Course Name: Watershed Hydrology

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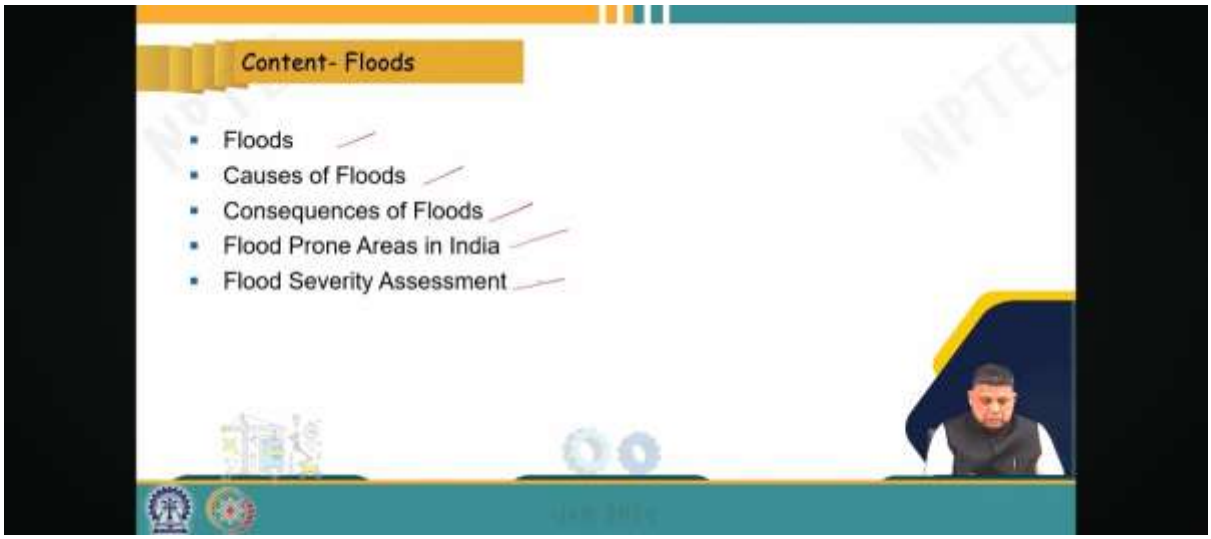
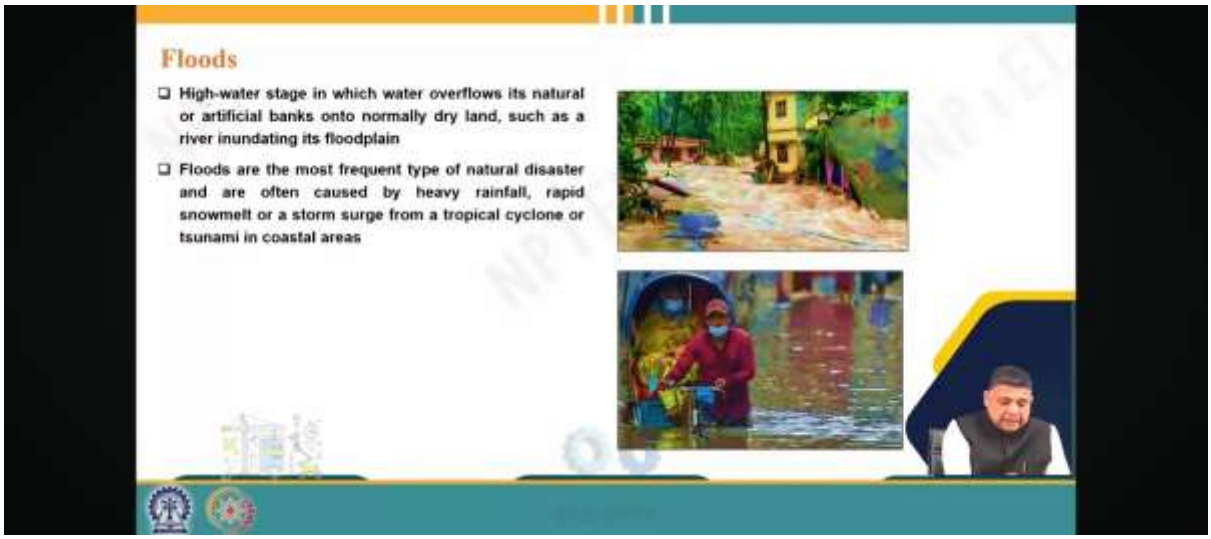
Week: 09

Lecture 41: Floods



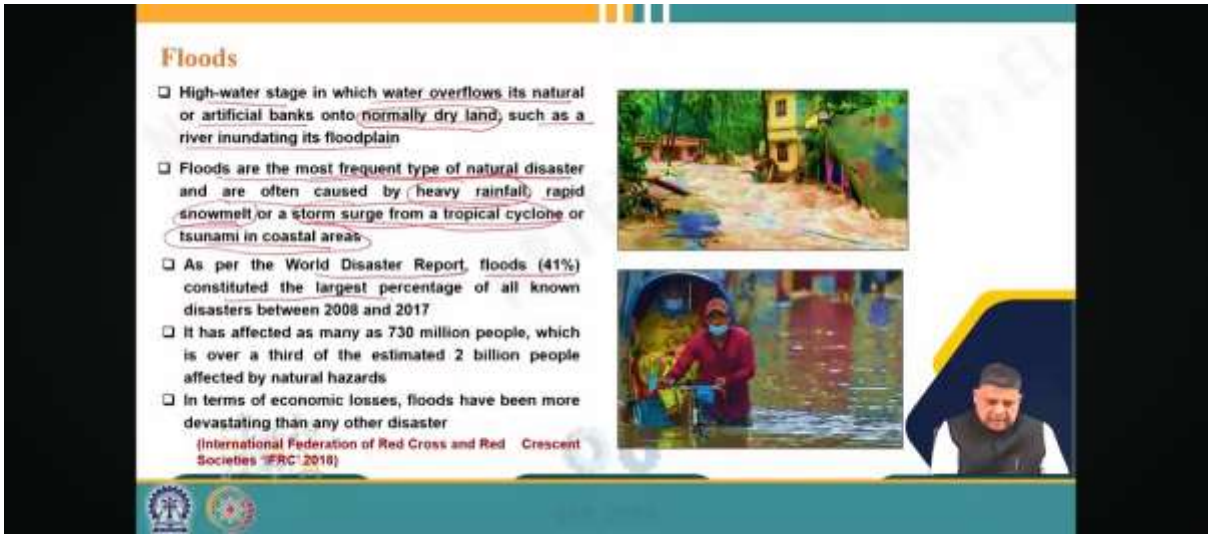
Hello friends, welcome back to this online certification course on Watershed Hydrology. I am Rajendra Singh, a professor in the Department of Agriculture and Food Engineering at the Indian Institute of Technology Kharagpur. We are beginning Module 9, and this is Lecture 1 where we will be starting with floods. So, in this lecture, we will be introducing floods, talking about the causes of floods, discussing the consequences of floods and addressing flood-prone areas in India and how to assess flood severity.



