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Hydrological Aspects of Flood Disaster Management

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Flooding is the major disaster bringing greater damage than any other disaster. Flooding remains a major unresolved problem and is a global phenomenon. There are climatological and part-climatological causes of flood. Several basin conditions, network conditions and channel conditions intensify the flood. Indirect causes like man's activity may also cause flood. The effects of disastrous flood are ; inundation, damage to transport and power supply, deterioration of surface water and ground water quality, and geomorphological changes. An effective flood disaster management (FDM) is essential. FDM is a multidisciplinary subject. Hydrology plays an important role in FDM. FDM is defined as the enhancement of the total productivity of the flood plain wherein losses are only a part of it. Present day trend in FDM moves away from structural measures to non-structural solution. FDM requires complicated computational methods. Flood plain zoning is one of the common techniques in FDM. The three approaches are a)Modelling susceptibility to flood damage and disruption b)Modifying flooding and c)Modifying the impacts of flooding. The areal inundation of a given flood depends on the flood plain character and the hydrodynamics of the flow. In case of coastal regions, effective methods to predict the effect of tidal rivers are to be adopted. Hurricane frequency are still to improve to have adequate lead time for issuance of warning and necessary evacuation. Cyclone warning and weather satellites are used for forecasting and monitoring. Geostationary satellites are in use. Satellite data can be used for preparation of flood inundation maps. The data bank for an optimal flood disaster management consists of values of cross-section and flood plain, discharge and water level, flood inundation map, flood loss, river bank and breach, sediment, morphological change, and land slide. Mega-floods are also caused by dam failures. Though many mathematical models are available, issues like dam failure mechanics and aggradation and degradation are still open. Different hydrological aspects concerning flood disaster management need furthur research.

HYDROLOGICAL ASPECTS OF FLOOD DISASTER MANAGEMENT

1.0 INTRODUCTION

Hazards such as earthquake, flood, drought, fire, landslide etc. are due to interaction of land, air and fire in space. Scientifically, these are governed by mass and momentum of material or other form of energy inside the surface and around the earth. Hazards are very deceptive and indiscriminate in their occurrence, location, frequency, duration magnitude etc.

Based on their origin disasters can be classified into four categories viz. Atmospheric, Seismic, Surface and Epidemic as shown in Table - 1.

TABLE - 1 HAZARD CLASSIFICATION

Sl.No	ORIGIN	PHENOMENA
1	Atmospheric	Rain, Hailstorm, Surge Tide, Hurricane, Cyclone etc.
2	Seismic	Movement of earth's crust
3	Surface	Floods, Drought, Wild fire, landslide etc.
4	Epidemic	Spread of Diseases

Human activities may also induce hazardous reaction of earth like improper management of water resources resulting flood and drought, chemical war, release of pollutant etc.

United Nations has declared this decade (1990-2000) as "International Decade for Natural Disaster Reduction" (IDNDR) with the main objective to reduce through concentrated international action, especially in developing countries, the loss of life, property damage and social and economic disruption caused by natural disasters. There were about 4000 events of hazard reported in a period of 6 decades (1900 - 1960). But the

same number of hazards were recorded in the next three decades. All the parts of the world are affected by these disasters to some extent. Bushfire is very common in Ghana and it is stated that 50% of vegetative cover was lost in one year. Ethiopia suffers from earth quake and famine regularly. South-East Asia ranks fourth in the global disaster scenario. India, because of its widely varying geographical and climatic conditions, tops the list of disaster-prone countries in the region. Hurricane induced flooding in 1900 in Galveston, Texas claimed 6000 lives - often cited (Linseley, 1983).

Nearly two third of our country is quake-prone. Flood and drought are frequent visitors. Apart from these the country suffers due to land slides in the Himalayan region and cyclone in the coastal region.

It is evident from history and mythology that disasters are accompanying human civilization since early days. Previously it was being attributed to some supernatural power. Scientific studies well establish the governing factors behind various natural disasters. Prominent among disasters is flood. Fig. 1 shows a worldwide view of different disaster events (Wijkman and Timberlake, 1984).

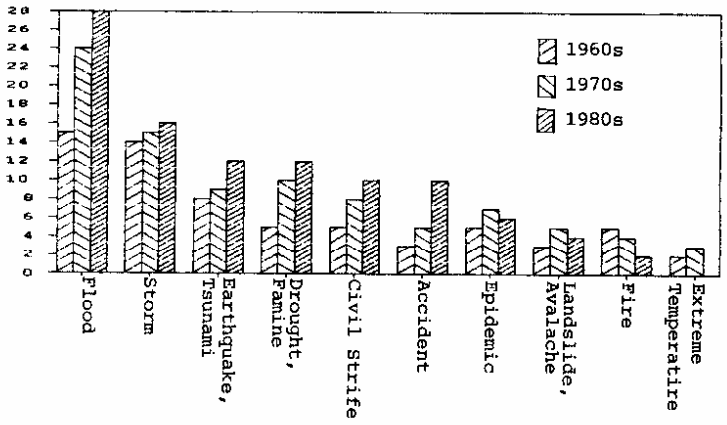

Fig. 1 Worldwide View of Different Disasters

As reported by Changnon et al.(1983) "Flooding is the major natural hazard of the nation bringing greater property damage than any other hazard and loss of life in the hundreds. Flood losses continue to grow. Our approaches for controlling and mitigating flooding have not fully succeeded.", is true not only for USA but for a global scenario. According to World Commission on Environment and Development Report(1986)- "The disasters most directly associated with environment and development - droughts and floods - affected the most people and increased most sharply in terms of numbers affected. Flooding remains a major unresolved problem."

Occurrence of a flood is a regular phenomena experienced by the riverine civilisation. The maximum observed flows in some of the major rivers of the world is given in Table 2.

TABLE 2: SOME OF THE LARGEST RIVERS OF THE WORLD

River	Length (in km)	Basin Area (in 1000 sq. km.)	Maximum Discharge (in cumec)	place /country
Amazon	6436	4688	227000	Obidos /Brazil
Lena	4827	2430	294000	Kusur /USSR
Yenisey	3797	2440	132000	Igarka /USSR
Godavari	1553	315	88350	India
Yangtze	5827	1942	84950	China
Mekong	4183	646	75700	Kratic /Cambodia
Mississippi	6259	2388	70792	Columbia /USA
Ganga	2506	1073	70790	Sarabridge /India
Brahmaputra	2906	580	72794	Pandu /India

The principal contribution of hydrology in this is realisation of the existence of the extreme events and an approach to quantifying them. Failure of some of the dam and the information derived from the hydrological analysis have caused serious attention of the planners. It has already been recognised that hydrologists can help in mitigating the effects of flood and also the catastropy by issuing warnings, planning for preparedness and in design of various structures. Hydrological analysis can further help in assessing the risk involved and the effect of any catastrophe on the river environment (morphological changes). Management activities include structural works like dam, levee, bank stabilization, improvements like channelisation, clearing and snagging.

Major deficit in all facets of flood hazard mitigation planning is the lack of a systematic collection of data. Fairly good records are maintained in some aspects.

