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ORIGINAL ARTICLE

A Case Study of the 12 July 2021 Bhagsunath (McLeod Ganj) Flash Flood in Dharamshala, Himachal Pradesh: A Warning Against Constricting Natural Drainage

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ABSTRACT

Extreme rainfall events leading to the occurrence of flash floods and cloudbursts are common in the Himalaya. Bhagsu nala in McLeod Ganj area of Dharamshala township, Himachal Pradesh has witnessed the worst flash flood in the morning of 12th July 2021 causing damage to property and infrastructure in the region. Though the catchment area of the Bhagsu nala is very small of the order of ~ 2.8 km^2, the geomorphological and hydrological characteristics of the catchment are susceptible to peak flow for a shorter duration. Further, the anthropogenic intervention of slopes in the form of constricting natural drainage has reduced the carrying capacity of the nala, exaggerating the consequences of the flash flood.

INTRODUCTION

Flash flood occurs when discharge in the stream exceeds its carrying capacity. This may be due to natural reasons, like sudden and abrupt increase in precipitation in an area, outbursting of landslide- or glacier- dammed lakes, or man-induced reasons like sudden release of the impounded water from the reservoir. The rapid and unexpected increase of precipitation in an area is usually termed as 'cloudburst' if the precipitation over a small area is > 100 mm per hour. However, when the intensity of rainfall is >200mm/day, it is referred as 'extremely heavy', while intensity >130mm/day as 'very heavy' (IMD 2003). Usually, these high concentrated rainfalls or the cloudbursts cause landslides along the course of the streams, blocking their courses for few minutes to couples of years, depending on the number of factors, like geotechnical characteristics of the impounded material, gradient of stream, discharge characteristics of the stream, etc. The outburst or the sudden release of water from these lakes cause flash floods and have proved to be disastrous (Joshi and Kumar 2006; Gupta and Sah 2008; Juyal 2010; Sati et al. 2011 Dobhal et al. 2013; Gupta et al. 2013).

It is observed in recent times that there has been an increase in intensity and frequency of flash floods in the Himalaya. These are mainly due to the changes in the climate pattern, resulting into increased frequency of higher concentrated rainfall and subsequent landslides (Gupta et al. 2017; IPCC 2021). The increased incidences of forest fire in the Himalaya may also contribute towards higher concentrated rainfall (Gautam et al. 2021).

In recent time, the Satluj valley in Himachal Pradesh has witnessed a worst flash flood in the human history during 2003 and 2005, when a small rockfall along the Pareechu nala had blocked its path, creating a landslide dammed lake, and subsequent breaching caused havoc in the downstream of Kinnaur and Shimla districts of Himachal Pradesh (Gupta and Sah, 2008). An extreme precipitation during June 2013 in Uttarakhand had also caused disastrous flash floods of the century claiming thousands of human lives, and damaged infrastructures worth crores of Indian rupees (Sati and Gahalaut 2013; Rana et al. 2013; Sundriyal et al. 2015). The change in rainfall pattern in the form of increased frequency of concentrated rainfall has also affected the landslides in many other hilly townships in Himachal Pradesh and Uttarakhand that includes the Nainital and Mussoorie municipalities (Gupta et al. 2017; Ram and Gupta 2021). In 2021 alone, the Uttarakhand and Himachal Pradesh states have witnessed ~ 200 landslides related to extreme rainfall (IMD 2022). Though there are numerous causes for the occurrences of landslides, most of the landslides in the Himalaya are triggered by the excessive rainfall.

Besides, many towns in the Lesser Himalaya have witnessed increased activities such as trekking, mountaineering, rafting along with the religious tourism, and hence increased influx of people. The Dharmashala township in Himachal Pradesh is known for its scenic beauty with picturesque Dhauladhar mountains to the north. There are many tourist places in the vicinity such as McLeod Ganj, also known as *'Little Lhasa'*, nearby Bhagsunath Temple and Bhagsu waterfall. Most of the local people earn their livings from the tourism, and due to this, the village has a lot of restaurants, hotels and guesthouses.

Recently, the Bhagsunath area has witnessed flash flood causing a lot of damages to the infrastructure. In the present article, the authors document and assess the reasons of the causes of flash flood that occurred in the morning of 12th July 2021 along the Bhagsu nala in McLeod Ganj area of Dharamshala township.

BACKGROUND OF THE STUDY AREA

The study area is located in the vicinity of 32°15'00"N; 76°21'00"E at about 7 km to the north of Dharamshala township in Himachal Pradesh (Fig.1). It lies along the third order drainage 'Bhagsu nala' having a catchment area of ~ 2.8 km^2 and is situated at an elevation between 1800 m and 3320 m above mean sea level (msl). The Bhagsu nala has its origin in the uninhabited Chakban-Dharamshala Protected forest. The catchment is funnel-shaped having a maximum width of ~ 1500 m in the central portion.