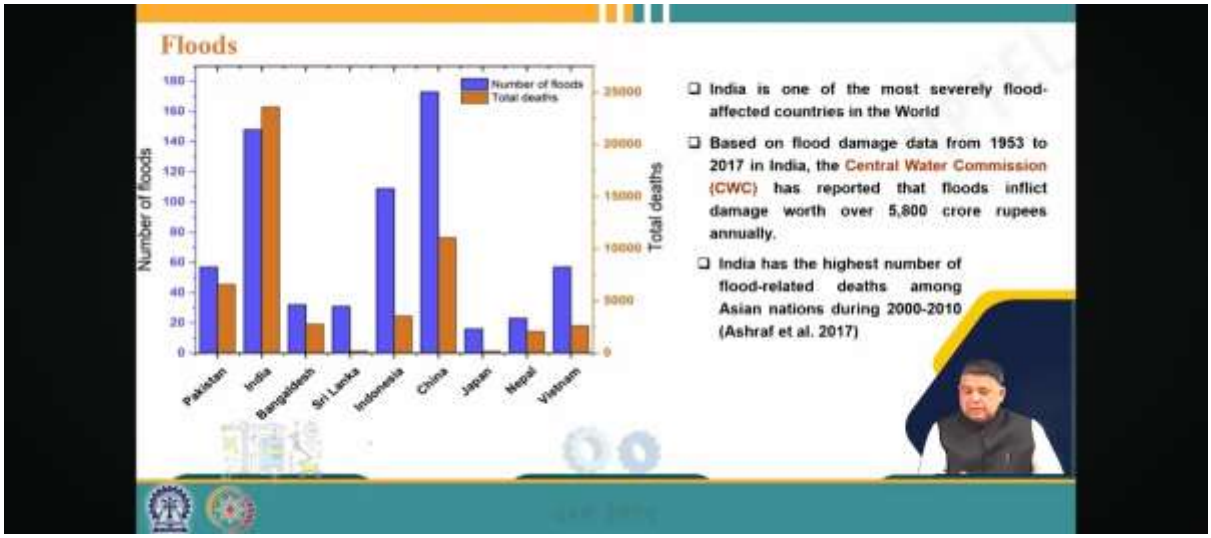
Now, coming to floods, a flood is basically a high-water stage in which water overflows its natural or artificial banks onto normally dry land such as river under dating its flood plain.

Floods are the most frequent type of natural disasters and are often caused by heavy rainfall, rapid snow melt or storm surge from a typhoon or tsunami in coastal areas.

So, basically, a flood is nothing but an unusually high-water level or discharge in a river, and because of this, the river banks are overflowed, causing the normally dry land adjoining the rivers to be flooded. This results in a high level of water on the floodplains. Floods are the most frequent type of natural disasters and are caused by heavy rainfall, rapid snow melt, storm surge from a typhoon, or tsunami. All the activities through which there is plenty of inflow or input into the basin alter the water balance of the basin and cause floods. According to the World Disaster Report, floods constituted the largest percentage of all known disasters between 2008 and 2017.



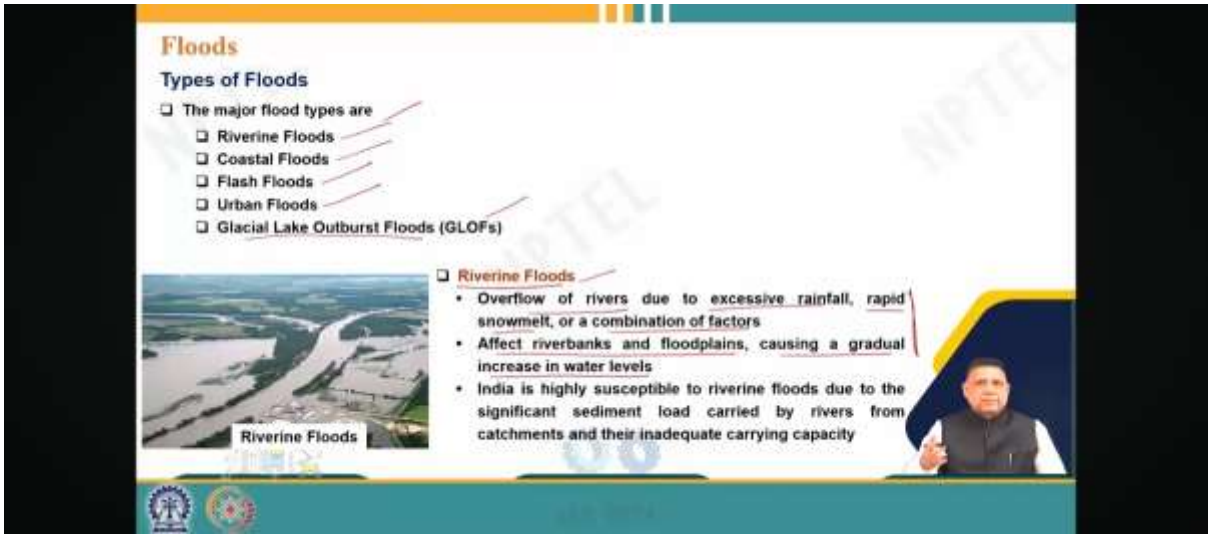
So, based on the data between 2008 and 2017, the World Disaster Report said that 40 to 41 percent of the disasters were floods. So, that is why they were the largest percent they carried, covering the largest percent of all known disasters and affecting as many as 730 million people, which is over a third of an estimated 2 billion people affected by natural hazards. So, around 2 billion people were affected during this period because of various natural hazards, and one-third of them, that is around 730 million people, were affected by floods only. And in terms of economic losses, floods have been more devastating than any other disaster, as reported by the International Federation of Red Cross and Red Crescent Societies (IFRC) in 2018. So, the flood is the most frequently occurring natural disaster and causes the most economic losses compared to any other natural disaster.



If you talk about India, India is one of the most severely flood-affected countries in the world. Based on the flood damage data from 1953 to 2017 in India, which means around 47 plus 17, that means 64 years of data, the Central Water Commission, which is a custodian of all flow data in the country, has reported that floods inflict damage worth over 5800 crore Indian rupees annually. So, in India, floods cost around 5800 crores of Indian rupees every year. It has also been reported that India has the highest number of flood-related deaths among Asian nations during 2000 to 2010, as reported by Asraff and others in 2017. This is the figure which shows that floods during 2000 to 2010 in different Asian countries. As you can see, the blue colour shows the number of floods whereas the orange colour shows the total deaths.

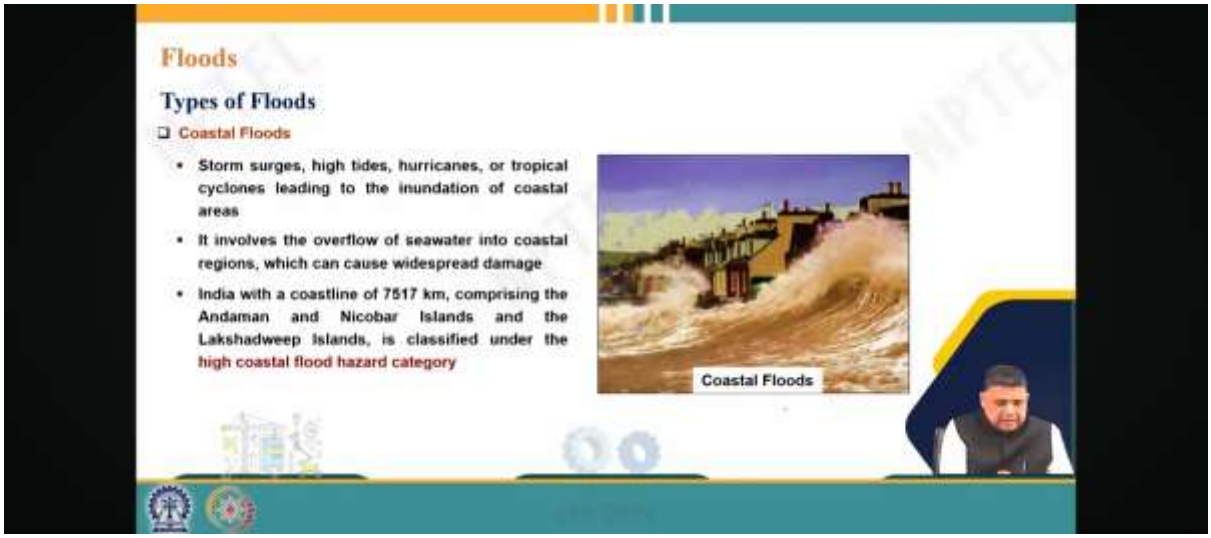
So, if you look at the number of floods, India is second after China. So, China has the most floods occurring over this 10-year period in this decade where in India was number 2, but if you look at the total deaths then India surpasses all other countries by a big margin. So, you can see that China is number 1 which is much below India. And if you look at the data over the period, we lost almost around 22 to 23,000 people and that makes it on average we lose 2000 human lives to floods. So, that means, adding to these 3 reports that annually India flood management cost India around 5800 crores rupees and also, we lose almost 2000 plus lives every year because of the floods.

