Forecasting of Floods in West Pakistan

by

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Introduction.

It was on a bright sunny morning in September 1950, that flood waters from the Ravi entered the city of Lahore and took its people by complete surprise, for who could think of flood on such a fine day. That flood broke previous records and resulted in a major calamity for the Punjab. About 600 lives were lost, 1500 villages destroyed, 4000 villages damaged and the losses to crops and property amounted to more than 10 crore rupees.

2. A similar tregedy struck Baluchistan in July 1954 when in Sanjwai Tehsil near Ziarat the sudden onrush of flood waters drowned more than 80 people, destroyed 500 dwellings and carried away hundreds of cattle. It took only a couple of hours for the flood to develop and recede back.

3. Such disasters may occur in any part of our country in any flood season without the least warning to the affected population. The questions naturally arise – "Can something be done to stop or reduce them ? Is it possible to forewarn the flood threatened populations by means of definite flood warnings ? In other words, is it possible to forecast the onset of floods with the same ease and confidence with which, for example. we do weather forecasting ? For answering these questions we shall have to analyse the causes of floods.

Causes of Floods in West Pakistan.

4. Among the major causes of floods may be listed the following :—

(1) Excessive rainfall in a river basin at a critical time.

(2) Excessive snowmelt with or without excessive rainfall.

(3) Failure of a dam, reservoir, bund or levy.

(4) Sudden removal of temporary obstructions in a river channel.

5. Floods in West Pakistan are almost always due to excessive rainfall. Other causes being either irrelevant or boyond forecasting possibility will be left out of discussion.

Possibility of Forecasting Floods.

6. We are now in a position to answer the questions raised earlier. The answer to all of them is an emphatic 'Yes'. Keeping in view that it is excessive storm rainfall that is almost always responsible for floods in West Pakistan, the problem of forecasting floods should not be impossible of solution. It is our duty to find a satisfactory solution and find it quickly. For, if we are able to warn the flood threatened populations well in time much of the loss of life can be averted and a good portion of flood losses can be cut down.

Methods of Forecasting Floods.

7. The problems involved in the forecasting of floods are easy to understand. On the basis of past experience, we have to determine the critical combinations of excessive rainfall and hydrologic conditions of a river basin that resulted in floods of different magnitudes. The results so established can be used for forecasting of future floods on the basis of recorded precipitation and the current hydrologic condition of the basin. Alternatively a point rainfall in a river basin can be correlated with significant river rises. Based on these concepts, there are several methods available for the prediction of floods. The important ones are summarised below :—

(1) Flood Frequency Method : is based on probability analysis and is used for long term prediction of floods of given magnitude.

(2) Statistical Method : in this rainfall at significant points in a basin or average over the basin is statistically correleated with the flood peaks at important river sites.

(3) Unitgraph Method : in which measured precipitation over a basin is averaged and net run-off is computed from it by deducting losses depending upon the initial soil moisture and season. The runoff is then distributed in form of the forecast hydrograph with the help of the appropriate unitgraph.

(4) Theoretical Method : in this an attempt is made to make a comprehensive theoretical study based upon field investigetions and experimental research of all factors involved in the flood flow and to develop forecast formulas from such a study.

(5) Analytical Method : detailed hydrometeorological studies of past floods are made for estimating all the factors influencing the generation of floods. These estimates are used in the forecasting of future floods.

(6) Experimental Studies : the behaviour of river basin models is studied in hydraulic laboratories with simulated rainfall.

Intensity, duration and progress of the resulting floods are observed.

Resume of Flood Computation and Forecasting Work Done in Pakistan.

8. The Meteorological Department has been engaged in the computation and forecasting of flood flows in the Indus Basing for the last five years. After the disastrous floods of 1950 in West Pakistan, a Flood Commission was appointed by the Government for investigating the causes of floods and for recommending remedial measures. This Commission recommended the setting up of an organisation at the Meteorological Centre. Lahore, for the computation and forecasting of floods in the Indus Basin. The work was started towards the end of 1951. In view of great urgency of the work and paucity of the requisite data, it was decided to develop the Statistical Method to begin with under the guidance of Mr. S.N. Naqvi. The main items of work done so for are summarised below :—

(1) All the available river-flow and precipitation data in the Indus Basin were collected for the period 1941-50, scrutinised, tabulated and means worked out.

