DEVELOPING THE EARLY WARNING PLATFORM

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1.0 INTRODUCTION

There are few places on Earth where people need not be concerned about flooding. Any place where rain falls is vulnerable, although rain is not the only impetus for flood. A flood occurs when water overflows or inundates land that's normally dry. This can happen in a multitude of ways. Most common is when rivers or streams overflow their banks. Excessive rain, a ruptured dam or levee, rapid ice melting in the mountains, or even an unfortunately placed beaver dam can overwhelm a river and send it spreading over the adjacent land, called a floodplain. Coastal flooding occurs when a large storm or tsunami causes the sea to surge inland.

According to reports from the World Meteorological Organization (2009), approximately 70% of all disasters occurring in the world are related to hydro-meteorological events. Among the disasters, flooding probably is one of the most severe disasters affecting the people across the globe.

India is the worst flood affected country in the world after Bangladesh and accounts for one-fifth of global death count due to floods. Nearly 75 percent of the total Indian rainfall is concentrated over a short monsoon season of four months (June-September).As a result, the rivers witness a heavy discharge during these months, leading to widespread floods. About 40 million hectares of land in the country is liable to floods according to National Flood Commission, and an average of 18.6 million hectares of land is affected annually.

2.0 EARLY WARNING SYSTEM

2.1 Background

> ***"The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss"*** (UNISDR,2009)

Early Warning System (EWS) evolved about 2 to 3 decades ago. The needs for EWS started to arise in 1970s and 1980s when the prolonged droughts and famines in the West African Sahel and in the Horn of Africa occurred. Since its early development, EWS started to be used for other hazard (technological, hydrological, meteorological etc.) for societal risk and vulnerability reduction and towards sustainable development (ESIG-ALERT,2004).

In January 2005, the United Nations convened the Second World Conference on Disaster Reduction in Kobe, Hyogo, Japan. During this conference, an agreement called the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" (HFA) was negotiated and adopted by 168 countries. The paradigm for disaster risk management was broadened from simply post-disaster response to a more comprehensive approach that also includes prevention and preparedness measures. HFA also stresses the need for, "identifying, assessing and monitoring disaster risks and enhancing early warning systems."

Following this agreement, efforts were underway to incorporate early warning systems as an integral component of any nation's disaster risk management strategy, enabling governments and communities to take appropriate measures towards building community resilience to natural disasters.

EWS are increasingly recognized at the highest political level as a critical tool for the saving of lives and livelihoods, and there are increasingly more investments by national and local governments, international development agencies, and bilateral donors to support such systems.

2.2 Key Elements of Early Warning System

An early warning system mainly consists of four elements: Risk Knowledge, Monitoring and Warning Services, Disseminations and Communication and Response Capability

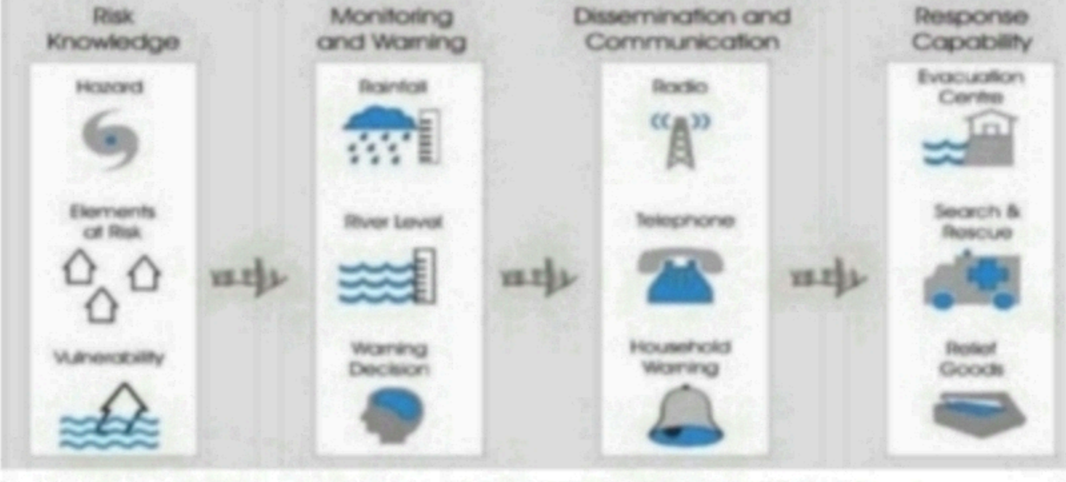


Fig.1: Key Elements of an Early Warning System

2.2.1 Risk Knowledge:

Risks arise when hazards and vulnerabilities appear together at a particular location. Assessments of risk require systematic collection and analysis of data and should consider the dynamic nature of hazards and vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation and climate change. Risk assessments and maps help to motivate people, prioritize early warning system needs and guide preparations for disaster prevention and responses.

2.2.2 Monitoring and Warning Services

Warning services lie at the core of the system. There must be a sound scientific basis for predicting and forecasting hazards and a reliable forecasting and warning system that operate 24 hours a day. Continuous monitoring of hazard parameters and contributing factors is essential to generate accurate warnings in a timely fashion. Warning services for different hazards should be coordinated with stakeholders and relevant agencies to gain the benefit of shared institutional, procedural and communication networks.

2.2.3 Dissemination and Communication

Warnings must reach those at risk. Clear messages containing simple, useful information are critical to enable proper understanding of warnings and responses in order to safeguard lives and livelihoods. Regional, national and community level communication systems must be pre-identified and appropriate authoritative mandates established. The use of multiple communication channels is necessary to ensure that as many people as possible are warned, to avoid failure of any one channel, and to reinforce the warning message.

Early warning communication systems are made of two main components (EWCII, 2003):

- Communication infrastructure hardware that must be reliable and robust, especially during the natural disasters; and
- Appropriate and effective interactions among the main actors of the early warning process such as the scientific community, stakeholders, decision makers, the public, and the media.

Many communication tools are currently available for warning dissemination such as Short Message Service (SMS), Email, Radio, TV, and web service.

Information and Communication technology (ICT) is a key element in early warning. ICT plays an important role in disaster communication and dissemination of information to organizations in charge of responding to warnings and to the public during and after a disaster.

Redundancy of communication systems is essential for disaster management, while emergency power supplies and back-up systems are critical in order to avoid the collapse of communication systems after disasters occur.

In addition, in order to ensure reliable and effective operation of the communication systems during and after disaster occurrence, and to avoid network congestion, frequencies and channels must be reserved and dedicated to disaster relief operations.

Dissemination of warnings often follows a cascade process, which starts at international or national level and then moves outwards or downwards in the scale, reaching regional and community levels (Twigg J., 2003). Early warnings may activate other early warnings at different authoritative levels, flowing down in responsibility roles, but all are equally necessary for effective early warning.

2.2.4 Response Capability

It is essential that communities understand their risks; respect and follow the warning and know how to react. Education and preparedness programs play a key role in reducing risks. It is also essential that disaster management plans are in place, resources allocated and standard procedures well practiced and tested. The community should be well informed on options for safe behavior, available escape routes, and how best to avoid damage and loss to property.

2.3 Flood Early Warning System

As the name indicates, Flood Early Warning System (FLEWS) is a system by which flood induced hazards can be minimized and prevented. Currently different organizations are working on flood forecasting and early warning at national, continental and global scale.

In a flood early warning system the most important input is real time hydro-meteorological observations provided by weather radar satellites and automatic hydro-meteorological station network (Billa et al.,2006; Budhakooncharoen, 2004). This real time data can be used in various ways to evaluate flood risks and issues of flood warning. Apart from real time data, probabilistic weather forecasts (Numerical Weather Prediction-NWP) are also playing an important role in providing input for hydrological models to generate warnings scenarios (Burger et al.2009; Thielen et al., 2010). Besides having forecasts of the most important input (precipitation), a model needs to be selected that characterizes and simulates the catchment responses for flood early warning.