So, that is the kind of damage floods do in our country. Now, coming to types of floods, the major flood types could be divided into different categories, 5 different categories. Riverine floods, coastal floods, flash floods, urban floods, and glacial lake outburst floods or lofts which are a special type of floods. Now, talking about riverine floods, overflow of rivers due to excessive rainfall, rapid snowmelt or a combination of factors results in riverine floods. And it affects river banks and floodplains causing a gradual increase in water level.



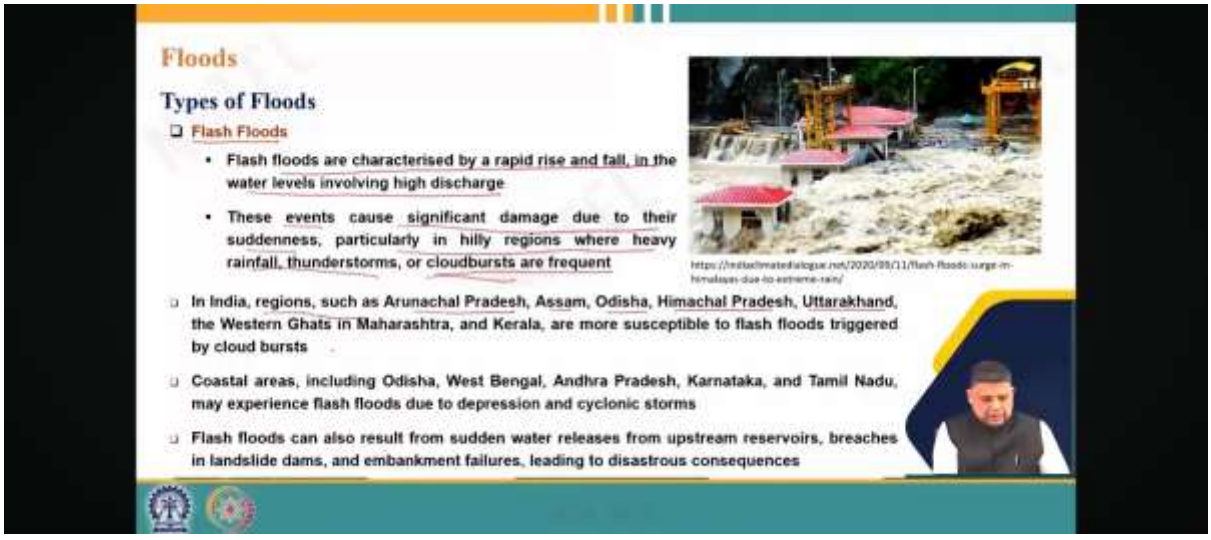
So, obviously, this is the most common type of flood which we come across every monsoon. You must have seen or must have read newspapers or you have seen in the news or even in person that because of the excessive rainfall or snowmelt or combination that means, excessive flow because of one region or the other the rivers overflow their banks. And of course, then floodplains, that is the adjoining area of the rivers, they get higher water levels than usual and that basically is nothing but flood and that is called riverine flood. And India is highly susceptible to riverine floods due to the significant sediment load carried by rivers from catchments and their inadequate carrying capacity. So, obviously, we know that when excessive rainfall occurs in the catchment, the flow reaches the rivers and that raises the water stage or the discharge basically. In a similar fashion, if the catchments are not properly at the soil conservation measures are not properly in place in those areas.

So, obviously, soil erosion will be significant due to the high rainfall or higher amount of flow, including overland flow, and that is why a huge amount of sediment passes through the rivers. And because of this significant sediment load carried by rivers, I mean if the sediment load increases, so obviously, their carrying capacity reduces, which causes even more, or rather, which creates more chances of flood. So, that means, the catchment, whether it is rainfall in the catchment or sediment loss in the catchment, all cause riverine flood problems downstream. Then the second type of flood is coastal floods, of course as the name suggests, we are talking about the coast only. So, storm surge, high tides, hurricanes or tropical cyclones lead to the inundation of coastal areas.



So, obviously, wherever there is a storm, storm surge or high tides or hurricanes, or tropical cyclones. So, because of that, of course, the sea water level rises and inundates the coastal areas. It involves the overflow of seawater into coastal regions which can cause widespread damage. So, obviously, flood damage, we have already seen, it could be loss of human lives or loss of property. We will talk about the consequences later, but all these are possible, and of course, it would cause seawater intrusion, also affecting water quality.

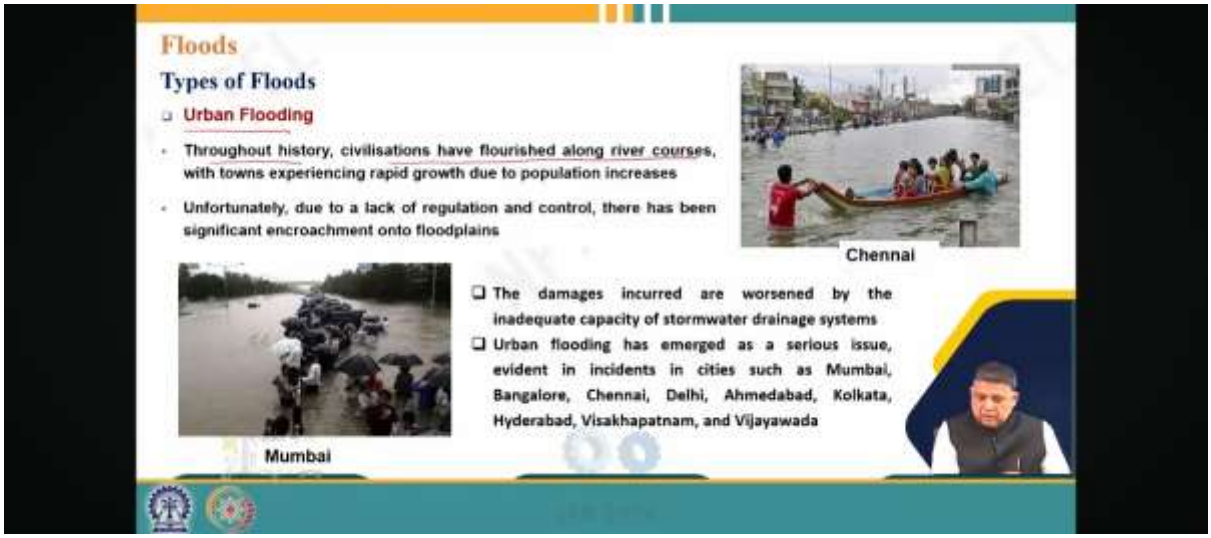
India has a coastline of 7517 kilometers, comprising the Andaman and Nicobar Islands and the Lakshadweep Islands. That means, including these two islands, India has a coastline of 7500 kilometers, a large number, and that is why it is classified under the high coastal flood hazard category. Because of the very high coastline, India always has a chance of high coastal flood and that is why that is a point of concern for the country. Then the third category is flash floods. Flash floods are characterized by rapid rise and fall in water levels involving high discharge. These events cause significant damage due to their suddenness, particularly in hilly regions where heavy rainfall, thunderstorms, or cloud bursts are frequent.



