Course Name: Watershed Hydrology

Professor Name: Prof. Rajendra Singh

Department Name: Agricultural and Food Engineering

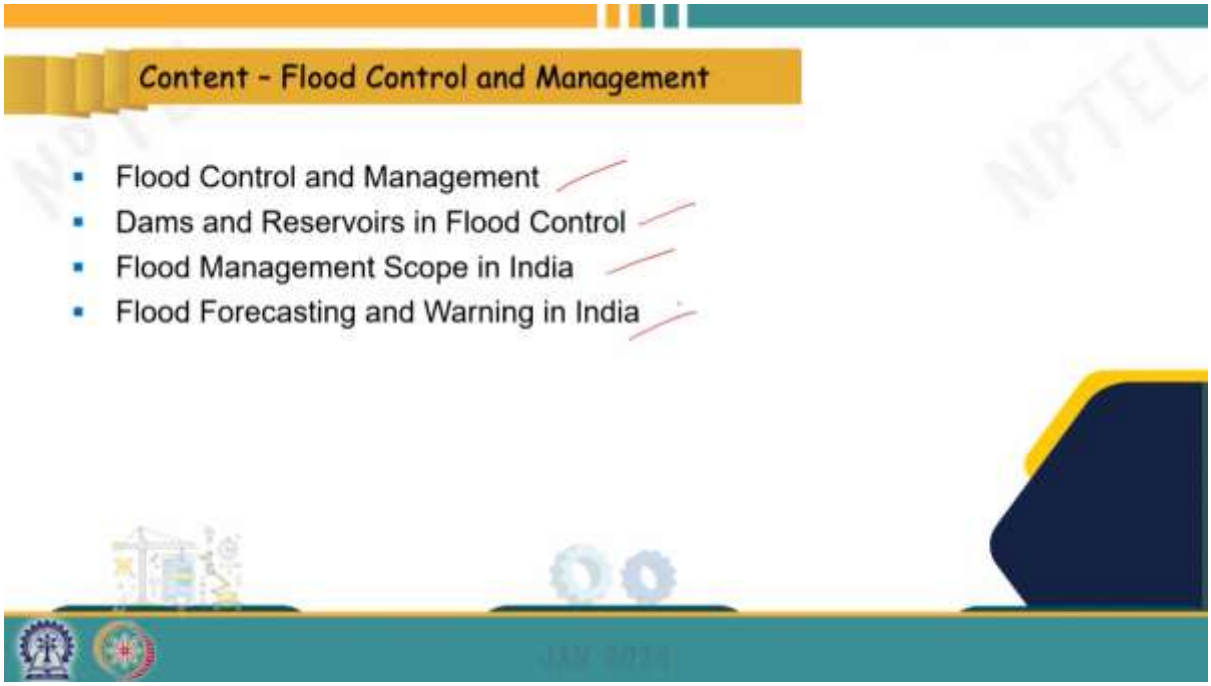
Institute Name: Indian Institute of Technology Kharagpur

Week: 09

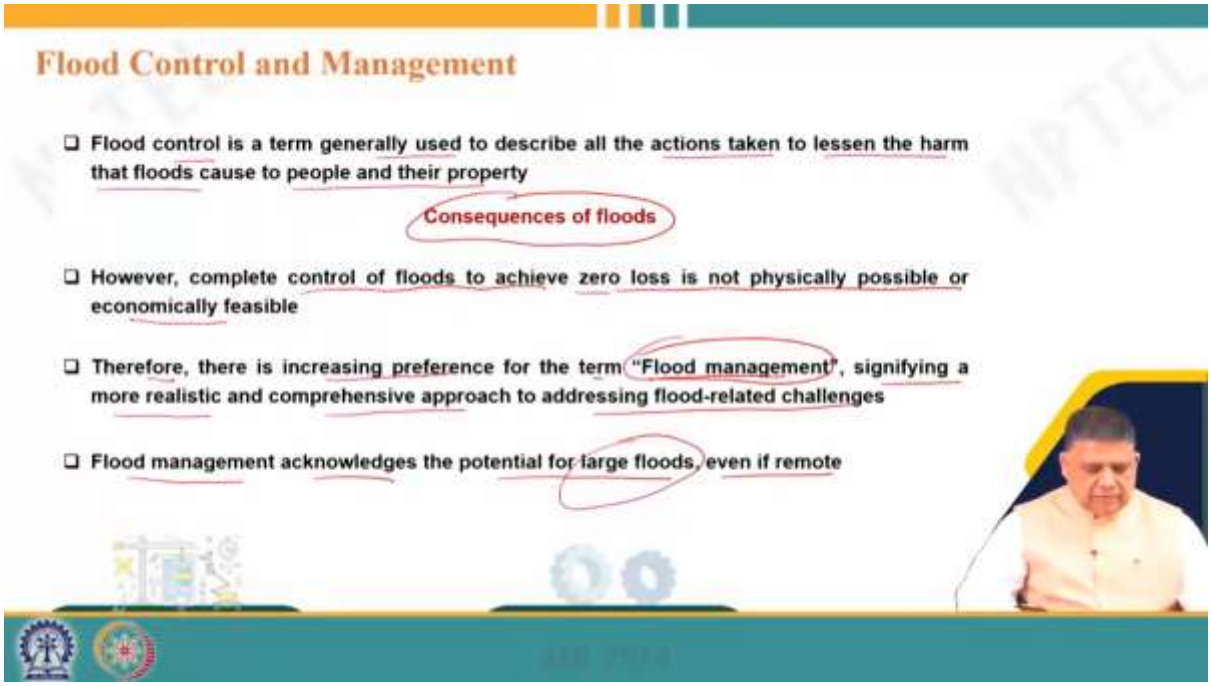
Lecture 44: Flood Control and Management

Hello friends, welcome back to this online certification course on Watershed Hydrology. I am Professor Rajendra Singh from the Department of Agriculture and Food Engineering at the Indian Institute of Technology Kharagpur. We are in Module 9, this is Lecture 4, and the topic is Flood Control and Management.

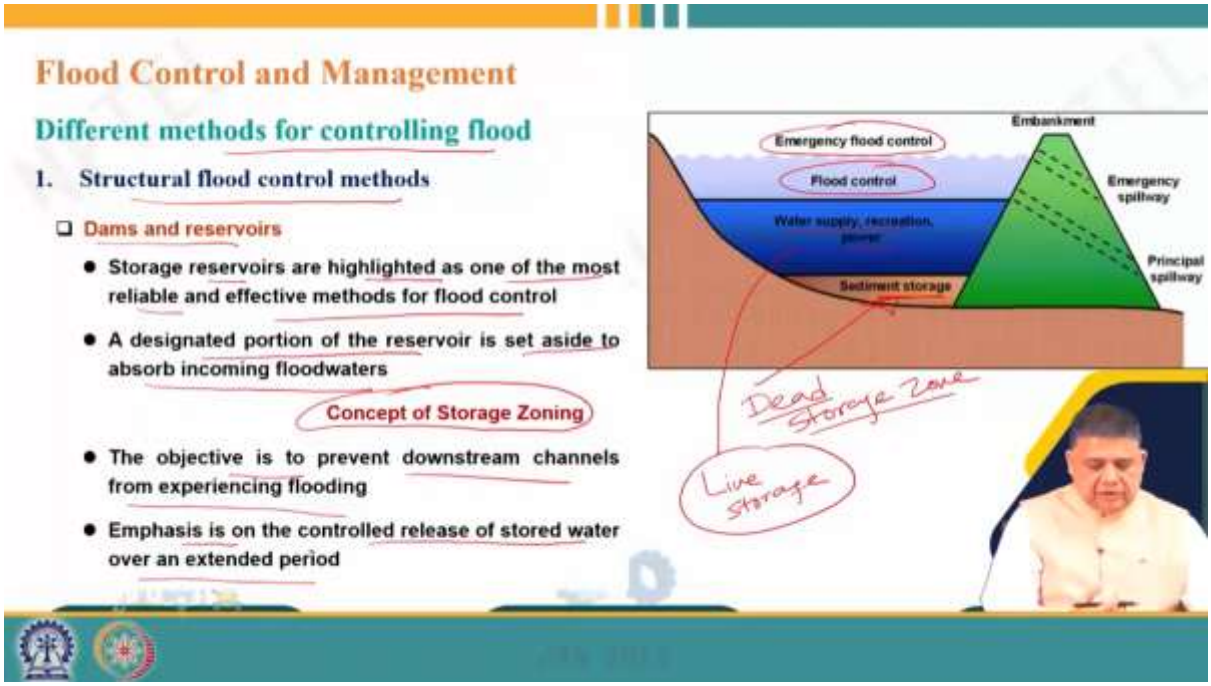
Now, in this lecture, we will introduce flood control and management. We will discuss the role of dams and reservoirs in flood control. Additionally, we will explore the scope of flood management in India and discuss flood forecasting and warning systems in the country.



