Post Flood Disaster Mitigation Strategy in Uttarakhand

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Abstract India is a very densely populated country with population over 1.25 billion people and experiences natural hazards like floods and drought simultaneously at the same time in the country causing severe damages because of its different geographical terrains. Earthquakes, cyclones, and landslides are other natural calamities, which affect the various parts of the Country on one or more occasions. Uttarakhand, predominantly a hilly State, also experiences floods, landslides and earthquakes very often.

In June 2013, the monsoon arrived almost two weeks earlier than expected in Uttarakhand with cloud bursts and very heavy rainfall in several parts of the State. This unprecedented rainfall created havoc in the State and thousands of people/animals lost their lives, besides infrastructural, financial and other losses. After the 2013 flood disaster, the Govt. of Uttarakhand took many structural and non-structural initiatives to manage and mitigate the floods in the upper Himalayan regions of the State. The paper describes in brief the flood defense structures constructed at many places in the State, there performance during the floods and flood plain zoning, early warning systems, real time flood forecasting system, planned to be adopted in the State to mitigate the impacts of floods in future.

Keywords: Floods, Disasters; Flood Defense Structures; Flood Plain Zoning; Early Warning System

1.0 Introduction

Floods are the most catastrophic and the most frequently occurring natural disaster across the world. Floods are responsible for 47% of all weather related disasters. About 6.8 million people died of floods in the 20th century. Statistically, 2.8 billion people have been affected with an average of more than 80 million affected each year across the globe in the last 30 years [Bhatt, 2014]. The repercussions include 4.5 million homeless, 540,000 deaths, 360,000 injuries and economic loss for the last thirty years amounts to more than 11 billion US$. Between 1994 and 2004, Asia has seen approximately 1,500 flood disasters [Bhatt, 2014]. The State of Uttarakhand is severely prone to floods and flash floods and it has witnessed heavy floods during the last 40 years, which include Uttarkashi floods in 1978, Malpa flood and landslide in 1998 in Pithoragarh, 2010 floods in the State besides 2013 flood disaster [Pande, 2010]. In June 2013, people of Uttarakhand witnessed one of the worst flash floods over a century. More than 5,000 people died, which is the highest for that year and thousands more were affected. On 17th June 2013, moraine dammed lake, Chorabari Lake got bursted due to heavy rains on 16th and 17th June 2013 at Kedarnath Dham and completely washed away Gaurikund (1990 m asl), Rambara(2740 m asl) and Kedarnath(3546 m asl) towns, besides damaging habitats and agricultural land along the banks of River Mandakini between Kedarnath and Sonprayag. The continuous heavy precipitation in the Kedarnath valley nearly resembled *cloud burst* type event. The aerial images of the settlement at Kedarnath Dham before and after 2013 flood disasters are shown in Fig. 1.

Even though, significant advances has been made in flood forecasting and early warning systems, flash floods are still a challenge because they occur due to intense short bursts of rainfall and measuring the intensity and duration of high intense rainfall is extremely difficult [Rao, 2014]. Flash floods mostly occur in complex mountainous regions. Historically, heavy rainfall and cloudburst have been the main factors for floods in the State of Uttarakhand [Bhambri, 2016]. High elevations, dense river network and the soil type have augmented the severity of flash floods.

Fig. 1 – Aerial Photographs of Kedarnath Area before and after June 17th , 2013

Flood disaster reduction strategy mainly includes preventive measures taken before floods, preparedness and mitigation measures, followed by flood management actions during and after an event. Mitigation measures require a change from *reactive* to *proactive approach*. Improvements in flood forecasting from short term to long term forecasting is one of the most important aspect of flood disaster reduction strategy, especially for upper Himalayan rivers. The perception of risk and safety due to floods, and communication means, need to be improved for the efficient and effective functioning of flood disaster reduction strategy in present situations and future. By resolving these issues, better sustainable flood risk reduction strategy can be developed for the future. Advancement in technology, communication means and reliability of forecasts has already reduced the flood damages and fatalities in plain areas in India. The paper describes in brief flood disaster reduction strategy adopted by the State of Uttarakhand after the 2013 flood disaster. It would facilitate the planners and other stake holders working in mitigating the flood disasters.

