



**Full Length Research Article**

**IMPACTS OF RIVER SATLUJ FLASH FLOODS IN HIMACHAL PRADESH, NORTH WESTERN  
HIMALAYAN REGION**

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**ABSTRACT**

Civilization has lived along the River Satluj basin for centuries, but the impacts of Satluj flash floods were not felt to the same extent in the past as is experienced now. Rapid increase in population and urbanization along River Satluj basin accelerated the economic and developmental activities in the region. Human activities within Satluj valley, land clearance for farming, upstream development and construction of channels, levees and reservoirs change results in increased runoff. This change in natural phenomena of the river has diverse impacts, which is destructive to the natural and human environment.

**INTRODUCTION**

The flash flood is a sudden and destructive rush of water down a narrow gully or over a sloping surface, caused by heavy rainfall, slow-moving thunderstorms, dam break, artificial blockages and cloud burst (Llasat, 2009, and Gaume *et al.*, 2009). It occurs due to sudden upward drift of moisture-laden clouds as a tall vertical column termed "cumulonimbus clouds" which is usually associated with cloudbursts. The hilly terrain and heavy moisture contents facilitate rapid condensation and the cloud formation sheds its water load with ferocity over localized area with high rainfall intensity. Flash floods are the most destructive acts of nature because they combine the destructive power of a flood with incredible speed and unpredictability (Hauenstein, 2005). They have the power to move boulders, tear out trees, destroy buildings and obliterate bridges. Walls of water can reach heights of 3 to 6 meters and generally carry a huge amount of debris with them. Worldwide statistics indicate that even if it consider only the three basic indicators of the adverse impacts of disasters (significant damage, persons affected and number of deaths) flash floods are the most destructive of all natural disasters.

One of the highly destructive characteristics of flash flood is that it covers a small area and recurrent in nature (as compared to the floods). In such circumstances, whenever the River Satluj is in spate, colossal of lives and properties are affected. The impacts of flash floods on natural as well as on human being are often very complex and highly interactive (Hauenstein, 2005)

**MATERIALS AND METHODS**

Present study is based on primary (field survey) and secondary data (published material, literature and newspaper). The secondary data on flash floods impacts under study were obtained from the report of National Hydropower Corporation (NHPC), Himachal Pradesh State Electricity Board (HPSEB), Revenue Department, State Census Department, State Government Reports and Economic and Statistics Department. The areas for field study were selected on the bases of different flash flood incidents which intensity effect on nature as well as human lives. The data has been systematically tabulated and flash floods impacts have been mapped on the bases of available information.

**STUDY AREA**

The study area, River Satluj (flows in the southwesterly direction) catchment lies under Kinnaur, Shimla, Kullu, Mandi