There are a number of references available in the literature. For the purpose of hydrological studies of Flood Disaster Management, NERC(1975), USOTA(1980), NTIS(1983), UNEP(1991),Cudworth(1991), form a general source of information. Hladny and Buchtele(1989) presented different hydrological aspects of flood; predictability of flood, accuracy of basic elements and present state-of-the-art of equipment and organisastions. Linseley(1983) described the specific research needs in hydrology and hydraulics with respect to Flood Disaster Management. He also presented other important research needs in this regard. He recommended seventeen items concerning Flood Risk, Flood Plain Mapping, Flood Warning, Data Flooding from the sea, Debris and ice and landslides. The present report is different from the previous reports in dealing only different hydrological aspects linked with flood disaster management. The main objectives of the report is to present, causes of flood disaster and measures in flood disaster management in this context. This report also presents information on approaches and discussions on the research needs.

1.1 FLOOD DISASTER PRODUCING CONDITIONS

These conditions have great variability both in time and space. Major type of flooding are *Riverine,* along non-tidal rivers and *Coastal flooding.* These floods are caused by many different factors as given in Table 3(a). The flood intensifying factors are given in Table 3(b).

TABLE:3(a) CAUSES OF FLOOD (Courtesy: Newson, 1995)

CLIMATOLOGICAL	PART-CLIMATOLOGICAL,
(a) Rain (b) Snowmelt (c) Icemelt (d) Combined rain and melt	(a) Streamflow and Tidal (b) Coastal Storm Surge

TABLE - 3(b) FLOOD INTENSIFYING CONDITIONS

BASIN CONDITIONS	NETWORK CONDITIONS	CHANNEL CONDITIONS
Stable (i) Area (ii) Shape (iii) Slope (iv) Aspect (v) Altitude Variable (i) Storage capacity (ii) infiltration (iii) Transmissibility	Stable (i) Pattern Variable (i) Surface storage (ii) Channel length (iii) Underdrainage	Stable (i) Slope (ii) Flood control Variable (i) Roughness (ii) Load (iii) Shape (iv) Storage

Indirect causes:

(a) Increased density of population in inundation areas,

(b) the process of urbanization and the higher density of housing in such regions, and,

(c) Peoples' markedly changed way of life in respect to nature and natural resources,

Linkage between Floods and Global processes:

(a) Processes taking place outside and inside the earth. Most fundamental is earth's gravitational and inertial movements.

(b) Extraterrestrial influences headed by solar activity.

1.2 EFFECTS OF FLOOD DISASTER

Extraordinary floods can affect far-reaching, long term and complex responses in stream channels (Osterkamp and Costa 1987). They effect the river bed changes, river bank damage, changes in geomorphic features and vegetation in the flood plain. Sediment size distribution changes along, both vertical and longitudinal as the existing bed material may be removed or burried.

Numerous public health problems arise during such flooding and remains for a long time. Mosquito-borne diseases outbreak such as St.Louis encephalitis are known to have occurred following flooding. In 1976 Missouri and Mississippi river flooding resulted in an extraordinary high mosquito population. It is possible that groundwater is virus contaminated after a flood event. When raw ground water is used after a flood event caution is necessary. Heavy rain can desorb viruses which have been concentrated by adsorption to soils from the septic tank located and cause post-flooding problems. Ascepti memingitis cases were noticed in Florida (Wellings, 1983). Flooding frequently leads to rat and snake infestations of high elevation posing public health problems.

In some cases a warning to remain inside and avoid automobile travel result in less risk to public health. Fleeing from an area in automobile under adverse driving conditions over inundated roads has resulted in injury and death as for example Kansas city flood in 1982. The lack of data preclude informed planning before, during and after flood events. Epidemiological methods provide excellent approach to study of flood related health problem.

Water and wastewater treatment plants used to be located near by a river and are flood prone. Although plants are protected the sewers when become inundated raw sewage backs up

into the street. As raw sewage may contain as many as 200,000 virus particles per liter the seriousness of the problem should be well undertaken. In the case of severe flooding, even well protected treatment plants may be inundated, particularly when they are located near ocean.

Flooding may disrupt rail service, Canal system and road traffic. In complex urban areas short return period floods create havoc. Road disruption is acutely felt at bridge crossing. Several factors determine the actual effect. Some of them are;

1) Traffic flow,
2) Flood frequency,
3) Flood depth & extent,
4) Flood duration,
5) Diversion of traffic if any and the type etc.

Flood disrupts supply of electricity, gas and water, sewage disposal, telecommunication and postal utilities.

Chemical contamination of groundwater may be more threatening to public health than even microbial contamination. Industrial use of a flood plain needs cautious consideration.

2.0 FLOOD DISASTER MANAGEMENT

Being a major issue, flood disaster management draws the attention of government agencies, private agencies and population at risk. Flood disaster management is a multi-disciplinary subject and is of global concern. A successful program for flood disaster management depends on the individual and coordinated approach of experts from economics, social science, hydrology, geology, environmental science and many other subjects. Sometimes it is advocated also that in issues of flood disaster management social aspects are more important than scientific aspects (Changnon 1985). However, hydrology, being the science of water and water being the vital factor in a flood, plays a very important role in flood disaster management. Different aspects of flood disaster management are looked after by different research organisations. The hydrological aspects of flood disaster management is still at

the top of research programmes of hydrologists.

It is essential to present a clear definition of Flood Disaster Management. Figure 2 shows a flow chart showing the different hydrologic elements of work leading to flood disaster management. It is generally understood to minimize the losses due to flood disaster. But recent research articles show that the above definition is only partly correct. A more elaborate definition of flood disaster management is the enhancement of the total productivity of the flood plain where in losses are only part of the equation (Changnon 1985). Therefore in all the aspects of flood disaster management the focus should be to maximize the net gain from the flood plain rather than to minimize the flood losses. It is important to mention here that different programmes are influenced by these two different approaches.

Flood disaster management include all action that decreases the likelihood of property damage or loss of life as a result of floods. Number of techniques exist in practise. Storing of flood water in reservoir and pass the moderated flood if not fully stored for release later is well known to Water Resources Engineers. Certain areas which are subjected to flooding can be protected by building levees or flood walls around them or covering flood entry portions. Diversions of part of the river flow away from the area are to be protected. Certain restriction in the use of flood plain is also a management technique. Hydrological aspects of Flood Management include all the above techniques.

The frequency of occurence of the extreme floods can be arrived from the past records. Flood studies are made further for obtaining the aerial inundation. Management and disaster preparedness are planned for these floods. Such plans are valid only for a time period as the landuse may get changed in due course of time affecting the studies. Even the frequency of occurance of the flood needs to be revised. Hence periodical revision of the flood studies are to be carried out for flood management.

