RISK AND UNCERTAINTY IN HYDRO-POWER DEVELOPMENT IN UTTARAKHAND POST KEDARNATH AND CHAMOLI FLOOD DISASTERS IN UTTARAKHAND

S.K.Mazumder
Former AICTE Emeritus Professor of Civil Engineering, DCE (now DTU)
E-mail: somendrak64@gmail.com
Web: www.profskmazumder.com
&
Shivdayal Sharma
Expert – Hydrology and Hydraulics, M/s Growever Infra Pvt Ltd., Delhi,
E-mail: shivdayal.sharma@gmail.com

Abstract

The State of Uttarakhand is situated in the upper reaches of the Indian sub-continent. It is also locally termed as "Dev Bhoomi" as it houses many of the famous temples attracting millions of tourists and pilgrims from within and outside the country. This state is also blessed with rivers fed by natural glaciers as well as rains contributing to a huge hydro power potential. (UJVNL) The main source of income for the state is through Hydro power development and tourism. The state having a hilly terrain, does not support the establishment of large industries and hence migration is increasing year by year. Thus, promoting hydro-power production and promotion of tourism are some of the feasible options for economic development. If hydro power development is scuttled, it will be difficult to arrest mass migrations from these states. Uttarakhand has a hydropower potential of the order of 20,000 MW against which only about 3,164 MW (16% approx.) has been harnessed so far(Aggarwal & Kansal,2017). The State is gifted by nature with rivers like Ganga, Yamuna, Kosi providing an ideal location for hydropower development. Unfortunately, most of hydropower projects under development were stayed by The Supreme Court of India (2013) after Kedarnath flood disasters that occurred in Uttarakhand in June-2013. Situation has worsened further after the current Chamoli flood in Feb-2021.
In the present paper, authors have discussed about the above flood disasters and their impact on hydro-power development in the state.

Keywords: Hydro Power, Glacier, Land slide, Flood, Sedimentation Uttarakhand

1.0 Introduction

After independence, the necessity of constructing water-resource and hydropower projects were felt and many multi-purpose projects were conceived and executed. Uttarakhand was formed out of Uttar Pradesh after the bifurcation of the state in the year 2000. The status of an independent state, however, brought in pressures on the Govt. for development of infrastructures of Uttarakhand including its capital Dehradun. The growth process in Uttarakhand has been limited to the plain districts eluding the hilly areas, as most of the manufacturing units are located in the plain districts. There is an urgent need for meeting the productive employment demands of the poor population in the state. This can be achieved through an efficient and reliable access to energy for the rural population. The development , dependent on the conventional energy sources for the plains, might not prove much effective in the hills due to its difficult terrain.

2.0 Natural Resources of Uttarakhand

The state lies in the Himalayan range and has a highly diversified topography. The climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to subtropical forests at the lower elevations. The highest elevations are covered with ice and bare rocks. Only three districts, namely, Dehradun, Udham Singh Nagar and Haridwar lie mainly in the plains. The rest of the thirteen districts lie primarily in the hilly regions. The Yamuna and the Ganga - the two major rivers in the western Himalayan region - directly impact the lives of a large population living in the northern part of India, more so in Uttarakhand. The glacier-fed rivers of Uttarakhand are an important resource for the Ganga basin, with many rivers contributing to the irrigation potential of some of India's most densely populated states such as Uttar Pradesh, Bihar, Delhi, and Haryana. Despite the presence of glaciers and perennial rivers in the state, in addition to plenty of rainfall, the availability of water to local people is not up to expectations due to lack of storage,

3.0 Natural Disasters

Owing to the fragility of its mountain, economy of the state of Uttarakhand is vulnerable to natural disasters (CBIP,2013) due to a number of reasons e.g. earthquake, wild fire/forest fire, land slides, floods etc. During the last five years, the residents in Uttarkashi, Bageshwar, Rudraprayag and Pauri Garhwal districts (Fig.1) reported the same in higher proportion and the loss of life/property/assets/livelihoods, etc., from floods was reported as far greater compared to earthquakes.