2.3.1 Benefits of Flood Early Warning Systems

The development of flood forecasting and warning systems is an essential element in regional and national flood preparedness strategies, and is a high priority in many countries. Flood EWS are being considered as an alternative for dealing with flood problems, partly because these systems are less expensive compared to structural schemes. Despite the high priority accorded to flood warnings in flood risk management by governments, there is a lack of good data on the benefits and costs of these systems (Wallingford 2006).

The benefits of an early warning system can be calculated by assessing the possible savings of the quantity of flood damage to private and public assets resulting from action taken in response to the warning. This flood reduction benefit BEWS can be expressed as:

BEWS=Xwithout-Xwith

Where, Xwithout=without project economic flood damage; and

Xwith= economic damage if the project is implemented

The benefits of flood early warning systems come from the savings in flood damages. Floods are random events that cause damages and hence flood damages are also random or probabilistic events: the probability of any specific amount of flood damage depends on the probability of the flood event necessary to cause those damages. Determining flood damages combines a risk assessment in terms of the probability of future flood events to be averted, and a vulnerability assessment in terms of the damage that would be caused by those floods and, therefore, the economic savings to be gained by their reduction.

5.0 FLOOD EARLY WARNING SYSTEM (FLEWS) IN ASSAM

5.1 Statement of Problem

Flood forecasting and early warning is used for alerting the likely damage center well in advance of the actual arrival of flood, to enable the people to move and also to remove the movable properties to safer places or to raised platforms specially constructed for this purpose. Flood is an annual event in the State of Assam. More than 40 percent of its land surface is susceptible to flood damage. The total flood-prone area in the Brahmaputra valley is about 3.2 Mha. (Goswami, 2001). The Brahmaputra valley had experienced major floods in 1954, 1962, 1966, 1972, 1974, 1978, 1983, 1986, 1988, 1996, 1998, 2000, 2004 and 2007 & 2012 which clearly shows that floods are an annual event in the State. This affects a large section of the people of the riverine areas leaving them to cope with their annual losses.

Assam, inspite of suffering from annual flood events, unfortunately did not have a system of any early warning mechanisms that would alert the concerned districts/circles/villages from the occurrence of a disaster. The existing disaster management mechanism is primarily focused on strengthening rescue and relief arrangements during and after major flood disasters. Little work has been done in a scientific context on minimizing the incidence and extent of flood damage. To minimize flood damage the basic approach is to prevent floodwaters from reaching the vulnerable centres. The Central Water Commission (CWC) under the Ministry of Water Resources issues flood forecasts and warnings.

However, CWC gives the water level of only the major rivers of the State which does not indicate the areas/villages where the flooding would occur and leaves the administrative machinery clueless as to which village or revenue circle should be warned /evacuated. The government felt an inadequacy in the early warning system and therefore thought for the development of a flood early warning system and/or decision tools which relies on hydrological modeling and the use of near real time data and consulted different stakeholders to find a solution to the problem.

5.2 Motivators for the Project initiative

The primary motivator for the project initiative was to alleviate the sufferings of the local populace from the long standing problem of floods. The Government of Assam felt the inadequacy of not having an effective early warning system to alert the administration and the population from the probable occurrence of a flood event for taking necessary measures to minimize the loss of human lives and mitigating the damage to properties.

5.3 Purpose & Priorities of the Initiative

The main purpose of the initiative was to develop a location specific early warning system which could help the administration in taking advance precautionary measures and issue flood alerts to those specific areas so that necessary measures can be undertaken by the people.

With this purpose the project was initiated keeping in view the following objectives

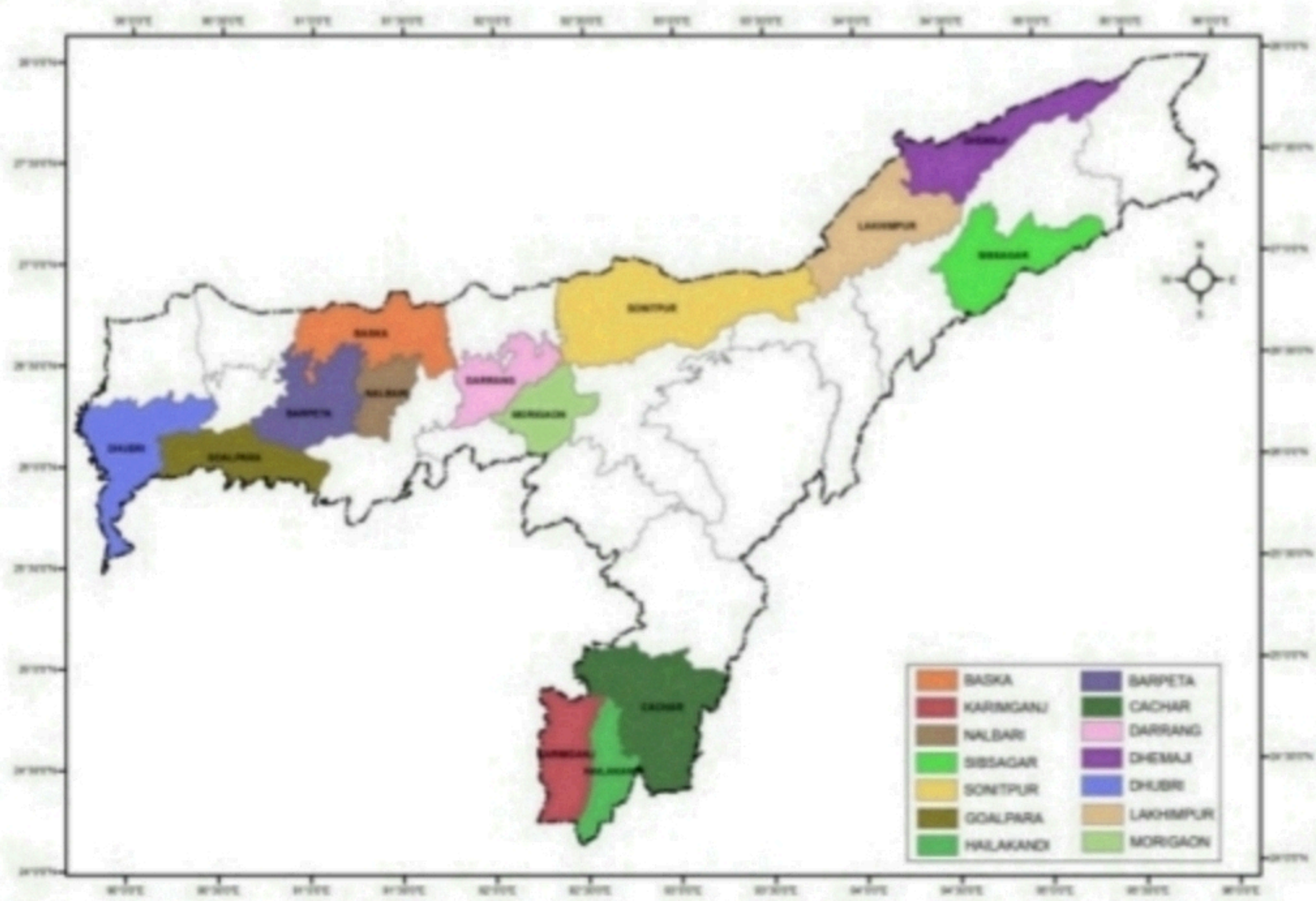
1) Issue of alert for possible flood situation in district/Circle level with best possible lead time.
2) Submission of annual periodic report on status of existing embankments.
3) Creating an environment of joint participation among all stakeholders in order to generate actionable product for management of flood in Assam
4) Development of optimum methodology for rainfall prediction from satellite based weather monitoring and numerical weather prediction models supported by insitu ground data.
5) Development of river specific rainfall-runoff models for forecasting of flood.
6) Development of inundation simulation for flood plain zonation.

