LECTURE - 9

INTRODUCTION TO FLOOD FORECASTING

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OBJECTIVES:

Every year floods occur in some part or the other of our country resulting in heavy damages and loss of life. Flood forecasting provides useful warning to the areas/people likely to be affected to enable them to take suitable measures. This lecture introduced various aspects of flood forecasting including development of river forecasting service in India.

1.0 INTRODUCTION

Some time immemorial, floods have been responsible for loss of crops and valuable property and untold human misery in the world, India has been no exception. India, which is traversed by a large number of river systems, experiences seasonal floods. It has been the experience that floods occur almost every year in one part or the other of the country. The rivers of North and Central India are prone to frequent floods during the South-West monsoon season, particularly in the month of July, August and September. In the Brahmaputra river system, floods have often been experiences as early as in late May while in Southern rivers floods continue till November. Floods are caused by excessive rainfall in the river catchments and the magnitude and severity depend upon the nature and extent of rainfall and the characteristics of the specific water-sheds. Flood control-which should more correctly be termed "Flood Management" can be planned through engineering measures. Wise application of engineering science has afforded ways of mitigating the revages due to floods and providing reasonable measure of protection to life and property. Such measures comprise multipurpose reservoirs and

retarding structures which store flood waters, channel improvements which increase floods carrying capacity of the river, embankments and levees which keep the water away from floods prone areas, detention basins which retard and absorb some flood water, flood-ways which divert flood flows from one channels to another and over all improvement in the drainage system. An area of 40 million ha. in India has been identified as flood prone. Various engineering measures could ultimately protect a large portion of such flood prone areas. Till 1985 about 13 million ha. of land has been covered by some measures of flood protection. The large back-log of unconstructed, though economically feasible, flood control projects will take quite some time to be cleared in view of the shortage of funds allocated and allocatable to flood control sector. This would in turn mean that many areas would remain unprotected for a considerable time thus calling for measures to ensure, mean while, flood loss mitigation.

It has also been recognised that permanent protection of all flood prone areas for all magnitude of floods by such structural means is neither possible nor feasible because of various factors such as financial constraints, cost-benefit criteria or topographic limitations of the region.

Experience has shown that loss of human life and property etc. can be reduced to a considerable extent by giving reliable advance information about the coming floods. The people could be moved to safer places in an organised manner as soon as the flood warnings are received. Valuable moveable property and cattles could be saved by transferring them to places of safety. The effectiveness of non-structural measures in reducing flood damage would depend upon how accurately the estimation of future stages or flow of incoming flood and its time sequence at selected points along the river, could be predicted.

This process of estimating the future stages or flows and its time sequence at selected vulnerable points along the river course during floods may be called "Flood Forecasting". Reasonably reliable flood forecasting and warning coupled with effective follow up measures constitute the most important non-structural measure of flood management and flood damage mitigation.

Some sort of flood warning arrangement had existed in a few states of the country, but these were largely aimed at transmitting information on flood levels from upstream points to the areas lower down. Such warnings has limited utility in as

much as they did not indicate the likely levels and the time of arrival of floods at the vulnerable places. Further, they did not often give adequate advance notice.

1.1 Classification of River Forecasting

Depending upon the length of period covered by forecast, it can be identified in following three groups:

i) short term,
ii) intermediate term
iii) long term

Short term forecasts of several hours or days provide flood warning and are used to warn, the people likely to be affected by inundation, to operate dams and emergency flood ways and to keep vigil on the engineering works on and along the rivers.

Intermediate term forecasts of several days or weeks are used to plan or modify operating procedures keeping in view the storage available and the water uses comprising hydro-power generation, navigation and domestic water supply etc.

Long term streamflow forecasts of several months or a full season are used to plan seasonal utilization of water likely to be available and for chalking out appropriate and periodic regulation schedule to match with the plan of utilization.

The river forecasting can be classified as shown in Fig.1.