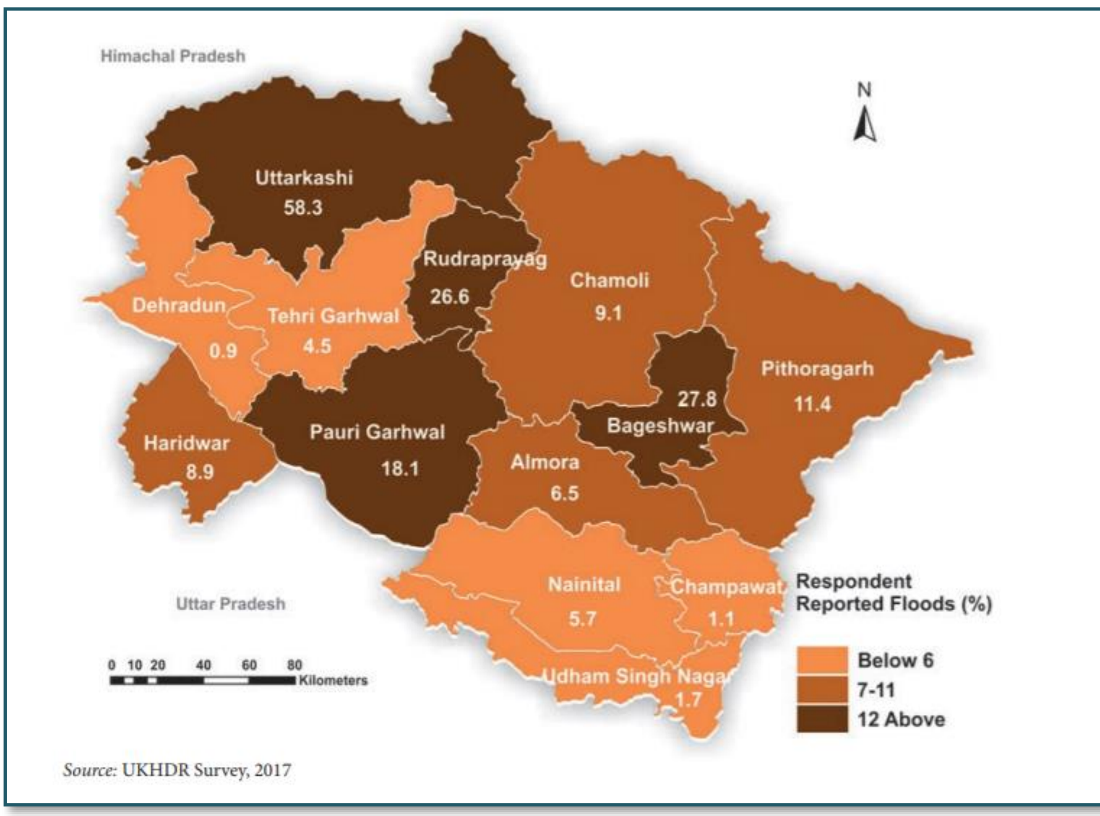


Figure-1: Uttarakhand Districts Vulnerable to Floods (%)-Source:Aggarawal (2021)

4.0 Kedarnath Flood

In June 2013, a mid-day cloudburst centered the North Indian state of Uttarakhand caused devastating floods and landslides, becoming the country's worst natural disaster since the 2004 tsunami. Debris blocked the rivers, causing major overflow. More than 5,700 people were "presumed dead" by 16 July,2013. Destruction of bridges and roads left about 3,00,000 pilgrims and tourists trapped in the valleys leading to three of the four Hindu Chota Char Dham pilgrimage sites. A joint study by the World Bank and the Asian Development Bank estimated that damage (Fig.2a and 2b) to public infrastructure-roads, water transport, buildings- amounted to nearly $700 million. (Madan, 2013)

