

Impact of Climate Change on Geo-Hazards: A Case study of Uttarkashi-Bhatwari and Gangnani Area, District, Uttarkashi, Garhwal Himalaya, Uttarakhand



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Abstract

Climate Change is the global phenomenon. Uttarakhand is a small developing state mainly with mountain terrain. Climate change influences the natural resources, bio-diversity, monsoon; earth processes, socio-economic activities and development of the countries. Climate Change refers to change in the statistical distribution of weather pattern or variation in weather for long time. High frequency of events such as cloudburst, landslides, flood, cyclones, tsunami and earthquake are also considered as signal of climate change.

The present paper deals with impact of climate change on Geo-hazards around Uttarkashi, Bhatwari and Gangnani area of District Uttarkashi, Garhwal Himalaya, Uttarakhand. Geologically the investigated area lies in the lesser and central Himalayan part of Himalaya. Main Central Thrust passes near Sainj along Kumaltigad and separate lesser Himalaya from Central Himalaya. MCT is very active and epicenter of recent earthquake is located near this thrust. There are number of landslides which were reactivated by earthquakes and cloudburst.

Engineering structures, forests, cultivated area, buildings and human settlement destroyed by peculiar climatic variation especially by heavy rain fall in the area. During last few years the events of cloudburst increases in Garhwal area which causes loss of property and life in the area. Cloud burst in the area during 2003,2007,2010,2012 and 2013 caused loss of property and life. Varunawat Landslide, Malla landslide, Bhatwari landslide Chadethi landslides, Sunagarh landslide and Gangnani landslide are examples of reactivated landslide due to heavy rainfall and earthquakes, The construction of branched road, all weather road, tunnels, building, dam and unscientific construction of buildings are the factors of anthropogenic hazards. Geomorphology, Geology, Structures and Climatic Change/Variation are responsible for Geo-hazards in the area.

Keywords: Climate Change, Geo-hazards, Landslides, Rainfall, MainCentral Thrust.

Introduction

Climate change refers to change in the statistical distribution of weather pattern or variation in weather for long time. Now days Climate Change refers specially to global warming and greenhouse gas effect. Climate Change impact on sea level, melting ice, changing eco-system, storm typhoon, floods and ocean acidification. Himalayan eco-system such as snowy peaks, green flora, fauna a vast reservoir of fresh water in the forms of perennial rivers are under stress and posing serious threat to mankind as these are depleting at alarming rates.

The investigated area lies in lesser and central Himalayan block of Himalaya in Uttarkashi District, Garhwal Himalaya, Uttarakhand. The area is highly sensitive to tectonic activity. The Main Central Thrust passes near Sainj along Kumaltigad ie. 20 Km from Uttarkashi along Uttarkashi Gangotri road, The high intensity earthquake of 1991 triggered the area and after that less intensity earthquake frequently triggered the area many times. It was noticed that most of earthquake epicenter was near to M.CT.

The incidents of cloudburst are common in Himalaya, the alarming fact is that these are increasing in frequent lately mainly after 2003. Cloudburst event causes debris avalanches, some time block the stream channel which on outburst causes loss of property and life by devastating flood. Impact of climatic change/variation reactivated landslide by toe erosion of Bhagirathi river and its tributaries, cloudburst, flashflood, in the area. Varunawat landslides, Malla landslide, Bhatwari landslide are reactivated by earthquake and Climatic variation.

Aim of Study

The area is very sensitive from tectonic and geohazards point of view. The area is subjected to earthquake of 1991 and minor other earthquakes. Now a days the events of landslides and cloudburst frequently takes place causes loss of property and life. The road join the famous Gangotri temple.

Methodology

Base map were prepared with the help of toposheet of survey of India. Geological mapping were carried out to locate various lithological units, Geomorphological map were prepared to locate various landforms. The earthquake and cloud burst events were observed by field study as author is doing work in the area since last 30 years. The rainfall data were collected from District office.