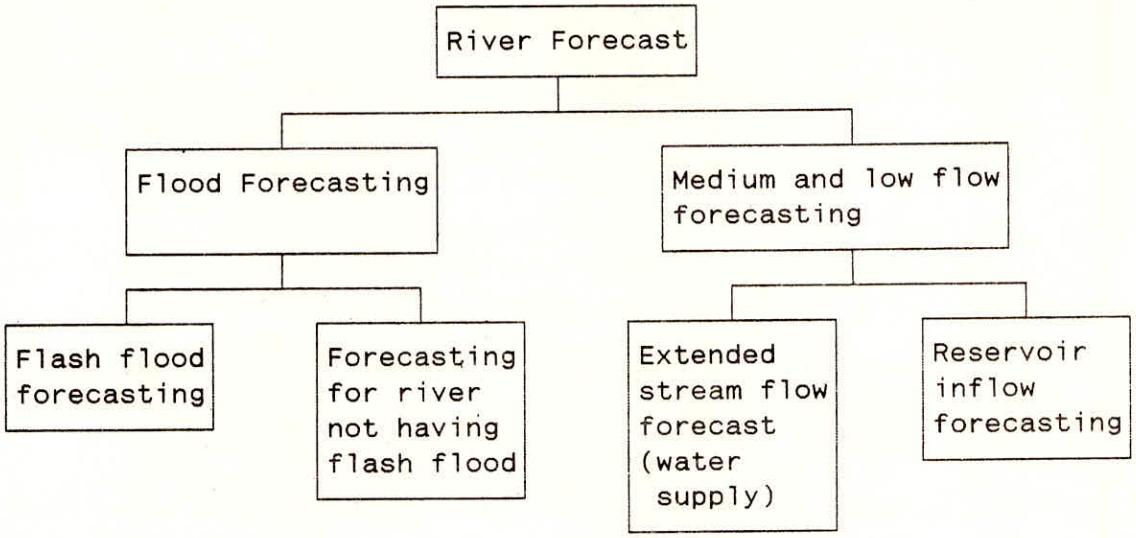

Figure 1: Classification of River Forecasting
(Reproduced from Fig.1.1, CWC, 1980)

Flash flood forecasting essentially refers to the flash flood guidance and it is generally needed for smaller river basins (having basin area < 1200 km^2 and time of peak < 6 hours).

3.0 TECHNIQUES EMPLOYED FOR ISSUE OF FORECASTS

The medium and low flow forecast are of great interest for water supply, irrigation, hydropower plant operation, pollution control and navigation, etc. The medium and low flow forecasts are formulated round the year irrespective of the river condition in respect of discharge.

1.2 Need for Flood Forecasting

Warning of the approaching floods provides sufficient time for the authorities:

(i) To evacuate the affected people to the safer places,

(ii) To make an intense patrolling of the flood protection works such as embankments so as to save them from breaches, failures, etc.

(iii) To regulate the floods through the barrages and reservoirs, so that the safety of these structures can be taken care of against the higher return period floods.

(iv) To operate the multi-purpose reservoirs in such a way that an encroachment into the power and water conservation storage can be made to control the imconing flood.

(v) To operate the city drains (outfalling into the river) to prevent bankflow and flooding of the areas drained by them.

All of these warrant accurate and time flood forecasts.

1.3 Development of Hydrological Forecasting

The development of methods and preparation of hydro-logical forecasts became possible when sufficient scientific knowledge was acquired on the most important phenomena occurring in rivers and lakes and observations of these phenomena were recorded.

The first hydrological forecasting service was organised in France in 1853 for the Loire. Forecasts were prepared mainly on the basis of corresponding stages. They were also based on an empirical evaluation of the effect of precipitation, on the formation of the floods.

The first scientific investigations, regarding the short range forecasting of the water stage on the navigable rivers of Russia, was conducted in 1890. In this work solutions to certain problems of forecasting water stages and water depths at shallow were thoroughly examined on the basis of data from upstream gauging stations. At the end of the 19th century, routine forecasting began in Germany.

Among the western countries, the U.S.A. has at present the most advanced hydrological forecasting services. The U.S. Weather Bureau includes hydrological departments which conduct research on forecasting methods and systematically divert the daily forecasting activity of field stations.

Extensive studies were initiated in recent years on the techniques of short range forecasting of storm floods, and on the technique of long range forecasting of various hydrological phenomena by the Chinese Ministry of Water Economy.