So, obviously, the flash flood means it comes as a flash, which means it occurs suddenly and that is primarily because of the release of a huge amount of water from the source. It could be because of heavy rainfall in hilly regions, thunderstorms, or cloud bursts, which are again instances of very heavy rainfall at 100 millimeters per hour intensity. Because of this sudden

release, a huge amount of water reaches the hilly terrains, and of course, due to the slopes, the velocity of flow is also very high. So, the flow moves very quickly, and that is why the name flash floods suddenly occurs as a flash. In India, regions such as Arunachal Pradesh, Assam, Orissa, Himachal Pradesh, Uttarakhand and Western Ghats in Maharashtra and Kerala are most susceptible to floods triggered by cloud burst. Cloud burst, as discussed earlier, quite often occurs, causing havoc almost every year in states like Himachal Pradesh or Uttarakhand. Coastal areas, including Orissa, West Bengal, Andhra Pradesh, Karnataka and Tamil Nadu, may experience flash floods due to depression and cyclonic storms.

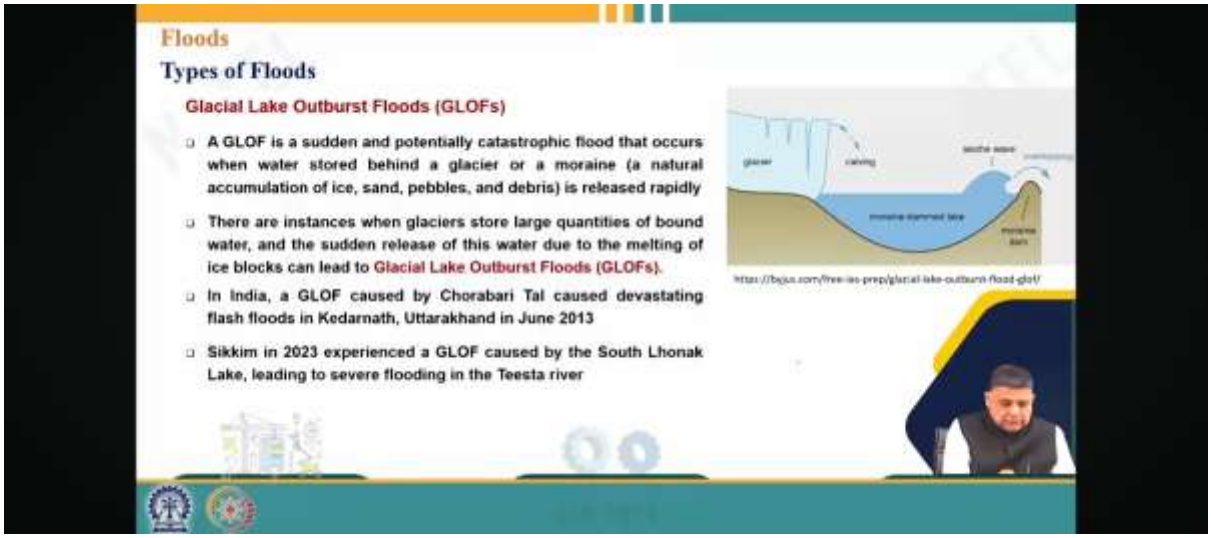
So, obviously, though the coastal areas in these states may experience flash floods due to depressions or cyclonic storms. Flash floods can also result from sudden water release from upstream reservoirs, breaches in landslide dams, and embankment failures, leading to disastrous consequences. So, obviously, if suddenly there is a dam break or heavy rainfall causing flow from the catchments, the reservoirs are in danger. So, the gates may be opened suddenly, which often happens during the monsoon season in India. Because the gates are suddenly opened, a huge amount of floodwater is released downstream, causing flash floods in downstream reaches and thus suddenly causing problems for the people living downstream.



Then we have urban flooding, the next type of flood is urban flooding and in this, of course, throughout history, we know that civilizations have flourished around river courses, with towns experiencing rapid growth due to population increase. So, obviously, historically, humans had a tendency to settle around river courses because of the easy availability of water, and of course, with time, we know that because of the population increase and the movement of people from rural to urban areas, towns have experienced rapid growth. And unfortunately, due to lack of regulation and control, there has been significant encroachment onto floodplains. So, that means the adjoining areas of rivers which were supposed to remain with a minimum of activity in order to take care of the sudden rise in the water levels in the river, but because we do not have serious regulations in place and controls in place, there has been encroachment and people have built constructed houses and all kinds of commercial activities are going on into floodplains you can see in any major town. And the damages incurred are worsened by the inadequate capacity of stormwater drainage systems too.

So, of course, the floodplains are choked because there is no place for river water to flow at the same time when the buildings and development take place the stormwater and drainage system

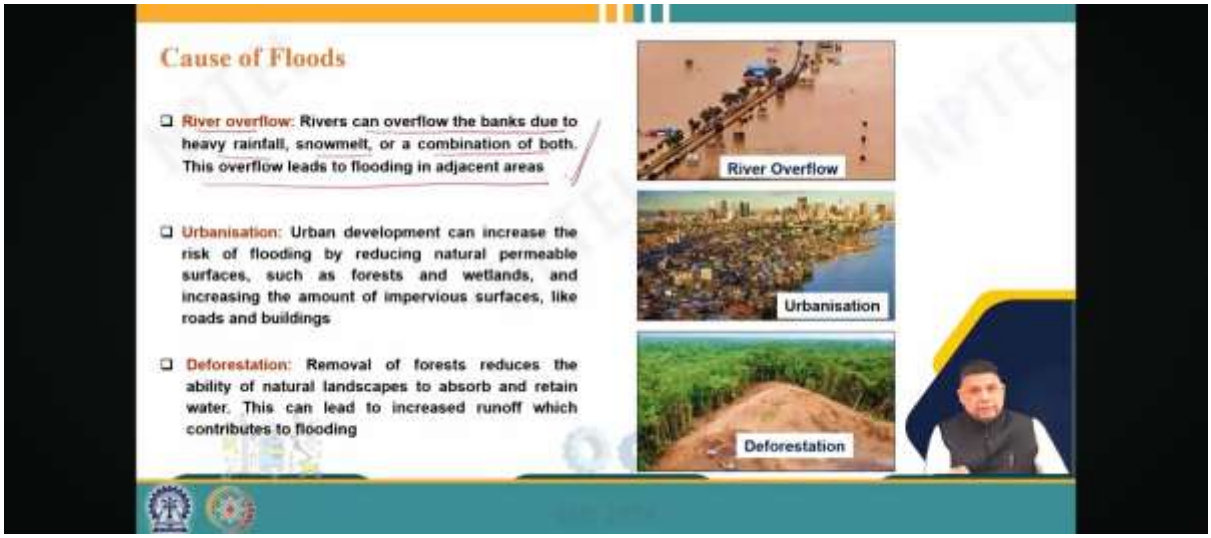
is not given proper thought and not developed properly and or whatever storm system is that also gets choked because of uncontrolled throwing of garbage. And as a result, there is no place for water to flow and that causes flooding and urban flooding. And in the same times, we have seen that urban flooding has been very common you can see the pictures I mean quite often almost every year you see get to see these pictures either in Chennai or Mumbai or Delhi or Calcutta or some major town. So, urban flooding has emerged as a serious issue evident in incidents in cities such as Mumbai, Bangalore, Chennai, Delhi, Ahmedabad, Calcutta, Hyderabad, Visakhapatnam, Bojanala. That means, you take any major city which has grown in the past few years or rather overgrown in the past few years you will find that there is an issue of urban flooding and there in such areas.