Fig.2 (a): Destruction of Buildings

Fig.2(b)Damage of Roads (CBIP,2013)

4.1 *Causes of the 2013 Flood Disaster*

Large parts of the state experienced about 250 to 400 mm rainfall. The uppermost glacial region between Gangotri to the Nandadevi National Park received an estimated 350-400 mm in a period of about 48-72 hours. Meteorological studies indicate that during the 1960s, the day and night temperature on mountains was the same. But in the last decade, the day temperature has increased considerably as compared to the night temperature building situation of cloud bursting and flash floods. Besides rainfall, rampant deforestation, slope cutting, blasting of rocks, haphazard disposal of debris, and riverbank constructions were also responsible for the huge destruction. The government also got pressurized and resorted to rapidly widen the roads and other infrastructure so as to accommodate the tourist inflow which is a major source of livelihood for a large number of people of the state. All these caused devastating floods and landslides in the Kedar valley and many other river valleys of Uttarakhand as shown in Fig.3 (Mazumder,2014; Misra et al 2013).

5.0 Chamoli Flood

The Chamoli flood disaster began on 7 February 2021 in the environs of the Nanda Devi National Park, a UNESCO World Heritage Site in Uttarakhand. It was caused by a large rock and ice avalanche consisting of material dislodged from Ronti peak. It caused flooding in the Chamoli district, most notably in the Rishiganga river,the Dhauliganga river and in turn the

Figure-3: Location of flood hit (June, 2013) areas in Uttarakhand

Alaknanda—the major headstream of the Ganges. The disaster left over 200 killed or missing, most were workers at the Tapovan dam site (Mazumder,2021)

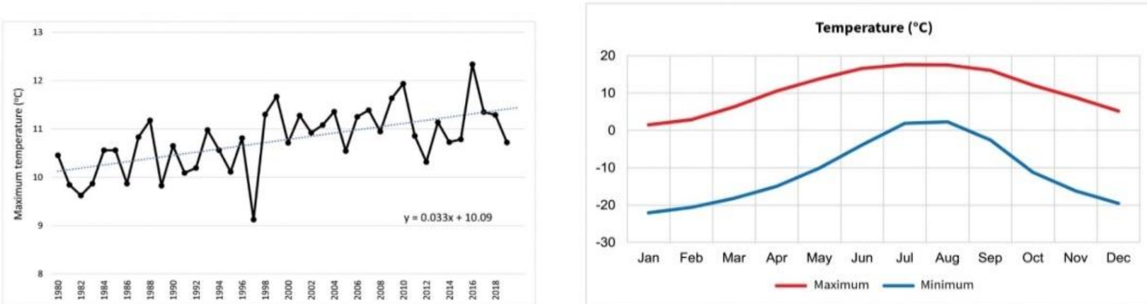
5.1 Sequence of Events

- Chamoli Floods occurred on 7-8 Feb. due to landslide triggered by detachment of massive rock from Nandadevi glacier from an elevation of 5600 to 3800 msl.
- Large amount of snow/mud/sediment/boulder/debris brought by the landslide caused aggradation of river bed and consequent rise in flood levels in the rivers Rishiganga and Dhauliganga and Alkananda-all tributaries of river Ganga.
- Due to steep slope of the terrain (S), heat generated in friction caused melting of snow and sudden increase in flow magnitude (Q) , flow velocity (V) and stream power ($P= \gamma QS$) resulting in wash out of several bridges and barrages and damage to several hydel projects under operation/ construction in the valley.

5.2 Causes of Chamoli Flood

Outer Garhwal Himalayas in Uttarakhand state, the average minimum temperature in the area falls below zero degree (Fig.4a). There is a steady rise in maximum temperature in the area (Fig. 4b) over the years (1980-2019) due to global warming/climate change. Also, the area is subjected to high rainfall (Fig.5) in February and July. It is believed these climatic factors caused landslide, avalanche or a glacial lake outburst flood (GLOF), resulting in flooding of Chamoli district, after a portion of the Nanda Devi glacier broke off. A large ice avalanche was previously released somewhere between 19 September and 9 October 2016 (Fig.6), which caused deposition of ice

~1.5 * 10^7 m^3 and bedrock in the valley below. The resulting destabilization of the rock mass was



(a) (b)

Figure 4 (a) Average monthly temperature (b) Maximum temperature trends in the Chamoli area (Data source: ERA5 reanalysis data, 1980-2019).