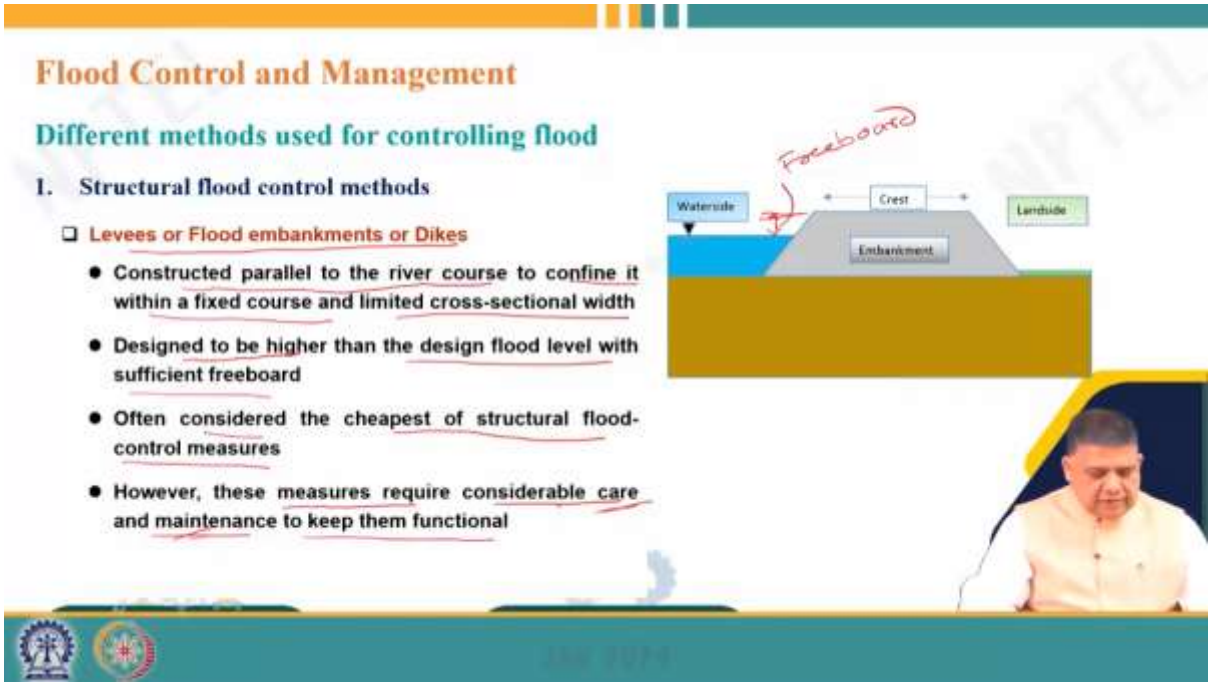
Starting with flood control and management, it is a term generally used to describe all the actions taken to lessen the harm that floods cause to people and their property. In one of the earlier lectures where we introduced floods and discussed their causes and consequences, we highlighted not only the loss of lives and property but also the health and psychological issues that arise. Therefore, any action taken to tackle or mitigate the burden of these consequences on human beings is referred to as flood control. However, achieving complete control of floods to minimize loss to zero is not physically possible or economically feasible. Hence, there is an increasing preference for the term "flood management," signifying a more realistic and comprehensive approach to addressing flood-related challenges. It is evident that during periods of high rainfall, snowmelt, or uncontrolled release of water from reservoirs or dams, floods occur with elevated water levels and discharges. Complete control of such events is not feasible. The required control measures would be prohibitively expensive both economically and technologically. Therefore, the focus is shifting towards flood management rather than flood control. The emphasis is on managing flood-related issues to a realistic level to minimize challenges associated with floods. Flood management acknowledges the potential for large floods even with mitigation efforts in place. While floods may still occur, the goal is to handle and manage them effectively. Thus, flood control management is about acknowledging the inevitability of floods and implementing strategies to handle them efficiently.



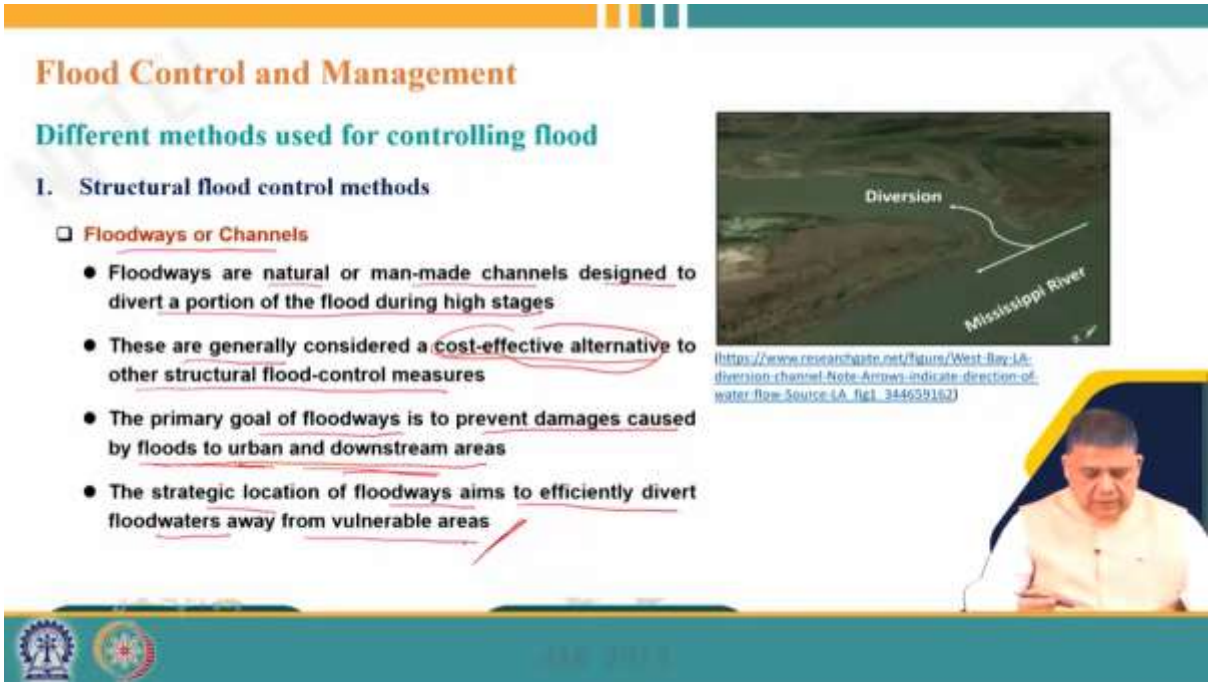
Now, coming to different methods of controlling floods, flood control methods are divided into two categories: structural measures and non-structural measures. So, we begin with structural flood control methods or measures, and the first and foremost is dams and reservoirs, the construction of dams and reservoirs. Now, storage reservoirs are highlighted as one of the most reliable and effective methods of flood control because a designated portion of the reservoir is set aside to absorb incoming floodwaters. So, typically, when we design a reservoir storage, we use the concept of storage zoning. That means the entire storage behind a dam or in the reservoir is divided into different components or zones. The lowermost zone is referred to as dead storage zone, which is more to handle sediment storage. It is expected that over the life of the structure or dam, there will be some sediment coming from the catchment, and of course, that will be filling up the reservoir capacity. So, in order to compensate for that, a dead storage zone is provided at the bottom. Then, of course, there is a zone from where water supply, recreation, power, everything—daily requirements—are managed, and this is referred to as live storage. So, basically, the day-to-day operation of the reservoir is limited to this live storage, whereas dead storage is for long-term storage requirements. Over and above that, we do have a flood control zone and also, in some cases, for large dams, there is an emergency flood control. These two are provided specifically in order to handle floods, and that is why it is said that it is one of the most reliable and effective methods of controlling floods. The objective is to prevent downstream channels from experiencing floods. So, floodwater is stored either in emergency or in flood control zones, and then it is released slowly, taking into account the downstream channel capacity, so that adjoining areas or the people are not affected downstream of the reservoir. The emphasis is on the controlled release of stored water over an extended period of time. So, you always keep the downstream channel capacity in mind while releasing the water, and that is why it will not have any impact on the downstream portion of the structure. So, that is why dams and reservoirs are supposed to be pretty reliable and effective methods of flood control.



