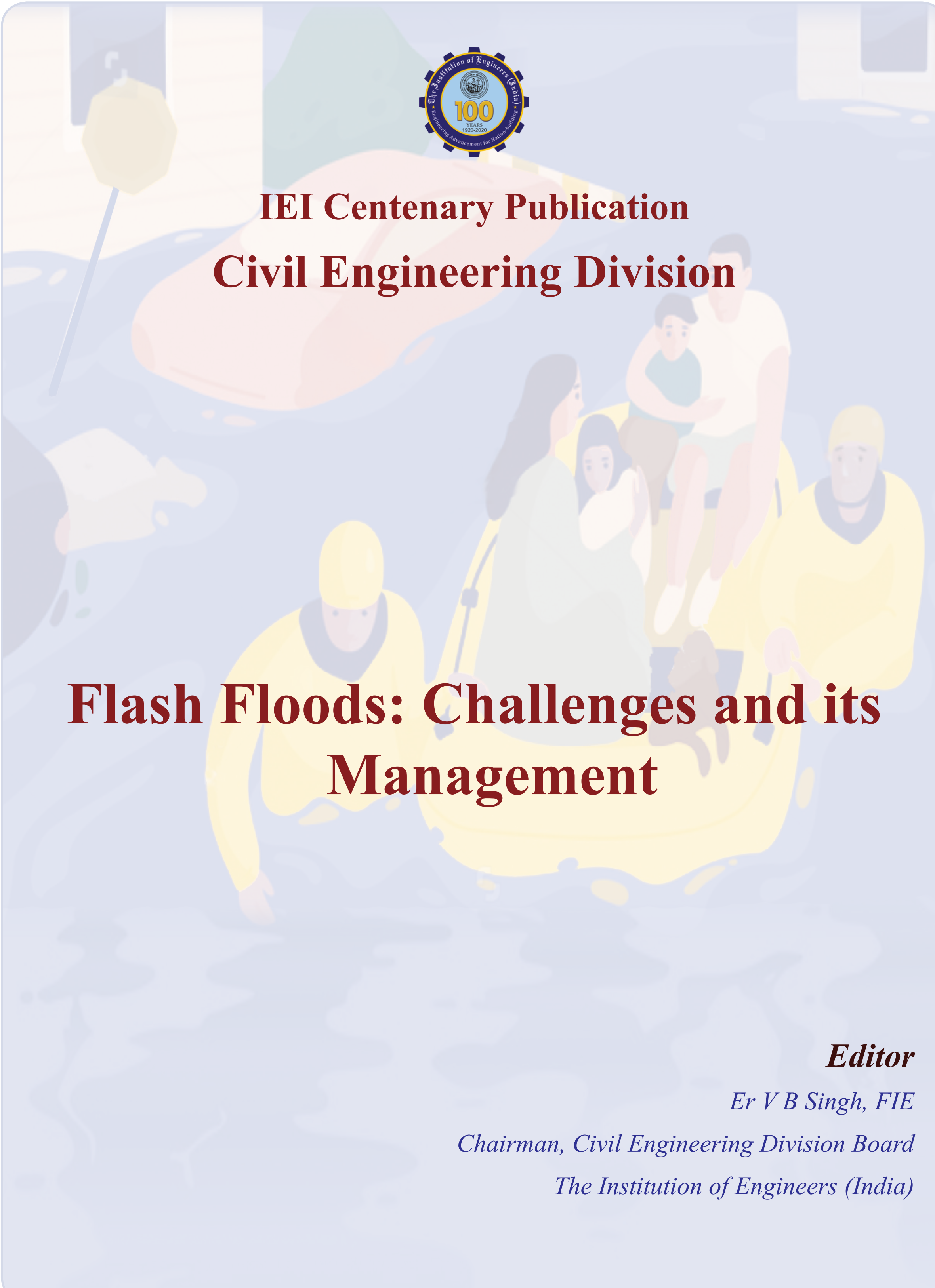
The Institution of Engineers (India)

Flash Floods: Challenges and its Management

– an IEI Centenary Publication

Civil Engineering Division



IEI Centenary Publication

Civil Engineering Division

Flash Floods: Challenges and its Management

Editor

Er V B Singh, FIE

Chairman, Civil Engineering Division Board

The Institution of Engineers (India)

The Institution of Engineers (India)
(ESTABLISHED 1920, INCORPORATED BY ROYAL CHARTER 1935)
Headquarters : 8 Gokhale Road, Kolkata - 700 020, India
Website : http://www.ieindia.org
A Century of Service to the Nation

Er. Narendra Singh, FIE
President

Message

It fills me with great pride and passion to inform to our erudite readers that the Civil Engineering Division Board of The Institution of Engineers (India) has successfully compiled and published this informative centenary volume on **"Flash Floods: Challenges and its Management"** concurrently with the 35th Indian Engineering Congress.

The purpose of this centenary volume is to provide an overview of the actions and measures that can be taken to manage and minimize the potential impacts of flash floods. The book provides an extensive coverage of various pertinent issues ranging from basic information about flash floods especially focusing on differences from riverine floods; identifying and assessing flash flood risk components, fresh perspectives of flash flood management strategies on how to reduce risks; and, provide guidance to involve communities and individuals in flash flood management and risk reduction.

Due to its characteristics, it is difficult to address flash flood issues by traditional flood management approaches as used for low land riverine floods. Integrated approaches as a combination of structural and non-structural measures are suitably covered through various articles. However, this book is a modest attempt towards providing a detailed insight towards flash flood management and mitigation based on experiences of the authors gathered over different time scale and over various terrains.

Er Narendra Singh, FIE
President, The Institution of Engineers (India)

Office : H No. 9/14, Mahant Flat, Idgah, Chakrata Road, Dehradun 248 001
Telefax: 0135-2620049, Mobile : 9412051590, E-mail : president@ieindia.org / nsinghfieindia@rediffmail.com

The Institution of Engineers (India)

An ISO 9001: 2015 Certified Organisation
(Established 1920, Incorporated By Royal Charter 1935)
8 Gokhale Road, Kolkata – 700 020

A Century of Service to the Nation

Prof (Dr) Swapan Bhaumik, FIE
Chairman,
Committee for Advancement of Technology and Engineering (CATE)

Message

Recent floods, both riverine and flash floods, in different parts of the world causing devastation of life and property are on the rise. Apart from natural factors like incessant and heavy rainfall during the monsoon, there are man-made factors that contribute to floods in India. The high losses and damages associated with floods in India show our poor adaptation and mitigation status and our inadequacy in disaster management and preparedness. The challenge lies in forecasting and warning, especially in the context of flash floods, because of the short lead times and much localized impacts. In this backdrop, this special centenary publication of the Civil Engineering Division Board of The Institution of Engineers (India) on "Flash Floods: Challenges and its Management" has evolved as an integrated response to floods providing an outline for a holistic flood management framework.

Based on the pilot projects of Government of India, recent experiences and available literature, this centenary volume seeks to synthesize and, as far as possible, conceptualize the approach that can be taken to address the issue of flash floods both on the national and on the lower administrative scales of districts and communities. As such, the book may serve as a comprehensive source of information to reach out to local communities, emergency services on various administrative scales and the National Hydrological and Meteorological Services on broader scales to maximize the impact of this initiative towards a significant reduction of the vulnerability of flash flood affected communities and the associated deaths and misery

The content of the book is well curated with inclusion of articles from professionals and academicians having field experience in facilitating and developing timely warning systems, evacuation, rebuilding and rehabilitation of the flood affected zones. Keeping in mind the contextuality of the subject and the synergistic involvement of such a wide variety of professional, many would find this book contextual and relevant.

Prof (Dr) Swapan Bhaumik, FIE
Chairman
Committee for Advancement of Technology and Engineering (CATE)

The Institution of Engineers (India)

An ISO 9001: 2015 Certified Organisation
(Established 1920, Incorporated By Royal Charter 1935)
8 Gokhale Road, Kolkata – 700 020

A Century of Service to the Nation

Er V B Singh, FIE
Council Member and Chairman,
Civil Engineering Division Board, IEI

Message

The Institution of Engineers (India), featuring all major disciplines of engineering with excellence in service domain, for technical education and engineering practice was established in 1920. The Institution was granted the Royal Charter on 21 February 1935. The objects and purposes of the Charter was to “promote the general advancement of engineering and engineering sciences and their application in India and to facilitate the exchange of information and ideas on those subjects amongst the members of and persons attached to the Institution” through its fifteen engineering Divisions.

The Civil Engineering Division of the Institution, since its inception, has been an ardent crusader in promoting pro-people and society centric science, technology and engineering practices particularly those which are inclusive and aimed at making life easier for the commoners. Statistics indicate that certain factors like unplanned land usage and removal of vegetative cover have resulted in severe global warming and consequent intensification of the hydrological cycle in pockets. This in turn has resulted in occurrences of natural disasters like flash floods which have resulted in high causalities and have rendered many homeless. The flash flood hazard is expected to increase in frequency and severity, through the impacts of global change on climate, severe weather in the form of heavy rains and river discharge conditions. The management of flash flood hazards and risks is a critical component of public safety and quality of life. Flash-floods develop at space and time scales that conventional observation systems are not able to monitor. Consequently, the atmospheric and hydrological generating mechanisms of flash-floods are poorly understood, leading to highly uncertain forecasts of these events. Flash flood forecasting and warning are basic measures implemented to reduce risks in flood prone areas. There are some difficulties in developing timely and accurate warnings due to localized and short lead times for flash floods. Besides, they run at inappropriate temporal and spatial scales and lack the high resolution data needed to improve the models.

As a basis for better use of non-structural measures, a participatory approach can make local communities and residents understand their risks and responsibilities for flash flood management. For flash flood management actions to be effective, detailed planning is a key for participation of users such as local communities. Flash flood management touches upon several sector-specific areas, so responsibilities and roles in each stage of management should be defined within solid legal and institutional framework. For flash floods, local communities especially have much more decisive responsibilities than those for riverine flood management.

To this end, the Civil Engineering Division Board (CVDB) of The Institution of Engineers (India) has come up with a special centenary publication on "Flash Floods: Challenges and its Management" with contributions from renowned researchers, practitioners as well as young professionals. This publication emphasizes on proper assessment of flash flood data to improve the scientific basis of flash flood forecasting by extending the understanding of past flash flood events, advancing and harmonizing a innovative flash flood observation strategy and developing a coherent set of technologies and tools for effective early warning systems and all other pertinent issues. This publication will help us to comprehend and gain insight into the latest developments in the areas of flash flood management. The compiled volume will be shared with all the interested stakeholders and also with the policy makers for consideration.

Er V B Singh, FIE
Chairman, Civil Engineering Division Board
The Institution of Engineers (India)

IEI Centenary Publication

Civil Engineering Division

Flash Floods: Challenges and its Management

PUBLISHER

Dr H R P Yadav, *FIE*
Secretary and Director General for
The Institution of Engineers (India)

PUBLICATION OFFICE

The Institution of Engineers (India)
8 Gokhale Road
Kolkata 700020
Ph: 2223-8311 /14-16 / 33-34
Fax: (033) 2223-8345
Website: www.ieindia.org
E-mail: icc@ieindia.org

CONTENT

CONTENT

CONTENT

A Review on Flash Flooding: Challenges and Its Management for Urban Areas

Prof Prabhat Kumar Singh
Department of Civil Engineering, Swami Vivekananda School Of Engineering & Technology, Bhubaneswar, Odisha
✉ *sprabhatkumar99@gmail.com*

ABSTRACT

Floods are globally a great natural hazard. Floods cause loss of property and lives and poor economic development. Although flooding cannot be prevented, its negative impacts could be greatly minimized through proper planning and effective preparedness. Vulnerability to floods could be reduced by accurate and timely predictions (forecasts and warnings) and by impact reduction measures. India faces flooding problems almost every year in the recent past. For the period 1947-2015, a financial loss of $ 75.516 billion was estimated as a result of 16 major & 25 minor floods across in India. Approximately more than 1,20,000 humans died and 865,916 km^2 of land area were affected due to these floods. Climate change is projected to lead to an increase in the frequency and magnitude of future floods in India due to high glacial melting and thawing of mountain ice caps and high monsoon precipitation. The situation calls for effective and sustainable flood management to reduce flood damage. This document reviews the current state of flood management, highlights the challenges of flood management and identifies the prospects for effective and sustainable flood management in India. The document also seeks to make certain recommendations for effective and sustainable flood management in India. Participatory community-based flood hazard mapping provides essential detail such as flood areas, depth information, evacuation centers and routes, critical facilities, communication channels, evacuation criteria, emergency kits, and many other items They need an evacuation on the hazard maps. Vulnerability is based on numerous components such as the internal side of vulnerability (it evaluates the coping capacity of people or systems) and external (exposure of people). The risk assessment consists of two main components, such as hazard (related to source and pathways) and vulnerability (related to receptor and consequences). Flood-related risk has increasingly become a global concern, and its vulnerabilities are related to demographic changes, socio-economic conditions, unplanned settlements, environmental degradation, stress on natural resources, and climate change.

Keywords: Flood management, Current state, Challenges, Prospects, Vulnerability, Risk, GIS and Remote sensing.

INTRODUCTION

A flash flood or a rapid-onset flood refers to short-lived floods with a comparatively high peak discharge of water at a particular location. Flash floods occur within a few hours of heavy rain, rapid thaw, or after a sudden explosion of a glacial lake or a fault in the embankment or a very rapid rupture of an ice block due to the rapid rise in temperature [1, 2]. Flash floods stimulate shortly after severe rainfall reaching up to 100mm in 6 hours and extreme high water flow and normally occur in small dry valleys. In flash floods, the unexpected rise in water closes in streams and rivers and the very high flow rate brings large amount of rubble, boulders, uprooted trees, destruction of infrastructure and built buildings stand in their way [3]. In the emergency response phase, the time of a flash flood is usually less than 6 hours. Flash flooding generally occurs after high intensity rainfall in a given area or small basin with a particular geological environment such as relief, slope, and a form factor, drainage density of a basin [4,5]. Soil contours have a persuasive effect on flash flood runoff, such as soil permeability, shrinkage, expansion, root distribution, and human activities [6]. Hydro-meteorological vagueness under flash flood conditions continues to show real-time forecasting problems. The flash flood prediction process should evaluate and answer questions for flood prediction parameters, such as basin conditions (how will the water move once it reaches the ground?), Rain (how much and how intense will the rain be?) and thaw (how much and how fast will it melt?) [7]. Over the past ten years in developed countries, the cumulative struggle has advanced to advance the flash flood forecast. Thus, there has been effective delivery time progress of up to six hours, such as improved quantitative estimates and forecasts in precipitation and flow forecast models. Operational forecasting with a convenient delivery time remains a major challenge in meteorology, showing primarily suspicions associated with rain [8-10]. Monitoring and illustrating fast-onset flood events are challenging because space and time are fast and violent, and they are also frequent. Careful observations and data collection from previous events can play a vital role in risk assessment [11]. Conventional estimation of maximum indirect discharges and highest rainfall records can be used to document these flash flood events in an area. Observation and forecasting of the next flash flood event requires an accurate estimate of precipitation in a small geographic area with a scale of less than 1 km and on short time scales. Assessing community perception of flash flood factors can also provide a deep understanding of events. Therefore, flash flood risk assessment with effective mitigation measures and forecast delivery time is essential for disaster risk reduction. Floods are globally a great natural hazard. Floods cause loss of property and lives and poor economic development. Although flooding cannot be prevented, its negative impacts could be greatly minimized through proper planning and effective preparedness. Vulnerability to floods could be reduced by accurate and timely predictions (forecasts and warnings) and by impact reduction measures. In the literature, there are numerous definitions of flash floods; it refers to highs and lows rather quickly, without prior warning, that are commonly associated with extreme rainfall or any natural / artificial dam failure in a relatively small area [12]. According to Kelsch et al. [13] can be activated at any catchment location, where there is less time for warning and defense, especially in the downstream area of the basin. Therefore, due to the existing knowledge and the meteorological instruments installed, they cannot reach the delivery time to activate the security measures [14]. Flash Flood Risk Assessment Reviews provide essential insight into flash flood concerns. Focusing on the highest rainfall and discharges mostly provides limited insight into the response to events. Most of the studies revealed that many countries carried out their own local experience, but reducing the impacts of flash floods is a major challenge for the authorities [15].

BRIEF HISTORY OF FLOODS

The rapid increase in human population, economic development and a huge burden on current services, environmental degradation and intensive use of land, such as human settlements, are spreading to risk areas [16,17]. With today's complexity in societies, became a serious concern to develop effective mitigation measures and preparedness for such risks [18]. Flash floods can surprise people in the midst of everyday activities and especially has serious effects on the public crossing flood-prone roads. Over the past decade, approximately 13,000 causalities from such type of events all over the world [19]. In recent decades, many differences have been found between social and natural scientists in the vulnerability assessment approach, but in recent years, some attempts have been made to close this gap [20-21]. Current trends in the social sciences to assess vulnerability are based on a set of socio-economic aspects that regulate competition in the social order to cope with pressure and prepare to change or recover from the effects of exposure to danger [22-23]. So far, in each field, susceptibility is defined in a mean that matches your field objective. There are some important extensions of susceptibility that are mainly associated with social and economic vulnerability, while in a different but related description. Disaster vulnerability research can focus on two main dimensions. The first is based on the inner side that focuses on people's coping skills, while the second focuses on people's exposure to stress [24-26]. Community-based study allocation can improve sudden risk reduction and also provide effective results in the early warning phase. Strong and advanced scientific methods are used in developed countries, such as North America and Western Europe, in addition to more recently social studies is also cooperating in reducing the risk of flash floods [27]. The contribution of community-based approaches and methods often brings a qualitative and quantitative form that focuses on participatory flash flood assessment, which includes all perceptions of social class, their participation, communication problems, and response. However, now the physical sciences and engineering recognize that their studies become very significant by involving the findings of the social sciences. Therefore, it plays an important role in collaborating and implementing all the findings in disaster preparedness, early warning, in the response and recovery phases as well. The mountainous areas of Europe, the US and Mediterranean regions are vulnerable to flash floods, and each year severely damage mountain habitat in the form of loss of life, property and infrastructure. Recently, in developed countries, researchers have called for increased attention to short wait time warnings also in mountainous regions [28]. Mountains (HKH) are the youngest mountains on earth and are still tectonically active, and the region faces various natural hazards each year such as landslides, earthquakes, debris flows, and flash floods. During the last decade, a series of flash floods occurred throughout the HKH Mountains, consequently hundreds of lives were lost with severe damage to human settlements, property, agriculture and infrastructure. It is considered powerful natural disasters throughout the HKH region. For this type of danger there is still no adequate consideration, mainly due to the lack of scientific research on sudden mountain flood processes [29-30].

URBAN AREAS MATERIALS AND METHODS

In the current study, the PRISMA methodology was used to review the literature related to flash floods. A total of 90 articles were retrieved using a Google academic database, after a brief evaluation almost 60 articles have been included to meet our goals. Some articles were omitted after the evaluation because they did not relate the objectives of the topic. To collect relevant articles, several keywords have been used in web browsing. The author used several keywords to obtain relevant articles; natural hazards, hydro-meteorological risks, flood types, flash flood, flash forecast, flash flood risk assessment, GIS and remote sensing for flash flood risk assessment and community-based flood risk reduction, climate change risks, Montana. The main journals included in this review article were from various journals such as, Journal of hydrology, Journal of geometrics and planning, Journal of Geographic Information System, Environmental hazards, Earth science of the environment, Natural hazards, Journal of analysis of risks, Mountain research and development, International Journal of Disaster Risk Science, Hydrological processes, Conference proceedings, Journal of Hydrometeorology, ICIMOD, reports and printed / electronic manuals.

FLASH FLOOD HAZARD ASSESSMENT

Flash floods are mainly caused by thunderstorms and heavy rains. They are very dangerous because of the maximum discharge received within six hours, events can occur in the small catchment area, and the steepness of the slope is also a major factor in destruction [31]. Risk assessment is an essential component of the risk management process. In the literature, many approaches and methods have been established to assess the risk of hazards. According to Colombo et al. [32], the Gouldby and Samuals flood risk assessment has four essential elements such as characterizing the area, assessing hazards, assessing vulnerability and assessing risk. According to ICIMOD, the flash flood hazard assessment has two essential parts, such as assigning the flash flood intensity and the probability level of the hazard scenario. To determine the incidence of flash floods, it is necessary to assess the risk and implement real forecasts with a useful delivery time. Flash floods are also called short fuse events. Hydrologically based studies address research and analysis of basin factors that affect flash floods, such as the geometric properties of the river basin and the flow of the water channel. GIS and satellite remote sensing approaches and methods offer a very decent display by combining, manipulating and analyzing the information for the assessment of possible flash risk extensions very quickly and efficiently [33]. In the flash flood hazard assessment, the assessment of various parameters of the river basin is very essential, such as the order of streams, the area of the basin, the density of drainage, the frequency of the stream, the bifurcation ratio , basin relief, roughness number and texture ratio. The drainage network of basins or sub-basins can be extracted using GIS and remote sensing technology. GIS and remote sensing can be used examine land exposure and vulnerability of society, such as hazard maps and monitoring of potentially dangerous areas [34].

URBAN FLOOD RISK

Floods are caused by natural factors or by a combination of natural and human factors. Risk is probability of loss and can be expressed as [34-35]:

Risk = Hazard x Vulnerability

Flood risk depends on flood quantities, such as depth, speed, and duration of the flood. Vulnerability can be defined as conditions determined by physical, social, economic, and environmental factors that increase a community's susceptibility to the impact of hazards **(Figs. 1)**. When flood waters physically invade people and infrastructure, then the vulnerability of people and infrastructure is decisive for the degree of damages. The impacts due to urban floods are significant in terms of economic losses, both direct and indirect. This is due to the high population density, the large impervious areas, the obstruction of the drainage systems, the high economic values of the properties and infrastructures, etc. The impacts of urban floods can be: physical, economic, social and environmental. Direct and indirect primary potential losses can be prevented through better land use planning, which also impacts potential secondary losses. The best emergency response mechanisms help reduce potential secondary losses. While in rural areas the damage caused by floods is mainly direct in terms of loss of agricultural production.

