Flood Disaster Management 20

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Abstract

Over the past several years, the intensity and frequencies of both riverine and urban flooding are showing increasing trends. In many of the Asian countries including India, flooding due to inundation in low lying areas along river channels as well as localized unprecedented precipitation has become a common feature that has gained the status of disasters causing devastations in terms of loss of lives and huge economic losses every year. The number of people affected by riverine and urban floods is more than any other type of natural disasters. The J&K Floods in 2014, Uttarakhand Floods in 2013 and the mega flood of Chennai (Tamil Nadu) in December 2015 highlight the vulnerability status of India.

The prime reasons of flooding being the reduced carrying capacity of river channels, unusual amount and intensity of rainfall in a localized area, climate change over the past decades, poorly managed land use planning, faulty drainage design, construction & management, lack of real time warning etc. Sometimes, sudden release of water from dams along with other localized phenomena also creates flooding. The increasing ramifications of such disasters have afflicted policy planners, scientists, researchers, academicians and others concerned across the world to find out ways and means to deal with the emerging threats of this typical hydro-meteorological phenomena.

The present chapter discuss in details about the fundamental concept of the management of disasters due to floods. The flood vulnerability status in SAARC countries is also discussed along with the existing vulnerabilities of Indian states. In addition the flood management and mitigation strategies are also suggested along with do's and don'ts.

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N. Sharma (ed.), *River System Analysis and Management*, DOI 10.1007/978-981-10-1472-7_20

20.1 Introduction

Flood is a unique hydrometeorological phenomenon having widespread occurrence across the globe with varied severity and dimensions. The World Disaster Report 2014 highlights the impacts of flood with another high-profile disaster like earthquake and declares that flood incidences in the world are nearly eight times more than that of earthquakes and the number of people affected by floods is nearly 12 times more.

There are different perceptions of flood for different stakeholders. For common people, it means devastation, destructions, damage, starvation, loss of lives, damage to properties and infrastructures, etc. Those living in urban areas may treat this phenomenon as disruption in their normal functioning of society. The government machinery and policy planners treat this situation as a factor of retardation in developmental planning with additional overburden on economy and additional expenditure on rescue, relief, rehabilitation, mitigation, etc. The engineering community, especially civil engineers, considers this as a situation review of existing flood protection measures.

In some of the South Asian countries including India, there is a typical condition of flood and drought occurrence at the same time. It is therefore essential to analyze the dynamics of floods and associated phenomenon so that appropriate flood management strategies and techniques can be adopted.

The *International Commission on Irrigation and Drainage* (1995) has defined "flood" as "relatively high flow in a river markedly higher than the usual". The *World Meteorological Organization* (*WMO*)/*UNESCO International Glossary of Hydrology* (*WMO 1974*) defined flood as "rise, usually brief in the water level of a stream or water body to a peak from which the water level recedes at a slower rate" and "relatively high flows as measured by stage height or discharge."

20.1.1 Types of Floods

Floods have been classified in various ways depending upon the nature, severity, and sources of inundation:

Riverine flooding is the main flooding type that occurs due to various reasons but primarily due to heavy precipitation or glacial melt with resultant runoff. The increased discharge in river channels with decreasing carrying capacities leads to overflow causing inundation in the adjoining low-lying areas.

Flash flooding is an unprecedented situation that occurs in hilly regions and sloping lands where torrential heavy precipitation, thunderstorm, or cloud burst commonly occurred without any prior warning. This sometimes cause huge loss of lives and damage to properties.

Urban flooding occurs in regions where developmental planning has not been in tune with the geomorphological, ecological, and environmental set up, which results in the increased vulnerability in urban regions. Many urban agglomerations in India are suffering from the problem of flooding even after moderate rainfall. The situation aggravates when rainwater mix up with drain water causing many additional problems including spread of epidemics.

Coastal flooding occurs due to a number of reasons like cyclones and associated storm surge, high tides, tsunami, etc., wherein the low-lying areas in coastal tracts are inundated, as a result of which losses occur on a larger scale. In addition, salinity increases in the coastal groundwater and wells.

Glacial Lake Outburst Flood (*GLOF*) occurs in the downstream of glacial regions, where glaciers holding large quantities of water suddenly release them due to melting of ice jam. Glacial outburst is one of the prime reasons of flash floods in some of the Himalayan rivers.

Cloud Burst Flood is the manifestation of climate change and hydrological imbalance that primarily occurs as sudden heavy rainfall. Cyclonic circulations in monsoon may also lead to cloud burst.

Cyclone and storm surge flooding mainly occurs in coastal areas due to rainstorms associated with low-pressure systems. Movement of cyclonic storms in quick succession leads to severe flooding, especially in low-lying coastal areas.

20.2 Flood Vulnerability in SAARC Countries

The menace of flood in some of the SAARC countries like Bangladesh, India, Sri Lanka, and Pakistan is a recurrent phenomenon that directly affects their populace and economy and indirectly affects neighboring countries having trade relations with them. Despite adoption of several structural and nonstructural measures, flood causes huge loss of lives, damage to properties and infrastructures, and loss of economy and livelihoods. Every year about thousands of people lose their lives due to this annual hydrometeorological phenomenon with millions get homeless.

Even though several measures are being adopted in almost all the affecting nations to minimize the impact of floods, it's still a matter of concern that damages due to floods are showing an increasing trend. The impacts are so severe that during the entire period of flood, the only companions with graved communities are despair, hope, anger, stress, and agony besides their disrupted life activities.

The worst repercussion of this phenomenon is damages to infrastructures like bridges, residential buildings, road networks, electricity transmission networks, telecommunication lines, etc. For the agricultural sector, it comes as an anathema causing huge damage to standing crops, vegetation, and overall agricultural productivity.

The flood also create disasters within a disaster, when the outbreak of epidemics and other waterborne diseases sets in affecting communities, which are already crippled in a disastrous situation.

It's a matter of great concern that floods are now affecting areas in the entire South Asian regions which were otherwise considered flood-safe zone. This is showing an alarming trend in countries like India, Bangladesh, Pakistan, and Sri Lanka. The Climatologists, Hydro-geomorphologists, and other domain experts are citing this phenomenon as possibly arising due to the impact of global warming and climate change. Besides, the vast expansion of industrial and urban agglomerations and increasing developmental activities are also causing threats to the situation (Table 20.1).

The entire South Asian countries except Maldives and Sri Lanka receive most of the precipitation from the southwestern monsoon which, in general, prevails from June to September and contributes about 70–80 % of rainfall in the region. On the other hand countries like Maldives and Sri Lanka receive mostly North Eastern Monsoon. Occasionally, climatic phenomenon like western disturbance also causes rainfall in some parts of Sri Lanka, India, Pakistan, etc.

20.2.1 Afghanistan

Flood is the most common hydrometeorological disaster in Afghanistan, mainly affecting foothill regions of mountains and alluvial plains of rivers in the northern provinces. The main river of Afghanistan is *Amu Daria*, which is connected with branches having their sources lying in the mountains. During spring and early summer, these rivers are fed by snow melts, which increase discharge volume in rivers, causing

Table 20.1 Decadal flood damages and deaths in South Asia (2005–2015)

Sr. No.	Year	No. of occurrence	Total deaths	Affected	Injured	Homeless	Total affected	Total damage (000 $)
1.	2005	41	3281	36,889,173	584	268,525	37,158,282	6,220,000
2.	2006	36	1915	3,808,350	890	4,013,615	7,822,855	3,409,000
3.	2007	37	4362	53,071,942	342	3480	53,075,764	841,719
4.	2008	21	1886	13,509,075	97	2,435,818	15,944,990	248,029
5.	2009	19	1807	7,201,224	166	60,000	7,261,390	2,514,000
6.	2010	21	3236	25,653,988	3181	400,000	26,057,169	11,754,000
7.	2011	16	1358	19,213,054	948	1,069,973	20,283,975	4,657,000
8.	2012	20	1217	15,153,391	3239	2445	15,159,075	2,746,200
9.	2013	15	7139	5,015,385	5437	4314	5,025,136	2,860,000
10.	2014	17	1871	11,373,645	1433	660,000	12,035,078	18,475,000
11.	2015	13	406	319,800	333	1000	321,133	100,000
Total		256	28,478	191,209,027	16,650	8,919,170	200,144,847	53,824,948

(Source – emdat.be)

floods in low-lying areas. The heavy rainfall or avalanches in the region also sometimes cause flood, especially flash floods, e.g., flash floods in Faryab and Baghlan province on May 8, 2015. The Avalanche-induced floods occurred in provinces like Panjshir, Nangarhar, Laghman, Kapisa, Parwan, Nuristan, and the capital Kabul in February 25–27, 2015; flash floods in Jawzjan province and Badakhshan province in April to June 2014; etc. (SAARC Disaster Knowledge Network Portal) (Table 20.2).

(Courtsey-theguardian.com) (Courtsey-en.trend.az)

Floods in Afganistan

20.2.2 Bangladesh

Geographically, the People's Republic of Bangladesh is located at the confluence of Padma (Ganges), Jamuna (Brahmaputra), and Meghna rivers and their tributaries. On account of being located in the downstream of these three rivers, the country is extremely vulnerable to

Table 20.2 Decadal flood damages and deaths in Afghanistan (2005–2015)

Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Riverine flood	30	1116	226,005	20,000
Flash flood	13	797	195,431	3000

(Source – emdat.be)

Table 20.3 Decadal flood damages and deaths in Bangladesh (2005–2015)

Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Riverine flood	15	1544	24,908,777	274,000
Flash flood	4	42	1,795,559	0

(Source – emdat .be)

flooding. Some of the historic floods in the years 1987, 1988 and 1998 had created great disasters in the country, leaving behind the trials of devastations and destructions. In addition, floods have also been affecting the country due to localized reasons like collapse of embankments and tidal effects in the coastal regions.

There are two types of flood occuring in Bangladesh – *annual* (*moderate*) flood known as *barsha*, which does not cause significant damage of communities, whereas high-intensity flood *Banna* creates destruction and devastation, inundating about 35 % of the areas. Some of the recent examples of flood are that due to heavy rainfall in the southeastern district of Cox's Bazar and neighboring Bandarban in June 2015 and flooding due to collapse of embankments of river Kholpetua in southwest district of Satkhira in March 2015, which caused substantial losses in the country (Table 20.3).

20.2.3 Bhutan

On account of unique geological and geographical location, Bhutan is not much prone to annual floods. The country is located in the high mountainous regions with deep, narrow gorges through which rivers flow in a confined channel. This unique topographic characteristic has made the country less vulnerable to annual floods except occassional flash floods somewhere in the lower reaches due to heavy precipitation. This sometimes carries boulders, pebbles, and cobbles along with a high flow of waters which causes substantial loss of lives and damage to properties and infrastructures of downstream cities and communities. In May 2009 heavy precipitation due to the impact of cyclone *Aila* exceeded the water bearing capacity of rivers *Punakha* and *Wangdue* affecting almost all the districts.

There are other threats of flood in Bhutan known as *Glacial Lake Outburst Floods* (*GLOF*). Due to the impact of climate change and other localized hydrometeorological factors, the Himalayan glaciers are shrinking rapidly. The retreating glaciers increase the volumes of water in the existing lakes created by glacial erosion, as a result of which lakes burst with consequent flooding occurs in the foothill regions. As per the study conducted by the Department of Geology and Mines, Bhutan, in collaboration with ICIMOD, there are 2674 glacial lakes existing in Bhutan, out of which about 562 are associated with glaciers. Twenty-five of them are considered as potentially dangerous lakes that could pose a GLOF threat in the near future (SADKN Portal).

20.2.4 Nepal

The mountainous country of Nepal is considered among the most vulnerable flood regions in South Asia. The rivers like Narayani, Kosi, Karnali, Mahakali, etc., are perennial in nature. They are fed by waters coming from snow clad mountains. During monsoon period, all the rivers receive excess water in addition to glacial melts. This causes flooding especially in Terai regions

Table 20.4 Decadal flood damages and deaths in Nepal (2005–2015)

Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Riverine flood	16	923	12,048,61	63,429
Others	1	294	184,894	0
Flash flood	1	119	4320	0

(Source –emdat.be)

Table 20.5 Flood damage in Maldives (2005–2015)

Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Coastal flood	1	0	1649	0

(Source – emdat.be)

of Nepal. Some of the devastating floods occurred in 1978 (Tinao basin), 1980 (Tadi basin), 1987 (Sun Koshi basin), and in August 2008, Kosi floods, that caused devastation in eastern Nepal affecting about 200,000 people. One recent flood also occurred in Taplejung district in June 2015 (Table 20.4).

20.2.5 Maldives

The group of 142 inhabited islands (source-SADKN) is particularly vulnerable to localized floods of lesser severity. These include rainfall-induced flooding, tidal flooding in low-lying coastal areas due to high tides, flooding due to storm surge during cyclones, etc. The long-term perspective also predicts climate change with the resultant sea level rise as a potential threat of flooding especially in low-lying coastal areas.

Some of the remarkable flooding in Maldives occurred in 1987 and 2007 affecting more than 2000 people in the country (source-The International Disaster Database) (Table 20.5).

20.2.6 Pakistan

Pakistan is among those South Asian countries, where flood is considered a major annual hydro-meteorological phenomenon. There are several types of flood occurring due to spatial and temporal variations across the country causing disasters. The most common among them are riverine flood due to the monsoonal impact, mostly from July to September. Due to this impact, the majority of the river basins, especially Punjab and Sind provinces, are inundated causing severe floods. The snow melt in the upper reaches aggravates the situation. Flash flood also occurs in northern provinces of Pakistan, which causes great devastations in the region. During monsoon, cities like Islamabad, Lahore, Peshawar, Karachi, etc., are severely exposed to urban flooding. In addition, provinces like Sindh and Balochistan are particularly affected by coastal flooding due to cyclonic impact and resultant storm surge. The Makran coastal regions have gained notoriety of having frequently exposed to coastal flooding.

For the last 114 years, flood hazards have claimed about 12,156 lives with a total affected population of about 5.70 crores in the region. Flood alone has caused total damages of more than 19 billion dollars. Some of the remarkable floods in recent past includes flash flood in the Pakhtunkhwa province in northwest Pakistan (June, 2015), Balochistan province due to heavy torrential rainfall (June, 2015) (SAARC Workshop Report 2012) (Table 20.6).

