Earth Imagery

On 5 August 2025, the village experienced a high-magnitude flash flood event, characterized by extreme peak discharges and hyper concentrated sediment flows. The flood wave destroyed residential buildings, hotels, homestays, sections of the motorable road, terraced agricultural fields, and commercial apple orchards. Field evidence suggests the event comprised a debris flow–flood hybrid, with a water-sediment mixture transporting large boulders (>1 m in diameter), cobbles, pebbles, and massive volumes of fine sediments. The momentum of the flow was sufficient to induce structural scour**,** displacement of building foundations, and rapid burial of single-story structures under several meters of debris

Preliminary geospatial analysis and rapid post-event assessment estimate that approximately 3.6×10^8 m^3 (Nick Lagon: CBC News, 9August 2025) of debris and water were mobilized, with the entire surge reaching the settlement in 34 seconds. The estimated peak discharge likely exceeded 10,000 m^3/s, placing this event in the extreme range for Himalayan Mountain catchments. Casualties include six confirmed fatalities, with at least 50 individuals **missing.** The total economic damage has been provisionally assessed at ₹500 crore**.**

Causes and Consequences

The source area of the Khirganga glacier exhibits close morpho dynamic similarity with the Chorabari (Kedarnath) glacier. The terminal moraine complex attains a maximum relative height of ~500 m, indicating a phase of intense glacial activity in the past. Notably, the longitudinal gradient of the Srikantha valley glacier is significantly steeper compared to that of the untidily glacier, enhancing its transport and erosive capacity. The lower ablation zone is extensively mantled by mega-boulders, angular detritus and coarse rock fragments, which are chaotically strewn across the valley floor and adjacent slopes because of recurrent glacial disintegration and gravity-driven mass-wasting processes.

The disaster that occurred at Dharali at 1:30 pm on 5 August lasted only 25–30 seconds. This raises the question of how such a huge volume of water was generated in such a short time to mobilize the sediments. A detailed field investigation and visual analysis of high-resolution historical Google imagery were carried out to identify the possible causative factors behind this specific event. In close proximity to the source area, no glacial lake, pond, or any other large water body that might have breached was observed.

As far as cloud burst is concerned, historical cloud-burst occurrences have predominantly been documented on the south-facing slopes of the Himalayan ranges. Since the Kheerganga catchment lies on the north-facing aspect of the Srikanta peak, the likelihood of cloud-burst occurrence in this area is comparatively low due to the prevailing topographic and orographic conditions

Although continuous rainfall had been recorded since 3 August**,** there was no evidence of a cloudburst, as the total rainfall measured at the Harshil IMD Station was only 80 mm 5th August. According to IMD officials that Kheerganga did not overflow due to excessive rainfall or cloud burst. More studies are needed to know the real reasons beyond speculations.

For a cloudburst to occur, at least 100 cm of rainfall is generally required. Secondly, under high-intensity rainfall, stream discharge normally remains elevated for a relatively long time; however, such discharge was not observed in this case. The possibility of a landslide-dammed lake forming is also very low in a high-gradient stream**,** and no evidence of such lake formation was observed.

Another plausible scenario for the initiation of the observed event involves the mechanical failure of an ice mass originating from a transverse crevasse near the threshold zone of the Srikantha cirque glacier. A large detached ice block may have collapsed onto the underlying glacier surface, resulting in a substantial pulse of dynamic loading on the main glacier body over approximately 1 km distance. This sudden loading could have triggered a rapid downslope displacement of snow and ice, ultimately impacting the 500 m high terminal moraine wall.

The failure of the moraine—analogous to the 2013 Kedarnath event—would have resulted in a sudden release of ice, sediment and meltwater stored behind or within the moraine small water pits. Concurrently, high-intensity rainfall and enhanced melt rates due to elevated air temperatures could have augmented the water volume and mobilized a large quantity of unconsolidated and weakly consolidated materials located on the steep gradient of the Ksheer Ganga Channel.

The rapid release of this combined mass of water, snow, ice and debris produced a high-energy debris flow, characterized by elevated velocity and discharge. According to SSP Pradhan, IIT Roorkee estimated that approximately 3 million cubic meters of debris were mobilized in the Ksheer Ganga. The flow propagated downslope and, within approximately 30 seconds, expended most of its energy upon reaching the lower gradient reach at the valley base, leading to rapid deposition of entrained sediments and a sudden cessation of the event.

Given the event's rapid onset, high sediment load, and geomorphic transformation of the channel, the Dharali disaster may be classified as a high-intensity, short-duration mass-wasting, rainfall and glacio-fluvial hazard typical of unstable Higher Himalayan headwater environments. Investigations are exploring deep causes such as cloudburst, landslide lake breach, glacier-related events, or a multi-hazard chain.

Mitigation Measures

The Bhagirathi Valley in the Garhwal Himalaya represents one of the most sensitive regions in terms of tectonic activity, geomorphic processes, geology, topography and the incidence of natural hazards. In high-mountain environments, natural processes operate continuously and cannot be halted. Such events have occurred throughout the geological history of the Himalaya and will continue to occur in the future. The pertinent question, therefore, is how disaster risk and associated losses to life, livelihoods and infrastructure can be reduced. In this regard, planners and administrators are expected to adopt and implement the Sendai Framework for Disaster Risk Reduction (2015–2030) with the objective of minimizing existing disaster risks. Based on the current scenario and past experience of mountain hazards and disasters, the following mitigation measures are proposed as:

Identify disaster-prone areas where any type of natural hazard – particularly climate-related events – is likely to occur in the future, as most disasters take place during the monsoon season. Assess the existing landforms to determine which are safe and suitable for human activities and which are not. For example, Dharali township is situated at the river mouth, which is a highly vulnerable landform. Likewise, floodplains, riverbanks, toes of old landslides, snow-avalanche tracks, rockfall zones, and valley slopes whose catchments include hanging glaciers are extremely hazardous locations for any type of construction. If rural service centers, villages, tourist facilities (such as resorts and home-stays), offices, vehicle stands, etc., are located in hazardous areas along pilgrimage routes, they should be formally advised to relocate. If they refuse to shift, the administration should immediately evacuate them from these dangerous locations. Government departments should also relocate army camps, police stations, block and tehsil headquarters, guest houses, schools, colleges or any other infrastructure from probable hazard sites, since residents often begin to carry out activities in those areas under the perceived protection of government structures**.** Improve regional connectivity by strengthening roads, helipad services, ropeways and other communication networks. Unplanned urbanization has become a serious issue across the Himalayan region. Inhabitants are increasingly settling near service centers and towns in search of better facilities, often encroaching upon riverbanks, floodplains, stream mouths and landslide toes. These areas later become disaster-prone zones. It is therefore necessary to regulate and clearly demarcate permissible areas for construction. Tourist and pilgrim inflow should be controlled according to the carrying capacity of the Dhams. Proper management of these religious sites is essential. Numerous recommendations have been proposed by government agencies, researchers, environmentalists and geologists after previous disasters. Unfortunately, most of these remain academic exercises and are not implemented in practice. Ultimately, self-initiated safety and preparedness become the only means of protection.

Conclusions

The Dharali disaster highlights the urgent need for proactive landform assessment, careful planning, and strict enforcement of regulations in the fragile Himalayan region. Settlements and infrastructure should never be located on vulnerable landforms such as river mouths, floodplains, old landslide toes, or avalanche and rockfall zones—even if they appear stable under normal conditions. At the same time, public awareness of the natural processes and inherent risks of high-mountain environments must be strengthened. Ultimately, sustainable development that respects geomorphic and climatic realities is vital to minimizing future loss of life and property.