Geological Setting of the Area

Geologically the investigated area lies in lesser and central Himalayan part of Uttarkashi area

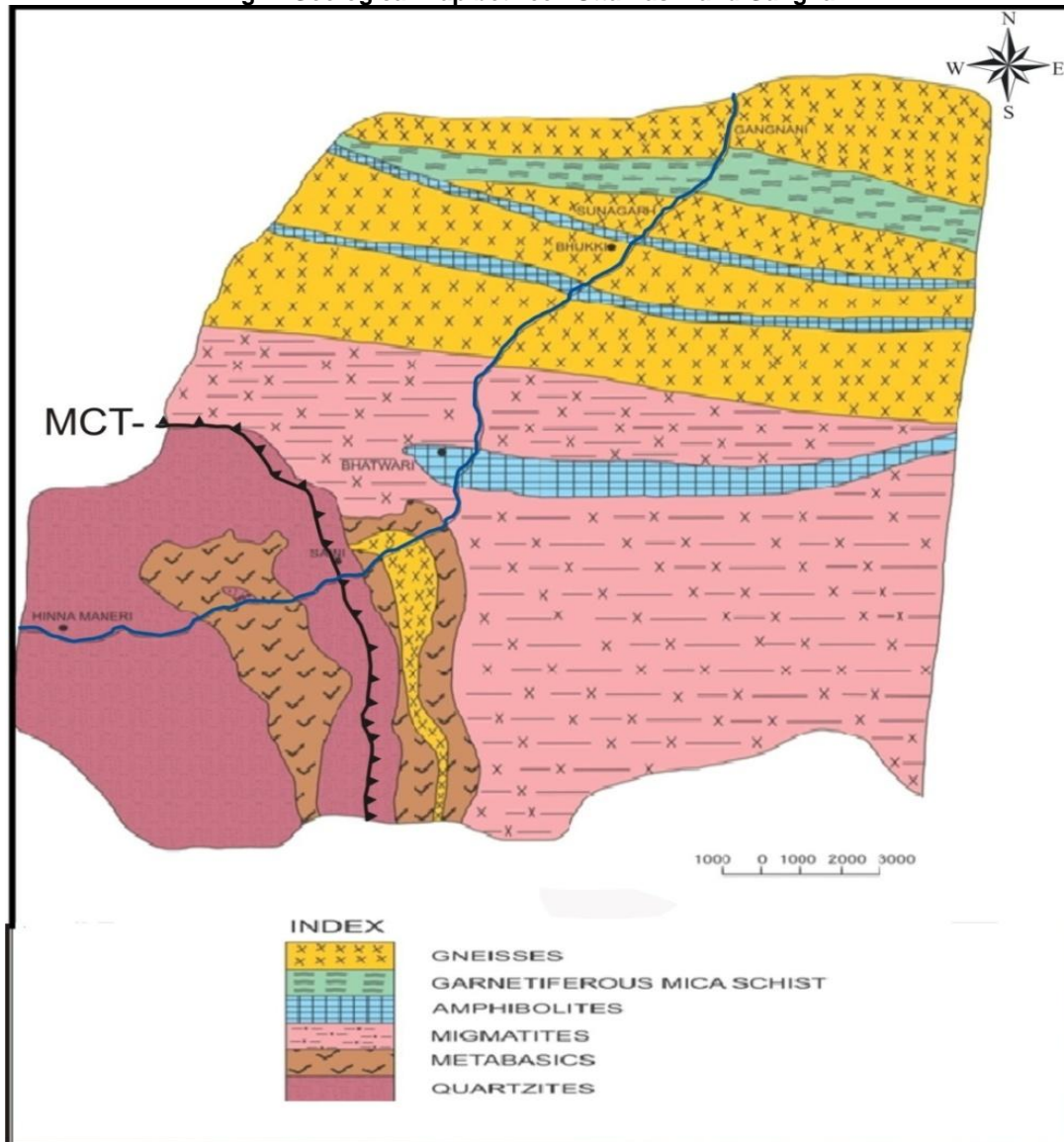
along Bhagirathi river between Uttarkashi and Gngnani. Geologically the study area lies in Geo-tectonic block of lesser and central part of Garhwal Himalaya. The Main Central Thrust is main structural feature and is mainly responsible for earthquake and landslides in the area. Main Central Thrust passes near Sainj along Uttarkashi- Gangotri high way which is 20 km from Uttarkashi. It is dipping 50 to 60 degree N and follow NW-SE trend and is exposed along Kumalti gad and Dogadda gad. Main Central Thrust separates the rocks of Garhwal group in south from the Central Crystalline in north. The rocks of Garhwal group mainly comprises of Quartzites, Limestones, Slates, Epidiorites, Mylonitic Quartzites and schistose quartzites while Central crystallines by Augen gneisses, Migmatites, Garnetiferous Mica Schists and Amphibolites. Several Geologist worked on this part of Himalaya. Heim&Ganser (1939) used the term central crystallines. Jain (1971) Agarwal and Kumar (1973) worked on the lesser Himalayan region of the Uttarkashi area. Dave & Gupta (1982) worked on Petrology of Upper Bhagirathi valley. Saklani & Nainwal (1986) studied the migmatites of the Sainj area. Purohit and Thakur (1988) made attempt on geo-chemistry of upper Bhagirathi valley. Naithani (1992) studied the Quaternary sediments of Bhagirathi valley between Maneri and Gangnani area. Naithani and Bhatt (2011) made some observation on geo-hazards of Uttarkashi area. Litho Tectonic succession is shown in table-1, and geological map depicted in fig-1.