5.4 The Project

On 14th June, 2008 a devastating flash flood occurred in Lakhimpur district of Assam affecting more than 3 Lakh of population and more than 75,000 Hectares of land thereby bringing untold suffering and misery downstream. This event of Assam drove the government to consult the different organisations like Indian Meteorological Department (IMD), Brahmaputra Board, Central Water Commission (CWC), Assam Remote Sensing Application Centre (ARSAC), Assam Water Resources Department (AWRD) and North Eastern Space Application Centre (NESAC) for developing a model which could provide location specific flood early warning advisory. Finally NESAC, Shillong decided to take up the responsibility of developing an effective flood early system as they were already working for development of a flow forecasting system for Ranganadi Dam site on a pilot basis for NEEPCO.

Subsequently the whole of Lakhimpur district i.e the rivers other than Ranganadi were taken up as a pilot exercise . This activity was decided to be taken up in project mode and was named as

Flood Early Warning System (FEWS) project which remained so till the monsoon of 2010. During a review meeting held on the 16th June, 2010 it was pointed out from NDMA that FEWS is an already existing terminology in United Nation Disaster Management Programme which stands for Famine Early Warning System. Hence the project name was changed to Flood Early Warning System (FLEWS).Further, the project which started with one district in 2009 was extended to another district in upper Assam namely Dhemaji and three districts of lower Assam namely Barpeta, Nalbari & Baksa in 2010. With the achievement of some success, the project was further extended to Cachar, Karimganj and Hailakandi districts of Barak Valley in the year 2011. With the increasing demand from the district administration of other districts the project was further extended to 6 more districts of Assam namely Dhubri, Goalpara, Morigaon, Sonitpur, Sivasagar and Darrang districts during 2012. The total coverage, therefore, as of till now is 14 nos. of districts.



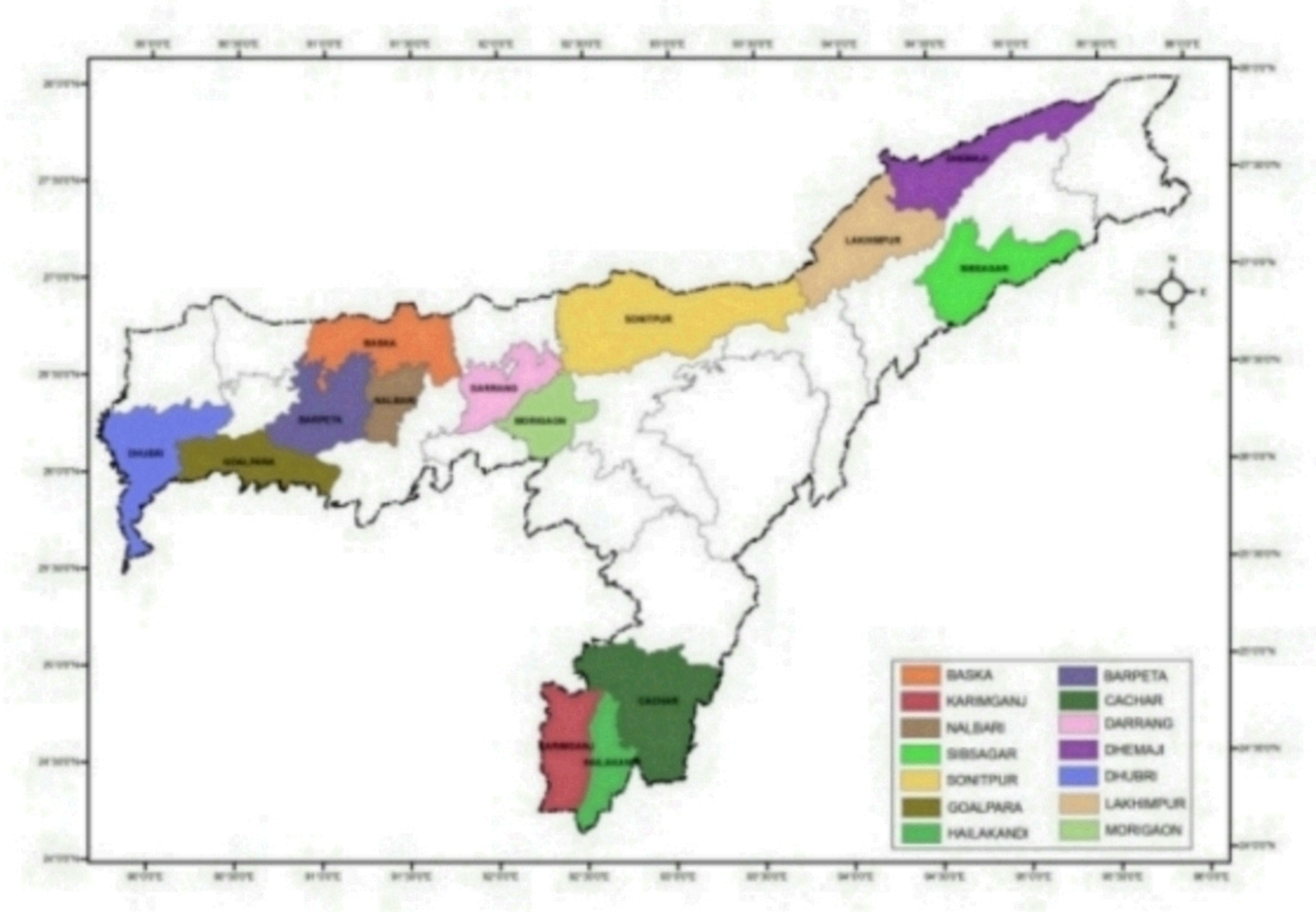


Fig.4: Districts Covered under FLEWS

5.4.1 Major Technical Components of the project.

(1) The meteorological components comprises of two major sub components of Weather Research Forecast (WRF) model for grid based rainfall prediction through numerical schemes and multi-parametric (CTT, CMV, Vorticity etc.) synoptic weather monitoring for overall probability of rainfall in a particular basin.

(2) The hydrological component comprises of a hybrid approach of a lumped grey box model known a Rational model in combination with a quasi distributed hydrological model known as the HEC-HMS in Arc-GIS platform. White the first approach provides the forecast of the peak value for a river basin, the distributed model provides the forecast for the daily hydrograph for that basin. Comparing both the forecast with the established flooding thresholds for that river, issue of flood warning is decided.

(3) The third component is the post flood identification of embankment breaches and general monitoring of embankments.

Figure 5 below depicts the overall methodology involving the three major components.