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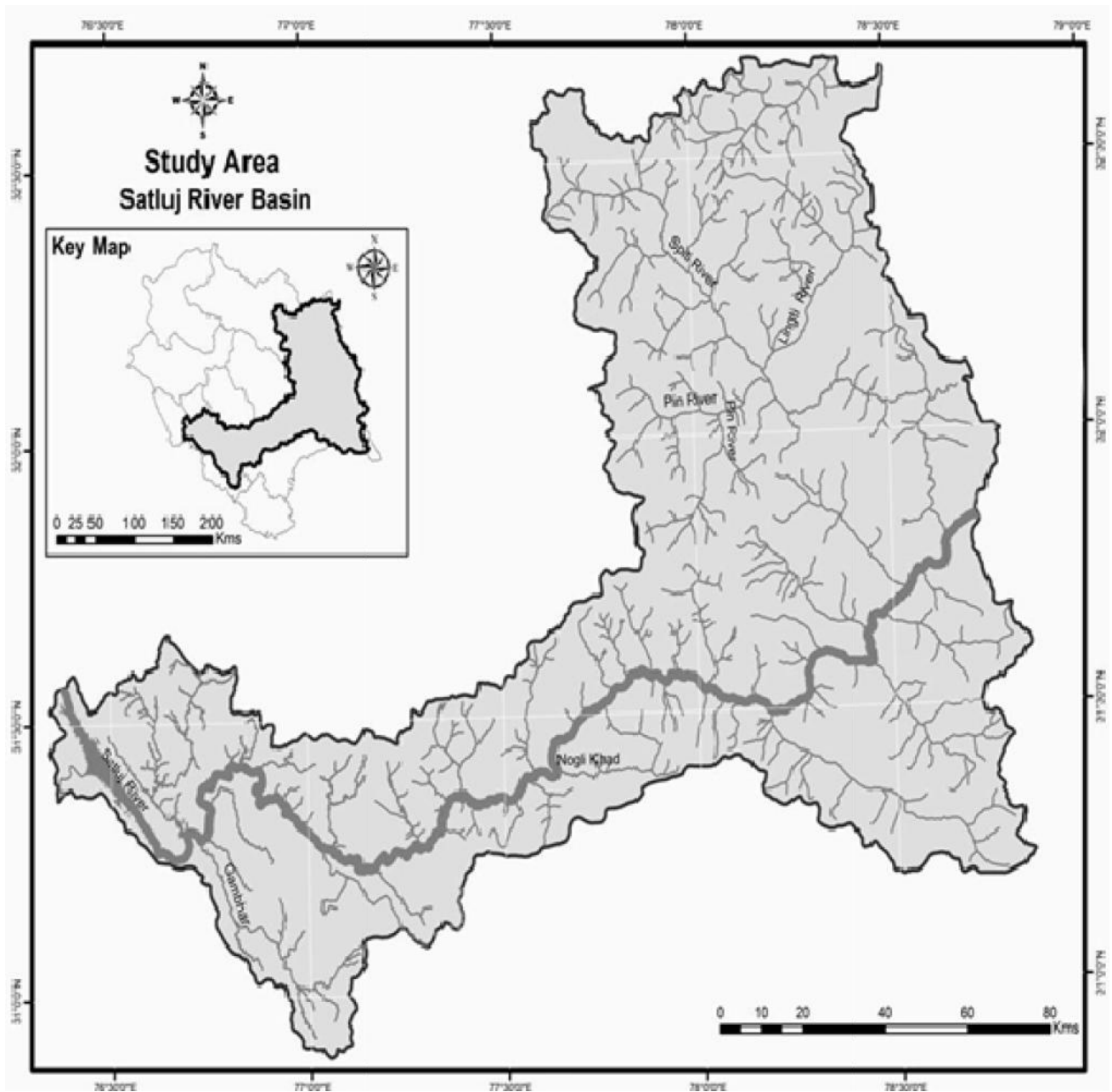


Figure 1. Study Area

and Bilaspur district of Himachal Pradesh in the north western Himalayan region (Figure 1). The River Satluj originates at Mansarovar and enters into Himachal Pradesh at Shipkila pass. Before joining River Spiti it is called River Tibet and just after the Khaab (where Spiti and river Tibet join) it is named as a river Satluj. Its course in Himachal Pradesh is 320 km. from Rakastal to Bilaspur (Chauhan and Sharma, 2012). The topography of River Satluj is suitable for the hydropower generation. On account of varying geographical feature and topographically the Satluj basin is highly vulnerable to flash floods.

## RESULTS AND DISCUSSION

### Impacts of Satluj flash floods on nature

The occurrences of Satluj flash floods are mostly the part of physical and biological processes in which the involvement of

human beings is always there. The Impacts of flash floods are directly seen on forest, soil, landslide, and water quality.

### Forest

In Himachal Pradesh forest cover is 37,033 square kilometers (66.5 percent) of the total geographical area of the state. Out of 37,033 square kilometers, 22152 square kilometers comes under those districts from where River Satluj passes through.

The River Satluj basin has several types of forest species broadly, coniferous forests dominate mid to high hills while foothill forests constitute dry deciduous and scrub forests, thriving in a low water table and dry soil conditions. In dry localities, Chil pine (*Pinus roxburghii*) occurs as a dominant species, while moist temperate region is characterized by the presence of Deodar (*Cedrus deodar*) forests. During the time of flash floods all these species are affected by the River Satluj.

## Soil

When forests are being damaged due to flash floods, its direct impact can be seen on the soil. Soil erosion is a natural as well as human induced process due to various climatological anomalies, such as flash floods, cloudburst, landslides and avalanches. River Satluj is generally characterized by a very high silt load coming from snow melts in China and cold desert areas of Spiti valley. The average annual sediment load in the Spiti River (a major tributary of river Satluj) was estimated at 7.66 million tonnes while that for River Satluj as 7.30 million tones. The annual sediment transport for the Spiti River has been reported at 7.84 million tonnes and correspondingly 7 million tones for River Satluj. Snowmelt and the related erosion processes (rapid mass wasting in combination with glacier runoff) are the major sediment sources. The local developmental activities like construction of roads, hydro projects, residential areas, tourism also contribute to soil erosion and of great importance for estimating erosion potential of the study area. Loss of topsoil through surface run-off is the most common type of soil erosion. This type of soil erosion is mainly due to deforestation. The problem of topsoil erosion is severe on the gentle slopes in the plains (from Tattapani to Bilaspur) during the flash flood time. Terrain deformation through mass movement is another type of soil degradation. These mass movements take place along the Satluj valley by virtue of river erosion. A river with its kinetic energy leads to down-cutting of the toe of a hill by which mass movement activities are accelerated by a river. This is primarily confined between Rampur and Kinnaur regions. Bank erosion is also common along the River Satluj. During field work it was observed that a few kilometer stretch of Satluj banks along which are situated villages, such as Tapri, Rampur and Pooh experience much erosion by the flash flood, washing away the fertile agricultural lands and roads.