URBAN AREAS MANAGEMENT FOR INTEGRATED RISK OF FLOOD

A major cause of local flooding due to heavy rains in many cities is the blocking of drainage facilities with garbage. Cleaning and maintenance of drainage facilities are essential to their operational reliability. Storm-water retention measures are vital for urban flood mitigation as well as downstream flood prevention. Storm-water retention can be accomplished by building basins or ponds that temporarily store surface runoff and release it at a controlled rate. Reducing surface runoff can be achieved through other measures, such as increasing infiltration, evaporation from catchment areas, such as preserving unsealed and green spaces in the city. The main objective of urban flood risk management is to minimize human loss and economic damage. Flood risks cannot be completely avoided, therefore they must be managed. Consequently, flood management does not strive to eliminate the flood hazard but to mitigate it. The basic steps of risk management

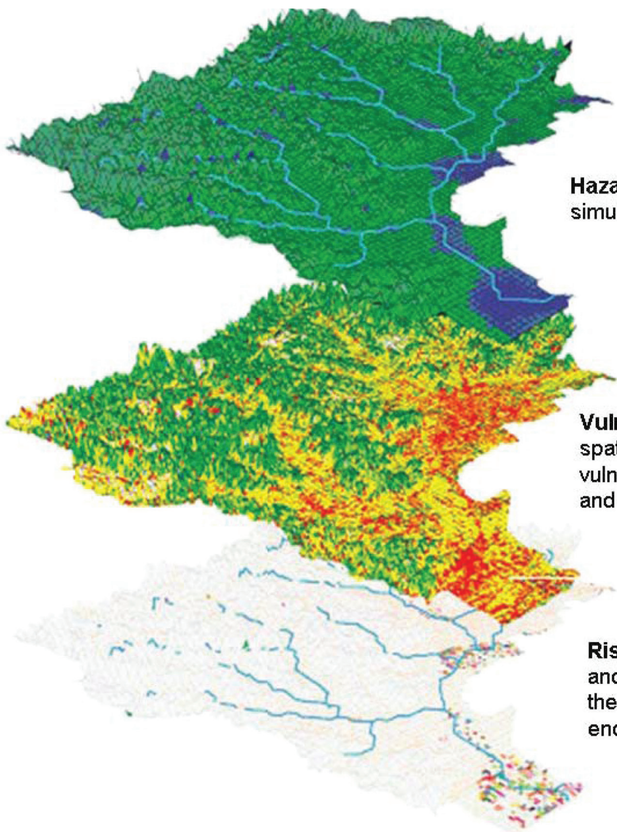


Fig. 1 Risk map with a geographical information system (GIS) [4]

(Fig. 1) are: risk assessment before and after implementing flood mitigation measures. To reduce the risk of floods, it is mandatory to evaluate the performance of the implemented measures and to re-evaluate the residual risks [36]. Risk assessment should be carried out in an integrated way, that is, identify all possible risks related to water. Therefore, the quantification of risks should start with the analysis of hydro-meteorological data and the hydraulic simulation of floods. A number of different scenarios should be modeled to account for the consequences of possible future changes in urban flooding. The results of such models provide information on the expected flood frequencies and magnitudes (extension, depth, duration and flow velocities), thus marking those areas and subjects that are exposed to floods. Risk maps can be developed that allow users to clearly identify risk areas. The advantage of such comprehensive risk assessments is that it is possible to compare the risk components in quantitative terms. Flood disaster management has to follow the stages of a management cycle **(Fig. 2)** [37], through preparedness, response and recovery / rehabilitation. Preparedness measures attempt to avoid potential risks that become disasters, both socially and individually. This involves mitigating flood risks to an acceptable and affordable level and, at the same time, developing activities to deal with residual risks. Fighting floods by people helps reduce flood damage during the impact of the flood [38-40]. Response measures are implemented during or immediately after a flood incident. They need advance planning and preparation to respond to the emergency situation. Urban flooding due to river bank flow in cities is not an isolated phenomenon, but is closely related to the general characteristics of the basin. The comprehensive and coordinated approach to flood risk management helps develop a common understanding of flood risk issues among all stakeholders at various administrative

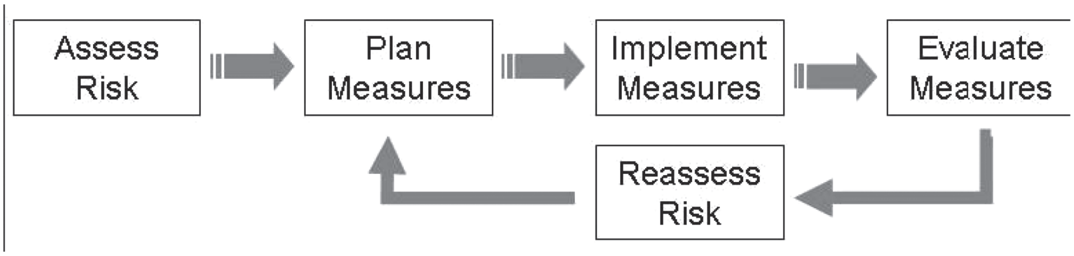


Fig. 2 Steps of risk management process [6]

levels. Modeling flood processes is required and should not be seen as a single task but as a continuous learning process.

CONCEPTUAL FRAMEWORK FOR URBAN FLOOD RISK MANAGEMENT

Three general concepts that provide the basic conceptual framework for urban flood risk management **(Fig. 2)** are: Integrated Flood Management; Total Water Cycle Management; and Land-use Planning [41]. Integrated water resources management (IWRM) embraces all its principles and at the same time incorporates risk management principles. It integrates land and water resources development in a river basin and aims at combining the efficient use of flood plains and the reduction of loss of life due to flooding. The IFM concept is based on the following principles: a) Employ a basin approach; b) Treat floods as part of the water cycle; c) Integrate land and water management; 4) Adopt a mix of strategies based on risk management approaches; enable cooperation between different agencies and ensure a participatory approach. Total Water Cycle Management (TWCM) [42] is applied in order to stress the linkages between storm water management on one hand and water supply and sanitation on the other. Thus there is a need to deal more explicitly with these overlapping parts between the three basic fields of urban water management namely: drinking water supply, sewage and waste water disposal and surface run-off disposal. Land use planning calls for a closer integration or coordination between flood management plans and land use plans. The regulations and bye-laws concerned with land use planning should consider the flood risks and local disaster management authorities.

URBAN FLASH FLOOD VULNERABILITY ASSESSMENT

The term vulnerability has served in the field of risk reduction, hazard and disaster management as well as in the areas of global environmental changes such as climate change [44]. Vulnerability relates to the degree of threat to a particular population or the capacity of a system, which can suffer and respond harmfully during the occurrence of any kind of hazardous event [45]. The concept of vulnerability assessment involves with various levels of risk, such as physical, social and economic aspects. Physical vulnerability is related with building, livelihood related infrastructures, agriculture, hospitals, roads, communications systems and many other functioning of a society. Social vulnerability includes women, children, mentally and physically handicapped persons, elderly persons, poor people, and refugees. Whereas, economic vulnerability assessment is related to risk of the hazard and its impact on economic assets and processes. It is also associated to direct and indirect damages such as damages to livelihood and social infrastructures, replacement expenditures and crop damages, loss of production and income disparities [46]. The frequency and magnitude of floods or flash floods are raised over the last few decades and the leading amount of deaths and property damage than any other natural hazard. Flash flood brings various types of vulnerabilities of societies which can be seen as economic, social, structural, agricultural and psychological. Vulnerability is based on various components. Internal side vulnerability refer to coping capacity of people or systems, while the external side of vulnerability focused on

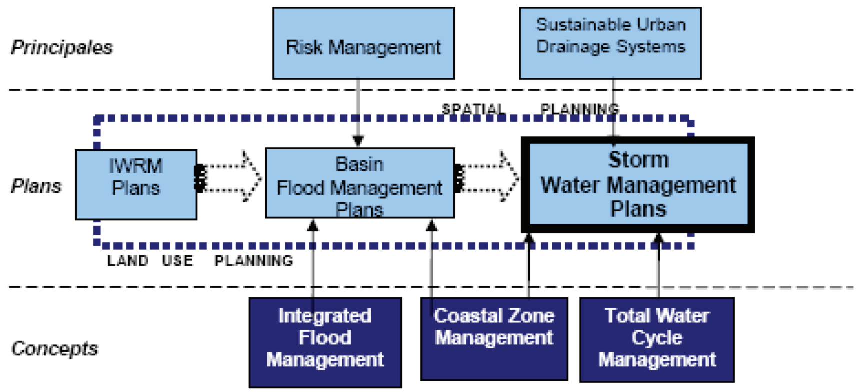


Fig. 3 Conceptual framework of urban flood risk management [6, 11]

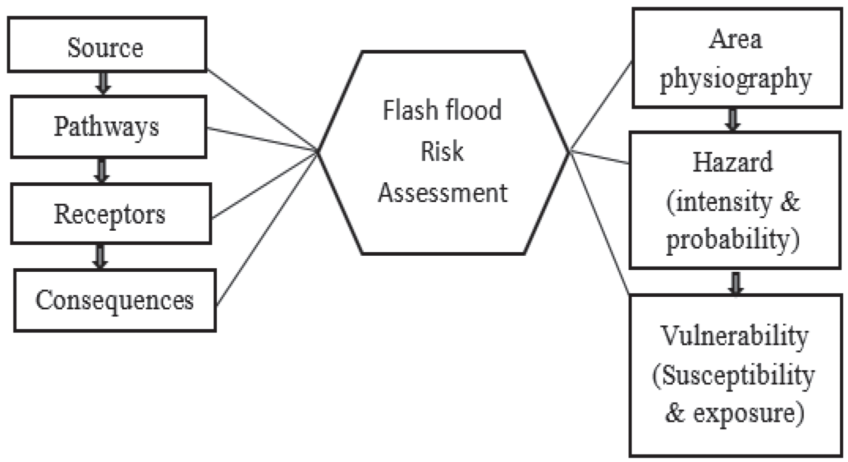


Fig. 4 Urban Flood risk analysis

external influence such exposure of people to the flash floods. Physical vulnerability can be valued by exposing elements at risk in a populated area, during the process of surface runoff or peak discharge of water, like flow depths, accumulation heights, flow velocities and pressures can damage exposed elements. The physical vulnerability can be measured by means of cost-effective approach through ratio analysis between loss and value of every individual element at risk [47].

FLASH FLOOD RISK ASSESSMENT AND MANAGEMENT

Risk assessment is a key measure in disaster management. Various approaches and methods have been developed and reported in the literature to assess threat hazard. The Source-Pathways-Receiver-Consequence (S-PR-C) model is very convenient to understand the concept of danger, vulnerability and risk as shown in **Fig. 4**. To assess risk there must be danger and vulnerability (source / initiator, track and receivers). Risk assessment has two main components, such as hazard (related to source and pathways) and vulnerability (related to receptor and consequences).

CONCLUSION

Urban flood risk depends on a combination of components that comprise hazard and vulnerability. It underlines the combination of natural and human factors that create flood risks. Flood management measures must be planned across administrative and sectoral boundaries. Institutionalized links between concerned authorities facilitate cooperative planning. Successful urban flood risk management is obtained if structural and non-structural measures are implemented. The implementation of multi-purpose measures allows municipalities to achieve multiple objectives, such as flood mitigation, water supply, space for recreational activities, groundwater recharge, and improvement of the urban environment. Monitoring and evaluation of the measures implemented allow the identification of best practices in specific circumstances and help to constantly improve flood risk management plans. Community involvement in flood risk assessment, as well as in planning and implementing risk management measures is key to the success of flood risk management plans. Flash flood is a hydrological event that develops within six hours of rain. It occurs within a short duration with relatively high precipitation, high flow, and rapid flooding in a dry area. Flash floods are also called short fuse events, due to some distinctive feature that the forecasting process is very different and challenging for this hazard than other types of hydro-meteorological hazards. In meteorology, forecasting flash floods and early warning of delivery time remain one of the most difficult tasks [48-50]. Flash floods frequently occur in small basins or on a small dry land, such areas often poorly calibrated or un-calibrated. Therefore, the quality of remote sensing data is critical to the flash flood forecast. Mountainous areas are very sensitive to flash floods. Every year, in the HKH regions, the danger of flash flooding has serious impacts on human society [51-53]. The main causes are thunderstorms, monsoon depression, rapid snow melt, and glacier lake flooding.

REFERENCES

1 National Oceanic and Atmospheric Administration (2010) Flash flood early warning system reference guide pp: 1-204.

2. World Meteorological Organization (2012) Management of flash flood. Integrated Flood Management Tools Series No.16.

3. Douvinet J, Delahaye D, Langlois P (2013) Measuring surface flow concentrations using a cellular automaton metric: a new way of detecting the potential impacts of flash floods in sedimentary context. Geomorphology, Relief, Environment, Processes 1: 27-46.

4. Creutin JD, Borga M (2013) Radar hydrology modifies the monitoring of flashfloodhazard. Hydrological Processes 17: 1453-1456.

5. Pratomo RA (2016) Sensitivity analysis of flash-flood modeling in Grenada, as a small island Caribbean states. The 5th International Symposium on Earth hazard and Disaster Mitigation. AIP ConfProc 1730, 070002-1-070002-10.

6. Tiwari KR, Sitaula BK, Bajracharya RM, Borresen T (2008) Runoff and soilloss responses to rainfall, land use, terracing and management practices in the Middle Mountains of Nepal. ActaAgriculturaeScandinavica, Section B-Soil and Plant Sciences, pp: 1-11.

7. Pedzisai E (2010) Rainfall-runoff modelling for flash floods in Coung Think Catchment: Yen Bai Province: International Institute for Geo-information Science and Earth Observation, Netherlands.

8. German U, Joss J (2003) Operational measurement of precipitation in mountainous terrain. In: Meischner P (ed.) Weather Radar: Principles and Advanced Applications, Springer Verlag, pp: 52-76.

9. Richard GA, Masahiro T, Anthonym M, Ricardo T (2005) Satellite-based evapotranspiration by energy balance for Western States water management. In Proceedings of 2005 World Water and Environmental Resources Congress, Anchorage, Alaska, pp: 15-19.

10. Hapurachchi HAP, Wang QJ, Pagano TC (2011) A review of advances in flash forecasting. Hydrological Processes 25: 2771-2784.

11. Borga M, Gaume E, Creutin JD, Marchi L (2008) Surveying flash floods: gauging the ungauged extremes. Hydrol Process 1-3.

12. American Meteorological Society (2000) Glossary of Meteorology, Glickman TS (ed.) (2ndedn), Boston MA-USA.

13. Kelsch M, Lanza L, Caporali E (2000) Hydrometeorology of flash floods, NATO

Advanced Study Institute: Coping with Flash Floods, Grunfest E, Handmer J (ed.) Kluuwer Press, The Netherlands.

14. ACTIF (2004) Some Research needs for River flood forecasting in FP6, EVK1- CT-2002-80014.
15. Scolobig A, De Marchi B, Borga M (2012) Themissing link between flood risk awareness and preparedness: findings from case studies in an Alpine region. Nat Hazards 63: 499-520.
16. Ruin I, Gaillard JC, Lutoff C (2007) How to get there? Assessing motorists' flash flood risk perception on daily itineraries. Environmental Hazards 7: 235-244.
17. Pradhan B, Shafie M (2009) Flood hazard assessment for cloud prone rainy areas in a typical tropical environment. Dis Adv 2: 7-15.
18. Comfort LK (1999) The impact of information technology upon disaster mitigation and management. In: Proceedings of the Second Conference on the Applications of Remote Sensing and GIS for Disaster Management, Washington.
19. CEOS (2003) The use of earth observing satellites for hazard support: assessments and scenarios. Final report of the CEOS Disaster Management Support Group (DMSG).
20. Jonkman S, Kelman I (2005) An analysis of causes and circumstances of flood disaster deaths. Disasters 29: 75-97.
21. Menoni S, Molinari D, Parker D, Ballio F, Tapsell S (2012) Assessing multifaceted vulnerability and resilience in order to design risk-mitigationstrategies. Nat Hazards 64: 2057-2082.
22. Wisner B (2004) Assessment of capability and vulnerability. In: Bankoff G, Frerks G, Hilhorst D (eds.) Mapping vulnerability. Disasters, development and people.Earthscan, London pp: 183-193.
23. Birkmann J (2006) Measuring vulnerability to promote disaster-resilient societies: conceptual frameworks and definitions. In: Birkmann J (ed.) Measuring vulnerability to natural hazards. United Nations University Press, Tokyo, pp: 9-54.
24. Fuchs S (2009) Susceptibility versus resilience to mountain hazards in Austria - Paradigms of vulnerability revisited. Nat Hazards Earth SystSci 9: 337-352.
25. Karagiorgos K, Thaler T, Hubl J, Maris F, Fuchs S (2016) Multi-vulnerability analysis for flash flood risk management. Nat Hazards 82: 63-87.
26. Karagiorgos K, Heiser M, Thaler T, Hubl J, Fuchs S (2016) Micro-sized enterprises: vulnerability to flash floods. Nat Hazards 84: 1091-1107.
27. De Marchi B (2007) Flood risk management with the public. In: Proceedings of the European Symposium on Flood Risk Management Research, 6-7 February, Dresden, Germany pp: 153-154.
28. Kortenhaus A, Samuels PG (2004) Flood site-European research on flood risk management. Flood site Paper, Contract no: GOCE-CT-2004-505520, Hydraulics Research Ltd., Wallingford, Oxfordshire, UK.
29. Shrestha AB (2008) Resource Manual on Flash Flood Risk Management- Module 2: Non-structural Measures. Kathmandu, ICIMOD.
30. Shrestha AB, Ezee GC, Adhikary RP, Rai SK (2012) Resource Manual on Flash Flood Risk Management - Module 3: Non-structural Measures. Kathmandu ICIMOD.
31. Khan AN, Rahman A (2005) An Assessment of Flood Hazard Causes for Efficient Flood plain Management: A Case of Neelum-Jhelum Valley, Muzaffarabad, AJK. Pakistan Geographical Review 60: 42-53.
32. Colombo AG, Hevas J, Arllam ALV (2002) Guidelines on Flash Floods Prevention and Mitigations. Ipsra (Italy): NEIDES.
33. Kumar R, Kumar S, Lohani AK, Nema RK, Singh RD (2000) Evaluation of geomorphological characteristics of a catchment using GIS. GIS India 9: 13-17.
34. Chen J, Hill AA, Urbano LD (2009) A GIS-based model for urban flood inundation. J Hydrol 373:184-192.
35. SrikanthaHerath, Geographical information systems in disaster reduction, Institute of Industrial Science, The University of Tokyo, Japan; 2001.
36. ingsanchali T, Keokhumcheng Y. Flood damage functions for surrounding area of Second Bangkok International Airport, Proceedings, International Symposium on Urban Safety of Mega Cities in Asia, Phuket, Thailand, November, 2006; p. 291-300.

37. WMO/GWP. Urban flood risk management, a tool for integrated flood management, Associated Programme on Flood Management, World Meteorological Organization; 2008.

38. Tingsanchali T. Flood disaster and risk management, Invited Paper, Proceedings, 1st EIT International conference on water resources engineering, Petchaburi, Thailand, August, 2011; p. 15-24.

39. UNESCO. Fighting floods in cities; Project training material for disaster reduction; Report, Delft, Holland; 1995.

40. ESCAP/UNDP. Manual and guidelines for comprehensive flood loss prevention and management.UN-ESCAP, Bangkok, Thailand; 1991, 92p.

41. Moll R. Co-operation within Europe on flood management and spatial planning. In: Szöllösi-Nagy, A. and Zevenbergen, C. [Eds.]. Urban Flood Management.A.A. Balkema Publishers; 2005.

42. APFM. Integrated flood management – Concept paper. Associated Programme on Flood Management, WMO Series No. 1047, Geneva, Switzerland; 2009, 27p.

43. Chanan A, Woods, P. Managing the Water Cycle in Sydney Metropolitan: Local Governments Do Matter! In: Khan, S.J., Schäfer, A.I. and Muston, M.H. [Eds.]. Integrated concepts in water recycling; 2005.

44. APFM. Land use planning for IFM. In Flood management tools series. Associated Programme on Flood Management, WMO, Geneva, Switzerland; 2008.

45. UN-HABITAT. Tools to support participatory urban decision making, United Nations Centre for Human Settlements (Habitat), Nairobi, Kenya; 2001, 150p.

46. Christian K (2010) The dynamics of vulnerability. Some preliminary thoughts about the occurrence of radical surprises and a case study on the 2002 flood (Germany). Natural Hazards 55: 671-688.

47. Fothergill A, Peek LA (2004) Poverty and Disasters in the United States: A Review of Recent Sociological Findings. Natural Hazards 32: 89-110.

48. Smith K, Petley DN (2009) Environmental hazard, accessing risk and reducing disaster, (5thedn), British Library, UK.

49. Singh P, Gupta A, Singh M (2014) Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques. Egypt J Remote Sens Space Sci 17: 111-121.

50. WMO (1999) Comprehensive risk assessment for natural hazards. Technical document, no. 955. World Meteorological Organization.

51. UNISDR-United Nations International Strategy for Structural and non-structural measures (2009) Prevention Web, Serving the information needs of the disaster reduction community, Geneva.

52. Yatheendradas S, Wagener T, Gupta H, Unkrich C, Goodrich D, et al. (2008)Understanding uncertainty in distributed flash flood forecasting for semiarid regions, Water Resources Research 44: 5-19.

53. Zoccatelli D, Borga M, Zanon F, Antonescu B, Stancalie G (2010) Which rainfall spatial information for flash flood response modelling? A numerical investigation based on data from the Carpathian range, Romania. Journal of Hydrology 394: 148-161.

