INTEGRATED FLOOD FORECAST MODELLING

Sunil Kumar
Director, NWA

1.0 Introduction

All major ancient civilisations were developed in the river valleys because river served as source of water, food, transportation and protection to the mankind. On contrary, now days even a small, slow-flowing stream or gentle river could cause severe damage to the people and their businesses by flooding. With the changing patterns of rainfall and global climate, floods are matter of greater concern now as it has enhanced damage potentials. Not only river plains are vulnerable to riverine or fluvial flooding but also places far away from river are prone to surface water flooding due to heavy rainfall. 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. Anarea of more than 40 million ha in India has been identified as flood prone. India is traversed by a large number of river systems, experiences seasonal floods. It has beenthe 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 basin, floods have often been experiences as early as in late May while in Southern rivers floods continue till November. Floods have been affecting millions of people throughout the country. There is every possibility that figure may increase due to population growth, urbanization in the flood plains& probable impact of climate change. The real time flood forecasting is one of the most effective non- structural measures for flood management. For formulating the flood forecast in the real time, the observed meteorological and flow data are transmitted to the forecasting station through the different means of data communication which include telephone, wireless and network of telemetry stations etc. The collected meteorological and flow data in real time are then used into the calibrated & validated real time flood forecasting model to forecast the flood flow and corresponding water levels for different lead periods varying from few hours to few days depending on the size of catchment and purpose of the forecast. The structure of the model should be simple and it should not have excessive input requirements, but at the same time the forecasted flood must be as accurate as possible.

2.0 Existing Flood Forecasting System

Central Water Commission (CWC) is the national agency entrusted with the responsibility to provide flood forecasting services to all major flood prone inter-state river basins of India. CWC accomplishes this task through a network of 175 flood forecasting stations which include 147 level & 28 inflow forecasting station. On the basis on long term observed data, gauge-to-gauge correlation chart has been developed. Therefore, once discharge/water level at base station (upstream) is observed, discharge/water level at forecast station (downstream) is forecasted. Selection of base station was made is such a way that it may give long lead for the forecast station. [Lead is the time period between issue of forecast till actual arrival of the forecasted event]. Locations vulnerable for flooding historically have been selected as forecasting stations.