Then we go to glacial lakes and which is glacial lake outburst floods (GLOFs). A GLOF is a sudden and potentially catastrophic flood that occurs when water is stored behind a glacier or a moraine, which is a natural accumulation of ice, sand, pebbles, and debris, and it is released rapidly. There are instances when glaciers store a large quantity of bound water, and then sudden release of this water due to melting of ice blocks can lead to glacial lake outburst floods. So, basically, it's kind of a flash flood because of the suddenness of this activity, where water stored behind the glacial or moraine is released rapidly because of the melting of ice. And in India, GLOFs have been happening in the previous few years; we have seen some major incidences.

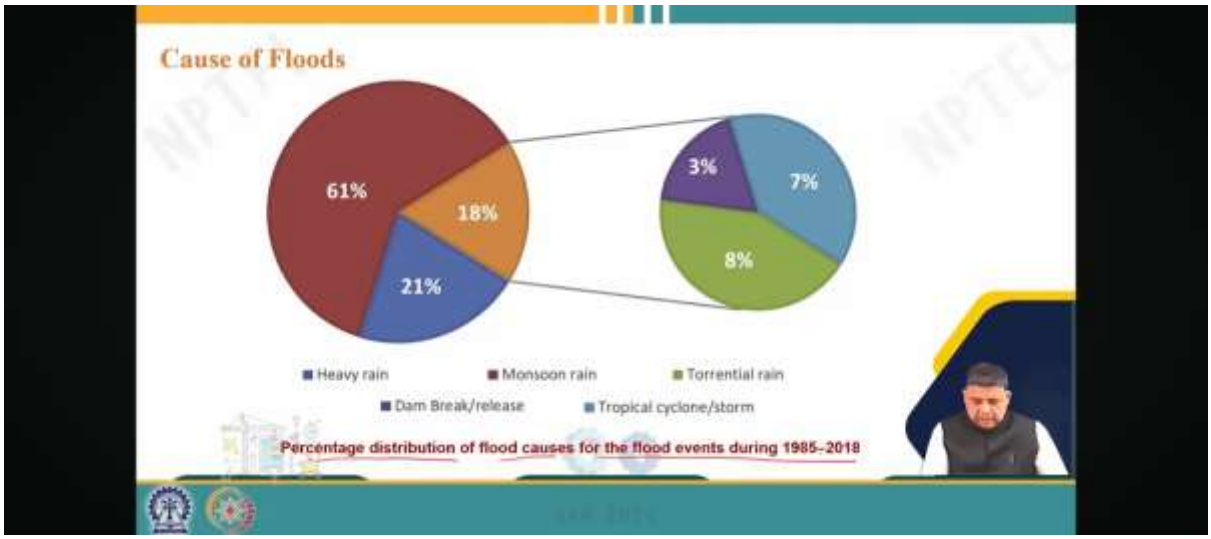
For example, a GLOF caused by Chakrabarti Tal caused devastating flash floods in Kedarnath in Uttarakhand on June 13, which was a huge flood event in the country. And finally, just last year in Sikkim, experienced a GLOF caused by South Lonak Lake which led to sewer flooding in the Teesta River and resulted in loss of lives and property to a large extent. So, GLOFs are now, of course, more prevalent because of the rising temperatures, due to the melting of snow and ice or glaciers; this is becoming quite a common phenomenon. So, this is also a major type of flood now. Now coming to causes of floods, already we have discussed these to a large extent that most often it is heavy rainfall that is intense and prolonged rainfall, especially during monsoon seasons, can lead to excessive runoff, overwhelming rivers, streams and drainage systems.

So, many times heavy rainfall is the major cause of flooding in the monsoon season in India. Then storm surges, tropical storms, hurricanes or cyclones, particularly in coastal areas, can cause storm surges leading to coastal flooding. So, of course, this is also quite a phenomenon because we always, once or twice a year, find tropical cyclones occurring either in the Bay of Bengal or in the Arabian Sea, and then the coastal areas are affected because of the sudden floods. Then snowmelt, rapid melting of snow especially in mountainous regions, can contribute to increased river flow and lead to flooding downstream, and this has become a major issue in recent times. Just now we discussed about the glacial runoff also because of the rising temperature; snowmelt is becoming quite a frequent phenomenon and a major cause of flooding also in the downstream areas. Then of course, river overflow; rivers can overflow their banks due to heavy rainfalls, snowmelt or a combination of both and this overflow leads to flooding in adjacent areas.



So, because of high flow but at the same time as we have also discussed, because of not taking proper care of watershed management in the upstream or the catchments, because of that, a lot of sediment also moves and reaches these streams, which reduces capacity and also causes river overflow. Then urbanization is a major reason; urban development can increase the risk of flooding by reducing natural permeable surfaces such as forests and wetlands and increasing the number of impervious surfaces like roads and buildings. So, obviously, whenever

urbanization occurs, we always see that development is at a cost of either forests or wetlands, and also obviously, when development takes place, we cover the natural soil by bringing up impervious surfaces like roads and buildings. So, as a result, what happens is that whatever rainfall occurs gets translated into runoff, which we have discussed earlier also in the rainfall-runoff transformation process, and as a result, there is a heavy amount of water available for causing damage. And also, we have also discussed that in urban areas, there is an urban flooding problem; urban flooding we have already discussed because of the choking of either insufficiently developed drainage systems or choking of whatever drainage network we have in the cities because of that also urban flooding takes place.

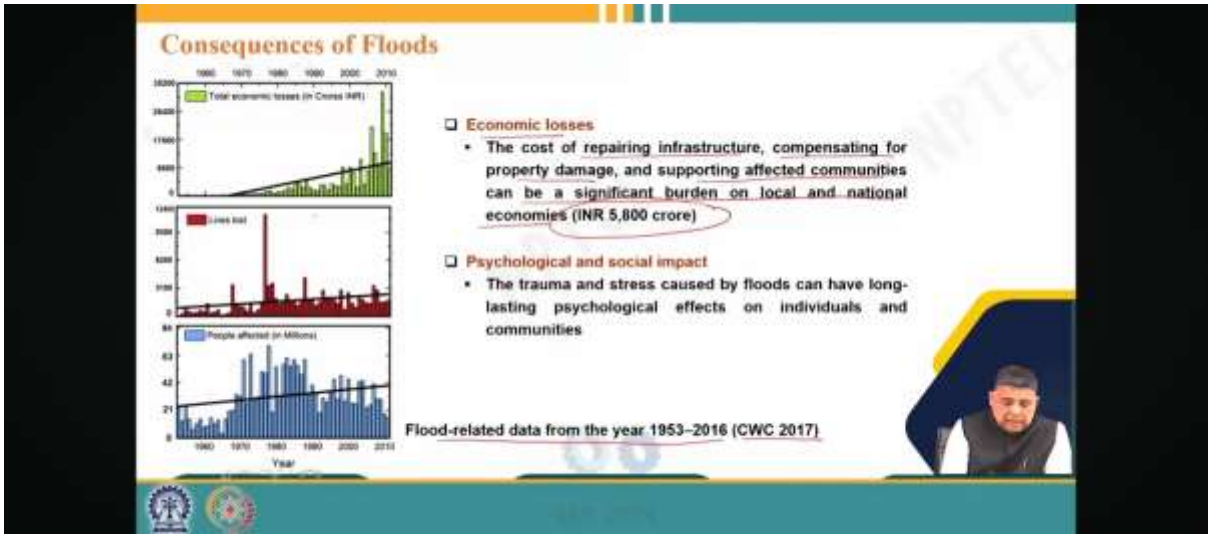


Then, deforestation is a major cause, as the removal of forests reduces the ability of natural landscapes to absorb and retain water. This can lead to increased runoff, which contributes to flooding. Already, we have seen that in forest watersheds, a lot of rainwater gets absorbed due to the covering of the surface with litter, leaves, branches, etcetera. Additionally, we have previously discussed that deforestation could release almost 20 to 40 percent of rainfall. So, that means deforestation can release 20 to 40 percent of rainfall, which otherwise would have been absorbed in the forest, into runoff, and of course, that causes flooding in downstream areas. If you look at this picture here, it gives the percentage distribution of flood causes for flood events during 1985 and 2018 in India.