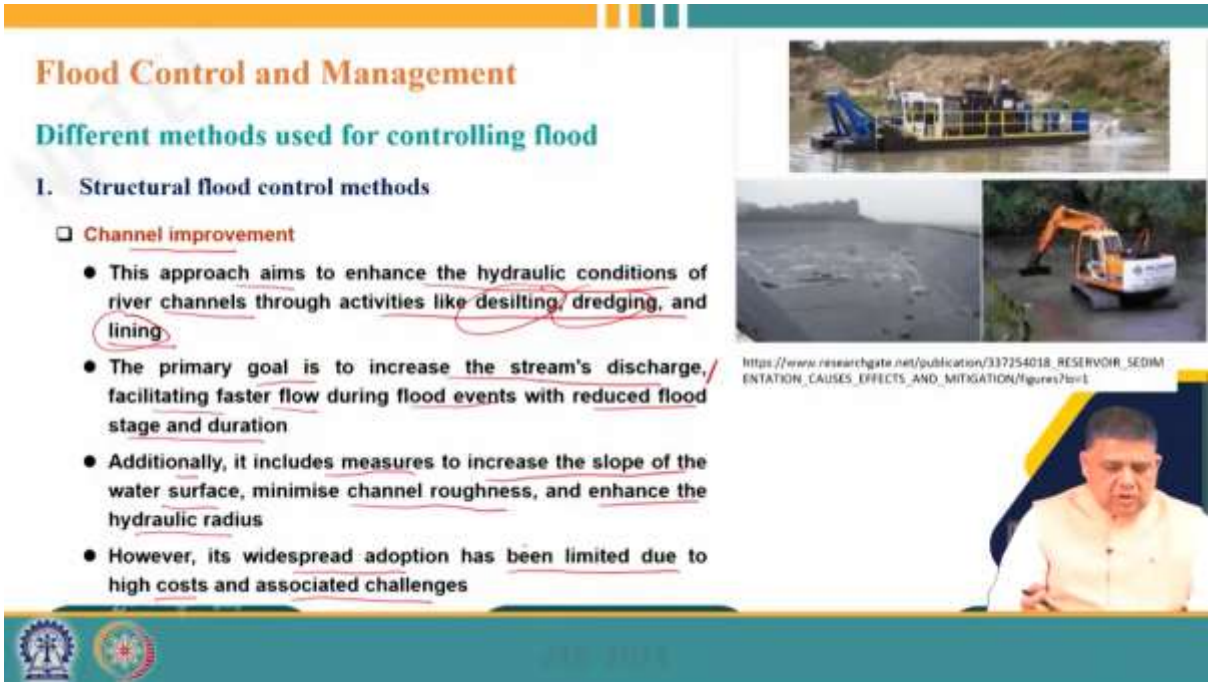
Then the next one is levees or flood embankments or dikes. So, these levees of flooding embankments or dikes are constructed parallel to the river course to confine it within a fixed course and limited cross-sectional width. So, basically, all along the channel or stream or river, especially when major towns or cities are present, you will find that these levees or flood embankments or dikes, mostly these are earthen structures, are constructed. And these are designed to be higher than the design flood level with sufficient freeboard. So, obviously, historically while designing or deciding their height, the historical flood level is taken into account, determining the maximum stage that has occurred over a significant period of time. And then of course, you also provide certain freeboard; that freeboard is basically the gap between the height of this structure and the maximum water level which you expect, referred to as freeboard. And of course, you have read about this in most other subjects as well. This freeboard is provided in order to take care of any additional flow coming or because of the currents, etc. So, that the levees or embankments or dikes are not overflown. These are often considered the cheapest of the structural flood control measures because, as I said, the material of construction is typically earth or soil. So, obviously, it is a relatively cheaper construction. However, these measures require considerable care and maintenance to keep them functional because they are constructed out of soil or earth. So, obviously, they need to be compacted properly, but even then there might be a chance of seepage or cracks. That is why you have to take care and maintain them. Otherwise, if there is any breach, then obviously, in the case of high waters, the entire water will flow to their adjoining areas. So, these are levees or flood bank embankments or dikes.



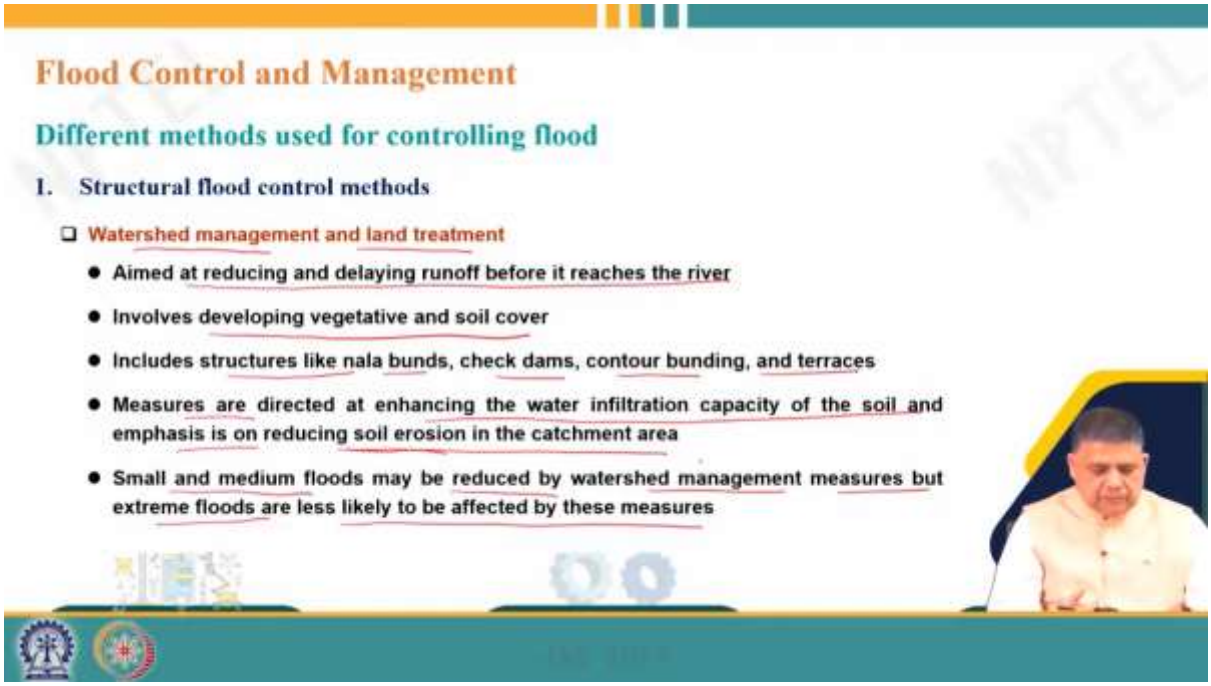
Then the third measure is through flood ways or channels, and flood ways are natural or man-made channels designed to divert a portion of the flood during high stages. These are generally considered a cost-effective alternative to other structural flood control measures. The primary goal of the floodway is to prevent damage caused by floods to urban and downstream areas. So, obviously, in this case, no additional construction or anything like in dams or reservoirs or levees or embankments or dikes is involved. In this case, only what is done is that the floodwater, the river water in case of high floods, is simply diverted to another channel. And of course, because there is no cost involved, it is a cost-effective alternative, and because there is no structure basically constructed here. And of course, once the water is diverted, especially if the diversion is made near major towns or any other major structure, these areas could be safeguarded against the high floodwater. The strategic location of flood ways aims to efficiently divert floodwaters away from vulnerable areas. So, as I said, whenever a big town is coming or some serious installation is there, obviously, you do not want that area to be flooded, and just before high water is likely to come there, you divert the water to a nearby area so that you are able to take care of the extra floodwater or higher water levels.