Table-1

Litho-Tectonic Succession of The Area. (After Jain(1971), Dave & Gupta (1982) And Naithani (1992)

<p>CENTRAL CRYSTALLINES</p> <p>-----M-A-I-N-----C-E-N--</p>	<p>Garnetiferous Mica Schists Amphibolites Banded Gneisses Augen Gneisses Foliated Gneisses Augen Gneisses Migmatites Mylonitic Migmatites Quartz Muscovite Schist Biotite Schist Quartz Chlorite schist Chlorite Schist</p> <p>T - R- A - L--- T-H-R-U-S-T-----</p> <p>Schistose Quartzites Mylonitic Quartzites Epidiorite Gamri Quartzites Upper Uttarkashi Limestone Pokhri slate Lower Uttarkashi Limestone Netala Quartzites</p>
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Fig-1: Geological Map between Uttarkashi and Gangnani

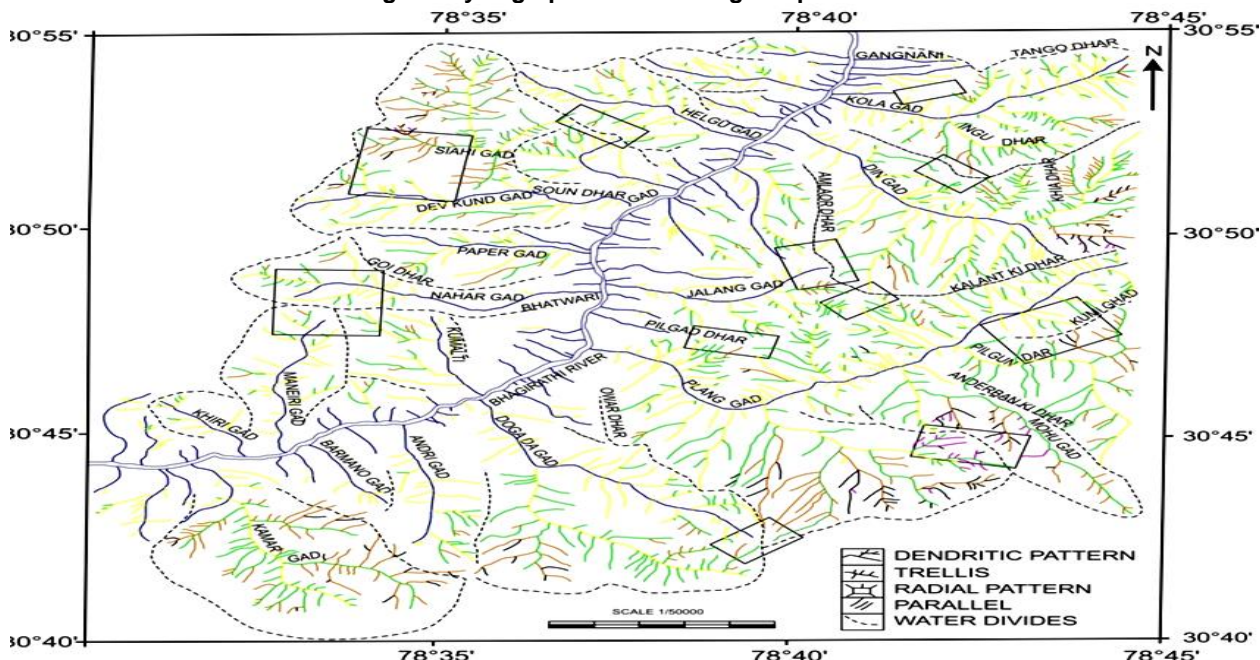


Physio Graphy and Drainage Pattern

Bhagirathi is the main River which originate from Gangotri glacier near Gaumukh. It flows NE-SW direction from Gangnani to Bhatwari and N-S direction from Bhatwari to Malla and again follow NE-SW direction up to Uttarkashi. It has carved out deep gorges at Bhukki. Large number of tributaries join Bhagirathi as Helgu gad, Din gad, Saundhar Gad, Kamar gad Jalang gad Andri gad, Paper gad, Nahar gad, Pilang gad and Asigang river which meet Bhagirathi at Gangori. Topographically the area is highly rugged with steep escarpment, high ridges and high relief which make it difficult terrain. The main ridges are