## Landslides

The problem of landslides is common and frequent in the study area. Flash floods, particularly in the narrow river gorges are one of the leading causes of landslides, along the River Satluj. Landslides in the region are triggered by downhill movement of soil, debris and rocks. The mass movement varies in magnitude. Some of the mass movements have often created an artificial lake in River Satluj. For example; debris blockage in Wangtu formed a lake of 5 kilometers long and 2 kilometers deep during 1997 flash floods. In the study area landslides occupy about 1 percent of the land surface of five districts of Himachal Pradesh from where Satluj passes through. Some of the major landslides are Thangi Slide, Khadra Dhang Slide Zone, Khadra Dhang Slide Zone, Tapri Slide, Jhakri Landslide and Urni slide. Thangi Slide is on the right bank of River Satluj opposite the confluence with Tirung khad. The high discharge of Tirung khad has forced the River Satluj towards west to undercut the slope. Khadra Dhang Slide Zone is located on the old Hindustan Tibet road along the right bank of River Satluj opposite to Ribba. The toe-cuttings by River Satluj make it an active landslide zone. Tapri Slide is along the lower slope on the right bank of River Satluj on national highway- 22. Over steepening of the slopes due to toe cuttings by Satluj is very common. Jhakri Landslide is located on the left valley slopes of the Satluj valley on national

highway 22. The slide occurred on 24<sup>th</sup> February 1993, following heavy winter rains. The slipped mass temporarily blocked the River Satluj and within 48 hours a lake was formed which was about 1.5 kilometers long, 25-30 meters deep.

## Impacts of water quality on soil

The water quality of River Satluj has been deteriorated due to continuous recurrent of flash floods. Flash flood waters are heavily contaminated with varieties of pollutants. They are slowly dissolved into the river water. There are many possible sources of chemical contamination after the flash floods, such as the dumping grounds, graveyards, decay of animal bodies and unused throughway chemical works, such as car batteries containing acid, pesticide and fertilizers, for example, in Rampur and Kinnaur districts. During the Satluj flash floods water treatment plant goes out of order and the sewage discharges directly enter the watercourse without passing through purification process. At a number of inundated places high concentration of polychlorinated biphenyl (PCB), absorbable organic halogens (AOX) and polycyclic aromatic hydrocarbons (PAU) were found in River Satluj, the sources of which were the flooded industrial plants (hydro plants, HIMFED) in majority of cases. The use of this polluted water creates health risks. Maximum nitrogenous (N) is used by Mandi district, whereas maximum Phosphate (P) is used by Shimla district (Table 1). In the whole of Shimla district 6603 metric tons of fertilizers are being used. Some of these transported by the rain waters into the River Satluj which spoil the river water quality. During the Satluj flash flood all the garbage and other waste materials, such as fertilizers, chemicals and oils transported by the flash flood waters falls into the main river, thereby reducing its water quality tremendously. Such water is unhygienic for both humans as well as for riverine life, especially from Khab to Govindsagar region.

**Table 1. Use of fertilizers (In metric ton MT) (Source: Director of Agriculture, Himachal Pradesh)**

Districts	Nitrogenous (N)	Phosphate (P)	Potassic (K)	Total (N+P+K)
Bilaspur	1494	274	140	1908
Kinnaur	87	66	45	198
Kullu	1757	928	964	3649
Mandi	4495	1296	812	6603
Shimla	3382	2478	3312	9172

## Impacts of Satluj flash floods on human beings

Satluj flash floods devastate any location, the whole of a village, (such as village Tapri) even a hot spring, (such as Tattapani) and modify the living states and activities. Some of the economic, social and environment impacts of Satluj flash floods are summarized in the Table 2.

