Recent and past floods in the Alaknanda valley: causes and consequences

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Uttarakhand Himalaya in general and Alaknanda and Bhagirathi valleys in particular have experienced one of the worst forms of disaster in recent times (Figure 1). Flash floods are common in the Himalaya, but the kind of destruction witnessed this time was unparalleled in recent history. Houses collapsed like a pack of cards and the roads and bridges swept away in the turbulent flood waters. Probably the worst causality of the century was the destruction of Kedarnath valley. According to the data published in various national dailies, nearly 4000 people were either killed or lost, 2232 houses were damaged, 1520 roads in different parts of Garhwal were badly damaged and about 170 bridges have been washed away. According to economists, the tourism industry in Uttarakhand will suffer a loss of ~12,000 crore rupees, which is around 30% of the state's GDP.

Over the years increased frequency and magnitude of flash floods in Uttarakhand Himalaya is worrying the inhabitants. Was it due to the commercial forest felling that was prevalent until around 1980s, or the recent rampant terrain tampering for hydropower projects? In order to appreciate the sensitivity of the terrain towards unusual weather events like cloudburst, let us look into the genesis of two major flash floods, viz. 26 August 1894 and 20 July 1970. These floods are reasonably well documented[1–5]. The 1894 flood occurred well before the commercial forest felling extended into the inner catchments of the Alaknanda, whereas the 1970 event occurred when the commercial forest felling was at its peak in the Alaknanda valley. However, both floods owe their genesis to the breaching of dams created by landslides on the tributaries of the Alaknanda river, a common geomorphic expression during unusual rainfall events in the monsoon-dominated Himalaya[1,3].

On 6 September 1893, a tributary of the Alaknanda river called Birahi Ganga (Figure 1) was blocked by ~5000 million tonnes of rock mass that rolled from 900 m high valley flank. The debris blocked the river forming a lake 270 m high, 3 km wide at the base and 600 m wide at the summit[1,2]. It was estimated that the lake would have taken at least a year to fill. The dam would partially breach only after the water began to topple it, which would cause flash floods in the downstream till Haridwar. The untiring efforts of Pulford, the then superintending engineer and his team, particularly Pandit Hari Krishen Pant (district surveyor of Garhwal), helped to meticulously estimate the magnitude of downstream inundation. An excellent telegraph system was installed between Birahi Ganga and Haridwar for real-time monitoring and timely warning of the flood. Around May 1894, pilgrim traffic on the way to Kedarnath and Badrinath was diverted to the new pedestrian route

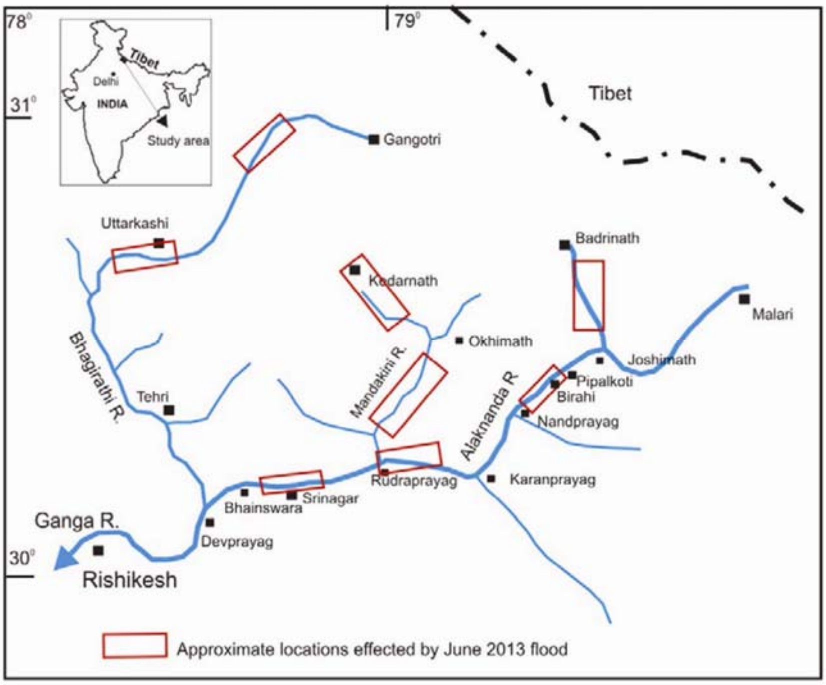

Figure 1. Map showing the Alaknanda and Bhagirathi valleys; red polygons show the approximate location of flood damage.