20.2.7 Sri Lanka

Flood in Sri Lanka is a commonly occurring phenomenon, causing destructions and devastations more than other disasters in the country. Physiographically, northeastern and southwestern parts are particularly vulnerable to floods. Flooding is mostly triggered by both the branches

Table 20.6 Decadal flood damages and deaths in Pakistan (2005–2015)

Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Flash flood	11	2278	20,447,593	9,827,118
Riverine flood	27	3157	22,305,462	8,633,000

(Source –emdat.be)

Table 20.7 Decadal flood damages and deaths in Sri Lanka (2005–2015)

Disaster subtype	Events count	Total deaths	Total affected	Total damage ('000 US$)
Flash flood	7	65	1,387,775	50
Riverine flood	15	408	4,442,332	609,200

(Source –emdat.be)

of monsoonal precipitation – southwest and northeast monsoon. The former strikes and inundates districts like Kegalle, Ratnapura, Kalutara, Colombo, Gampaha, and Galle, whereas the latter causes extensive flooding in districts like Ampara, Trincomalee, etc. (Table 20.7)

20.3 Flood Vulnerability in India

In the entire Indian subcontinent, the flood gains the status of disaster, when normal channels of rivers are breached or flow in excess of their carrying capacity. Flood is a recurrent phenomenon in India that normally starts with the onset of monsoon; however, due to localized hydrometeorological aberrations, there has been specific flooding in localized areas. The United Nations International Strategy for Disaster Reduction (UNISDR) Report 2015 observed that out of the average annual loss of 9.8 billion USD in India, about 7.4 billion USD are accounted by the damage caused by floods.

Rashtriya Barh Ayog (RBA) constituted in India to assess the flood situation in the country has listed the flowing situations for flooding:

- Streams flowing in excess of the transporting capacity
- Backing up of water in tributaries
- Heavy rainfall
- Ice jams or landslides blocking stream courses
- Heavy localized rainfall
- Cyclones and typhoons

Out of the total geographical area of 329 million hectares, about 40 million hectares is liable to floods in India as estimated by the RBA in 1980. Subsequently 11th five-year plan working group has compiled the area liable to flood as 45.64 million hectare. It is estimated that about 25 out of 36 states and union territories are flood prone in the country. The areas stretching north to south from the extrapeninsular regions to the tip of the peninsula and from extreme desert regions of the west to the east coastal regions and northeastern regions are all prone to floods in varying magnitude and nature.

The following table shows annual and decadal damage status in India due to floods (Table 20.8).

There are about 22 major river basins in India, out of which four major river basins are typically known as flood-prone basins:

1. Brahmaputra and Barak basin
2. Ganga basin
3. North West River basins
4. Central India and Deccan river basins

The Brahmaputra basin covering northeastern states, northern part of West Bengal, and Sikkim is affected by severe and recurrent floods. The entire catchment area of this basin receives heavy rainfall from June to September. The frequently occurring earthquakes and landslides in hills upset the flow regime of rivers causing imbalance in flow dynamics. In addition, spilling of rivers, drainage congestion and tendency of some of the rivers to change courses also cause flooding. In Assam and Tripura, flooding primarily occurs due to inundation by spilling of Brahmaputra and tributaries as well as bank erosion along the Brahmaputra.

Table 20.8 A damage due to floods/heavy rains during 2000–2012 in India

India

Statement showing damage due to floods/heavy rains during 2000–2012

Sr. no.	Year	Area affected in m.ha.	Population affected in million	Damage to crops		Damage to houses		Cattle lost nos.	Human live lost nos.	Damage to public utilities in Rs. crore	Total damages crops, houses and public utilities in Rs. crores (col.6+8+11)
				Area in m. ha.	Value in Rs. Cr.	Nos.	Value in Rs. Cr.				
1	2	3	4	5	6	7	8	9	10	11	12
1	2001	6.175	26.463	3.964	688.481	716,187	816.474	32,704	1444	5604.461	7109.416
2	2002	7.090	26.323	2.194	913.092	762,492	599.368	21,533	1001	1062.083	2574.543
3	2003	6.120	43.201	4.268	7307.230	775,379	756.481	15,161	2166	3262.154	11,325.866
4	2004	5.314	43.725	2.888	778.694	1,664,388	879.601	134,106	1813	1656.090	3314.385
5	2005	12.562	22.925	12.299	2370.923	715,749	380.531	119,674	1455	4688.219	7439.672
6	2006	1.096	25.224	1.822	2850.668	1,497,428	3,636.848	266,945	1431	13,303.926	19,790.922
7	2007	7.145	41.402	8.795	3121.532	3280233	2,113.108	89,337	3389	8,049.037	13,283.677
8	2008	3.427	29.910	3.186	3401.563	1,566,809	1,141.891	101,780	2876	5046.481	9589.935
9	2009	3.844	29.537	3.592	4232.609	1,235,628	10,809.795	63,383	1513	17,509.353	32,551.758
10	2010	2.624	18.297	4.994	5887.380	293,830	875.952	39,706	1582	12,757.253	19,520.586
11	2011	1.895	15.973	2.718	1393.847	1,152,518	410.475	35,982	1761	6053.570	7857.892
12	2012	2.141	14.689	1.950	1534.108	174,526	240.572	31,558	933	9169.968	10,944.648
Total		**62.433**	**341.669**	**57.67**	**34,486.127**	**13,835,174**	**22,669.096**	**951,878**	**21,374**	**88,173.595**	**14,5315.3**

In the *Ganga Basin*, flood problems are mostly confined to the northern bank of the Ganga. This recurrent phenomena occurs mostly due to spilling over banks and change in river courses; however, erosion problems are confined to a few places. The problem increases from west to east and from south to north.

In *North West River basin*, covering Punjab and Haryana, inadequate surface drainage along with high rainfall causes flooding and waterlogging over vast areas.

The *Central India and the Deccan basin* covers all southern states where most of the rivers have well-defined and stable courses, but inadequate capacity in lower reaches and delta regions causes flooding. In addition, urban flooding also occurs due to heavy rainfall. The deltas of Mahanadi, Godavari, and Krishna periodically face flooding in the wake of cyclonic storm.

The varied climatic and rainfall patterns in different parts of the country create typical situation in a way that while some of the regions are

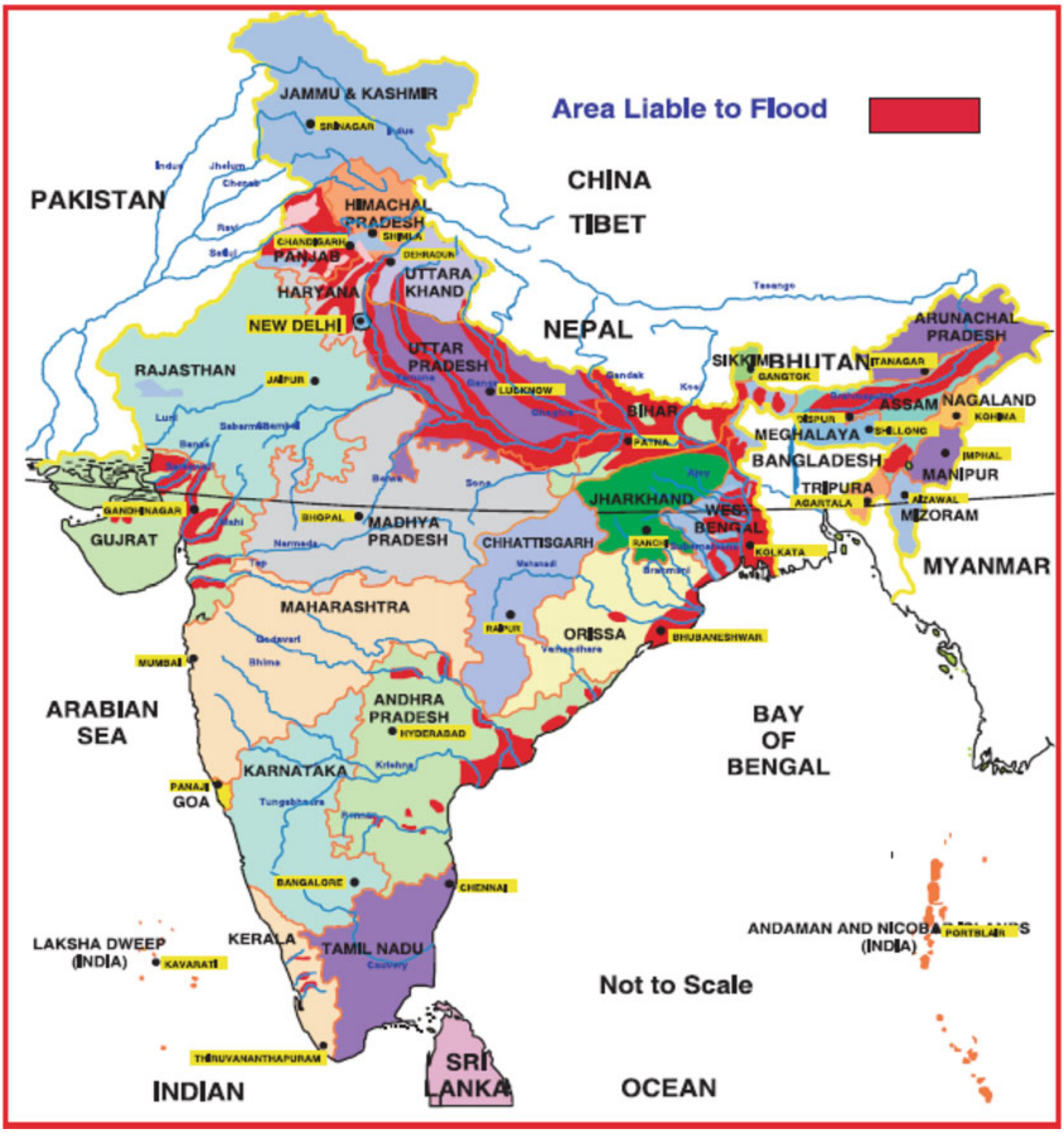


Table 20.9 Areas liable to floods in India

Sl. no	State	Geographical area (Mha)	Area liable to floods (Mha)	Percentage of areas liable to flood	Area protected (Mha) as considered by RBA
1	Andhra Pradesh	27.51	1.39	5.05	0.700
2	Assam	07.84	03.15	40.18	1.305
3	Bihar	17.39	04.26	24.50	1.566
4	Gujarat	19.60	01.39	07.09	0.362
5	Haryana	04.42	02.35	53.17	1.095
6	Himachal Pradesh	05.57	00.23	04.13	–
7	Jammu and Kashmir	22.22	00.08	00.36	0.012
8	Karnataka	19.18	00.02	00.10	0.001
9	Kerala	03.89	00.87	22.37	0.011
10	Madhya Pradesh	44.34	00.26	00.59	–
11	Maharashtra	30.77	00.23	00.75	0.001
12	Manipur	02.23	00.08	03.59	0.073
13	Meghalaya	02.24	00.02	00.89	0.075
14	Orissa	15.57	1.40	08.99	0.351
15	Punjab	05.04	3.70	73.41	2.407
16	Rajasthan	34.22	3.26	09.53	0.016
17	Tamil Nadu	13.01	00.45	03.46	0.029
18	Tripura	01.05	00.33	31.43	0.009
19	Uttar Pradesh	29.44	07.34	24.93	0.739
20	West Bengal	08.88	02.65	29.84	1.001
21	Delhi	00.15	00.05	33.33	0.023
22	Pondicherry	00.05	00.01	20.00	Neg.
	Total		**33.52**		**9.776**
	Say		34 Mha		10.00 Mha

Areas liable to floods in India (Source – MoWR, GoI)

suffering from floods due to excess of waters, at the same time, other regions might be affected due to drought conditions (Table 20.9).

The above table indicates the widespread occurrence of flood across the country, but states like Uttar Pradesh, Assam, Bihar, West Bengal, Odisha, etc., are typically more vulnerable to perennial flooding. The brief account of flood vulnerability in some states are discussed below.

20.3.1 Assam

The Rashtriya Barh Ayog (RBA) has declared the state of Assam as the most flood-vulnerable state in the country. Out of the total geographical area of 7.84 million hectares, about 3.15 million hectare land (40.18 %) is prone to floods. This makes 9.4 % of the total flood-prone areas of India (source-ASDMA). In addition to annual flooding, the state is also affected by flash floods during monsoon (Flood hazard Atlas of Assam).

Assam is situated in the middle of the two major river basins – *Brahmaputra* and *Barak*. Due to typical geo-climatic condition, there are high risks of floods in these basins. Besides, there are a number of natural and anthropogenic reasons of flood occurrences in the state. The heavy monsoonal precipitation combined with a unique physiographic setup makes the region highly susceptible to flood hazards. The situation gets aggravated when the narrow valley of the Brahmaputra compounded with steep gradient

Table 20.10 Vulnerability status of Assam

State (total distt. flood-prone districts)	Area prone to flood as assessed by RBA (Lakh hectare)	Most vulnerable flood districts	Vulnerable flood districts	Flood-vulnerable districts (as per GFCC report 2006) Distts.	Percentage area flooded
Assam (total districts, 27; flood-prone districts, 27)	31.50	1. Nalbari	1. Barpeta	1. Dhubri	51.47
		2. Morigaon	2. Sibsagar	2. Lakhimpur	35.04
		3. Darrang	3. Jorhat	3. Morigaon	27.69
		4. Lakhimpur	4. Udalguri	4. Dhemaji	26.77
		5. Dhemaji {source – Assam Flood Hazard Atlas}	5. Nowgong	5. Barpeta	25.04
			6. Goalpara	6. Jorhat	23.76
			7. Kamrup (rural)	7. Nalbari	15.13
			8. Bongaigaon	8. Sibsagar	17.22
			9. Dhubri	9. Goalpara	17.71
			10. Dibrugarh		
			11. Sonitpur		
			12. Golaghat		
			13. Tinsukia		
			14. Karimganj		
			15. Hailakandi		
			16. Cachar		
			17. Kamrup (metro)		
			18. Kokrajhar		
			19. Baska		
			20. Chirang		
			21. Karbi Anglong		
			22. North Cachar {source – Assam Flood Hazard Atlas, NRSC}		

of channels create the situation of drainage congestion and consequent flooding (Table 20.10).

20.3.2 Uttar Pradesh

Flood is a commonly occurring disaster in Uttar Pradesh that is also a recurrent phenomenon every year. Due to typical hydrometeorological and geomorphological conditions, eastern, central, and Terai regions of the state are more vulnerable to flood.

As per RBA estimation, 73.36 lakh hectares of the total geographical area are prone to flood, that are mostly concentrated in eastern Uttar Pradesh. Out of the total 76 districts in the state, 34 are flood prone (Table 20.11).

