# Uttarakhand Flood Disaster: Role of Human Actions

While we try to reconstruct the chronology of events that culminated in the tragedy at Kedarnath on the 16th and 17th June as well as the whole of Uttarakhand between 15th-18th June, we are faced with severe limitations: there are no daily rainfall figures for any regions worst hit by floods, rainfall and landslides. This includes Kedarnath, Badrinath, Gangootri, Pithoragarh and surrounding areas. In fact, while answering a question raised by Himanshu Thakkar in a program aired on national television[1], Vice Chairman of National Disaster Management Authority M Shashidhar Reddy accepted that we do not have the account of events with us. This shows the poor monitoring situation from all concerned. We do not have inflow and discharge figures from hydropower projects in the region, including 1000 MW Tehri Hydroelectric Project on Bhagirathi.

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Central Water Commission's (CWC) flood forecasts and warning systems have failed in either giving flood warnings or monitoring the situation. In fact, the CWC has only one flood forecasting station in the entire Upper Ganga Basin that is Srinagar and that too failed to give a flood warning even as Srinagar faced disastrous floods!

What we do have is reconstruction of the event based on satellite images released (much delayed, had these been released when the events were unfolding it may have helped greatly) by National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO), [2] some expert analysis and most importantly, harrowing eye witness accounts. Based on this, we attempt a reconstruction of chronology of events that unfolded.

**Chronology of Events: A combination of massive rainfall, glacier flow, snowmelt, debris and landslides** From all accounts it is clear that areas around all four Pilgrimage centres (Gangotri, Yamunotri, Kedarnath and Badrinath) and the fifth one of Hemkunt Sahib faced severe rainfall and floods during 15-18 June 2013.In addition, areas of Pithoragarh (Goriganga basin), Himachal Pradesh (Kinnaur district, mainly Kashang area, a tributary of Sutlej) basin and adjointing parts of Nepal also faced flood disaster during the same period.

The rainfall events that led to these floods started on June 15 and went on till June 18. It is strange to see such vast area facing simultaneous high intensity rainfall. IMD officials tried to explain this (http://www.hindustantimes.com/India-news/NewDelhi/Westerlies-collided-with-monsoon-to-rain-death/Article1-1081810.aspx) as collision of western disturbance with the upcoming monsoon clouds. "It was the interaction between the well-formed low-pressure system of the south-west monsoon from east to west and the upper air westerly trough running from north-west Rajasthan to the east that resulted in the heavy rainfall over Uttarakhand", explains R Ramchandran (Frontline 260713). The catchments of all these basins in their uppermost ranges are not too far from each other.

There are no rain-gauges at Kedarnath and Badrinath and hence we may never know the rainfall at those sites. The best we have is weekly district wise rainfall in Uttarakhand districts for the week June 13-19, from India Meteorological Department:

**Table 1 District-wise rainfall distribution from 13.06.2013 TO 19.06.2013**

| DISTRICT | ACTUAL (mm) | NORMAL (mm) | % DEP | CAT. |
|---|---|---|---|---|
| ALMORA | 208.7 | 26.3 | 694% | E |
| BAGESHWAR | 391.2 | 26.3 | 1387% | E |
| CHAMOLI | 316.9 | 22.6 | 1302% | E |
| CHAMPAWAT | 351 | 33.5 | 948% | E |
| DEHRADUN | 565.4 | 36.8 | 1436% | E |

[1] NDTV INDIA badi khabar programme on June 21 evening (see: http://khabar.ndtv.com/video/show/badi-khabar/280131)
[2] http://www.nrsc.gov.in/

| | | | | |
|---|---|---|---|---|
| GARHWAL PAURI | 149.7 | 15.8 | 847% | E |
| GARHWAL TEHRI | 327.7 | 22 | 1390% | E |
| HARDWAR | 298.8 | 21.6 | 1283% | E |
| NAINITAL | 506.5 | 38.8 | 1205% | E |
| PITHORAGARH | 246.9 | 73 | 238% | E |
| RUDRAPRAYAG | 366.3 | 53.9 | 580% | E |
| UDHAM SINGH NAGAR | 157.7 | 40.2 | 292% | E |
| UTTARKASHI | 375.6 | 25.8 | 1356% | E |

Note that the actual rainfall in this week was upto 1436% of normal rainfall and was excessive in all districts of Uttarakhand. The state received 322 mm of rainfall in the week, which was 847% higher than the normal rainfall of the week at 34 mm. This quantum and excess percentage seems unprecedented. Please do not do the mistake of adding up rainfall figures of different places as one of the senior correspondent and editor of National economic newspaper did in their July 1, 2013 edition. This was an example of how some newspapers can go overboard in N attempt to argue against the culpability of some of the hydropower developers. *Indian Express* is another newspaper guilty of such excesses. Its editor Shekhar Gupta does not seem to have an idea of river basins, and so goes on to claim that without Tehri (in Ganga basin), Delhi (in Yamuna basin) would have tasted *gangajal* (see interview of Uttarakhand CM in July 24, 2013 issue)!