## Loss of human life and its properties

Due to Satluj flash floods Himachal Pradesh is experiencing the loss of human lives and their properties. The incidences of flash floods on 29<sup>th</sup> September 1988, at Soldang washed away 15 houses and claimed the lives of 32 persons and 35 cattle heads. The Table 3 shows the affected prominent villages, their distance from the Tibet border.

**Table 2. Economic, social and environment impacts of Satluj flash floods**

Economic Impacts	Social Impacts	Environmental Impacts
Infrastructure losses, such as transportation, communication network, water supply and sewer system	Human endangerment, loss of life	Destruction of flora
Government facility losses(including military)	Human injury (physical, emotional, psychological)	Destruction of fauna
Residential losses, such as property, furniture	Displacement of people	Damage to habitats, food chains, species diversity and stability
Public facility losses, such as schools, hospitals	Health hazards; polluted water, communicable diseases, shortages of food supply, exposure to cold, rain due to lack of shelter	Damage to Rare endangered species
Employing business losses, sales losses	Emotional and psychological trauma associated with loss of relatives and loved ones, loss of personal property and memorabilia, homes Communities	Damage to natural recreational resources
Displacement of business and farm	Loss of social (community) cohesion	Damage to scenic resources
Job losses, income losses	Disruption of educational programs	Damage to archaeological and historical resources.
Agricultural losses, damage of agriculture land and facilities, loss of crops, animal losses	Loss of security related to job and income interruptions	
Loss of recreational facilities and resources	Loss of recreation opportunity	
Increase in operational cost such as fuel and lost time due to traffic delays and use of alternative routes and resources	Disruption of cultural programs (sports events, church programs)	
Cost of emergency measures	Disruption of law enforcement programmers	
Increased taxes due to cover cost of replacement, repair and rehabilitation of infrastructure and public facilities		

Source: Petersen M.S 2001

**Table 3. Estimated population and number of households likely to be affected during 2005 flash flood**

Name of Villages/Towns	Distance from Lake (Kilometers)	Flood Depth(meters)	Total Population	No. of Households
Jangi	122	3.29	794	176
Kilba	166	5.06	738	177
Tapri	175	5.58	800	258
Rampur town	220	5.01	72,026	16,173

Source: Census of India, 2001

The affected towns in the worst-case scenario were identified as Nangial, Labrang, Jangi, Kilba, Tapri and Rampur as per the house census 2001. Most of the houses in the region are constructed with stone masonry walls, tiled or other types of flexible roofs, mud and wooden floors. It also affected the human and animal health directly as well as indirectly. Some of these effects are summarized in the Table 3.

### Food

Not only human and animal life, the food sector is also affected by the flash floods. During the Satluj flash floods on 26<sup>th</sup> June 2005, electricity supply was cut off, especially in Rampur and Tapri villages. Without electricity, cold stores and refrigerators stopped functioning. Normally, the food stored in these facilities starts decaying after 4 hours. Moreover the food stores in Tapri village were washed away. There are also probabilities of the increase of the animal pets, such as rats and snakes during and after the flash floods as they are displaced enormously. Such displaced rats and snakes contaminate food storages and make the food unhygienic for use.

### Epidemics

As per the primary water quality criteria laid by the Central Pollution Control Board the Himachal Pradesh State Pollution Control Board has kept the River Sutlej under 'A' category of water quality with respect to pH, DO and BOD in general. But

during flash floods, water quality has been very low by which people of Satluj valley cannot use the water for drinking purposes. Failure of wastewater ponds, treatment plants, sanitary sewers, and septic systems often contaminate floodwater with the disease.

Flash flood water in Tapri village on 26<sup>th</sup> June 2005 washed away septic tanks containing fecal materials from sewage system. Everyone was at risk of disease from that contaminated flash flood water. During the field surveys it was found that during summers (April-July) about 50 cases at an average have been recorded related to gastroenteritis, diarrhea and dysentery from the Rampur site (Table 4).

**Table 4. Disease profile of Rampur year 2005**

Months	Diarrhoea (numbers of patients)	Dysentery (numbers of patients)
January	1	9
February	2	-
March	-	2
April	-	1
May	4	3
June	10	2
July	4	1
August	5	3
September	1	2
October	7	-
November	-	6
December	-	7

Source: Khaneri Government Hospital, Rampur, 2005

## Fisheries

Fishes are the most sensitive species and affected by even relative low cyanide concentrations. They are killed by the microgram per liter range of cyanide concentration. Some communities depend on the fish that live in or travel along rivers. Contaminated surface water risk the metabolic processes of the aquatic species. These can lead to the deaths of fishes. During the incident of Satluj flash flood 2005, from Khab to Jeory, Jeory to Slappar and in Govindsagar most of the fisheries were affected in this way by the flash floods. The total loss which was estimated by the Public Works Department (PWD) was 8000 lacs of rupees (Table 5). The fish is mainly brought from downstream areas, such as from Bilaspur. In the upper stream, a few sites, such as Sangla, are being developed by the state fisheries department for sport fishing. The Mahseer is a migratory fish, and was historically reported to be present in Satluj.