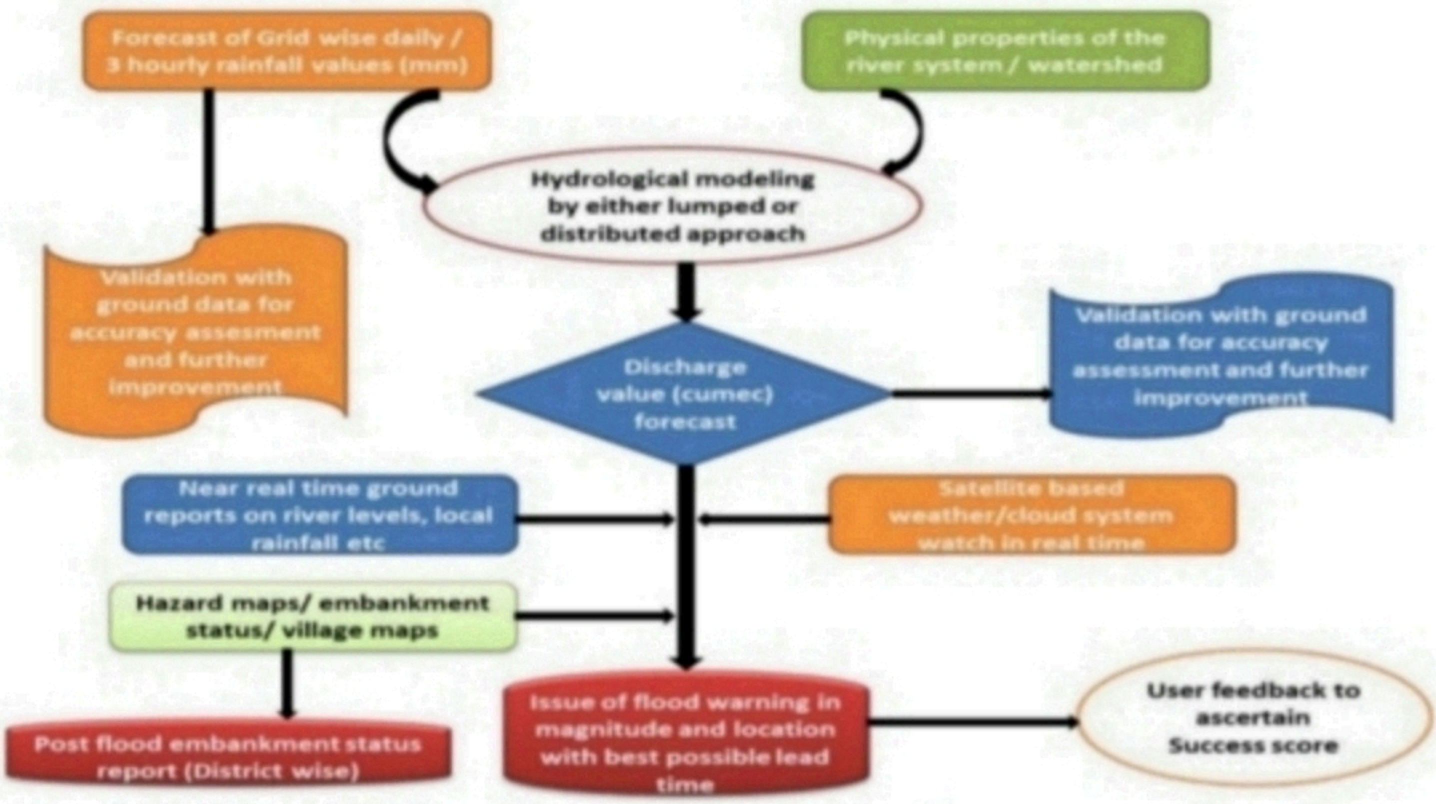


Fig.5: Flow chart of the overall methodology of FLEWS

5.4.2. The Meteorological Component

Numerical Weather Prediction

Numerical Weather Prediction (NWP) is the science of predicting the weather using models of the atmosphere and computational techniques. There are a number of NWP model to forecast meso-scale weather system andWeather Research and Forecasting(WRF) model is one of such which is extensively used worldwide due to its highly developed physics schemes and better time integration method to give improved forecast at shorter duration. It also includes a data Assimilation module called WRFDA where observed data can be fed to update the model's initial condition to generate realistic forecast. Figure 6 gives basic architecture of the WRF model.

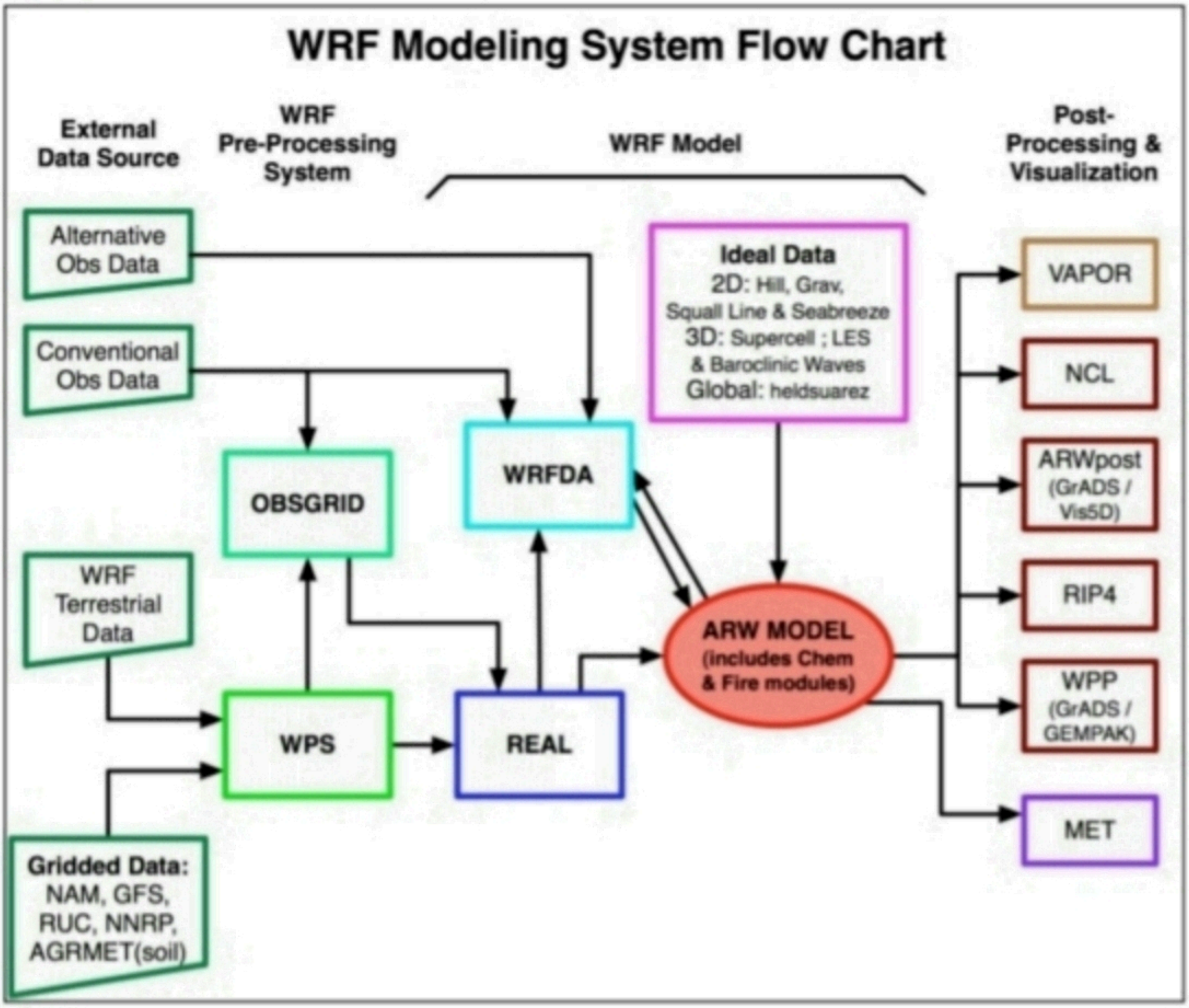


Fig.6: WRF Modeling system flow chart

condition of the atmosphere in terms of its ability to allow or suppress convection, etc. Different data were used to analyze the synoptic weather condition for the project as mentioned above. The overall flow chart for preparation of synoptic scale rainfall forecast is shown in figure 8.