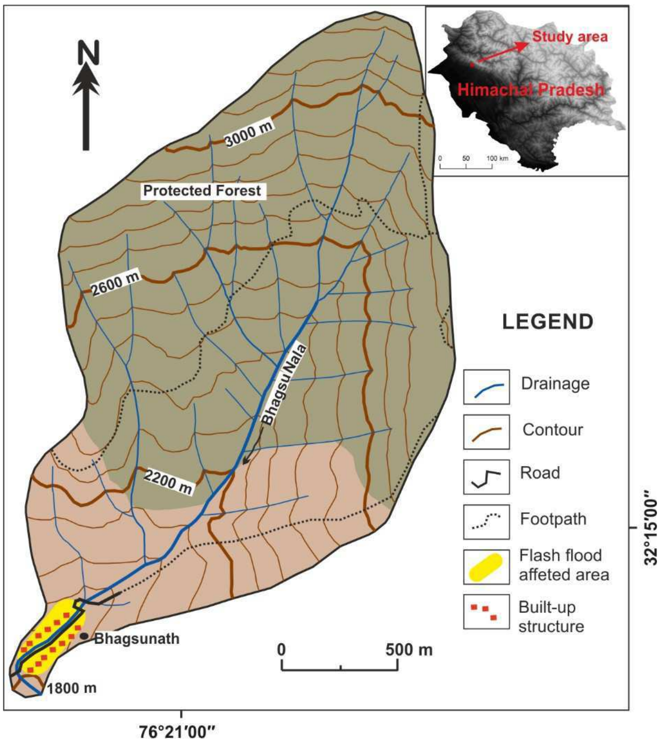

Fig.1. Location map of the Bhagsu nala having a small catchment of ~2.8 km^2 located in the vicinity of the Bhagsunath in the McLeod Ganj area of Dharamshala, Himachal Pradesh.

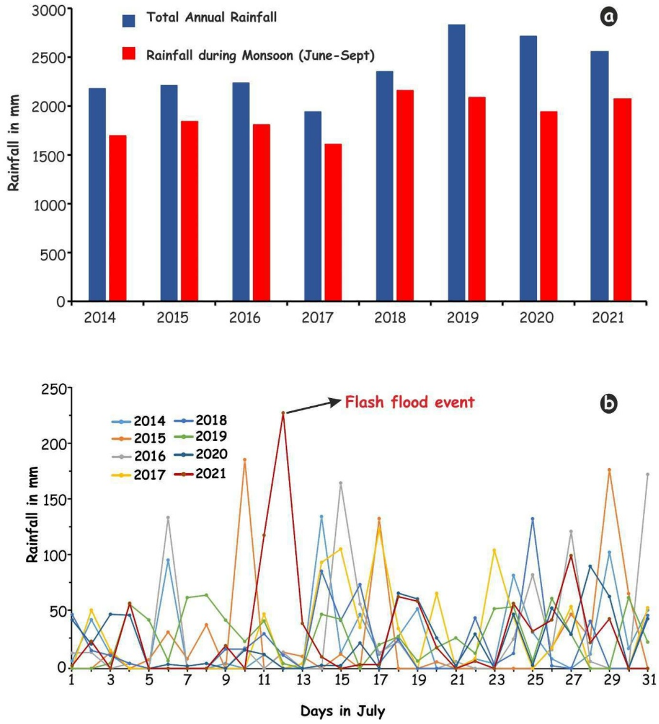

Fig.2. **(a)** Annual rainfall of the Dharamshala township of the years 2014 – 2021 indicating ~ 80% rainfall during monsoon in the month of June – September. **(b)** Line diagram of the precipitation for the month of July for years between 2014 and 2021

The width of the Bhagsu nala towards the lower end is of the order of ~150 m. Most of the commercial and residential establishments in the Bhagsunath area are located towards the lower reach of 'Bhagsu nala'.

Geologically the Dharamshala and its surroundings including McLeod Ganj and Bhagsunath form a part of foothill zone i.e. Outer Himalaya and dominantly constitutes sandstone with alternating bands of clays, shale and siltstones. It is bounded by the Main Boundary Thrust (MBT) in the north and the Drini Thrust (DT) in the south. 1986 Dharamshala earthquake of 5.5 magnitude was triggered due to tectonic activity along the DT, which made damages in the area (Ram et al. 2005). In general, the hill slopes are moderately steep to steep ranging between 40° to 70°, and are covered with glacial and colluvial deposits consisting of pebbles and boulders of siltstones and sandstone embedded in a mixture of clay-silt and sand.