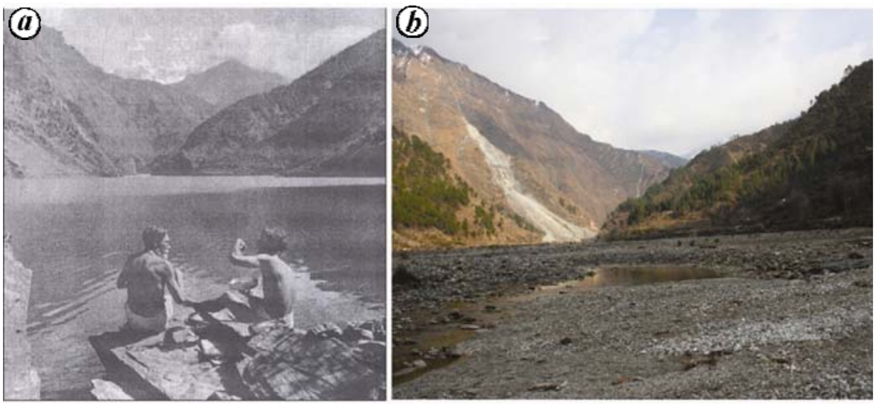

Figure 2. Gohna lake during early 1930 (***a***) and 2008 (***b***).

which was constructed much above the anticipated flood level. Similarly, eight suspension bridges between Chamoli and Haridwar were dismantled in order to protect them from being washed away from the anticipated flood. As predicted, on 25 August 1894, water began to trickle over the dam and at midnight the dam was partially collapsed, sending flood surges downstream. The flood lasted until the morning of 26 August causing unprecedented damage to the property around Srinagar town; however, no loss of life was reported.

During July 1970 (after 76 years), the Alaknanda valley witnessed the second major flood. This was attributed to a cloudburst on the night of 20 July 1970, on the southern mountain front in the Alaknanda valley (between Joshimath and Chamoli). According to an estimate, flood transported about 15.9×10^6 tonnes of sediment within a day[6]. The catastrophe was so large that it wiped out the leftover of the 1894 Gohna lake (Figure 2). In addition, a roadside settlement between Pipalkoti and Helong called Belakuchi in the Alaknanda valley was washed away along with a convoy of 30 buses by the roaring Alaknanda river. However, around 400 pilgrims en route to Badrinath were saved due to the alertness of a police constable who guided them to run uphill[7]. Besides, 13 bridges were swept away and far away at Haridwar, around 10 km stretch of the Ganga canal was clogged with sediment and uprooted trees. This time again Srinagar town had to bear the brunt, virtually the lower town was completely destroyed by the flood.

This flood was widely debated in the country. There were people who were of the opinion that it was independent of deforestation. According to them, deforestation in the Himalaya has a trivial effect on erosion, run-off and thus flooding. Although in minority, there were groups of people particularly the local inhabitants, who strongly believed that the flood owed its genesis to the large-scale commercial forest felling in the preceding years. In fact, recent scientific studies support the suggestion that flood and deforestation in the Alaknanda valley are closely related[3,4]. The 1970 Alaknanda flood was responsible for raising the ecological consciousness of the people that finally resulted in the birth of the now world-famous Chipko movement in 1973 (ref. 3).