There are about eight prime rivers crossing the state that create devastations, when they are in full spate- Ganges, Yamuna, Ramganga, Gomati, Sharda, Ghaghara, Rapti, and Gandak. The annual precipitation due to southwest monsoon is the main flood-inducing factor in the region. About 80 % of the total rainfall (60–190 cm) received by the state is in the form of SW monsoonal precipitation. The pattern of flood occurrence follows the pattern of precipitation that increases from west to east and from south to north. As per the rough


NDRF ON A MISSION DURING ASSAM FLOOD-2012

Table 20.11 Vulnerability status of Uttar Pradesh

(Total distt. v/s flood-prone districts)	Area prone to flood as assessed by RBA (Lakh hectare)	Most vulnerable flood districts	Vulnerable flood districts	Flood-vulnerable districts (as per GFCC report 2006)	
				Distts.	Percentage area flooded
(Total districts, 76; flood-prone districts, 34)	73.36	1. Pilibhit	1. Gazipur	1. Mirzapur	20.77
		2. Lakhimpur Kheri	2. Unnao	2. Sidharthnagar	20.72
		3. Sitapur	3. Bulandshahar	3. Basti	17.97
		4. Bahraich	4. Lucknow	4. Ballia	15.23
		5. Barabanki	5. Bareilly	5. Farrukhabad	16.50
		6. Gonda	6. Bijnor	6. Gorakhpur	19.71
		7. Faizabad	7. Banda		
		8. Ambedkar Nagar	8. Saharanpur		
		9. Basti	9. Muzaffarnagar		
		10. Sant kabir Nagar	10. Shamli		
		11. Azamgarh	11. Gautambuddha Nagar {source – UPSDMA}		
		12. Mau			
		13. Ballia			
		14. Deoria			
		15. Kushinagar			
		16. Gorakhpur			
		17. Siddharth Nagar			
		18. Badaun			
		19. Farrukhabad			
		20. Kasganj			
		21. Balrampur			
		22. Shravasti			
		23. Maharajganj {source – UPSDMA}			

estimate, the average annual loss to crops, houses, and livestock in the state is to the tune of about INR 2000 crores {source-UP Govt. Report}.

20.3.3 Bihar

The state of Bihar is known as the *theater of natural disasters* especially flood on account of its recurrent nature every year with resultant loss of lives and substantial damages. As per the estimation done by the Water Resources Department, Govt. of Bihar, about 56 % of the total geographical area of the state is affected by flood and permanent waterlogging (Taal).

Bihar is geographically divided by river Ganges into two main regions – North Bihar and South Bihar. The former is fed by rivers flowing from the Himalayas and covering the entire North Bihar. Rivers like Ghaghra, Gandak, Burhi Gandak, Bagmati, Kamla, Kosi, Mahananda, and Adhwara have their catchment extending from Nepal to Bihar. Mostly being of glacial origin, these rivers are perennial in nature, thus maintaining an optimal level of flow round the year. During monsoonal precipitation, these rivers get an additional volume of water leading to large-scale flooding situations in the entire stretch of North Bihar. As per the estimation, 73.63% area of North Bihar is considered as flood prone {5}.

The river Ganges on its left bank receives tributaries like Ghaghra, Gandak, Kosi, etc. Since they are mostly of Himalayan origin, they carry along with them a large amount of silts, which are deposited all along their channels in the Indo-Gangetic plains. Heavy siltation combined with anthropogenic obstructions lead to overtopping of excess river water, causing widespread inundation and consequent flooding in the catchment area. The situation gets aggravated by further inundation through rivulets existing in the interfluves of all these tributaries. Due to prolonged siltations, some of these rivers have acquired characteristics of changing their courses, thereby destructing habitations and agricultural cultivation in the adjoining locations. The river Kosi is one such river, which has gained the notoriety of changing course drastically. During the last two centuries, this river has moved nearly 110 km westward, devastating the entire area that came in her path. Being very destructive in nature, this river is termed as *River of Sorrows*.

The geographical and geological setup in the south of river Ganges (South Bihar) is somewhat different. The region having a total geographical area of 44,000 km^2 is drained by rivers like Karmanasa, Sone, Punpun, Kiul, Badua, Chandan, etc. They are mostly rain fed. During monsoon period, the surplus water in these rivers get accumulated along the southern tracts of the natural levee of river Ganges, causing flood. The wetland region, lying south of river Ganges known as *Taals*, are also inundated by these surplus waters.

There are 28 flood-prone districts in Bihar, out of which 15 are considered as the most vulnerable and 13 are less vulnerable (Table 20.12).

Table 20.12 Flood-vulnerable districts of Bihar

State (total distt.; Flood-prone districts)	Area prone to flood as assessed by RBA (Lakh hectare)	Most Vulnerable flood districts	Vulnerable flood districts	Flood-vulnerable districts (as per GFCC report 2006)	
				Distts.	Percentage area flooded
Bihar (total districts, 38; flood-prone districts, 28)	42.60	1. Darbhanga	1. Araria	1. Sheohar	45.40
		2. East Champaran	2. Bhojpur	2. Sitamarhi	39.63
		3. Katihar	3. Buxar	3. Darbhanga	38.69
		4. Khagaria	4. Gopalganj	4. Gopalganj	36.94
		5. Madhepura	5. Kishanganj	5. Saharsa	35.38
		6. Madhubani	6. Lakhisarai	6. Muzaffarpur	30.61
		7. Bhagalpur	7. Nalanda	7. Supaul	22.61
		8. Saharsa	8. Patna	8. Madhubani	20.53
		9. Samstipur	9. Purnia	9. Katihar	19.88
		10. Sheohar	10. Saran	10. Samastipur	19.66
		11. Sitamarhi	11. Sheikhpura	11. Bhagalpur	17.77
		12. Muzaffarpur	12. Siwan	12. Vaishali	17.53
		13. Supaul	13. West Champaran {source –Bihar Govt.}	13. East Champaran	16.94
		14. Vaishali		14. Purnea	15.69
		15. Begusarai {source –Bihar Govt.}		15. Araria	15.51

The historical Kosi flood in 2008 is considered as the worst disastrous flood ever occurred in the country. On August 18 2008, an unprecedented flood situation occurred when the river Kosi breached eastern afflux embankment near village Kusaha in Nepal. This led to the formation of new scattered channel east of the old channel releasing about 1.66 lakh cusecs of water spreading across the channel causing devastations mostly in districts like Saharsa, Madhepura, Purnia, Supaul, Forbesganj, Araria, Katihar, etc. Over 3.3 million people affected due to sudden onset of this disaster with over a million rendered homeless. The loss of about 3000 km^2 of fertile land was reported. About 412 g panchayats under five districts were severely affected due to this natural calamity. A total of 3,40,742 houses collapsed with more than a thousand animals died. All the basic amenities were severely disrupted in the affected districts. The railway tracks submerged, the electricity lines were disrupted, and many roads and communication networks were damaged in this catastrophe. The state government immediately started disaster response operations with the help of central government.

20.3.4 Punjab and Haryana

In the alluvial plain of Punjab and Haryana, the main reason of flooding is waterlogging and drainage congestion. In Punjab, the entire alluvial plains are basically old floodplains of rivers. The alluvial plains of Ravi Beas, Satluj, Ghaggar, and Markanda rivers along with other rivulets constitute about 10 % of the state geographical area. Rivers like Ghaggar and Markanda sometimes inundate the adjoining low-lying areas after their courses are choked and obstructed especially during the monsoon period.

The drainage system in parts of Jind, Rohtak, Hisar, and Gurgaon districts of Haryana are either poorly developed or damaged causing severe flooding (Table 20.13).

Table 20.13 Flood-prone districts of Punjab

State (total distt.v/s; flood-prone districts)	Area prone to flood as assessed by RBA (Lakh hectare)	Most vulnerable/ vulnerable flood districts
(Total districts, **20**; flood-prone districts, **11**)	37.00	1. Ropar
		2. SBS nagar
		3. Jalandhar
		4. Ludhiana
		5. Moga
		6. Ferozpur
		7. Fazilka
		8. Kapurthala
		9. Taran Taran
		10. Gurdaspur
		11. Amritsar {source –Punjab Govt. memo no. 11/12/14-5DM1/5157 dated 3-4-14}

The Punjab and Haryana plain together accounts for about 45 % of the total flood loss incurred by the country. There are various factors leading to higher degree of vulnerability to floods in both the states. In Punjab, almost 80 % of the total annual rainfall is concentrated over a short period of 3 months, which coincides with the cropping seasons. In addition, the increased developmental practices in the region have resulted to more encroachments in the floodplains, causing enhanced vulnerability of flood. The natural geomorphic structure of Haryana is like a saucer-shaped depression, along the linear axis of Delhi-Rohtak and Hisar-Sirsa. Due to heavy precipitation and poor drainage network, sometimes the entire area gets flooded, e.g., Rohtak flood (1995). In addition, some of the recently emerged urban agglomerations are facing the problems of drainage congestion and localised urban flooding due to inadequate or faulty drainage system.


Rohtak Flood 1995 (courtsey –indiatimes.com)

20.3.5 Rajasthan

The state of Rajasthan is typically known as the drought-prone region of India with generally little or scanty rainfall. There are about 13 river basins and sub-basins in the state out of which basins of three rivers – Chambal, Banas, and Luni are particularly prone to flooding due to reasons like excess rainfall in the catchment areas, sudden release of water from dams, breach in the embankment, decreased water bearing capacity of dams, etc. Besides these, the change in rainfall pattern has also increased the risk of flash floods. In 2006, the Barmer flood occurred due to unprecedented heavy rainfall in the region. Districts like Barmer, Jalore, Sirohi, Pali, Chittorgarh, Kota, Bharatpur, Bundi, etc., are among the flood-prone districts in the state.

Barmer Flood 2006

20.3.6 Odisha

On account of typical geomorphological and hydrometeorological setup combined with maritime impacts, the state of Odisha is vulnerable to flood in several ways. Primarily, flooding occurs due to heavy monsoonal precipitation, as about 80 % of the total annual rainfall is received over a short period of 3 months. Because of the heavy siltation in rivers like Mahanadi, Brahmani, and Baitarani. The surplus water overtops the main channels and inundate adjoining areas. Sometimes, embankments are also breached due to heavy pressure of flood water. Since these rivers

Table 20.14 Flood-prone districts of Odisha

State (total distt.; flood-prone districts)	Area prone to flood as assessed by RBA (Lakh hectare)	Most Vulnerable flood districts	Vulnerable flood districts	Flood-vulnerable districts (as per GFCC Report 2006)	
				Distts.	Percentage area flooded
Odisha (total districts, 30; flood-prone districts, 24)	14.00	1. Balasore	1. Angul	1. Cuttack	19.55
		2. Bhadrak	2. Bargarh	2. Jagatsinghpur	31.70
		3. Cuttack	3. Balangir	3. Kendrapara	28.86
		4. Jagatsinghpur	4. Deogarh	4. Bhadrak	23.83
		5. Jajpur	5. Gajapati	5. Puri	22.01
		6. Kendrapara	6. Ganjam	6. Jajpur	37.32
		7. Khurda	7. Kalahandi		
		8. Nayagarh	8. Kandhamal		
		9. Puri {source – Govt. of Odisha}	9. Keonjhar		
			10. Koraput		
			11. Mayurbhanj		
			12. Nabarangpur		
			13. Rayagada		
			14. Sambalpur		
			15. Sonepur (Subarnapur) {source – Govt. of Odisha}		

have common delta, they create a disastrous situation, while in the high spate. The situation gets aggravated when flood synchronizes with the condition of high tide.

The linear coastal tract of Odisha is also vulnerable to storm surge, especially during cyclone season. This situation is often accompanied by heavy precipitation that resulted in flooding in the lower reaches of the coastal districts. The deforested catchment areas and offshore bars choke the river mouths and obstruct the free flow of waters into the sea. In 1960, the region was hard hit by unprecedented flood. In super cyclone of 1999, many of the low-lying coastal districts were completely inundated. The high population density along with poor socioeconomic condition has led to increased encroachment in the entire stretches of floodplain, which ultimately increased the vulnerability of floods in the state. Out of the total 30 districts, 24 are flood prone, including nine most vulnerable districts as depicted in Table 20.14. For the last 10 years, floods in the state have caused great havoc with

Ganjam Flood, Odisha (Source-NDRF)

resultant loss of lives, properties, and infrastructures. The most severe flood that occurred in 2006, 2007, 2008, and 2011 had caused huge devastation.

20.3.7 Gujarat

On account of the maritime impact and typical geomorphic setup, the state of Gujarat receives heavy precipitation, which often results in the inundation of low-lying areas and consequent flooding. In addition, there are other factors responsible for flooding in the state. In 1979, a flood in Morbi city occurred due to dam break in which about 12,000 people died. In August 2006 Surat city and South and Central Gujarat got affected by flood wherein about 250 people died of drowning and leptospirosis.

20.3.8 West Bengal

The state of West Bengal has the total geographical areas of 88.75 lakh hectares out of which about 37.6 lh of land is identified as flood prone spreading over 111 blocks. The state is typically vulnerable to three main types of flooding – flash floods, riverine floods, and coastal floods. The flash floods occur due to the impact of heavy torrential rainfall supplemented with cloud burst, storm surge, and cyclonic impact. In urban agglomerations, the condition gets aggravated due to poor and choked drainage system coupled with poor urban planning. Riverine flooding occurs when the surplus volume of water due to high precipitation added in the river channels, particularly when they are in full spate. Most of the rivers flowing in the state are having their origin in Nepal, Bhutan, and Sikkim (India), and they flow downstream to meet either

in the sea or neighboring country of Bangladesh before meeting to the ultimate destination. The rivers like Teesta, Torsa, Jaldhaka, Raidak (I&II) flows through the districts of Jalpaiguri and Cooch Behar. They cause intense flooding in these districts when there is high precipitation in the upper reaches.

The river Mahananda when gets high discharge in the upper catchment area, causes flooding in Uttar and Dakshin Dinajpur. The district of Malda is flooded due to high discharge of rivers Fulhar-Mahananda-Ganga. The river basins of Bhagirathi-Hooghly create flooding primarily due to excessive discharge in these rivers on account of high precipitation in the catchment area associated with drainage congestion and decreased carrying capacity of river channels. The most affected regions are from Jangipur (Murshidabad) to Kalna (Bardwan). The South Bengal in general is flood prone having threats of riverine flooding and tidal flooding. The situation acquires an alarming position when tidal bore is also at peak during flooding in rivers. The districts like Darjeeling (N Bengal), Bankura, and Purulia (S Bengal) are comparatively free from flood threats. Out of the total 20 districts in the state, 15 are considered as flood prone (Table 20.15).