Flood disaster management requires complicated computational methods. The depth of flow and the magnitude of the discharge are

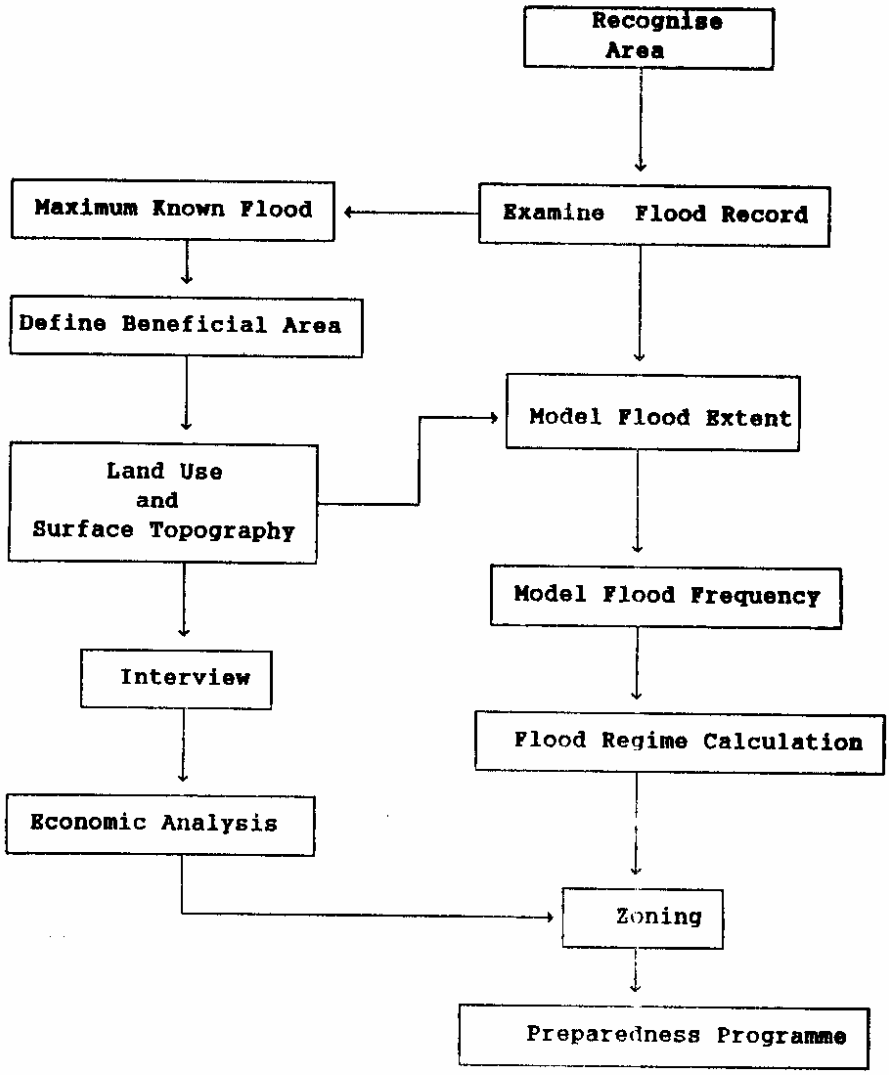

Fig.2 DISASTER MANAGEMENT

very high that usual assumptions and computational methods applied for gradually varied flows and flood routing may fail in some cases and in some cases they may provide reasonable solution. The results of the application of present day methods can not be used for rigid decisions because of the uncertainties involved. There is only an inadequate knowledge exists on the kind of unsteady flow that would occur. Sound and more reliable computational models for practical engineering purposes is yet to be evolved.

Organisms living in stream adopt to the natural flow conditions. These condition also include flood flows. Displaced organisms has to adopt to maintain position and to recolonize as soon as the flood recedes. It is well known that organic matter stored in the stream bed material form an important source of organic development. With the transport of the sediments these organism also get moved. Erosion due to huge flood flow displaces the spots of spawning ground. Eco system readjusts and establishes. A link of organic material between channel and the flood plain is strong. Huge flow can be viewed as a reset mechanism of biological activity. It is nature's reorder of bio-processes.

Movement and deposition by floods of inorganic sediments and nutrients is the mechanism of creating fertile flood plains. The details of how this deposition processes and the exchange of material between channel and flood plain needs attention of researchers.

2.1 PROBLEMS IN COASTAL AREA

Flood stages in lower reaches of coastal streams which discharges into estuaries/tidal river may be influenced by the tide at the time of the peak. Effective methods to predict the combined effect are to be used in these occasions. A storm surge is a result of a hurricane or other extraordinary storm that takes place in the sea. Other causes of coastal flooding are Tsunamis or other tidal waves. These waves can be set by submarine tectonic movements and may be lasting for 10 to 20 minutes. Coincidence of normal high tide and other flood peak is

another condition of concern.

As surges are not an annual phenomena, the location where the next surge will strike is unknown. Hence creating an extensive network of observation·choosing an area is difficult to provide information concerning the surge. Although tracking of hurricane has vastly improved in the past three decades, the dangers to life and health along the coastlines have not diminished. Storm development, their future movements, and their fall are complex that advance prediction of time and precise location of land fall is difficult. Hurricane forecasting are still to improve to have adequate lead time (12 to 24 hours) for issuance of warning and necessary evacuation.

2.2 REMOTE SENSING APPLICATION

Cyclone warning and weather satellites are used for forecasting and monitoring. Geostationary satellites like INSAT or polar orbiting NOAA series are in use. India uses a network of S-band radars along its coast to monitor the cyclone activities. These can provide information on cloud related information such as cloud patterns, cloud temperature, eye and its size, eye wall cloud width, direction of movement of low pressure etc. Geostationary satellite can provide monitoring coverage of 3 hours. IMD issues three hourly bulletins based upon INSAT cloud imagery. Hourly advisories are issued by IMD's Cyclone Warning Centre on the position and intensity of cyclone storms in Bay of Bengal and Arabian Sea. Landsat TM data can be analysed to delineate areas inundated by cyclone derived floods as done for the case of Godavari floods occurred on 9th May 1990. The INSAT-DWS (Disaster Warning System) is found to be useful in saving lives in coastal area. The INSAT system has Meteorological Segment, Telecommunication segment and Broadcasting segment. Very High Resolution Radiometer Operating in visible and infrared bands was added to the configuration which help in getting cloud cover image. The INSAT-DWS is unique in many ways in bringing the benefit to rural areas. The system enable the Cyclone Warning Centre (C.W.C.) to directly and selectively address a particular area likely to be hit by a

cyclone. Community TV receivers are located in coastal villages which are continuous and unattended operative. Polar satellite can not provide continuous monitoring capability. Data from ERS (earth resources satellite like IRS, LANDSAT, SPOT) are used to assess the cyclone impact. But due to clouds, usable data may not be available in the emergence period.

Satellite data can be used for preparation of flood inundation maps. ERS-1 data are helpful inspite of cloud cover. High resolution satellite data from SPOT and Landsat TM can be used to map post flood river configuration.

2.3 FLOOD PLAIN ZONING

This is one of the common techniques in practice to the management of flood plain to minimise the loss and also to maximise the productivity. A practice of this kind of technique can only made possible by an act is passed on it. This kind of act provides an authority to the concern to conduct survey, delineation of area which are subjected to flooding including classification of land use and the risk involvement.

A conceptual frame work within which flood plain management policy could be formulated along with a set of strategies & tools to guide decision making was made in 1976 in India.

The conceptual framework consisted of general principles and working principles. In summary, the general principles are:

1. The federal Govt. has a fundamental interest in how the nation's flood plains are managed but the basic responsibility for regulating flood plains lies with the state & local Govt.

2. The flood plains must be considered in the context of total community, regional and national Planning & Management.

3. Flood loss reduction should be viewed in the larger context of flood plain management, rather than as an objective in

itself.

The working principles set forth include definitions (of flood plains, flood hazard, flood evaluation, serious flood condition and flood disaster assistance) as well as series of general statement regarding the nature of flooding and flood plain management that provide further guidance for the development of flood plain management policies (for example, existing & new development should be treated differently in flood plain management). Flood characteristics are likely to change as development and land use changes take place and cost of flood plain management programmes ought to be shared equitably among the beneficiaries.