You can see that a heavy 61 percent goes to monsoon rain, and besides, 21 percent goes to heavy rainfall events, which also could include crowded buses. The reminder of 18 percent can be divided into three categories here: around 7 percent of the floods are due to tropical cyclones/storms, mostly in coastal areas. Then, of course, torrential rains cause around 8 percent of the floods, and a minute 3 percent is caused by dam breaks or religious dam incidents, because of the sudden closing or opening of the dam gates, causing floods downstream. So, this simply shows that rainfall is a major cause as you can see that heavy rain, monsoon rain, and torrential rain sum up to 82 plus 90 percent, covering around 10 percent of floods.

So, monsoon or other rainfall is the main cause of floods, at least in India. Now, we come to the consequences of floods, and the consequences of floods, of course, one major consequence is the loss of lives. So, one of the most tragic consequences of floods is the loss of human life; swift and severe floods can lead to drowning and other water-related fatalities. And of course, this is just an example we discussed about the Glove in Sikkim. So, because of this that happened on October 23, the floods caused by high-altitude glacial lake burst resulted in the tragic death of almost 56 individuals in the Tista River basin, as you can see here.

And as far as flood data of CWC says, the maximum lives were lost in 1977, and that was 11,316 in a given year, and the average life lost is around 1651,650 as per CWC 2017 data. Then, besides the loss of life, property damage is another significant issue. Floods can cause extensive damage to homes, buildings, roads, infrastructure, and personal belongings, and the force of floodwaters can erode foundations, weaken structures, and lead to collapses. So, of course, whenever a flood is reported, you might have seen in the news reports that especially the buildings which have recently been constructed in the floodplains, that is adjoining areas of the rivers, they get heavily damaged. And you might have seen the structures because of the weakening of the structure or foundation, the collapse of buildings also we see quite often in the news chain. This happens because of the uncontrolled construction in the floodplains in recent times. If we talk about the economic losses, the cost of repairing infrastructure, compensating for property damage, and supporting affected communities can be significant, putting a burden on local and national economies. And already we have a CWC report that in India it costs around Indian rupees 5800 crores every year for managing floods.

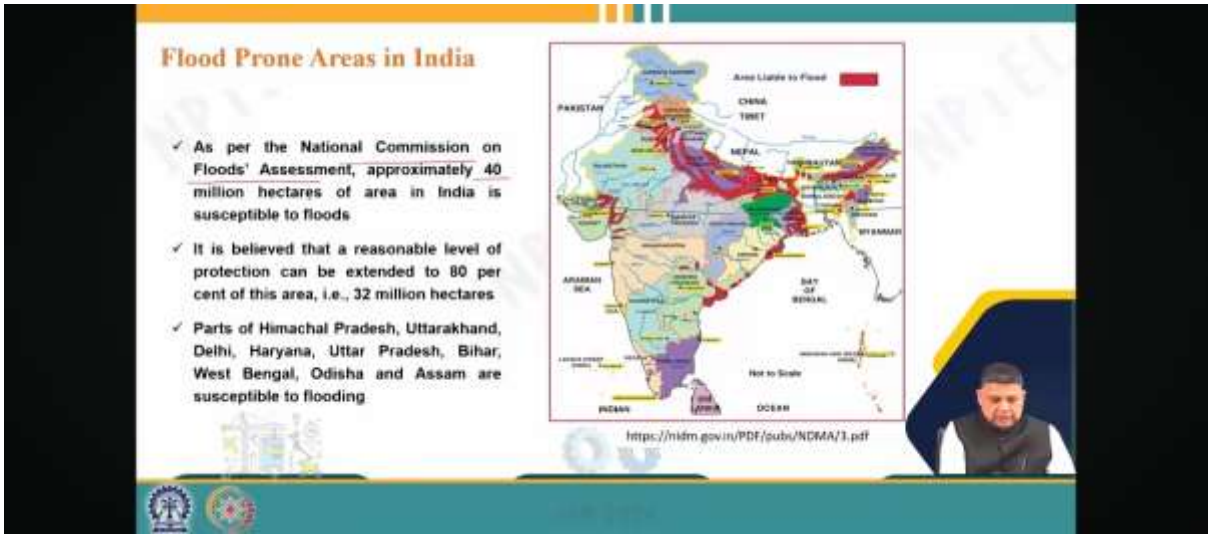


And this is the flood-related data from 1953 to 2016 released by CWC in 2017, and as you can see, with the passage of time, ah, the economic loss is going also. The ah human lives lost, they are also an uprising and also are the people affected. So, all these are matters of concern. Then psychological and social aspects, besides loss, ah, ah, the economic loss, the trauma and stress caused by floods can have long-lasting psychological effects on individuals and communities. Another problem is the displacement of people. Floods often force people to evacuate their homes, leading to temporary or permanent displacement. This can result in the loss of homes, possessions and livelihoods and you can see that these are the kinds of scenarios we see quite often, ah, nearly, and this is the scenario in Delhi in July 2023.