RAINFALL CHARACTERISTICS

Indian Meteorological Department daily rainfall data of Dharamshala town for the period between 2014 and 2021 has been analyzed. It shows that the area receives an average of ~ 2,350 mm rainfall per year, and ~80% of this rainfall occurs during the rainy season between June – Sept (Fig.2a). Figure 2b depicts the daily rain plot for the month of July for years 2014-2021. It has been noticed that the area received 120 mm rainfall on 11th July and 230 mm on 12th July 2021.

Local people confirmed that heavy precipitation started in the evening of 11th July 2021 at 8.30 PM and continued till the next day, and the flash flood occurred between 8:30 AM and 9:00 AM on 12th July 2021. As per the newspaper report from the source of IMD daily bulletin, the cumulative rainfall during 8:30 PM of 11th July to 8:30 AM of 12 July was ~ 80 mm, which is ~ 275% higher than the normal. (https://www.downtoearth.org.in/news/climate-change/flash-floods-in-dharamshala-after-heavy-rains-in-kangra-district-77894).

Hydrological Characteristics and Longitudinal Profile of the Bhagsu nala

Bhagsu nala originates at an elevation of 3,320 m above msl in the Chakban -Dharamshala protected forest. It is mainly fed by rain and the spring water. The upstream catchment area of the Bhagsu nala is ~ 2.8 km^2. There are ~ 22 first order and 4 second order visible drainages in the area having a length of ~ 12,800 m and 2,784 m, respectively. The Bhagsu nala is a third order drainage and its length is about 2,250 m. The drainage density of the entire catchment is ~6.36 km/km^2, indicating that the catchment rapidly responds to the rainfall events and water quickly enters into channel leading to the increase in discharge (Horton 1932).

In addition to drainage density, the hydrological characteristics or the hydrograph of the catchment also depends on the form factor of the catchment, which is the ratio of the catchment area and square of

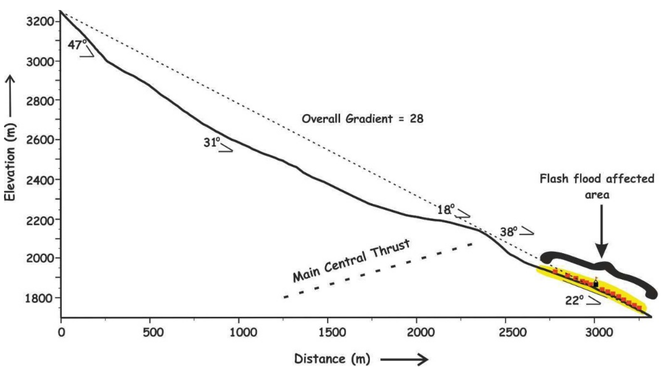

Fig.3. Longitudinal profile of the Bhagsu nala indicating general concavity in the overall gradient. The slope break is marked by a knick point where the Main Central Thrust cut across the channel. Please note the flash flood affected area at the outlet of Bhagsu nala catchment.

its length. Bhagsu nala catchment exhibits form factor of ~0.53 that indicate somewhat circularity in the shape of the catchment *cf* 0.786 form factor exhibiting absolute circular shape of the catchment (Horton, 1932). The circularity of the catchment represents high peak flow for a shorter duration, whereas elongated and low circulatory of the catchment represents lower peak flow for longer duration. Therefore, both drainage density and shape of the Bhagsu nala catchment favor peak discharge for shorter duration, which is responsible for the flash flood in the area.

The longitudinal profile of the Bhagsu nala indicate that the overall gradient of the nala is 28° in the entire study area (Fig.3). It ranges between 50° in the upper part and gradually decreases towards downstream. There is a major knick point in the profile at an elevation of ~2100 m, marked by convexity in the profile (Fig.3). It is represented by major thrust 'Main Central Thrust' in the area. At this point, the gradient of the nala abruptly changes from 18° to 38°. Further downstream towards the lower end of the Bhagsu nala, the gradient is ~ 22°.