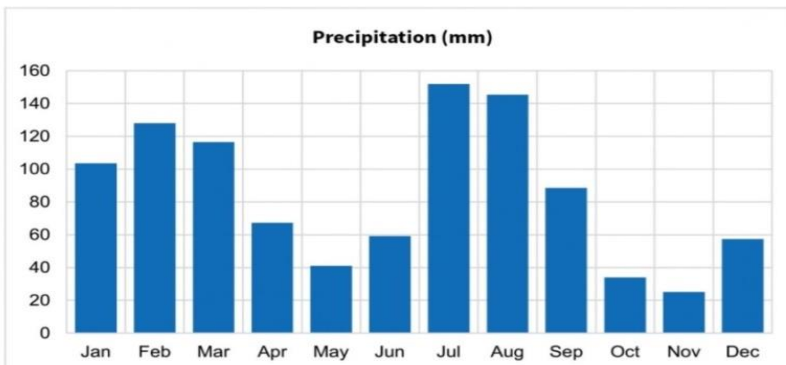
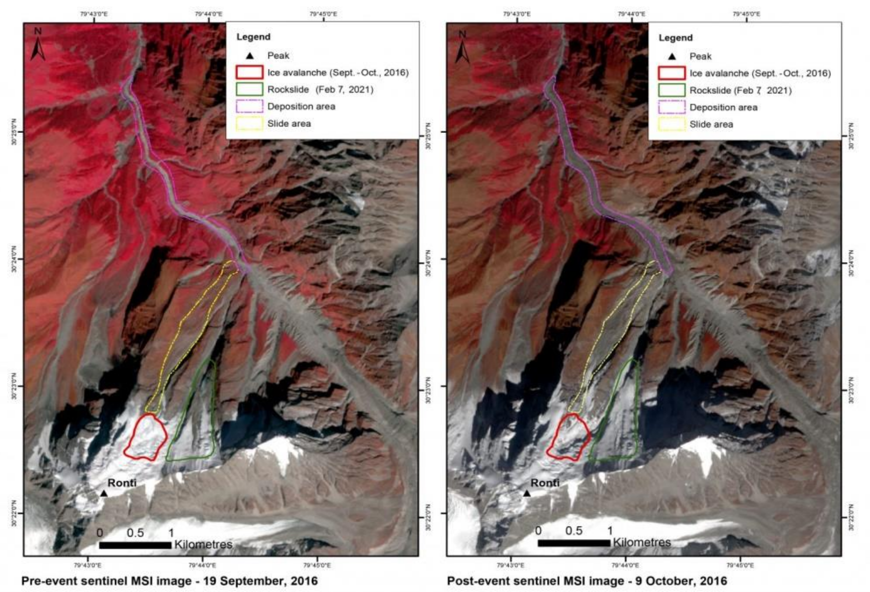


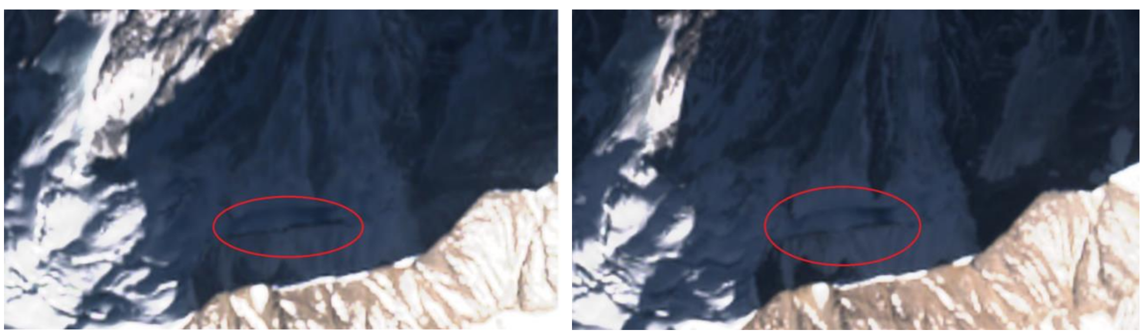
Figure 5: Average monthly precipitation of the area (1980-2019).