In Russia, the hydrological forecasting service, which consists of various departments prepares the forecasts and conducts the research.

One of the principal aim of scientific efforts has been to establish the basic laws governing the physical processes which determine the state of bodies of water, define these processes quantitatively and finally, develop on the basis of these data, a technique of hydrological forecasting. This approach has greatly increased the role of theory and experiments in the development of hydrological forecasting methods. Accordingly, statistical methods, which were the basic investigation tools in pre-war period, became an auxiliary implement and the genetic analysis of the phenomena has begun to acquire decision importance.

In the post-war period, much attention has been paid to the investigation of the time of flow and storage of water in river systems on the basis of water balance methods. These studies permitted a theoretical substantiation and a considerable development of forecasting by the method of corresponding stages.

Methods of forecasting summer runoff of low land rivers were also improved during this period. Much attention in forecasting low water runoff has been given to a close analysis of the recession curves; these are considered integral characteristics of the storage capacity and the rate of its depletion in a basin. Due consideration of the water storage capacities of a drainage basin and ground water storage capacities made it possible to develop more accurate methods of forecasting summer and autumn-runoff.

1.3.1 Development of flood forecasting in India

In 1969, the Government of India created a Central Flood Forecasting Directorate headed by a Superintending Engineer. In 1970, under Member (Floods), six flood forecasting divisions were set up on inter state river basins. These covered the flood prone basin/sub-basins of the Ganga. The Brahmaputra, the Narmada, the Tapti, the Teesta and coastal rivers of Orissa. By the year 1977, the Central Flood Forecasting Organisation comprised of one Chief Engineer's Office, 3 circles and 11 divisions.

Now, in most of the States there are arrangements for the issue of flood warning from the upstream stations to the downstream stations. These warnings include:

(i) Whether the river is rising above a certain specified level, known as danger level or not;

(ii) Whether the river is rising or falling;

(iii) Whether the stage of the river is 'low', 'medium' or 'high'.

The above warnings, issued by telegrams, telephone or wireless systems are of purely qualitative in nature and they give only an indication of the nature of the flood. Such procedures are at present being followed in West Bengal, Andhra Pradesh and Bihar States.

After the completion of certain multi-purpose projects like the Hirakud in Orissa, DVC Projects in Bihar/Bengal, Bhakra in Punjab, forecasting techniques have been evolved using the data of rainfall and stream gauges in the catchment upstream of the dam. Correlation diagrams have been prepared with the previous data to predict the inflow into the reservoir. Based upon this, the reservoir operations are carried out. Such flood forecasting systems have also been set up for Yamuna in Delhi, Koshi in Bihar, and Krishna and Godavari in Andhra Pradesh.

1.4 Status of Setting of Inter-State Flood Forecasting System

By the year 1985 the Central Water Commission has established a network of 145 flood forecasting and warning sites on various inter-State rivers (Rangachari, 1986).

The data of the river gauges and the rainfall are transmitted to the flood forecasting centres from all the key stations by means of wireless or telegrams. Based on these data and the correlation curves already developed with the previous data, the forecasts are daily issued to the concerned authorities so that they can take the appropriate measures.

Some of the salient features of the existing flood forecasting organization under Central Water Commission are given in Appendix I.

2.0 DATA REQUIREMENT

Basically gauge/discharge and or rainfall data are required for flood forecasting purposes. The number of reporting stations depend upon hydrologic need and availability of observers and communications.

The number of raingauge stations in the basin should be such that:

(a) The areal rainfall in the catchment can be estimated with the desired accuracy, and

(b) The variation in the areal distribution as well as time distribution can be identified

For network design of river gauges, the following points should be kept in mind:

(a) Wherever the forecast is being issued on the basis of gauge correlation, the base station and forecasting station must be equipped with gauges.

(b) In case more than one tributary are joining the main stream and the forecast is based on multiple coaxial diagram, there should be at least one gauge on each of the tributaries. The location of gauges on the tributaries should be such that the time of the travel from base station to forecasting station in respect of tributaries as well as main stream is constant.