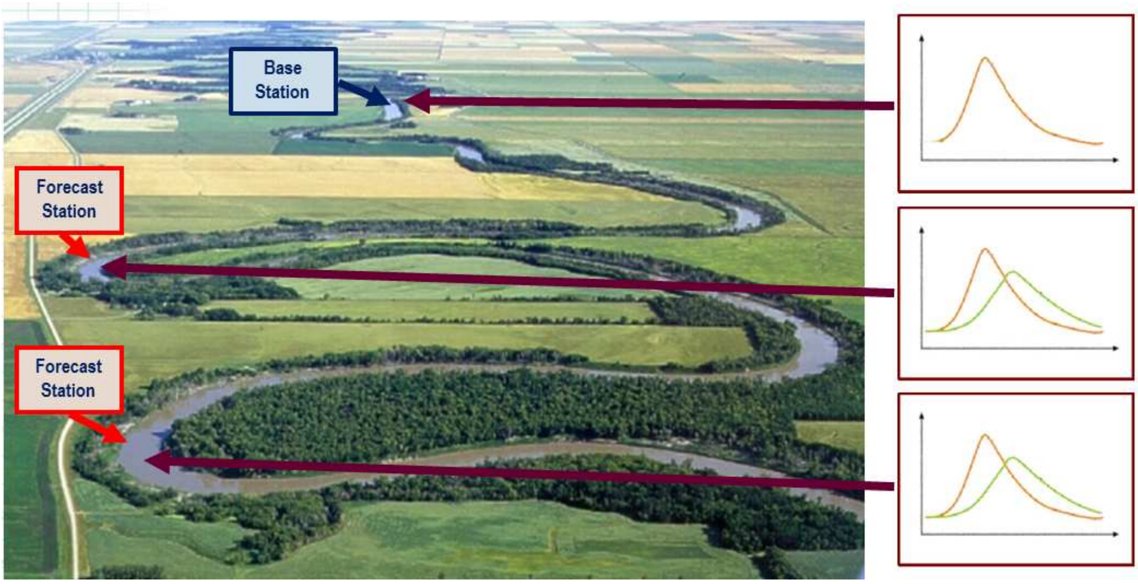

Figure 1: Base Station and Forecast Station

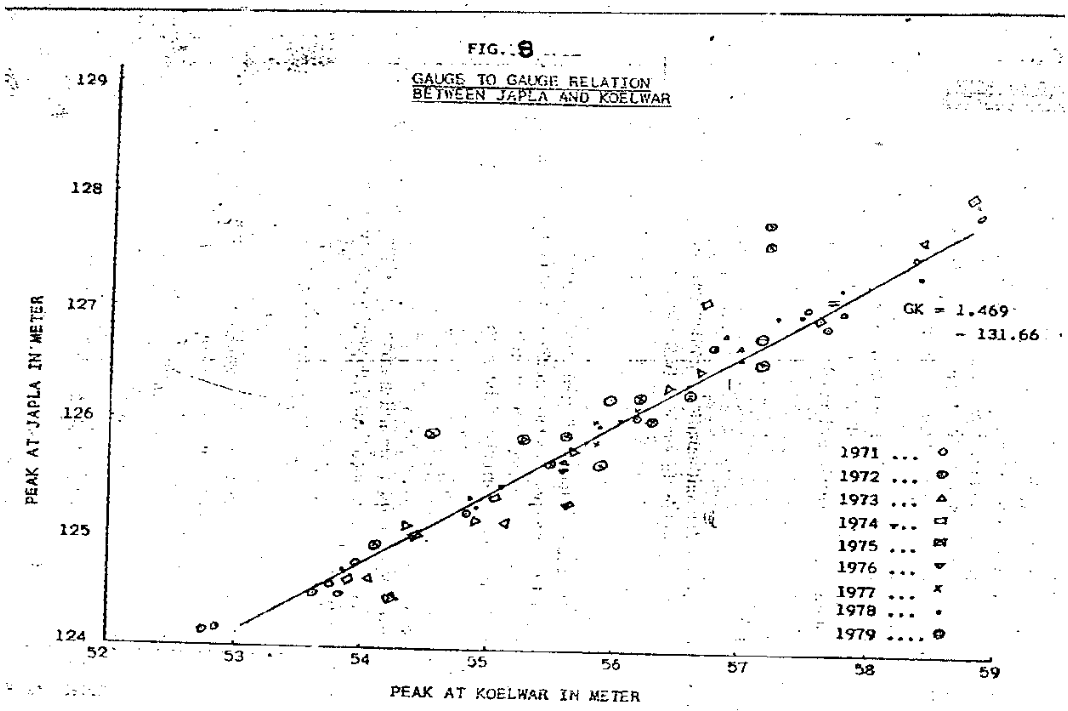

Figure 2: Gauge to Gauge Co-relation Chart

Though fairly accurate, the flood forecast issued on the basis of Gauge to Gauge correlation has following limitations:

1. Forecast is issued only after measurement at base station, therefore lead time is insufficient for appropriate disaster preparedness.
2. Since rainfall is not incorporated, lead time can't be enhanced by including duration of rainfall forecast.

   For eg. If rainfall forecast issued in 5 days advance, Time of concentration is 1 day and travel time of flow from base station to forecast station is 14 hours. In present scenario, lead time is just 14 hours and it could have been enhanced upto 6 days 14 hours (5days + 1 day + 14 hours).
3. Locations other than forecast station prone to flooding are not under consideration. Since selection of these locations took place long ago, there may be other locations in the river reach which are prone to flooding in changing climatic and other conditions.
4. Generally water level forecasts are issued at forecast station in terms of earmarked danger line. No information is given in terms of movement of water in flood plain viz. depth, extent, duration of flooding.
5. Only riverine flooding is taken into consideration. However, surface water of pluvial flooding which is common nowdays in urban areas are not considered.

Figure 3: Flood Forecast Shorcomings

3.0 Urban Flooding

Urban Flooding is extremely complex phenomena and affected by various factors. It can be caused by excessive precipitation in small duration, flash floods, coastal floods, or riverine floods. Urban floods are a great disturbance of daily life in the city. The economic damages are high as well as number of casualties. The main problem with urban flooding is the fact that they occur in highly populated areas. If the area would have not been urbanized, the waters that flood the area would be more likely to infiltrate into the ground or move to nearby streams, therefore adding up to surface or ground water. For analysis of urban flooding, variety of data is required which is not generally available in Indian scenario. In the urban area accurate information of buildings, roads, fences, kerbs need to be incorporated as it affects the flooding substantially.