Advance Planning and Flood Preparedness Measures in Mahanadi Delta Basin

Jyotirmaya Behera
Department of Water Resources, Model Studies & Research Division, Burla, Odisha
✉ *jmbehera67@gmail.com*

ABSTRACT

This paper recalls the various issues of flood and flood control measures to be adopted for advance planning and preparedness in delta region by creating a technical and organizational framework for reducing flood damage. The idea is to introduce a sustainable approach that will prepare the state for potential problems in long term with provision for climate change and other phenomena. The paper highlights issues on how we can give rivers the room they need to handle a larger discharge of water. The Government should remain committed to researching the most advances in flood control.

Keywords : Flood, Planning, Climate, Flood control, Embankments or Dikes, Flood barrier, Flood-proofing, etc.

INTRODUCTION

Floods are becoming more and more frequent as the world's climate changes and water levels rise. Preliminary research suggests that rising global temperatures have already led to an increase in extreme weather patterns in the region including cyclones, typhoons, droughts, and floods [1, 2]. Uncontrolled urbanization in recent decades has exposed many inhabited areas along the river to the risk of flooding during such high flows. It is estimated that in 2030, approximately 75% of the world's population will live in delta regions threatened by floods [3]. Floods are as much a part of life in India as are the monsoons [4]. The floods in Kerala during the year 2018 due to unprecedented rainfall, force the authorities to open the gates of all major dams, resulting in the worst flooding in 100 years, with 12 out of 14 districts affected [5]. In the history of Odisha severe floods caused widespread devastation [6]. It is true that rivers have been trained, but floods have never been controlled [7, 8]. Each year, plans are made and washed away, rescue is conducted and experiences drowned. The loss of life and properties has been increasing every year. However, for the early warning systems to be effective, continuous and collaborative efforts are required, rather than a one-time action [5]. In the last few years, the number of incidents and scale of floods has sharply increased and experts believe that effective and structured flood management is urgently required to handle this challenge [9-12].

Improper or inadequate river embankments contribute flood with consequent increase in the cost of lives and property. Inadequate maintenance has various causes, but institutional failure is the only explanation for its wide extent. At the heart of this failure is the absence of public accountability. Such changes require today's engineers to come up with ever more complex state policies that offer sustainable flood management solutions. The present day engineer should meet this objective by creating a technical and organisational framework for reducing flood damage, focusing on to upgrade the existing flood forecasting system and to improve long term flood management planning. This paper describes various issues of flood management and proposed measures to be adopted for advance planning and preparedness in delta region.

CLIMATE AND FLOOD

Odisha is situated along the eastern coast of India, bordering the Bay of Bengal, has a vast coastline. The coastal areas are highly vulnerable to such natural hazards as cyclones, heavy rain, high winds, and flooding. The river system passes through tropical zone and is subject to cyclonic storm and seasonal rainfall. The cyclonic storms in Odisha usually originate in the Bay of Bengal and travel generally in a north western direction opposite to the flow of River Mahanadi. They occur primarily during the monsoon season (June-Sept) and also occur during pre-monsoon and post-monsoon seasons, the cyclones in the latter season being more severe. A tropical cyclone is an intense low-pressure area associated with high winds, heavy rains and storm surges in coastal areas. The storm surge is most dangerous phenomenon associated with any cyclone, and it is usually responsible for large-scale loss of life. The wind speeds of up to 200 km/hr, rainfall of 50 cm/day for several consecutive days, and storm surges of up to 5-6 m are not uncommon. Heavy rainfall first occurs in delta and then spreads inlands covering about several days. The maximum precipitation is observed in the months of July and August, which causes flood if heavy rainfall continues for about a week, in the catchments.

The floods in the major River Mahanadi are divided into two distinct reaches such as upper Mahanadi basin and lower Mahanadi basin (known as Mahanadi delta). It is observed that the catchments of upper Mahanadi basin (82,430 sqkm) and that of downstream (50,360 sqkm) which can cause a flood at head of delta. The River Mahanadi in the state passes through Sambalpur and then it follows further down course up to Sonepur where it meets with its largest tributary Tel and then turns to east and flows up to head of delta at Naraj about 322 kms down stream of Hirakud Dam and thereafter it bifurcates into several branches (see **Fig. 1**).

The main branches are Mahanadi and Kathajori at Naraj. The River Mahanadi and its other branches are discharged directly into the sea (area called delta I stage). But at Naraj, River Kathajori divides into several sub branches (area called delta II stage). These are Birupa, Kuakhai, Kusabhadra, Bhargavi, Daya Sarua Devi, Chitropola, Luna karandia, Paika and Badagenguti etc. However, Daya and Bhargavi fall into Chilika Lake and other branches fall into Bay of Bengal (sea). In between two branches there are also several drainage channels, which are Gobari, Alaka, Baghuni, Kula, Prachi, Dhanua, Nuna etc. These drainage channels are tidal in nature near the Bay of Bengal. **Fig. 2** depicts the percentage of discharge at the head of delta I and delta II areas which are 40% and 60% approximately. One is only concerned about 60% flood in delta II area as this caused loss of lives and damage of properties.

Presently, the delta embankments are safe for approximately 9 lakhs cusecs at head of delta [13]. They can however pass a flashy flood of

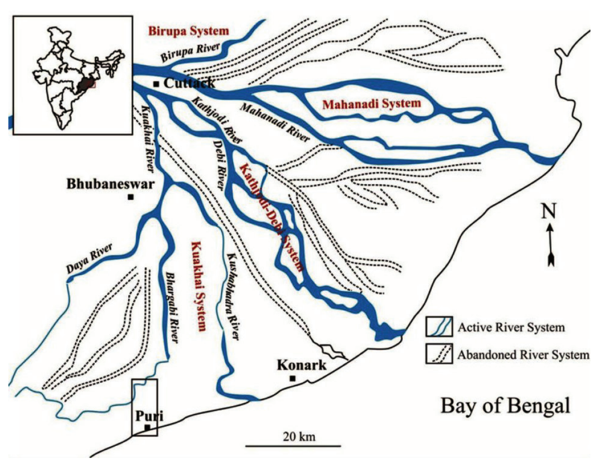


Fig. 1 Map of Mahanadi delta in Odisha

9.5 to 10 lakhs cusecs if the duration is not too long. During high floods they are subject to over topping, erosion of river side slope, cavity in all banks, infiltration from the foundation, infiltration from the dike and slipping on the landside slope, leaks as a result of holes dug by rats, crabs, white ants or from the rotten roots and cracks due to shrinkage of soil, human action, other miscellaneous causes like improper supervision and paucity of flood materials and flood fighting labours. **Fig. 3** shows discharge recorded at the head of delta in different years of flood. One can easily see the average discharge of 12.85 lakh cusecs if we considered all the years. This shows clearly our embankment system is inadequate to accommodate such high discharge in peak flood time. **Fig. 4** indicates types of different embankments and their lengths in delta stage II. Maintenance of all embankments in delta stage is a big challenge due to paucity of funds. **Table 1** shows the district wise embankment lengths in delta stage II, which indicates Puri district has maximum embankment lengths compared to other districts.

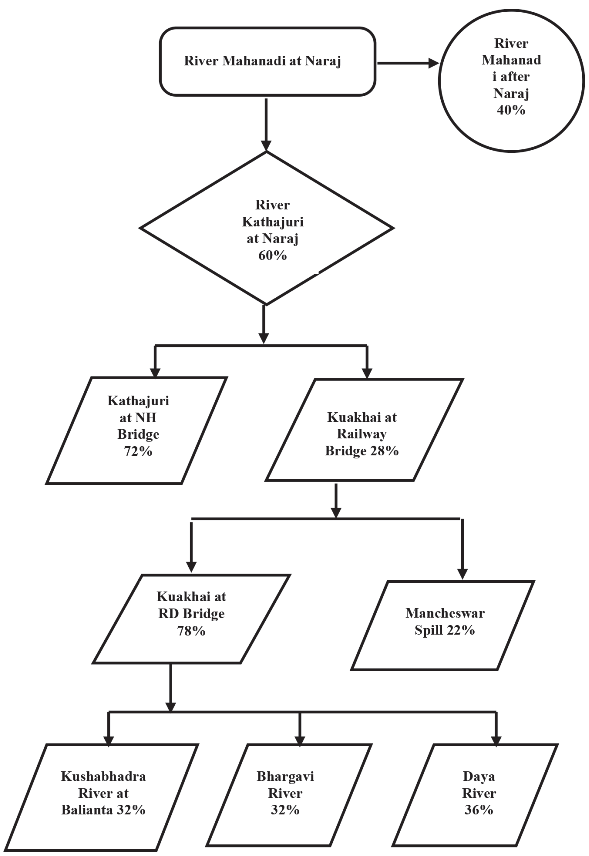


Fig. 1 Typical flow chart of flood water passing at the head of delta at Naraj

Out of total discharge at the head of delta, contribution due to base flow is about 3 lakhs cusecs considering the lower catchments independently and the contribution due to Hirakud Dam is of about 8 lakhs cusecs [7, 8]. Though there is control over the release from Hirakud dam reservoir but in fact the release from the reservoir during August and September is dictated by the existing or expected flood situation. It can be argued that Hirakud dam is incapable of moderating a flood of about 16 lakhs cusecs [8]. Once the reservoir is full and another rainstorm is approaching fast, it will not be possible to hold water in reservoir.

To river engineers floods mean measurements of stage and volumes under the worst possible conditions; the study of ways to reduce damages and the design construction and operation of

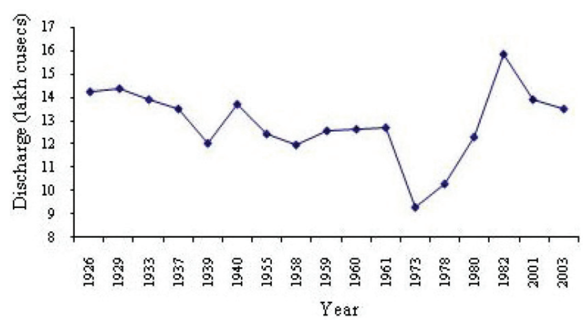


Fig. 3 Discharge observation data at the head of delta

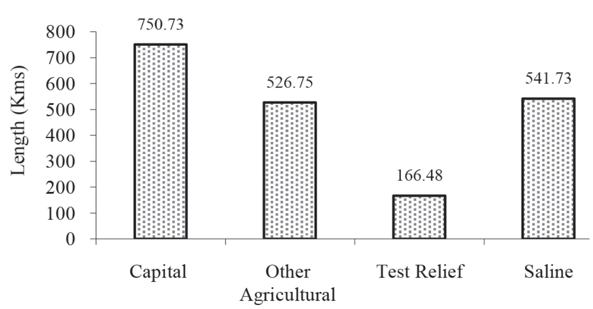


Fig. 4 Types of embankments and their lengths in delta stage II

Table 1 Types of embankment in delta stage II district wise

Types of Embankments	Cuttack District (km)	Jagatsinghpur District (km)	Khurda District (km)	Puri District (km)	Nayagarh District (km)
Capital	147.63	8.00	160.60	416.00	18.50
Agricultural	58.93	2.40	68.40	203.20	193.82
Test Relief	1.40	-	4.00	151.58	9.50
Saline	-	-	69.82	471.91	-

extensive embankments levels, flood walls, channels, dams and reservoirs – protective works which must not fail but which must function effectively to the limits of their designed capacity.

FLOOD MANAGEMENT

The flood management is planning and implementing long-term measures to prevent flooding and/ or alleviate the immediate effects of flooding. Managing actual floods caused by excessive rainfall and the impending inundation of inhabited zones is a challenge to flood managements. With respect to managing actual floods, the first is to observe flood levels and forecast how water levels are likely to develop over time; the second is to control the situation once flooding occurs and a state of emergency exists, something that requires civil protection measures including requisition and acquisition of land for flood works.

Flood Planning

Modern planning methods which require a logical sequence analysing cause and effects, setting objectives, contemplating a wide range of possible measures and preparing action plans with priorities based on cost effectiveness. The action plan will address issues related to flood management in terms of action, time, responsibilities and resources [11, 14, 15].

Public participation in preparing such plans is indispensable and will be encouraged by means of demonstration projects implemented at local level. The demonstration projects will moreover, show the impact of alternative measures such as the use of polders as retention reservoirs and the ecological restoration of floodplains. In general the public is not well informed about the causes and effects of flooding, and the emergency procedures to be followed during actual floods are unclear and not properly explained. Engineers should attempt to correct this by preparing and distributing printed materials, holding public meetings and seminars and developing a website.

Flood Control Measures

The flood control measures are to draw up measures that minimize the flood risk on one hand and the damage due to flooding on the other. The integrated flood action plan consists of emergency measures, short-term measures and long term measures between different periods and between the nature of the various measures action plans could be structural, non-structural and institutional. To launch a joint operation in which the local authorities will co-operate closely on flood management within the delta region.

EMERGENCY FLOOD CONTROL MEASURES

Special attention should be given for guarding over the river embankments at critical vulnerable points.

The measures should guard all weak and vulnerable points scrupulously and supervises the flood protective works in order to prevent breaches. It is much cheaper to prevent a breach occurred. Following are the emergency flood control measures, which are currently in practice by the authorities:

a) The engineers are responsible for protecting the embankment from the flood damages by taking protective measures such as sand bagging with bamboo or bullah pilling for which sand and gunny bags should be procured during pre-monsoon at vulnerable points. If necessary, bamboos should be stacked in nearby areas of the weak and vulnerable points so that it can be carried quickly in case of exigency.

b) Flood watching of the embankments should start when the floodwater is at 0.5 m below the danger level in case of coastal rivers and 1.0 m below in case of rivers located in hilly areas. The watching should continue till the river falls below warning level. The engineers should inspect for piping, seepage, and erosion in their respective jurisdiction of the section.

c) Night guarding with spotlight should be started. During daytime one labourer and night time one spotlight with two labourers for every 2 kms should be arranged. The officers in charge of flood duty should keep close contact with local people and cooperation can be availed during alarming condition. All the impending breaches due to over topping and piping can be attended timely for flood fighting. List out the location where boats are required and avail motorboats in case of exigency.

d) Use of wireless either from local police or Central Water Commission (CWC) wireless network for receiving and transmitting the flood message, situation of flood etc., during flood season. CWC has got a network of wireless transmitting system, which also functions during flood season. The message to be transmitted should be brief and digestive.

Flood Damages

Apart from reporting of flood situation the damages caused by floods should be reported promptly after the flood recedes. Location should be normally identified and intimated in the proper format indicating block, district and constituency, cause of damage, amount required for temporary/ permanent restoration.

SHORT-TERM FLOOD CONTROL MEASURES

Short-term flood control measures are action plans for pre-flood arrangement which are explained below:

- Procurement of required flood fighting materials such as empty gunny/polythene bags, sand, bamboo etc.
- Dowel bund protection at the locations having less free board may be provided corresponding to 14 lakhs cusecs of floodwater at Mundali Barrage site.
- Repair of all sluices and sluice gates.
- Raising and strengthening of embankments and bank protection works as per specifications.
- Turfing to the newly constructed embankments may be done to check rain cut in the monsoon period.

Maintenance of River Gauges and Flood Discharge

Maintenance of river gauges is essential for taking readings. So, marking of gauge readings must be painted periodically and gauge site is required to be approachable by any vehicle. Gauge readings and discharge of river should be recorded in 6 hrs intervals during the monsoon period and in 1 hr interval during high flood. Flood discharge should be intimated to flood control room by telephone. Flood messages from the field officers should be clearly worded identifying the location, gauge report, flood situation and report regarding conditions of embankments. Discharge shall be recorded by current meter method and must be cross checked with stage discharge curve if available. Unfortunately, water levels and current speed are measured manually. In the event of an impending flood, it is up to the individuals who read the instruments to keep a close eye on the situation. It is worthwhile to install fully computerized measuring instruments at a number of these stations.

Vulnerable Points in Embankments

Vulnerable points in embankments shall be checked thoroughly and the criteria for checking the embankments is that at a specified reach or point if free board is less than 1.2 m in case of capital embankment, other agricultural embankment and saline embankment respectively and 0.9 m in case of test relief embankments. Besides, other vulnerable points should be considered which are as follows:

- Where the embankments are below the standard section.
- In a bend of the river where the velocity of flood directly hits the embankments.
- Where the embankment is susceptible to wave action of tides in case of sea facing embankments.
- Where the riverside berm is narrow and near to the deep channel of the river and tendency of scour.
- Where the houses are built on embankments. It is a potential danger point for breach due to possible existence of rat holes, initiating piping.
- Breach closing works and new embankments not tested even in one flood.
- Natural gaps in embankments, flush escapes at natural surface level. Earlier breach sites which are restored full designated level and section and tested during last flood. Sections with sandy soil with proper slope as per standard sections are considered to be stable.

Drainage Clearance

There are several reasons for obstruction of free flow of water at several places. These obstructions are either in shape of residual of fair weather road or in shape of cross bunds across drainage constructed by cultivator's in an unauthorized manner. Approaches to fair weather road acting as spur which restricts the flow of water. The other reasons are growth of hypomia and water hythensia in the drainage water. Proper care should be taken for removal of such obstructions before onset of monsoons.

LONG-TERM FLOOD CONTROL MEASURES

The most important factor that has contributed to flooding is over development in flood plain areas, which has intensified in recent years. This development has blunted nature's abilities to contain flooding, such as allowing rivers to flow more naturally and thereby enable them to better absorb high water levels. Besides, the draining of marshlands - mostly for agricultural purposes – results in harder, less porous ground. The straightening of rivers and their often artificial banks to reclaim land for agricultural banks to reclaim land for agricultural or construction gives them less capacity to absorb water. In this context, long-term flood control measures should be structural, non-structural and institutional. Various long-term measures are discussed in the succeeding sections.

Construction of Embankments or Dikes

The effect of dikes parallel to the course of the river on the silt flow is to increase the velocity of the flood flow as compared with an undiked river. It has been seen that the riverbed has been raised due to silting of the riverbed. Past studies have shown the rise of riverbed for Mahanadai, Kathajori, and Kuakhia [6, 8]. The dikes should have been strengthened for undivided flood of 12 lakhs cusecs at delta head and another 2 lakhs cusecs by way of encroachment into the free board. But the present dikes fall short of the said standard. The River Kathajori and its sub-branches must have master dikes on both sides of it up to its mouth as this is now taking the major share of the Mahanadi floods. However, raising the height of its dikes is no longer the first or only option to the event of flooding. Innovations are happening in the USA with dikes and other large structures that are wired with nervous systems of electronic sensors that sound alarms if a weakening dike threatens to open a breach or failures, giving crews time to make emergency repairs [1].

Any dike construction project involves an environmental impact assessment (EIA), fund allocation plans and detailed design calculations. The EIA assesses the dike's effects on the river, the groundwater, nature, traffic, soil, pollution, archaeology, cultural heritage, transportation in river, and special quality [16]. The height by which the dikes along the river branches will be raised is based on low-probability, extreme discharge calculations obtained by extrapolating historical data. The calculations identify the amount of water that the dikes must be able to withstand without it breaking through to the areas they are protecting.

Improving Channel Capacities of the River

The main issue is to find as much additional water retention capacity as possible by deepening the riverbed. River becomes inefficient in discharging its flood flow, which gets further aggravated by sea tide. Riverbed dredging can be considered to improve the flow characteristics. But sometimes funds and infrastructural scarcity prevent the government from undertaking ambitious plan to dredging riverbeds at one go. Diversion of a part of the river discharge either to a natural basin or to a lake or to the sea by a different channel, escapes in the embankment or dikes will also come under this category.

Construction of Storage Reservoirs

At least one or more storage reservoir across the main river and or across its tributaries of sufficient flood storage capacity is needed on the Mahandi somewhere between Naraj and Khairmala to control the floods of Mahanadi to a desirable extent at the head of delta. This point however is subject to conformation by detailed study and quantitative detailing. In all the major tributaries of Mahanadi multipurpose reservoirs may be constructed with special flood control space reserved for it.

Land Management and Maintaining Ecological Balance

It is found that effect of vegetative cover and land management on flood runoff have substantial effect which can reduce delay the flood flows by about 30 to 40%. Deforestation should be stopped in the catchments and wide scale afforestation and soil conservation measure should be taken up. The land management should also be made in this respect to contribute to the control of run off.

Early Warning

A flexible early warning system for real-time flood forecasting is essential. It can be linked to a meteorological forecast module that predicts the development, strength and tracks of a depression, a hurricane, a typhoon or a tropical cyclone. Based on these data, it is possible to model a storm surge and inundation without delay. The system can accommodate real-time observation data to enhance accuracy. It can be linked to other modules, such as rainfall or river models. The prediction can also be updated every 2 to 24 hrs, depending on data availability. In addition to models, the system contains a Geographical Information System (GIS) based decision support system for analysing input/output data from the models and integrating the model's output automatically with spatial data information taken from a database. The spatial database may contain data on the population, the location of shelters, communication channels and social and economic characteristics of the population in the area to be modeled. The system integrates the model's output with the spatial data and produces information in the form of concise reports and maps that can be easily interpreted, This information allows officials dealing with evacuation and relief operations and taking appropriate decisions. The aim is to prevent loss of life and to increase the efficiency of disaster management by integrating information.

Flood warning system offers distinct benefits which include minimum impact of an impending flood, greater likelihood of saving human lives and protecting investments, policy advice for short term relief operations and greater potential use of technology in disaster and hazard management. Effective and timely forecast should be done so that warning is received in time about the time of quantity of the incoming floods. This will greatly help in keeping oneself prepared for the flood. It will also make the flood fighting appropriate and easier.

Natural Flood Defence

Re-establishing of flood plains is an interesting offer, which reduces the risk of flooding while also allowing for the development of natural habitats. Such flood plains will then become "natural flood defences". The construction of effective natural flood defences that can also serve as valuable wetland ecosystems requires a multidisciplinary approach involving biogeochemistry, hydrology, sociology and economics, and ecology. Each of these fields must be investigated in detail. There is a knowledge gap when it comes to the interfaces between them.