Field Observation: Anthropogenic Intervention

Field survey was carried out at the end of July. It has been noticed that two second order streams of about 7-8 m wide join at an elevation of ~ 2500 m to form the Bhagsu nala, which is about 10-20 feet wide in the upper reaches (Fig. 4a). Towards the lower reach of the catchment, there is a connecting road by the side of the Bhagsu nala and new road of ~ 10 feet wide has been cut up at an elevation of ~2000m above msl to join the habitation on the upper slope. This new road cut crosses the Bhagsu nala at an elevation of ~ 1900 m and 1920 m. Thus, two culverts 12 feet x 10 feet and 6 feet x 5 feet were constructed on the nala (Fig.4b). This has greatly reduced the carrying capacity and affected the normal flow during the high discharge. Further downstream, the width of the nala has been constrained and restricted with an average width between 6-8 feet. At places, it is observed to be just 2-3 feet. This has greatly reduced the carrying capacity of the nala. In the lower reaches, the nala has been completely covered to be a part of the connecting road, and was utilized by the commercial establishment for their easy access. Even a temple was built right on the nala (Fig.5a). There were about 90 commercial and residential establishments on either side of the nala (Fig.5b).

Fig. 4. (a) View of the Bhagsu nala looking upstream **(b)** View of the culvert reducing the carrying capacity of the Bhagsu nala

Fig.5 (a) A temple constructed right on top of the Bhagsu nala and **(b)** view of the constricted drainage towards the lower reach of the Bhagsu nala.

On the fateful day of 12 July, the flash flood occurred in the morning between 8:30hrs and 9:00hrs, with the previous 12 hours cumulative rain of ~80 mm. As per the local eyewitness, the discharge in the Bhagsu nala started rising in the morning and subsequently became higher than the carrying capacity of the culvert resulting into overflow of water onto the connecting road. This overflowing water has washed away the light vehicles parked on the road and swept into the nala that resulted into chocking of the Bhagsu nala and aggravated the flash flood towards the lower slope. The gushing water has eroded the slopes on either side, risen to about 2-4 feet and entered into the commercial establishments, located on both side of the nala, causing their damage (Figs. 6a & b).

DISCUSSION AND CONCLUSIONS

Flash flood in an area depends on the geomorphological and hydrological characteristics of the catchment, besides the precipitation regime of the area. The Himalaya has witnessed several flash floods in the past, dominantly during the monsoon season in the month of July and August when the cumulative rainfall in a day is ~ 200 mm (Dimri et al. 2017). Further, the anthropogenic intervention of the stream directly enhances the impact of flash flood depending on the carrying capacity of the stream.

The Himalaya during recent years has received variable precipitation in the form of extreme rainfall, at times cloudbursts, (IPCC 2021) leading to higher incidences of landslides. This has been attributed primarily to the global warming because of which the water vapour and specific humidity in the atmosphere have increased significantly (Easterling et al. 2000). Further the Himalaya has been observed to be warmed up at a faster rate than the rest of the world, causing increase in frequency of extreme rainfall events, flash floods and landslides along the terrain (IPCC 2021).

Previous few years have witnessed concentrated rainfall at isolated places in the Himalaya that led to the occurrences of numerous landslides at number of places (Gupta et al. 2017). The year 2019 and 2020 have observed numerous landslides in the hilly townships of

Fig.6. (a) Damage to connecting road and **(b)** damage to the residential and commercial establishments located by the side of the Bhagsu nala

Mussoorie and Nainital in Uttarakhand leading to damage of their approach road. In the year 2021, Himachal Pradesh alone has witnessed more than 87 landslides due to enhanced precipitation killing >55 people at different places (Govt. of HP, 2021; IMD 2022). The report of the Inter-Governmental Panel on Climate Change (IPCC) indicated that the climate change in the form of increase in frequency of extreme precipitation in the Himalaya will lead to cascading consequences of landslides and flood causing an irreversible and irreparable impact to the environment (IPCC 2021).

The present flash flood in the Bhagsu nala in McLeod Ganj area near Dharamshala township, Himachal Pradesh occurred in a small catchment of about 2.8 km^2. This catchment with higher drainage density and circular shape is prone to have peak flow for short duration during extreme rainfall. On the fateful day of July 12, 2021, the 80 mm cumulative rainfall for 12 hours prior to the occurrence of the flash flood resulted in the accumulation of high discharge in the Bhagsu nala. The flood got worsened near the outlet at the lower reach of the Bhagsu nala due to multiple anthropogenic activities in the form of restricting the natural course of drainage by constructing culvert and covering the channel. This has greatly reduced the carrying capacity of the nala. Therefore, the causes of the flashflood in the Bhagsu nala may primarily be attributed to extreme rainfall event that got exaggerated at the lower reach of the nala due to its funnel shape, which got amplified by the anthropogenic intervention on the free flow of water in the Bhagsu nala.