2.0 Flood Disaster in June 2013 In Uttarakhand

Uttarakhand has a total geographical area of 53,484 km^2 and its economy primarily depends on agriculture and tourism. The State is also famous for **Char-Dham**, i.e. Gangotri, Yamunotri, Kedarnath and Badrinath, important pilgrimage centres.

2.1 Disaster in Kedarnath Dham

Mandakini River at Kedarnath originates from the Chorabari Glacier(3895 m asl), which has a total catchment area of 67 km^2, out of which about 23% area is covered by glaciers. Mandakini river joins Saraswati River at Kedarnath and passes through Rambara and Gaurikund. Son-Ganga, which originates from Vasuki Lake(4040 m asl), confluences with Mandakini River at Sonprayag(1709 m asl). The river Mandakini merges with Alaknanda River at Rudraprayag to be called as Alaknanda river in the downstream of Rudraprayag.

400 m long, 200 m wide moraine dammed Chorabari Lake (3960 m asl), also known as Gandhi Sarovar Lake had a depth of 15–20 m and was a snow melt and rain fed lake, located about 2 km upstream of Kedarnath town. The bursting of this lake on 17th June 2013 led to release of huge water, completely draining within 5–10 min, as reported by the eye witnesses.

The bursting of Chorabari Lake caused a massive devastation to the Kedarnath town. Old photo and recent status of Chorabari Lake, filled with sand has been depicted in Fig. 2.

Fig. 2 – Old Photo and Post Disaster Sand Deposited in Chorabari Lake

2.2 Disaster in other Areas

Heavy precipitation on 16th–17th June 2013 in the State of Uttarakhand resulted in catastrophic destructions in the Rudraprayag, Chamoli, Uttarkashi, Pithoragarh and Bageshwar districts of the hill State. About 5000 people and hundreds of animals lost their lives besides loss of several hectares of fertile agricultural land, damages to property and other infrastructural developments[Chalisgaonkar, 2014, 2017]. Fig. 3 depicts the impact of disaster on confluence of river Mandakini and river Alaknanda at Rudraprayag and indicates that confluence of river Mandakini and river Alaknanda at Rudraprayag has shifted in the downstream and bed level at the old confluence point has risen by 5-6m. Fig. 4 shows the eroded river banks and damaged building in Distt. Rudraprayag and Pithoragarh.

Fig. 3: Confluence of river Mandakini and Alaknanda at Rudraprayag, before and after June 16, 2013

Fig. 4: Damages in District Rudraprayag and Pithoragarh during 2013 flood

3.0 Flood Disaster Reduction Strategy

The concept of flood disaster reduction strategy is centuries old and with time they have been updated regularly with the advancement of technological development. But, till today, in spite of decades of flood damage reduction strategy, flood losses continue to rise.

Intergovernmental Panel on Climate Change(IPCC) in the late 1980s had also realized the impact of climate change on natural disasters in general and flooding in particular.

In early 1990s, the process of flood disaster reduction strategy was introduced in flood management. In the late 1990s, risk-based approaches were used by the researchers in developing flood management strategies. Later in 2000s, *strong defense structures* were suggested to be used to increase safety. However, there has been a general agreement that absolute safety from flood hazards is not possible and therefore acceptable risk levels be also considered for providing flood safety.

Misconceptions and myths about floods and flood defenses are deeply rooted in our society. Many people believe that floods occur at large and regular time intervals and terms such as *return period* and *recurrence interval* can be taken literally, where as one has to understand that these are statistical terms and be taken as averages. However, due to the hydrological and climatic uncertainties, flood risk assessment has remained a challenging task, to date, for all the countries. Thus it can be said that it is better to protect against floods up to a desired safety level. The Central Water Commission, Ministry of Jal Shakti, Govt. of India has already defined these levels in terms of return periods for urban and rural habitats. Once we clearly understood that no flood defense measures can guarantee complete safety, a general change of paradigm is needed from reactive to proactive approach and emergency action plan must be prepared for events exceeding the design flood, adopted for flood defense(i.e. when protections provided are bound to fail). Thus, it can be said that attitude of *living with floods* and preparing Standard Operating Procedures(SOPs) for extreme events seems to be more sustainable strategy rather than hopelessly striving to protect for all conditions.