(c) Where the routing model forms the basis of formulation of forecast, the reach has to be divided into various

sub-reaches. For each sub-reach, in addition to the gauge reading discharge observation should also be carried out.

(d) For incorporating the effect of intervening catchment on well designed channel, one gauge has to be installed. If the channel is not well designed, it will be imperative to install adequate number of raingauges to account for the contribution from the intervening catchment.

Apart from gauge/discharge and/or rainfall data interception, evaporation, evapotranspiration, interflow, infiltration, ground water and percolation are used as inputs to several conceptual models which are in operational use in many advanced countries.

3.0 TECHNIQUES EMPLOYED FOR ISSUE OF FORECASTS

The various steps involved in the operation before issue of forecasts and warning are as follow:

(i) Observation and collection of hydrological and meteorological data.

(ii) Transmission/Communication of data to the forecasting Centres.

(iii) Analysis of data and formulation of forecasts.

(iv) Dissemination of forecasts and warning to the Administrative and Engineering Authorities of the States.

The above phases are described briefly in the following paragraphs:

3.1 Data Collection

Observation and collection of hydrological data are done by the Hydrological Observation and Flood Forecasting Organisation (HO & FFO), Central Water Commission. Flood Meteorological offices (F.M.O.) collects and transmits the meteorological data. The farmer is responsible for planning of river gauge/discharge network, collection of gauges and discharge data and communication of the data to its Flood Forecasting Centres, while the later is

responsible for planning of rain gauge network in consultation with HO & FFO and for collection and transmission of rainfall data to the Flood Forecasting Centres. The F.M.O. provides information regarding general meteorological situation, rainfall amounts of last 24 hours and heavy rainfall warning for the next 24 hours for different regions to the concerned flood forecasting centres of HO & FF Organisation.

At present data of nearly 380 hydrological and 500 hydro-meteorological stations are collected everyday and utilised by flood forecasting centres for formulation of forecasts during monsoon period. Similarly, the meteorological data which includes rainfall amounts, heavy rainfall warning, general synoptic situation and weather forecast are being supplied by F.M.O. to concerned Division and Sub-divisions/Control Rooms of HO & FFO daily on telephone failing which the informations are being collected by the special messenger of HO & FF Organisation from the F.M.O. office. Now a days, the data of operational sites are mostly being transmitted to the forecasting centres over wireless network, of HO & FFO, most of which are 15 watt SSB sets.

3.2 Data Transmission

Transmission of data on real time basis from the hydrological and hydrometeorological sites to the Flood Forecasting Control Rooms is a very vital factor in flood forecasting. Transmission of data should be as quick as possible to issue forecast as much in advance as possible in order to enable organisation of relief measures to take protective steps. Transmission of the observed data on real time basis is, therefore, extremely necessary for efficient flood forecasting system.

The land-line communication i.e. by telephone/telegram was the earliest and very commonly used mode for data transmission in Flood FOrecasting Services till 1970. This system was having the following major drawbacks:

(i) The telegraph offices were not always located very close to the data observation sites and consequently a lot of time was wasted in performing the journey between the site and the telegraph office.

(ii) During heavy rainfall period, when timely requirement of the data becomes extremely essential, the telegraph/telephone system becomes frequently out of order.

The communication system was further improved by installing VHF/HF wireless sets at the data collection sites most of which are 100W/15W HF sets. The wireless stations generally operated by the Wireless Operators for transmission of data to the Control Rooms. Provision of wireless mechanics has also been made for repairs of the sets and their maintenance. Planning, operations, maintenance and improvement of the communication net work is looked after by officers and supporting staff.

3.3 Data Analysis and Forecast Formulation

After receipt of the hydrological and hydro-meteorological data at the Control Room, the data are compiled scrutinised and analysed by Engineers/Hydro-Meteorologist engaged in this work. The system of data processing before use in forecast formulation has been introduced to prevent chances of errors. Many forecasting centres have been provided with micro computer facilities for data processing.

The next important step is the formulation of forecast. In fact, the analysis of data and formulation of forecast is the most important stage in the process of forecasting system.