(2) Daily hydrographs of the river sites on the Ravi, the Chenab and the Jhalum were drawn for the flood months—July to September; significant flood peaks were picked out and classified, their probability calculated and thc time lag from one site to another computed.

(3) Linear correlations were established between point rainfall basin rainfall, discharge at the upper site and that at the lower site.

(4) Based on these correlations ready computation tables for the forecasting of river stage with the help of observed rainfall and riverflow data were prepared.

(5) Inundation maps showing the extent of inundations at different flood stages were drawn.

(6) Flood forecasts have been prepared by the Lahore Meteorological Office for the Ravi and the Chenab for the last three years on an experimental basis. Flood warnings are issued to the Police Headquarters, Lahore, who have been made responsible for their dissemination to the officials and public concerned. The procedures developed have been explained in the papers presented by Mr. S.N. Naqvi and Mr. Wirasatullah Khan to the Pakistan Science Conferences—1952 & 1953. (see list at the end).

Appraisal of the Forecasts Issued.

9. Although the results have been encouraging on the whole yet

it has been noticed that in some instances the forecast values are much in error. This is due mainly to the following reasons :—

(1) The river regimen has appreciably changed, mostly due to river control works raised since, 1951 and the earlier relations no longer hold.

(2) Soil moisture and seasonal indices have not been worked out so far.

(3) The routing relations do not take account of variable stages.

Suggested Programme of Work for Next 5 Years.

10. We in the Meteorological Service propose to undertake the following studies to develop the procedures beyond the stage which has so far been reached.

(1) Fresh relations would be worked out from the data after 1952.

(2) The new forecasting procedures would include indices reflecting the basin moisture deficiency.

(3) Unitgraphs would be developed and applied wherever possible.

(4) New routing procedures would be worked out for main stream forecasting.

11. To sum up, forecasting methods based on precipitation data, use of unitgraph and flood routing procedures would now be introduced. The remaining methods of flood forecasting as enumerated in para 7 are either of specific application or are still in the formative stage and may be left out of consideration at present.

Basic Concepts of the Unitgraph Method.

12. Before proceeding further, let us be clear about the unitgraph technique. The unitgraph can be defined in simple words as the most typical hydrograph of a basin produced by all storms of a critical duration, irrespective of total precipitation, provided the storm rainfall is more or less uniform over the basin. This is one of rhe most useful tools in flood forceasting.

13. Flood forecasting means prediction of flood hydrographs at important points along a river. Flood hydrographs represent stream rises of abnormal magnitude which in turn are the result of excessive rainfall as already pointed out. Therefore if storm rainfall over a basin could be measured correctly, it should not be difficult to compute the runoff or volume of flood water resulting from it under the given conditions of dryness of the basin. With the help of the unitgraph of the basin, this runoff volume can be distributed in time giving the forecast hydrograph.

14. But I do not want to suggest that the problem is as simple as that in actual practice, Far from it. Flood hydrology is rather complex

and its study becomes all the more difficult because direct observations of important hydrologic factors involved in the generation of a flood wave are not available. They have to be determined indirectly. Therefore, at least two to three years sustained research will be required before satisfactory procedures can be established. Further, as the hydrology of a basin keeps on changing, all this work will need constant revision and modification.

Kinds of Flood Forecasts.

15. I will now detail the different kinds of flood forecasts that a Forecasting Office may be required to prepare. They can be divided into three general kinds depending upon the length of notice available to the warnees.

(1) Long Range Forecasts : can be issued a few weeks to a few months in advance. If issued as water supply forecasts for a given river in a given season, they are generally based on snow surveys or snow accumulation measurements and precipitation in a given period. It will also be possible to issue them as flood forecasts when the technique of "quantitative precipitation forecasting" has been developed satisfactorily.