Long term and short-term structural measures and non-structural measures are the two essential primitives of any Flood Disaster Reduction Strategy. In the structural measures, the floods are kept away from the people and the non-structural measures try to keep the people away from floods. Among the various structural measures, new flood defense/mitigation structures constructed by the State of Uttarakhand after the 2013 disaster and some of the Non-Structural measures adopted by the State of Uttarakhand has been presented in the paper.

4.0 Post Disaster Mitigation Strategy

Flood mitigation refers to long term structural and non-structural measures that can be adopted to mitigate the adverse impact of flood hazards. The structural measures basically includes construction of defense structures and the non-structural measures include early warning, flood plain zoning regulations, planning, public awareness programmes, etc.

4.1Flood Defense Structures

Since the early 20th century, structural engineering solutions, Flood defense, have taken a key role in flood disaster reduction management, to provide protection to human and animals, agricultural land and other infrastructural development. Flood defense does not necessarily mean complete protection from floods, but it protects up to a desired level of safety. The Guidelines issued by Central Water Commission, Ministry of Jal Shakti, Govt. of India, New Delhi[CWC, 2012] clearly states that urban areas be protected for 100 year return period of floods and rural areas for 50 year return period of floods. The objective of flood defense is to ensure that normal activity can continue within the protected area during and after a flood event. Sometimes Flood Defense Structures are needed to be constructed longitudinally along the river, sometimes transverse to the direction of flow or hybrid i.e.

combination of both, depending on the type of terrain, type of the rivers, material available locally and engineering requirements, to protect the river banks from erosion, flood protection and safety of the habitants residing near the bank of a river.

After the 2013 flood disaster in the State, the Govt. has planned and constructed flood defense structures of more than 1000 crore. Typical flood defense structures constructed at different geographical locations in the State using different materials have been depicted in Fig. 5.

Solani River

Kailash River

Sitarganj

River Assiganga

River Tons

Dehradun

Mana

Hemkund Sahib

Fig. 5 - Flood Defense Structures Constructed after Disaster

4.2 Effectiveness and Efficacy of Flood Defense Structures

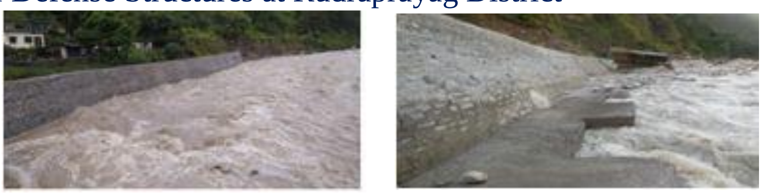
The effectiveness and efficacy of structural flood defense structures depend on many factors which include planning, desired safety level, availability of materials locally, climatic conditions, geographical terrains etc. In the short period after the disaster in 2013, many structural flood defense structures have proved their performance by preventing flood damages and this outcome has led to a strong belief that effective and efficient engineering solutions are capable of providing protection from floods to a large extent. Fig. 6 shows the performance of few defense structures constructed of different materials and types under floods.

Performance of R. R. Masonry Defense Structures

Performance of Defense Structures at Kedarnath, Kalimath and Srinagar, Uttarakhand

Performance of Defense Structures at Rudraprayag District

Performance of Gabion Defense Structures in Haridwar District



Performance of Gabion Defense Structures at High Altitudes

Fig. 6: Performance of Flood Defense Structures during Floods

However, some of these structural measures may be found to be inefficient in the long term, during catastrophic flood events and other unplanned developmental activities in the areas. In such eventualities, different risk assessment and management approaches shall be required to mitigate the losses due to such catastrophic events.

Now-a-days, the paradigm of flood risk management has shifted from a *reactive approach* to a *proactive approach* [Tarrant, 2012]. However, the efficacy and effectiveness of these flood defences can only be ascertained when flood events actually occur. It has also been observed that the same type of structural flood defence structures may not be effective in all floodplains, because behaviour and characteristics of rivers are altogether different in hilly terrains and plains.