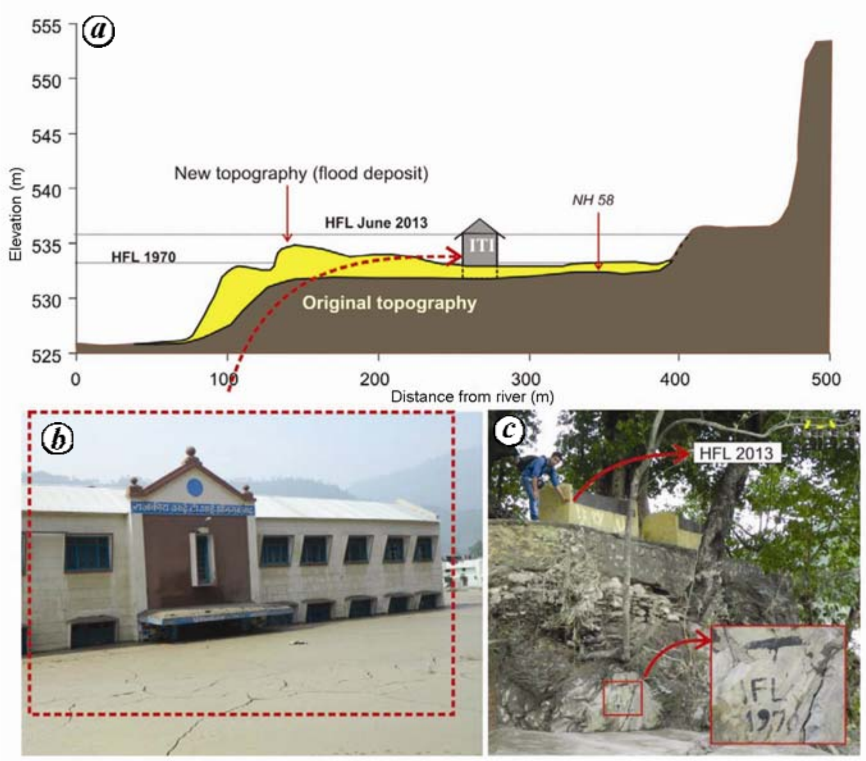

Figure 3. ***a***, Profile taken along the left bank of the Alaknanda river at Srinagar indicating the highest flood levels (HFLs) measured using differential GPS. ***b***, Photograph of ITI building partially buried under mud. ***c***, Photograph shows the HFL of 1970 and 2013 floods near ITI Srinagar (Garhwal).

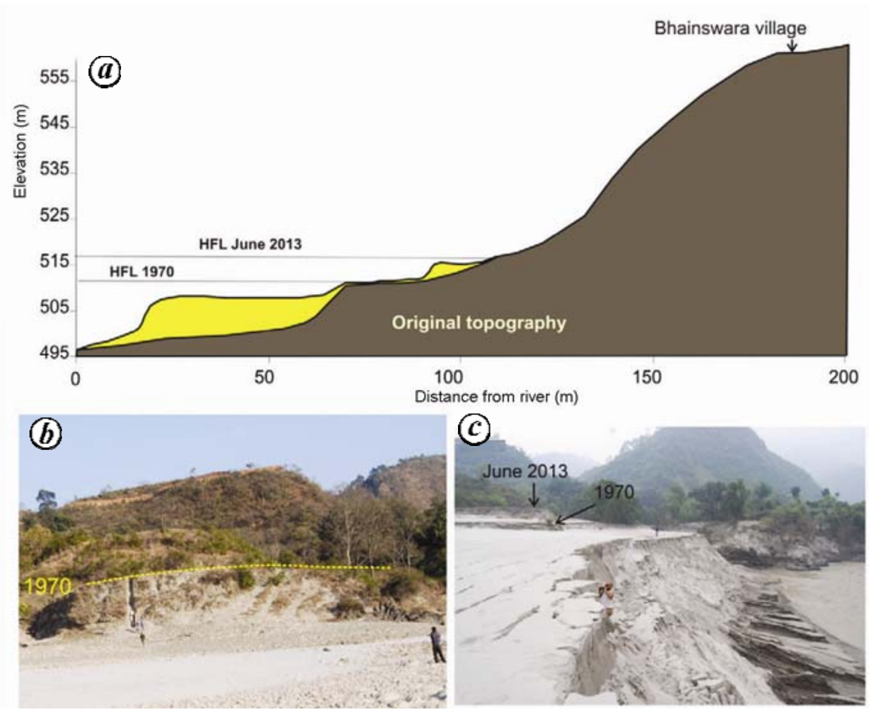

Figure 4. ***a***, Cross profile from river bed to Bhainswara village showing HFLs, ***b***, Photograph of past 600 year flood deposit at Bhainswara. Dotted yellow line shows the height of the 1970 flood. ***c***, Sediment deposited after the June 2013 flood (photograph taken on 20 June 2013). Note that the 2013 flood deposit over topped (~4 m) the 1970 flood sediment.