due to the lack of ice cover, glacial de- buttressing, stress-release fracturing and increased exposure to solar radiation. An increased freeze-thaw cycle, in combination with a large snowfall event, preceding the event of 7 February 2021 and rapid melt water production, may have favored the fracturing of rock. Fracture zones at the runout of the rockslide visible before the event suggest that such detachments have happened at the same location previously too. Permafrost thaw and frost cracking has been used to explain increased rockfall activity in the Alps (Deline et al. 2014;Gruber and Haeberli 2007). At roughly 5,600 above msl, a crack had formed on the side of the mountain. Researchers monitored satellite images to investigate the cause of landslide; but it is difficult to conclude. Crack can be seen in Fig.7(a) in a satellite image of the peak, which was captured on 2 February - five days before the disaster. The horizontal line of the crack is much more visible when the satellite is zoomed in, as shown in Fig.7 (b). Using satellite imageries, it was possible to see that the crack had been developing for some time - with evidence of the first crack visible in the satellite image from 1 January 2020. Enormous block of rock and ice fell into the valley on 7 February. It is estimated that the block was over 2 million cubic meters in size and fell nearly 2 kilometers, almost vertically, before impinging on the valley floor. As mentioned, the block fell 1800 metres (from 5600 to 3800 masl) into the valley below. Dr Scott Watson,(Anon n.d.,2021), University of Leeds, believes that the mass of rock and ice ploughed through a deposit of rock and ice due to the lack of ice cover, glacial de- buttressing, stress-release fracturing and



(a) (b)

Figure 6: (a)Pre event Picture (b) Post Event Pictures Showing Avalanches



(a) (b)

Fig.7 Close-up View of the Crack Propagating in The Mountain (Pic: SentinelHub)

previous avalanche in 2016 triggering landslide with a huge trail of dust as it travelled down the valley generating immense heat and melting of ice illustrated in Fig.8 (a) and 8(b)

Fig.8 (a) Rock/Ice mass Fall Hilltop to Valley (b) Huge trail of dust (red)in the Valley
(Satellite Image: Dr Scott Watson, COMET, University of Leeds)

6.0 Risk And Uncertainity Of Hydropower Development In Uttarakhand

The flash floods have raised public anger over hydropower projects that the government considers essential to decarbonize the nation's electricity generation. Experts say the event, induced by the effect of global warming on melting glaciers, was made worse by construction of infrastructures like roads and hydro-power plants. Large-scale blasting, tree felling and tunneling, loss of sensitive eco-system most certainly add to the risk and uncertainty of hydro-power projects planned by the Govt. of India for the development of the country in general and Uttarakhand in particular . As per Himanshu Thakkar, (Anon (a), n.d.2021) coordinator of the New Delhi-based South Asia Network on Dams, Rivers and People (Anon(b) n.d.2021), which studies the social and environmental impact of water-related projects in India "they are a force multiplier in the destruction". Table-1 gives the details of damages due to Chamoli flood in 2021.The fate of NTPC's 520-MW Tapovan-Vishnugad hydel project hangs in balance as India's largest power company is estimated to have suffered a loss of Rs 1,500 crore due to damage to their construction caused by the flash flood. The event and related avalanche made of debris flow/flood caused damage to four hydropower projects along the Rishi Ganga, Dhauliganga and Alaknanda river path. The Rishi Ganga Hydropower Project (13.2 MW) near Raini village, located 14 km downstream from the impact site, was the first to be hit by the debris after the rockslide. The unfinished Tapovan -Vishnugad Hydropower Project (520 MW), 8 km downstream from Rishi Ganga Hydropower Project, was the second hydropower plant hit by the flood. The diversion dam of this run-of-the river type project faced massive damage from sedimentation and the dam was filled with debris, which can be seen in the remote sensing images taken before and after the event. Two power projects — NTPC's Tapovan-Vishnugad hydel project and the Rishi Ganga Hydel Project — were extensively damaged with scores of laborers trapped in tunnels as the waters came rushing in. At least 32 people were dead and over 190 missing.