4.3 Flood Forecasting Practices in India

Now, most of the States in India uses one form or other for communicating the flood warning messages during the four rainy months so that appropriate actions can be taken during the floods to safeguard the life and property of people. These warnings include:

i) Whether the river is rising above a danger level or not;
ii) Whether the river is rising or falling;
iii) Whether the stage of the river is *low, medium* or *high*.

The above warnings are generally issued by emails, sms, and whatsapp in almost all the States including the State of Uttarakhand. These data are purely qualitative in nature and they give river gauges, discharges and the rainfall, which is only an indication of the nature of the flood. This kind of information is circulated to all the organizations concerned with floods during the rainy season on hourly and daily basis through SMS, email, whatsapp and web site etc., so that appropriate actions can be taken.

With the big leap in the technological development, it has now become possible to collect a data through sensors and transmit to the data management and processing centres through VSAT etc. for carrying out the further processing using sophisticated mathematical models. Indian Meteorological Department is planning to install 107 automatic weather stations, 28 auto rain gauges and 16 snow gauges in Uttarakhand with two Doppler radars, one each at Mukteshwar, District Nainital at El. 2285m and Surkanda Devi near Mussoorie, Distt. Tehri at an El. 3030m. Maharashtra is the State where Real Time Flood Forecasting is being used in Krishna and Upper Bhima basins and other States including Uttarakhand are planning to develop the same under World Bank aided National Hydrology Project.

4.3.1 Flood Alert Facility in Uttarakhand

After the 2013 disaster, the State of Uttarakhand carried out a River Morphological Study for the following four rivers under the Uttarakhand Disaster Recovery Project(UDRP), funded by World Bank:

Table 1 – Stretches of Rivers considered for River Morphological Study

Name of River	Stretch of River		
	Length, km	From	To
Mandakini	98	Kedarnath	Rudraprayag
Alaknanda	190	Badrinath	Devprayag
Bhagirathi	205	Gangotri	Devprayag
Kali	96	Tawaghat	Pancheshwar

Under the UDRP, a Uttarakhand River Morphological Information System(URMIS) has also been developed and made available in the public domain. A very unique tool has been made available in the URMIS, with the help of which administrator/authorized departmental user can run the mathematical models of these four rivers for carrying out the flood routing studies, developed on MIKE 11 software, by entering the discharge at any point and the model sends the results in five minutes by email of the user, who is running the model and gives the water levels at different locations, discharge, travel time from the starting point with water level and discharge at each location for 25, 50 and 100 year return period. With this facility, the concerned district officials and State Disaster Management Authority(SDMA) can be informed timely about the consequences of the floods and appropriate measures can be taken up by theses authorities quickly to minimize the losses.

4.3.2 Real Time Stream Flow Forecasting for State of Uttarakhand

Irrigation Department, Uttarakhand has proposed to develop Real Time Data Acquisition System(RTDAS) for meteorological & surface water monitoring under National Hydrology Project. It has also planned to install Automatic Rain Gauge(ARG), Manual Rain Gauge(MRG), Automatic Weather Stations(AWS), Snow Gauges, Automatic Water Level Recorders(AWLR) at various locations in the entire State in consultation with IMD and other stake holders so that the data can be collected, transmitted and shared with other stake holders in the Govt. Sector. The Govt. of Uttarakhand has also planned to develop the Decision Support System(DSS) for Real Time Flood Forecasting in the State.

5.0 Flood Plain Zoning

The basic concept of flood plain zoning is to regulate land use in the flood plains to restrict the damage caused by floods. Flood plain zoning, therefore, aims at determining the locations and the extent of areas for developmental activities in such a fashion that the damage is reduced to a minimum. The Central Water Commission, New Delhi has been continuously impressing upon the states the need to take follow-up action to implement the flood plain zoning approach. A model draft bill for flood plain zoning legislation has also circulated by the Government of India to all the States. But there has been a stiff resistance on the part of the states to follow-up the various aspects of flood plain management including possible legislation. The State of Manipur enacted the flood plain zoning legislation way back in 1978 and Rajasthan in 1997, but they have not taken any action to enforce it. The reluctance of the states to enact flood plain zoning regulation is mainly due to population pressure and want of alternative livelihood systems. The lukewarm response of the states towards the enactment and enforcement of the flood plain regulations has fuelled a significant increase in the encroachments into the flood plains.