The three approaches or strategies for achieving flood loss reduction objective were set forth as.

1. Modify susceptibility to flood damage & disruption - action to avoid dangerous uneconomic and undesirable or unwise use of flood plains.

2. Modify flooding : The traditional strategy involving construction of dams, dikes, levees , channel alterations, high flow diversions and land treatment measures.

3. Modify the impact of flooding on individuals and the community action designed to assist the individual and the community in the preparatory, survival & recovery phases of floods.

STRATEGIES AND TOOLS EVOLVED FOR FLOOD LOSS REDUCTION

strategy A. Modify Susceptibility to Flood Damage and Disruption

1. Floodplain Regulations
   a) State Regulations for Flood Hazard Areas
   b) Local Regulations for Flood Hazard Areas

1) Zoning
2) Subdivision Regulations
3) building Codes
4) Housing Codes
5) Sanitary and Well Codes
6) Other Regulatory Tools

2. Development and Redevelopment policies
   a) Design and Location of Services and Utilities
   b) Land Rights, Acquisition and Open Space Use
   c) Redevelopment
   d) Permanent Evacuation
3. Disaster Preparedness
4. Disaster Assistance
5. Floodproofing
6. Flood Forecasting and warning Systems and Emergency Plans

Strategy B. Modify Flooding

1. Dams and Reservoirs
2. Dikes, Levees and Floodwalls
3. Channel Alterations
4. High Flow Diversions
5. Land Treatment Measures
6. Onsite detention Measures

Strategy C. Modify the Impact of Flooding on Individuals and the Community

1. Information and Education
2. Food Insurance
3. Tax adjustments
4. Flood Emergency Measures
5. Post Flood recovery

Emphasis on structural measures for tackling the acute problems has not provided the desired results. Use of non-structural measures of flood management and regulation of developmental activities in the flood plains is very essential.

Appendix-I gives the Flood Plain Zoning Act, 1978 (Manipur Act 10 of 1978) to provide the kind of regulations that are needed for riverine managements. This allows the *Flood Zoning Authority* the following:

i) To carry out survey of flood plains of the rivers - this will allow the determination of extend (spacial) and the ground elevation of the land.

ii) To delineate the area which are subjected to flooding.

iii) To classify the land with reference to relative risk.

Appendix -II provides the demarcated boundary along different rivers in Manipur.

The areal inundation of a given flood depends on the flood plain characters and the hydrodynamics of the flow. There would be a concentration of flow energy at the central part of the flow. This may include the usual channel and part of adjoining flood plain. Huge flow can uproot or dislocate trees/structures on its way especially at this central zone whereas the buildings situated little far away and are surrounded by the flow are subjected to different destructive forces. The flow may enter through the openings if any and move around. The failures are not mainly due to flow forces in the direction of main flow in this zone of flow. They also depend on the position of doors/ windows with reference to the main flow. Hence zones are to be identified not only keeping in view of frequency but also hydrodynamics (flow energy regime) into consideration. This indicates the need for two dimensional flow modelling. In the case of disastrous flow separate zoning principle is to be adopted.

2.4 DATA BANK OF FLOOD RELATED INFORMATION

Systematic gauging of streams are recent phenomena in our country. A length of data of 5-7 years can be seen for most of the rivers. Longer records can be seen for most of the important rivers. The meteorological and hydrometric data are systematically collected at present. They should be stored and utilized properly for planning further projects. Certain type of non-conventional information that are not recorded properly or not stored properly needs attention. For example records of

events such as levee failures, bank erosion, breach of bank etc. are useful in defining the mechanics of failures. They can also be used to define probability of the event. The use of cross-section data at a proper interval need not be emphasised. The longitudinal profile of the bed and its material need to be collected and published. The growth of various plants and its effect on bank stability or otherwise failure are to be recorded. Record of land use are normally available with revenue departments. The corresponding reachwise sediment data are to be maintained. Data collecting network should be directed to meet the data requirement of State-of-the art hydrologic methodology and accuracy requirement of flood managements. Predictive capability of any can not be tested without a data base. Data requirement for flood management are listed below. No attempt has been made to make exhaustive list of data in this section. But only briefly the identified data considering the possible use and development of the methodologies are given.

Cross-section & Flood Plain:

A cross-section is defined by the geometric coordinates, Rls & Rds (Reduced length and reduced distance) from a reference point. These sections are available for any river only at gauging sites and considered dam sites if any. They only describe the portion of the channel and a limited distance on either side of the flood plain. They are inadequate for any modelling purposes. Each of the cross section should extent fully on either side to the extend of expected flood flow. Further the cross sections should explain its variation with respect to distance i.e. they should be at close intervals. An interval of 1 km would be sufficient enough for most of the models expect for detailed planning for a specified river reach of importance.

Discharge & Water Level:

There is a systematic river gauging on all major rivers. They should be processed and stored for ready retrieval. Water level are to be recorded automatically to describe the hydrograph. Further research should be aimed at improving the

sensors used in the field, and recording devices (computer compatible); improved techniques of cost effective storage and retrieval with necessary accessibility.

Flood Inundation Map:

There is no systematic collection of flood inundation data. High levels that a flood occupies and its duration are to be observed and inundation maps are to be prepared as they provide details of the flood flow. This will enable the hydrologist to improve flow prediction.

Flood Loss Data:

Just as inundation details, these are also not being recorded properly. There is also inconsistency between data of local bodies and those of State/Central agencies. Public health effects of flood as they inundate water facilities, chemical waste disposal sites, sewage plants etc. are also to be assessed and recorded.

Recognising flood damages is usually limited to man made structures and use of land. On the basis of argument that it is illogical to claim that natural system is damaged by a natural event, any loss of Eco system that has occurred only due to man made activity need to be accounted. However, a particular benefit that the society is deriving like.fishing is affected that needs to be accounted. Strong theory does not exit on this subject

River Bank and Breach data:

The river flow is contained by the banks so long as the flow is less than the highest inbank flood. Banks are distinguished by the steep slope as one traverse on either side from the centre of the channel. These banks are classified as clayey bank, sandy bank or composite banks. Strength of the banks differ not only because of the composition but also due to the vegetation cover. Data on the strength of these banks and the vegetational cover (grazing etc.) are also to be recorded. Occurrence of breach in any should immediately be recorded along with the water level.

Sediment:

Floods invariably associated with huge sediment load. The sediments present on the river bed and transported are usually non-uniform. The details of sediment movements and the type of the sediment in terms of the size distribution are to be recorded. The bed material size distribution should be recorded to assess the amount of sediment transport.

Morphological Changes:

Flood movement changes the river morphology. In fact it is a huge flood that carve the cross-section. Changes in the longitudinal form and also plan form will be of immense use for future use.

Land slide:

The rainfall causing huge flood often trigger the land slide and introduce huge mass of earth or mud to enter into the river and cause additional damage. Land slide can cause a temporary dam to be created. Occurrence of such slides should be recorded. Studies in this regard require joint effort of geologist and hydrologists.