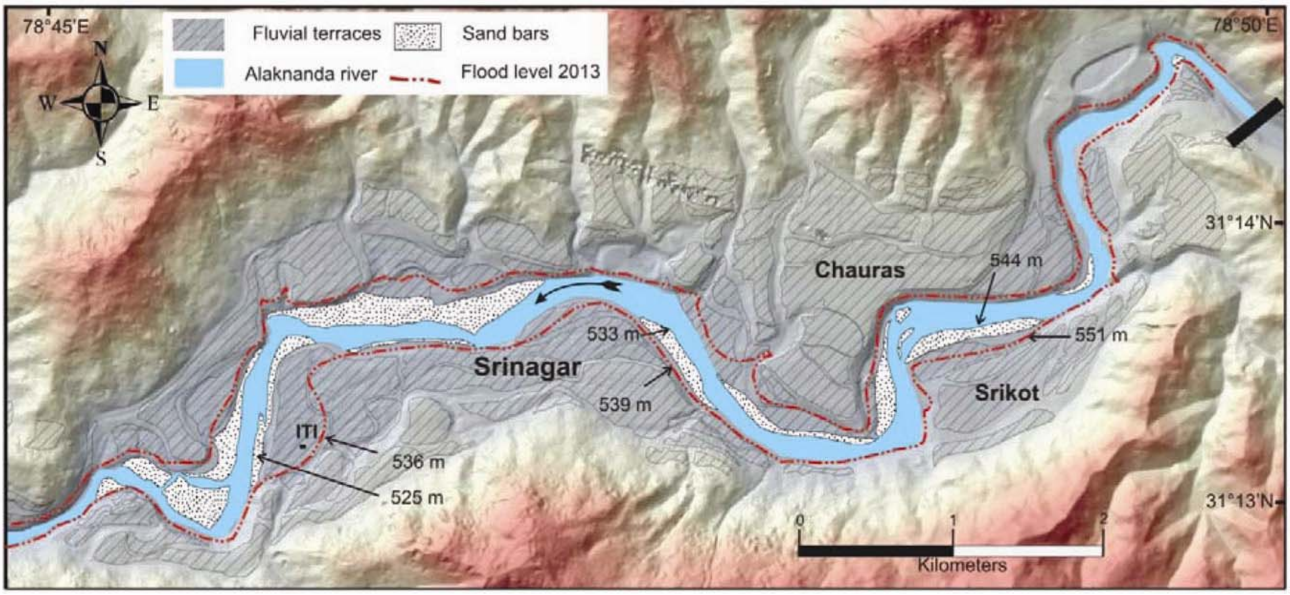

Figure 5. Extent of flood inundation around Srinagar (marked with red dashed line).

Summarizing the above incidences, it can be suggested the flood of 26 August 1894 was a natural landslide-induced dam burst phenomenon and hence anticipated well in advance thus precious lives were saved. On the contrary, the 1970 Alaknanda flood which caused large-scale damage to the life and property was undoubtedly conditioned by the large-scale commercial forest felling (anthropogenically induced); hence we failed to predict it.

Geological evidences of past floods (e.g. slack water and palaeoflood deposits) are scanty; however, in some sheltered locations around Srinagar, Bhainswara and Devprayag (Figure 1), at least 1000-year-old history of floods in the Alaknanda valley can be reconstructed[4,5,8]. Wasson *et al.*[5] concluded that during the last 600 years, the floods were an outcome of the natural dam bursts in the upper Alaknanda catchment and the 1970 event was the highest in magnitude. But this record seems to have been broken by the recent flood. It was found that (i) the 16 June 2013 flood deposits invariably overlie the 1970 flood sediment and occur at an elevation of 536 m at ITI to 516 m at Bhainswara (Figures 3 and 4), implying that June 2013 flood was the highest in the Alaknanda valley at least during the last 600 years. (ii) Flood sediments are incised into two surfaces, e.g. at Bhainswara before the Alaknanda river attained its pre-flood base level, implying that the flood peak receded in two distinct pulses (Figure 4). On the basis of field observations, the vertical and lateral extent of flood is prepared (Figure 5), which can be used as a reference map for preventing any constructional activity below this zone in a fast-growing Srinagar town.