5.1 Enactment of Flood Plain Zoning Act in Uttarakhand

State of the Uttarakhand is the 3rd State in the Country, who has enacted the Flood Plain Zoning Act in the Country after Manipur and Rajasthan and first to implement the same for flood management. In the first phase, flood plain zoning study in the Uttarakhand State was carried out for 55km stretch of river Ganga in Haridwar and 10km hilly stretch in river Bhagirathi in Uttarkashi town. The sample inundation maps for the river Ganga in District Haridwar and river Bhagirathi in Uttarkashi town have been depicted in the Fig. 7 and 8 respectively.

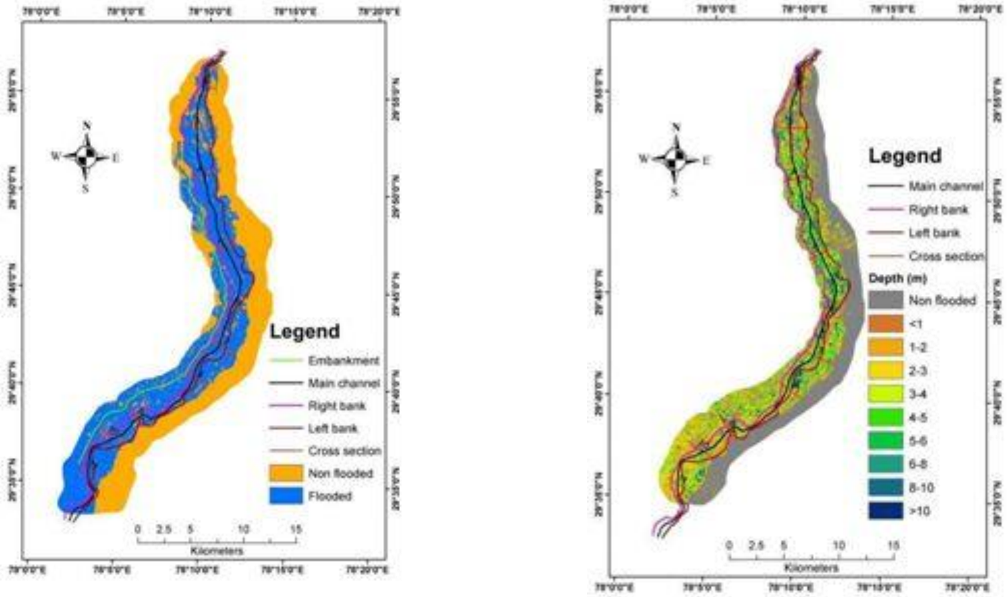


Fig. 7– Flood Inundation Mapping for river Ganga in District Haridwar for 2013 flood