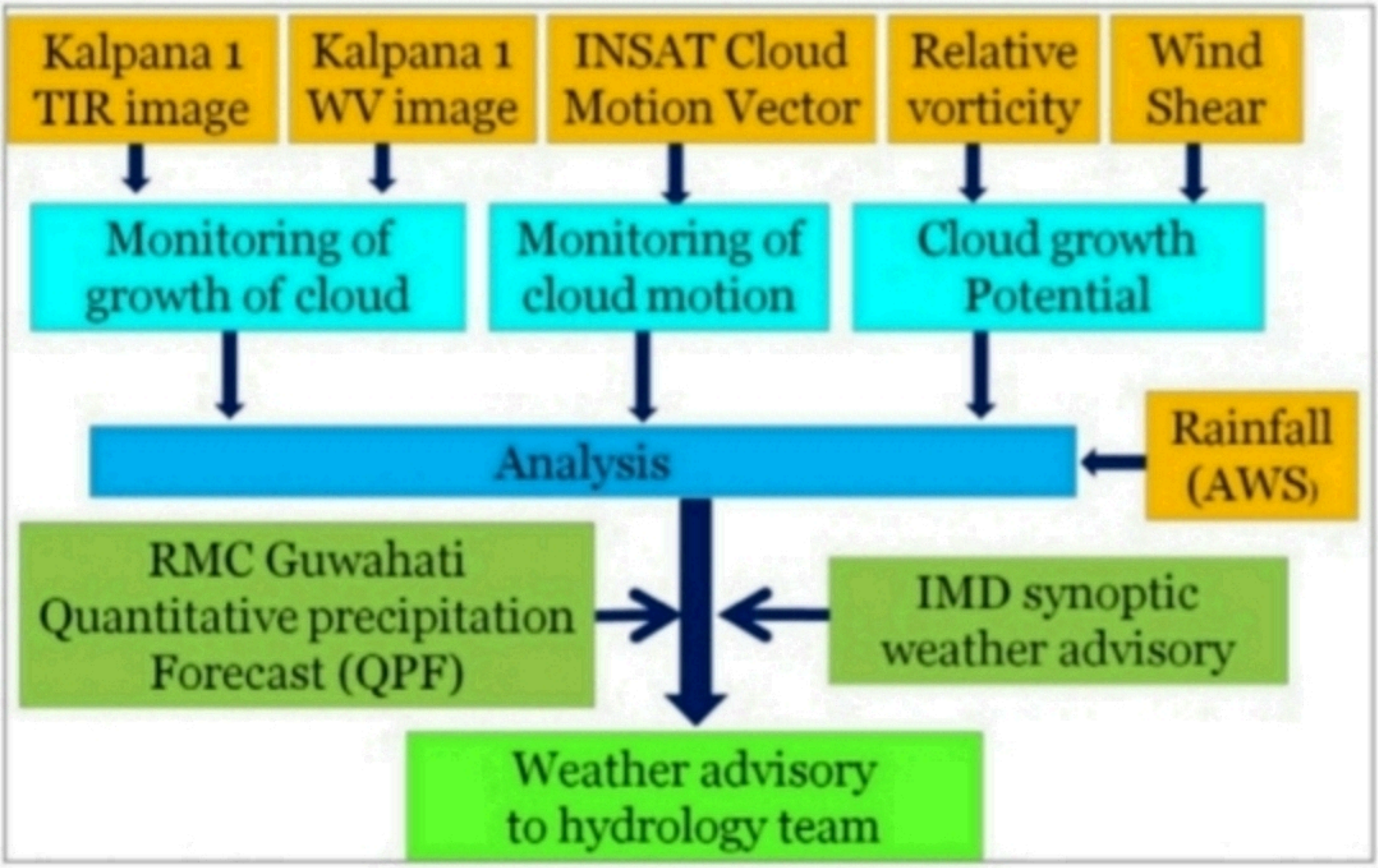


Fig.8: Methodology flow chart for synoptic and meso scale rainfall forecast

Information on cloud strength and columnar moisture content are collected from Kalpana 1 TIR and WV channel imagery. Successive imageries were analyzed along with wind vector at different level, 850 mb relative vorticity, wind shear, and wind divergence and convergence trends to forecast rainfall for the basins under study. The synoptic weather forecast proved very useful for flood forecasting, particularly flash flood forecasting. The rainfall forecast has been issued for different range bins like 0-10mm, 10-20 mm, 20-30mm, 30-50mm, and more than 50 mm.

The synoptic weather forecasting has helped in minimizing errors that could have happened because of overestimation or underestimation of NWP model based rainfall forecast. On a few

	93	93.25	93.5	93.75	94	94.25	94.5	94.75	95
27.5	[illegible]	2.86	4.02	[illegible]	[illegible]	[illegible]	5.5	6.1	[illegible]
27.75	0.14	[illegible]	6.65	10	13.96	10.32	9.27	[illegible]	[illegible]
28	1.17	[illegible]	4.55	4.68	8.45	8.47	9.23	[illegible]	6.44
28.25	0.52	0.45	1.82	1.74	2.78	5.41	6.95	[illegible]	6.35
28.5	0	0.28	1.18	0.5	1.12	2.36	4.09	[illegible]	3.89
28.75	0.47	0.16	0.68	0.42	0.7	1.36	2.21	[illegible]	[illegible]
29	0.98	0.35	0.64	[illegible]	[illegible]	0.89	[illegible]	[illegible]	[illegible]

Suban	0.0028	0.4995	0.3381	3580000	2781.36
Ranga	0.0028	0.5896	0.267	238456	105.11
Singora	0.0028	0.75	0.093	44600	53.28
Dickrong	0.0028	0.63	0.044	126048	77.6
Jiadhal	0.0028	0.423	0.233	134600	98.21

Fig.9: The rational model daily peak discharge forecast

The quasi distributed HEC-HMS model

This model have been developed by the Hydrologic Engineering Centre of the US army corps of engineers for studying natural hydrologic response of a system of streams or a watershed to a certain rainfall event. A physically based distributed hydrologic model forms the core of HEC-HMS. The model is designed to simulate the precipitation run-off processes of dendritic drainage systems of watersheds. The physical representation of the watershed is accomplished with a basin model. Different hydrologic elements are connected in a dendritic network to simulate run-off processes. A variety of methods are embedded for simulating infiltration losses, transforming excess precipitation into surface runoff, calculating base flow contribution to sub basin outflow, flow routing etc.

Two main components that are being used in the present study are the rainfall to run-off conversion component and the flow routing component. The first component is based on Soil Conservation services (SCS) curve number (CN) method which gives us the surface run-off at certain upstream locations where as the second component is based on Muskingum flow routing equations that gives us the corresponding flow at different downstream locations. The execution of both the above mentioned components is done in GIS platform. A number of flood related studies have shown that this model provide useful near accurate result.

The popular form of the SCS-CN method is

$$Q = (P - Ia)^2 / P - Ia + S$$

Where

Q is the runoff (m) and P is the rainfall (m)

S is the potential maximum soil moisture retention after beginning of runoff (m)

Ia is the initial abstraction(m) i.e the amount of water before runoff such as infiltration, rainfall interception by vegetation etc. Generally **Ia** is taken as **0.2 S**

In the curve number method the S and the curve number CN is related as

$$S = (1000/CN) - 10, \text{ where}$$

The value of CN ranges from 30 to 100. Lower numbers indicates low runoff potential and higher numbers indicate increase in runoff potential. Low CN values also indicate good soil permeability.

The flow routing component is taken care of by the above mentioned Muskingum hydrologic routing. As the term "hydrologic" suggests, this method ignores the momentum equation and based solely on the continuity equation. The peak is attenuated as a result of diffusion caused by storage effect, which is given by

$$Q = x\,I + (1 - x)\,O$$

$$S = K\,Q$$

Where, K is the travel time between two channel sections and x is a dimensionless factor between 0.0 to 0.5 that weighs the influence of the inflow and outflow hydrographs on the storage within reach.

Substituting the storage equation into continuity equation yields

$$O2 = C0I2 + C1\,I1 + C2\,O1$$

Where

$$C_0 = \frac{Kx - 0.5\,\Delta t}{K - Kx + 0.5\,\Delta t}$$

$$C_1 = \frac{Kx + 0.5\,\Delta t}{K - Kx + 0.5\,\Delta t}$$

$$C_2 = \frac{K - Kx - 0.5\,\Delta t}{K - Kx + 0.5\Delta t}$$

The sum of all the three coefficients is 1.

The critical part of the calculation is to estimate suitable values of K and x. These values should be obtained by calibrating to available sets of measured inflow and outflow hydrograph data for the channel reach. In case of non availability of data, the value of x between 0.2 and 0.5 is recommended.

Once K and x are known for a channel reach, the computational procedure to obtain the outflow hydrograph is as follows

Step 1: Discretization of the inflow hydrograph in time increment of *Delta t*.

Step 2: Calculation of the three coefficients.

Step 3: Computation of the outflow hydrograph with Muskingum equation at the end of the channel reach.

Step 4: Repeating of step 3 till the end of the inflow hydrograph is reach

Figure 6 & 7 below explains briefly the WRF data input into the quasi distributed HEC-H model set up and the HEC-HMS operational block.