Table-1: Hydro-Power Projects Damaged in Chamoli Flood

SN	**Name**	**(Latitude/longitude)**	**Capacity (status)**
1	Rishi Ganga Hydropower Project	30.478 / 79.699	13.2 MW (Operational)
2	Tapovan Vishnugad Hydropower Project	30.493 /79.628	520 MW (Under construction)
3	Vishnuprayag Hydro Electric Project (Jaypee Group)	30.566 /79.547	400 MW (Operational)
4	Vishnugad Pipalkoti Hydro Electric Project	30.433 /79.424	444MW,under construction)

The risk and uncertainty in the development of hydro-power in the Himalayan areas in general and Uttarakhand in particular after the disasters of 2013 and 2021 floods has to be accepted. The only way to overcome such uncertainty and risk lies in more advanced research study (Mazumder,2017) of the Himalayan area with high untapped potential for future development of hydro-power in the Himalayan region in general and Uttarakhand in Particular.

9.0 Summary and Recommendations

Conservation of environment is a serious issue all over the world. It is more so in states like Uttarakhand- a land that witnessed the Chipko Movement.- India is a developing country and the country needs electric power for the development of its infrastructure and livelihood opportunities for the large and aspiring Indian population. In the light of this, we have to decide the suitability of hydro-electric projects in the Himalayan states like Uttarakhand where thermal and solar power generation are not popular due to non-availability of coal and its undulating terrain full of mountains.
The Himalayas are the source of a large number of perennial rivers. The slope of the mountains is very steep with largely uninhabited valleys at many places. Due to nature's gift of water and terrain head, run-off the river type hydro- electric development is ideal for power generation. However, the floods of 2013 and 2021 cast shadow on the Govt. proposal as it was found that dams like The Tehri actually acted like a flood-control measure. It should , however, not forgotten that risks and uncertainty are there in all walks of life. Attempt must be made to analyse and understand the risk with real time data obtained from both physical survey and remotely sensed satellite imageries--areas where India has made phenomenal progress over the years. Real-time and accurate data about meteorological conditions can help to better regulate the reservoir levels to accommodate and forecasr the floods. More research in the area of climatology is the need of the hour to accurately predict rainfall and other extreme events like cloudburst etc. so that the reservoirs can be emptied before the rains. The construction activities need to be regulated and zoning norms need to be developed scientifically in areas near river-banks and implemented strictly. Many studies have have revealed that the debris left over near the river banks during construction of dams flow back into the river increasing the sediment load of rivers during the floods. The government agencies should frame clear-cut rules for the disposal of leftover debris in dam construction sites. Safety measures also need to be implemented and developed during the construction stage. The construction activities should also be properly rescheduled keeping in mind the rainfall season.

It is necessary to undertake model studies of the structures across the rivers to develop a prior understanding of river behaviour after construction and particularly during massive floods. Disaster preparedness is also critical because all of the Himalayan states lie either in seismic Zone IV or V. These areas are the most vulnerable to strong earthquakes. The Disaster Management Plans of HEPs need to be carefully reviewed and approved. The local communities must be involved in all stages of the project right from inception to monitoring to operation. Afforestation must be done in tracts that are denuded. The selection of trees should be made judiciously taking local conditions into account. There are some varieties of vegetation that arrest erosion and hold the soil. Such varieties should be planted in sites denuded by construction of dams.In the design of hydraulic structures planned in the slide prone areas like Uttarakhand, it is essential to consider the extraordinary rise in water level due to landslides and consequent aggradation and sudden rise in flood level (HFL) much higher than the normal design HFL corresponding to design HFL of a given return period.