Table 20.15 Flood-vulnerable districts of West Bengal

State (total distt.; Flood-prone districts)	Area prone to flood as assessed by RBA (Lakh hectare)	Vulnerable flood districts	Flood-vulnerable districts (as per GFCC report 2006)	
			Distts.	Percentage area flooded
West Bengal (total districts, 20; flood-prone districts, 15)	26.50	1. Jalpaiguri	1. Murshidabad	19.92
		2. Cooch Behar	2. Birbhum	15.55
		3. Uttar Dinajpur	3. Nadia	17.60
		4. Dakshin Dinajpur		
		5. Malda		
		6. Murshidabad		
		7. Nadia		
		8. North 24 Parganas		
		9. Birbhum		
		10. Burdwan		
		11. Hooghly		
		12. Howrah		
		13. Paschim Medinipur		
		14. Purba Medinipur		
		15. South 24 Parganas {source – govt. of West Bengal}		

20.3.9 Andhra Pradesh

Traditionally Andhra Pradesh is affected by multifaceted problems of flooding. While rivers like the Godavari and the Krishna along with other smaller rivers inundate surrounding areas due to excessive inflow in their channel beyond the carrying capacity, storm surge along the coastal belt also results in flooding. In addition, the drainage congestion mostly in delta regions is also responsible for flood problems in the state. In Telangana region (now a state), Khammam district is vulnerable to monsoonal flooding that occurs due to NE monsoon. The coastal belt from Nizampatnam to Machilipatnam is affected by storm surge flooding mostly due to cyclonic impact. The delta regions of Godavari and Krishna that are the most fertile regions of Andhra Pradesh experience problems of recurrent flood and drainage congestion.

Besides monsoonal and storm surge flooding, the riverine districts are also vulnerable to floods occuring due to peak discharges. The dams located along various rivers release excess water in the downstream when they are in high spate. To cite some examples, peak discharge of river Krishna at Vijaywada from NS Dam in the years 1989, 1990, 1991, 1998, and 2009 caused flood in the districts of Guntur, Krishna, Nalagonda, Kurnool, and Mahaboobnagar, and peak discharge of river Godavari at Perur affected districts of Khammam and East and West Godavari in the years 1986, 1990, 1992, 1994, 2004, 2005, and 2006. Peak discharge of river Penna at Nellore affected Nellore district in 1988, 1991, and 2001. Similarly, peak discharge at river Vamsadhara at Gotta barrage (I & CAD) badly affected Srikakulam in 1990 and 1992. Peak discharge at river Nagavalli also affected Srikakulam and Vijayanagaram in 1990, 1991, 1992, 1994, and 1996 (source-KSNDMC)

20.3.10 Flooding in Highland States

Flooding in the highlands or extrapeninsular regions of India is unique in terms of nature and magnitude considering the unique geomorphological topography. They are also known as upstream flooding that mostly occurred in the form of flash floods, cloud burst, or glacial lake outburst floods. They occur in a small, localized, and upper parts of the basin. The states mostly affected by this hydrometeorological phenomenon are Uttarakhand, Himachal Pradesh, J&K, Sikkim, etc.

20.3.10.1 Uttarakhand (Flood 2013)

On June 16 and 17, 2013, the state of Uttarakhand received more than 340 mm of rainfall, which was 375 % more than the normal benchmark of 65.9 mm rainfall during a normal monsoon. The sudden occurrence of cloud burst near Kedarnath temple and flooding in rivers like *Bhagirathi*, *Mandakini*, *Ashiganga*, *Kali* caused flash floods. This created one of the greatest disasters in the Indian history. Four out of 13 districts were heavily affected by floods, which created huge devastations in terms of loss of lives, properties, and infrastructures. At least 5000 people reported to have been killed in the deluge that inflicted heavy damage especially in the Kedarnath valley. Many thousands of pilgrims of "Char-Dham" Yatra were also affected. The unprecedented cloud burst and subsequent flash floods caused huge loss of lives and properties particularly in *Rudraprayag*, *Pithoragarh*, *Uttarkashi*, and *Chamoli* districts.

Damaged Houses in Uttarakhand Flash Floods

Damaged Roads in Uttarakhand Flash Floods

20.3.10.2 Jammu and Kashmir (Flood 2014)

The Jammu and Kashmir state has a very peculiar geography and climate. Most of the valley regions of the state are fed by rivers like Jhelum, Indus, and Chenab. The low lying areas of the Kashmir Valley, especially Srinagar, along with parts of Jammu, are prone to floods that occur due to heavy rainfall in upper catchment areas. Heavy rain followed by flash flood in September 2014 caused great devastation in the valley that claimed at least 280 lives and stranded hundreds of thousands of residents. The flood was unprecedented in nature, where the most part of the southern district has received very high rainfall. The weekly total rainfall for most of the stations during the period Sept 2 to Sept 8, 2014, was more than 200 mm. This is very high for a terrain like Jammu and Kashmir. The table below shows spatial distribution of weekly rainfall for select India Meteorological Department stations in J&K.

Rainfall status during 2 weeks in August to Sept. 2014

Actual (mm)	Normal (mm)	Departure (percent)	Category
43.2	27.9		E

August 28 to Sept. 3 2014

Actual (mm)	Normal (mm)	Departure (percent)	Category
267.7	30.0	792	E

Sept.4 to Sept.10, 2014 (Source –IMD/Frontline)

The primary cause was incessant rainfall that occurred due to western disturbance on September 3rd 2014 and continued for 4 days. The melting of snow also added the severity of floods. The districts like *Anantnag*, *Baramulla*, *Doda*, *Jammu*, *Kulgam*, *Pulwama*, *Ramban*, *Reasi*, *Sopian*, and *Udhampur* received extremely heavy rainfall which inundated many low lying areas of the state. Huge devastation occurred in these districts in the form of loss of houses, livestock, crops, and livelihoods. Many cities were badly affected. The capital city Srinagar was marooned due to flood for many days. Many localities turned into lakes with collapsed houses and communication networks.

Geomorphologically, it is said that the huge devastation occurred due to the absence of floodplain along the river Jhelum which could have accommodated excess of runoff averting floods in the valley. The massive urbanization in the urban localities of J&K along river Jhelum led to the destruction of floodplains almost all along the river, which added the severity of floods in the valley.

After the disaster, the National Disaster Management Authority took control of the situation and started disaster response at different locations in the valley. National Disaster Response Force (NDRF) battalions pressed into action along with Indian Armed forces to provide rescue and relief. The armed forces (including Army, Navy, and Air Force) and National Disaster Response Force (NDRF) launched one of the biggest search and rescue operations in the state. Operation "Megh Rahat" and operation "Sahayata" involved all the three wings of armed forces and NDRF which rescued people from inundated areas and provided them food, water, medicines, and shelters. By September 19, 2014, over 2.37 people were rescued by the joint efforts of these forces. The army deployed about 30,000 troops for search, rescue and relief operations.

The following table gives an account of flood occurrence in India from 2005 to 2014 (Table 20.16).

20.4 Flood Forecasting and Early Warning System

The forecasting and early warning is an integral and important component of flood risk management, which enables authorities and communities to take appropriate preparedness measures for

Table 20.16 Flood occurrence in different states of India (2005–2014)

No.	Year	Date of occurrence (dd/mm)	Location (city/village, state)	No. of Population affected	No. of Population Lost	Estimated value of Damage (in 000 US$)
1.	2005	27/05	Nagaland	12	14	
2.		28/06	Gujarat	405,000	239	2,300,000
3.		09/07	Maharashtra		25	
4.		26/06	Himachal Pradesh	5000	6	23,000
5.		07/07	Assam, Arunachal Pradesh, Uttar Pradesh, Uttaranchal	1,908,000	70	–
6.		02/07	Madhya Pradesh	49,000	62	–
7.		10/07	Andhra Pradesh	10,000	12	–
8.		24/07	Gujarat, Madhya Pradesh, Maharashtra, Goa, Odisha, Karnataka, Himachal P, J&K	20,000,055	1200	3,330,000
9.		26/08	Uttar Pradesh	800,000	27	
10.		23/07	Andhra Pradesh	100,000	126	
11.		16/09	Himachal Pradesh, Uttar Pradesh, Uttaranchal	2504	23	
12.		14/09	Chhattisgarh, Orissa, Maharashtra, Madhya Pradesh	550,000	89	420,000
13.		21/10	West Bengal, Orissa	2,250,000	19	117,000
14.		22/09	Gujarat		15	
15.		23/10	Tamil Nadu	2,000,000	162	
16.		02/12	Tamil Nadu	200,000	30	
17.		05/07	Himachal Pradesh, Punjab, J&K, Haryana	2000	10	
18.	2006	15/04	Andhra Pradesh	–	20	
19.		31/05	Assam, Tripura	504,000	21	
20.		25/05	Kerala	10,800	32	
21.		31/05	Maharashtra, Gujarat		41	
22.		24/06	U.P.	300,000	130	
23.		04/07	Gujarat	8400	24	
24.		03/07	Odisha		33	
25.		24/07	J&K	800	15	
26.		28/07	Andhra Pradesh, Gujarat, Maharashtra, Chhattisgarh, Rajasthan, Madhya Pradesh, Odisha, Karnataka,	4,000,065	350	3,390,000
27.		13/08	Gujarat	50,000		
28.		18/08	Rajasthan	20,000	135	
29.		31/08	J&K	15,000	19	
30.		29/08	Uttar Pradesh	100,000	42	
31.		26/10	Tamil Nadu, Andhra Pradesh	225,000	47	
32.		01/08	Odisha, Andhra Pradesh, Chhattisgarh	2,000,000	185	
33.		26/10	Tamil Nadu, Andhra Pradesh	225,000	47	
34.		01/08	Odisha, Andhra Pradesh, Chhattisgarh	2,000,000	185	
35.		09/03	Madhya P, Maharashtra, Rajasthan	113	61	
36.		01/10	Madhya Pradesh		39	
37.	2007	18/06	Assam	200,000	15	
38.		01/07	Gujarat, Rajasthan, Madhya Pradesh	63,000	225	
39.		01/07	Maharashtra	10,000	62	
40.		30/06	Chhattisgarh	50,000	29	
41.		22/06	Andhra Pradesh, Kerala, Karnataka, Maharashtra	200,000	127	

(continued)

Table 20.16 (continued)

No.	Year	Date of occurrence (dd/mm)	Location (city/village, state)	No. of Population affected	No. of Population Lost	Estimated value of Damage (in 000 US$)
42.		21/07	Tripura			
43.		03/07	U.P., Bihar, Assam, Odisha, West Bengal	18,700,000	1103	
44.		12/08	Himachal Pradesh	15,000	76	
45.		08/08	Gujarat		16	
46.		22/09	Odisha, W Bengal	7,200,000	80	275,000
47.		16/09	Andhra P, Karnataka	20,000	94	
48.		27/10	Andhra P, Tamil Nadu	50,000	29	
49.		03/08	Odisha	500,000	15	
50.		12/07	Assam, Arunachal P, Meghalaya, Manipur	11,100,000	96	
51.		16/07	Kerala,	35,000	44	101,151
52.		11/02	Rajasthan, U.P., Madhya Pradesh, Kashmir	8	40	
53.	2008	20/03	Tamil Nadu, Karnataka	10,278	37	2000
54.		11/06	West Bengal, Odisha, Assam, Bihar, Gujarat, Goa, Haryana, Kerala, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Odisha, Rajasthan, U. P., Tamil Nadu, West Bengal, Arunachala, Uttarakhand, Jharkhand	7,900,000	1063	123,000
55.		05/07	Assam, Bihar, Gujarat, Goa, Haryana, Jharkhand, Kerala, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Odisha, Rajasthan, Uttarakhand, U.P., Tamil Nadu, West Bengal	50,000		
56.		05/09	Andhra Pradesh		74	
57.		14/09	Odisha, U.P., Himachal P,	2,400,000	173	
58.		30/08	Bihar, Assam	2,600,000	47	20,000
59.		27/11	Tamil Nadu	803,740	54	
60.		20/07	Assam, U.P., Bihar	225,333	142	
61.	2009	29/07	Delhi		11	
62.		00/07	Bihar, Odisha, W Bengal, Assam, Kerala, Gujarat, Karnataka,	1,886,000	992	220,000
63.		25/09	Karnataka, Maharashtra, Andhra Pradesh	4,100,000	355	2,150,000
65.		09/10	Meghalaya		20	
66.		03/11	Tamil Nadu	08	70	64,000
67.		26/08	Bihar,		52	
68.	2010	05/07	Haryana, Punjab, Kerala, Assam	400,000	53	447,000
69.		18/05	Andhra Pradesh	50,000	27	
70.		13/07	New Delhi		11	
73.		05/09	Assam	30,000		
74.		18/09	Uttarakhand, Bihar, Uttar Pradesh	3,267,183	200	1,680,000
75.		09/09	Punjab, Haryana, Uttar Pradesh	12,500		
76.		15/11	Tamil Nadu		203	22,000
77.	2011	10/08	West Bengal	700,000	47	275,000
78.		23/09	Odisha	3,443,989	239	930,000
79.		15/08	Eastern Assam, Western Meghalaya,	1000	07	

(continued)

Table 20.16 (continued)

No.	Year	Date of occurrence (dd/mm)	Location (city/village, state)	No. of Population affected	No. of Population Lost	Estimated value of Damage (in 000 US$)
80.		15/08	Assam, Bihar, Uttar Pradesh	5,549,080	204	
81.		23/07	Uttar Pradesh, Rajasthan	200,000	19	
82.		05/09	Odisha	2,100,000	42	432,000
83.		15/06	Uttar Pradesh, Uttarakhand		50	20,000
84.	2012	26/06	Assam, Arunachal Pradesh	2,200,000	120	
85.		21/08	Rajasthan,		37	
86.		19/09	Assam, Sikkim, Arunachal Pradesh	260	21	98,000
87.		21/08	Himachal Pradesh	9460	26	16,000
88.	2013	12/06	Uttarakhand, Himachal Pradesh, Uttar Pradesh, Bihar, Karnataka, Kerala, Gujarat, West Bengal	504,473	6054	1,100,000
89.		09/07	Uttar Pradesh	500,000	174	
90.		23/06	Assam	2,000,000	80	
91.		22/08	Madhya Pradesh, Uttar Pradesh, Assam	40,000	73	
92.		21/10	Odisha, Andhra Pradesh, Bengal	375,000	72	260,000
93.	2014	26/06	Assam,	18,500	27	
94.		16/07	Uttarakhand, Himachal Pradesh		26	
95.		03/08	Odisha	179,000	35	
96.		00/09	Jammu	275,000	298	16,000,000
97.		11/08	Uttar Pradesh	4000	31	
98.		24/09	Assam, Meghalaya	650,000	95	163,000
99.		16/08	Uttarakhand		27	
100.		09/08	Odisha	3,600,000	47	100,000

(Source –CRED/emdat.be)

impending flood situations in order to reduce flood damages and loss of lives.