(2) Medium Range Forecasts : are issued a few days to a few weeks in advance. They concern large streams like the Indus and the Ganges and their main tributaries. Thus most of the forecasts will be of medium range.

(3) Short Range Forecasts : can be issued a few hours to a day or two in advance. These forecasts will be required for points in headwaters, rivulets or small tributary streams. Flood forecasts for headwaters and flashy streams although difficult to prepare and less reliable are nevertheless extremely useful to the affected population on account of flashy nature of floods in those areas.

Types of Flood Forecasts.

16. Flood forecasts can be of three types with respect to the nature of streams they serve :—

(1) Headwater Advisory Forecasts : In their headwaters most streams have rocky and steep slopes and are therefore flashy. That means flood waters begin to rise almost simultaneously with excess rainfall and crest stages are reached within a few hours of the end of rainfall, In such situations it is impracticable to prepare a crest forecast in Forecast Centre and transmit it to the area concerned well in advance of the flood peak. To cope with this difficulty advisory forecasts can be issued by a Forecast Centre to a responsible person in the locality indicating the amount of average rainfall in his area necessary to bring about flood

stage in the stream at that point. He receives the rainfall reports from his area without loss of time and if the reported rainfall reaches the danger point, he immediately warns the threatened population. This method is based on the use of unitgraph which can only be developed if the stream in question is gauged and rated and a few years data are available. Since few of our headwaters fulfil these conditions this method cannot be applied at present and I will not go into its details. It should, however be possible to develop rough relations if rainfall data for a few years are available and if information about crest stages reached in past floods can be collected Data of adjoining basins of similar characteristics can also be used. Keeping in view the huge losses resulting from flashy floods as occurred in Sanjawi Tehsil in Baluchistan in 1954 and in the Swat River Valley in the North West Frontier Province in 1955, even rough warnings can be of great help.

(2) Tributary Forecasts : are prepared for small streams or for gauged tributaries of big streams like the Indus. The reported rainfall in a basin is processed through rainfall-runoff procedures with the help of the current indices of the moisture deficiency in the basin. The end product is a stage forecast issued from a few hours to several days in advance.

(3) Main Stream Forecasts : are issued for the downstream areas on major streams where the time-lag is sufficient so that upstream stages can conveniently be routed downstream. Such forecasts can be issued several days to several weeks in advance. The accuracy of the forecast peak increases as the day of crest approaches.

Development of Forecasting Procedures.

17. I will now give brief outlines of the methods that can be used for developing the forecasting procedures for tributary and main stream forecasting.

(1) Rainfall—Runoff Relations : Constitute the most important procedure to be developed. The purpose is to determine average relations holding between rainfall and resulting runoff in different seasons and varying conditions of soil moisture. The region under study can be divided into hydrologically homogeneous zones. In each zone a number of stations for which discharge data are available should be selected. Annual discharge hydrographs for selected stations should be plotted for the last 10-15 years. From these significant stream rises should be selected for study. Storms corresponding to these rises should then be picked up from the relevant rainfall records. Total storm precipitation for each station in the zone should be plotted on

rence, its duration and the "Antecedent Precipitation Index" (API) at the beginning of the storm. Averages of all the plotted variables should be worked out. From the hydrographs of selected stream rises storm runoff should be calculated by substracting base flow. The average storm precipitation should then be correlated with runoff by throwing in the three indices of earlier precipitation (API) week number and storm duration. The relations can be put in form of convenient graphs.

(2) Development of Unitgraph :—The next step should be to develop one or more unitgraphs for the area under study. For this purpose suitable storms should be selected and corresponding discharge hydrographs plotted on open scale. Storm runoff should then be computed and unitgraph ordinates calculated by dividing the surface flow at the ordinate point by the total storm run-off. Several unitgraphs should be developed in this mannor and adjusted to a common duration and rainfall distribution. Average unitgraph for the basin should then be traced out graphically.