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**Events of June 16-17 at Kedar Nath on the banks of Mandakini River, a tributary of Alaknanda** Based on information from various sources, it seems Kedarnath shrine saw two massive flood events, one starting around 8.15 pm on June 16 and second at 6.55 am on June 17. The flood witnessed at the shrine (located at 3584 m above msl) originated from catchment that includes two mountain peaks: Kedarnath and Kedarnath Dome (6831 m elevation).

*Vishnuprayag dam filled with boulders, the river bypassed the dam (Photo: Matu Jansanngathan)*

**Cloud burst or not?** While the high intensity rainfall event upstream of Kedarnath has been reported as a cloud burst, some experts disagree. Dr. Srinivasan from Divecha Centre for Climate Change
Research,
cloudburst
occurs when hourly rainfall is
more than 100 mm. According to
him, satellite images (in the
absence of rain gauges) do
not suggest such high intensity
rainfall. The highest spell which
lasted for a few hours was of
20 mm/hr rainfall.[3]

**Chorbari Glacier** The Chorabari glacier that played a role in June 2013 Uttarakhand floods in Kedarnath lies between latitudes 30°44′50″N and 30°45′30″N, and longitudes 79°1′16″E and 79°5′20″E, from an altitude of approximately 6,000 m (20,000 ft) at the slopes of Kedarnath peak, to 3,800 m (12,500 ft). The glacier is around 7 km in length, while the basin area of the glacier is approximately 38 sq km and the glacier ice cover is 5.9 sq km. The glacier slope is around 11 degrees and faces south. The glacier has two snouts. It is hypothesized by R. K. Chaujar that an original single glacier covered the area, which while receding, split into two snouts. One of the snouts is the source of the Mandakini River at 3,865 m (12,680 ft). The other snout, at 3,835 m (12,582 ft), drains into the Chorabari Tal.

This is further supported by David Petley, Professor of Hazard and Risk in the

[3] http://www.thehindu.com/news/national/no-evidence-of-cloudburst-says-climate-scientist/article4895584.ece

Department of Geography at Durham University in the United Kingdom. He says: "Automatic weather station at Chorbari reservoir recorded 315 mm rain on 15th and 16th June. This level of rainfall is not unprecedented, but usually occurs at the peak of the monsoon in July or August. The important factor here is that the rainfall fell at a time when there was still snow on the ground – and any high mountain landslide expert will tell you that the combination of heavy rainfall on melting snow is the tailor-made for landslides."[4] The effect of the heavy rainfall and rapid snow melt was to generate huge amounts of water in the landscape. Petley points out that the amount of debris and rubble below the glacier on the left side of the Kedarnath in a 1882 picture suggests that transportation of sediment and debris from the upper reaches was active even then, and adds that the steep slope that is upstream of Kedarnath would have aided rapid transportation. An initially reasonably small failure quickly accumulated sediment and water, turning into a highly energetic debris flow that swept to the foot of the slope, and then ran along the margin of the glacier before sweeping into the town in the evening on 16th June."[5]

**The recommendations of the Expert Committee on Uttarakhand Glaciers included, "Monitoring of glacial lakes, their formation and potential for hazards… Risk assessment to understand the impact of glaciers on safety of dams, reservoirs and power projects." Unfortunately, none of these recommendations were implemented.**

K Vinod Kumar, geologist, National Remote Sensing Center, Hyderabad was quoted by NDTV saying, "The Kedarnath town is situated in a glaciated valley which is fed by two major glaciers on the northern part. The whole area is vulnerable and in the surrounding areas, we have a lot of landslides. So this valley has the influence of the landslides, debris coming from the glaciers and also a chance of glacial lakes bursting."

Petley says in the mountainous terrain around Kedarnath, there were two massive debris flows from above, a glacial-related flow from north-west and the glaciated area in the north-east. First the flow from the north-east came down the margin of the glacier and spread out to strike the town. Next, the north-west flow descended from the other glacier to the town on its west side, and struck it directly.