Flood forecasting a non structural mitigation measures, which are considered complimentary to structural mitigation measures. There are primarily three types of forecasts prevalent in India and many South Asian countries – *Stage forecast*, *Inundation forecast and Inflow forecast*. While the *stage forecast or level forecast* gives information about water level in rivers, *inundation forecast* gives estimation about areas likely to be inundated or submerged during the high flood situation. The *inflow forecast* provides information about the amount of discharge in the river.

The flood forecasting system in India was established in the year 1958 in a scientific manner, when the *Flood Forecasting Unit* (*FFU*) was set up by the erstwhile Central Water and Power Commission (CW&PC) for generating and issuing flood warning at river Yamuna in Delhi. Since then, the system has been gradually expanded to other parts of the country with more advanced and scientific technology.

20.4.1 Stages of Flood Forecasting

There are four main stages of flood forecasting and warning in India

4.1.1 Real-time data collection
4.1.2 Transmission of data
4.1.3 Data processing and preparation of forecasts and warning
4.1.4 Dissemination of flood forecasts and warning

20.4.1.1 Real-Time Data Collection

The collection of real-time meteorological (rainfall) and hydrological (gauge discharge) data is the prime requisite for generating flood forecasts and warnings. While, at the central level, India Meteorological Department (IMD) and Central Water Commission (CWC) receive meteorological and hydrological data respectively through their base stations located across the country, a few states like Bihar, Karnataka, Andhra Pradesh, Tamil Nadu, etc., have established their own automatic weather stations generating and utilizing data for flood forecasting and early warning besides getting information from few national organizations.

IMD through its 10 flood meteorological offices receive daily rainfall data from more than 7000 centralized and state rain gauge stations in addition to forecasts of heavy rainfall and quantitative precipitation forecasts for various river basins. All these data are supplied to the respective flood forecasting centers of CWC.

20.4.1.2 Transmission of Data

The data generated at various hydrological and hydrometrological stations are transmitted to flood forecasting stations through different means of communication systems like VHF/HF wireless sets, telephones, V-Sat, Internet, etc.

There are 544 wireless stations owned by the Central Water Commission meant for near real-time data transmission. The high-frequency (HF) wireless sets are having 3–30 MHz frequency used for long-distance transmission of data, whereas very high-frequency (VHF) wireless sets with frequency range 30–3000 MHz are used for short-distance communication.

In addition, about 445 stations of CWC are equipped with (or somewhere under installation) satellite-based "telemetry stations" for generating automatic data communications (CWC Annual Report 2013).

During the Xth five-year plan, CWC established sensor-based telemetry stations at 223 locations across the country in basins of river Krishna, Godavari, Mahanadi, Chambal, Damodar, Yamuna, and R. Brahmaputra. Further, 222 telemetry stations were established during 11th five-year plan. It is proposed to establish another 600 stations during XII plan, which covers the entire country. All the sensors located at these stations will transmit data to earth stations located at Jaipur (Rajasthan) and Burla (Odisha) through INSAT or Kalpanasat satellites. All these received data are further transmitted through V-Sat to different modeling centers (CWC Annual Report 2013).

The transmission of data takes place twice to thrice in a day, depending upon flood situation. In case of extreme flooding, the transmission frequencies are even increased to hourly basis.

20.4.1.3 Data Processing and Preparation of Forecasts and Warnings

After receiving hydrological and hydrometeorological data from ground stations, the various modeling centers of CWC undertake data processing by using advanced software.

Primarily the precipitation and discharge data are utilized for forecast generation on a real-time basis. For example, *inflow forecasts* are generated by using rainfall runoff correlation through Windows-based hydrodynamic simulation modeling software MIKE-11. The Central Water Commission has developed a site-specific model for different locations under various divisions by using MIKE-11.

The flood forecast model for Srinagar (J&K) is currently under formulation based on MIKE-11. Similarly, the development of flood forecast models for rivers like Sankosh, Godavari, Brahmaputra, Jhelum, Alaknanda, and Yamuna basin has been taken up by the Central Water Commission (CWC).

20.4.1.4 Dissemination of Flood Forecasts and Warning

The final flood forecast information generated through various processes are disseminated to user agencies for issuing early warning and undertaking appropriate flood preparedness measures. The information is also circulated in print and electronic media for dissemination to local populace. Some of the user agencies like National Disaster Management Authority (NDMA), National Disaster Response Force (NDRF), state governments, railways and roadways authorities, defense forces, etc., are regular recipients of flood forecast information.

20.4.2 Agencies Involved in Flood Forecasting and Early Warning

20.4.2.1 Central Water Commission

The *Central Water Commission* is the technical agency dealing with water resources and flood management working under the *Ministry of Water Resources*, *River Development and Ganga Rejuvenation*, *Government of India*. The agency is entrusted with the general responsibilities of initiating, coordinating and furthering in consultation of the state government concerned, schemes for control, conservation and utilization of water resources throughout the country, for the purpose of flood control, irrigation, navigation, drinking water supply and water power development" (Central Water Commission, Ministry of Water Resources, River development & Ganga Rejuvenation, Govt. of India).

A separate *River Management Wing* has been established in CWC specifically for undertaking all activities related to flood management in the country. The wing is headed by Member (River Management) having an ex-officio status of Additional Secretary to the Govt. of India. There are various directorates in this wing headed by respective directors.

The role of this wing in the management of flood is primarily centered on collection, compilation, collation, and analysis of hydrological and hydrometeorological data and sharing of flood forecast analysis and early warning information to concerned state government and other user agencies except Ganga and Brahmaputra river basins for which two separate organizations have been created. The other functions of river management wing are as under:

- Formulation and dissemination of flood forecasts for all flood-prone rivers
- Providing support to state governments in technical matters of river and flood managements
- River morphology studies, appraisal of flood management schemes
- Provide advisory support to all user agencies including National Disaster Management Authority (NDMA)

The systematic approach of flood forecasting and early warning was initiated by CWC in 1969 with the establishment of *flood forecasting* and *warning organization* (Annual Report 2013). With the advancement of new technology, the flood forecasting network of CWC got strengthened. At present, there are 175 flood forecasting stations working under the *National Flood Forecasting* and *Warning Network* of CWC, out of which 28 stations are working for inflow forecasting and 147 are for level forecasting as listed in the table below.

River system-wise distribution of flood forecasting state

Sr. No.	River system	Types of forecasting station: Level forecasting	Inflow forecasting	Total
1	Ganga system	77	10	87
2	Brahmaputra system	27	–	27
3	Barak system	5	–	5
4	East flowing river system	8	1	9
5	West flowing river system	9	6	15
6	Southern system	3	1	4
7	Mahanadi	14	4	18
8	Godavari	3	6	9
9	Krishna	1	–	1

CWC Report (2013)

State wise distribution of flood forecasting station

Sr. no.	River system	Types of forecasting station: Level forecasting	Inflow forecasting	Total
1	Andhra Pradesh	9	7	16
2	Assam	24	–	24
3	Bihar	32	–	32
4	Chhattisgarh	1	–	1
5	Gujarat	6	5	11
6	Haryana	–	1	1
7	Jharkhand	1	4	5
8	Karnataka	1	3	4
9	Madhya Pradesh	2	1	3
10	Maharashtra	7	2	9
11	Odisha	11	1	12
12	Tripura	2	–	2
13	Uttarakhand	3	–	3
14	Uttar Pradesh	34	1	35
15	West Bengal	11	3	14
16	Dadra Nagar Heavily	1	–	1
17	NCT of Delhi	2	–	2
Total		147	28	175

CWC Report (2013)

The river management wing of CWC operates with the help of regional offices each headed by a Chief Engineer. At present, 14 circle offices and 25 divisions of CWC are actively engaged in flood forecasting activities.

20.4.2.2 India Meteorological Department (IMD)

India Meteorological Department (IMD) is an apex organization in the Government of India actively involved in weather forecasting and early warning in association with the Central Water Commission (CWC). Established in 1875, the organization is a leading meteorological service provider in the country with specialization in hydrometeorology, seismology, and allied subjects (India Meteorological Department, Government of India).

IMD supports CWC in formulating flood forecasts of different river basins by way of providing various meteorological inputs like *Quantitative Precipitation Forecast* (*QPF*) for 24 h and *weather condition* and *the rainfall probability forecast warning* for 24–48 h period. There are 10 flood meteorological offices located in Agra, Ahmadabad, Asansol, Bhubaneswar, Delhi, Guwahati, Hyderabad, Jalpaiguri, Lucknow, and Patna that provide region-specific weather information to flood control rooms and forecasting stations.

In addition, IMD also has the specialization in short-range weather forecasting by using Doppler Weather Radar (DWR). The DWR data are useful in numerical weather prediction models for better estimation of rainfall. The velocity and spectrum width data of DWR can provide weather forecast information in detail. The functioning of Doppler Radar is based on the principle of Doppler's effects. In case of relative motion between the source of the electromagnetic waves and the target, the waves reflected from the target has the change in frequency as compared to the transmitted waves. This change in frequency is called 'Doppler Shift' that is directly proportional to the relative velocity between target and the source of the electromagnetic waves. The DWR is operational round the clock in auto acquisition mode. The range of surveillance is 500 km; however, for the purpose of structural analysis, the range is 300 km. In India, there are six DWR installed along the east coastal regions viz. Chennai, Karaikal, Machilipatnam, Visakhapatnam, Paradip and Kolkata. One at Gopalpur is likely to be installed shortly. A Doppler Radar is installed in Mumbai in the west coastal region with three more at Kochi, Goa and Bhuj likely to be installed shortly. There are 11 DWRs installed in the inland locations in India at Agartala, Bhopal, Hyderabad, Jaipur, Lucknow, Mohanbari, Nagpur, New Delhi, Patiala, Patna and Srinagar. The DWR can be useful in the following observations:

- Amount and rate of rainfall
- Cyclone intensity and wind speed
- Direction and speed of the movement of thunderstorms, tornadoes and cyclones
- Expected storm surge height, potential destruction, etc

There are various IMD centers of prime importance operational through Delhi headquarter that provides support in weather forecasting and early warning-

(A) *National Weather Forecasting Center (NWFC)* is an integrated and automated wing of IMD that provides services in all types of weather forecasting as well as advisory support to all its regional and state offices. The center is based in IMD headquarter, New Delhi, with backup support server at IMD Pune. There are various under mentioned cells of NWFC, which generate weather forecast information by using GIS-enabled modeling software.
   - General forecasting cell
   - Aviation cell
   - Public weather service and multi-hazard monitoring cell
   - Cyclone warning and marine cell
   - Radar and satellite application cell
   - Nowcasting cell
   - Numerical weather prediction cell
   - Hydrometeorology cell
   - Agrometeorology cell
   - Climatology cell

     The products are used by different agencies working on different disasters.

20.4.2.3 National Centre for Medium-Range Weather Forecasting

National Centre for Medium Range Weather Forecasting is engaged in medium-range weather forecast and climate modeling through research, development, and application of advanced technology. The center uses various forecasting models like NGFS, NCUM, NGEFS, and VSDB for generating wind forecast, rain forecast, MSLP, meteogram, trajectory, dust forecast, temperature change forecast, etc. for India as well as Africa, Afro-Asia, Southern Ocean, and Antarctica (ncmrwf.gov.in). The products are used in operational forecasting by organizations like IMD, Indian forces, Snow and Avalanche Study Establishment (SASE), Bhabha Atomic Research Centre (BARC), Indian Institute of Tropical Metrology (IITM), Pune, INCOIS, etc.

20.4.2.4 State Agencies

In addition to CWC and IMD, there are few agencies in some of the states which are involved in weather forecasting and early warning through automatic weather stations (AWS). The information generated through these agencies is useful in the prediction of flood occurrence in the concerned river basins. At present, the states of Andhra Pradesh, Karnataka, Bihar, Tamil Nadu, Odisha, Rajasthan, etc., have established their automatic weather stations either on application or experimental basis; the details about few of them like Karnataka, Andhra Pradesh, and Bihar are as under.

(A) *Karnataka State Natural Disaster Monitoring Centre*

The government of Karnataka has established *Automatic Weather Stations* through Karnataka State Natural Disaster Monitoring Centre based in Bangalore. The automated and timely weather alerts and forecasts are helping farming communities as well as policy planners, including disaster managers to a great extent. The most significant feature of the system is automated generation of weather-related data and instant dissemination to user communities through electronic communication media.

The scope is focused on the real-time weather monitoring, data analysis, vulnerability mapping, risk assessment, report generation, and disseminating information to users (source-KSNDMC).

In the current AWS system, a dense network of GPRS-enabled solar-powered telemetric rain gauge (TRG) stations covering all the 5625 g panchayats and telemetric weather stations at all the 747 hoblies (cluster of few gram panchayats) have been designed and installed in Karnataka. Thus there is a rainfall monitoring station at every 250 km^2 in the state (source-KSNDMC).

The organization, with the help of TRGs and advanced software, generates data on rainfall, dry spells, aridity anomaly, agriculture sowing status, crop condition status of the major reservoir levels, etc. The accumulated reports are generated automatically at KSNDMC and disseminated through e-mails, SMSs, etc., to the concerned government officers and community dwellers.

An interactive help desk *Varuna Mitra* has also been established by KSNDMC to disseminate weather-related information, forecasts, and advisories to farming communities and the general populace. An AWS-based project on *urban flood monitoring and management* has been undertaken by KSNDMC for the city of Bangalore. The aim is to provide alerts and early warning to *Bangalore Municipal Authority* (*BMA*) for onward dissemination to citizens of Bangalore.

In the current system, automated data on the intensity and amount of rainfall is collected at every 15 min interval. Forecast information is generated at KSNDMC by using such data that are sent to concerned government officials of Bruhat Bangalore Mahanagara Palike (BBMP) through SMSs and e-mails.

During the situation of high rainfall, a *High-Intensity Rainfall Alert* (*HIRA*) is automatically generated and sent to these officials through the same media. Hourly rainfall maps are also generated, which are useful in rainfall variability analysis (source-KSNDMC)

(B) *Andhra Pradesh State Development Planning Society*

The state of Andhra Pradesh has established *Integrated Flood and Cyclone Warning System* by using automatic weather stations (AWS). The system is developed and implemented *by Andhra Pradesh State Development Planning Society* (*APSDPS*) based in Hyderabad.