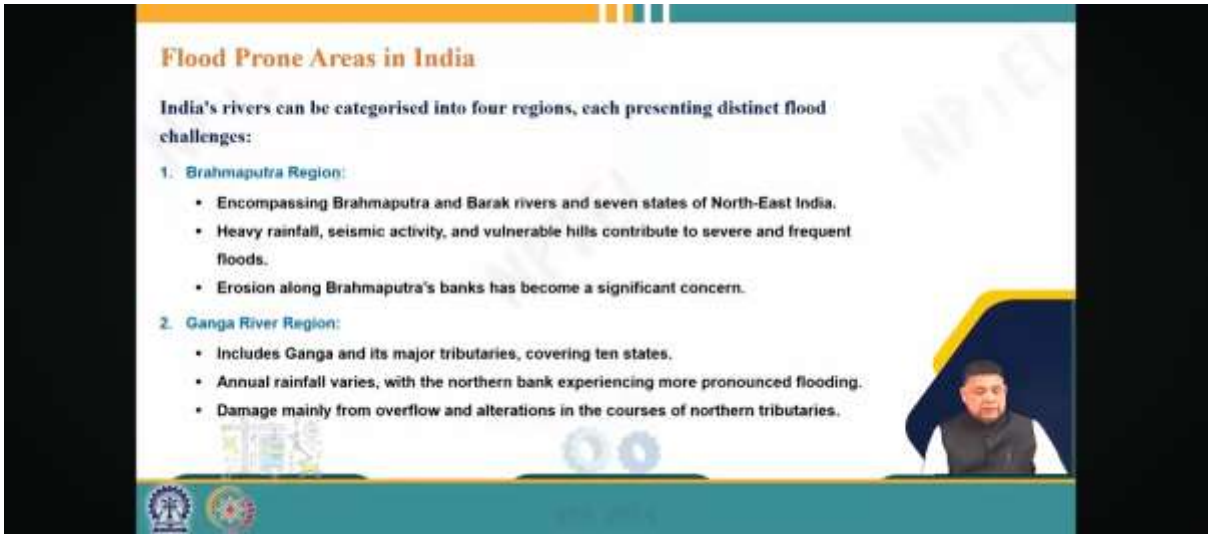
Then contamination of water sources. Floodwaters can carry pollutants, chemicals, sewage, contaminating drinking water sources, and this can lead to waterborne diseases and health issues. So, not only during the flood, but post-flood scenarios also and there, this contaminated water could cause damage, and also, there is an increased risk of diseases. Stagnant water and unsanitary conditions in the aftermath of floods create a breeding ground for disease vectors. So, vector borne diseases could go up, ah, after the flood event has occurred in a particular area. Then, of course, ah, the impact on agriculture. Agricultural areas are vulnerable to flooding, leading to crop damage, soil erosion and loss of livestock, and this can have long-term economic consequences for farmers and impact food supply, especially because, ah, the sediments can also come and, ah, get dumped on the agricultural lands, and it takes a few years for those sands to be taken off. Then, of course, there are distress of services like, ah, essential services, electricity, communication, healthcare, that get disrupted, and of course, ah, this also can complicate rescue and relief efforts and worsen the challenges faced by affected communities.

So, of course, as you can see, all around losses can take place. Besides all these, there is an environmental impact also that leads to soil erosion, habitat destruction, and changes in the component plant and animal population. Water pollution, floodwater can also harm aquatic sources. So, not only human beings but even the other flora, fauna, and habitats are affected,

and the biodiversity of a place can also be affected. The floods can affect the habitats of various species, leading to a change in biodiversity. In 2018, Kerala had a severe flood, and the government decided to assess the biodiversity loss caused by the floods. Of course, there were 400 lives lost, but the biodiversity was also affected. So, the government has initiated an inquiry into what happened to biodiversity because of the floods.



Now, coming to flood-prone areas, as per the National Commission on Floods assessment, approximately 40 million hectares of area in India are susceptible to floods. As you can see here, the red-coloured areas show the most susceptible areas. So, the level of protection can be extended to 80 percent of these areas, which is 32 million. Parts of Himachal Pradesh, Uttarakhand, Delhi, Haryana, Uttar Pradesh, Bihar, West Bengal, Odisha and some others are susceptible to flooding, as you can see in this picture. Of course, some other parts are also there, but these are the major places where flooding is prone besides the coastal areas here.

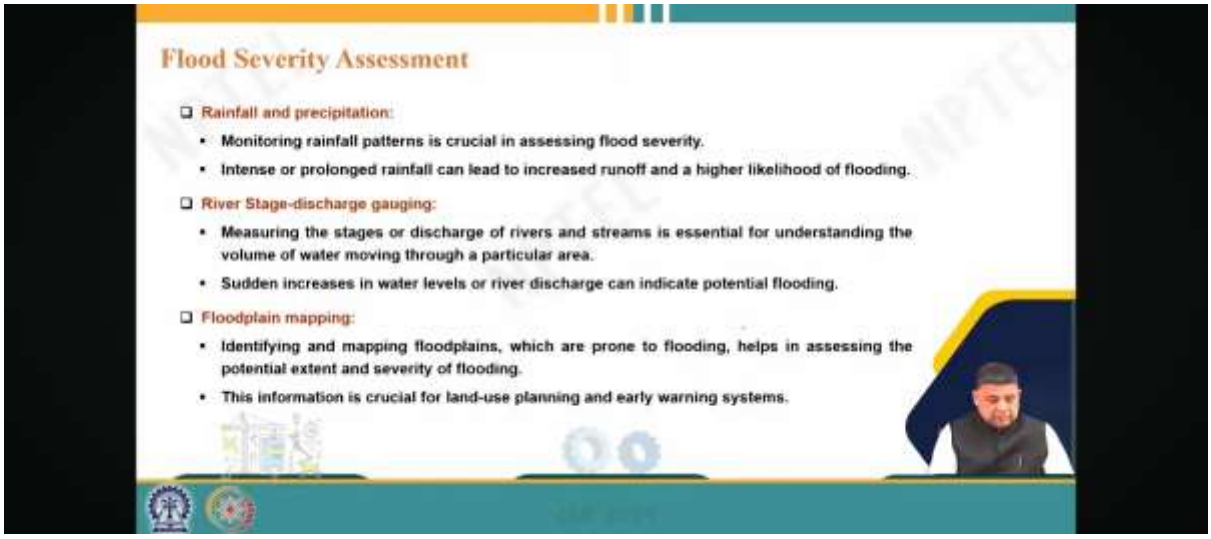


And these are the states like Uttar Pradesh, which had 21.9 percent, Odisha had 4.1 percent, West Bengal 7.9 percent, some 9.4 percent, and Bihar 12.7 percent, and other states have combined to have 49.9 percent flood-prone areas in India. Now coming to if we talk about India's river system, they are categorized into four regions, and they have distinct flood challenges. Like we have the Brahmaputra region, which encompasses Brahmaputra and Barak rivers and seven states of northeast India. Heavy rainfall, seismic activity, vulnerable hills

contribute to severe and frequent floods in these Brahmaputra regions and erosion along Brahmaputra banks has become a significant concern at the same time. Then we have the Ganga River region which includes Ganga and its major tributaries covering 10 states.

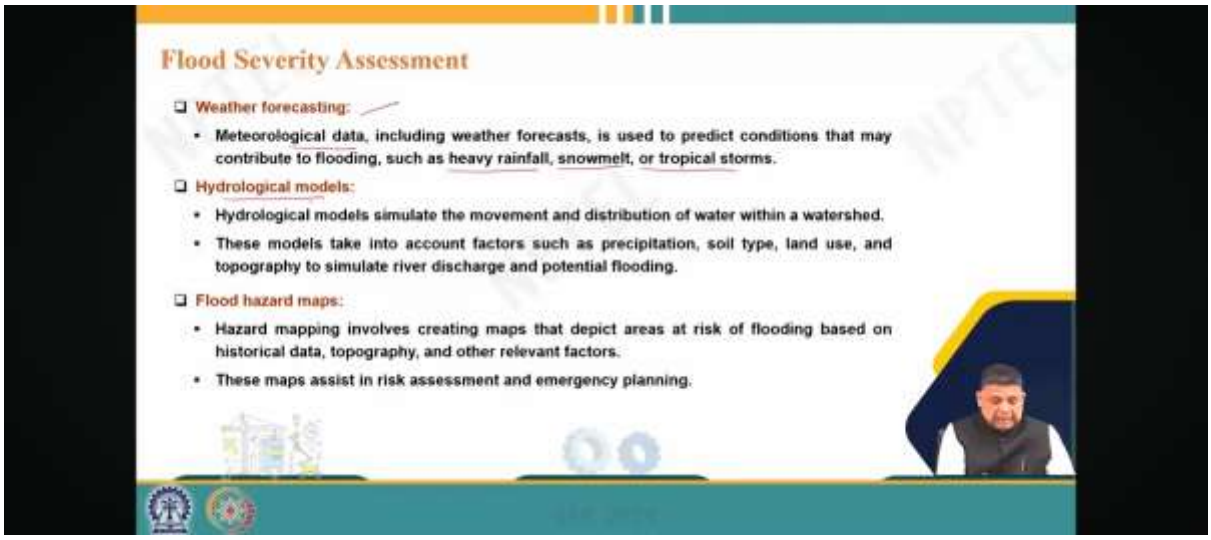
Annual rainfall varies, with the northern bank experiencing more pronounced flooding and damage, mainly from overflow and alteration of the course of northern tributaries. Because of this deltaic region, the meandering or shifting of these rivers is very common, making it difficult to properly protect river banks, thus causing even more severe damage.