3.0 DAM BREAK

Megaflood are also caused by dam failures. The destructive potential of a dam break flood is known since 689 BC when a dam built across Euphrates river was destroyed to inundate the city of Babylon (Gill 1986). During World War II, Dam Break was used as hydraulic weapon. Britain is said to have carried out air raid on dams in Germany. In the recent Gulf War in 1991, only one of the hydroelectric project was not damaged by bombing. Peruc'a dam in Yugoslavia was damaged in 1993 conflict. A complete history of dam failure can be seen in Jansen 1980. Some major disasters are presented in Table-4. There is no doubt that a dam failure can lead to massive life destruction. However, the total number of death due to dam failure is much less than due to other accidents. Floods from other causes have been responsible for

TABLE 4: SOME MAJOR DISASTERS (Source Goubet 1979 , Reiter 1992)

DAM & Country	Height m	loss of life	year
Jhonston, USA	22	600	1802
Dale Dyke, U.K.		250	1864
Iruka, Japan		1200	1868
Puentes, Spain	21.9	2000-4000	1889
Bouzey, France	15	86-100	1895
Austin U.S.A.	14	80-700	1911
Gleno Italy	22	100-600	1923
Eigian G.B.	10.5	16	1925
Saint Francis U.S.A.	55	400-2000	1928
Vega de Terra Span	34	144-400	1959
Malpasset France	66.5	421	1959
Babu Yar USSR	<15	145	1961
Vaiont Italy	265	2600	1963
Nanaksagar India	15.6	100	1967
Shivaji Sakar India	103	180	1967
Sempor Indonesia	-	200	1967
Buffalo Creeck U.S.A.	-	125	1972
Teton U.S.A.	120	11	1976
Del Monte Colombia	-	80	1976
Santo Thomas Philippine	-	80	1976
Vaiont Italy	265	2600	1963
Belci Romania	18	78	1991

about eight times as many deaths as dam failures (Lave et al. 1990). Due to improvement in design and construction the failures percentage have been decreased (Goubet 1979, Serafim 1981). The probability of failure is worked out to be 10^{-4} by Bacher et al. (1980) . The meaning and validity of the probability of a dam failure is controversial. Each dam can be said to have unique probability. This can be understood by a physical interpretation of the failure mechanism. Large number of failures can be seen in the case of earth/ rockfill dam than concrete or masonry dam. (failure ratio of 3:1 compared to population ratio of 16:10). Dams seem to have much more vulnerability during and immediately after the construction (5-7 years). After this period, the risk decreases and again increases after the useful life of the dam.

3.1 INDIAN SCENARIO

Damage due to floods is enormous in India and has been a blocking stone to the development of our country. Figs. 3 and 4 show, respectively, the area affected and the total loss due to floods over the period from 1956 to 1992. In Appendix-III other losses are presented in a tabular manner.

National Centre for Diaster Management was set in March 1995 by Ministry of Agriculture to prepare exhaustive information base on damage caused and resources spent on mitigation practices and relief work for various types of natural diasters , as one of its main objective. There are several cases of failures documented. Only one case is given below to illustrate the causes of failure that had occurred in India.

CHANDORA DAM

Chandora Dam across the river Tapi (Multai tehsil of Betul Dist. M.P.) is a earth dam of 17.26m. Salient features are given in Table 5.

Heavy rainfall occurred on 29.7.91, 8 am to 30.7.91, 8 am (totalling 450 mm) causing the inflow. The reservoir level was at 683.67 m at 8am (29.7.91) and increased by 10 cm by 1.30pm.

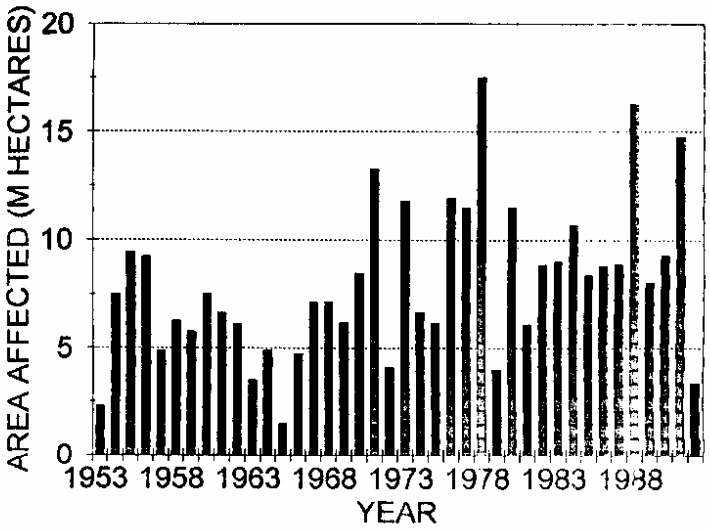

FIG. 3 AREA AFFECTED DUE TO FLOODING

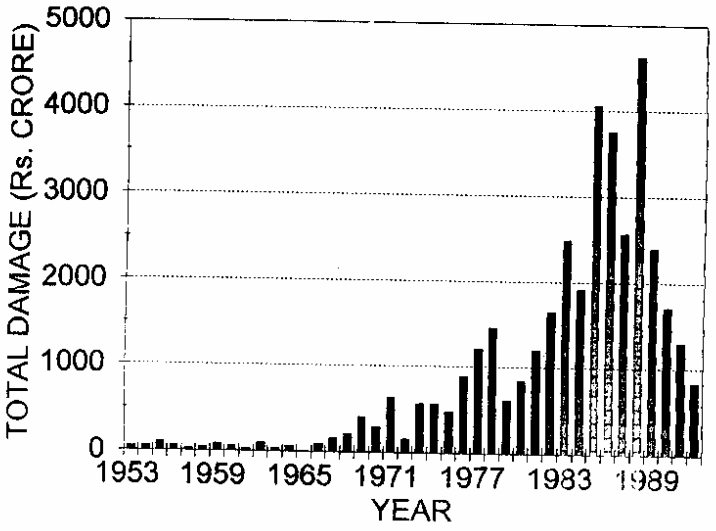

FIG. 4 TOTAL LOSS DUE TO FLOODING

TABLE 5: SALIENT FEATURES OF CHANDORA DAM

Hydrology		Reservoir		Dam	
Catchment area	71.23km²	subm. area	434 ha.	Height	17.26 m
Annual Precipitation (avg.)	1060 mm	Live stor.	16.48 M.Cum.	Length	2043 m
Design Flood	681 m³/s	Gross Stor.	18.20 M.Cum.	Top of dam	688.54 m
		FRL	685.95m	Spillway Length	Masonry 67.07m
		MWL	686.71m	Crest El	682.45m
		River Bed level	671.28 m	Number Size	8 gates 5.5x3.5m

At the late night the need for opening of the spillway gates was felt. But due to electrical failure including diesel generator and also failure of raising up of the gates manually with single handle desired opening could not be made. Further the rope of one of the gate which was opened broke and completely closed the opening. The operation could not be completed as the reservoir level had almost reached the top of the dam and left the site. The dam breached between 7am to 9am. The estimated loss was Rs 8 crores. Complete breach length of 180 m was observed to occur (between Rd 810m to 990m at Ground levels 855 m and 945m). There was a partial breach between 1110m - 1170m. Two more breaches of small width were complete. Downstream slope were damaged due to over flowing water. Very deep and wide gulleys were formed on the downstream slope. No damage was noticed between the portion Rd 0m to 810m which has slightly higher elevation. This indicates that the overflow occurred in the other portions only with a depth of water of few centimetres.