(3) Routing Procedures :—Flood routing means reproducing the hydrograph of upstream site at a downstream site. A number of procedures are available, for example (i) The Tatum Method, in which coefficients are determined which when applied successively to the upstream hydrograph, will reproduce the downstream hydrograph. (ii) Lag Routing and (iii) Stage Routing. The method giving most satisfactory results for a given reach of stream should be selected. (iv) The Electronic Stream Routing Maching is a great help in reducing the manual labour greatly in the development of complex routing procedures and should be procured if possible.

Preparation of Forecasts.

18. When the forecasting procedures have been developed, charts drawn and work sheets prepared, the preparation of flood forecasts would be easy. A day-to-day account of Antecedent Precipitation Index (API) at a representative network of stations in the basin should be maintained. From the days API, the loss Index (LI) can be determined with the help of rainfall-runoff relation mentioned earlier. When a storm commences over a basin, the LI's at all stations should be held constant. With the day's (LI) and the reported rainfall at a station, the run-off can be calculated at each station in the basin with the help of rainfall-runoff tables. This, should be averaged over the basin. This average runoff should be converted into discharge hydrograph with the help of basin unitgraph. This hydrograph should be routed to main stream and if there is any local ungauged flow in between, its unitgraph should also be added to the routed hydrograph. The resulting hydro-

graph will be the forecast hydrograph for main stream station. This forecast should be revised as later reports of rainfall and stage are received.

Recommendations.

19. Before concluding this paper I would venture to make a few recommendations for the proper organisation and successful operation of flood forecasting in West Pakistan.

20. **To the Central Government :—**

(1) The Flood Forecasting Organisation and the Organisation for research on the problems of flood forecasting should be strengthened.

(2) The setting up of Flood Forecasting and Warning Organisations and their activities should be covered by specific legislative sanction and should be fully publicised through the Press and Radio.

(3) The Government should be prepared to finance the opening if considered necessary, of new precipitation and river gauge stations at strategic points in the upper catchments of our rivers lying in foreign countries in cooperation with those countries.

21. **To the Irrigation Department :—**

(1) The Irrigation Department should extend full cooperation to the Meteorological Department in supplying the available river flow data and information about the irrigation canals, river regulation and control works etc.

(2) They should offer their communication facilities to the Meteorological Department for the transmission of the observed hydrologic data to the Forecast Centres.

(3) They should make immediate arrangements to open new gauging stations on the recommendations of the Meteorological Department as dictated by flood forecasting needs.

(4) They should help the Meteorological Department in opening new precipitation stations in the Indus basin.

22. **To the Meteorological Service :—**

(1) The precipitation network in the basin should be expanded, particularly in the upper catchments of rivers with special emphasis on the recording raingauges. The immediate aim should be to equip all the departmental observatories with a self recording raingauge. With the cooperation of the Irrigation Department, it should be possible to install rain-

(2) The Flood Forecasting Service should be expanded into a full fledged River Forecasting Service which in addition to preparing routine river forecasts and flood warnings should serve the interests of irrigation, agriculture, navigation and power development.

(3) The Meteorological Service has already trained some scientists in flood forecasting techniques. More persons should continue to be trained abroad to keep the Service abreast with the latest advances.

List of

Papers written in the Meteorological Department on the problems of floods in West Pakistan.

1.	Classification of floods in the Ravi and correlation between peak discharges at different stages along the river.	by S.N. Naqvi
2.	Estimation of peak discharges during floods in the Ravi at Mukesar, Jassar and Shahdara.	by S.N. Naqvi & Manzar Hasan
3.	A note on the Meteorological Causes of floods in the Punjab and introduction of flood warning system.	by S.N. Naqvi
4.	Sorting out of homogeneous random groups from heterogeneous population showing the method of sorting out the rates of advance of flood peaks affected by different variants.	by S.N. Naqvi
5.	Correlation between peak discharges at different stages along the river Chenab.	by W.U. Khan
6.	Causes of floods in West Pakistan and technique for their forecasting.	by S.N. Naqvi
7.	Forecasting of Floods in West Pakistan.	by W.U. Khan