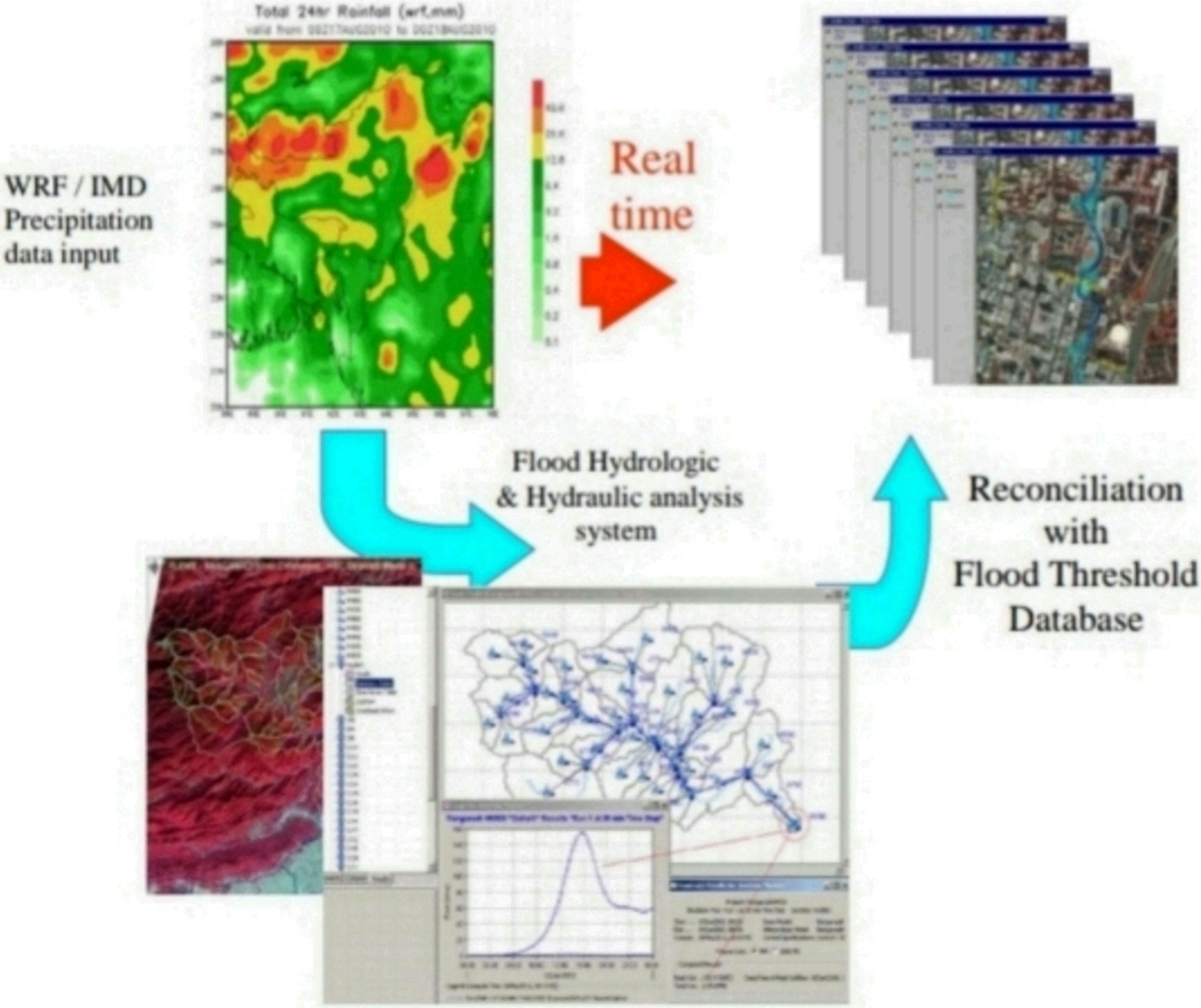


Fig.10: The HEC-HMS model set up

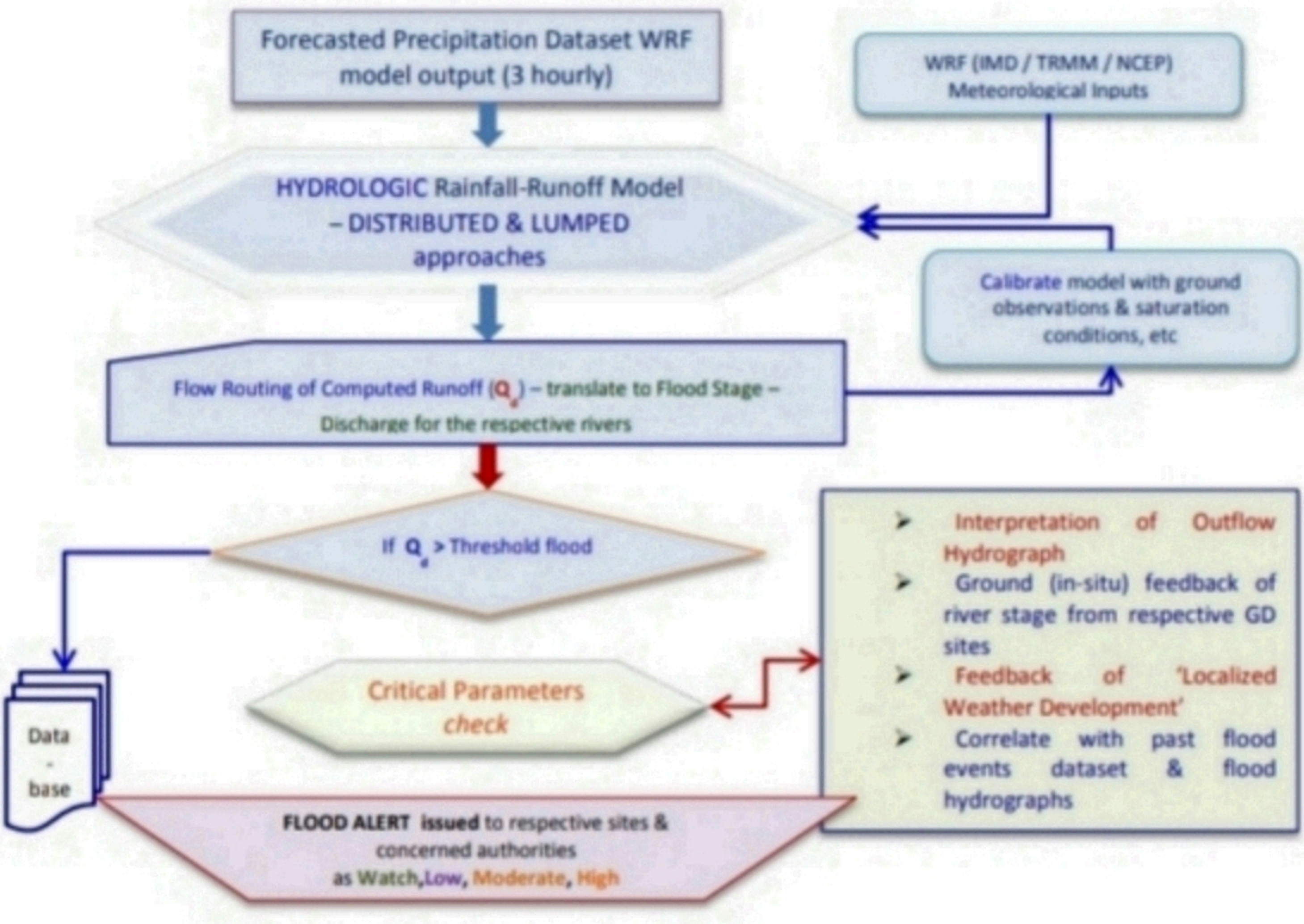


Fig.11: The HEC-HMS operational block

5.5 Generation and dissemination of Flood Early Warning

Once the peak discharge from the rational model and the daily outflow hydrograph from the HEC-HMS are computed and compared with flooding threshold and the synoptic weather monitoring advisory, warning are issued for the concerned river and its corresponding revenue circle.