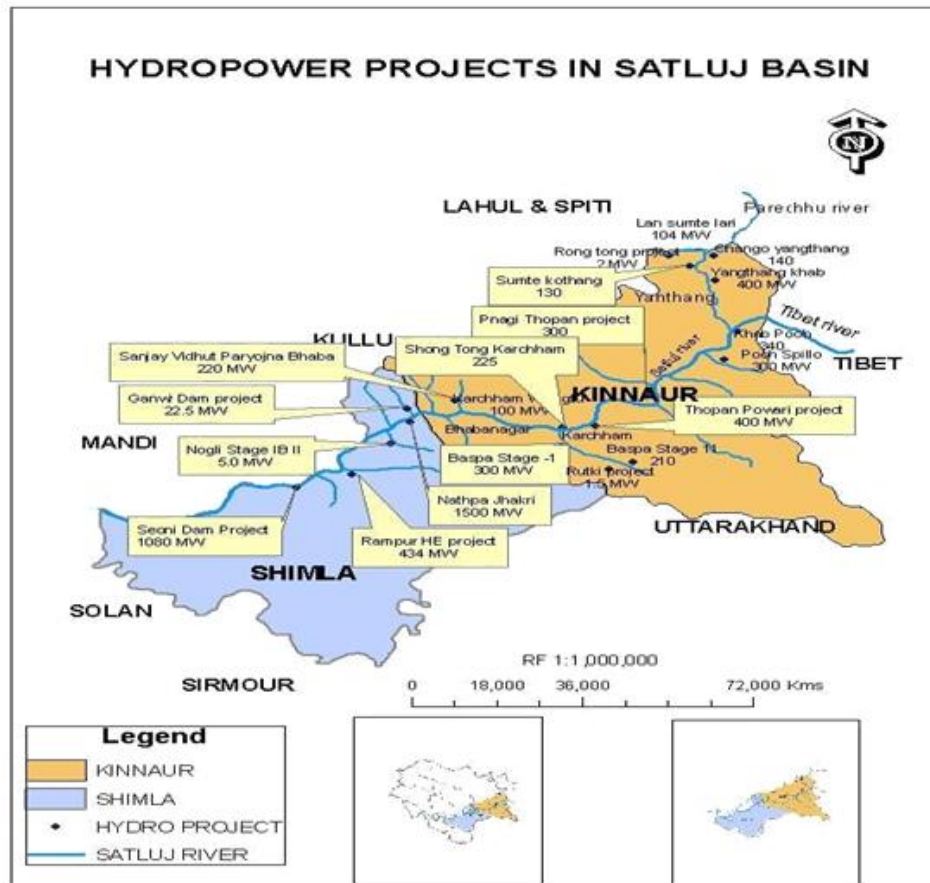
## Hydro-power

Himachal Pradesh has been blessed with vast hydro-power potentials in its five major river basins namely, Yamuna (1015.57 megawatt), Satluj (9496.75 megawatt), Beas (4326.50 megawatt), Ravi (2049.77 megawatt) and Chenab (3301.3 megawatt). So the potential of 20,690 mega--watt has been identified and this is about one fifth of the potential of the country as a whole. Among these, Satluj basin generates largest amount of hydro-power. The major projects of Satluj basin include Bhakra and Nathpa Jhakri (Figure 2). This mean, during the time of flash floods, the total 9496.75 megawatt (MW) of hydro power has been affected in River Satluj basin. During Satluj flash floods of 2005, the 1500 megawatt (MW) Nathpa-Jhakri hydro power project was shut down in the wake of the rise of Satluj. Flash flood waters entered into 50 houses in Baroh. A cloud burst that took place on 29<sup>th</sup> September 1988, at Soldang area caused flash floods.