The real-time flood warning system is being implemented for 24 river systems, including rivers like Pennar, Krishna, Godavari, Nagavali, and Vamsadhara covering a total area of 6.85 lakh square kms. The APSDPS, with the help of automatic weather stations, capture spatial and temporal rainfall data that are used for forecasting rainfall in advance for next 48 h using weather forecasting models. The forecasted rainfall data is then converted into runoff forecast by using hydrological models. This gives an estimate about the potential water levels in the rivers at certain time interval. For this purpose, the *MIKE-11* hydrodynamic model is used. The obtained data is finally loaded in the *MIKE GIS* software to generate potential *inundation map* of the area 48 h ahead of the event. This may enable local administration, policy planners, and local communities to respond appropriately to the emerging situations. The various models used for generating forecast data are *hydrological models* (for runoff estimation), *hydrodynamic models* (flood forecasting), and *rainfall atmospheric model* (precipitation estimation).

The system is providing support to the state government in getting real-time flood forecast information for the next 24 h, runoff estimation, rainfall forecast, potential areas likely to be inundated during high rainfall, etc. (source-APSDPS).

(C) *Flood Management Information System (FMIS)*

The Water Resources Department, Government of Bihar has established a network of flood forecasting and inundation modeling and information system with the help of World Bank known as the *Flood Management Information System (FMIS)*. The main objective of this system includes long-term objectives of developing and implementing a comprehensive information system to support policy planners and administrators of flood-prone areas. The other objectives are to develop flood hazard characterization and operational flood management information products, updated flood control manuals, etc. The system is based on technologies of GIS, remote sensing, rainfall forecast modeling, etc. FMIS may be extremely useful in the state in terms of providing rainfall forecasts; flood forecasting and inundation predictions; flood hazard zonation mapping; hazard, vulnerability, and risk analysis; etc. The system is being installed in a phase-wise manner in the state covering most vulnerable and vulnerable flood districts like East Champaran, Muzaffarpur, Begusarai, Samastipur, Darbhanga, Sitamarhi, Sheohar, Madhubani, Supaul, Saharsa (first phase) and Patna, Bhagalpur, and Munger districts (second phase).

20.5 Flood: Hazard and Risk Management

While defining flood, two main concept emerges out to understand – firstly flood is the phenomenon of water, streams, and rivers in a particular area and secondly no flooding may occur if the water is easily and quickly drained out or managed. Hence the concept of flood as a hazard should also incorporate these two points. The dimension of flood has different connotation for different countries in the world. The annual flood in the river Nile in Egypt is considered as the gift of God, which brings life and prosperity in the form of water and fertile silts for the people of Sahara deserts; the similar natural phenomenon brings a calamity somewhere in other parts of the world including India.

It is significant that regions where flooding gain the status of calamity are those where society or community gets affected. Flooding in uninhabited regions does not affect the society and therefore human concerns are less, whereas the same phenomenon that occurred in populated regions seriously affects the society and ultimately gains the status of disaster.

Flood as a disaster has long been a matter of concern for policy planners in India as it brings benefits as well as losses for communities. The annual floods in the Indo-Gangetic plains maintain the fertility of soil by depositing silt containing different minerals carried out from different parts of the mountains. They bring additional water for irrigation, thereby contributing to enhanced fertility in the region, whereas the same flood in larger dimension or in unprecedented situation seriously affects communities living in the floodplain or low-lying areas. In other parts of the country, the flooding occurs due to heavy torrential rainfall combined with poor drainage, that causes disasters in the society resulting in the loss of lives populations and infrastructures. The recent examples are Uttarakhand flood (2013) and J&K flood (2014).

In order to prevent this hydro-meteorological phenomenon attaining the status of disasters, there is a need to adopt a comprehensive, integrated, and scientific approach. Flood disaster management approach is essentially required in India because it affects the normal functioning of societies or communities, but above all, the optimal utilization of land and water resources is of vital importance to bring prosperity in the country.

On the account of unique and varied geo-climatic condition right from the extra peninsula in the north to peninsular tip in the south and from Arunachal Pradesh in the east to the extreme western Thar Desert, the nature and scope of flood risk varies greatly; therefore the risk management strategies and disaster management plan during the flood disaster must address all the topographical, geographical, and climatic conditions to effectively combat the potential threats.

The "National Water Policy" has suggested that there should be a master plan for flood control and management, for each flood-prone basin. It is essential to promote watershed management practices through water management, soil conservation, catchment area development, etc. to reduce the intensity of floods.

The systematic approach of flood management and mitigation in India at the policy level was started by the Government of India in the year 1954 after the unprecedented floods in different parts of the country. A policy statement by the Ministry of Planning, Irrigation, and Power was placed before the parliament under two separate categories – "floods in India (problems and remedies)" and "the floods in the country." The objective was to suggest a comprehensive framework for the management of flood disasters in the country. Since then, various committees have been constituted from time to time to suggest recommendations, strategies, and policies on various flood management and mitigation issues.

Table 20.17 Agencies constituted for flood management (1954–2004)

Sl. No.	Committee/working groups/task forces	Year	Highlights/recommendations of the report
1.	Policy statement	1954 (3rd Sept)	Submitted by union ministry of planning, irrigation and power before the parliament Highlighted two main statements – “floods in India (problems and remedies)” and “the floods in the country” Objective was to get rid the country of the menace of floods by containing and managing them
2.	Supplementary statement	1956 (27th July	Came after the policy statement in a less modified form Emphasized to “curb and confine the floods and do all the possible to save people from the harm and devastation they bring” Absolute immunity from flood damage was not physically possible, even in the distant future
3.	High level committee on floods	1957 (Dec.)	Absolute or permanent immunity from flood damage is not physically attainable by knowing the methods of flood control Measures like floodplain zoning, flood forecasting, and warning should be given due importance Flood control schemes should fit in other water related plans Future multipurpose project should consider inclusion of flood control aspects Effects of embankments on river regimes should be considered in project proposals Priority for soil conservation work relating to flood control Priority for watershed management
4.	Policy statement	1958	While substantial diminution of flood related distress is possible, immunity against flood is impracticable
5.	Minister’s committee on flood control	1964 (February)	To review the national flood control policy outlined in 1954 Recommended more attention to nonphysical measures like flood warning and forecasting, floodplain zoning, flood insurance, etc.
6.	Working group on flood control for the 5-year plans		Suggested appropriate strategies to formulate proposals, including mobilization of resources for each 5-year plan and recommended measures required for effective flood management programs in the country
7.	Rashtriya Barh Ayog (RBA)	1980 (March)	A total of 207 recommendations given covering the entire gamut of flood problem in the country Data collection on long-term performance and their impact Legislation and enforcement by states to prevent unauthorized river bed cultivation and encroachments into drains, etc.

(continued)

Table 20.17 (continued)

Sl. No.	Committee/working groups/task forces	Year	Highlights/recommendations of the report
			Separate reporting of flood damage for protected and unprotected areas and areas situated between embankments
			Legislation for management of floodplains
			A comprehensive, dynamic, and flexible approach to the problem of floods
			Priority for measures to modify the susceptibility of life and property to flood damage
			Priorities for the completion of continuing schemes
			Provision of adequate funds for maintenance
			Intensifying studies on sedimentation of reservoirs
			Forming a national council for mitigating the effect of the disaster
8.	Pritam Singh Committee Report	1980	To examine the erosion problem in West Bengal on both river Ganga upstream and downstream of Farakka barrage
			Suggested priority areas for undertaking anti erosion measures
9.	National Water Policy	1987	Basin-wise master plan for each flood-prone basin
			Sound watershed management and catchment area treatment
			Adequate flood cushion should be provided
			Emphasis on flood forecasting and floodplain zoning to minimize flood damage
10.	Report of the committee on flood management in northeastern states – **Naresh Chandra committee**	1988	Committee constituted after the great flood of Brahmaputra valley in 1987
			Recommendations of the RBA should be implemented by the state governments
			Anti-erosion works are costly and can be justified only when protection is provided for vital installations
			For drainage improvement, the adequacy of existing sluices and drainage channels should be checked in a timely manner
11.	Committee on flood management in Bihar, West Bengal, Uttar Pradesh and Orissa	1988	Committee constituted after the severe flood of Bihar, West Bengal, U.P., etc., in 1987
			Embankment should continue as cost-effective and quick measure
			Early completion of projects should be ensured
			Construction of raised platform for government or acquired land

(continued)

Table 20.17 (continued)

Sl. No.	Committee/working groups/task forces	Year	Highlights/recommendations of the report
			Ensuring adequate waterways to ease out drainage congestion
			Operation of existing reservoirs, keeping flood moderation in mind
			Floodplain zoning implementation
			Setting up of Tal development authority
			More funds for unfinished schemes in the Sundarbans of West Bengal
12.	Recommendations of the regional task forces	1996	Committee constituted after the monsoonal floods of Rajasthan and Haryana in 1996
			Govt. of India (GoI) had constituted 5 regional task forces:
			Eastern Region task force
			Northeastern Region task force
			Northern Region task force
			Northwestern Region task force
			Southern Region task force
			Main thrust of task forces was to implement the main recommendations of RBA, preparing a catalogue of embankments existing in various river systems
			10% of the annual outlay to be earmarked for flood control structure
			Studies and reviews on major reservoirs and operation/rule curves
13.	Expert committee for bank erosion problem of river Ganga-Padma in districts Malda and Murshidabad (West Bengal) – **G R Keskar Committee**	1996	Short-term measures for left bank upstream of Farakka barrage in Malda district, construction of two long spurs at Farakka barrage, repair/ restoration of existing protection works
			Short-term measures for right bank downstream of Farakka barrage in Murshidabad district – construction spurs near Bindugram, repair/ restoration of existing protection works
			Long-term measures include monitoring of performance of two long spurs upstream of Farakka
14.	National commission for integrated water resources development plan	1999	To shift strategy toward efficient management of floodplains, flood proofing, flood forecasting, etc.
			Performance of embankments has to be evaluated and suitable changes be made in design, construction, and maintenance for better results
			Network of flood forecasting and warning to be extended to remaining flood-prone areas
15.	Expert group for flood Management in U.P. and Bihar – **G N Murthy committee**	1999	Need for building the realistic data bank on hydrology, topography, geology, morphology, etc.
			Closure of gaps in the embankment
			Construction of storage reservoirs and watershed management

(continued)

Table 20.17 (continued)

Sl. No.	Committee/working groups/task forces	Year	Highlights/recommendations of the report
16.	Working group on flood control program for the 10th five-year plan – **R Rangachari working group**	2001	Suggested on the future strategy of FM
			International dimension of flood management
			Review of the implementation of RBA recommendations
17.	Report of the committee on Silting of Rivers in India – **Dr. B K Mittal committee**	2002	Studied the problem of silting in Indian Rivers and feasibility of desiltation
			Recommended catchment afforestation, right practice of land use, catchment area treatment, etc.
			Construction of suitable hydraulic structures
			Embankments along the aggrading rivers
			Selective dredging may be undertaken
18.	National Water Policy	2002	Basin-wise master plan for flood control and management
			Adequate flood cushions in reservoir projects
			More emphasis on nonstructural measures
			Strict regulations of settlements
			Flood forecasting activities to be modernized
19.	Expert committee to review the implementation of the recommendation of Rashtriya Barh Ayog – **R Rangachari committee**	2003	Flood damage assessment is not done realistically or on a scientific basis as per RBA recommendations. This needs corrective steps
			Lack of representative, scientific, and credible post-project performance evaluation
			Unabated and unplanned intrusion into the floodplains and river beds has now reached alarming dimensions
			Most of the recommendations of RBA have not been implemented
			Interstate issues in multi state river basins are a very important matter waiting to be effectively addressed
20.	Committee for the identification of critical "Anti Erosion schemes of Ganga basin states for inclusion in CSS to be implemented during 10th plan" – **C B Vashistha committee**	2003	Recommendations came after the committee visited river Ganga in Uttar Pradesh, Bihar, and West Bengal for assessment of the problem and gave its recommendations
21.	Technical group on flood control and erosion problem of North Bengal- **M K Sharma committee**	2004 (July)	Rivers like Teesta, Torsa, Raidak, and Mahananda, draining the North Bengal along with their several tributaries causes serious flood erosion problems in the region
			Design flood estimation may be done in accordance with the subzonal report of CWC (Manual of Estimation of Design Flood 1961)
			River training/activation of channel may be attempted
			Maintenance of embankments during the pre monsoon and monsoon period may be undertaken
			Comprehensive plan for flood management for the North Bengal may be prepared
			Materials such as bamboos, branches of trees, river shingle, etc., can be utilized for inducting siltation thus diverting the river flows and preventing bank erosion

(continued)

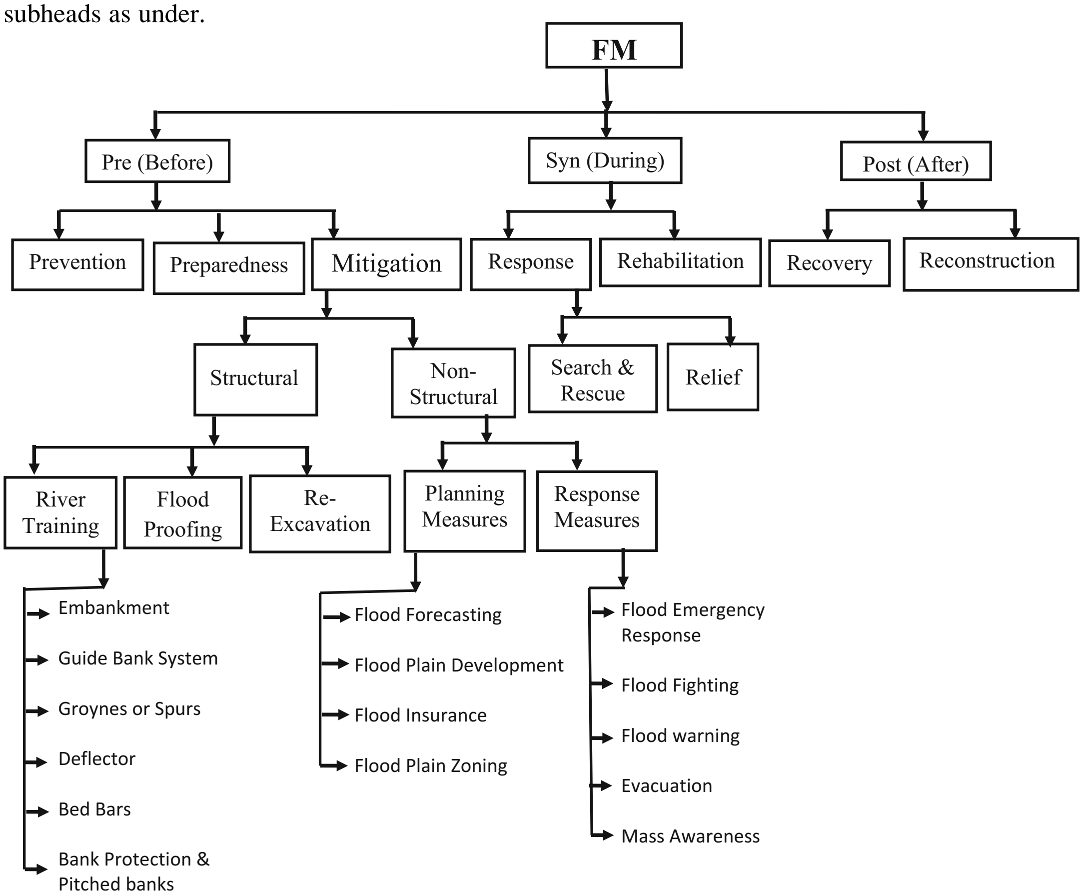
Table 20.17 (continued)

Sl. No.	Committee/working groups/task forces	Year	Highlights/recommendations of the report
22.	Task force on flood management/erosion control	2004	Looked into the recurring problem of floods in Assam and neighboring states like Bihar, West Bengal, and Eastern Uttar Pradesh
			Flood control schemes should be funded through the centrally sponsored scheme in the ratio of 90 % central and 10 % state
			Total investment of plan/flood management may be increased
			Funds in the state sector are earmarked as additional central assistance for the maintenance of embankments
			A revolving fund of Rs. 50 Crores is available to MoWR to take up emergent flood management schemes
			Funding the flood control component of the reservoir projects
			Authority in the northeastern region with all the statutory powers be set up
			Sikkim and North Bengal River Management Board be established
			Ganga flood control commission be strengthened by the addition of the post of member (works), etc.