According to Wasson *et al.*[5] all of the large floods in the Alaknanda river catchment appear to be the result of landslide dam bursts rather than glacial lake bursts, and these are likely to continue and possibly worsen as the monsoon intensifies over the next century. The floods generated by the breaching of landslide-induced dams carry large amounts of sediment that may dominate the sediment yield in the Himalaya[9]. According to Korup[10], the sediment yield associated with the breaching of landslide dams is second only to post-volcanic eruption yields, but is greater than yields from glacier lake outburst. The past floods (at least 1894 and 1970) were associated with landslide-induced dam breaching; the current flood does not seem to fit into such a conventional category. It has now been demonstrated[3,4] that deforestation coupled with cloudburst in the upper Alaknanda catchment was the major factor responsible for the 1970 flood. Commercial deforestation in the region is banned since 1980; hence deforestation cannot be implicated for the recent flood. If the rivers were not blocked by landslide dams, because breaching of such dams not only sends short-lived, high-intensity flood surges, but also transports enormous sediment load into the lower reaches[9,10], how was such a large quantity of sediment flushed by the Alaknanda river during 16 and 17 June 2013? In case of the upper catchment of the Mandakini valley (around Kedarnath) natural pile of sediment was available, which was left by the receding glaciers (moraines). When the cloudburst occurred, the sediments dominated by glacier boulders were lifted by the high-density water flow and transported down the valley towards the temple town destroying everything on its way. Shall we blame the debris flow or the obstruction caused by the recent pattern of construction that mushrooms around the temple? Over the years we have occupied every space for making commercial settlement around the temple defying the law of the nature. Figure 6 *a* shows how the Kedarnath valley looked during 1882 (ref. 11). When we compare it with the 2008 photograph, one can see the large number of commercial settlements in the Kedarnath valley (Figure 6 *b*). Coming back to the Alaknanda valley, in absence of large-scale landslides during the recent flood and the glacier deposits located far up in the rain-shadow zone, it is pertinent to speculate that the sediments were locally generated by unnatural processes. According to an estimate, nearly 11,100 km of road has been constructed during 2000–2012 (ref. 12) and currently 45 hydropower projects are operational and

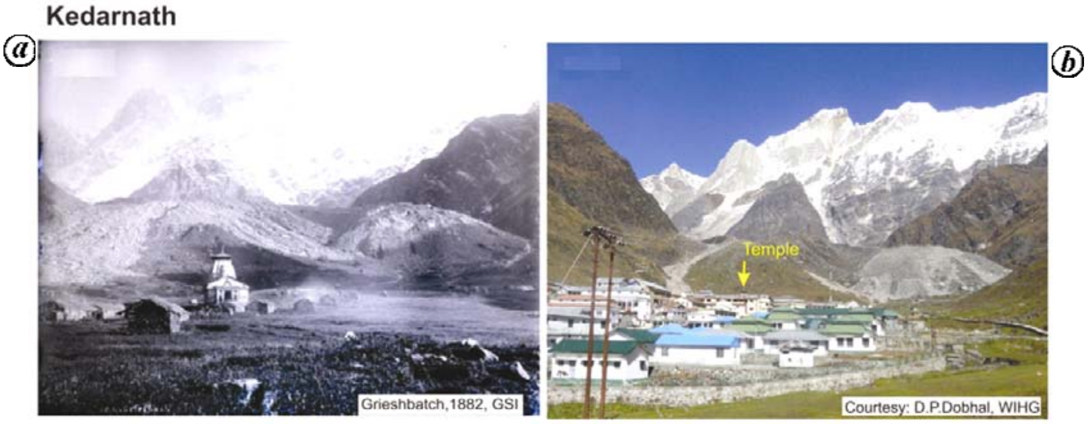

Figure 6. View of Kedarnath valley during (***a***) 1882 and (***b***) 2008.

199 are at various stages of development[13]. Considering the extent of human interference, it is likely that the terrain sustainability is precariously balanced. A minor perturbation would have been enough to generate a cascading effect on the terrain instability. And the impetus was given by the unusual rain during 16 and 17 June 2013, which caused the Himalaya to respond violently against the unscientific human interference.

Let us not blame nature alone; unusual rainfall events have been taking place in the Himalaya. But the Himalaya has not witnessed such clogging of its rivers by the concrete structures. Not only this, the repeatedly damaged banks (during 1894 and 1970 flash floods) have been reoccupied at most of the places. In the past nature warned us not to venture into areas that are flood-prone. But we greed ignored such warnings; we occupied the river banks and had to pay dearly this time. It was nature's fury indeed to begin with, however, the tragedy was amplified by human folly.

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