References

Aggarwal, V.(2021) "Climate Change Impact on Water Power Project In Himalayan Region- A Case Study For Chamoli District Of Uttarakhand", M.Tech. Thesis Submitted to Dehi Technology University, Delhi.

Agarwal, Sanchit & Kansal, M.. (2017). Issues of Hydropower Development in Uttarakhand region of Indian Himalaya. Water and Energy International. 59.

Anon.(a)n.d.(2021)"Himanshu Thakkar – SANDRP." Retrieved May 22, 2021a(https://sandrp.in/tag/himanshu-thakkar/).

Anon.(b) n.d.(2021) "The Catastrophic Landslide and Flood in Chamoli in Uttarakhand: The Sequence of Events - The Landslide Blog - AGU Blogosphere." Retrieved May 22, 2021b (https://blogs.agu.org/landslideblog/2021/02/08/chamoli-2/).

CBIP (2013) "Natural Disaters With Special Referece to Uttarakhand", Souvenir, Pub. by CBIP, Dec

Deline, Philip, Stephan Gruber, Reynald Delaloye, Luzia Fischer, Marten Geertsema, Marco Giardino, Andreas Hasler, Martin Kirkbride, Michael Krautblatter, Florence Magnin, Samuel McColl, Ludovic Ravanel, and Philippe Schoeneich. (2014) "Ice Loss and Slope Stability in High-Mountain Regions." Pp. 521–61 in *Snow and Ice-Related Hazards, Risks, and Disasters*. Elsevier Inc.

Gruberber, S., and W. Haeberli (2007) "Permafrost in Steep Bedrock Slopes and Its Temperatures-Related Destabilization Following Climate Change." *Journal of Geophysical Research: Earth Surface* 112(2):2–18. doi: 10.1029/2006JF000547.

Madan, M. M. (2013), "Hydro-Power-A Key to Disaster Management", paper pub. in the Souvenir of 'Natural Disasters with Special Reference to Uttarakhand'-org.by CBIP, New Delhi, Dec.20th.,

Mazumder,S.K.(2021) "Future of Hydro-Power Development in Himalayas post Chamoli Flood Disaster"pub. in J.'Viewpoint' pub.by CEAI, June

Mazumder, S. K. (2017) "Hydro Power Development- Some Problems & Remedial Measures", Invited paper published in the ISH News bulletin by Indian Society for Hydraulics, Vol.26, No.1&2,March-July

Mazumder, S. K. (2014) "Flood Damages in Kedarnath and its Impact on Hydro-Power Development", pub. in ISH News Letter, Vol. 23, No. 1, July.

Misra, R. N., S. C. Aggarwal & A. Sharma,(2013) "Disaster in Uttarakhand -Its Causes, Impact on Infrastructure Development and Mitigation measures"- paper pub. in the Souvenir of 'Natural Disasters with Special Reference to Uttarakhand'-org. by CBIP, New Delhi, Dec.2

Supreme Court of India (2013) “Report of Expert Body constituted on the directions issued by the Hon’ble SupremeCourt of India- vide judgment dated 13.08.2013 in the case of Alaknanda Hydro Power Co. Ltd. versus Anuj Joshi & others arising out of Civil Appeal no. 6736 of2013 (SLP (C) no. 362) of 2012), with appeal no. 6746-6747 of 2013 arising out of SLP (C) no. 5849-5850 of 2012 and TC (C) no. 55-57 of 2013Assessment of Environmental Degradation and Impact of Hydroelectric projects during the June 2013 Disaster in Uttarakhand

UJVNL Hydropower projects in Uttarakhand, , https://www.ujvnl.com/hydro-power-projects-in-uttarakhand