Figure 4: Urban Flooding

For developing an integrated flood forecasting model for urban catchments, following are required:

- Flow data in the river reach (in case of riverine flooding)
- Drainage model of the project area.
- Flood data for calibration & validation of the stream & drainage network.
- Flood-flow/ flood-depth data.
- Finer grid DTM.
- Clear methodology.

4.0 Integrated Flood Forecasting Model

An integrated modeling approach need to be followed which includes rainfall-runoff model of upstream catchment, hydraulic model of the river & drainage network of the urban area and a coupled 2-D flow simulation model for flood analysis. Only such integrated state-of-the-art flood forecasting model may be capable of giving fairly accurate information of the extent and duration of flooding at any location in the project area corresponding to a rain event. Since rainfall time series is the main input to the flood forecasting model, correctness of model-outcome is largely dependent on the correctness of rainfall forecast by Meteorological Office.

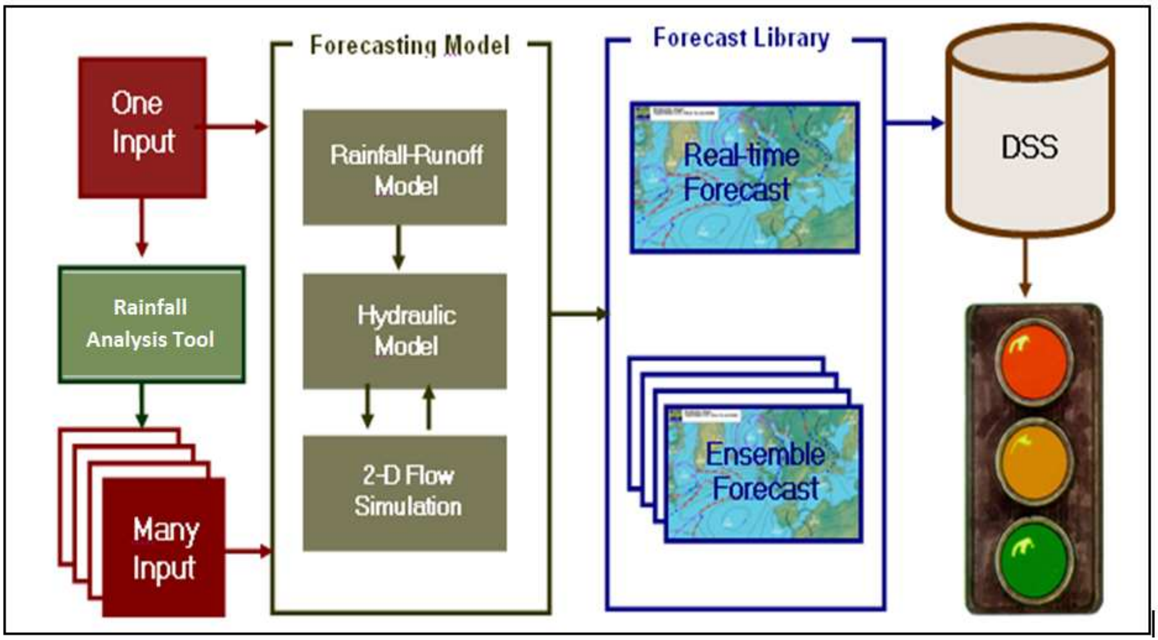

Figure 5: Integrated Flood Forecasting Model

4.1 Rainfall Analysis

The meteorological data is collected from land, sea& air and fed into the dedicated super computers, which, by solving a number of complex mathematical equations gives a variety of weather solutions up to a week or so ahead. The Super computers provide one solution to the evolution of weather is called a 'deterministic forecast' and it gives very little information about the probability of the occurrence of the event. Where, a new evolving technique known as ‘ensemble forecasting’ shows the probability of the occurrence of certain weather events. In this method, the deterministic forecast is run several times with a slightly different starting point and several possible events are generated. Therefore, rather than solely relying on a single event, probabilistic forecasting provides several possible scenario and hence an idea of possible extremities. This enables a better risk based approach to decision making in case of flooding and which in turn facilitate a better allocation of emergency services, flood control measures. Considering, numerous benefit the flood forecasting approach is shifting from deterministic to probabilistic. However, the lead time is the limiting factor for the ensemble forecasting as quick analysis of several scenarios is not feasible.