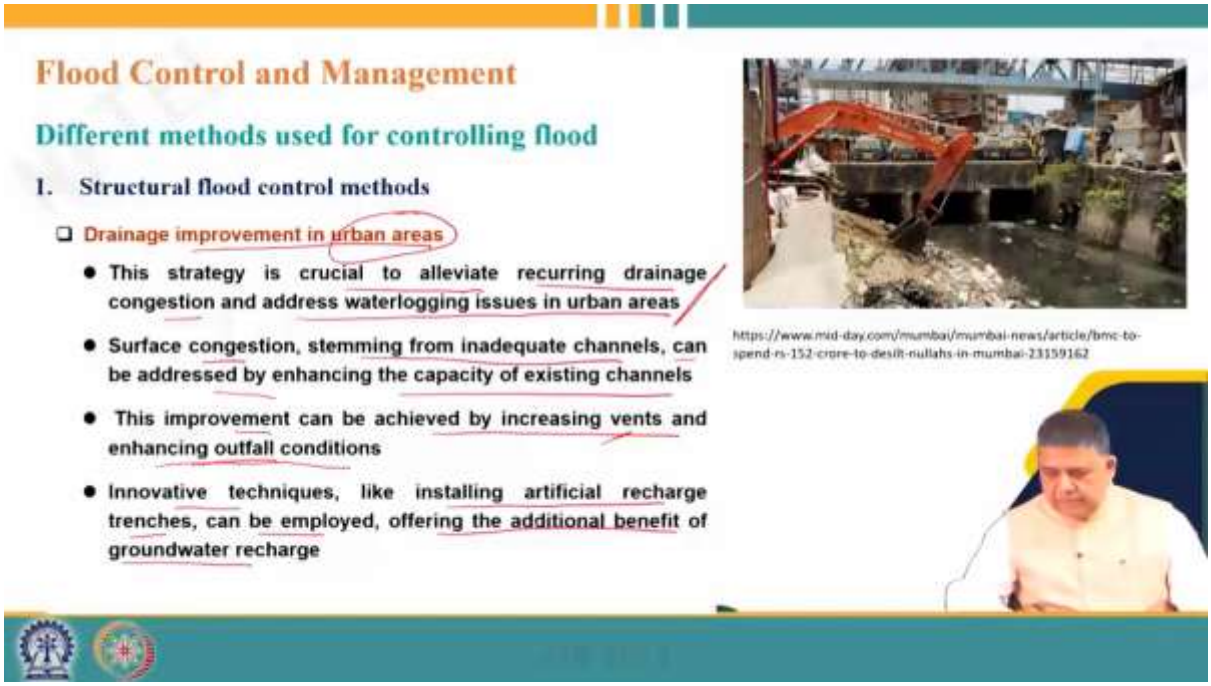
Then the next one is channel improvement. Another structural flood control major is channel improvement. And this approach aims to enhance the hydraulic conditions of the river channels through activities like desilting, dredging, and lining. So, basically here you work on the channels which carry water, and that is desilting, meaning through dredging you desilt, meaning you clear the path of sediments. So that the cross-sectional area goes up and also you line the sides so that the sides are blocked and there is no chance of seepage or leakage through the sides. The primary goal is to increase the stream's discharge, facilitating faster flow during flood events and reducing flood stage and duration. So obviously, you want to increase the discharge, and that is, as I said, when you desilt or dredge. So, the cross-sectional area goes up, and once the cross-sectional area goes up, then obviously, the flow carrying capacity will go up, and that is how you increase the stream's discharge. And obviously, during this process, you also work on the slope of the channel. So, the velocity of flow could also be controlled. So, once the cross-section is more, velocity is more, then it will carry more flow and it will take more flow away at a quick pace so that the flood stage and duration will be lower. Additionally, it includes measures to increase the slope of the water surface, minimizing channel roughness, and enhancing the hydraulic radius. So, all these act on basically hydraulic radius or cross-sectional area. However, its widespread adaptation has been limited due to high cost and associated challenges. So obviously, cleaning such a huge amount of rivers or streams or even artificially built canals is a huge challenge because it requires huge investment. And of course, there is an associated challenge also that when you desilt, you bring out a huge amount of silt to the sites. Then what to do, how to manage that silt, that is also a challenge actually when we go for channel improvement.



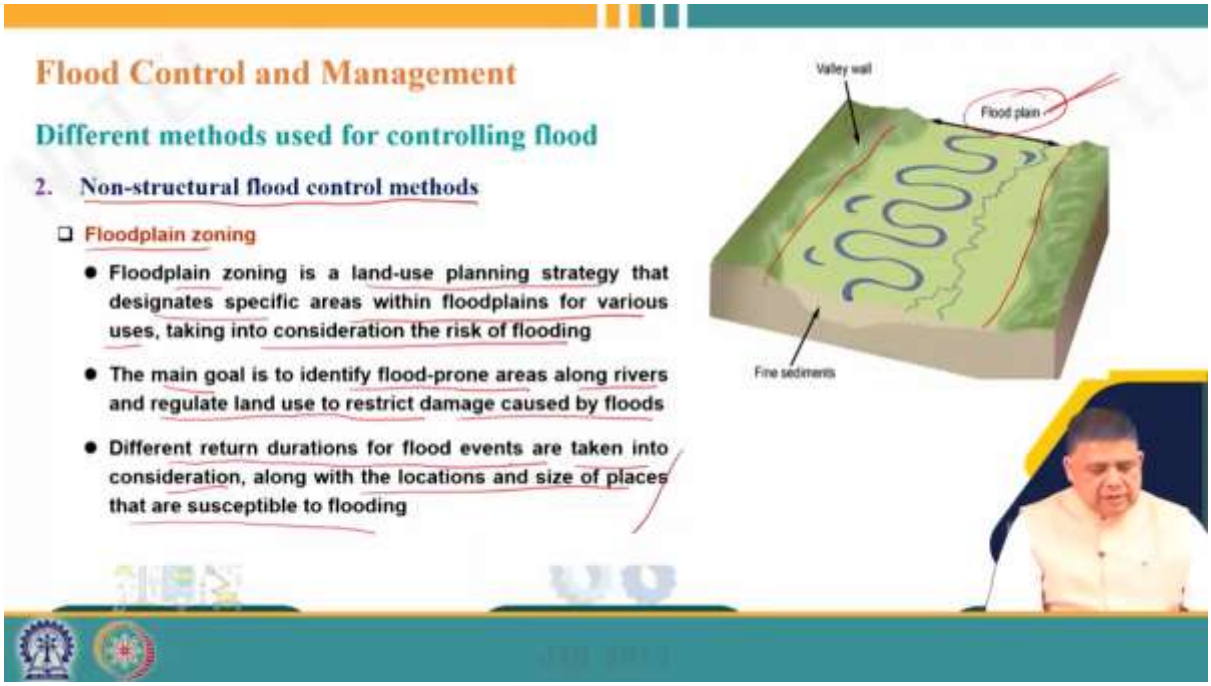
Then, of course, the next one is watershed management and land treatment. So, of course, it aims at reducing and delaying runoff before it reaches the river, meaning you treat the catchment area itself so that you retain more water there, thus through soil and water conservation measures, less flow reaches the stream. Involves developing vegetative and soil cover, includes structures like Nala bunds, check dams, contour bunding terraces. So, of course, all these, I am sure that you have read about under soil control structure design; some of them we have also referred to from time to time in our discussions here in hydrology. So, obviously, all these structures are meant for soil and water conservation. So, you conserve more and more water on the catchment itself rather than allowing it to flow to the outlet. Measures are directed at enhancing the water infiltration capacity of the soil and emphasize reducing soil erosion in the catchment area. So, obviously, through these measures, you enhance the infiltration capacity, so more of the groundwater recharge takes place, less runoff is generated, and of course, because most of these are soil conservation measures, soil erosion is also minimized. Small and medium floods may be reduced by watershed management measures, but extreme floods are less likely to be affected by these measures. So, of course, watershed management measures are more effective for small and medium floods; in the case of large floods, they may not be so effective. So, this is the limitation of this particular control measure.



Then, of course, comes the drainage improvement in urban areas, which is, of course, targeted to urban areas and urban flooding. It is crucial to alleviate recurring drainage congestion and address waterlogging issues in urban areas. We have discussed in great detail about urban flooding, and while introducing this objective also when we were talking about the types of flooding, then also urban flooding was a type of flooding, which is a major concern. So, obviously, you aim at improving the drainage system by removing the congestion or addressing the waterlogging issues. Surface congestion stemming from inadequate channels can be addressed by enhancing the capacity of the existing channel. So, obviously, you take care of the clogging, etc., so that the capacity of the existing channel could be improved, and this improvement can be achieved by increasing widths and enhancing outflow conditions. So, obviously, you can also improve the condition by increasing the events or the outflow conditions. Innovative techniques like installing artificial recharge trenches can be employed, offering the additional benefits of groundwater recharge. So, obviously, in the areas, you can always install artificial recharge trenches so that more of the water is stored there whenever there is excess rainfall or flow, surface flow that goes into those trenches and retained there and recharge the groundwater rather than flowing to the drainage system and creating havoc there.



Then, of course, we now move to non structural flood control methods or flood control measures, and one major one is floodplain zoning. Floodplain zoning is the land use planning strategy that designates specific areas within the floodplain for various uses, taking into consideration the risk of flooding. So, basically, when we say floodplain, it is basically the adjoining area. If this is the river, then the adjoining area is referred to as a floodplain. So, that is a floodplain, and of course, this is the area which is always susceptible to flood whenever there will be high waters in the stream. So, that is why you have to have a land use planning strategy for this particular area, and you take specific measures so that when in the event of a flood, the harm to public property or lives is minimized. The main goal is to identify flood-prone areas along rivers and regulate land use to restrict damage caused by floods. So, obviously, the first thing will be that you identify the floodplains, that is what is referred to as floodplain zoning, and then you regulate the land use so that in the case of higher waters, the damages will be controlled. Different return period durations for flood events are taken into consideration along with the locations and sizes of places that are susceptible to flooding. So, of course, while deciding the floodplain, the recurrence interval or the return period that we have discussed in great detail, we decided the design flood in the previous lecture, of course, that was for a structure, but for deciding the floodplains also, we can have different return periods considered: 2 years, 5 years, 10 years. Earlier, we were talking about 100 years or 1000 years, but in this case, it would be 2 years, 5 years, 10 years, a smaller return period, but based on that, we can decide the floodplains and then regulate the land use in these floodplains.