According to Petley, the debris flow from the north-east was triggered by a 75 m wide landslide caused by heavy rainfall, which then came down the steep slope about 500 m, gathering the debris in its path. The flow was initially channeled into a narrow gully formed by the glacier and on exiting it the flow spread out in the floodplains before striking the town after traversing about 1200 m. The steepness of the slope would have given the debris enormous velocity.

In the north-west, the Chorabari glacier has retreated about 300 m since 1960 according to D.P. Dobhal, a glaciologist at the Wadia Institute of Himalayan Geology. The moraine left behind had created a block for a basin to form, allowing the water to build up in Chorabari Tal. The moraine was breached by the rapidly building water because of heavy rainfall and overtopping of the moraine wall. The breach led to the sudden release of the impounded water and resulted in a massive flood sweeping the Kedarnath valley.

According to the NRSC scientists, this lake would have had a depth of about 15 m, and the event is not considered a glacial lake outburst flood (GLOF), which occurs when a dam or moraine wall is breached because of the sheer pressure exerted by the stagnant glacial water and ice that it encloses. This was a case of lake flooding because of excessive rainfall and consequent overtopping of the moraine wall, which eventually breached. The breach created three flows: one moving south-east to join the earlier debris flow from the north-east and enhancing it. Another is a new channel that opened up, perhaps exploiting an existing old channel. Moving down the slope towards the town at great velocity, it gathered sediment and debris en route and resulted in a much-widened flow.

[4] http://blogs.agu.org/landslideblog/2013/07/04/reconstructing-the-events-at-kedarnath-using-data-images-and-eye-witness-reports/
[5] http://blogs.agu.org/landslideblog/2013/06/27/new-high-resolution-images-of-kedarnath-the-cause-of-the-debris-flow-disaster-is-now-clear/

However, the bulk of the debris flow moved southwards towards Kedarnath town down the main channel on the south-western side, which is the normal channel for glacial water flow. According to Petley, this flow must have carried the many huge boulders and rocks seen in the post-flood image of Kedarnath. Closer to the town, the flow spread before striking. Petley suggests that this latter flow must have been more efficient because of the preceding events and also because it struck the town from both the west and the east simultaneously.

DP Dobhal told NDTV, "Early in the morning on 17th the lake burst. It rushed and took a lot of water together and just removed all the sediments, glacier material and threw it down the valley. And there is a 300 meter drop. All the water was vacated in just five minutes."

**NRSC: "In the preliminary assessment, a total of 1356 landslides have been identified along the river valleys" in Alaknanda basin alone.**

The glacial regions above Kedarnath had received fresh and excess snowfall when heavy rainfall hit the region, according to scientists of the National Remote Sensing Centre. Rainwater, with higher temperature, falling on the snow must have led to heavy snow melt and this runoff would have added to the rainwater runoff, resulting in a huge water flow that carried with it a huge debris flow, which struck the town with enormous ferocity. The snow cover has, in fact, increased in general subsequent to the extreme rainfall and flooding events (the NRSC image on May 28/June 1 shows less snow cover). The detailed dynamics of water flow due to snow melt caused by rain, particularly when snowfall is in excess, and the hydrology of it are not well understood.

**Uttarakhand Expert Committee on Glaciers** Here it should bbe noted that the Expert Committee on Glaciers formed by the Uttarakhand government with B R Arora as Chairman submitted its report in Dec 2006 with short and long term suggestions. These suggestions included monitoring of the glaciers, formation of five study groups and action plan. The recommendations included, to illustrate, "Monitoring of glacial lakes, their formation and potential for hazards... Risk assessment to understand the impact of glaciers on safety of dams, reservoirs and power projects." Unfortunately, none of these recommendations were implemented.

**Situation at Devprayag** According to Dr. Bharat Jhujhunwala staying at Devprayag along the confluence of Bhagirathi and Alaknanda, peak floods happened on early morning of June 17, though severe flood event in Alaknanda started the previous evening. He also mentioned that the massive amount of muck deposited on the Alaknanda riverbed by the under construction 330 MW GVK Srinagar Alaknanda Hydropower Prooject (the project has no credible environmental impact assessment) accentuated the flood disaster in the downstream area.

It is interesting to note that if these accounts are correct, the peak of flood event at Devprayag and Kedarnath (separated by about 150 km) happened on the morning of June 17, which possibly indicates that there were multiple cloud burst or very high intensity rainfall events in Alaknanda valley alone. Uttarkashi Apda Prabanthan Jan Manch had sent a report with photos of unfolding disaster on the evening of June 16, 2013 itself so the high rainfall event and beginning of flood disaster at Uttarkashi began about a day earlier. The news channels were already showing live footage of the event unfolding in downstream Rishikesh and Haridwar on June 17, again indicating that the flood event in the upstream mountains must have started at least two days earlier. Unfortunately we still do not have an accurate account of this whole episode from any of the official agency.