The current flash flood in the small catchment of Bhagsu nala in the present day climate change scenario in the Himalaya is an eye opener, particularly to the planners and administrators. With the increased frequency of extreme rainfall or cloudbursts, the number of such flash flood will increase and may prove to be disastrous particularly along the constricted drainages. Therefore, it is important that development in the hilly townships of the Himalaya must be made in such a way that the natural flow of the streams be maintained without any hindrance along their flow path.

References

Bhasin, R., Shabanimashcool, M., Hermanns, R.L., Morken, O.A., Dehls, J.F., Gupta, V. (2020) Back Analysis of Shear Strength Parameters of a Large Rock Slide in Sikkim Himalaya. Jour. Rock Mech. Tunn. Tech., v.26, pp.81–92.

Dimri, A.P., Chevuturi A., Niyogi, D., Thayyen, R.J., Ray, K., Tripathi, S.N., Pandey, A.K., and Mohanty U.C. (2017) Cloudbursts in Indian Himalayas: A review. Earth Sci. Rev., v.168, pp.1–28.

Dobhal, D.P., Gupta A.K., Manish, M. and Khandelwal, D.D. (2013) Kedarnath disaster: facts and plausible causes. Curr. Sci., v.105, pp.171–174.

Easterling, D.R., Meehl, G.A., Parmesan, C., Changnon, S.A., Karl, T.R., Mearns, L.O. (2000) Climate extremes: observations, modeling, and impacts. Science.sciencemag.org, v.289, pp.2068–2074.

Gupta, V. and Sah, M.P. (2008) Impact of the Trans-Himalayan Landslide Lake Outburst Flood (LLOF) in the Satluj Catchment, Himachal Pradesh, India. Nat. Hazards, v.45, pp.379-390.

Gupta, V., Dobhal, D.P., and Vaideswaran, S.C. (2013) August 2012 cloudburst and subsequent flash flood in the Asi Ganga, a tributary of the Bhagirathi river, Garhwal Himalaya, India. Curr. Sci., v.105, pp.249–253.

Gupta, V., Tandon R.S., Venkateshwarlu, B., Bhasin, R.K., and Kaynia, A.M. (2017) Accelerated mass movement activities due to increased rainfall in the Nainital township, Kumaun Lesser Himalaya, India. Zeitschrift fur Geomorphol., v.61, pp.29–42.

Horton, R.E. (1932) Drainage basin characteristics; Eos, Trans. Am. Geophys. Union, v.13, pp.350–361.

IMD (2003) Climatology of the Himalayas and neighbourhood, National Climate Centre, Office of ADGM(R). IMD, Pune

IMD (2022) Annual statement on climate of india 2021. accessed at - https://mausam.imd.gov.in/ on Jan 18, 2022

IPCC (2021) Summary for Policymakers. *In:* Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]; Cambridge University Press. In Press.

Juyal, N. (2010) Cloudburst-triggered debris flows around Leh. Curr. Sci., v.99, pp.1166–1167.

Gautam, A.S., Tripathi, S.N., Joshi, A., Mandariya, A.K., Singh, K., Mishra, G., Kumar, S., Ramola, R.C. (2021) First surface measurement of variation of Cloud Condensation Nuclei (CCN) concentration over the Pristine Himalayan region of Garhwal, Uttarakhand, India; Atmos. Environ., v.246 p.118123.

Govt of Himachal Pradesh (Revenue Department - Disaster Management Cell) (2021) Memorandum of damages due to flash floods, cloud burss and landslides during Monsoon-2021; accessed at - https://hpsdma.nic.in/ on Jan 18, 2022

Ram, P. and Gupta, V. (2021) Landslide hazard, vulnerability, and risk assessment (HVRA), Mussoorie township, lesser himalaya, India. Environ. Dev. Sustain., v.24, pp.473–501.

Rana, N., Singh S., Sundriyal, Y.P. Juyal, N. (2013) Recent and past floods in the Alaknanda valley: causes and consequences. Curr. Sci., v.105, pp.1209–1212.

Sati, S.P., Sundriyal, Y.P., Rana, N. and Dangwal, S. (2011) Recent landslides in Uttarakhand: nature's fury or human folly. Curr. Sci. v.100, pp.1617–1620.

Sati, S.P. and Gahalaut, V.K. (2013) The fury of the floods in the north-west Himalayan region: The Kedarnath tragedy. Geomatics, Nat. Hazards Risk v.4, pp.193–201.

Sundriyal, Y.P., Shukla, A.D., Rana, N., Jayangondaperumal, R., Srivastava, P., Chamyal, L.S., Sati, S.P., Juyal, N. (2015) Terrain response to the extreme rainfall event of June 2013: Evidence from the Alaknanda and Mandakini River Valleys, Garhwal Himalaya, India. Episodes, v.38, pp.179-188.