Then the next measure is flood forecasting and warning, and forecasting produces sets of predicted time profiles for channel flows and river levels. So, obviously, you can have a very sophisticated system or the simple flood routing, the channel routing which we discussed that can also be employed, and basically where you would like to predict the levels, high levels of water, and their time of occurrence, time profiles, and of course, the levels of the water. These two things you focus on flood forecasting basically, and warning involves decision-making based on forecasts to issue warnings or retract previous warnings .Of course, based on the flow conditions or the forecast, you will issue warnings or you will retract the previously issued warning if you feel that the floods are within control. It utilizes hydrodynamic and flood routing models for accurate prediction. So, just now I mentioned that flood routing models can be used, and of course, the hydrodynamic model also we discussed while discussing the flood routing. So, that is also a type of, I mean, the use of Saint Venant equations in different forms. So, that can be used for flood forecasting and warning. It provides a time profile of channel flows and river levels at various locations. So, obviously, you know that knowing a flood level at a particular point, you know what is when a high level of water is going to come, arrive in the downstream side, and what will be the water level. So, obviously, you can take precautionary measures based on that forecast.

Flood Control and Management

Different methods used for controlling flood

2. Non-structural flood control methods

- Flood forecasting and warning
  - Forecasting produces sets of predicted time profiles for channel flows and river levels
  - Warning involves decision-making based on forecasts to issue warnings or rescind/retract previous warnings
  - It utilises hydrodynamic and flood routing models for accurate predictions
  - Provides time profiles of channel flows and river levels at various locations

https://doi.org/10.3390/s21134598

Then you have floodproofing, which is a comprehensive strategy encompassing long-term non structural, minor structural measures, and emergency action. So, whatever you do so that you can protect the area from flood. Its significance lies not only in minimizing flood-related damages but also in preventing adverse environmental impact. So, of course, if you are able to flood-proof an area, then obviously, all the environmental issues related to floods, which we have discussed earlier, they can be taken care of. Additionally, flood-proofing measures include relocating goods, equipment, and potentially harmful chemicals beyond areas prone to flooding. So, of course, while flood-proofing, you also want to take measures so that if any potentially harmful chemical or equipment is there, that should be taken out from the area under the planning.

Flood Control and Management

Different methods used for controlling flood

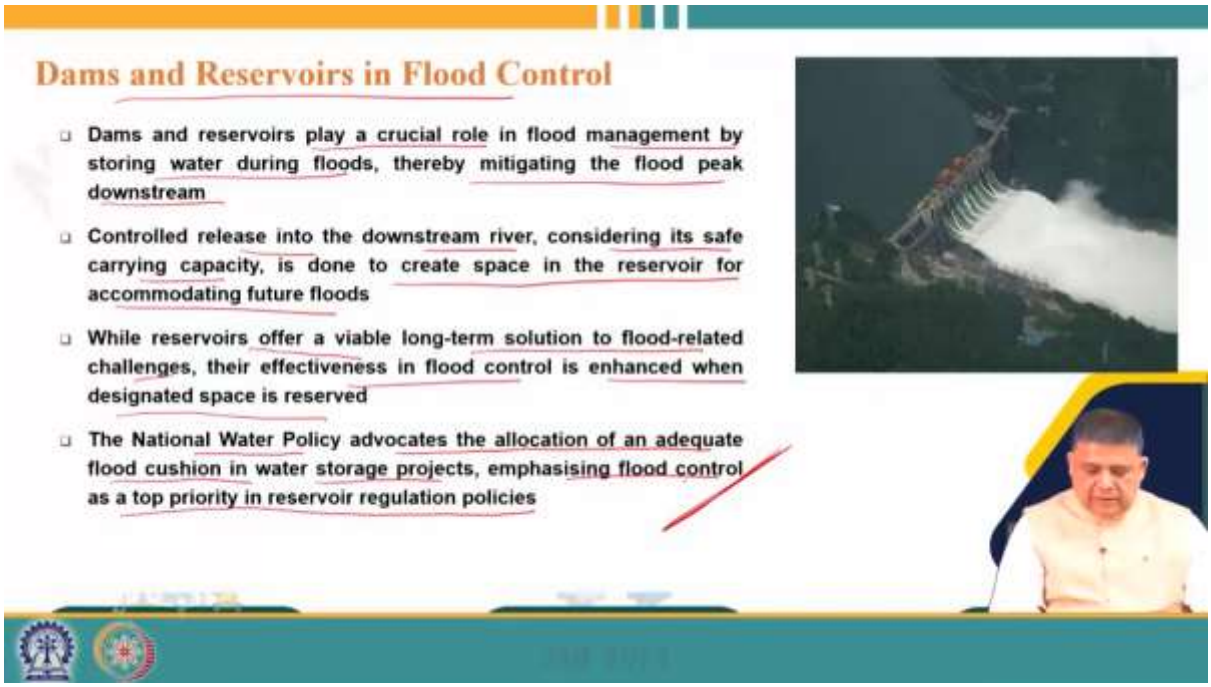
2. Non-structural flood control methods

- Floodproofing
  - Floodproofing is a comprehensive strategy encompassing long-term non-structural, minor structural measures, and emergency actions
  - Its significance lies not only in minimising flood-related damages but also in preventing adverse environmental impacts
  - Additionally, flood proofing measures include relocating goods, equipment, and potentially harmful chemicals beyond areas prone to flooding

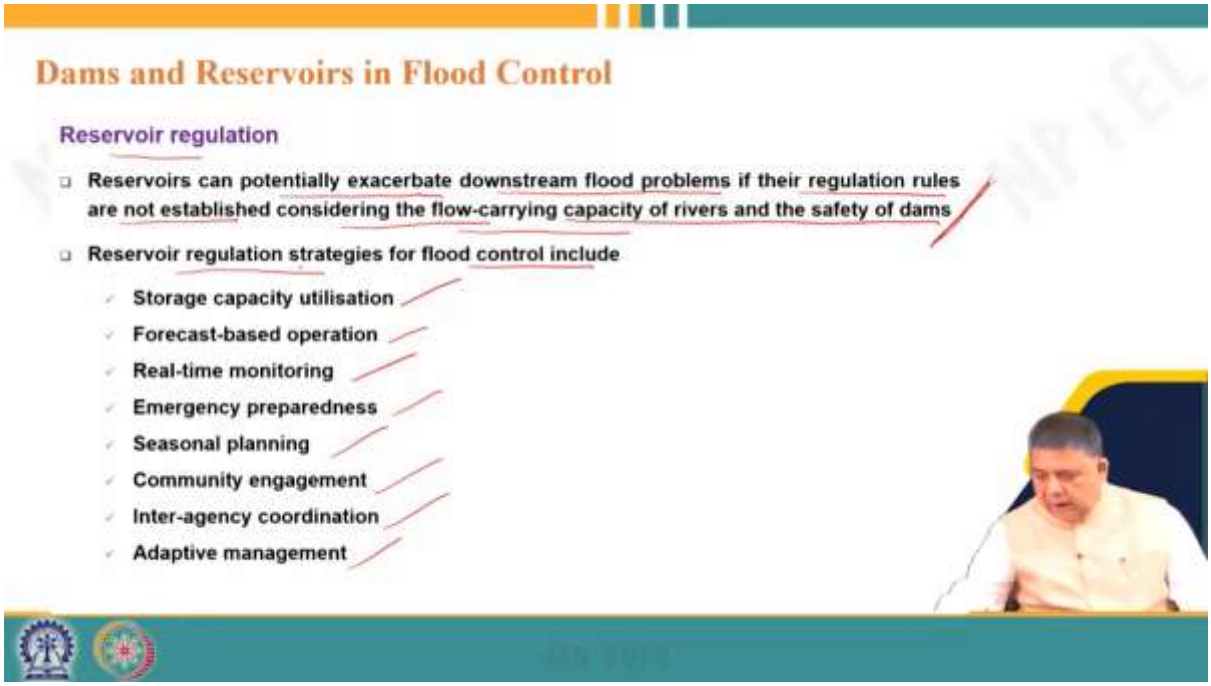
Then, of course, you have evacuation and relocation plans. So, evacuation and temporary relocation of communities in chronic flood-prone areas constitute a strategic non structural major in flood management. So, obviously, you know that there are certain typical flood-prone areas where floods occur almost every year. So, the administration there has to have an evacuation and relocation plan, and that is why quickly people are taken off from the flood-prone areas to safer locations. And these are tailored to specific areas, an approach that aims to safeguard lives, livestock, and valuables during the high flood period. So, whenever a high flood comes, you would like to protect these areas, and that is why you have to have an evacuation and relocation plan. Then, of course, nowadays, a thing which is being talked about is flood insurance, which mitigates individual financial burdens by spreading losses across a larger population and fostering community resilience. So, if you have installations or buildings or properties that are insured against flood, then obviously, in case of any mishap, there will be financial support available if we have taken flood insurance. So, that is also a major thing that is coming.