The aim is to create more room along the major rivers so that higher discharges will flow safely to the sea without causing peak water levels in the rivers to rise (See **Fig. 5** for flood plain). Of course it is true that it is impossible to restore natural flood plains completely in many densely populated areas. Flood plain restoration will therefore frequently mean controlled inundation areas surrounded by dikes. The question is whether and how nature can benefit. Research has shown in Germany and Belgium that such projects are succeeded as they pay due attention to natural water dynamics [16]. These projects show that nature development and flood control can be combined, even when space is scarce. The road to success involves preparing nature for inundation. The key factors are year-round natural water level fluctuations, maintaining a good soil moisture level and natural flooding patterns: in short, natural dynamics. The design of any natural flood defense must begin with natural dynamics.

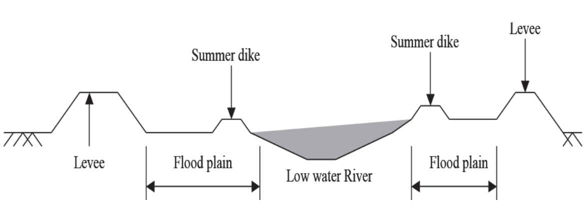


Fig. 5 A typical example of flood plain

Geophysical Approach

Construction and maintenance of reliable flood defenses such as dikes and dams therefore deserve the attention of engineers worldwide. The safety provided by these structures largely depends on soil and subsoil conditions, which are frequently unknown. Geographical data required for the risk assessment of flood defenses requires efficient management of surveying methods. Flood defenses are designed to safely withstand hydraulic loads induced by high water levels and wave impacts in rivers or at sea. The level of safety provided depends on geo-technical behaviour and local soil and subsoil conditions. Several geo-technical mechanisms can cause dikes to fail in their water-retaining function. The most important mechanisms include overflow by extremely high water levels and wave over topping, seepage of water due to weakness within the structure, and under-seepage, where water flows through naturally porous soil material underneath the dike, eroding its foundation base.

Actual topographic data and information about local soil and subsoil conditions are required to perform these safety assessments. Unfortunately, design calculations and records of material types used to construct defenses are often unavailable, particularly if the structures were built a long-time ago. Furthermore, the soil stratification and soil and subsoil conditions can show large spatial variations. Data must be collected continuously over large areas in order to measure all the local changes in conditions and to ensure that small features, which can still cause instability, are not missed. Necessary data up to depths of 30 m below the earth's surface is needed to be obtained by using airborne surveying techniques by flying over a river embankment or dikes in a helicopter equipped with laser scanners and magnetic induction meters. The electromagnetic (EM) mapping data obtained by multi frequency

EM induction meters are compiled into ground conductivity data, laterally and vertically and correlated to the soil material through density and moisture content measures. Three-dimensional maps and sections of conductivity distribution in the subsurface help to detect buried man-made objects such as abandoned structures and drains, or natural paleochannels. The later can be identified as potential hazards for under-seepage, because the river sediments within the channel are usually more porous than the surrounding floodplain clays, increasing the risk of under-seepage.

The fast lager imaging and mapping airborne platform provides high density and accurate terrain elevation data. The system determines X, Y, and Z co-ordinates of terrain points using laser scanners. By flying over a section of river embankment, it is possible to determine the elevation to an absolute accuracy of 5 cm. A GIS process the results and the actual elevations of the defenses are compared with the prevailing standards. Sections with insufficient height or subjected to soil settlement are easily identified.

The analysis of airborne geophysics and mapping data makes it easy to identify high-risk levee sections. With the aid of a spatial modelling system, for example a GIS, all data is visualised in geographical cross and longitudinal sections, providing engineers with a detailed understanding of potential geo-technical failure mechanisms. The results of the integrated data acquisition process provide water management authorities with tools to priorities high-risk sections to take appropriate and preventive measures.

Flood Barrier

The flood barrier is to offer the river engineers protection against flooding. When critical water levels on the river forecast, the flexible structures are put into position. Preparing an operational flood barrier is a complex process that involves many different components and people. Such barrier is successfully operated in the Dutch town of Kampen, which provided modern flood barrier without affecting its cultural heritage [16]. Closures take place in different phases. Each phase is indicated by a specific forecast water level and involves specific actions, for example a public warning, the mobilization of teams, mounting guard at structure to be closed, or closing the structure. Structures with the lowest thresholds or the longest operating times are closed first using the state-of-the-art engineering. A example of flood barrier in St Petersburg of Russia which consists of 23 km of dams, 6 sluice complexes, and a main and secondary navigation opening. London has built floodgates on the Thames River. Venice is doing the same on the Adriatic. Japan is erecting super levees. Even Bangladesh has built concrete shelters on stilts as emergency havens for flood victims.

River Management

The river management study involves researching the hydraulic effects of the intended rivers measures. A two-dimensional hydraulic modelling system may be applied to our river system. The objective is flood defense. The model results are used to assess the effects of the measures on water levels and flow velocities under different conditions like daily, bank full, design and extreme conditions.

Flood poofing

Selective flood proofing can be considered and often more economically than other forms of floodplain management. Flood proofing is the design of buildings that can resist floods; helps to reduce potential damage to structures built in floodplains. Existing structures, located in fringe flood zones or in areas where defense works such as embankments, may not be adequate and can be protected by changes in their design. If flood control works are not economically feasible, the flood proofing of new buildings may be an alternative form of flood protection. In the Netherlands houses are designed to float during flooding and houses perched above the water on supports are new concepts of flood-proofing technology as pressure is being exerted to use underdeveloped land on the fringes of defined flood zones.

LACK OF SKILLED MANPOWER

The level of maintenance that could be carried out would still be limited because of inefficiencies in maintenance organisations. Our departments have large labour forces, which are unproductive because of poor management, lack of training, lack of incentives and lack of resources to carry out maintenance. This has been compounded now because of the failure to establish priorities both by governments and maintenance authorities. There are still shortages of skilled personnel despite considerable past efforts with technical assistance and training. Maintenance is normally carried out by the Water Resources Department, which because of low salaries and lack of pay incentives, compared with local industry, often finds it difficult to attract and retain high quality staff. There is also frequent reassignment of the staff because of political and administrative changes.

ATTITUDE TOWARDS MAINTENANCE

Our politicians, planners, sometimes show poor attitudes to maintenance and engineers who often prefer to be associated with more construction projects rather than day-to-day problems of maintenance. The same view can also be seen among donors who seem to prefer to fund a new project rather than a maintenance project.

CONCLUSIONS

Vulnerability to floods is a function of human action and behaviour. There are many different ways to reduce the risk of flooding by means of development policies. These are institutional reform, improved analytical and methodological capabilities, education and capacity building, awareness raising, early warning, financial planning and political commitment. Capacity buildings mean providing skills resources and technology that will enable the development and implementation of sustainable methods, thereby reducing vulnerability to floods.

Public-private partnerships are important in planning, as close cooperation can be essential for creating well-developed policy that integrates different disciplines and fields. Behind the policy, the importance of expert knowledge enables decision makers to do more than merely respond to disasters. Expert knowledge and its integration into policy are considered increasingly important. The state is to accept that higher water levels will become in common in the future. The proposed flood control system should be designed to protect citizens by warning and informing them if their houses are at risk of being flooded. Suitable solutions should be integrated in nature and be based on a multidisciplinary approach. It is better to live with water rather than fight against it. The overall objective should to protect people and property more effectively against flooding in the delta basin.

REFERENCES

1. “Global warming can kill 10,000 in Asia-Pacific”, Times of India, dated 24 Sept 2005, BBSR, pp.10.

2. “Global warming behind fires and floods in Europe”, Times of India, dated 29 Aug 2005, BBSR.

4. Sharma, S. (2005), “Flood P(l)ains”, The Times of India, dated 28 June, Bhubaneswar.

5. Jafar, E., (2018), Disaster management: India is not completely ready, Disaster management plans exist on paper, but implementation remains a challenge, Hindustantimes, New Dehi, Sep 03, 2018.

6. Jena, A. B. (1982), “Some flood problems of Mahanadi”, Proceedings of flood control in Mahanadi system, Orissa Engineer’s Services Association, BBSR, pp. 49-64.

7. Das, B. (1982), “Flood problem in Mahanadi basin and possible measures for flood moderation”, Poceedings of flood control in Mahanadi system, Orissa Engineer’s Services Association, BBSR, pp. 82-84.

8. Das, R. C. (1982), “Flood Control in the Mahanadi basin”, Proceedings of flood control in Mahanadi system, Orissa Engineer’s Services Association, BBSR, pp. 27-39.

9. Joshi, H., (2020), "Floods across the country highlight need for a robust flood management structure", Mongabay Series: Flood and drought, https://india.mongabay.com/2020/08/floods-across-the-country-highlight-need-for-a-robust-flood-management-structure/

10. Krishnan, M. (2017), "Poor preparedness caused flood disaster in India" New Delhi, https://www.dw.com/en/poor-preparedness-caused-flood-disaster-in-india/a-40329541

11. Tripathi, P. (2015), "Flood Disaster in India: An Analysis of trend and Preparedness", Interdisciplinary Journal of Contemporary Research, vol. 2, No. 4, August-September, ISSN : 2393-8358.

12. Thattai, D. V., Sathyanathan, R., Dinesh, R., and Kumar, L.H. (2017), "Natural disaster management in India with focus on floods and cyclones", ICCIEE , IOP Conf. Series: Earth and Environmental Science 80 (2017).

13. Revised Report on Gabkund Cut Project, Engineer-in-Chief, Department of Water Resources, April 1996, Bhubaneswar.

14. Singh, M.P. (2004), "Flood Management", Proceedings of Work Shop on Emergency Action Planning, 25-27th Feb, CWC, New Delhi.

15. Tripathy, K.L. (2004), "Guidelines for preparation of emergency action plan", Proceedings of Work Shop on Emergency Action Planning, 25-27th Feb, CWC, New Delhi.

16. "Flood Management", Land + Water International, July 2004, NEDECO, The Netherlands.

An Overview of Flash Floods in Hyderabad: Triggers, Consequences and Measures

B Asritha Reddy
Masters student, Construction Project Management, Department of Mechanical and Construction Engineering, Northumbria University, Newcastle upon Tyne, United Kingdom
✉ *srithabattina@gmail.com*

Dr Chandra Bogireddy
Assistant Professor, Department of Civil Engineering, Vardhaman College of Engineering, Hyderabad,Telangana
✉ *hari2006chandra@gmail.com*

ABSTRACT

Floods are among Earth's most common and most damaging natural hazards ever since the earth was formed. Flash floods have been the recent problem for many countries and billions are lost in damages every year. This paper discusses about the recent floods in Hyderabad due to the Bay of Bengal depression, as well as the causes, consequences and potential steps to mitigate future floods.

Keywords : Flashfloods, Depression, Hyderabad.

INTRODUCTION

As the Covid-19 pandemic in several areas of the country continues to show signs of decline, some states are facing another threat that is floods. It also raises important questions concerning urban development, conservation of water bodies, climate change, flood warning systems and policy response to climate change. Focusing on one aspect and leaving out the others could lead to a faulty understanding of the situation [1].

Urban floods have been a nationwide trend since 2000 and because of these floods, many cities have been flooded, everyday life has been crippled and the economy has suffered immense losses. The Indian cities which suffered due to these floods are mainly Mumbai, Chennai, Srinagar, Jaipur, Baroda, Kochi, and recently Hyderabad. Floods have been the product of severe rain occurrences in each of these cases. Also science researchers have ample evidence that heavy rainfall has risen in India and has tripled from 1950 to 2015 in Central India. The area includes vast parts of land covering Gujarat to north Karnataka and south Kerala, including Chhattisgarh and Telangana [1].

Hyderabad is the capital and largest city of the Indian state of Telangana. It occupies 625 square kilometres(241 sq miles) on the Deccan Plateau along the banks of the Musi River in the northern part of South India. According to the

2011 Census of India, Hyderabad is the fourth-most populous city in India with a population of 6.9 million residents within the city limits, and has a population of 9.7 million residents in the metropolitan region, making it the sixth-most populous metropolitan area in India and has the fifth-largest urban economy in India [2]

If water is running over sewer and rivers in turn leading towards homes, backyards, streets and any other constructed buildings, an urban flood occurs [3, 4].Former flood catastrophe research concentrated primarily upon riverine flooding affecting mainly coastal and rural areas. Latest floods occur in urban areas more often due to an increase in high-intensity rainfall in a short span [5]. Flooding is a natural occurrence, but human intervention dramatically changed the mechanisms of natural drainage and thereby created an increased likelihood of flooding [6]. Urbanization resulted in a lot of land-use pressure that is indorse to intrusion into floodplains and lowland regions [7]. Moreover, urbanization contributes to decline in porous fields which contribute to a large rise in the level of runoff. Then the adjacent areas are filled with this excess runoff from storm water drainage systems. Invasion of waterways, poor drainage capacity and lack of maintaining continue to cause problems with floods. All of these results have resulted in urban inundations even for moderate precipitation, which is why "urban floods" are considerably different from riverine inundations [1].Based on rapid urban development, the flood can be more damaging at these areas in the country at given time.

In India, urban flooding is not recent. The majority of Indian cities as a developing country experience urban flooding. Some of the past major floods in India are Hyderabad-2000, Ahmedabad-2001,Delhi-2002,2003,2009,Chennai-2004, Mumbai-2005, Surat-2006, Kolkata-2007, Jamshedpur-2008, Guwahati-2010 and Srinagar-2014 [1]. The most recent devastating in the county ones are Chennai-2015, Hyderabad-2016,Kerala-2018and recently Hyderabad-2020.

A depressed down turn across the north coastal area of Andhra weakened in October 2020 and triggered heavy and very hard rain in the district in the month of October 2020 [8]. The record of Hyderabad's 32 cm torrential rainfall triggered flash flooding in town on 13 October 2020 [9]. On 18th October, 2020 during second cyclone, rainfall crossed over 110 mm in parts of Hyderabad, with heavier rainfall amounts outside of the city with parts of Hyderabad still flooded, more rain forecast, 2020 [10].

High-level short-lived rains are at the core of urban floods in Hyderabad. Three flash flood events have occurred since 2016. In hard reality, the city has significant rainfall before recent forecasts of climate change. Although it may now seem difficult, in the span of 24 hours the region could receive even 400-500 mm of precipitation in the near future [11].

The floods can be estimated in about 45% of the submerged colonies have witnessed the effects of the flood during the recent heavy rains for the first time and 35% for the second or third time. However, even after 1908, the remaining ten percent residential areas suffered floods many times and is it possible to estimate by technology. The floods are an ominous reminder of the Musi River 1908 floods, which pass through the city for the majority of the Hyderabad population. Nearly two-thirds of the city residents were hit by the flood and one-fourth of the city's houses were destroyed [12].

One of the research study warns that if the current condition in Hyderabad is the same, runoff water from rain will triple, the Musi River will rise 22 percent and about 51 percent of the town is more vulnerable to fluctuating waters than they are at present. The expected heavy rainfall in the city of 266 mm is focused on a prediction of climate change in the next 20 years within 24 hours. The research also emphasizes the importance of ground cover in disasters of this kind. The concrete area in Hyderabad was raised in 1995 from 55% to 73% in 2016. It is predicted that in 2031 this will rise to 80%. The region under water sources reduced from 16 sq. km to 7 sq. m between 1995 and 2016. Additionally, there was a reduction in vegetation area which is from 232sq. km to 117sq.km [12]

History of the Hyderabad Floods

Hyderabad was smarter at the turn of the 1900s than today's Hyderabad. A cloud-affected destruction and the Musi flood took 15,000 lives in 1908 and left 80,000 homeless. To control the flood damage, Mokshagundam Visvesvaraya suggested three solutions, building of two major reservoirs to store Musi's waters and its branch, the subterranean drainages scheme and separate storm water drains for the city, increasing the Musi's reservoirs because most flooding were triggered by north bank lower than southern and frequent storm watersheds. During the reign of Mir Osman Ali Khan, 7th and last Nizam, many of these works were executed, which won him honors for becoming a modern king. The city, including the residence and cantonment of Secunderabad, had approximately half a million inhabitants, but Visvesvarayya estimated to cope with a potential population rise of up to one million. For upcoming generations, he also introduced the implementation of an electric tram service, which took place in many of British India's major cities [1].

The rains were again destructive in August 2000. A total of 469 mm of rain was reported in the region, which resulted in one of the worst floods since 1908 (Times of India (b), 2020). In the city up to 90 residential areas were submerged in flood water. The rainfall in Hyderabad in 2016 ranged from 3-5 cm up to 8 am and varied at midday between 11.8 cm and 6.5 cm [13].

Causes of Floods in Hyderabad

From all the previous information available it is known that Hyderabad is a system of catchments. The western side of the city lies in the Godavari River basin (from Kukatpally, Ramchandrapuram, to Gachibowli) whereas the east is in the Krishna River basin. Apart from that, Hyderabad is in the Deccan region having a chaotic drainage pattern due to which the water flows in multiple directions as it has varied slope regions. The tanks present in Hyderabad served agricultural purposes and the places around them were 'protected local catchment areas'. But from the last 40 years, the city was built on these agrarian lands with all the concrete structures surrounding these water bodies creating solid boundaries without any buffer zones. A striking feature of this is the Necklace route. In the command area and the waterfront of the tanks, real estate has seen its peaks. In present scenario, all the slopes in Hyderabad are at same level. Most of the nalas, storm drains and culverts are occupied by land filling, built or just filled with garbage, debris and left forgotten. Due to this the water which used to flow along a particular course has lost its way and started flowing in different directions. To support this, Alwal is the best example which used to have 15-20 ponds or lakes and their bunds and is a naturally low-lying area but now it has become one of the most urbanized place in Hyderabad. The ponds Lothukunta and Tadbund explaining their natural history by their names itself are close to Alwal region but now there is neither pond or bund [14].

In order to reduce the mixing of dry waste in garbage disposal,the High Court passed an order in January 2016 on segregation of dry and wet waste, but they are collecting all waste together and dumping them even though the households are dumping separately. Although there are laws like Muncipal Solid Wastes(Management and Handling) Rules, 2000, and the Water(Prevention and Control of Pollution) Act, 1974 in place, the execution is not up to the expected levels [14].

The Centre for Science and Environment (CSE) assessed and published in its 2016 report of 'State of India's urban water bodies' that Hyderabad has lost almost 3245 Ha of its wet lands in the past 12 years. It also emphasized that urban areas are about to face major problems regarding intrusion of lands with water, sewage disposal and reduction in groundwater levels due to unplanned urbanization [14].

This intense rainfall occurs not because of low-pressure systems that form in the Bay of Bengal or local temperatures, but due to moisture transport from the Arabian Sea. Owing to the transfer of contaminants from land the North Arabian Sea is warming, and this increased temperature causes a rise in water vapour, which causes extreme precipitation across the central Indian belt. This link between carbon dioxide pollution and the warming waters causing transformation in transportation of moisture content is now apparent.

If natural soaking systems such as dams are transformed in a developed infrastructures such as bridges, waterways and buildings that do not value natural drainage flows, which lawfully or unlawfully infringe floodplains and rivulets, anything of this kind doesn't specifically apply to climate science but to flawed, short-sighted and politicised community planning. The authorities conceal erroneous urban planning practises by blindly attributing urban floods [14].

EFFECTS OF THE FLOODS

The susceptibility to urban flooding reflects the degree of harm to the exposed population caused by urban floods either directly or indirectly and recognizes the potential to separate direct and indirect loss into tangible and intangible damage. The physical losses of the land and the costs sustained in rebuilding the exposed community are direct tangible damages. The immediate immaterial loss is the suffering of living creatures (casualties, illnesses, injuries, etc.). Indirect tangible harm involves trade and trade distortion and decreased purchase power while indirect intangible damage raises susceptibility to disasters and emigration. The physical and socio economic susceptibility to fluctuations are both incorporated in visible and intangible damages to flooding. In terms of damage to properties, organizations and facilities, the natural vulnerability of urban flooding is possible [15]. The societal vulnerability of urban flooding reveals the intangible losses to the human system, with related impacts on education, health, social security etc. There is widespread literature on social insecurity elements and factors. The economic insecurity relates to the lack of access to adverse shocks for the exposed population (UNISDR, 2009). In particular the economic vulnerability indicators are indicated in flood vulnerability studies [16] as the basis for employment, reliance, financial privations and living disturbances. The latest changes in volatile literature promote the use of subsistence approaches to socio economic elements assessing vulnerability. The livelihood strategy attempts to consider the social and economic aspects of flood risk by analysing exposure and adaptive potential [17]. The heavy floods in Hyderabad damaged the city over night, as shown in the **Fig. 1**.

For two days after the flooding, most areas of Hyderabad lost electricity and internet access. It has already been reported that the State government has lost Rs 5,000 crore [18]. It is evident that Hyderabad has undergone direct tangible and intangible harm due to these floods. The flood water in house during recent Hyderabad as shown in **Fig. 2**.

MEASURES TO BE TAKEN

Unless treated conjecturally, urban storm water control cannot be successful. In order to address this problem, a multidimensional approach is required. Any of the management options that are needed to solve the issue concurrently are [14]:

- In order to determine the vulnerability linked to urban flooding, by using GIS technologies risk mapping should be worked out in city areas.
- For impermeable surfaces, the use of modern

Fig. 1 Hyderabad floods (Source: [9])

Fig. 2 Flood water in house during Oct 2020 Hyderabad floods

technological methods such as existing roads can be restricted, eliminated and/or minimized, as far as possible previous parking lots should be considered and enforced to decrease the drainage of the watershed.

- In order to avoid intrusion, the Town planning department of the city involved should periodically track the areas forbidden.