**Table 5. Damage to fisheries department due to June 2005 flash flood**

Sr.No.	Name of the districts	Loss of fisheries	Number of fish destroyed	Estimated loss (Rs in lacs)
1	Kinnaur	Khab to Jeory trout fish area 100 kilometers	Total loss of fisheries due to turbidity ranging up to 30,000 parts per million (ppm). as adul fish could survivor up to 1000 parts per million (ppm) maximum only.	1500
2	Shimla, Kullu and Mandi	Jeory to slapper (200 kilometers)	Fingerlings up to 100 parts per million (ppm) maximum.	1500
3	Bilaspur	Govindsagar reservoir 16000 hectares (partial loss to feeding and breeding grounds of endemic as well as exotic carps).		3500
Total loss				8000

Source: Revenue Department 2005, Himachal Pradesh



**Figure 2. Hydro Power Projects in Upper Satluj Basin**



It affected the hydro project work of Bhabanagar which suffered a complete damage. The project which generates over 36 million units of electricity daily and its closure is costing the Satluj Jal Vidhyut Nigam 9 crores of rupees per day. Generation will be resumed only after the level of silt falls down to the permissible limit of 5,000 parts per million (ppm) (Plate 1). The Himachal Pradesh State Pollution Control Board had initiated a sediment-sampling programme at several gauging stations in the actual river system. The total suspended load for the Spiti River (tributary of River Satluj) has been reported to be 7.66 million tones per year and for River Satluj of 7.30 million tones per year. The estimated suspended transport at Wangtu is 26.2 million tones per year. This implies that estimated suspended transport at Luhri project area, which is a relatively dry, yield about 11million tones per year. Most of the sediment contribution is likely to originate from area along the main river and can be seen as a contribution from the rapid mass wasting processes and by erosion of ancient glacio-fluvial sediments. Due to these, silts machines are damaged after passing silt load of 3.5-4 lacs million tones (Plate 2). The data of average silt concentration at a few locations, such as Khab, Powari, Nathpa, Jhakri, Bael, Nirath and Suni has been plotted from January to August 2006 in Table 6

### Loss to agriculture

Agriculture is the main occupation of the people of Himachal Pradesh. They provide direct employment to about 69 percent of the total workers of the state. The December 1988, incidence of flash flood represents the impacts of Satluj flash floods on agriculture sector when it washed away about 35 big has of agricultural land and about 600 apple trees in the Soldang village. During 2001 and 2005 Satluj flash floods, the farmers of Tapri, Marong, Nogli, Rampur and Suni villages suffered crop damages, animal losses and the inundation of thousands of hectares of farmland. Wheat, barley and fodder crops were the most affected (loss estimated was about 55.34 crores of rupees in 2000) and in a few isolated incidents, sheep and cattle were trapped as the flash flood waters rose. In case of River Satluj beyond Suni, farmers experienced horticulture damages and agriculture losses (Table 7). The lands which are far from the banks of River Satluj mainly depend on rains and irrigation through canals, especially in the downhill parts of the areas. These canals are known as 'khuls'. They are damaged during the flash floods.

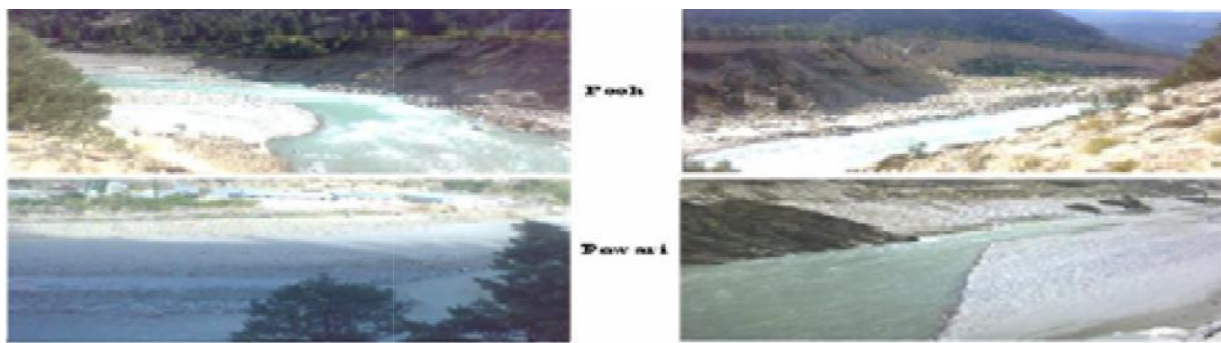


Plate 1. Silt problem in Satluj Basin



Cracking and breakage of runner vanes at outlet

New Guide vane Bushes

Plate 2. Machines were damaged after passing silt load of 3.5-4 lacs million tones (After 2005 flash flood)