Now coming back to dams and reservoirs in flood control, dams and reservoirs play a crucial role in flood management by storing water during floods, thereby mitigating the flood peak downstream, which we just discussed. And controlled releases into the downstream river, considering its safe carrying capacity, is done to create space in the reservoirs for accommodating future floods. So, that is why we already discussed that flood control or emergency flood control is there in the reservoir, which you will try to release, keeping into account the downstream channel capacity. So that adjoining areas are not affected, but at the same time, you would like to release water so that there is enough space available for adjusting the incoming flow. While reservoirs offer a viable long-term solution to flood-related challenges, their effectiveness in flood control is enhanced when designated spaces result. So obviously, you have to have sufficient, depending upon the height of the dam, the reservoir capacity, and enough space has to be available in order to accommodate the flow. And national water policy allocates the allocation of an adequate flood cushion in water storage projects,

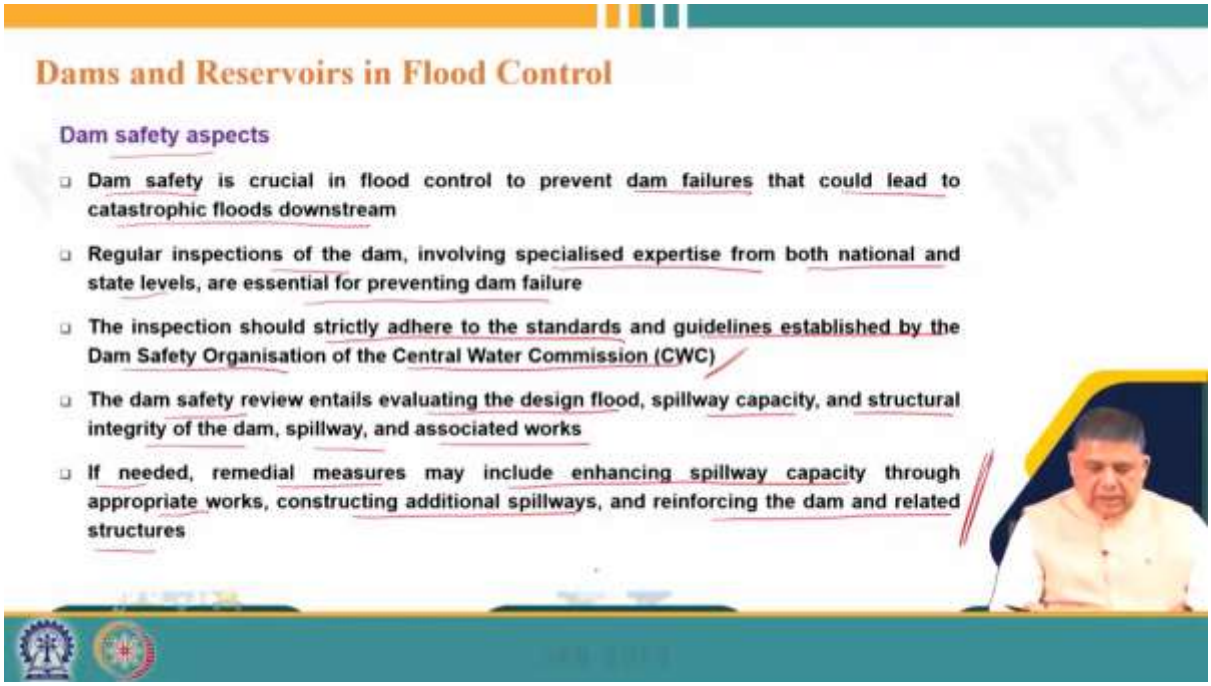
emphasizing flood control as a top priority in reservoir regulation policy. So, obviously, whenever there is a dam or a reservoir built, so obviously, flood control is a top priority because that is one of the major functions of dams and reservoirs.



Coming to reservoir regulation, reservoirs can potentially aggravate downstream flood problems if their regulation rules are not established considering the flow-carrying capacity of rivers and the safety of the dams. So, obviously, you have to take into account the capacity of the channel and also how much water the structure can handle. And regulation strategies for flood control include storage capacity utilization. So, obviously, as you say, we have different zones, the concept of storage zoning. So, all zones should be utilized correctly, forecast-based operation, and then if your reservoir is being operated based on the forecast. So, if you know that in the next 48 hours you are likely to get heavy flow, then if you can release the water, then obviously, things will be under control. Then, of course, real-time monitoring, emergency preparedness, seasonal planning, community engagement, interagency coordination, and adaptive management, all these could help in reservoir regulations properly.

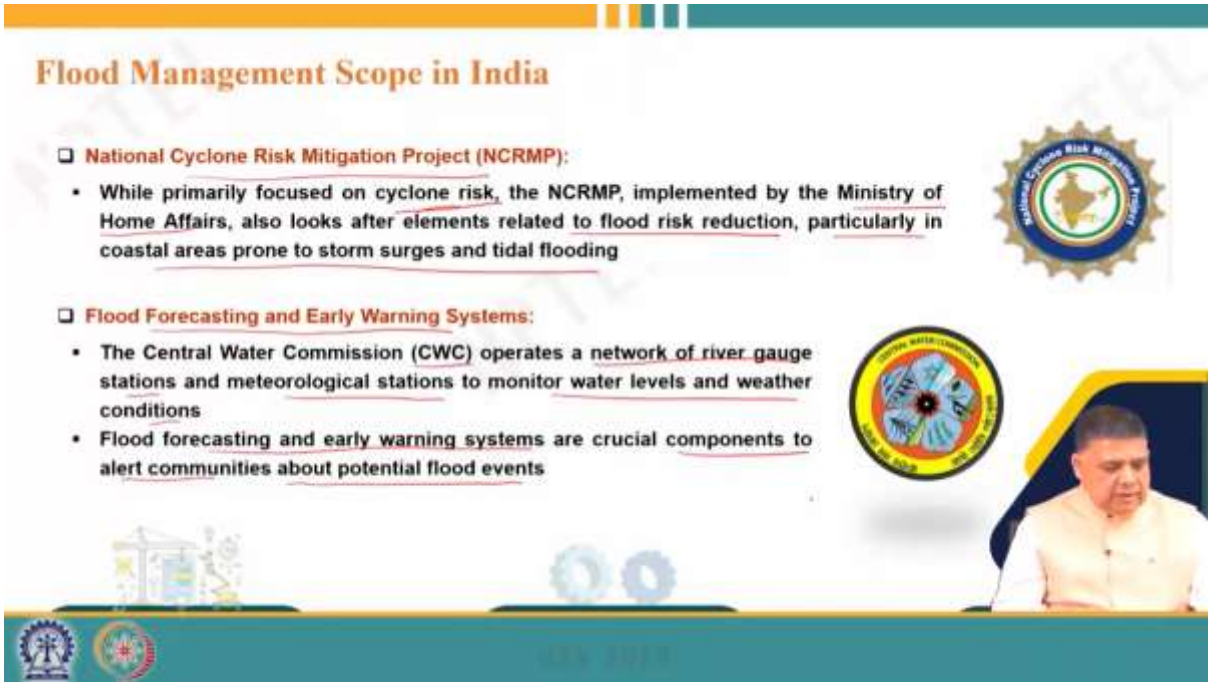


Then dam safety aspects also need to be taken into account for flood control to prevent dam failures that could lead to catastrophic floods downstream. So, obviously, dam safety, and that is why many times during the monsoon season, we hear that suddenly the dams were open, the gates were open, and also while discussing the flush flood, we discussed this possibility is always there. Regular inspections of dams involving specialized expertise from both national and state levels are essential to prevent dam failures .The inspection should strictly adhere to the standards and guidelines established by the dam safety organization of the Centre Water Commission. So, we have certain standards and guidelines that should be followed during inspection so that proper care is taken. That review entails evaluating the design flood spillway capacity and structural integrity of the dam spillway and associated works. And if needed, remedial measures may include enhancing spillway capacity through appropriate work, constructing a regional spillway, or reinforcing the dam and related structures. So, depending on the expected flood levels and the facility that is provided already, we can enforce the outflow from the reservoir.