Fig 6: Rainfall Analysis: Ensemble rainfall

Considering above advantages and limitations of both deterministic and ensemble forecasting system, the best methodology is one which is intended to harness the benefit of both. It envisages an elaborate rainfall analysis which consists of generating several ensemble rainfall scenarios from deterministic one (*Fig 5*). Further, the single deterministic and few extreme ensemble rainfalls are fed into the flood forecasting model. The main purpose is to maintain a small model run time and hence longer lead time in order to facilitate an advance flood warning system. Though all rainfall inputs are later fed to the flood forecasting model and the results are stored into the forecast library. For generating many ensemble rainfalls from a single deterministic rainfall, several tools may be used.

4.2 Forecasting Model

A holistic approach is to be adopted using integrated state-of-the art model for simulating the river & drainage network along with two-dimensional flow. Forecasting model has 3 main components and output of one is used as input of subsequent model:

[1]. Rainfall-Runoff Model

Rainfall-runoff modeling of upstream catchment is the starting point of forecasting model. This approach specifically enhances the lead time substantially. If rainfall forecast is available in 4-5 days advance, the corresponding runoff may be estimated immediately by running this rainfall-runoff model. Commonly used softwares for rainfall-runoff modeling are HEC-HMS, SWAT, Infoworks, Mike SHE etc.

[2]. Hydraulic Model

Hydraulic model includes the river-reach under consideration, hydraulic structure (if any) in the reach, drainage (storm water/ foul water) network of the area of concern, any other abstraction / lateral inflow to/from the river reach. Commonly used softwares for Hydraulic modeling are HEC-RAS, Mike 11, Mike Flood, ISIS, Inforworks RS/CS etc.

[3]. 2-D Flow Simulation Model

Further, the hydraulic model is to be well coupled with the two dimensional flow zone. Two-dimensional zone is to be well represented by accurately incorporating roads, buildings, fence, kerbs, soil-type, culvert features etc. Two-way interaction between hydraulic and 2-D models signifies the fact that when river breaks its bank or drain overflows, water flows into 2D-zones (*Fig 6*). But subsequently after few hours/days water drains back to river/drainage network when flood recedes. Commonly used softwares for 2-D flow simulations are Infoworks 2D, Mike Flood, ISIS, Mike 21 etc.

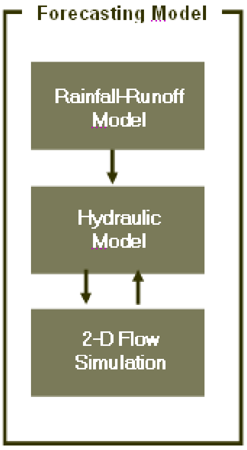

Fig7: Flood Forecasting

4.3 Forecast Library

All flooding scenario corresponding to various rainfall input will be stored into the forecast library. Considering the lead time constraints, all rainfall inputs can not be fed into above flood forecasting model in the real time. Rather the deterministic rainfall along with few extreme ensemble rainfalls will be fed into model for real-time forecast. However the forecast library will be enriched later by model results corresponding to all other ensemble rainfall events. This may be proved highly beneficial in case a particular rain event shows resemblance to any previous rain event against which the flood forecast is available in the forecast library. Therefore, it will enable a quick flood forecast even without running the model and will facilitate a long lead time.

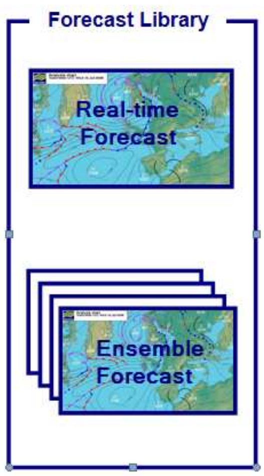

Fig8: Forecast Library

4.4 Decision Support System

There could be several components of flood forecasting & warning decision making but the forecast library is definitely the most important one. However, the decision making may also be assisted by previous actual rainfall record and measured flow data. The ultimate aim of the project is to device a simple traffic-light type flood warning system. The low, medium and high extent of flooding may be defined by the stakeholder and researchers altogether for their clear understanding.

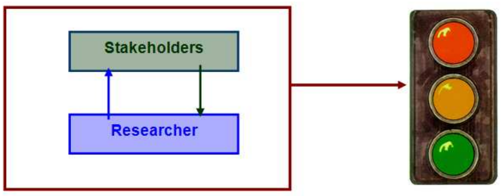

Fig9: Estimation of Flood Warning signals