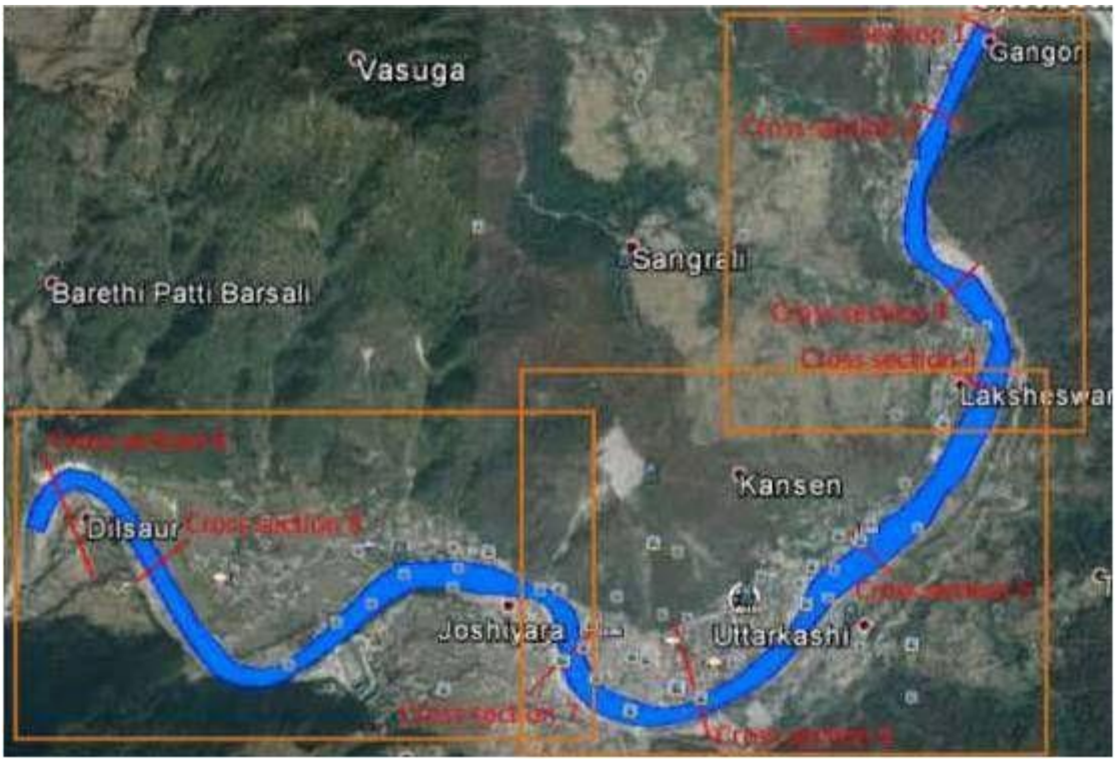


Fig. 8 - Flood Inundation Mapping for river Bhagirathi in Uttarkashi Town for 2013 flood

On the basis of the study carried out by National Institute of Hydrology, Roorkee[NIH, 2017] for the Irrigation Department, Uttarakhand, the 55km stretch of river Ganga and 10km stretch of river Bhagirathi was divided in to two zones, namely prohibited zone and restricted zone on the basis of return periods of 25 year and 100 year flood. Prohibited Zone and Restricted Zone for river Bhagirathi and river Ganga were marked on the Maps/Sajra Sheets and then as per the provisions of the act, the gazette notification in this regard were published in the newspapers, website, district administration offices etc. and objections were invited from the inhabitants in the area, whose land/building was falling in the prohibited zone or restricted zone.

In 10km hilly stretch of river Bhagirathi in Uttarkashi town, it was observed that the anticipated levels for the 100 year return period are below the top level of the bank protection wall constructed all along the river and accordingly the Gazette notification has been issued by the Govt. Where as the Govt. is in the process of finalizing the prohibited and restricted zone for the river Ganga in District Haridwar.

For other rivers, the process has been initiated by the Irrigation Department, Uttarakhand and prohibited and restricted zones will be marked on all major rivers in the State and accordingly flood plain zoning authority shall take actions as per the provisions of the act. It will thus enhance the safety of the people residing along the banks the rivers.

6.0 Conclusion

Over the period of time, since centuries, several flood disaster management strategies have been evolved, but till date it has been a challenge to frame versatile flood disaster management strategy because of uncertainty in climatic changing conditions and river morphological characteristics. Therefore, it is better that flood protections be made to a pre-decided desired safety level, depending upon the prevailing conditions and flood risk. Once we accept that safety cannot be guaranteed/achieved in all the conditions, a paradigm shift is needed in terms of proactive approach to reduce human vulnerability due to floods and an emergency action plan for extreme events be prepared in advance. Thus attitude of *living with floods* and preparing Standard Operating Procedures(SOPs) for extreme events seems to be more sustainable strategy rather than hopelessly striving to eradicate them. Structural and Non Structural Measures adopted by the Govt. of Uttarakhand will facilitate the planners, administrators and other stake holders of other States of the Country to plan such measures.

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