A lot can be done to reverse the effects which should initiate by taking stock of the whole drainage system instead of just the nalas. The city should be viewed as a catchment area and critical areas of invasion should be clearly stated. Although it does seem as if there is a variety, it's just about smart adaptation that can be achieved at a low rate. All of this involves an Executive and Ecological Authority like a "Lakes and Parks Authority," in the development authority of the local councils, in the townships and in the offices, such as revenue, drainage, bridges, and houses, to rely upon and collaborate with the related functions [14].

Experts believed that the surplus overflowing of the Osmansagar (Gandipet) and Himayatsagar water could be interconnected to the Musi downstream command zone by taking off the invasions along the river to ensure unimpeded flow through the length of the river. Furthermore, the runoff and waste water released into Musi should be handled daily until it is allowed to flow outside of the city [1].It is also emphasized that more refined statistical models are needed to forecast possible climate change scenarios that will lead to improved environmental planning. Extreme rainfall events are likely to become routine, but the government needs to urgently take urban flood prevention steps to rehabilitate existing dams to improve storage capacity and at least now monitor the invasion of the Hyderabad lakes.

CONCLUSION

Based on past information, it is evident that the flash floods are not just a product of climate change but also involves other factors such as unplanned urbanization and dense population. The geologists and design engineers need to focus more on construction site coordinates along with reference levelling of construction areas in order to reduce the potential floods.

REFERENCES

1. Tribune India News Service. 2020. New Warnings From Hyderabad Floods. [online] Available at: <https://www.tribuneindia.com/news/comment/new-arnings-from-hyderabad-floods-160305> [Accessed 31 October 2020].
2. https://en.wikipedia.org/wiki/Hyderabad
3. Rangari, V., Gonugunta, R., Umamahesh, N., Patel, A. and Bhatt, C., 2018. 1d-2d Modeling Of Urban Floods and Risk Map Generation for the Part of Hyderabad City. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-5, pp.445-450.
4. Zameer, A., Rao, R. M. and Reddy, K.: Urban flooding-case study of Hyderabad. Global Journal of Engineering Design and Technology, Vol.2 (4):63-66. (2013).
5. Awakimjan,I.,2015.Urban Flood Modelling Recommendations for Ciudad Del Plata. Bachelor Thesis,University of Twente, Netherland.
6. Gupta, A. K.,and Nair, S., 2011. Urban floods in Bangalore and Chennai: risk management challenges and lessons for sustainable urban ecology. Current Science (Bangalore), 100.11 (2011): 1638-1645.

7. SOPUF Ministry of Urban Development, GOI, 2017. Urban flooding standard operating procedure. Government of India. https://amrut.gov.in/writereaddata/SOP_Urbanflooding_5May2017.pdf

8. News, C. and News, H., 2020. Hyderabad Floods 2020 (a): Nine Dead As Rain Batters Hyderabad, Boats Out On Flooded Roads | Hyderabad News - Times Of India. [online] The Times of India(a). Available at: <https://timesofindia.indiatimes.com/city/hyderabad/nine-dead-as-rain-batters-hyderabad-boats-out-on-flooded-roads/articleshow/78651371.cms>[Accessed 31 October 2020].

9. Telangana, F., 2020. Flood Toll 32 And Counting In Telangana. [online] The New Indian Express. Available at: <https://www.newindianexpress.com/states/telangana/2020/oct/15/flood-toll-32-and-counting-in-telangana-2210447.html> [Accessed 31 October 2020].

10. Hyderabad, W., 2020. Worse Yet To Come? Climate Change To Aggravate Flooding In Hyderabad. [online] The New Indian Express. Available at: <https://www.newindianexpress.com/cities/hyderabad/2020/oct/20/worse-yet-to-come-climate-change-to-aggravate-flooding-in-hyderabad-2212460.html> [Accessed 31 October 2020].

11. Vemula, S., Raju, K., Veena, S. and Kumar, A., 2018. Urban floods in Hyderabad, India, under present and future rainfall scenarios: a case study. Natural Hazards, 95(3), pp.637-655.

12. The Hindu. 2020. 'Hyderabad Flood Manageable With The Help Of Technology'. [online] Available at: <https://www.thehindu.com/news/cities/Hyderabad/hyderabad-flood-manageable-with-the-help-of-technology/article32937887.ece> [Accessed 31 October 2020].

13. Staff, T., 2020. Rain And Flooding In Hyderabad: What Caused It And Why Both Govt And People Are Responsible For It. [online] The News Minute. Available at: <https://www.thenewsminute.com/article/rain-and-flooding-hyderabad-what-caused-it-and-why-both-govt-and-people-are-responsible-it> [Accessed 31 October 2020].

14. News, C. and News, H., 2020. Hyderabad Floods: Why Floods Occur In Hyderabad | Hyderabad News - Times Of India. [online] The Times of India (b). Available at: <https://timesofindia.indiatimes.com/city/hyderabad/why-floods-occur-in-hyderabad/articleshow/78656057.cms> [Accessed 31 October 2020].

15. Samuel Debionne, Isabelle Ruin Saif Shabou Céline Lutoff, cJean-Dominique Creutin, 2016. Assessment of commuters' daily exposure to flash flooding over the roads of the Gard region, France, Journal of Hydrology,Volume 541, Part A, October 2016, Pages 636-648.

16. Effah Kwabena Antwi, John Boakye-Danquah, Alex Barima Owusu, Seyram Kofi Loh, Ruby Mensah, Yaw Agyeman Boafo, Priscilla Toloo Apronti, 2015. Community vulnerability assessment index for flood prone savannahagro-ecological zone: A case study of Wa West District, Ghana, Weather and Climate Extremes, 10 (2015) 56–69.

17. Chaiechi, T., 2020. Economic Effects of Natural Disasters: theoretical foundations, methods, and tools.

18. Nagaraja, G., 2020. Years Of Poor Urban Planning Contributed To Hyderabad's Flash Floods - The Wire Science. [online] The Wire Science. Available at: <https://science.thewire.in/environment/hyderabad-floods-rains-poor-urban-planning/> [Accessed 31 October 2020].

Flash Flood: Challenges and Its Management

Neelam Prasad Choudhary
Deputy Manager Civil, Project Division Vertical C, VRMP, HPCL Refinery Project, Engineers India Limited, Visakhapatnam, Andhra Pradesh
neelam.choudhary@eil.co.in

ABSTRACT

Flood is the situation in which water temporarily cover the areas where normally it does not exist. Here the water comes from rivers, sea, lakes canals, sewers and rainfall etc. Flooding, in India, has been mostly falling under these three types, namely, Flash flood, Urban flood and Riverine flood etc. Flood is the major disaster that affects our country in all respect. This is the natural phenomena that cannot be avoided occurring from time to time in all rivers and natural drainage systems. It can lead to loss of life, natural resources and environment as well as loss of economy. This impact is going to increase day by day with increased flood plains, climate change leading to global warming and rising sea water level. Flash flood occurs due to slow moving thunderstorm and heavy rain. It is developed in few minutes to hours resulting from failure of manmade water structures as like dam collapse and overflowing of canal etc. Flash flood is generated after stacking of water of heavy rain.

Keywords : Flash flood, Rain, Flood disaster, Natural and manmade structure, Global warming and climate change

INTRODUCTION

Flash flood is the weather related destructive phenomena in which flood water moves with high velocity and carries substantial debris, stone, sand and soil etc. It is also occurs when barrier holding back water fails or when water falls in saturated soil or soil with low water absorption. When the structure fails then huge quantity of water spreads down in low lying areas, causing flash flood. Flash flooding occurs so quickly that people are caught off guard.

Their situation may become dangerous if they encounter high, fast-moving water while traveling. If people are at their homes or businesses, the water may rise quickly and trap them, or cause damage to the property without them having a chance to protect the property. Urban areas are also prone to flooding in short time-spans and, sometimes, rainfall (from the same storm) over an urban area will cause flooding faster and more-severely than in the suburbs or countryside.

The intensity of the rainfall, the location and distribution of the rainfall, the land use and topography, vegetation types and growth/density, soil type, and soil water-content all determine just how quickly the flash flooding may occur, and influence where it may occur. The area covered by water in a flash flood is relatively small compared to other types of floods.

Because of the sudden onset and the high travelling speed of the water, flash floods can be very dangerous. The water can transport large objects like rocks, trees and cars. Never drive through a flash flood, even if it doesn't seem to be very deep: the car may be swept away by the sheer speed of the water.

When a dyke breaks along the sea or along a river, the water may flow in so suddenly and with such speed that you could compare it with a flash flood.

Learning a flash flood disaster is the main objectives of our study with some specific objectives-

- Analyse the reason behind the flash flood
- Situation analysis of the flash flood
- Damage and loss assessment owing to flash flood
- Find out the probable solution of this flash flood.
- What are the triggering factors for this flood ?
- What is present situation of flood ?
- What are the damage and loss ?
- What are the feasible solutions ?

CAUSES OF FLASH FLOOD

Flash floods can occur under several types of conditions. Flash flooding occurs when it rains rapidly on saturated soil or dry soil that has poor absorption ability. The runoffs collect in gullies and streams and, as they join to form larger volumes, often form a fast flowing front of water and debris.

Flash floods most often occur in dry areas that have recently received precipitation, but they may be seen anywhere downstream from the source of the precipitation, even many miles from the source. In areas on or near volcanoes, flash floods have also occurred after eruptions, when glaciers have been melted by the intense heat. Flash flooding can also be caused by extensive rainfall released by hurricanes and other tropical storms, as well as the sudden thawing effect of ice dam. Human activities can also cause flash floods to occur. When dams fail, a large quantity of water can be released and destroy everything in its path.

Flood simply means inundation of extensive land area with water for several days in continuation. The most common cause of flooding is prolonged and heavy rains. There are also several natural as well as anthropogenic factors which contribute to flooding that are:

Rainfall

Rainfall is the most important natural factor for flood. More than 70% rainfall takes place in the monsoon. The two key elements cause flooding are rainfall intensity and duration. Intensity is the rate of rainfall and duration is how long the rain continued.

Infiltration Capacity

Infiltration is controlled by how readily the water can seep into the soil, be absorbed by the soil and work its way down to the water table. If the soil is already saturated with water and the water table has risen as a result of rainfall prior to a heavy storm, then little further water can infiltrate through the soil, and the rate of infiltration will be highly decreased.

Nature of Flood Plain Soil

The type of soil has direct influence on its rate of infiltration capacity and consequently it also affects the run off. Soils of alluvial origin (flood plain soils) vary in texture, from sand to clay. When a river floods and overflows onto its flood plain, its velocity immediately decreases and it starts dropping its sediment load. The larger, heavier sand particles drop out first, near the banks. Finer particles get deposited after the floodwater recedes and causes blocking of soil pores. Silt or clay-sized 72 particles settle down in these areas. The concentration of muds is high in silt and clay. This soil is suitable for agriculture but it is also the cause of next flood. Because a soil with a high percentage of silt and clay particles, i.e. fine soil, has a higher water holding capacity and lower infiltration capacity which leads to more overland flow or stagnant flood situation.

Shape of the Basin

Basin shape controls the rate of discharge after a sudden heavy rainfall. Therefore, it is necessary to determine the shape of the basin to study chances

A flash flood greatly inundates a small ditch, flooding barns and ripping out newly installed drain pipes

of flood. The shape of the basin can be calculated using Elongation Ratio and Circularity Ratio.

Elongation Ratio

The Elongation Ratio of a drainage basin is the ratio of the diameter of a circle with the same area to the length of the basin. The ratio usually remains between 0.6 and 1.0 over a wide variety of climatic and geological type.

Circularity Ratio

Circularity ratio is a dimensionless index to indicate the outline form of drainage basins. The Circularity ratio is the ratio of the basin area to the area of a circle having the same perimeter as a drainage basin.

Gradient

Slope or gradient of the river is also a controlling factor of flood. Stream gradient is the change in elevation over a specific horizontal distance, gradually decreases along the length of a stream channel. It is a measure of how far a river drops in elevation as it travels a certain horizontal distance. Channels of greater than 12% gradient are considered by geologists to be source reaches since any material falling into a channel of that steepness in a storm event will immediately move down stream.

Deforestation

It is the anthropogenic factor of flood. Deforestation in the upper catchment of the rivers is one of the important causes of flood. Forest has a natural ability to absorb water when it rains and to release that water slowly into rivers. The large trees of the forests can store two-third of the rainfall, but due to lack of vegetation nearly 85% (except some portion of infiltration) of the total rainfall directly mixes with the river water as sheet wash.

Increased Urbanization

Increasing urbanisation generally leads to the expansion of built up area and consequently decrease forested and vegetated areas. Urban areas, where much of the land surface is covered by roads and buildings, have less capacity to store rain water. Because the permeable soil is replaced by impermeable surfaces through the construction of buildings, metalled roads, parking lots and sidewalks that store little water, reduce infiltration capacity of soil and accelerate runoff to streams.

EFFECT DUE TO FLASH FLOOD

Primary Effect

The velocity of water tends to be high in floods and consequently, discharge increases. Because of excess rainfall, the rivers and streams flow with higher velocities wherein they are able to transport larger particles like rocks. Such large particles include not only rocks and sediment but during a flood it could also include large objects such as automobiles, houses and bridges.

- Massive amount of erosion can be accomplished by flood waters. Such erosion can undermine bridge structures, levees and buildings causing their collapse.
- During floods, water will also enter human built structures causing water damage. The flood damage to houses include ruining of furniture, damage to the floors and walls of the house and damage to any other item that comes in contact with the water.
- Automobiles on the roads get stranded in the floods and they get carried away by the flood waters or water enters into the automobile, which results in damage that cannot be easily repaired.
- The flood water carries sediment as suspended load. As the flood waters recede, the sediments

get deposited and things and structures including the interior of buildings usually get covered with a thick layer of stream deposited mud.

- Farmlands affected by floods face a huge loss as they usually result in crop loss. Livestock, pets, and other animals are often carried away by the strong currents of the flood water.
- Humans who get caught in the high velocity flood waters often get drowned.
- Submersion of pump houses may cause interruption in irrigation.
- Floodwaters can concentrate garbage, debris and toxic pollutants that can cause the secondary effects of health hazard.

Secondary Effect

The secondary effects of flood damage are the disruption of many essential services like gas, electricity and telephone lines. During flood, the service holders cannot attend their offices. The service activities get hampered by this way. Trees break down on roads and disrupt the transport system. For water logging problem students cannot go to schools and vehicles also face problem to run on the streets.

MANAGEMENT OF FLASH FLOOD

Some points that are towards prevention and implementation of post-flood remedial measures are:

Introduce Better Flood Warning Systems

India must improve its flood warning systems, giving people more time to take action during flooding, potentially saving lives. Advance warning and pre-planning can significantly reduce the impact from flooding.

Modify Homes and Businesses to help them withstand Floods

The focus should be on “flood resilience” rather than defence schemes, according to National Disaster Relief Agency. They advised concreting floors and replacing materials such as MDF and plasterboard with more robust alternatives. “We are going to have to live with flooding.

Construct Buildings Above Flood Levels

In India should construct all new buildings one metre from the ground to prevent flood damage, the former president of the Institution of Civil Engineers has suggested. Professor David Balm forth, who specialises in flood risk management, said conventional defences had to be supplemented with more innovative methods to lower the risk of future disasters.

Tackle Climate Change

Climate change has contributed to a rise in extreme weather events, scientists believe. Earlier this month the leader of the Green Party, Natalie Bennett, welcomed the landmark Paris Agreement, whereby governments from 195 countries pledged to “pursue efforts” to limit the increase in global average temperatures to 1.5°C above pre-industrial levels. “It is now crucial that world leaders deliver on the promise of Paris,” Ms Bennett said.

Protect Wetlands and Introduce Plant Trees Strategically

The creation of more wetlands – which can act as sponges, soaking up moisture – and wooded areas can slow down waters when rivers overflow. These areas are often destroyed to make room for agriculture and development, the WWF said. Halting deforestation and wetland drainage, reforesting upstream areas and restoring damaged wetlands could significantly reduce the impact of climate change on flooding, according to the conservation charity.

Restore Rivers to their Natural Courses

Many river channels have been historically straightened to improve navigability. Re-meandering straightened rivers by introducing their bends once more increases their length and can delay the flood flow and reduce the impact of the flooding downstream.

Improve Soil Conditions

Inappropriate soil management, machinery and animal hooves can cause soil to become compacted so that instead of absorbing moisture, holding it and slowly letting it go, water runs off it immediately. Well drained soil can absorb huge quantities of rainwater, preventing it from running into rivers.

Put up More Flood Barriers

The Environment Agency uses a range of temporary or “demountable” defences in at-risk areas. These can be removed completely when waters recede. Temporary barriers can also be added to permanent flood defences, such as raised embankments, increasing the level of protection. “As the threat and frequency of flood risk increases, the use of passive flood defence has to be the only realistic long term solution.

CONCLUSION

Flash flood is the result of complex geophysical and anthropogenic process. We have seen how a disaster can affect a society if we don’t take any preventive, adaptive, preparedness measure against this flood. We all know about the flash flood that occurs in the Maharashtra (Mumbai) area but we don’t know the time frame of this flood. We have no perfect projection on climate change so does not generate any effective early warning.

From the above discussion it is clear that heavy rainfall, nature of soil, high discharge, meandering characteristics of river etc. are the main causes of flood in these two rivers.

The incidences of flood mainly occur in the monsoon months. Intense rainfall with long duration saturates the soil so much that overland flow increases and due to alluvium nature of soil and low gradient, water stagnation occurs and creates flood.

Not only natural factors but also anthropogenic factors like deforestation and increased urbanization play a vital role in this hazard. It may be pointed out that these factors should never be considered separately because it is the cumulative effect of several factors which ultimately cause severe floods. Beside this, due to poor drainage network some areas are suffered from water logging problem.

After this study we have found some important points that are used for applying preventive measures against flash flood that are:

WHAT TO DO DURING A FLOOD WARNING WHEN A FLOOD OR FLASH FLOOD WARNING IS ISSUED

- Listen continuously to a battery-powered radio (or television) for updated emergency information. Local stations provide you with the best advice for your particular situation.
- Be alert to signs of flooding. A WARNING means a flood is imminent or is happening in the area.
- If you live in a flood-prone area or think you are at risk, evacuate immediately. Move quickly to higher ground. Save yourself, not your belongings. The most important thing is your safety.
- Follow the instructions and advice of local authorities. Local authorities are the most informed about affected areas. They will best be able to tell you areas to avoid.
- If advised to evacuate, do so immediately. Move to a safe area before access is cut off by flood water. Evacuation is much simpler and safer before flood waters become too deep for vehicles to drive through.
- Follow recommended evacuation routes. Shortcuts or alternate, non-recommended routes may be blocked or damaged by flood waters.
- Leave early enough to avoid being marooned by flooded roads. Delaying too long may allow all escape routes to become blocked.
- Stay out of areas subject to flooding. Dips, low spots, canyons, washes, etc., can become filled with water.

- If outdoors, climb to high ground and stay there. Move away from dangerous flood waters.
- If you come upon a flowing stream where water is above your ankles, stop, turn around, and go another way. Never try to walk, swim, or drive through such swift water. Most flood fatalities are caused by people attempting to drive through water, or people playing in high water. If it is moving swiftly, even water six inches deep can sweep you off your feet.

REFERENCES

1. "Flash Flooding Definition". National Weather Service. Retrieved August 31, 2017.
2. Shailes, Sarah. "How flooding affects plants". Plant Scientist. Retrieved 14 July 2020.
3. National Weather Service Forecast Office Morristown, Tennessee (2006-03 07). "Definitions of flood and flash flood". National Weather Service Southern Region Headquarters. Retrieved 2009-09-09.
4. "Watches, Warnings & Advisories—Flash Flood Warning". National Weather Service. Archived from the original on 2008-01-11. Retrieved 2007-06-25.
5. "Flash Floods Turn Deadly In Southwest France's Aude Region". NPR.org. Retrieved 2020-03-02.
6. McGuire, Thomas (2004). "Weather Hazards and the Changing Atmosphere" (PDF). Earth Science: The Physical Setting. Amsco School Pubns Inc. p. 571. ISBN 0-87720-196-X. Archived from the original (PDF) on 2008-06-25. Retrieved 2008-07-17.
7. "A Preparedness Guide to flash floods #1 weather related killer in the United States". U.S. Department of Commerce, National Oceanic and Atmospheric Administration National Weather Service, Federal Emergency Management Agency, American Red Cross. July 1992. Retrieved 2007-06-25.
8. Frederick, Prince (22 November 2011). "Memories of Madras: Story of a submerged city". The Hindu. Retrieved 28 May 2015.
9. Sonawane, Vishakha (26 June 2015). "Heavy Rains In India: 70 Dead in Gujarat, Flood Alert In Jammu And Kashmir". International Business Times. Retrieved 26 June 2015.

Flash Floods: Challenges and Its Management

P Jayakumar
Construction& Contract Management Consultant, Mumbai
✉ *p_jykmr@yahoo.com*

ABSTRACT

The flash floods, as a result of intensive rainfall in various regions of India, their frequency and magnitude are discussed in this paper. Because of the vast area and large number of streams subject to flash floods, many difficulties of practical/financial nature are involved in providing an extensive warning system. Mention is made of some flash floods which have occurred in the past. The flash floods cause loss of life, damage to property, crops, loss of livestock, and deterioration of health conditions owing to water borne diseases. The 'Flash floods' are the most dangerous kind of floods, as they combine the destructive power of a flood with incredible speed of run-off from heavy rainfall. According to the World Meteorological Organization, flash floods account for 85% of flooding cases across the world. The flash floods occur mainly due to the extreme spatial and temporal variation in the quantity of rainfall and meteorological conditions during monsoon season (June– September). About 80% of the total annual rainfall is concentrated during the period.

INTRODUCTION

Flood control measures like detention reservoirs, embankments, and drainage works have been undertaken for protection from flash floods. However, due to paucity of funds, it will take many years before all areas of the country can be protected. In order to minimize the flood damage, arrangements for flood forecasting and warning are being provided, so that people, along with their movable property and cattle, can move to safer places in an organized manner on timely warnings about approaching floods. The scientific flood forecasting service began in 1959 with the setting up of a small unit at Delhi to warn the inhabitants of Delhi and neighbouring villages about approaching floods in the River Yamuna. However, it was only after the disastrous floods of 1968 in many parts of the country, that flood forecasting and warning arrangements for other rivers like the Ganga, Brahmaputra, Narmada, etc. were set up.