Kalantiki dhar, Amlu ki dhar Goidhar, Lingu dhar, Kothidhar which act as water divider. The valley is v shape generally but at MCT it is U shape. Four hot springs are also located along NE-SW direction and their temperature increases towards NE direction. Due to climatic variation when water increases in river and as well as in channels which causes loss of property and life by toe erosion. Drainage pattern is mainly dendritic type because most of the tributaries join Bhagirathi at acute angles while other at right angle give rise trellis pattern. Radial pattern observed at summit surfaces and parallel at higher altitudes. Physiographic map of the area is depicted in fig-2.

Fig-2: Physiographic and Drainage Map of Area



Geo –Hazards in Uttarkashi

Uttarakhand is the home of geo-hazards. Geo-tectonically Uttarkashi is very sensitive from tectonic point. NAT passes near Dharasu and MCT passes near Sainj. These structures are responsible for earthquakes and landslides. Some geo-scientist are with the view that MCT-I Passes near Sainj and MCT-II passes near Gangnani while other Mtcaif (1991) with the view that Sainj to Gangnani is MCT shear zone. Geo-hazards in the form of earthquakes, cloudburst, landslide and flashflood have become common and events increases during last 20 years. These natural hazards are mainly influenced by Climate change/variation .while anthropogenic hazards increased by construction of dam, tunnel, roads, building etc.

Natural Hazards

Earthquake

The investigated area is geologically very ensitive. Main Central Thrust is the main structural feature which is extended 2400 kms all over the Himalaya and separates the rocks of lesser Himalaya from Central Himalaya. According to the Geologist and Geophysicist the Indian plate moving towards NE directions beneath Tibetan plate at the rate of 5cm per year Due to continuous movements and impact, the energy releasing in the form of earthquakes in the area. The Uttarkashi earthquake of 20 October 1991, at 2:55 A.M. was more disastrous and tremor the Northern parth of the Himalaya including the Pakistan and the Nepal. Its epicenter was Agora near M.C.T with focus of 10kms depth with Intensity of 6.2. About 2000 people were killed, 5067 injured, 1800 buildings destroyed, 1294 villages and 3, 00,000 peoples were affected. Total loss of property was estimated about 93 crores. It damaged all the houses around the MCT but in Uttarkashi district mostly affected places were Jamak, Maneri, Dedsari, Lata, Saura, Siaba, Kamar, Gangnani and Bhatwari town. The Ganeshpur Bridge

was tilted and many cracks appeared at the various places which reactivated the number of landslides in the area. At Saura, Ganeshpur, Maneri, Jamak and Bhatwari the cracks were observed in NE-SW, NW-SE, N-S & E-W directions in rock. Earthquakes in such geo-tectonic block with minor intensity take place frequently. The following Table- 2 shows the earthquake events in the area with intensity. Widening of cracks and percolation of water through these cracks support and reactivated the landslides in the area.

Table 2: Earthquakes and Their Intensity in Uttarkashi Area

Date & Month	Intensity	Epicenter
20 th October 1991	6.2	Agora
17 th August 2005	4.1	Bhatwari
23 rd July 2017	5.1	Kharsali
18 th March 2009	4.7	
21 st September 2009	5.1	
20 th June 2011	5.0	
28 th August 2011	2.1	
21 st September 2011	3.0	
20 th November 2011	2.2	
10 th February 2012	5.0	
27 th November 2012	4.8	Rainthal
11 th February 2013	4.2	
25 th December 2013	4.0	

Cloudburst and Landslides

Monsoon becomes a potential cause for the loss of property and life as extremely high intensity rainfall for a short period. Cloudburst and heavy rainfall disturbing the hill slope stability in the form of landslides in this Himalayan terrain. Malpa & Ukhimat landslides of 1998, Varunawat landslides 2003 and The Bhagirathi flash flood (2010), Asiganga flood of 2011 and 2012 caused loss of life and property due to high intensity rain and cloudburst events. In last 20 years the events of cloudbursts increases which indicate the climate change in the area. Due to

cloudburst the water suddenly increases in the streams and river causes toe erosion and flash flood in the area. Due to toe erosion and clouds burst 69 shops and houses were slump down by flashflood in the Bhatwari area. Cloudburst even in Uttarkashi area is shown in Table 3.