Table 6. Silt data, 2006

Months	Khab	Powari	Nathpa	Jhakri	Bael	Nirath	Suni
January	-	126.41	11.97	89.21	98.59	101.61	41.13
Febury	48.79	95.18	108.09	106.04	118.3	126.78	31.95
March	92.52	98.55	108.8	88.24	127.12	133.65	-
April	1181.54	816.95	478.3	1324.63	1211.86	1229.78	-
May	2553.11	2663.4	2007.89	3604.77	3246.56	3637.96	-
June	685	818.52	583.22	1261.36	1208.75	1248.42	-
July	7985.45	4086.79	4296.41	4342.68	4004.92	-	-
August	13155.74	8368.56	8846.56	5979.19	6310.56	-	-

Source: Community Impact Assessment (CIA) 2006

Table 7. District wise production of different crops

Districts	Wheat	Maize	Rice	Barley	Ragi	Pulses	Common Millets	Total Food Grains	Chilies	Ginger	Oil Seeds
Bilaspur	13983	37900	1937	236	-	186	-	54242	3	1166	53
Kinnaur	527	590	31	1098	90	1243	637	4216	-	-	-
Kullu	39810	42962	1449	6431	308	3344	187	94491	17	-	-
Mandi	63460	114692	29167	6103	825	8789	372	217408	22	595	716
Shimla	17969	32415	1966	1539	2001	4286	4179	67955	33	1122	142

Source: Director of Land Records, Himachal Pradesh

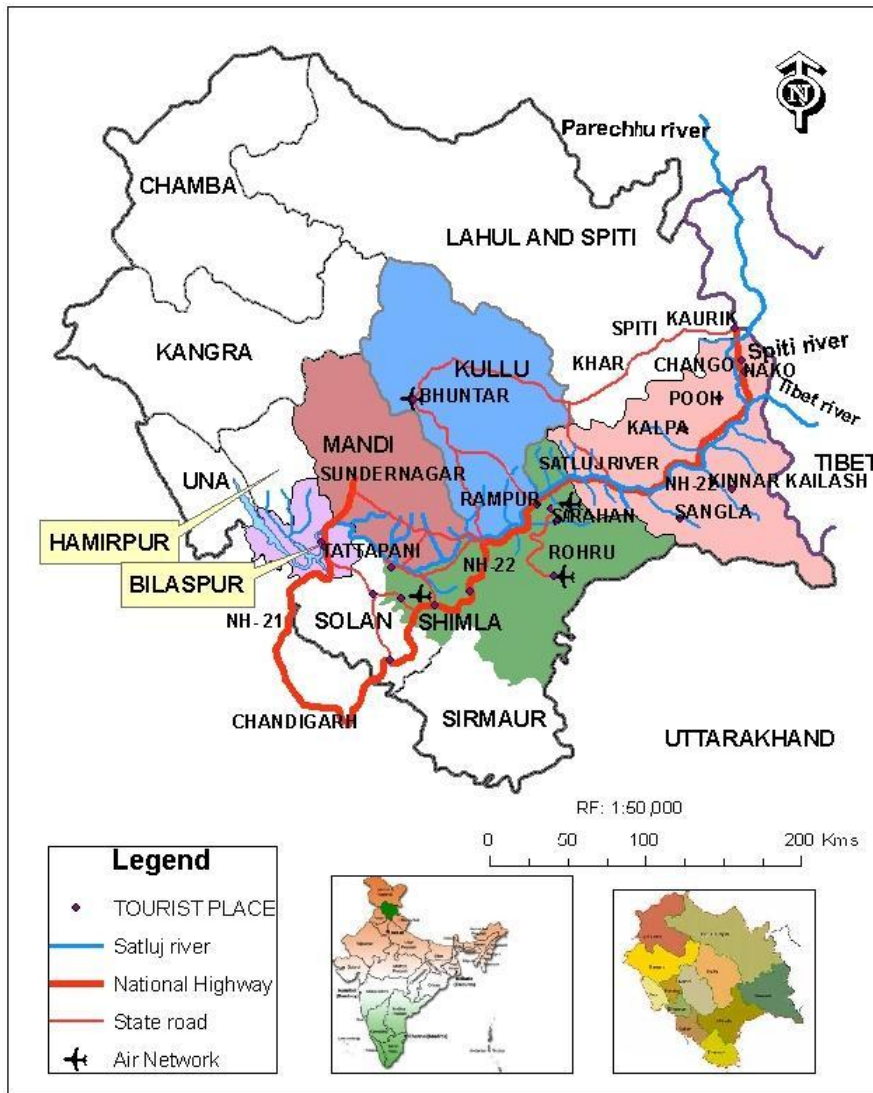


Figure 3. Tourist places in Satluj valley

**Transportation network**

The road networks have been cut off by which people faced difficulties during apple season to transport their products to market. The 1998, flash flood washed away 2 kilometers stretch of national highway-22 across Soldang khad. Field observations reveal that Shakrori, Chabba, Marola and Suni are the worst agricultural affected areas.