TABLE:6 RAIN AND CORRESPONDING INFLOW FOR 24 HOURS SINCE 8AM 29.7.91 (SOURCE : Mande 1993)

Time	Rain mm	Inflow M.cum	Time	Rain mm	Inflow M.cum	Time	Rain mm	Inflow M.cum
8	-	-	5	6.0	0.0	2	8.0	1.7
9	3.6	0.0	6	6.0	0.45	3	34.0	0.9
10	4.95	0.0	7	7.5	0.8	4	60.0	0.6
11	21.45	-	8	20.0	0.7	5	58.0	0.7
12	8.25	0.2	9	10.0	4.3	6	46.0	0.2
1	1.75	0.1	10	10.0	1.7	7	34.0	0.4
2	0.5	0.1	11	36.5	4.3	8	22.0	0.4
3	0	0.05	12	19.5	0.1	Tot.	450.0	20.2
4	0	0.0	1	32.0	2.5			

4.0 CONCLUSIONS

Occurrence of a disastrous flood is not an uncommon phenomena experienced by the riverine civilisation. Hydrologists realise the existence of such extreme events and provide methods to quantifying them. A periodicity is always associated with them. However there are also extreme events where periodicity has no meaning. For example dam break failures. Failure of some of the dam and the information derived from the hydrological analysis have caused serious attention of the planners.

Hydrologists can help in mitigating the effects of flood by issuing warnings, in planning for preparedness and in design of various structures. Hydrological analysis can further help in assessing the risk involved and the effect of any catastrophe on the river environment (morphological changes).

Major deficit in all facets of flood hazard mitigation planning is the lack of a systematic collection and retrival of data.

Flood plain management should orient towards maximising the

benefits derived from it. Zoning of this area of activities is useful for this purpose. Flood plain zoning should include energy regime and economic aspects also. Concentrated research efforts are needed to solve the complex flow phenomena in the flood plains especially in the presence of agricultural crops like paddy ,sugarcane , urban structures etc. Field measurements in this regard will help in building mathematical models.

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APPENDIX - I

THE MANIPUR FLOOD PLAIN ZONING ACT, 1978
(Manipur ACT 10 of 1978)
As
ACT

to provide for the zoning of flood plains of rivers in the State of Manipur

Be it enacted by the Legislature of the State of Manipur in the Twenty-ninth Year of the Republic of India as follows:-

CHAPTER - 1
PRELIMINARY

1. (1) This Act may be called the Manipur Flood Plain Zoning Act, 1978.

(2) It extends to the whole of the State of Manipur

(3)This section shall come into force at once and the remaining provisions of this Act shall come into force on such date as the State Government may, by notification in the official Gazette, appoint;

Provided that different dates may be appointed for different provisions of this Act and for different areas or different rivers.

2. In this Act, unless the context otherwise requires -

(a)"Flood plain" includes water channel, flood channel and that area of nearly low land susceptible to flood by inundation;

(b)"flood plain zoning" means restricting any human activity in the flood plains of a river where the plains are created by overflow of water from the channels of rivers and streams;

(c)"flood zone" means the area which is required to carry the flow of the maximum probable floods;

(d)"flood zoning authority" in relation to a river, means the authority appointed by the Government under Section 3;

(e)"Gazette" means the official gazette of the Manipur State Government;

(f)"Government" means the State Government of Manipur;

(g)"land" includes interest in lands, benches arising out of lands and things attached to the earth or permanently fastened to anything attached to the earth;

(h) "occupies" in respect of any land, means any person who has an interest in the land and cultivates the land himself or by his servants or by hired labour and includes a tenant;

(i) "owner" in relation to any land, includes any person having interest in such land;

(j) "prescribed" means prescribed by rules made by the State Government under this Act;

(k) "water channel" means the channel in which the flows of a river are generally confined;

(l) "river" includes its tributaries.

CHAPTER -II

FLOOD ZONING AUTHORITY AND ITS POWERS

3. (1) Where the State Government considers it necessary or expedient to do so. It may, be notification in the Gazette, declare that flood plain zoning shall be made in the manner hereinafter specified.

(2) The State Government may direct that a survey be made of a river for the purpose of determining the limits within the provisions of the Act are to be applied and that proper charts and registers be prepared specifying all boundaries and landmarks and any other necessary matter for the purpose of ascertaining such limits.

(3) The Statement Government may , by notification the official; Gazette, appoint the Deputy Commissioner of the District or such other authority as that Government considers necessary, as the flood zoning authority for the purpose of making a survey of the area s required under subsection (2) and may specify in such notification, the duties to be discharged by such authority.

4. The Flood Zoning Authority shall exercise the powers and discharge the duties in accordance with the provisions of this Act and the terms and conditions specified in the notification under sub-section (3) of section 3.

CHAPTER - III

SURVEYS AND DELINEATION OF FLOOD PLAIN AREA

5. (1) The Flood Zoning Authority shall carry out surveys of flood plains of the rivers and determine the nature and the extent of flood plains of the rivers.

(2) The Flood Zoning Authority shall on the basis of the survey carried out under sub-section (1), establish Flood Plain Zones and delineate the areas which are subject to flooding including classification of land with reference to relative risk of flood plain use intended to safeguard the

health, safety and property of the general public.

(3) The Flood Zoning Authority shall prepare charts and registers indicating the areas delineated under sub-section (2).

6. It shall be lawful for the Flood Zoning Authority or any of the officers generally or specially authorised by it on this behalf.

(a)to enter upon and survey and take levels of any land within its or his jurisdiction.

(b)to mark such levels, boundaries and line by placing marks of boundary stones;

(c)to measure the land;

(d)to do all other act necessary for the purpose of ascertaining the limits referred to in sub-section (2) of section 3.

(c Where otherwise the survey cannot be complete and the levels taken, to cut down and clear away any part of standing crop, fence or jungle;

Provided that no Flood Zoning Authority or any other officer shall enter into any building or open any enclosed court or garden attached to a dwelling house or cut down and clear away standing crops or fence unless with the consent of the occupier (thereof) without previously giving such occupier at least seven days notice in writing of it or his intention to do so.

7. (1) The Flood Zoning Authority or any other officer generally or specially authorised by it in this behalf who has entered upon any land under section 5 shall, before leaving, tender compensation to the owner or occupier of such land for any damage which may have been caused and in case of dispute as to the sufficiency of the amount so tendered, the Flood Zoning Authority of such officer shall refer the matter to the Government of Manipur for decision.

(2) The decision of the officer under sub-section (1) shall be final and no suit shall lie in a civil court to have it set aside or modified.

CHAPTER - IV

NOTIFICATION OR LIMITS OF FLOOD PLAINS

8. The Government may on the basis of a report from the Flood Zoning Authority of otherwise by notification in the Gazette declare its intention in demarcate the Flood Plain Area and either prohibit or restrict the use of land therein as specified under the rules.

9. (1) The Flood Zoning Authority shall on the issue of

notification under section 8, cause public notice of the substance of such notification to be given at convenient places in the area.

(2) The Flood Zoning Authority shall also give notices individually to the owners of the lands situated in the area.

(3) The Flood Zoning Authority shall exhibit records, charts, maps, registers and such other documents showing the river channel, flood channel and the flood plain area, specifying the nature and extend to which the use of limits of the area is either prohibited or restricted in his office for inspection by the general public at the timings specified therein.

Objection.