Now coming to flood management scope in India, the Government of India has provided financial assistance to states and union territories for implementing various projects in critical areas, and one major is the National Disaster Management Authority (NDMA), which is a apex body responsible for formulating policies, plans, and guidelines for disaster management in India. And this possibility includes the implementation of structural measures such as dams, embankments, and reservoirs to regulate workforce and minimize the impact of floods. Then we have the Integrated Flood Management Program, which is by the Ministry of Water Resources, IWA Development Ganga Regeneration, which focuses on comprehensive flood management, including structural non-structural measures, early warning systems, and community involvement.

Then we have the National Cyclone Risk Mitigation Project, which basically looks at national cyclones and cyclone risk, and it is implemented by the Ministry of Home Affairs, which looks related to flood risk reduction particularly in coastal areas prone to storm surges and tidal flooding. Then flood forecasting and early warning systems, CWC operates a network of river gauge stations and meteorological stations to monitor water levels and weather conditions, and flood forecasting and warning systems are crucial components to alert the community about potential floods. And there are several flood forecasting and warning systems installed on major river systems in the country.



Then of course, you have community-based disaster risk reduction (CBDRR), which takes up various programs emphasizing on community involvement in disaster risk reduction. Community-based approaches include training programs, awareness campaigns, and establishment of local disaster management committees, which involve people so that they can take care of in case of minor floods. Then of course, NRSC is there, which basically utilizes satellite imagery and remote sensing technology for flood monitoring assessment, and of course, it helps in identifying flood-prone areas, monitoring changes in river courses, and supporting disaster response efforts.

Then coming to flood forecasting and warning in India, flood forecasting provides advanced notice regarding when the river will inundate its floodplain and extent of flooding, and the anticipated that we have already discussed during flood routing in great detail. And having dependable advanced information and warning about imminent floods can significantly minimize the potential loss of life and property. Among the various non structural measures for flood management, flood forecasting and warning has emerged as particularly noteworthy and is garnering sustained attention from planners and gaining acceptance from the public. And CWC has implemented a comprehensive nationwide flood forecasting and warning system encompassing major interstate rivers, which I just mentioned that several major rivers have now this flood warning and forecasting and warning system employed. So, states often complement the CWC system by making arrangements for advance warning at additional stations strategically significant to them. So, even state governments put their efforts in adding to whatever is done by CWC.

Flood Forecasting and Warning in India

- Flood forecasting (FF) provides advance notice regarding when the river will inundate its floodplain, the extent of the flooding, and the anticipated duration
- Having dependable advance information and warnings about imminent floods can significantly minimise the potential loss of life and property
- Among the various non-structural measures for flood management, flood forecasting and warning have emerged as particularly noteworthy. This approach is garnering sustained attention from planners and gaining acceptance among the public
- The Central Water Commission (CWC) has implemented a comprehensive nationwide flood forecasting and warning system, encompassing major inter-state rivers
- States often complement the CWC system by making arrangements for advance warnings at additional stations strategically significant to them

Now, in this case, flood forecasting and warning basically methodology include data collection and, of course, you have to have real-time hydrological data including gauge and discharge information as well as meteorological data. So, data from 945 stations in 62 river subsets are collected and lies on a daily works basis for this purpose. Then we use hydrological and hydrometeorological data from CWC, and IMD also provides you daily rainfall data, 24-hour heavy rainfall warnings, and quantitative precipitation forecasts for various river basins to CWC flood forecasting centers. And communication facilities are there to ensure the transmission of rainfall data from gauge stations located at various CWC gauges and discharges. So, all kinds of facilities are provided for data collection.

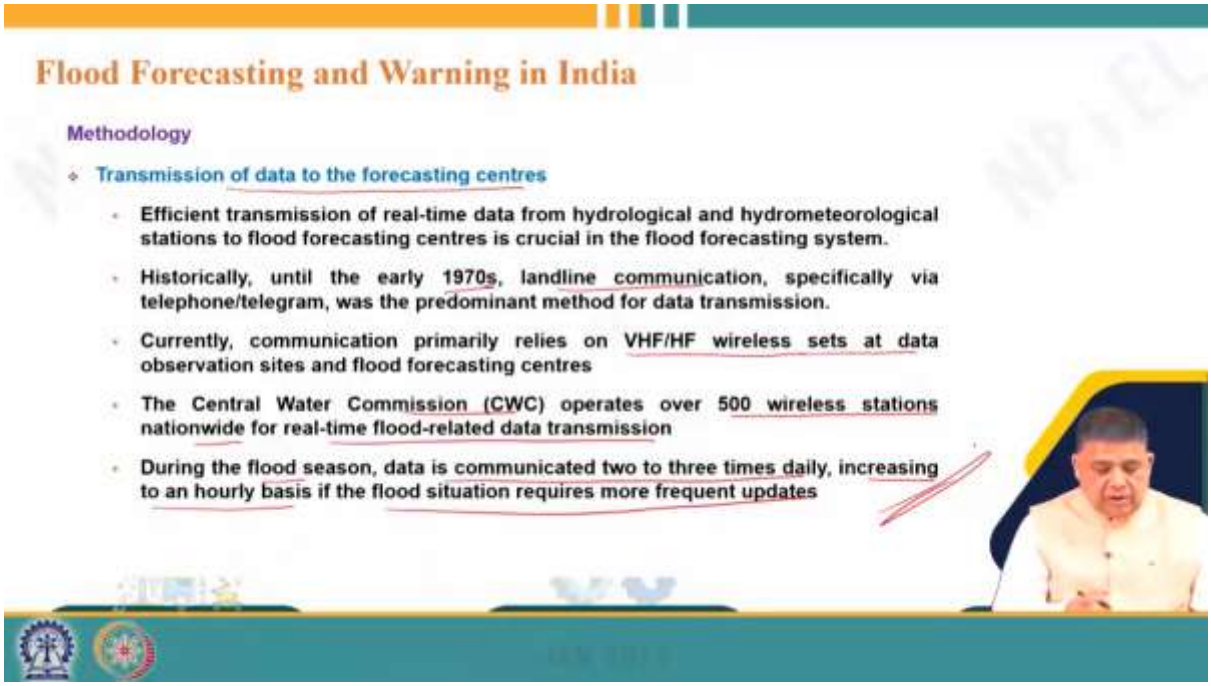
Flood Forecasting and Warning in India

Methodology

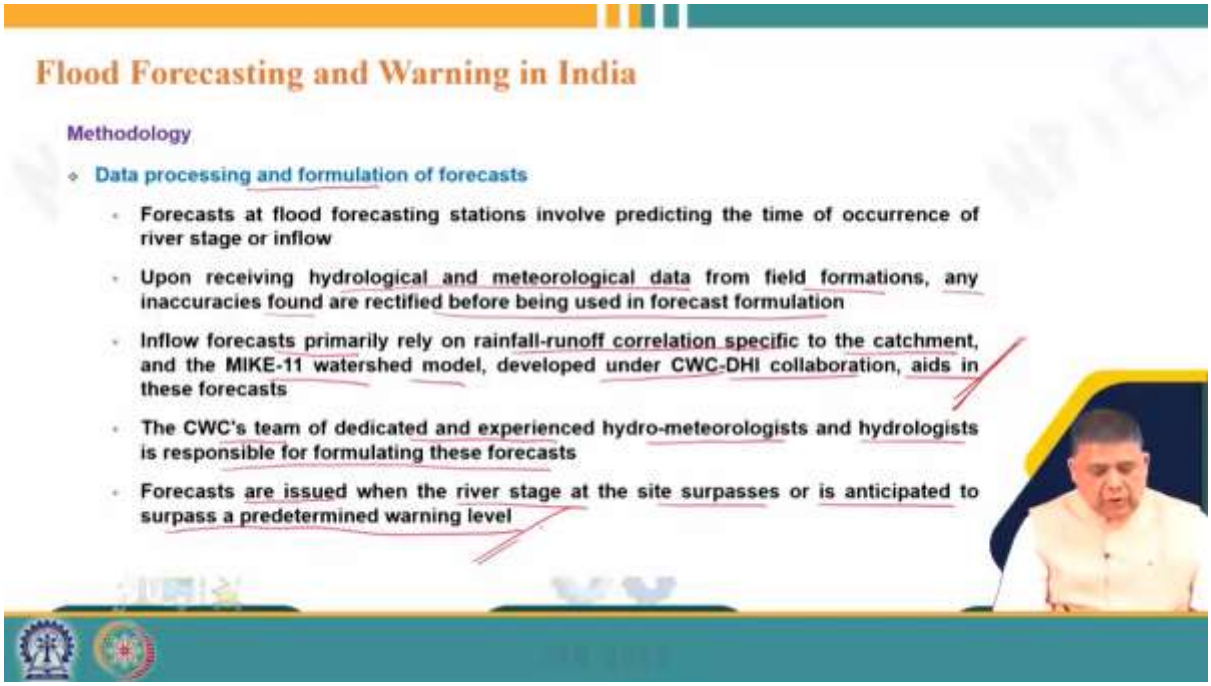
- Data collection
  - The formulation of a flood forecast relies on real-time hydrological data, including gauge and discharge information, as well as meteorological data such as rainfall
  - Data from over 945 stations in 62 river sub-basins are collected and analysed on a daily basis for this purpose
  - The hydrological and hydrometeorological data are predominantly observed and gathered by the field formations of the Central Water Commission (CWC)
  - India Meteorological Department (IMD) contributes daily rainfall data, synoptic situations, 24-hour heavy rainfall warnings, and quantitative precipitation forecasts for various river basins to CWC's Flood Forecasting (FF) centres
  - Communication facilities are facilitated by the CWC to ensure the transmission of rainfall data from gauge stations located at various CWC gauge and discharge stations