The various flood forecasting centres are using different forecasting models, based on availability of hydrological and hydro-meteorological data, the basin characteristics, computational facilities available at forecasting centres, warning time required and purpose of forecast. However, some of the common methods being used by various centres are given below:

(i) Simple correlation - based on stage-discharge data.

(ii) Co-axial correlation - based on stage, discharge and rainfall data etc.

(iii) Routing by muskingum method.

(iv) Successive routing through sub-reaches.

The forecasts obtained from the correlation diagrams or mathematical models etc., are modified as necessary to arrive at a final forecast based on the prevailing conditions in the river. This requires intimate knowledge of the river by the forecaster. Forecasts once issued are further modified and revised forecasts are issued if any additional informations are received after the initial forecasts are made, if necessary.

3.4 Dissemination

The final forecasts are being communicated to the concerned administrative and engineering authorities of the state and other agencies connected with the flood control and management work on telephone or by special messenger/telegram/wireless depending upon local factors like vulnerability of the area and availability of communication facilities etc.

On receipt of flood forecasts, the above agencies disseminate flood warnings to the officers concerned and people likely to be a affected and take necessary measures like strengthening of the flood protection and control works and evacuation of the people to safer places etc. before they are engulfed by floods. Generally, the State Govts. set up control rooms at States and District Headquarters which receive forecasts and then further disseminate the flood warning to the affected areas and organise relief as well as rescue operation. Flood Forecasts are also passed on to the All India Radio, Doordarshan and the local Newspaper for wider pubilicity in public interest.

4.0 MODERNISATION OF FLOOD FORECASTING SERVICES

The flood forecasting services provided by the Govt. of India through Central Water Commission, which has over 25 years of experience in the field and commendable performance to its credit, is presently poised for big leap forward by application of modern technology in the field of communication and introduction of high speed computers for forecast formulation.

In order to improve the warning time and the accuracy of the forecast, it was considered necessary to adopt latest technology for real time collection and transmission of hydrological and hydro-meteorological data and application of the

high speed computer using hydrological and mathematical models.

In order to achieve these objectives, a pilot project to establish fully automatic operational river and flood forecasting system in the country with the assistance of World Meteorological Organisation (W.M.O.)/United Nations Development Programme (U.N.D.P.) has been implemented in the Yamuna basin upto Delhi. The experience gained from this project is being applied to modernise other forecasting centres in the country.

Another scheme called C.W.C. - DHI (Central Water Commission & Danish Hydraulic Institute, Denmark) collaboration project, with the Damodar river basin as focus project, has also been implemented and computerised mathematical models developed in the DHI is being used for inflow forecasting for formulation of flood control scheme. A scheme on similar line has been taken up for Godavari Basin.

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APPENDIX-I

SALIENT FEATURE OF FLOOD FORECASTING ORGANISATION,

Central Water Commission

(January 1986)

1.	Establishment of First Scientific Flood Forecasting Unit (F.F.U. Delhi)	:	November, 1958
2.	Date of issue of 'First Flood Forecast'	:	25th July
3.	Name of first forecasting site/river	:	Delhi Railway Bridge/Yamuna
4.	Year of commencement of flood forecasting system on the inter-State rivers	:	1969
5.	No. of Chief Engineer's Office	:	2
6.	No. of Superintending Engineer's Office including one P and D (Flood Forecasting) Circle, New Delhi	:	8
7.	No. of present flood forecasting Divisions excluding Snow Hydrology Division and also other divisions which are engaged in hydrological observations only	:	22
8.	No. of control rooms/ sub-divisions engaged in flood forecasting work under above division.	:	64
9.	No. of inter-state rivers (main/ tributaries) covered by flood forecasting programme	:	59
10.	No. of States including Union Territories covered under F.F. programme	:	12

11.	No. of forecasting sites	:	145
12.	No. of gauge/gauge and discharge sites	:	380
13.	No. of raingauge stations (ordinary/ self-recording)	:	500
14.	No. of wireless stations	:	402
15.	Maximum number of forecast issued in any one year	:	7385 (in 1978)
16.	Seventh Five Year Plan outlay	:	1,000 lakhs (for 1986-90)
	Non-Plan	:	586 lakhs (per year)