10. (1) Any person who desires to raise any objection to the limits and either the prohibitions or restriction specified in the public notice referred to in section 9, many within a period of sixty days from the date of publication of the notification in the Official Gazette, forward to the Flood Zoning Authority a statement in writing setting forth his objections.

(2)After the expiry of the period aforesaid, the Flood Zoning Authority shall issue a notice in the manner prescribed and consider the objections after giving the party concerned a reasonable opportunity of being heard in the manner.

(3)The Flood Zoning Authority shall forward to the State Govt. its or his proposes together with the records referred to in sub-section (3) of section V, along with, objections received under sub-section (1).

11. (1) The Government may, after considering the report of the Flood Zoning Authority, and the objections; if any, order such alternations in the limits of the area as it considers necessary, or drop the proposes.

(2) The Decision of the government shall be final.

(3)The Government shall be notification in the official Gazette, declare that the provisions, of this Act shall apply to the said river with the boundaries and limit, as specified.

(4) The areas delineated and approved by the Government shall be deemed to by the flood plain and the limits shall, where necessary, be marked either by boundary stones or other suitable marks.

(5)The Flood Zoning Authority shall maintain the charts and registers of such areas so delineated and such charts and registers shall form part of the permanent records of the office.

(6) The charts and registers maintained under sub-section (5) shall be furnished to the Deputy Commissioner of the District in which any part of the river is situated and shall be open for inspection by the general public at such times as may be prescribed.

CHAPTER - V

PROHIBITION OR RESTRICTION ON THE USE OF THE FLOOD PLAINS

THE FLOOD PLAINS

12. (1) Where the Government is satisfied that it is necessary to do so in the interest of public health, safety of property or in the interest of reducing the inconvenience to the general public or that it is necessary to prohibit or the restrict the activities in the flood plain, it may, by notification in the gazette specify the area where such prohibition or restriction is to be enforced and the nature and extent of such prohibition or reservation.

(2) Upon the publication of a notification under sub-section (1), notwithstanding anything contained in any law, custom, agreement or instrument for the time being in force, the prohibition or restriction specified in such notification shall prevail.

(3) No person shall undertake any activity within the prohibition area or restricted area except with the previous permission of the Flood Zoning Authority.

Provided that where a person makes an application in the Flood Zoning Authority for permission under this sub-section to undertake any activity and the Flood Zoning Authority, does not, within a period of ninety days from the date of receipt of such application, communicate to the person that permission applied for has been refused, it shall be presumed that the Flood Zoning Authority has granted such permission.

13. If any person commence or carriers on or attempts to carry on any activity in the area specified in the notification under such-section (1) of section 12 contrary to the terms and conditions specified in such notification, he or she shall be punishable:-

(a) with fine which may extend to the hundred rupees or in default of payment of fine, to simple imprisonment for a term which may extend to two months; and

(b) with further fine which may extend to one hundred rupees for each day in care when the offender continues the offence under clause (a) after the conviction under clause (a).

14. Subject to such conditions a, may be prescribed any officer authorised by the Government by a general or special order in this behalf may either before or after the institution of proceedings under this Act accept from the person who has committed or in reasonable suspected of having committed an offence, under this Act, by way of composition of such

offence, a sum of money not exceeding five hundred rupees.

(2)On the payment of such sum of money, such person shall be discharged and no further proceedings shall be taken against him in respect of such offence.

14. (1)Any person aggrieved by any decision of the Flood Zoning Authority may prefer an appear to the prescribed authority within a period of ninety days from the date on which such decision was communicated to him;

Provided that the prescribed authority may entertain the appeal after the expiry of the said period of ninety days if it is satisfied that the appellant was prevented by sufficient cause from filling the appeal in time.

(2)The prescribed authority may after giving a reasonable opportunity to the appellant of being heard in the matter, make such orders as it deems fit and the decision thereof shall be final.

16. (1)Where no appeal has been preferred under section 15, the Government may, for the purpose of examining the legality, propriety or correctness of any order made by the Flood Zoning Authority, call for the records of any inquiry or proceedings of the Flood Zoning Authority and make such order in the case as it thinks fit.

Provided that no such record shall be called after the expiry of six months from the date of such order.

(2)No order of the Flood Zoning Authority shall be varied by the Government so as to prejudicially effect any person without giving such person a reasonable opportunity of being heard in the matter.

CHAPTER-VI
COMPENSATION

17. (1) Where any permission to undertake any activity in the flood plain has been refused to any person or where as result of the prohibition or restriction imposed on any person under this Act, such person suffers any damage he shall be entitled to the payment of compensation not exceeding the difference between the value of the land as determined under section 23 or section 24 of the Land Acquisition Act, 18/4 and the value which it would have had the permission for carrying on any activity had been granted or the prohibition or restriction had not been imposed.

(2) In determining the amount of compensation under sub-section (1) any restriction to which the land is subjected to under any other law for the time being in force in regard to the right of the person claiming compensation to carry on any activity on the land or otherwise to the use of land shall be taken into consideration.

IS(1)The person to whom the compensation under section 17 is to be paid and the appointment of such amount among the persons interested therein shall be determined by agreement between the Flood Zoning Authority and the person or persons claiming interest therein.

(2)In default of any such agreement, the Flood Zoning Authority shall, after holding such inquiry as it considers necessary, make an award determining:-

(a) The amount of compensation to be paid under section 17 and
(b) The appointment, if any, of such compensation among persons known to be interested therein.

Provided that where the amount of compensation exceeds ten thousand rupees, no award shall be made without the previous approval of the Government or such other officer as the Government may authorise in this behalf.

19. (1) No compensation shall be awarded:

(a) if and in so far as the land is subject to substantially similar restriction in force under some other tax in force on the date on which the restrictions were imposed by or under this Act: or

(b) If compensation in respect of the same restrictions imposed by or under this Act or substantially similar restrictions in force under some other law has already been paid in respect of the land to the claimant or any predecessor in interest of the claim: or

(c) for removal of any encroachment:

(2) If any person has without lawful authority undertaken any activity, any increase in the value of land from such activity shall not be taken into account in estimating the value of land.

20. (1) Any person aggrieved by the award of the Flood Zoning Authority under sub-section (2) of section 19 may be an application in writing, apply to the Government of such other officer at the Government may authorise in this behalf.

(2) An application under sub-section (1) shall be made in such form and in such manner or may be prescribed and shall be made within forty five days from the date of communication of award.

(3)The application under this section shall be deposed off in such a manner as may be prescribed.

21.(1) The Government or such other authority, while exercising the powers under section 20, shall be deemed to

be a Civil Court under section 141 of the Code of Civil Procedure, 1908 and shall have the powers of Civil Court under CWP Procedure Code (Central Act 5 of 1903).

(2) The scope of inquiry shall be restricted to the consideration of the matter inferred to the Government or such other officer as the Government may authorise in this behalf.

22. The decision under section 21 shall be enforceable as a decree of civil court.

23. On the determination of the compensation under sub-section (1) of section 18 or on the making of an award under sub-section (2) of section 18 or if an application is made under section 20 against such award after decision of the authority, the compensation shall be paid by Flood Zoning Authority and the provisions of sections 31 to 35 (both inclusive) of the Land Acquisition Act, 1894 (Central Act 1 of 1894) shall apply to such payment.