A cloud burst and flash flood happened on 30th August 2012 at around 10'O clock at the night in Bhatwari tehsil of Uttarkashi district of Garhwal Uttarakhand. The affected villages were situated above the sides of ASI Ganga and Bhagirathi. Heart-

wrenching scene were witnessed at Gangotri where the maximum numbers of deaths were reported so far. There were about 700 pilgrims were stuck and efforts were made to move them to safer places on foot, as the roads were totally damaged and the hostile weather was not allowing air lifting of the people.

In Garhwal Himalaya 15th August 2014 at 7 places cloudburst events take place in lesser Himalaya part, which causes loss of property and life in Pauri, Chamoli, Dehradun and Uttarkashi area.

Table 3: Cloud Burst Events In Bhatwari Area District Uttarkashi

Locality	Year	Affected area
Saura gad	24 th July 2007	Three bridges cultivated area washed away
Aungi	3 rd August 2010	Aungi, Bhatuksaura and Maneri
Hurri, Gangnami	12 th August 2010	Hurri, Gangnani, Bhatwari and Malla
Bhatwari	13 th August 2010	29 houses and 29 shops washed away
Aghora	August 2011	Asiganga valley
Nald and Rewara	5 th July 2012	Asiganga valley
Dayarabhadg	3 rd August 2012	Dayarabhadg area of Bhatwari
Siaba	16 th June 2013	Siaba Cultivated area washed away

Table 4: Major and Minor Landslides In Bhagirathi Valley.

Major Landslides In Bhagirathi Valley

6 th August 1978	Kanolduyagad landslides
9 th September 1980	Dabrani Landslides
30 th August 2001	Sukhi Landslides
3 September 2003	Varunawat landslides

Landslides in the Investigated Area

S.No	Location of Landslide
1.	Heena landslide
2.	Maneri dam debris landslid
3	Maneri Reservoir Denris slide
4.	Aungi slide (Reactivated slide) Rock cum debris slide
5.	Lata slide (New slide) Debris slide
6.	Malla slide-1 (Reactivated slide) Debris slide
7.	Bhatwari slide (Reactivated slide) Rock cum debris slide
8	Chadethi slide (Reactivated slide) Rock cum debris slide
9	Helgu slide (New slide) Debris slide
10	Sunagaur slide-1 (New slide) Debris slide
11	Sunagaur slide-2 (New slide) Debris slide
12	Gangnani slide (New slide) Rock cum debris slide

Most of the new landslides are due to the heavy rain during 13th-16th June 2013. Author noticed that before the earthquake of 1991 only few landslides were present, but after that due to minor earthquake and surely due to climate change the number of new landslides were reactivated which also affected the

tourism industry of the area. The rocks around the main central thrust are mylonitic in nature and overlain by debris and river born material which accelerates the events of landslides. Rainfall data of Bhatwari Tahsil shown in table 5.

Table-5 Rainfall (mm) "Bhatwari Tehsil Uttarkashi 2006-2016

Month	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
January	131.8	0	122	9	21	38	66	36	23	56	5
February	8	155	20	9	113	96	40	137	125	1205	67
March	101	111	30	30	12	51	52	17	108	136	9
April	70	22	110	42	21	81	152	42	53.5	94	11
May	53.9	38	235	121	74.5	129	36	10	91.4	7	107
June	66.5	99	286	23	112	235	51	327	56	110.5	111
July	246	359	436	228.5	373	449	324	458	429	320	530
August	201	225	272	122	439.8	605	461	311	322	249	316
September	58	250	168	186	407	212	188	96	117	15	48
October	61	24	7	311	16	3	10	39	24	12	18
November	12	0	13	6.9	10	0	7	0	0	3.8	48
December	40	12	0	7	28	2	18	0	26	31	34

Between Malla and Bhatwari, road were subjected to the subsidence due to the toe erosion of Bhagirathi River. Landslide of Sunagrah and Gangnani are also due to toe erosion of Bhagirathi River. In the upper part of Gangnani temple new landslide reactivated which is very dangerous to Gangnani temple and hostsprings at Gangnani. Rocks in this area are highly mylonitised nature and comprises of Schists and gneisses.