Figure 12 below explains the daily flow of events leading to the issue of flood early warning system. Two parallel formats of early warning, one brief alert message by SMS followed by a detailed message attached with relevant maps by email are generated by the FLEWS hydrology

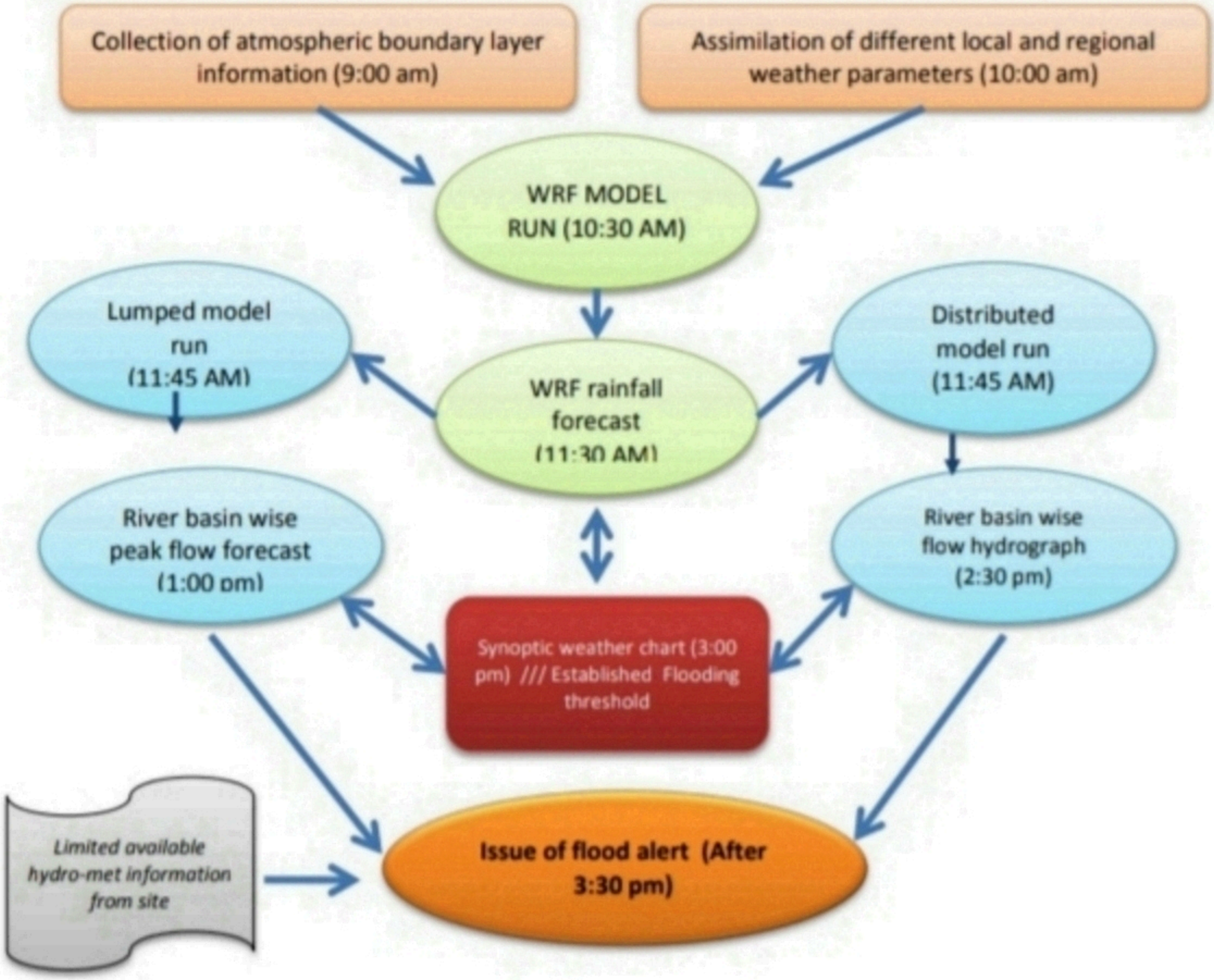


Fig.12: Daily flow of events leading to Flood Warning

team and disseminated to three concerned user groups (Comprising of ASDMA control room, Deputy Commissioners, ASDMA DPOs, NDRF etc) namely Upper Assam, Middle Assam/Barak valley and lastly Lower Assam. The dissemination part is taken care of by the FLEWS communication team of NESAC. The 24/7 ASDMA control room at Dispur, Guwahati further forwards the FLEWS alert to the grass root level (Circle officers and beyond) for ground preparatory actions in anticipation of an upcoming flood wave. Figure 13 below explains the user groups to whom both the SMS and email flood alerts are disseminated under FLEWS.

Figure 14 depicts the sample geospatial maps attached with the alert as a value addition for the geographical knowledge of the flood managers.