The list of all the committees/working group constituted since 1954 is as under (Table 20.17).

Though several good policy initiatives were taken by the government of India to minimize the menace of floods in the country, the one which is of greater significance was the constitution of *Rashtriya Barh Ayog* (RBA). In 1976, the government constituted RBA under the chairmanship of Mr. Jaisukhlal Hathi, the then governor of Punjab/Haryana, to look into the contemporary situation of floods in the country and to carry out in-depth study of the long-term flood management approach. This was the most comprehensive study of flood carried out by any committee since independence. It looked into various flood problems and submitted its report in 1980 with 207 recommendations covering almost all the aspects of flood management. However, the implementation of recommendations by different states remained mostly under the slow pace. In order to review the progress of implementation of RBA, few committees were further constituted including an expert committee setup in 2001 by the Ministry of Water Resources under the chairmanship of Sri R. Rangachari. The committee reviewed each of the recommendations of RBA and opined that its implementation has been slow which requires more attention by the concerned stakeholders. The committee further suggested 40 out of 207 recommendations to be taken up on priority basis.

In many of the recommendations listed in previous pages by different committees/commissions, it was strongly felt that practically it is not possible to protect all areas against high flood and structural mitigation measures alone cannot be considered as appropriate for flood management, there should be a combination of both structural and nonstructural measures on flood mitigation, so that overall losses could be minimized. The flood management measures can be classified into the following categories and subheads as under.



20.5.1 Flood Prevention, Preparedness, and Mitigation

Flood is a natural phenomenon of rivers and channels at the time of high discharge that cannot be prevented or checked through human interventions; however, its impact in the form of disasters may be prevented to a greater extent through better response planning, preparedness and mitigation approach. Disaster prevention, preparedness, and mitigation are such measures through which potential disaster threats can be minimized or even prevented (Ghosh 1997).

20.5.1.1

There are various preventive measures, which, if adopted in a right manner, at the right time, and at the right place, can avert the threats of potential disaster situations. The flood prevention measures can be the combination of both structural and nonstructural measures as mentioned below:

(A) *Rainfall Runoff Balance* – A complete balance of rainfall-runoff can be the best preventive measure for flood hazards. Due to the occurrence of high-intensity rainfall, resultant runoff becomes heavier and faster, which decreases the carrying capacity of rivers with resultant flooding in the adjoining areas. A large-scale catchment area treatment, including *Afforestation* and *reforestation*, may delay the surface runoff to reach river channels, thus minimizing the risk of flood disaster. The forest and vegetation cover can be helpful in a number of ways which includes delaying surplus water to reach river channels. They can promote infiltration of rainwater, thus preventing threats of flood as well as saturating groundwater. Forest and vegetation cover can also reduce soil erosion, thus preventing silts to be deposited in the river beds, thus increasing the water carrying capacity of rivers.

(B) *Smooth flow of discharge through river channels* – Developing smooth flow of discharge through river channels may be a good option for flood prevention, provided the socio-economic viability is ensured. This includes making meandering course of rivers straighter and linear, so that flood discharge may move downstream more rapidly. This was successfully experimented in 1933–1936 in river Mississippi (USA) near Greensville and on the river Missouri (USA) in Sioux city.

(C) *Detention of surplus water* – The flood storage reservoirs and detention basins are the structural measures of flood prevention that reduce the volume of water to reach river channels at the time of high discharge thus averting threats of disasters. The construction of reservoirs and detention basins helps in retaining surplus waters during peak flow, thus reducing threats of floods in downstream areas. In addition, the stored water may also be used for the purpose of irrigation and drinking water. The Tennessee Valley project in the USA and Damodar Valley project in India were undertaken for multipurpose utility, the prime being flood control (Sinha and Sinha).

(D) *Diversion of excess water to deficit regions* – At the time of high discharge, there is a need to divert flood water in low-lying areas, depressions, or secondary channels so that excess water may be used for other purposes and can be transferred to deficit areas. For example, Ghaggar Diversion Scheme in Rajasthan had used to divert about 340 cumecs of water discharge to a low-lying depression before entering Rajasthan.

20.5.1.2 Flood Preparedness

The preparedness for flood is an integral and most crucial element of the flood management plan which aims to minimize the adverse impact of flood hazard through effective precautionary measures and to ensure effective response at the time of disaster. The primary responsibility of flood preparedness in India lies with the state and district administration to make preparedness plans based on risk assessment and vulnerability analysis of floods. The following preparedness measures should be undertaken in any flood management program:

- State Authorities and the district administration should regularly check the early warning notices issued by the India Meteorological Department (IMD) and flood forecasting information issued by the Central Water Commission and other agencies.
- State governments or State Disaster Management Authorities must take prohibitive action for the blocking of natural drainage channels and sluices through appropriate policies and laws and also to improve their capacities and construct new channels and sluices to ensure the flow of excess rainwater in the area.
- In flood-prone areas, buildings constructed of earth, weak foundations, and water-soluble materials may collapse and endanger human lives and properties. Such structures may be checked in advance, so that precautionary measures can be taken in advance.
- During excessive rainfall, especially in hilly areas, physical damage in the form of landslides may occur. In addition, some structures may also get damaged due to high-intensity flowing waters. Such areas may be demarcated with the adoption of suitable mitigation strategies.
- Flood preparedness programs should be conducted at the community level, which may comprise of awareness campaigns, mock drills, NGO coordination, resource management, etc.

- District administration in the state should review the existing danger levels and warning levels in their districts, and if required, these level marks should be updated.
- Pre-monsoon inspection of rail tracks, roadways, canal networks, and drainage networks should be conducted periodically.
- In order to prevent outbreaks of epidemics and viral infections, well-coordinated medical preparedness strategies must be adopted well in advance, which may include stocking of emergency medical equipments and medicines and availability of medico and paramedic staffs.

20.5.1.3 Flood Mitigation

The flood mitigation measures are broadly categorized into *Structural* and *Non-structural* based on the kind of interventions. In structural mitigation measures, the emphasis is toward "preventing flood from affecting the society or population," whereas nonstructural mitigation measures aim to "keep people away from the flood."

A. Structural Mitigation This involves the process of constructing structures along the rivers or areas which are annually or perennially affected by floods in order to make rivers flow in a guided manner so as not to cause much damage during high discharge. Some of the prominent structural measures are as under:

1. *River Training Works* are types of engineering interventions applied on rivers to regulate and control the flow to river channels and river bed configurations, smooth navigation, control of sedimentation, etc., thereby contributing to flood protection, prevention, and mitigation in the catchment area. This is considered as one of the effective structural measures of flood management. The construction of dykes along the river Ganges for protecting adjoining cities from flood threats was an earlier attempt in the country to adopt river training works. This is considered as one of the successful techniques of preventing sedimentation and river bank erosion in perennially flood affected areas in Assam and Bihar.

There are various types of river training works that are considered helpful in flood management. They are *Bed Bar*, *Bank Protection and Pitched Bank*, *Guide Bank System*, *Groins or Spurs*, *Deflectors*, etc.

Transverse structures	Longitudinal structures
Check dams, Spurs, Sills, Screen dams, Porcupines, etc.	Embankments, Levees, Guide banks, Revetments, etc.

The river training structures are broadly classified into two types based on the alignment of structures with respect to rivers – *transverse structures* and *longitudinal structures*.

Transverse Structures

(i) *Groins or Spurs* are structures constructed in such a way that one part of it is projected toward the river course. They are also known as Spur Spur Dykes, Transverse Dykes etc. This is primarily useful for providing a directional flow to rivers and preventing river bank erosion. The "backward" sides of spurs are zones of moderate to slow flow, which promote siltation in between two spurs thereby creating natural banks along the river.

(ii) *Sill* is a transverse structure constructed on the river bed across the river to reduce downward erosion. This can be of different shapes and materials depending upon the utility of the structure and availability of materials

(iii) *Check dams* are constructed across rivers to stabilize the flow of river channels. These structures decrease the morphological gradient of the torrent bed and reduce the water velocity during a flood event by increasing the time of concentration of the hydrological basins and reducing the flood peak and solid transportation capacity of the river (Shrestha et al. 2012).

(iv) *Sediment retention structures* are created across rivers to filter debris, boulders, and other sediments reaching downstream through flood waters. Whereas the structure like *beam dam* is constructed to retain sediments and silts, s*creen dams* are used for filtering materials like wood, tree trunks, branches, etc.

(v) *Porcupine structures* are useful for retarding the flow of water during peak discharge, thus helping to reduce river banks and bed erosion. They are designed mainly by timber or bamboo in such a way that they are protruded in different directions; however concrete structures are also in use. The common shapes are tetrahedral and prismatic (Shrestha et al. 2012).

Groins on river Narayani, Nepal (Source – northstarnepal.com)

Longitudinal Structures These are technically designed structures constructed along the river course for providing protection against river bank erosion, inundation in low-lying areas, and preventing rivers from meandering its course. They are of the following types:

(vi) *Embankment or Levee* is an earthen longitudinal protection structure, constructed along the course of river channels in such a way as to protect the area behind it from the overflow of flood waters. In India, since 1954, about 35,200 km of embankments have been constructed by March 2011 (XII plan report, GoI). Some of the rivers like the Ganges, Gandak, Damodar, Mahanadi, Godavari, Krishna, and Cauvery are known to have been protected by embankments on a larger scale.

The highlands or high ridges along the rivers are considered as suitable for the construction of embankment provided the soil and ground conditions are suitable. They should also be maintained and protected after construction to avoid any further disasters. In case an embankment is likely to be collapsed or likelihood of flood is more, a *loop bund* is constructed behind the embankment to provide a second line of protection.

(vii) *Bed bar* is a submerged longitudinal structure which divides the flow horizontally in two parts. The flow above the bed bar follows the weir flow, whereas the flow below the top level is obstructed by the bar and diverted toward the nose.

(viii) *Bank protection structures* are artificially constructed surface on river banks or slopes, designed to absorb energy of water waves and to protect them against erosion. Revetment is one of the most common structures of river bank protection wherein artificial slopes or surfaces are created along the bank. This can be done through "rip rap" which is a kind of arrangement of loose rocks or boulders to make the revetment structure.

(ix) *Guide banks*, as the name denotes, are embankment-like structures constructed on rivers to guide the flow of rivers or in other words to provide a directional and controlled flow of rivers. The guide bank system works on the principle that a flood partially controlled and directed by the groins should confine in a directional flow to ensure its safe passage without destroying the river banks or other structures.

2. *Flood proofing* is the long-term measure to mitigate the effects of flooding through modification of building and other infrastructures in the immediate surroundings of flood-

vulnerable locations in order to minimize the damage due to flood.

B. Non-structural Mitigation This involves planned activities to mitigate the adverse impacts of flooding without undertaking any structural changes/modifications. Unlike structural measures, this aims to adopt strategies for keeping people away from the flood vulnerability. Some of the common non-structural measures are as under:

(i) *Flood forecasting* and *warning* is the most common and important mitigation measure being adopted in India. This has already been discussed in the previous pages of this chapter.
(ii) *Floodplain management* is one of the major thrust areas of government's flood management programs, wherein more emphasis is on the developmental activities in floodplain areas, to make them encroachment-free to minimize flood damages. The objectives of such programs are:
   - To reduce future potential damage in floodplain and adjoining locations
   - To develop strategies for maximum utilization of floodplains for developmental activities during non-flood peak periods
   - To regulate and control floodplain through regulations, by-laws, building codes, policies, etc.

20.5.2 Flood Response and Rehabilitation

Flood response measures are activities undertaken at the time of flood occurrence or at the time when flood threats are imminent. The response measures undertaken by responder teams/organizations are usually planned, organized, coordinated, and effective at all levels, so that the affected communities get adequate relief at the time of calamity. In India, flood response measures are undertaken at different levels depending upon the severity of floods. In order to have a better management and control over the situation, it is essential to identify the scale of response required and the role of various responders right from the national level to the district and the village level. At the time of flood emergency, institutionalization of the system had to be properly managed at various levels. The response activities should not be confined to a single organization either by the government body or the private agencies, but this should be made as multi-organizational with close coordination of multiple stakeholders.