Anthropogenic Hazards

Human intervention with nature in the name of development and creation of assets and wealth is one of the major causes of disaster in Himalaya. Numbers of branch roads were constructed; multi stories building were constructed along the river and on valley slide slope in unscientific way that leads to destabilization of the slope. Tunnels were constructed using high explosives below the village located over the debris and glacial moronic deposit. Asia's largest dam was constructed at Tehri, others are constructed near Maneri and joshiyara at Bhagirathi River. Few examples of manmade disaster are given below in the investigated area.

1. Kamar village is located over moronic material with moderate slope; Tunnel was constructed below Kamar village from Maneri to Uttarkashi. Earthquake of Uttarkashi 1991 destruct the village and maximum causalities of human happened in this village.

2. Due to Uttarkashi earthquake the cracks were observed at various places over rocks, debris material and rock fall others. Varunawat landslides started in 1998 but no attention was given by Government. In the name of development and tourism the multi stories buildings were constructed by cutting the foot slope of Varunawat. On 3 August 2003 the Varunawat landslide causes the loss of property and life in Uttarkashi.
3. Between Malla and Bhatwari the mylonitic migmatites are there. Roads were constructed along the Bhagriathi River. Due to toe erosion of Bhagirathi River the roads were damaged and land slide started in the upper part of road. This may block the Bhagirathi river may cause the disaster in future in the valley.
4. In Bhatwari and Chadethi river is flowing in a V shaped valley. These amphibolites are the rocks which are steeply dripping towards Bhagirathi River. Bhatwari market is located over debris and mylonitic migmatities. During Earthquake the cracks were observed at various places. Local people constructed multi stories hostel here it is located in the Uttarkashi Gangotri high way. In 2010 and 2012 due to toe erosion of Bhagirathi river 69 shops and residential houses slump in Bhagirathi River.

Photograph-1; Varunawat Landslide of Uttarkashi





Photograph-2; Uttarkashi Flood 2012



Photograph-3 ; Slumping Of Shops In Bhatwari (2013)



Photograph-4 ; Landslide Near Malla



Photograph-5; Landslide Near Sunagarh(2016)



Photograph-6 ; Gangnani Landslide(2016)

Discussion and Conclusion

The famous Gangotri temple is located in the Uttarkashi district. The investigated area joins the Uttarkashi-Gangotri highway. Geologically the area is very sensitive as M.C.T and NAT passes in the area. Earthquake of 1991 and Bhagirathi flashflood of 2010, 2012 and 2013 causes loss of life and property. Newly reactivated landslides and cloud burst event made the life difficult in the area. Construction of building and roads in unscientific way, use of high explosive in the construction of dam, tunnel road also accelerate the disaster in the area. Monsoon and climate changes also played important role for cloudburst event and flashflood in the area. To minimize the loss of property and life, the author suggests that:

1. The multistory hotels and building construction should be banned as the area comes under earthquake zone of IVth and Vth. From past history of earthquake the epicenter of earthquake is near MCT which is very active thrust zone.

- Houses, hotels and other buildings should be earthquake resistant.
- Greedy people to earn money construct multistory hotels near streams and river path, Due to cloud burst and heavy precipitation water increase in the stream and rivers which causes loss of life and property so the construction must be 200 meters away from the channel path.
 - Bhatwari town is located over the debris and mylonitic migmatites. During the earthquake the number of cracks appears in the rock and debris material. Rocks are steeply dipping towards the river so generally in rainy season this start slowly slumping towards river since 1998, 2010 and 2012 so author suggest to shift the town somewhere in the safe side, The area between Bhatwari to Chadethi in sinking towards the river toe erosion.
 - Disaster should be managed by the local people; training should be given to villagers, retired teacher and army person by Disaster management of state. Communities are equipped, educated and empower to fight disaster.
 - From past history, we can mark the thrust area of disaster in the district. The streams velocity and their water should be checked by proper drainage by check dam.
 - Women in the village should be encouraged to work to stop deforestation; they should given service in soil conservation and watershed management. Early warning system should be developed in the villages.
 - To face the disaster the team from Village – Panchayat-Block-Tehsil-District-State- National level should be prepared. The education, training and disaster awareness program should be for the community of villages.

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