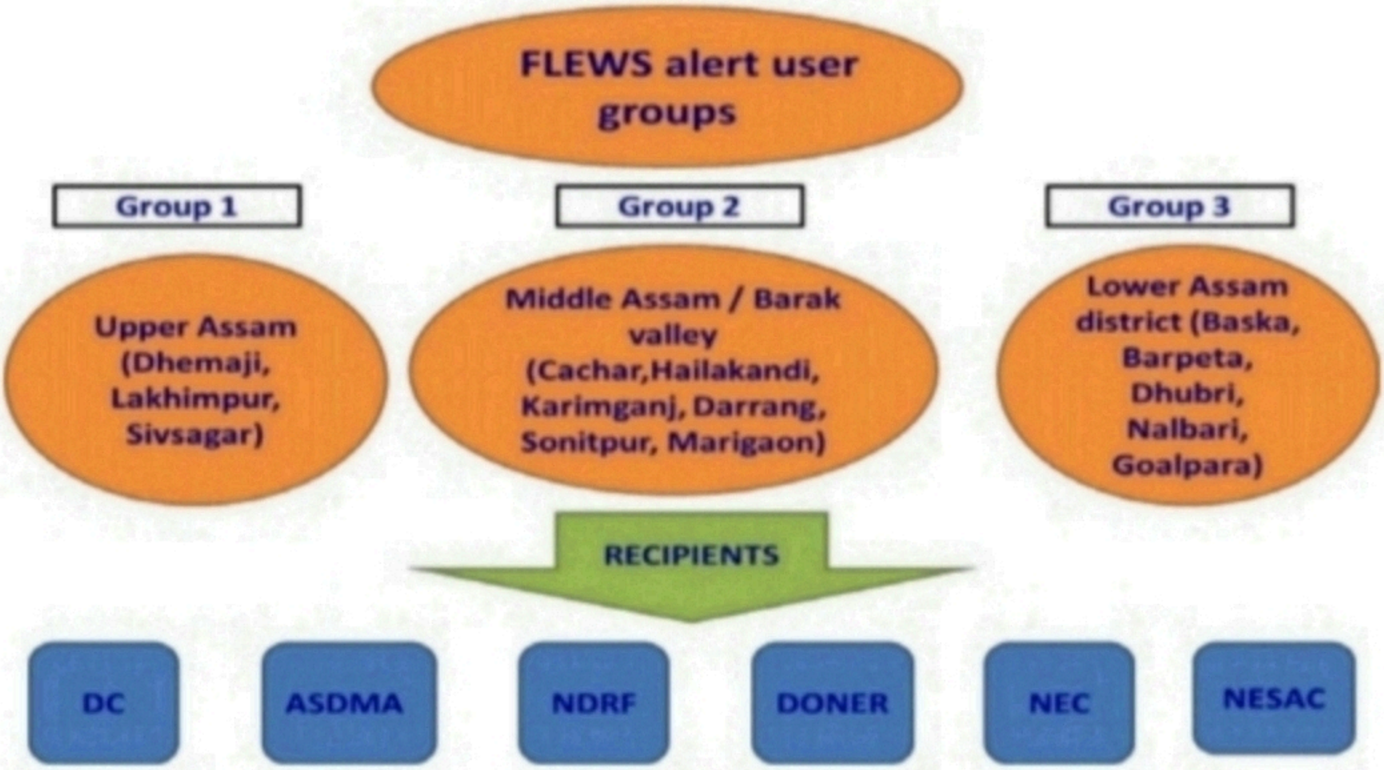


Fig.13: FLEWS alert user groups in 14 districts of Assam

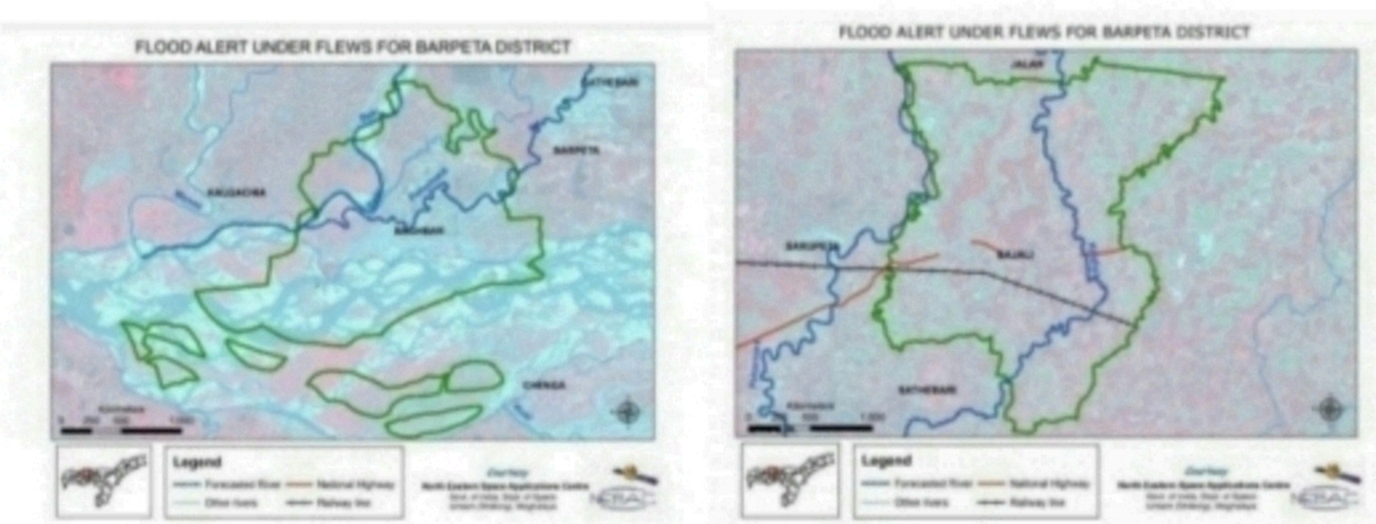


Fig.14: Sample flood alert maps of Baghbar and Bajali revenue circle of Barpeta district

5.5.1 Methodology for dissemination of flood warning alerts to districts

Once the Flood Warning alert is received at the State HQ., the same is disseminated to the District Deputy Commissioners and the District Project Officer (Disaster Management) for alerting the concerned Circle Officers, Water resource Deptt., PWD (Roads) Deptt., through SMS, phone/mobile and personnel messenger.

The flow chart for Flood Warning dissemination is shown in Figure 15

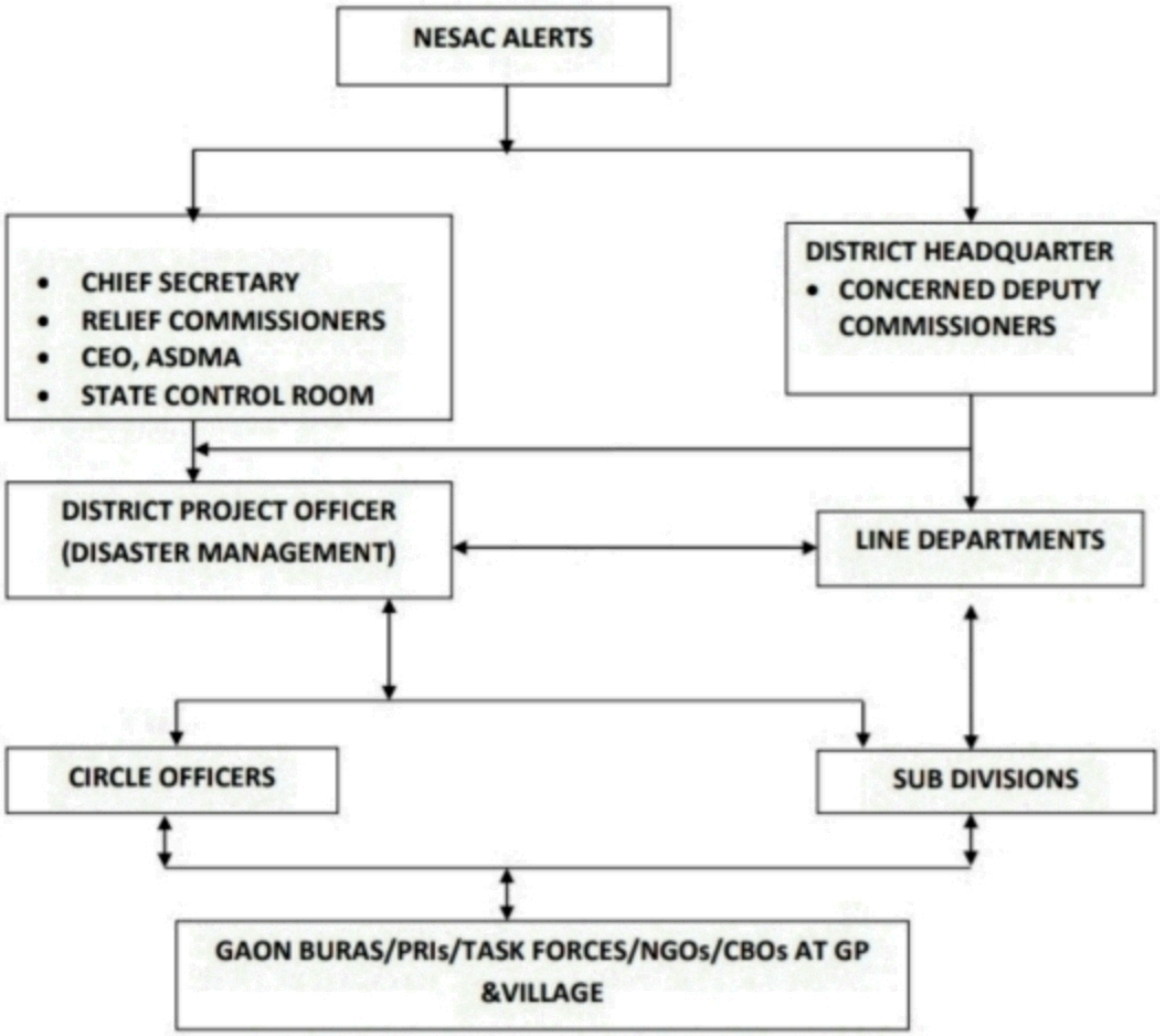


Fig.15: Flow Chart for Flood Warning Dissemination

```python
import RPi.GPIO as GPIO
import time
import requests

# Set GPIO mode and pin number
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)
GPIO.setup(21, GPIO.IN) # Water level sensor pin

# API endpoint for sending alerts
API_ENDPOINT = "https://example.com/alert"

def send_alert():
# Define alert payload
data = {'message': 'Flood detected!'}

# Send POST request to the API endpoint
response = requests.post(url=API_ENDPOINT, data
=data)

# Print response
print(response.text)

try:
while True:
if GPIO.input(21) == GPIO.LOW:
print("Water level is normal")
else:
print("Flood detected!")
send_alert()

time.sleep(1)

except KeyboardInterrupt:
GPIO.cleanup()
```

THANK YOU