MAJOR RIVER BASINS

The occurrence of flash floods mainly depends on the river system, topography of the place, and flow phenomenon. Flooding problem in different river basins of India shown in figure **(Fig. 1)** has been presented in the following subsections.

The Ganga River Basin

The River Ganga originates from the Gangotri Glacier, located at an elevation of 7010 m (average mean sea level-amsl) in the Garhwal

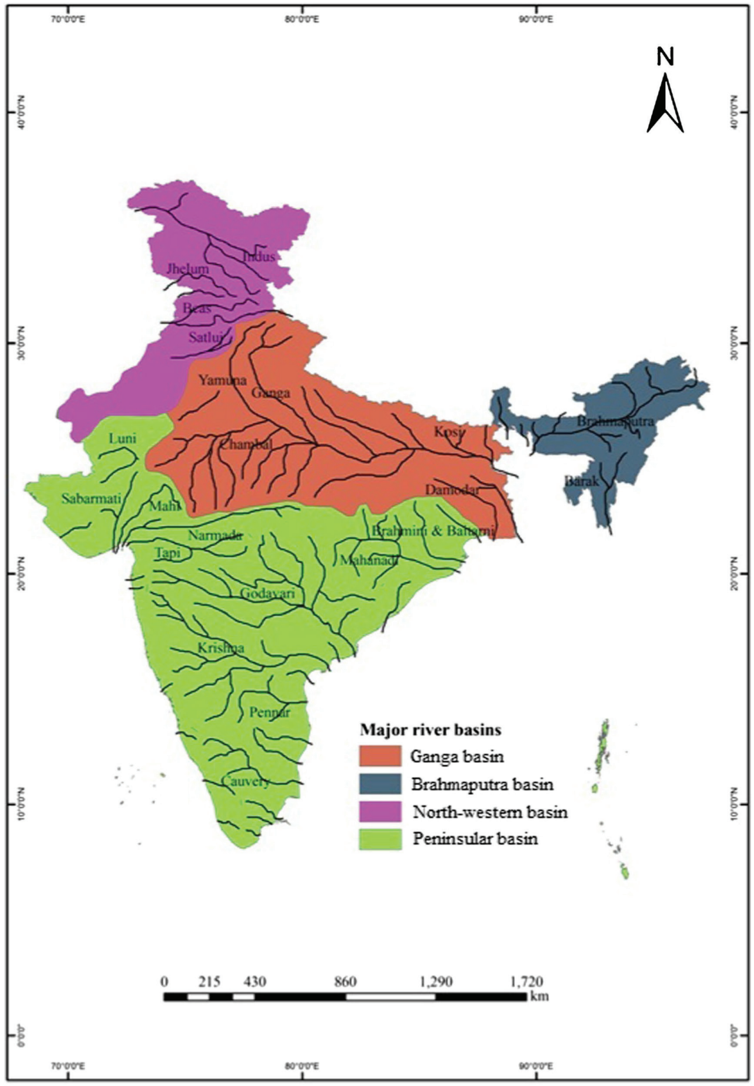


Fig. 1 Major river basins of India

Himalayas. The total basin area of the Ganga is about 8,61,404 sq. km and total length of about 2525 km from its source to its outfall into the Bay of Bengal. The average annual discharge of the Ganga River at Farakka, India, and Harding Bridge, Bangladesh, is about 4,10,000 and 3,52,000 million cubic meter, respectively. The monsoon run-off flows fluctuate from 57,000 to 80,000 cubic meter per second. The highest annual peak discharge of 80,230 cubic meter per second, has been recorded at Harding Bridge in 1998. The major tributaries of the Ganga include Yamuna, Sone, Ghaghra, Rapti, Gandak, Bagmati, Kosi, and the Mahananda. The basin covers the states of Uttarakhand, Uttar Pradesh, Jharkhand, Bihar, south and central parts of West Bengal, parts of Himachal Pradesh, Haryana, Delhi, Rajasthan, and Madhya Pradesh. The normal annual rainfall in different parts of the basin varies from about 60 cm in southern and western parts to 190 cm in northern and eastern parts of which 70 to 90% occurs during the south-west monsoon months of June to September.

Brahmaputra River Basin

The River Brahmaputra rises in South-Tibet from the glaciers of Mount Kailash at an elevation of about 5150 m (amsl). It has an annual average discharge of about 510,000 million cubic meters and a total length of about 2900 km, and basin area of about 580,000 sq. km. in Tibet, India and Bangladesh. The average annual discharge in the river is nearly twice that of the Ganges. The highest annual peak discharge of 98,600 cubic meter per second, has been recorded during the year 1988 at Pandu. It is regarded as one of the world's largest braided river systems in terms of discharge, sediments transport, and channel process. During its long course, it is joined by important tributaries from the Himalayan ranges of Arunachal Pradesh and Bhutan in the north, viz., Subansiri, Kemang, Dhansiri, and Manas, and from the southern side, it is joined by Dihing, Disang, Dikhu, and Kopili. The basin covers the states of Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Tripura, Nagaland, Sikkim, and the northern parts of West Bengal. The discharge of the river Brahmaputra in upstream areas is mostly contributed by the snowmelt, whereas in downstream areas, rainfall is quite heavy and this results into substantial amount of flooding in the river.

North-West River Basins

The main rivers in north-west India are the Indus and its tributaries such as Sutlej, Beas, Ravi, Chenab, Jhelum, and Ghaggar, all flowing from Indian Himalayas. These rivers carry substantial discharges during the monsoon season and also large volumes of sediment, thereby causing rise in their beds progressively and inundating larger areas. These basins cover the states of Jammu and Kashmir, Punjab, parts of Himachal Pradesh, Haryana, and Rajasthan. The major problem in these states is that of inadequate surface drainage which causes inundation and water logging over vast areas. In addition, cloud bursts have often been found to cause severe floods over small Himalayan basins but these floods last only for a short duration, say a couple of hours.

Peninsular River Basins

Peninsular river basins comprise the important rivers of central and Deccan India, namely the Narmada, Tapi, Mahanadi, Godavari, Krishna, and Cauvery. However, it is observed that compared to north and north-eastern rivers of the Indian subcontinent, flood magnitudes and frequencies, generally speaking, are far less in the peninsular rivers. Most of the river basins have their origin on the lee side of the Western Ghats, which experiences less rainfall activity on account of their location in the rain-shadow zone of the Western Ghats, and hence, rainfall activity is not that severe over this region, unless the region comes under the influences of cyclonic disturbances. These basins cover all the southern states, namely Andhra Pradesh, Chhattisgarh, Karnataka, Kerala, Tamilnadu, Odisha, Maharashtra, Gujarat, and parts of Madhya Pradesh. The delta areas of the Mahanadi, Godavari, and Krishna rivers on the east coast periodically face flood and drainage problems, in the wake of cyclonic storms. The Tapi and the Narmada are flashy and occasionally in high floods with velocities exceeding 6–7 meter per second, affecting areas in the lower reaches of Gujarat. The 1968 flood on the Tapi River at Ukai is the highest since 1849; the 1970 flood on the Narmada River is the highest for the last 107 years and the 1982 floods on the Mahanadi River is the highest since 1834. It is remarkable to find that the highest floods of 9340 cubic meter per second for a 735 sq. km area and 16,307 cubic meter per second for a 1930 sq. km area occurred in the arid region of the state of Gujarat.

OCCURRENCE OF FLASH FLOODS

In order to get an idea of the region of occurrence of flash floods, their intensity and frequency, it is necessary to go into details of the rainfall pattern in the country during the rainy season, especially the rainfalls of 24 hours, or shorter, duration. Studies by many meteorologists (Parthasarathy, 1958; Jagannathan, 1970; Harihara Ayyar and Tripathi, 1974) show that a large area of the country is subjected to very heavy rainfall mainly caused by cyclonic storms and depressions, especially during the southwest monsoon season. While locally heavy falls of 10 to 20 cm per day occur over wide areas of thousands of square kilometres, falls of 30 to 40 cm per day have been recorded in the neighbourhood of hills and in coastal areas in the track of storms. Parthasarathy (1958) analysed maximum 24 hours, rainfall in different districts and showed that heavy rainfall of 10 in. (25 cm), or more in 24 hours, can occur even in the semi arid regions of West Rajasthan and Kutch. Some places have, at times, received the entire year's rainfall in one day.

The rainfall in 6 hours and 3 hours duration can be about 75 and 60 per cent of the 24 hours rainfall, and it is intense rainfall such as this which gives rise to flash floods in small rivers. An examination of the ten-year frequency 3-hour rainfall of India will show that almost the whole of India is subject to a 3-hour rainfall of 80—160 mm. Thus the occurrence of flash floods is quite widespread.

SOME EXAMPLES OF FLASH FLOODS

The town of Mandi and the Suketi valley in Himachal Pradesh in northern India experienced unprecedented rainfall of 25 cm in 3 (three) hours period in the early hours of 31st August 1960 and caused flash floods and at least 103 persons and 600 cattle perished in the disaster.

On 4th October 1968, the water level in the River Teesta rose to an unprecedented height of 20.4 metres above the extreme danger level at Anderson Bridge and waters reached Jalpaiguri, they overtopped the embankment and caused wide breaches. The whole town was flooded with water up to a depth of 2-3 meters in the early morning hours and the people of the town were taken completely unaware. The flooding lasted for over 18 hours resulting in a large number of deaths and a heavy deposit of silt all over the town.

The Alaknanda floods in July 1970, were caused by heavy and concentrated rainfall in the upper catchment leading to huge landslides. When the temporary blocking in the main river and in one of the tributaries gave way, the water rushed downstream and rose by about 15 metres above the road in a nearby village. The rise was so sudden that many people were engulfed in the floods.

In August 2010, Ladakh experienced one of the worst natural disasters in its history. The desert district received 350 millimetres (13.8 inches) of rain in just two days – three and a half times its annual average. As per reports, 234 people died and more than 800 went missing due to the floods.

The disaster-prone hill state Uttarakhand has suffered from several natural calamities in succession over the last 20 to 30 years. Between June 14 and 18, 2013, Uttarakhand suffered one of the worst natural disasters as widespread heavy rains resulted in floods across the state, that claimed thousands of lives and caused damage worth billions of rupees. The most affected districts were Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi.

In September 2014, Kashmir saw one of its worst natural disasters in 50 years due to torrential rains from the southwest monsoon resulting in the Chenab and Jhelum rivers to breach their embankments affecting nearly 2,600 villages in the state further causing 390 of them completely submerged. Some 280 people died and half a million people were trapped in their homes for nearly three weeks, with the city of Srinagar drowning under nearly 5.5 meters (18 feet) of water.

CLOUD BURST AND HIMALAYAN FLASH FLOODS

The Cloud burst is characterized by extreme amount of precipitation in a short span of time creating flash flood conditions and is often accompanied by thunder and lightning. A 'Cloud burst' occurs by convective weather systems as India is surrounded by oceans from three sides and the hence a favourable location for convective weather systems. Convective weather system in Bay of Bengal result in rainfall over the Indian subcontinent and a convective weather system in western Pacific Ocean diverts rain bearing winds away from the Indian subcontinent. During Cloud burst, massive coagulated clouds with heavy water content hover over a very small location. The dead weight of the cloud is so massive and unbearable that it simply collapses under its own weight and cause extreme precipitation within a short span of time resulting in flash flood.

EVENTS THAT RESULTED IN THE '2013 HIMALAYAN FLASH FLOODS'

1. March, April & May 2013: heavy snow in Himalayas.
2. June 14 to 16, 2013: Non-stop intense rainfall helped the snow to melt fast from Chorabari Glacier as water has a higher heat capacity than air, and the molecules in liquid water are more tightly packed than the molecules in air, and therefore, when water molecules touch snow causes greater rate of heat transfer and the same accelerates the process of snow melting. e.g heavy snow melting from 'Chorabari Glacier' led to increased water level in the River 'Mandakini and Chorabari'.
3. June 16, 2013: Cloud burst over Chorabari Lake lead to the lake to explode and caused flash floods. The flash floods washed the mud, stones and slush (partially melted snow) from mountains into Rivers. Bhagirathi, Alaknanda and Mandakini rivers were already flowing with lot of water due to snow-melting. The rivers filled with mud, snow, ice rushing through the hills and cliffs caused more erosion, and swept away whatever came in their way and thus, all those shops, hotels, apartments that were constructed very close to the river banks got washed away. Additionally, landslides destroyed the road network in the mountains hence relief could not reach on time.

FACTORS THAT RESULTED IN 2013 HIMALAYAN FLASH FLOODS

The Cloud bursts have happened in past also, but the amount of death and damage in Uttarakhand in 2013, was unprecedented, owing to:

1. Roads causing landslides

The Himalayan Mountains would have remained steady if it were not tampered with. But landslides caused by the huge expansion of roads and transport, heavy machines plying the earth everyday and even dynamites are used to cut the mountains and make roads. Such activities had already rendered the mountains unstable leading to rainfall associated landslides further blocking the rescue team that can't go in, victims can't go out.

2. Too Much Construction activities

a. Hydro project in Bhagirathi: too many hydropower projects caused change in courses. The problem was compounded by poor structural safety.

b. Mining: use of dynamites weakened the mountains

c. Construction activities, especially hotels and resorts, guest houses and travel-lodges on the river bed, built without sound engineering or structural safety.

3. Fragile Polity of the State

a) Uttarakhand had seen frequent change of Chief Ministers in 13 years, resulting in average tenure of a CM to mere 2 years.

b) This has resulted in lack of continuity and failure in getting a firm grip on the issues plaguing the state including disaster management.

c) Successive CAG reports have made scathing remarks on the lack of disaster management preparations in the Uttarakhand state. Yet no action was taken.

d) Political fragility has resulted in ad-hoc and unplanned development.

e) Successive governments have failed in creating any sort of medium term or long-term plan or vision for the state.

4. Lack of Coordination in Organizations

a) IMD (Indian Metrology Dept.): IMD was unable to alert State-authorities in time. It didn't have Doppler radars in the Himalayan region to predict onset of cloudbursts. Only after this disaster happened, Dept. of Science and Technology made efforts about setting up Doppler radars in the region.

b) NDRF (National Disaster Relief Force):National Disaster Management Authority (NDMA) was formed after Tsunami in 2003-but has grossly failed both in planning and implementation. It didn't even have sufficient life-jackets in Rudraprayag.

MANAGEMENT OF FLASH FLOODS

Management of floods involve structural measures like construction of physical structures like embankments, dams, drainage channels, and reservoirs that prevent flood waters from reaching potential damage centers, also adopting environment friendly 'construction & development projects' by not tampering with nature/forest and not constructing structures obstructing the natural flow streams. The non-structural measures like flood forecasting to improve the preparedness to floods by keeping people away from flood waters. The knowledge of factors that help to learn about the possibility of intensive rainfall is of prime importance to predict rainfall in 'real time frame' to pre-empt damages/destruction.

WEATHER FORECASTING AND WEATHER VARIABLES/FACTORS

The task of forecasting weather is with the IMD (India Metrological Department), headquartered in Delhi and operating hundreds of observation stations across India. Regional offices are at Mumbai, Kolkata, Nagpur and Pune. The IMD uses Satellites INSAT 3A, MEGHA TROPIQUES and INSAT 3D launched respectively, on April 9, 2003, on October 12, 2011 and on July 26, 2013, and these Satellites enable good understanding of India's monsoon cycle and to measure several parameters that will be helpful in monitoring the monsoon.

The weather is impacted by weather variables/ factors/conditions of the atmosphere. These elements, such as air temperature, wind speed and directions, and precipitation, are normally called the weather variables because each element changes with time yet are all related. The factors that affect weather include latitude, elevation, nearby water, ocean currents, topography, vegetation, and any changes that occur within global climate system also influence local climate.

Doppler radar is used to measure the weather variables. The Doppler radar is different from the conventional radar as the Conventional radar provides information about the location and intensity of precipitation associated with a storm, while Doppler radar adds the capability to discern air motions within a storm and its severity and intensity. The weather variables/factors are extrapolated on scientific principles to predict the intensity and extent of rainfall in real time frame.

REFERENCES

1. Flood occurrences, damages, and management challenges in India: a geographical perspective by Omvir Singh & Manish Kumar (Arabian Journal of Geosciences).
2. Weather forecasting in India: Recent developments by SANDEEP PATTNAIK, School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar.
3. Flash floods in India by Pritam Singh, A. S. Ramanathan and V. G. Ghanekar.
4. Rainfall prediction using modified linear regression by S. Prabakaran, P. Naveen Kumar and P. Sai Mani Tarun, Department of Computer Science and Engineering, SRM University, Kattankulathur, Chennai, India.
5. Real time flood forecasting - Indian experiences by R. D. Singh.
6. Rainfall studies by meteorologists (Parthasarathy, 1958; Jagannathan, 1970;Harihara Ayyar and Tripathi, 1974).

Flash Floods Challenges & Its Management

H C Singh
Executive Engineer, Irrigation Division, Nainital, Irrigation Department, Govt. of Uttarakhand
✉ *singh.harish.harishchandra@gmail.com*

INTRODUCTION

Flash floods are characterized by very fast rise and recession of flow of small volume and high discharge, which causes high damages because of suddenness. This occurs in hilly and not too hilly regions and sloping lands where heavy rainfall and thunderstorms or cloudbursts are common. Depression and cyclonic storms in the coastal areas of Odisha, West Bengal, Andhra Pradesh, Karnataka, and Tamil Nadu also cause flash floods. Arunachal Pradesh, Assam, Odisha, Himachal Pradesh, Uttarakhand, the Western Ghats in Maharashtra and Kerala are more vulnerable to flash floods caused by cloud bursts. Sudden release of waters from upstream reservoirs, breaches in landslide dams and embankments on the banks of the rivers lead to disastrous floods. Severe floods in Himachal Pradesh in August 2000 and June 2005, and in Arunachal Pradesh in 2000 are a few examples of flash floods caused by breaches in landslide dams. Floods in Assam, Bihar, Uttar Pradesh, Odisha and Andhra Pradesh are generally caused by breaches in embankments. Incidents of high intensity rainfall over short durations, which cause flash floods even in the area where rains are rare phenomena, are on the rise and the problem needs to be tackled in a scientific manner.

Floods are recurrent phenomena in India from time immemorial. Floods of varying magnitude, affect some or the other parts of the country, almost every year due to different climates and rainfall patterns. With the increase in population and developmental activities in the country, there has been a tendency to occupy the floodplains, often resulting in serious flood damages and loss of lives over the years. Of late, some areas, which were not traditionally prone to floods, also experienced severe inundation. Floods cause severe bank erosion if the river banks are fragile and not protected against the heavy flood discharges.

India is one of the most flood-affected countries in the world. There is not a single year when some or the other part of the country does not get inundated during floods.

The floods are now considered as natural disaster. But unlike other natural disasters such as, earthquakes, landslides, etc, it is possible to manage floods to a great extent. As widely known, there are two options for flood management viz. structural measures & non-structural measures. The modern flood management strategy is a judicious mixture of both options.

Measures for flood management and erosion control different measures have been adopted to reduce the flood/erosion losses and protect the flood plains. Depending upon manner in which they work, flood protection and flood management measures may be broadly classified as under.

Non-structural Measures

The non-structural methods to mitigate the flood damages are as under:

- Flood Plain Zoning;
- Flood Forecasting, Flood Warning and evacuation of the people;
- Flood Proofing; and
- Living with Floods.

Govt. of India has given model draft for flood plan zoning but unfortunately after lapse of about more than four decade most of the state governments have not implemented it in true sprite.

Structural Measures

The structural measures for flood management/ erosion control (may further be classified into long term measures and short term measures) which bring relief to the flood prone areas by managing the flood flows and thereby the flood levels are:

- Creation of reservoir;
- Diversion of a part of the peak flow to another river or basin where such diversion would not cause sizeable damages;
- Construction of flood embankments;
- Channel improvement;
- Watershed management;
- Construction of spurs, groynes, studs etc.;
- Construction of bank revetment along with launching apron;
- RCC porcupines in the form of screens, spurs, dampeners etc.; and
- Vetivers, geo-cells, geo-bags etc.

The structural measures for flood management mentioned above are designed as per BIS codes. However, many works like RCC porcupines, Geotextile materials, vetivers etc are not covered in the existing BIS codes.

Flood Damages in India

As per record available damage due to flood in India during 1953-2010 are shown in **Table 1**.

Causes of Floods

Inadequate capacity of the rivers to contain within their banks the high flows brought down from the upper catchment areas following heavy rainfall, leads to flooding. The tendency to occupy the flood plains has been a serious concern over the years. Because of the varying rainfall distribution, many a time, areas which are not traditionally prone to floods also experience severe inundation. Areas with poor drainage facilities get flooded by accumulation of water from heavy rainfall.

Table 1 Flood damages in India during 1953-2010

Item	Unit	Average Annual Damage	Maximum Damage	
			Extent	Year
Area affected	MHa	7.06	17.50	197
Population affected	million	36.86	70.45	1978
Human lives lost	nos.	1611	11316	1977
Cattle lost	nos.	93202	618248	1979
Cropped area affected	MHa	3.46	10.15	1988
Damage to crops	Rs crore	703	4247	2000
House damaged	nos.	1193877	3507542	1978
Damage to house	Rs crore	276	1308	1995
Damage to public utilities	Rs crore	828	5605	2001

Excess irrigation water applied to command areas and increase in ground water levels due to seepage from canals and irrigated fields also are factors that accentuate the problem of water logging.

The problem is exacerbated by factors such as silting of the riverbeds, reduction in the carrying capacity of river channels, erosion of beds and banks leading to changes in river courses, obstructions to flow due to landslides, synchronization of floods in the main and tributary rivers and retardation due to tidal effects.