Then we have a northern region featuring rivers like Sutlej, Bias, Ravi, Chenab, Jhelum with limited flood issues compared to other regions where drainage congestion is a primary concern. So, they have quite a lot of checked area. Fourthly, we have central India and Deccan, which comprise regions such as Narmada, Tapi, Mahanadi, Godavari, Krishnan, Kaveri with stable courses and adequate natural bank capacity except in delta areas. They are pretty protected, and the lower reaches of east coast rivers are embanked, reducing flood problems significantly. However, the Brahmaputra and Ganga regions are prone to flooding.

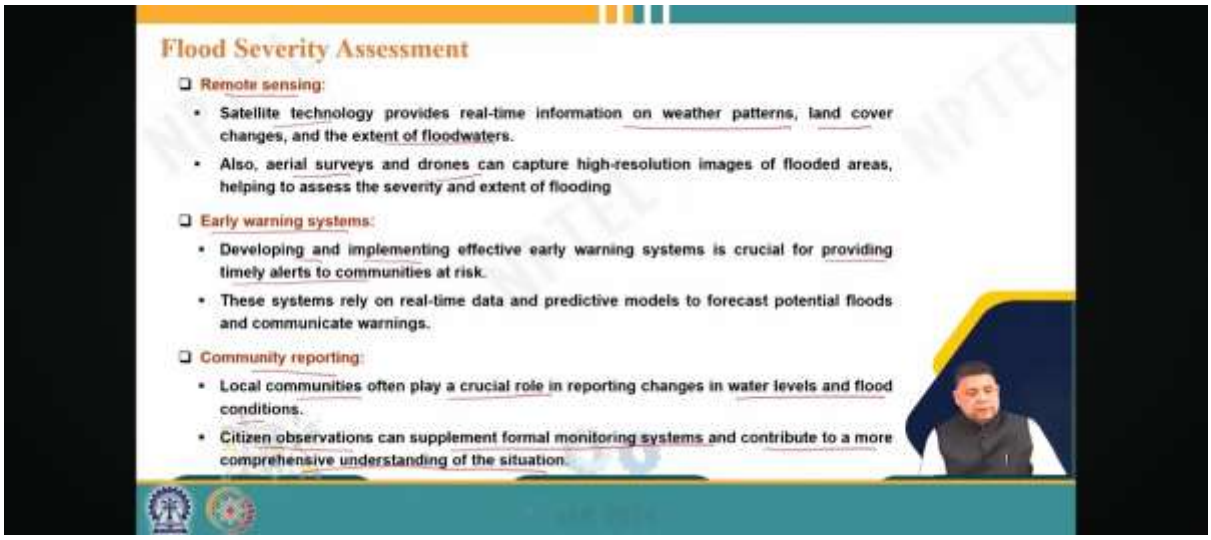


Coming to flood severity assessment, we can do it in similar ways. For example, rainfall and precipitation monitoring can give us a fair idea of a flood happening. Similarly, river stage discharge gauging provides a warning, as a sudden increase in water levels or river discharge

can indicate potential flooding. Flood plain mapping, identifying and mapping flood plains prone to flooding, helps in assessing the potential extent and severity of flooding, crucial for land use planning and early warning systems.

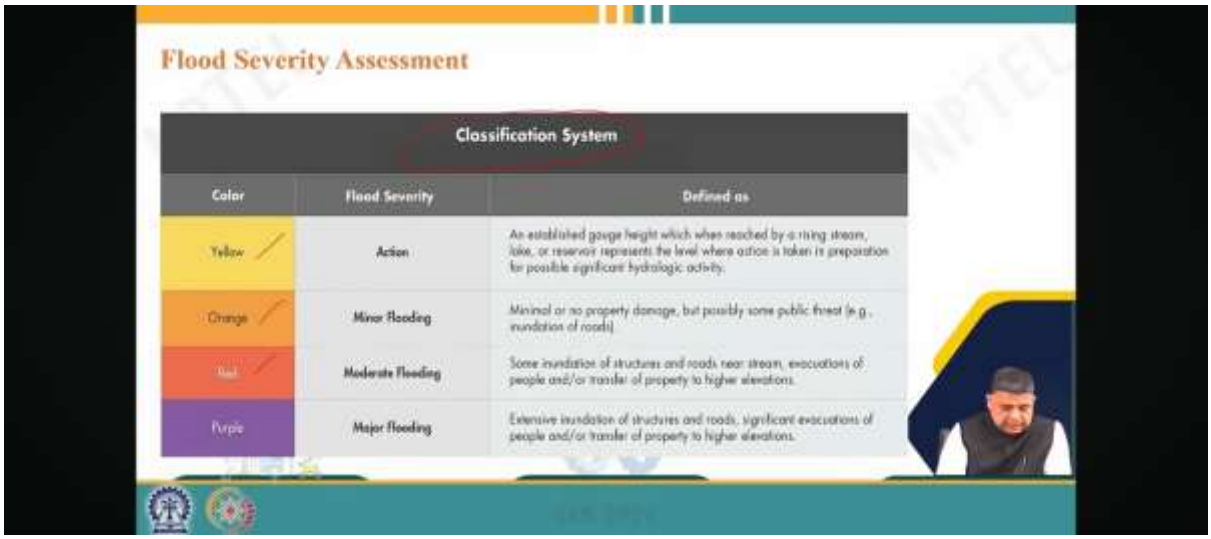


Then we have the possibility of weather forecasting. If we can forecast weather like meteorological data, then, of course, we can predict heavy rainfalls, snow melt, or tropical storms. Then, of course, hydrological models can help because the rainfall runoff transformation process can help in a significant way. They can take into account precipitation, soil, land use, topography to simulate river discharge and potential flooding. We can have flood hazard maps developed, which involves creating maps that depict areas at risk of flooding based on historical data, topography, and other elemental factors. These maps assist in risk assessment and emergency planning.



Then we can use technology like remote sensing, which is satellite technology or aerial surveys, or even drones nowadays to find out real-time information on weather patterns land cover changes, and the extent of floodwaters. Then we can have early warning systems, which are developed and implemented effectively. They are crucial for timely alerts to communicate with communities at risk.

And of course, the community open local communities often play a critical role in reporting changes in water levels and river conditions. Cities and observations can supplement formal monitoring systems and contribute to a more comprehensive understanding of the situation. And flood severity assessment has a color-coding system like yellow, orange, red, and purple. You must have seen warnings issued by India's meteorological department or central water commission.



If yellow, it indicates flood severity is action; purple shows major flooding, red shows moderate flooding and orange shows minor flooding. Definitions also vary; for major flooding (purple) extensive inundation of structures and roads, significant evacuation of people and property transfer to higher elevations are expected. If it's a yellow warning, an established gauge height is reached indicating rising streams, lakes or reservoirs prompting preparation for possible significant hydrological activity.

So, depending on the severity assessed, these warnings are issued. With this, we come to the end of this lecture. We have introduced floods, discussed their consequences, the regions prone to floods, and risk assessment. Thank you very much. Please give your feedback and raise any doubts or questions you may have, which we will be happy to address on the forum.

Thank you.