CHAPTER - VII
POWER TO REMOVE OBSTRUCTIONS AFTER PROHIBITION

24. (1) The Flood Zoning Authority may, in accordance with the provisions of this Act, within such time as may be specified, direct any owner or occupier of land to do any act or to remove any unauthorised obstruction within such time as may be specified by it and such owner or occupier shall do such act or remove the obstruction.

(2) If the owner or occupier fails to comply with the order of the Flood Zoning Authority within the time specified under sub-section (1) the Flood Zoning Authority may cause the act to be performed or cause the obstruction to be removed.

(3) All expenses incurred by the Flood Zoning Authority under this section shall be recovered from such owner or occupier as arrears of land revenue.

CHAPTER - VIII
MISCELLANEOUS

25. Any person who prevents the Flood Zoning Authority in discharging any Act imposed on such Authority by or under this Act, shall be deemed to have committed an offence under section 186 of the Indian Penal Code (Central Act 45 of 1860).

26. The Flood Zoning Authority and other officers and employees authorised under this Act shall be deemed to the public servants within the meaning of section 21 of the Indian Penal Code (Central Act 45 of 1860).

27 (1)No suit, prosecution or other legal proceeding shall lie

against the Government or any authority on person exercising any power of performing any duty under this act or anything which is in good faith done or intended to be done in pursuance of this Act or any rule or order made thereunder.

28. All fines imposed under this ACT shall be recovered in the manner provided in the Code of Criminal Procedure, 1973 (Central Act 12 of 1973).,

29. A civil court shall have jurisdiction to settle, decide or deal with any question which is by or under this ACT required to be settled, decided or dealt with Authority by the Flood Zoning Authority or such other officer authorised by the State Government in this behalf.

30. (1) The State Government may by notification in the official Gazette make rule to carry out the purpose of this Act.

(2) In particular and without prejudice to the generality of the foregoing provisions, such rules may provide for:-

(a) the manner in which charts and records shall be maintained.
(b)the form and manner in which application under section 20 shall be made and the manner in which such applications shall be disposed off.

(c) Any other matter which has to be, or may be prescribed.

(3)Every tulle made under this ACT shall be laid as soon as may be after it is made before the House of the State Legislature while it is in session for a total period of fourteen days which may be comprised in one session or two or more successive sessions and if before the expiry of the session immediately following the session or the successive sessions aforesaid, the House agrees in making any modification in the rule, or the House agrees that the rule should not be made, the rule shall thereafter have effect only in such modified form or be of no effect as the case may be, so, however, that any such modification or annulment shall be without prejudiced to the validity of anything previously done under that rule.

APPENDIX - II
DEMARCATED BOUNDARY ALONG THE RIVERS IN MANIPUR

MERAKHONC RIVER

1.	0m. to 5.275 Km. Yurembam to Tiddim Rd. crossing	32.5 m from the midstream	Imphal	22.5 m from the midstream	Imphal
2.	5.275 to 9.985 km Tiddim Rd.crossing to Langook	24.20m from the midstream	Imphal	24.20m from the midstream	Imphal
3.	9.985 to 16.563 Km Langpok to Chingphu	28m from the midstream	Bishenpur	28m from the midstream	Bishenpur

IRIL RIVER

1.	0 to 29km Sawombung to Lilong	50 m from the mid stream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal	50m from the midstream or 6m, from the outer toe of the bund whichever is farther from the midstream	Imphal

THOUBAL RIVER

1.	0 TO 32.70 Km Yairipok to Irong Ichil	40m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Thoubal	46m from the midstream or 6m from the outer toe of bund whichever is farther from the midstream	Thoubal

IMPHAL RIVER

1.	Koirengei to Lilolong	55m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal	55m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal

2.	28 to 60 km Lilong to Sekmaijin to Ithai	60m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Thoubal	60m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal
3.	60km to 80 km Sekmaijin to Ithai	62m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Thoubal	62m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal and Bishenpur
MANGJING RIVER					
1.	0 m to 17.745 km from Heirok bridge to Kharungpat	31m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Thoubal	31m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Thoubal
NAMBUL RIVER					
1.	0 m to 26 km from Iroisempa to Shamushang	30m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal	30m from the midstream or 6m from the outer toe of the bund whichever is farther from the midstream	Imphal

APPENDIX - III
LOSS DUE TO FLOOD IN INDIA

YEAR	POPULATION AFFECTED	DAMAGE TO CROPS AREA (in M HAC)	DAMAGE TO CROPS VALUE (RS. CRORE)	DAMAGE TO HOUSES NOS.	DAMAGE TO HOUSES VALUE (RS. CRORE)	CATTLE LOST (NOS)	HUMAN LIVES LOST
1953	24.280	.930	42.080	264924	7.420	47034	37
1954	12.92	2.610	40.52	199984	6.561	22552	277
1955	25.27	5.310	77.8	1666789	20.945	72010	865
1956	14.57	1.11	44.44	725776	8.047	16108	462
1957	6.76	.45	14.12	318149	4.979	7433	352
1958	10.98	1.40	38.28	382251	3.896	18439	389
1959	14.52	1.54	56.76	648821	9.418	72691	619
1960	8.35	2.27	42.55	609884	14.309	13908	510
1961	9.26	1.97	24.04	533465	.889	15916	1374
1962	15.46	3.39	83.18	513785	10.655	37633	348
1963	10.93	2.05	30.17	420554	3.701	4572	432
1964	13.78	2.490	56.87	255558	4.588	4956	690
1965	3.61	.27	5.87	112957	.195	7286	79
1966	14.4	2.16	80.15	217269	2.544	9071	180
1967	20.46	3.27	133.31	567995	14.264	5827	355
1968	21.17	2.62	144.61	682704	41.112	130305	3497
1969	33.22	2.91	281.9	1268660	54.423	270328	1408
1970	31.83	4.91	162.78	1434030	48.606	19198	1076
1971	59.74	6.24	423.13	2428031	80.241	12866	994
1972	26.69	2.45	98.56	897301	12.460	58231	544
1973	64.08	3.73	428.03	869797	52.482	261016	1349
1974	29.45	3.33	411.64	746709	72.434	16846	387
1975	31.36	3.85	271.49	803705	34.097	17345	686
1976	50.46	6.04	595.03	1745501	92.160	80062	1373
1977	49.43	6.84	720.61	1661625	152.29	556326	11316
1978	70.45	9.96	911.09	3507542	167.574	239174	3396
1979	19.52	2.17	169.97	1328712	210.606	618248	3637
1980	54.12	5.55	366.37	2533142	170.851	59173	1913
1981	32.49	3.27	524.56	912557	159.63	82248	1376
1982	56.01	5.000	589.4	2397365	383.869	246750	1573
1983	61.03	3.29	1285.85	2393722	332.327	153095	2378
1984	54.55	5.19	906.09	1763603	181.308	141314	1661
1985	59.59	4.65	1425.37	2449878	583.855	43008	1804
1986	55.5	4.58	1231.58	2049277	534.410	60450	1200
1987	48.34	4.94	1154.64	2919380	464.490	128638	1835
1988	59.55	10.15	2510.9	2276533	741.600	150996	4252
1989	34.15	3.01	956.74	782340	149.820	75176	1718
1990	40.259	3.179	695.61	1019930	213.733	134154	1855
1991	35.724	3.592	462.225	1050788	133.998	40012	752
1992	13.707	3.199	262.741	242349	73.746	6632	443

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