Planning & Design of River Embankment:- GFCC Guidelines has recommend that the embankments shall be designed as per the provisions of IS 12094-2000. This standard covers planning and design of river embankments (levees) on dry land. The salient features/main design aspects covered in this code are described in the following paragraphs:-

Design High Flood Level

Protection of agriculture land- 25 year flood frequency. Protection of township, Industrial area- 100 year flood frequency

Free Board

1.5 m over design HFL (for Q<3000 Cumecs) 1.8 m over design HFL (for Q≥ 3000 Cumecs)

Planning & Design of Groynes/Spur (IS 8408-1994)

This standard covers the planning and design of Groynes (Spurs) in alluvial rivers.

Design Discharge: should be equal to that for which any structure in close proximity is designed or 50 year flood whichever is higher.

Length of spur: Normally effective length should not exceed 1/5th of width of flow. Spacing of spur is normally 2 to 2.5 times the effective length.

Top level: Depends on the type namely submerged, partially submerged and non-submerged and will be best decided by model experiment.

Flood discharge: It may be worked out from Dicken's formula.

$$Q = C \times A^{3/4}$$

Where, Q = Estimated peak flood in m^3/sec ,

A = Catchments sq km

Value of C = (12-14 for Hilly area, 11-14 for North Indian region

The silt factor $f = 1.76\,(D50)^{1/2}$

Scour Depth - "D"= $0.473(Q/f)^{1/3}$

where, D = the depth of scour below HFL,

Q = discharge in Cumec,

f = silt factor

Lacey's Waterway (IS Code 6966- Part-I, Clause 10.2):

Lacey's Waterway = $4.89\ Q^{1/2}$

Computation of velocity of flow Q= A x V.

Spurs may be aligned either normal to flow direction or at angle pointing towards u/s or d/s of the flow. A spur pointing u/s of the flow repels the flow away from the bank and is known as repelling type spur/groyne. When a short length spur changes only direction of flow without repelling, it is known as deflecting spur/groyne. Spur pointing d/s of the flow attracts the flow towards the bank and is known as attracting spur/groyne. Generally, repelling type or deflecting spurs are provided for anti- erosion measures. Repelling type spurs may be kept at an angle of 5 to 10 degree against the direction of flow.

Checking for destabilizing forces e.g. Hydrodynamics Drag & Lift-

As per IS code 14262 (Planning and Design of Revetment- Guide Lines), Stone used in revetment for river bank protection is subjected to hydrodynamic drag and lift forces. Weight of the stone on horizontal bed may be expressed as:

$$W = 0.02323 \times S_s \times V6 / (S_s - 1)^2$$

Where, W = weight of stone in kg,

S_s = specific gravity of stone,

V = mean velocity of water in m/s

Computation of 'discharge for non-uniform and composite cross-sections (As per IS Code 2912- Liquid Flow Measurement In Open Channels - Slope-Area Method

The discharge of a stream in a particular reach shall be calculated from the formula (Para 10 of the IS Code)

$$Q = K \times S^{1/2}$$

$$K = 1/n \times (A \times R^{2/3}),$$

Where:- Q is the discharge in Cumec,

S is the friction slope in m/km, and,

n = Manning's Coefficient of Rugosity

Design of Launching Aprons

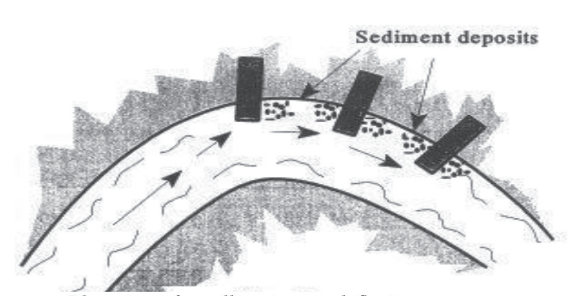
As per IS 8408 Clause 5.9.2, the S code, directs that the scour depth at the nose of spur is to be designed for a maximum scour depth of 2.0 to 2.5 times the normal scour depth.

Thickness of protection works

The slope of launched apron is to be taken as 1.5 H: 1V as per the provision in IS Code 10751 (Planning and Design of Guide Banks For Alluvial Rivers).

Report of working group on flood management and region specific issues for XII plan Published by the Planning Commission, Government of India During October2011.

In order to formulate 12th five year plan, the Planning Commission constituted various Working Groups. The Working Group on Flood Management and Region Specific Issues was constituted under the Chairmanship of Prof. Nirmal Sengupta of IGIDR, Mumbai with Commissioner (Ganga), MOWR as Member- Secretary. The working group recommendations submitted to planning commission for the 12th Plan regarding the river dredging/river channelization are as below are:



Plan view of repelling type or deflecting spurs

Channelization of Rivers

Some of the States are proposing channelization of rivers, at least in certain reaches, in the context of tackling the extensive meandering problems of the rivers, activating navigational channels and training these rivers into their original courses. While venturing to channelize rivers, thought must be given in allowing the river certain freedom to flow and right of way to pass its flood waters and silt load within its natural waterway. The dynamic nature of the rivers should be appreciated and preventive measures planned accordingly instead of pinning down the river by channelizing.

Channel Improvement

The method of improving the channel by improving the hydraulic conditions of the river channels by desilting, dredging, lining etc., to enable the river to carry its discharges at lower levels or within its banks has been often advocated but adopted on a very limited extent because of its high cost and other problems.

Dredging operations of the Brahmaputra, which were undertaken in the early seventies on an experimental basis, were discontinued because of their prohibitive cost and limited benefits. Dredging in selected locations may perhaps be considered as a component of a package of measures for channel improvement to check the river bank erosion subject to techno-economic justification. It may be economically justifiable as a method for channel improvement where navigation is involved. Dredging is sometimes advocated for clearing river mouth or narrow constrictions.

Comparison for measures taken in Mandakini Valley after Kedarnath flood & Jhelum Valley after Kashmir flood

Alluvial rivers are usually meandering in nature and, therefore, raise problems of erosion and silting at various locations. This is a natural phenomenon and results in loss of land at one location and gain at some other. Generally, there is a tendency of the meander to shift progressively downstream. The process of bank erosion is, therefore, consistently active and measures for protection of banks are a recurring necessity. Anti-erosion works are normally taken up only for protection of towns, industrial areas, groups of thickly populated villages, railway lines and roads where re-location is not possible on socio-technoeconomic grounds, long lengths of vital embankments benefitting large areas in case retirement is not technically or otherwise feasible and agricultural lands where the cost-benefit ratio justifies such works.

There was a catastrophe in Mandakini valley on 16th& 17th June 2013 due to bursting of Chorbari Lake which was situated at an elevation of approximately 3746 m above mean sea level upstream of Sri Kedarnath temple, After the catastrophe/cloud burst of June2013, when the debris deposited on the hill slopes were washed to the Mandakini River, the quantum of debris was much more than the carrying capacity of the river due to which Mandankini river bed was raised from 5 to 8. M. These extra debris are being transported to the downstream during the Monsoon period, the river is yet to achieve the regime conditions. Dredging will accelerate the movement of debris deposited in the upstream towards the dredged area, and during the first rain the dredged stretch of the Mandakini River may be aggregated to its original level due to deposition of eroded material from the upstream side of Mandakini & Songanga due to steeper slopes.

i. Upstream of Sonprayag, the river bed slope of Mandakini has been computed as approx. 66m/Km, and for the Songanga river as 63.70m/Km while as the Mandakini river bed slope in the proposed river stretch for dredging is 52.5m/km & after dredging this river stretch, the changed river bed slop will be 59.0m/km, this indicates that the debris in the river bed of Mandakini as well as Songanga will have a tendency to move towards the downstream side till the regime flow of the river is attained.

ii. After disaster in June 2013 in Kedarnath Valley, the Mandakini River slope downstream of Sitapur/Byung diversion side upto Ukhimath town has been computed as 30.44m/km, that indicates that the Mandakini River will not be able to transport the additional bed load from the upstream of Sitapur towards the downstream side due to gentler river bed slops in the downstream due to which, the river current will slack down and most of the bed load will drop there itself, thereby further reducing the river bed slope, resulting in more aggradation to the river bed.

iii. It is very difficult to maintain the straight dredged channel of the river due to the tendency of erosion of bed & banks and deposition of shoal in the river bed, again to form a sinuous channel. This tendency will be more dominant as the river flows in a concave shape in the river stretch proposed to be dredged, as the river have got a tendency to erode along the outer bank and deposition along the inner bank.

iv. Heavy bank protection will be needed to protect the bank to retard the meandering tendency of the river, which is a natural phenomenon for the rivers, especially in the hills where the bed slope are high.

Hence throughout Mandakini valley after disaster in Kedarnath in June 2013. Intensive anti-erosion/bank protection works have been executed to protect the area, from the probable erosion due to the river flow/meandering tendency of the river.

The low carrying capacity of the Jhelum river is due to very mild slope of the order of 1/10000 between Sangam and Wular lake resulting in very low flow velocity in the river reach of about 96 km. This slope also results in steep rise of river water level in case of high discharge in river. The bowl shape of the valley and very mild slope of river makes the area between Sangam and Wularlake susceptible to flooding in case of heavy rainfall in the drainage area. This aspect needs to be considered while taking any future development work in the adjoining area of Jhelum between Sangam and Wularlake.

To reduce flood damage and to increase the flood routing efficiency of Wullar Lake, & the enhancement of discharge capacity of River Jhelum in general and of out fall channel it requires immediate dredging on short term basis to develop hydraulic efficiency of water courses system of the valley. The bed grade of River Jhelum from its source up to Wular Lake and from Wular Lake up to Khadinyar Srinagar O.F.C is very mild and from Khadinyar onwards the grade increase rapidly while flowing through Uri into Pak Occupied Kashmir. Under regard of same there is a large scope of increasing the bed grade of out fall channel from Ningli (Sopore) up to Gantmulla, which can tremendously increase the discharge carrying capacity of out fall channel as well as that of Jhelum. Total Estimated quantity to be dredged out from river Jhelum from different stretches is approx. to the tune of 18.001 lac cum.

The above details indicate that in the channelization work of Jhelum River, the river section is being widened and slope is proposed to be steeped from very mild to enhance the discharge carrying capacity of the river, as to avoid the submergence of city population. This can be achieved as the river slope beyond the outfall channel is steeper than that of the Jhelum River in Srinagar City, while as in case of Mandankini River, it is not so & these is every possibility for scouring of bank, movement of debris & dredged bed may be silted in the very first rains/flood so intensive anti-erosion/bank protection works has been executed in Mandakini Valley as an protection measure.

Hence, from above it may be stated that various measures may be adopted as per situation which may be different for different locations.

Eroded bank of Mandakini Valley after Kedarnath flood

Flood protection work carried out in Mandakin valley

REFERENCES

1. G.F.C.C. Guide line, Jan. 2004.
2. National Disaster Management Guidelines, Management of Floods, National Disaster Management Authority, Govt. of India, Jan. 2008.
3. Handbook for flood protection, Anti erosion & river training works, Flood Management Organization, New Delhi, Central Water Commission, June 2012.
4. Flood Management and Region Specific Issues for XII Plan.

Flash Floods: Challenges and its Management- A Case Study of Krishna River in Andhra Pradesh

Dr I Satyanarayana Raju
Former Chief Engineer and Past Chairman IEI-TSC, Hyderabad
✉ *indukuriraju8@gmail.com*

PREAMBLE

Floods are the out flows of Rivers by over topping their hydraulic cross section on to either flanks causing inundation for a certain period of time and mostly happening during rainy seasons. The primary reason being insufficient carrying capacity of rivers during high precipitation in self-catchment areas in shorter duration of time. Flashy floods are those that occur with a very short notice and beyond advance forecasting. Such flashy floods are very difficult to manage with very little time left for advance precautionary measures such as evacuating people to safer places in pre-flood situation, monitoring flood for safe passing in the river to downstream, and restoration of damages in post flood scenario. It is difficult to prevent floods since they come under natural calamities and the only remedy is to mitigate losses or damages to the extent of minimality. Hence, an able environment needs to be created to face challenges by effective management strategies.

DISASTER, DISASTER MITIGATION AND MANAGEMENT

A disaster can be defined as a calamity that can be either natural or man-made that causes human suffering and creates human needs that victim cannot alleviate without assistance (American Red Cross).

Disaster mitigation is an ongoing effort to lessen the impact of disasters that are likely to affect people and property. Because of the varying degree of each natural disaster, there will be different mitigation strategies. Disaster management is the process of addressing an event that has the potential to seriously disrupt the social fabric of the community and is similar to mitigation. But it implies a whole-of-government approach to use community resources to fight the effects of an event and assumes that the community will be self-sufficient for periods of time until the situation can be stabilized. Through disaster management, we cannot completely counteract the damage but it is always possible to minimize the risks through early warning, provide developmental plans for recuperation from the disaster, generate communication and medical resources, aid in rehabilitation and post-disaster reconstruction.

FLOODS AND FLOOD DISASTER

Floods are the most common natural disasters. Flood is a natural calamity occurring repeatedly in every rainy season. Flood is an over flow of water from water bodies, such as a lake or river or it may occur due to an accumulation of rain water on saturated ground in an area of flood. Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel and may be local or affecting the entire river basins. Flash flooding is most dangerous and can occur when a man-made structure, like a dam or levee, collapses from too much water pressure.

Floods will be unprecedented and give little or no time to take preventive measures. Flood inundate agriculture fields, habitations and result in loss of property, livestock, and human lives. These are the direct effect of floods and indirect loss is multi-fold at the cost of state's economy. To attain normalcy we may resort to temporary restoration which takes few months or permanent restoration requiring 1-2 years depending on funds availability.

A flash flood is a rapid flooding of low-lying areas: washes, rivers, dry lakes and depressions. It may be caused by heavy rain associated with a severe thunderstorm, hurricane, tropical storm, or melt water from ice or snow flowing over ice sheets or snowfields. Flash floods are distinguished from that of regular floods by having a time scale of fewer than six hours between rainfall and the onset of flooding. Flash flooding occurs when it rains rapidly on saturated soil or dry soil that has poor absorption ability. The runoff collects in gullies and streams and, as they join to form larger volumes, often form a fast-flowing front of water and debris. Flash floods occur mostly in dry areas that have recently received precipitation, but they may be seen anywhere on the downstream from the source of the precipitation, even many miles away from the source.

Indian Scenario

India is having a geographical area of 329 million hectares of which about 45 million hectares is flood prone. Governments have tended to react spasmodically whenever floods occurred in disastrous form. The initial response to flood damage was to try to 'control' floods through structural means such as dams or embankments. On the other hand, while flood-moderation has been very modest, the extent of suffering, damage and economic loss caused by floods and the magnitude of government expenditure on 'relief' have been growing because of a number of factors. It is increasingly recognized that what we must learn to do is not so much to 'control' floods as to cope with them when they occur and minimize damage, partly through 'flood-plain zoning' (i.e., regulation of settlement and activity in the natural flood plains of rivers) and partly through `disaster-preparedness'. Unfortunately, `flood-plain zoning' has been found politically difficult. As for `disaster-preparedness', the most important element in this is timely knowledge. Governments, local bodies and people need to know how soon a flood is likely to arrive, and what its magnitude is likely to be. They can then take appropriate measures for the prevention or minimization of hardship, loss and damage and for relief where necessary.

Only 18.80 Mha, out of the total flood prone area of 45.00 Mha, is protected. The length of total embankment constructed for 35200 km and length of drainage channels provided in all River basins and deltas is of order of 39700 Km. The immediate challenge is to mitigate floods in India is to enhance present flood protected area to 45 Mha from present 18.8 Mha. Hence, there is an identified gap to protect flood prone areas in India which the Government is taking all steps in staged manner with financial planning.

DISASTER MANAGEMENT ACT-2005

The Disaster Management Act was enacted on 23rd December, 2005.The Act provides for establishment of three tier Authorities in respect of Disaster Management at National level, State Level and District level. They are National Disaster Management Authority (NDMA), State Disaster Management Authority (SDMA) and District Disaster Management Authority(DDMA). The Act also provides for establishment of National Institute of Disaster Management (NIDM),National Disaster Response Force (NDRF), National Disaster Mitigation Fund (NDMF) and National Disaster Response Fund (NDRF). The same are in place for management of all notified Disasters in the Country.

National Disaster Management Authority (NDMA)

It is an apex Body of Government of India, with a mandate to lay down policies for disaster management. National Policy on Disaster Management-2009 was released by Ministry of Home Affairs, Government of India. It covers all the aspects of disaster management - institutional, legal and financial arrangements, disaster prevention, mitigation and preparedness, techno-legal regime, response, relief and rehabilitation, reconstruction and recovery, capacity development, knowledge management and research and development. Disaster Management Act 2005 mandated the NDMA to lay down policies on disaster management.

National Disaster Institute of Management (NDIM)

NIDM is a Premier Institute mandated by NDMA as well as Guidelines of Disaster Management Act-2005 for training and capacity development programs for managing natural disasters in India on national level as well as regional basis. It is to be a Deemed University and Institute of Excellence on higher learning and capacity building. UGC has been working out with NIDM and developed a model curriculum for strengthening disaster management in higher education and research. Most of Central Universities have envisaged Centre for Disaster Management under their School of Environmental Studies. A core group is being formed with UGC-NIDM to promote the subject at Academic Staff Colleges as well.

A CASE STUDY OF KRISHNA RIVER FLOODS IN ANDHRA PRADESH

About Krishna River

Krishna is the largest river next to Godavari and flowing for a length of 1342 km from its origin Mahabaleswar in Maharashtra state before emptying in to the Bay of Bengal and it is an interstate river. It also traverses through Karnataka in between Maharashtra and Andhra Pradesh states. There are no major Dams in Maharashtra but Almatti dam and Narayanapur Anicut are the major projects which are in existence in Karnataka state.

Earlier in combined state of Andhra Pradesh, it flows for a length of 567 km and entering at Jurala Project which is now in new Telangana State after bifurcation in the year 2nd June 2016. The Krishna River further passes through Srisailam Dam, Nagarjuna Sagar Dam which are now the joint major multipurpose projects of Andhra Pradesh and Telangana states. Down below, the River passes in the State of Andhra Pradesh through Dr KL Rao Pulichintha Project and Prakasam Barrage, a terminal structure before it empties in to Bay of Bengal.

Flood of Krishna River

The Krishna River in October 2009 has received unprecedented floods at Srisailam Dam from Krishna basin of 25.40 lakh cusecs magnitude which is more than thousand-year return flood. The previous highest recorded flood in the past hundred years for Krishna basin is 9.11 lakh cusecs on 15th October 1998.The Irrigation Department and Government machinery adopted crisis management in mitigating such a volume of flood which is first of its kind in Krishna basin. The team of irrigation engineers monitored the flood meticulously through Srisailam Dam, Nagarjuna Sagar Dam and Prakasam Barrage and implemented strategy of Disaster Management Continuum of Preparedness, Management and Mitigation. This is a feather in cap of engineering fraternity of irrigation department who manned the projects at this crucial juncture and seen to it with minimal loss of life, property, no damage to structures and ultimately the flood got receded. Only two incidents have taken place during the floods. A breach on Krishna right flood bank at Oleru has occurred in Guntur District. The other one is outflanking of Sri Kotla Vijaya Bhaskara Reddy Sunkesula Barrage across Tunga Bhadra River in Kurnool District. These have resulted in inundation of Repalle town in Guntur District and Kurnool town, Sunkesula village in Kurnool District respectively. Also, Rajoli and Alampur villages in Mahaboobnagar Districts got inundated on other side of Sunkesula Barrage of Kurnool District. The breached flood banks were temporarily repaired on war footing within 3-4 days' time restoring normalcy. Apart the main Krishna River floods, there was a cloud burst in the tributary of Tunga Bandra catchment below Tunga Bhadra Dam of Bellary District in Karnataka and Kurnool District in Andhra Pradesh states. This cloud burst has resulted in 400-500mm rainfall in 48 hours exceeding earlier record precipitation since 1903 according to Indian Meteorological Department. This cloud burst is the lonely reason for Kurnool town inundation but receding of flood got delayed due to Srisailam Dam backwaters simultaneously.

Srisailam Dam Flood Management

The Srisailam Dam is designed for a thousand-year return flood of 20.20 lakh cusecs and for a discharge of 11.1 lakh cusecs at FRL +885.00 ft(+ 270.00M) and 13.2 lakh cusecs at MWL +892.00 ft (+272.38M) including the power draft. Whereas, the occurrence of 25.40 lakh cusecs flood flow is received to Srisailam Dam. The Probable Maximum Flood (PMF) estimated at dam site is computed as 26.80 lakh cusecs and the same is almost matching to the 2009 flood occurrence. Srisailam Dam is a gravity dam abutted by two high hillocks and the spillway located in between this short gap got a constraint for out flow of flood. Hence, the reservoir level shooted up to +896.50ft at 11am on3-10-2009 and continued up to 6am on 4-10-2009.At this flood level, the spillway could able to surplus 14.50 lakh cusecs flood and another 50,000cusecs passed through Pothireddypadu regulator and breaches of S.R.B.C canal and entered Kundu river of Pennar river basin. Srisailam Dam is a pride of engineering marvel of irrigation engineers who built the Dam with dedication and within available technology and machinery at that time in 1950s. The Dam stood against huge flood inflows of 25.40 lakh cusecs and after flood routing, the balance flood of 14.50 lakhs could be safely passed through spillway by regulating the flood without any damage to the dam. Thus, the dam was tested for the range of PMF of 26.80 lakh cusecs by properly managing and regulating a flood of 25.40 lakh cusecs.