The role of communities as first responders is now an established fact. After any flood disaster, the community responders primarily extend their support with all the available resources; thus any response plan must take into consideration the role of community responders. The local volunteers must be trained by National Disaster Response Force (NDRF) and district/state training institutions in various skills of flood response in each district with basic training in search and rescue, medical first aid, CPR, etc. The community volunteers thus trained can assist in planning and setting up emergency shelters, distributing reliefs, identifying missing people, and addressing the need of education, health care, water supply and sanitation, food, etc. In addition, community level organizations like NGOs, Self Help Groups, community-based organizations, National Cadet Corps (NCC), National Services Scheme (NSS), Nehru Yuva Kendra Sangathan (NYKS), women's group, civil defense, etc., volunteer their services during flood and other disasters. Thus, there is a need that various task forces may also be constituted through active involvements of these stakeholders for inculcating a culture of preparedness to respond at the time of flood. The community-based preparedness and response planning coordination are required among various agencies as under:

The flood response comprises a sequence of activities undertaken by a group of experts or skilled people or even unskilled community dwellers to carry out search and rescue of victims, mobilization of equipments, resources, and services. A successful response planning requires immediate planning, mobilization of resources, quick activation of essential functions etc.

During the situation of all the disasters, including floods, the response planning is strategically designed based on the severity of disasters and the ability of response authorities to deal with the situation. Accordingly, disasters are categorized as **L0**, **L1**, **L2**, **and L3** type (source-ASDMA).

Response severity level	Characteristics
L0	Normal times
	Stage to carry out prevention, preparedness, and mitigation activities
	Stage of research, documentation, and monitoring and planning
	State authority should focus on training and capacity building intervention
L1	Disaster severity is at the district level, which may be managed by the district authority at the district level
	State and central authority must be in readiness to provide assistance if required
L2	Disaster severity has expanded to more than one
	State intervention may be required
	Assistance may be provided from the state headquarters
	Central authority must be in readiness to provide assistance if required
L3	Disaster severity is large which is beyond the capacity of district and state administration to provide adequate response
	Central government intervention may be required
	Central assistance required (courtesy – asdma web site)

Immediately after receiving early warning information, the evacuation is required to be undertaken in a systemic manner. The successful evacuation planning for population and livestock is considered as the only means to save them from flood disasters. Evacuation planning for a larger group of population becomes a difficult task, which required effective *Incident Response System* to be in place. Responsibilities are to be fixed for each stakeholder in the form of *Standard Operating Procedures* (*SOPs*). The successful evacuation depends on a continuous dialogue with the following stakeholders:

The response activities should be carried out with preliminary estimation of the flood situation by studying the flood level data and inundation data received from satellites. This may help policy planners to undertake focused response activities at the right location at right time. While carrying out response activities, effective media management also plays a greater role. The state government may utilize different types of media, viz., print, electronic, and other social media to disseminate early warning of flood occurrence in any locality. This may help authorities to undertake smooth response operations. In addition, last mile connectivity is also ensured with the help of local administration and community-based organizations. Thus the effective response planning is much required in order to have a better culture of prevention, preparedness, and mitigation.

20.6 Role of Geographical Information System (GIS) and Remote Sensing (RS) in Flood Risk Management

The Mitigation of flood hazards can be successful only when the detailed knowledge is obtained about the expected frequency, character, and magnitude of hazardous events in an area as well as the vulnerabilities of the people, buildings, infrastructure, and economic activities in a potentially dangerous area. Remotely sensed imagery and the Geographical Information System (GIS) can be very effective in identifying the spatial component of flood for its better management. Remote Sensing offers a synoptic view of spatial distribution and dynamics of hydrological phenomena such as flood and River Erosion. They are used to measure and monitor the extent of flooded areas and provide a quantifiable estimate of the land area and infrastructure affected by flooding and erosion.

GIS may be defined in different ways, but the most commonly used definition is that provided by Burrough (1986) generally known as "tool box definition." He defined GIS as a *powerful set of tools that enables collection*, *storage*, *retrieval*, *analysis and presentation of geographically referenced information*. Remote Sensing (RS) on the other hand is defined as *the science of acquiring information about the earth's surface without actually being in physical contact with it*. The transfer of information is done using electromagnetic radiation with the aid of sensors. The Remote Sensing plays greater role in the development of GIS, both as a source of technology and as a source of data. Together with RS and modeling, GIS provides a wide range of applications in agriculture, geology, natural disaster management, hydrology, weather monitoring, business and service planning, government, logistics, and transportation and environmental management.

The role of this technology is vital in flood management as the information on the predicted flood extent is required by the government, the public, and the emergency departments in order to facilitate early preparations and plans well in advance before the actual flood event. Early preparations and planning result in the effective and efficient response, thus minimizing and/or mitigating the after flood effects. There has been widespread development in the use of hydrological models with a flood prediction component. These models are in most cases, either loosely or tightly coupled with GIS and remotely sensed data. Most of these models require different types of data input such as land cover, land use, river discharge rate, rainfall amount, surface roughness, Digital Elevation Models (DEM), and size of drainage basin, among others. In this case RS techniques can be used to obtain spatial and temporal information needed for parameterization of the distributed hydrological models. The general idea is that RS and GIS provide spatial and temporal data input required by the distributed hydrological models in order to simulate runoffs and thus floods. Remote sensing (RS) data in some studies have also been utilized to calibrate and improve the performance of distributed hydrological models. The REmote Sensing techniques provide an option of accessing information from otherwise physically inaccessible areas. GIS tools have been imbedded in the hydrological models to facilitate in data analysis, querying, and presentation of information in a more simplified way; thus they form a critical part of the distributed hydrological models used for flood prediction.

One of the key stages in flood management is the identification of areas with potential flood risk that is the product of flood hazard and vulnerability. Mapping of flood risk areas is not only important for the location of potentially hazardous zones but also for government, nongovernmental organizations (NGOs), and other planners to get an idea of where priority should be given while allocating resources. Evacuation agencies, insurance companies, and relief providers also require knowledge of spatial extent of inundated areas. This could be information about roads that may or may not be passable, worst affected areas, and areas suitable for camping during flood periods.

The Remote Sensing and GIS techniques have been proved resourceful at different stages of flood management. For example, areas of potential flood risk were able to utilize the overlaying function of a GIS to combine land cover maps with the flood-predicted zones. The resultant maps provide simplified information on the flood hazard (depth, velocity, direction of flow), elements at risk, their exposure, and vulnerability. In addition, flood hazard, vulnerability, and risk maps were drawn showing areas of low or high flood risk.

The GIS and modeling approaches, in particular, have been used in investigating the possible effects of land use changes during flood. Land use scenarios and their possible impacts in the generation of runoffs and consequently flood management may be useful. This may also be helpful in developing policy guidelines and recommendations for urban planning, land use planning, as well as settlements and types of buildings. In this way, flood impacts can be prevented or even mitigated.

The adequate knowledge of damage inflicted by flood is essentially required by the authorities and insurance companies in order to draw policy for compensation as well as to have an estimate of the cost of reconstruction. GIS has a function of overlaying layers and through this function, layers on inundated areas can be overlaid with land use maps, land cover layers, and infrastructure layers, among others. Remote sensing tool can be used for obtaining images before, during, and after flooding. These images are thereafter processed and analyzed in order to obtain information of land cover, buildings, roads, schools, and other infrastructures of the area under normal hydrological conditions (before flooding), inundated areas and flood extent (during flooding), and flood effects, deposits, and debris (after flooding). When the comparison of these images together with a pre-flood data is carried out, the extent of flood damage can be estimated.

In spite of the great potential that RS and GIS offer in flood management, their use has been limited to some extent. The presence of cloud covers during flood periods has been reported as the major challenge in the use of optical remote sensing in flood management. Using Synthetic Aperture Radar (SAR) is a better option since radar pulse has a higher penetration power to overcome the problem of cloud cover; however, its use, especially in developing countries, has been constrained by its high prices as well as limited coverage. One of the most pressing challenges of remote sensing technology is limited availability of imageries in time and space, seasonal variations, technical limitations, and above all the problem of low temporal resolution. With reference to the problem of temporal resolution, most radar images take some time before and also after the flood and in most cases the flood peak may not be captured. In other words, there is a time delay between the actual time the flood occurs and the time when satellite images are taken. Most of the current radar satellites have a long revisit time that can be up to 35 days. There are other challenges too in the application of GIS technology in natural disaster mitigation. These include high cost of digitization and raw data collection, the intrinsic complexity of predictive models, lack of appropriate raw data, inadequacy of hardware technology to handle large spatial data sets, and difficulty in GIS to manage historical data necessary for some natural hazard assessments. However, the technology has a great prospect in the country that may create revolution in the field of flood management.

20.7 Do's and Don'ts

Time	Phase	Do's	Don'ts
Before	Prevention	Design your houses as structurally flood proof	Don't encroach river channels and floodplain with illegal constructions
		The height of the plinth should be raised above the historic flood level	Don't cut trees & forests in the flood-prone areas. This may loosen soil and may cause river erosion and consequent flooding
		Always keep river channels and floodplain obstruction-free	Stop Deforestation, promote reforestation and afforestation
		Consider producing flood resistant crops	Don't cover topsoil layer with concretes/ metallic surfaces
		Promote/encourage afforestation/ reforestation in areas of flood vulnerability	Don't encourage river aggradation or degradation
		Keep some areas open for percolating excess runoff	Don't promote activities which may weaken the strength of embankment
		Maintain the depth of river channel to accommodate excess water at the time of flood	Don't compromise with the quality of materials for the construction of river training works
		Consider making strong embankments in the flood-prone areas. Embankment should be aligned on the high ridges or natural banks of the river, where land and soil is suitable	Don't release debris, concrete materials, or solid wastes in river channels which may obstruct the flow-causing floods
		If you are a policy planner/engineer, consider applying river training works like construction of groins, deflectors, and bed bars to confine and regulate the flow of river channel	
		Debris or concrete or solid wastes should be disposed off suitably without disturbing river ecosystem	
	Preparedness	Get information about the safe evacuation routes of your community to reach the nearest shelter	Don't keep these items preserved for longer duration. Replace them after 6 months with fresh items
		Keep an "emergency kit" ready. The kit may contain:	Don't give importance to rumors
		Torch with spare batteries	Don't be in panic
		Candles and match boxes	
		Bottle of fresh water (**pref. sealed bottled water**)	
		Bottle of kerosene oil	
		Portable radio with spare batteries	
		Dry foods	
		Umbrella and **rain coats**	
		Gum boots	
		Salt and sugar	
		Keep your "first aid and medication kit" ready. The kit may contain the following items:	
		Essential life savings medicines	
		Packets of ORS or electrical powder	
		Adhesive bandages of various sizes (**20 nos.0**	
		5 × 10 in. sterile dressings	
		Gauze roller bandage (**2 nos.**)	

(continued)

Time	Phase	Do's	Don'ts
		Triangular bandage with safety pins (**2nos**.)	
		Sterile gauze pads 4 × **4 in.** and **3** × **3 in.** (**1 pkt each**)	
		Antiseptic wipes	
		Hand sanitizer	
		Latex gloves (**disposable**)	
		Adhesive tapes (**25** × **5 mm**)	
		Non adhesive absorbent pad (**7.5** ×**10 c. m**)- **4 nos**.	
		Saline solution (**30 ml**)	
		Wound dressing with bandage (**1**)	
		Ambu bags	
		Thermometer	
		Chlorine tablets, **etc**.	
		Always keep a watch on the expiry dates of these items. Replace them with fresh items after a certain period	
		Keep a waterproof bag ready with all your essential documents, photo ID cards, valuables, personal papers, etc.	
		Make an indoor plan of your house indicating which items would be raised or managed if water enters in your house	
		Be a regular listener/viewer of local news from radio/TV for warning and advice	
		Gather regular updates on flood warnings from local authorities like gram panchayats, BDO/Tehsildar office, weather stations, etc.	
During	Leaving houses	Ensure all your personal essential items are packed in waterproof bags	Don't forget to take personal kit, emergency kit, and first aid medication kit with you
		Intimate your neighbors/friends/local volunteers about locations you are shifting to	Don't keep yourself and your family empty stomach. Take light foods at regular interval
		Display your contact number on your house wall, so that you may be contacted in case of emergency	
		Raise all wooden furnitures, carpets, clothings, and other valuables onto the top of the roof under shed or at higher places to avoid contacts with flood water	
		Turn off all electricity/power switches and main power supply. Unplug all electrical gadgets	
		Insert sandbags in toilet bowls and all drainage inlets/outlets to prevent backflow of sewerage/floodwaters	
		Lock your home cautiously. Move through known evacuation routes	
		Always spray disinfectant, bleaching powder, etc., to keep your surroundings free of infection	

(continued)

Time	Phase	Do's	Don'ts
		Extend helping hands to government officials/volunteers distributing relief materials	
	Health care	Always use boiled water for drinking purpose	
		Keep all eatables covered	
		Don't take heavy meals	
		If exposed to diarrhea, ORS solution, rice water, etc., should be taken on periodic intervals	
	Emergency shelter	Immediately rush to higher places preferable at railway tracks or highways	
After	Returning home	Update yourself with the local situation through radio/TV	Prevents children to play or roam in flood water
		Check and repair all electrical appliances before using them	Don't enter receded water of unknown depth
		Eat only fresh foods or sealed foods	
		Before getting supplied pure water, use boiled water by your own	
		Snake bites are common during and after floods. Be careful	
		Always keep antivenom with you	

References

Annual Report (2013) Central water commission, ministry of water resources, river development & ganga rejuvenation. Govt. of India

Flood hazard Atlas of Assam, NRSC-DMS, Hyderabad http://asdma.gov.in/project_flood.html

Ghosh SN (1997) Flood control and drainage engineering 92nd Edition 0; Oxford & IBH Publishers

Manual of Estimation of Design Flood (1961) CWP&C, India

Report of SAARC Workshop on Flood Risk Management in South Asia (2012) SAARc disaster management center & NDMA, Pakistan

Shrestha AB et al (2012)

Sinha SC, Sinha SB Flood problems and management in Bihar

Web References

Andhra Pradesh State Development Planning Society. http://www.apsdps.ap.gov.in/

Assam State Disaster Management Authority Portal. www.asdma.nic.in

Central Water Commission, Ministry of Water Resources, River development & Ganga Rejuvenation, Government of India. http://www.cwc.gov.in

Flood Forecast Information System, Central Water Commission. http://www.india-water.gov.in/ffs

Flood Management Information System, Water Resources Department, Govt. of Bihar. http://fmis.bih.nic.in/

Govt. of Bihar web page. www.bihar.nic.in, http://disastermgmt.bih.nic.in/

India Meteorological Department, Govt. of India http://www.imd.gov.in

Karnataka State Natural Disaster Monitoring Center. http://dmc.kar.nic.in/

Maldives Disaster Knowledge Network. http://saarc-sadkn.org

SAARC Disaster Knowledge Network Portal. www.sadkn.org

The International Disaster Database. http://emdat.be/

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