Then of course, for transmission of data to forecasting centers, until the 70s we were using landline communication, but now it is basically VHF or HF wireless sets that are being used,

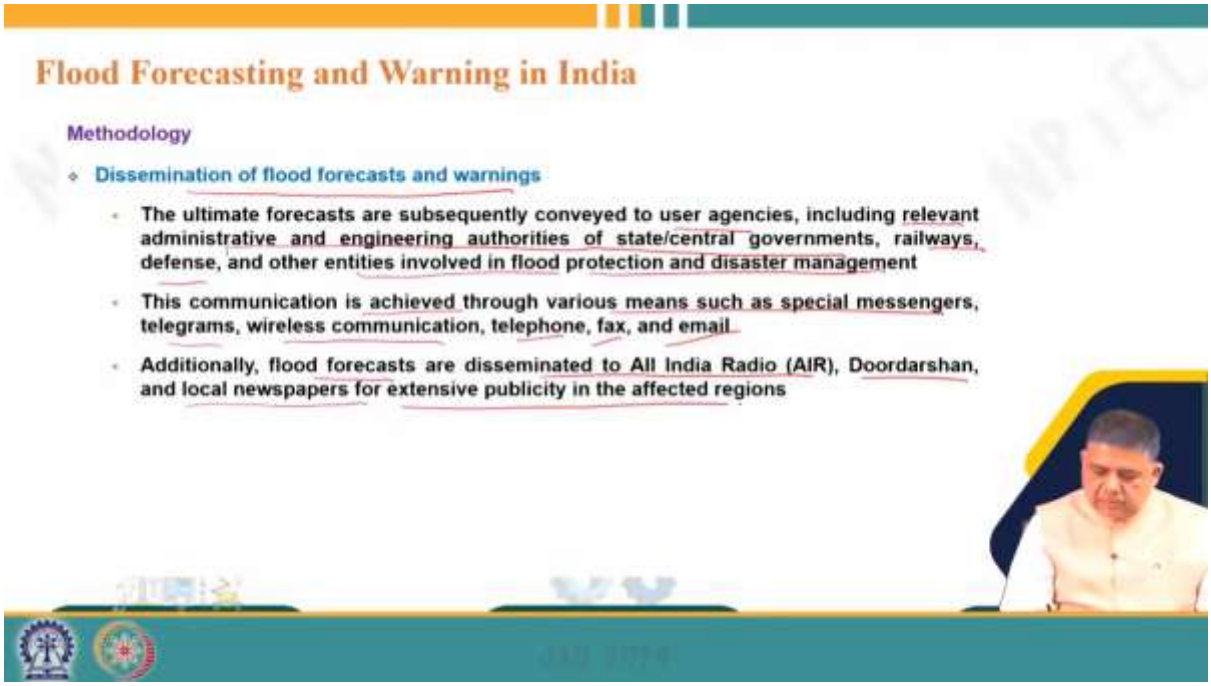
and CWC operates over 500 wireless stations nationwide for real-time flood-related data transmission.And during the flood season, data is communicated 2 to 3 times daily, increasing to an hourly basis if the flood situation requires more frequent. So, there is frequent data transmission from one station to the other so that through the forecasting centers, data can be processed and forecasts or warnings could be released.



Then data processing and formulation of forecasts basically involve receiving hydrological and meteorological data from field formations, and any discrepancies found are rectified before using the forecast. And info forecasts primarily rely on rainfall-runoff correlation specific to catchment and the MIKE 11 watershed model developed under CWC-DHI collaboration. So, it is one of the models which CWC uses, and CWC's team of dedicated and experienced hydrometeorologists and hydrologists are responsible for formulating these forecasts.And forecasts are issued when the real stage at the site surpasses or is in the fatal surpass a predetermined warning level. So, almost all these things are decided.

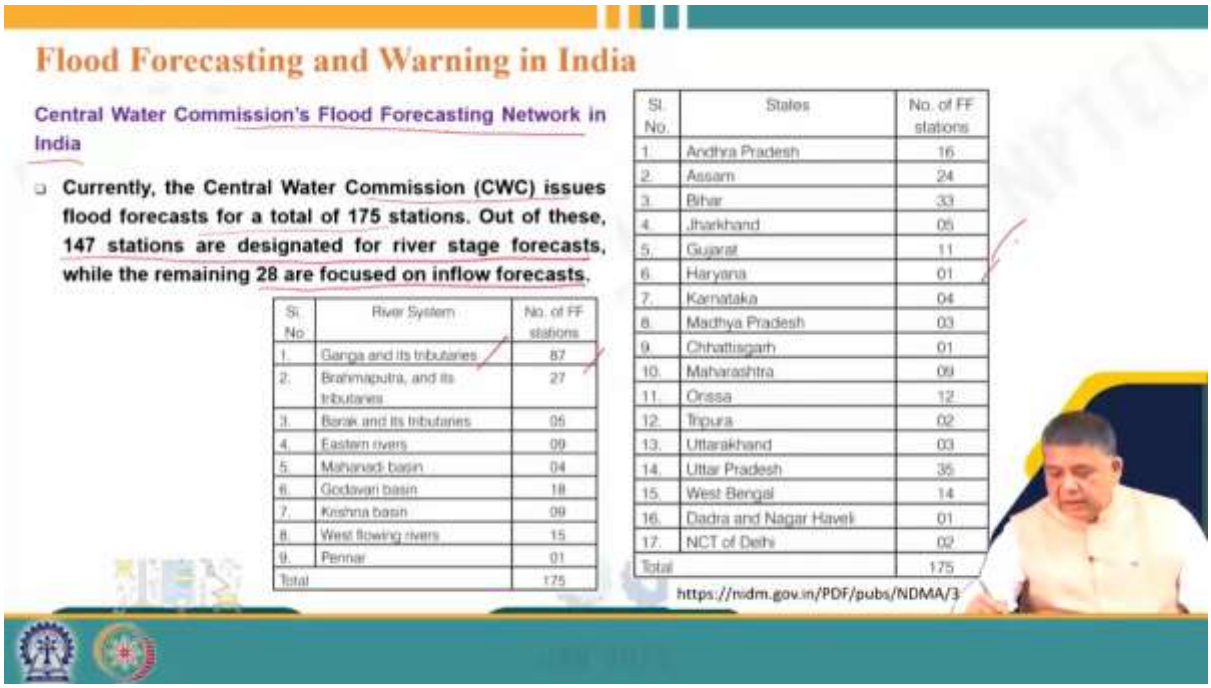


Then, of course, dissemination of flood forecasts and warnings is there. So, once the forecasts are ready, then, of course, it is disseminated to various user instances and agencies, including relevant administrative and engineering authorities of state central governments, railways, defense, and other entities involved in flood protection disaster. Communication is achieved through various means such as special messengers, telegrams, wireless communication, telephone, fax, email, so that means all communication measures are adopted.And additionally, flood forecasts are disseminated to All India Radio, Doordarshan, and local newspapers for extensive publicity in the affected region.



And ah this is the list of CWC flood forecasting network. Similarly, CWC issues flood forecasts for about 175 stations, out of which 147 stations are designated for river stage forecasts and 28

are for inflow forecasts. So, these, you see, different river systems, how many are involved, and also this is the state-wise distribution of this network.



So, with this, we come to the end of this lecture where we discussed flood control and management. We saw various possible structures, and there are non-structural measures like flood warning and flow routing, along with flood warning systems. We also observed some work being done, especially in India, including the CWC network. Please give your feedback and raise any questions or doubts; we shall be happy to answer on the forum. Thank you very much.