**Over a thousand landslides** In fact according to National Remote Sensing Centre, ISRO, a whopping 1356 landslides have taken place in only the Alaknnanda basin. "In the preliminary assessment, a total of 1356 landslides have been identified along the river valleys of Mandakini, Mandani, Kali, Madhyamaheshwar and parts of Alaknanda from Srinagar to Chamoli. Some of the towns included in this area are Kedarnath, Sonprayag, Gaurikund, Okhimath, Guptkashi, Mansuna, Phata, Agastmuni, Rudraprayag, Srinagar, Gauchar, Karnaprayag, Nandprayag, Chamoli etc."

**Landslides upstream Kedarnath** Dave Petley suggests that two landslides took place upstream of Kedarnath on the 16th, one from the North East and the other from the North West[6], both originating near glaciers. "In the north east, debris flow was initiated by landslide, which ran down the slope entraining debris en route. This flow eroded large amount of material, hence gaining in volume as it stuck the town. The second event, which came from the glacial area to the northwest, is very different. Landslides and morain left by retreating glaciers blocked drainage in this area, allowing water to build up a pool. Eventually this pool overtopped the moraine barrier –overtopping of the barrier occurred, it catastrophically breached. This generated a very rapid release of the impounded water. The flow was so large that it over-topped the moraine on the other side of the glacial area, such that three flows were formed. One went southwest to join the valley from the earlier debris flow before swinging to the south to strike the town. This exploited an existing channel. The second was a much smaller flow that reoccupied an palaeo-channel. The volume of water and sediment that entered this channel was small, but it appears to have entrained debris en route (the channel widens downslope).Most of the debris flow travelled south, down the main channel. The flow travelled southwards, eventually starting to spread and deposit sediments before striking the town."

**NIDM: "Thus, the natural terrain conditions combined with climatic / weather conditions and haphazard human intervention made a conducive environment for such a hazardous process to take place in this valley."**

**According to Report from National Institute of Disaster Management (NIDM)**,[7] "Seismo-tectonically, the area is traversed by several lineaments, faults and thrusts, which are considered to be geodynamically active. The area had suffered an earthquake on 29 March 1999 (M-6.8) which caused loosening of rock masses, ground cracks and landslides etc., besides killing more than a hundred people due to collapse of buildings. Thus, the natural terrain conditions combined with climatic / weather conditions and haphazard human intervention made a conducive environment for such a hazardous process to take place in this valley."

**SANDRP**

**Useful Links:** 1. For an account of Floods in Pithoragarh district of Uttarakhand, see: http://www.himalprakriti.org/?q=content/brief-report-spate-along-gori-river-basin-north-eastern-kumaon-uttarakhand-15th-17th-june; images of the Goriganga floods: http://www.himalprakriti.org/?q=content/images-gori-spate-june-2013; Before and after images of 5 Motighat hydropower project: http://www.himalprakriti.org/?q=content/and-after-images-uttarakhand-floods-2013
2. For a photo feature on damage to Vishnuprayag HEP, see: http://matuganga.blogspot.in/
3. For an excellent account of how Uttarakhand is a model of disaster, see: http://tehelka.com/uttarakhand-a-model-of-disaster/
4. Uttarakhand Disaster Mitigation and Management Centre: http://dmmc.uk.gov.in/
5. National Disaster Management Authority: http://ndma.gov.in/ndma/index.htm
6. National Institute of Disaster Management: http://nidm.gov.in/default.asp
7. India Meteorological Department: http://imd.gov.in/
8. Flood forecasting site of Central Water Commission: http://www.india-water.com/ffs/index.htm
9. Sphere India, coordinating disaster management from non govt agencies: http://www.sphereindia.org.in/
10. http://www.ndtv.com/article/india/uttarakhand-the-making-of-the-himalayan-tsunami-393901
11. http://www.frontline.in/the-nation/why-kedarnath-happened/article4894867.ece?homepage=true
12. http://chimalaya.org/2013/06/19/disaster-in-uttarakhand-india-huge-death-toll/

[6] http://blogs.agu.org/landslideblog/2013/06/27/new-high-resolution-images-of-kedarnath-the-cause-of-the-debris-flow-disaster-is-now-clear/
[7] http://nidm.gov.in/default.asp