**Tourism**

Tourism in Himachal Pradesh has been recognized as one of the most important sectors of the economy. The state's and village's economy is dependent on tourism. Rural tourism in Satluj valley include places, such as Kalpa, Sarahan, Rampur, Nathpa -Jhakri, Rampur (especially for lavi fair), Tattapani,

Suni, Kandour and Govindsagar. River rafting is major attraction for tourists in River Satluj (Figure 3). The flash floods have caused irreparable damages to the state tourism. During the flash flood the heartland is cut off from the facilities of road network and communication and thousands of tourists got stranded at various places. According to one estimate about 51.62 lacs tourists are affected by the news of Satluj flash floods during year 2000 (Table 8).

During 2005, flash floods 46 stranded tourists, including 23 foreigners were evacuated from flood ravaged areas of Kinnaur. Helicopters of the Indian Air Force made two sorties and the state helicopter one to airlift the tourists from Peo to Rampur. However, the helicopter could not fly to Sangla where more than 150 tourists were stranded due to inclement weather.

**Table 8. Estimated tourists affected due to Satluj flash floods**

Sr.No	Districts	Tourist arrivals (in lacs)		
		Domestic	Foreigner	Total
1	Bilaspur	6.82	0.00	6.82
2	Kinnaur	0.23	0.12	0.35
3	Kullu	18.68	0.90	19.58
4	Mandi	3.76	0.05	3.81
5	Shimla	19.72	0.90	20.62

Source: Satluj Jal Vidhyut Nigam, Himachal Pradesh

## POSITIVE IMPACTS OF FLASH FLOODS

Flash floods bring benefits as well as losses to human and animal lives and to nature. They provide fertile sediments for farming, enriches the aquatic ecosystems and in some cases help to keep land above the river levels. However, the lowlands near rivers depend upon river silt deposited by floods in order to add nutrients to the local soils. The River Satluj basin in Shakrori in Suni and Shakra in Tattapani makes floodplains which have the advantages of nutrient fertile land for the agriculture. These flood plains are resulted when the river overflows its banks, the velocity of its flow decreases and fine sand, silt, clay and organic matters are deposited on the banks. Flash floods help to flush out stream channels and remove debris that have accumulated, such as boulders, logs and tree branches. Such events generally have a positive effect on fish and other aquatic anti-malls. These benefits directly translated into societal benefits in areas where fishing is common. Floods also sweep nutrients and other food supplies downstream, potentially increasing the survival of aquatic organisms in those areas.

## Recommendations

All Development projects in vulnerable areas should be implemented carefully to minimize adverse effects of flash floods. During formation and implementation of policy most advance techniques such as remote sensing and Geographic Information System (GIS) should be adopt. Some of the recommendations for flash flood are as fallows

- Flash flood prone area mapping should be prepared for future preparedness plans.
- Forecast and warning system should be improved
- Strong law should be there for deforestation on mountain and river catchments.
- River bank protection should be proper and on priority. MNREGA should be implemented for water catchment plan.
- There should be linkage between forest, Rural Development, Center Water Commission and National Disaster Management Authority (NDMA)

## Conclusion

It was observed that both natural and anthropogenic causes were equally responsible for the occurrence of flash floods in River Satluj. No single factor could be held responsible for a particular flash flood. Flash floods are of varying intensities and occurring mostly during summer monsoons. However, the ever-increasing occupation of the flash flood-plains results in huge loss of life and damages.

Satluj valley experienced maximum damages due to flash floods during the years 1997, 2000 and 2005 as government gave less attention towards them. But after these incidences government started thinking about flash floods. Now warning systems are used in the Satluj valley to reduce the impacts of flash floods. Various measures are taken by the government and by the local residents to minimize the occurrences of flash floods along the Satluj River. These measures may include some improved warning systems, preparation of hazard maps and bringing public awareness regarding these hazards. To minimize the occurrences of flash floods, both structural and nonstructural approaches are used. Both are important. In structural approaches dams are made by the state government to minimize the flow of river flash floods. In nonstructural approaches people are made aware about different programs and approaches.

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