Nagarjuna Sagar Dam Flood Management:

Nagarjuna Sagar Dam is one of the largest dams in length and capacity in India. It is situated on the downstream of Srisailam Dam with its foreshore almost touching the toe of the Srisailam Dam. The FRL of Nagarjuna Sagar Project is 590.00ft/179.832M. The 1000-year return flood as finalized by CW & PC in the year 1966 is 19 lakh cusecs. The dam is designed for Maximum Flood Discharge (MFD) through its spillway and Power Houses of 13.15 lakh cusecs at FRL + 590.00ft(+179.832M) and 15.9 lakh cusecs discharge at MWL. The actual spillway capacity is of 15.3 lakh cusecs at MWL+594.00ft (+181.051M) and discharge of 35,000 cusecs through main power units and another 25,000 cusecs through canals) and 13.83 lakh cusecs at FRL.

During October 2009 floods, dam authorities effectively did the flood routing at Nagarjuna Sagar Dam. The inflows to Nagarjuna Sagar Dam have commenced initially with 56,000 cusecs from Srisailam Spillway and 69,000 cusecs through power draft on 30.9.2009 at 7.20 PM and gradually rose to a magnitude of 4.82 lakh cusecs at 6.00 AM on01-10-2009 and 10.41 lakh cusecs at 6.00 PM of the same evening. A maximum of 14.66 lakh cusecs flowed into reservoir at 6.00PM on 03-10-09. Then the flood started receding and by scientific operation of the spillway gates of NSP and the outflow could be restricted to a maximum of 10.22 lakh cusecs on 4-10-2009 at 12.00 noon. This is against the previous highest record of 8.60 lakh cusecs occurred on 16th October 1998. The maximum flood discharge that released was released through the dam is 10.50 lakh cusecs on 3rd October though there is a flood inflow of 14.66 lakh cusecs at 6.00 pm on 3rd October 2009. This was necessitated and done keeping in view of the safety of the downstream Prakasam Barrage which is designed for a MFD of 10.60 lakh cusecs.

Prakasam Barrage Flood Monitoring

Prakasam Barrage is an upgradation (1952-58) of erstwhile Krishna Anicut conceived by British Engineer Sir Arthur Cotton and built by Captain ORR during 1852-1855. The barrage is a lifeline of 5- south coastal districts viz., West Godavari, Krishna, Guntur and Ongole with a discharge of order of 13.00 lakh cusecs to Andhra Pradesh. It is designed for maximum flood discharge of

RESERVOIR CAPACITIES AND OUT FLOWS

Name of Reservoir	30/09/09		01/10/09		02/10/09		03/10/09	
	Capacity TMC	Flows Lakh c/s	Capacity TMC	Flows Lakh c/s	Capacity TMC	Flows Lakh c/s	Capacity TMC	Flows Lakh c/s
ALMATTI	128.0	0.27	128.0	**1.06**	123.7	1.73	113.0	3.25
Naray'pur	37.4	0.50	34.6	**2.10**	29.8	4.35	30.9	4.74
UJJAINI	99.7	0	99.8	**0**	99.8	0	99.8	0
TB DAM	104.0	0.31	104.3	**0.45**	103.4	1.96	103.0	1.21
JURALA	10.2	0.34	10.2	3.76	8.64	6.04	10.1	10.20
SRISAILAM	260.3	0.68	260.8	5.41	241.45	9.65	330.0	13.15
NS DAM	262.1	0.25	273.6	0.15	333.43	4.34	369.7	8.17

49

MAXIMUM OBSERVED INFLOWS OF THE RESERVOIRS

Sl No	Name of Project	Previous Highest			Present Floods(2009)		
		Date	Reservoir level Ft	Inflows In cusecs	Date	Reservoir level ft	Inflows in cusecs
1	JURALA	15/08/98	+1035.10	7,11,000	2/10/09	+1044.67	11,14,572
2	SUNKESULA	09/10/93	+957.76	4,00,400	2/10/09	+974.44	9,50,000
3	SRISAILAM	15/10/98	+884.50	9,11,000	3/10/09	+896.50	25,40,000

10.60 lakh cusecs at designed MFL of +72.00ft. The afflux is 4.05 ft above FRL + 57.05ft / 17.39 m. The barrage gates of 70 nos. of 12.87 m x 3.66m (40' x 12') surpluses floods through river in between Krishna and Guntur districts and there exists vulnerability on downstream of flood banks up to confluence of Bay of Bengal. The Prakasam Barrage is designed for 11.9 lakh cusecs.

The floods inflows at Prakasam Barrage were well monitored by advance action of opening all barrage gates on 2.10.2009 itself and by patrolling the flood banks down below with a crisis management plan. The inflows started with 50,000 cusecs and gradually rose to 11.10 lakh cusecs at 7.00 PM of 5.10.2009 and continued up to 9.00 AM on 6.10.2009. A flood of 10.94 lakh cusecs flood is discharged on midnights of 5th & 6th October, 2009.

Then onwards the flood started receding and normalcy was restored on 9.10.2009. This 11.10 lakh cusecs flood is a historic flood that is likely to occur once in 1000 years. The previous highest flood discharge from the barrage in last 100 years is only 9.32 lakh cusecs.

By meticulous flood management at barrage by department, it was safeguarded and so was also downstream flood banks on Krishna District. But a breach occurred at 60.80 km on right flood bank in Guntur District near Oleru village at early hours of 6.10.2009 on downstream of barrage and due to release of 10.94 lakh cusecs from barrage and existing flood bank vulnerability at that location quite common in case of earthen flood banks.

Damages to Kotla Vijaya Bhaskara Reddy Sunkesula Barrage

The barrage is situated on the Tunga Bhadra River on upstream of Kurnool town. The erstwhile Sunkesula Anicut was built during 1863-1870 by the French and the asset was then was passed on to Britishers. This Anicut was now replaced by barrage and commissioned in the year 2004. The barrage is designed for a maximum flood discharge of 5.25 lakh cusecs with 30 m. of 18 x 7.3 m gates at FRL + 292.00 m and storage capacity is 1.20 TMC. During October' 2009 floods, the inflows suddenly increased from 3.00 lakhs cusecs to 6.14 lakhs cusecs at 2.30AM on 2-10-09 and ultimately reached to an order of 9.00 lakh cusecs. This sudden flood caused the breaching and wash away of the barrage earth dam on right side and flood banks on either side inundating the Kurnool town and Sunkesula village in Kurnool District. Rajoli and Alampur villages in Mahaboobnagar District on other side of barrage were also inundated. This happened due to historic flood of 9.00 lakh cusecs that occurred against designed flood of 5.25 lakh cusecs. Also, the Handri River and Kurnool Cuddapah (KC) Canal are passing right through Kurnool Town and Tunga Bhadra is flowing parallel to the left side of Kurnool town. The earth dam and flood bank breaches were restored on war footing and water supply through K C Canal could be restored not only for drinking water requirements but also to sustain Kharif crop of order 2 lakh acres under K C Canal.

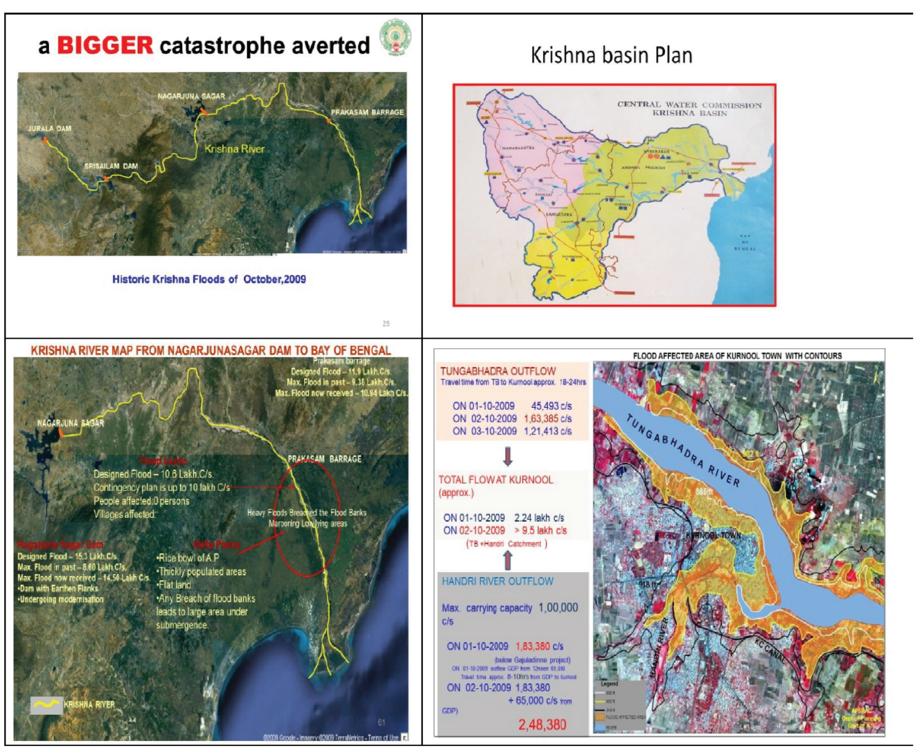
Krishna River Floods in August 2019

After the mighty historic floods of 2009, there are only occurrence of normal floods in Krishna River in the subsequent 10 years. Their magnitude is much below the designed out flow capacities of Srisailam Dam, Nagarjuna Sagar Dam, K L Rao Pulichinthala (newly constructed) and that of Prakasam Barrage. After a decade, a flood of order of 7.50 lakh cusecs has occurred in Krishna River on 16th August 2019 which are within designed outflow capacities of series of dams in the Krishna River Basin.

Mitigative Measures suggested for future management of floods of Krishna River:

A. Jurala Project(Telangana State)

1. The hydro mechanical components of barrage need to be kept up by regular maintenance and periodical replacements from time to time.
2. The new gantry crane and stop log elements need to be positioned and commissioned.
3. The damages to the spillway bucket to be kept up.



B. Srisailam Project(Joint Project of Andhra Pradesh and Telangana States)

1. The hydro mechanical components need regular maintenance and periodical replacements.
2. The balance scour protection works of plunge pool on downstream of Srisailam spillway to be expedited.
3. There is no possibility of enhancing spillway capacity due to narrow gorge site constraint. The Central Water Commission (CWC) suggested to explore possibility of tunnel escapes to accommodate additional flood outflows over and above designed discharges. Hence, the instrumentation of dam to be kept up for timely measurement of deformation due to higher floods over and above the designed and measures are to be attended on war footing.
4. The dam authorities and TSGENCO, APGENCO have to jointly conduct hydrographic survey on downstream plunge pool to replenish the scours periodically and constitute joint teams on permanent basis.
5. The existing cable car of Srisailam Dam needs to be kept up for emergencies as part of flood management.

C. Kotla Vijaya Bhaskara Reddy Sunkesula Barrage near Kurnool (Andhra Pradesh)

1. The washed away earthen bund and flood bank breaches occurred during 2009 floods were restored for normal floods. It is established that the barrage received higher flood than designed resulting in outflank over flows. Hence, the required additional vents of barrage need to be extended for additional discharge towards left side and new earth dam in continuation to be formulated. All these additional components need to be designed for Observed Maximum Flood Levels (O.M.F.L) of October 2009 floods. This aspect of structural measure is a priority item to be addressed by state of Andhra Pradesh as part of flood management of Thunga Bhadra River.
2. For Kurnool town of Andhra Pradesh, the flood protection works of Handri River and new Tungabhadra left side flood bank need to be strengthened to mitigate and manage floods to safe guard Kurnool town.

D. Nagarjuna Sagar (NSP) Dam(Joint Project of Andhra Pradesh and Telangana States)

By proper flood monitoring and management by dam authorities, the dam could safely pass a flood of 10.50 lakhs cusecs during October 2009 by flood routing of flood inflow 14.66 lakh cusecs on 3rd October 2019. Now it is established that there is likelihood of flood inflows over and above designed flood. Hence, the spillway capacity needs to be enhanced by an additional spillway or providing a breaching section in the earth bund on right flank. Repetitive scours are occurring on the glacis of spillway and permanent measures have been carried out in modernization of project under APWSIP. The dam safety measures of NSP have been attended by dam authorities under APWSIP (World Bank aided) programme during 2010-2016. The hydro mechanical components require regular annual maintenance and periodical replacements as per protocol.

E. Prakasam Barrage (Andhra Pradesh)

1. The stage-I,downstream protection works require review for implementation on observing the performance of stage-I works carried out prior to 2009 floods. Though all 70 gates were replaced during 2002-2003, the hoisting arrangements were not replaced. The same is now suggested to be carried out.
2. With regard to flood banks, the restoration and improvements of both left and right side of the river down below the barrage have been carried out. The same require annual and periodical maintenance with proper financial budget for upkeep as part of flood management.
3. On upstream of river also there are some vulnerable habitations and they need to be protected by new flood banks or protection walls due to space constraint.

4. Encroachments in the downstream river margin by dwellings of poor in Vijayawada Municipal Corporation is social issue to address by suitable steps of evacuation, otherwise the state has to incur expenditure on recurring temporary evacuation-relief measures in every flood season.

F. K L Rao Pulichintala Project (Andhra Pradesh)

The project with a storage capacity of 45 TMC was completed on upstream of Prakasam barrage near Jaggaiahpeta in Krishna District after 2009 Krishna floods. Now there will be additional flood routing and safety to the Prakasam barrage enhanced with flood regulation facility on upstream unlike down below Nagarjuna Sagar Dam. Because of this development the management of floods at Prakasam barrage was eased by regulation of flood at K L Rao Pulichintala project situated at about 50 km on upstream Prakasam barrage.

SUGGESTIONS FOR FLASHY FLOOD MANAGEMENT IN KRISHNA RIVER IN AP AND TELANGANA STATES

1. Software for flood estimation for hourly rainfall, dam break analysis and inundation assessment are to be procured.
2. One-meter contour interval digital contour maps for 5 km distance extended on either side of the river course are to be in place.
3. Relocation of people from low lying areas along Krishna, Thungabhadra Rivers specially at Alampur, Rajoli, in Telangana State and Krishna river margin in Vijayawada town of Andhra Pradesh.
4. Dam gates, gantry crane, stop log gates of dams on Krishna River must be ensured in working condition before every rainy season.
5. State Dam Safety committees of both Telangana and Andhra Pradesh must inspect the dams every year and ensure in implementation of guidelines for operational plans for the flood management.
6. Prakasam Barrage (Andhra Pradesh) flood banks works with modified TBL considering 1.8 meters free board to be kept up.
8. More numbers of floating bulk head gates to be procured against existing two gates for safety of Pakasam barrage in Andhra Pradesh in absence of emergency gate arrangements.
9. Flood banks of Sunkesula barrage and additional spillway with new left earth bund to be taken up for flood discharge over and above designed flood of 5.25 lakh cusecs in view of experience of maximum flood of 9.00 lakh cusecs in Andhra Pradesh and Telangana States.
10. Flood banks to Hundri and Tungabhadra to protect Kurnool city to be taken up for considering Observed Maximum Flood levels (OMFLs) of 2009 floods.
11. Protection of Alampur town by raising retaining wall and permanent restoration of the pumping scheme with new motors of higher capacity in Telangana State is suggested since the town is located in Srisailam foreshore adjoining to Krishna River left side flank.
12. Satellite phone placed in Andhra Pradesh coastal districts is now required in other parts of Andhra Pradesh and also in Telangana State.
13. Modernization of the existing flood control centre at Hyderabad (Telangana) and at Vijayawada (Andhra Pradesh) with the historical record and Decision Support Systems in place.
14. Request could be made to upstream inter-state Karnataka to retain flood water in Karnataka dams with transit time where there is forest or remote uninhabited areas inundation is likely.
15. The option of flood discharge tunnel for dams could be explored to increase the flood water disposal capacity for Srisailam Dam due to constraint of spillway expansion in river gorge.
16. During the flood rise, seepage along the rear side of the flood banks has to be observed as

part of patrolling. During the receding flood, there is a possibility of slippage of flood banks on the river side as they will be wetted and needs vigilant patrolling.

17. Installation of automatic recording rain and river gauges having capability of measuring at frequent intervals and to transmit the data to the places of decision making without loss of any time specially for the catchment area of Srisailam dam.

CONCLUSIONS

Floods are natural calamities which cannot be foreseen unlike other calamities. Even the forecasting with early warning systems can alert for preparedness, managing, mitigation of floods but cannot be prevented. History established that series of projects all along the river are effectively routing the floods as in case of Krishna River and severity is comparatively less. Also, the flood protection works such as flood banks either new or upgradation on all major rivers has to be expedited to withstand latest experienced historic floods. The government institutions and stake holders need to be trained on flood mitigation,management activities on a continuous basis be regularly organized to safeguard the projects with proper annual and periodic maintenance. A revolving fund is to be established in the annual state budget for dam safety of all projects in the states for upkeeping the safety of dams.

The Disaster Management Act-2005 has dealt with structural and non-structural measures, guidelines to prevent-manage -mitigate disasters and relief measures. The Act contains provisions with enforceability, roles and responsibility of Institutions- officials. The states have to implement the same to mitigate flashy floods happen to occur in every season. Hence Flood Disaster management by continuum of Preparedness-Management, Mitigation -Relief, Reconstruction is possible and the only way out for flashy floods management and mitigation.

REFERENCES

1. Revi, A (2005), "Lessons from the deluge: priorities for multi-hazard risk mitigation in Mumbai", Economic and Political Weekly Vol XL, No 36, pages 3911–3916.
2. Disaster Management Act-2005 of India.
3. National Policy on Disaster Management-2009.
4. Managing Historic Floods -In Krishna River Basin October 2009 in Andhra Pradesh, India (A publication of AP Water Resources Development Corporation-I&CAD Dept, AP (2010).
5. Raju, I S N (2010), "Flood mitigation of Kurnool town", Paper presented at a one-day seminar on Recent Floods in Andhra Pradesh – Retrospect and Prospect, Hyderabad, India, 12 January.
6. Srinivas Rao, A (2010), "Srisailam dam in October floods", Paper presented at a one-day seminar on Recent Floods in Andhra Pradesh – Retrospect and Prospect, Hyderabad, India, 12 January.
7. C Ramachnadraiah, "Coping with urban flooding: a study of the 2009 Kurnool floods, India" published in Environment and Urbanization (IIED Journal) Volume 23 No.2 October 2011.
8. WikipediaGoogle search dated 17th August 2020.

Flash Floods Challenges and It's Management: Case Study of Aji-III dam and Bhadar-II Dam Flash Flood – 2020

B P Bhimajiyani, D H Jadav, I K Shah, N H Patel
Rajkot Irrigation Circle, Rajkot, Narmada, W.R., W.S. and Kalpasar Department
Government of Gujarat
se.ric.nwrws@gmail.com

ABSTRACT

Short duration floods with moderate to high peak of inflow are cause of worries as it takes place in a short time duration that is span counted in few hours from the downpour event. It is with higher velocities and it provides least time to respond resulting heavy loss to life and potential damage to property and the economy. In minimum available time, response to such events is a great challenge. It requires establishment of flood forecasting, now-casting system, preparation of tentative action plans which may include well defined decision making mechanism, message dissemination system, way of creating mass awareness and preparedness programs for the public so that effects of such events can be reduced to possible extent.

Keywords : Flash flood, Forecasting, Action plan, Mitigation, Flood routing.

INTRODUCTION

Flood is an event of high stage in the river or stream due to heavy precipitation, ice-melt, outburst of lakes, dam break or releases from head work such as dam or barrage. In the recent past, due to climate change, incidents of high intensity rainfall in short duration has occurred frequently in India and almost in all continents. According to duration, floods can be categorized in three categories, long duration flood with moderate to high peak of inflow, medium duration floods and short duration floods. Long duration and medium duration floods are favourable from the point of forecasting and mitigation whereas short duration floods are cause of worries.

Flash Floods and It's Generation

A flash flood is a sudden local flood of great volume and short duration which follows within few (usually less than six) hours of heavy or excessive rainfall including cloud burst and heavy cyclonic storm, due to dam or levee failure or the glacier lake outburst flow (GLOF) generation in the river stream. From the hydrological point of view, factors that have a decisive influence on the occurrence of flash floods - apart from the intensity and duration of the rainfall are the topography, soil characteristics, soil conditions, shape of catchment and vegetation coverage of the terrain. Disadvantageous topographical conditions such as high-exposure (steeply sloping) highland terrains, narrow valleys or ravines hasten the runoff and increase the likelihood of flash flood occurrence. Saturated soil or shallow watertight geological layers increase surface runoff. Leaf shape catchment generates low peak with more period of time compared to fan shape catchment having rest of physiographic parameters same.

The phenomenon of the flash flood is one of the most difficult natural hazards to predict in terms of time, place of occurrence and magnitude. As a result, it is challenging for the concerned authorities and communities to respond appropriately and hence response plans are indispensable tools.

Danger Due to Flash Floods

As flash flood can take place in a time duration of few hours from the event that causes it to happen (excessive rainfall, failure of hydraulic infrastructure etc). There is a sudden rise in the water level in rivers and streams with higher flow velocity. The force of the water can be so great as to tear away boulders, uproot trees, and destroy bridges and buildings that stand in its path. A strong current of water only 60 cm deep can carry along most passenger automobiles. Therefore, all road depressions, via duct passes, bridges, and roads leading past riverbanks are unsafe during a flash flood.

Response to Flash Flood

Timely warnings could be the key element in reducing the risk to life and property. Unfortunately, forecasting flash floods is very difficult. Hydrologists and meteorologists claim that with the present progress in measurement, forecasting and now-casting technologies, the exact place and time of the flood occurrence is known only few hours before it transpires. The flash floods can take place almost anywhere, as intense rainfall can occur almost anywhere.

Technological means of flood protection and water storage constructions can and do help in many circumstances but cannot provide absolute safety from flooding.

Whether a given area is at risk of flash floods or not, and in what time periods, can be estimated by taking into consideration the climate, topography, drainage network and the scale and frequency of their past occurrence. For the estimation of hazard, it is also essential to have access to meteorological and hydrological data, as well as geological data and information collected from the residents concerning the floods that have taken place in the past. Real time telemetry system of rain gauges, river gauges, reservoir water levels, inflows and outflows from the river valley projects in the basin can provide decision support system to synchronise releases from integral system of dams in the basin so as to rationalize the combined outflow to reduce the effect to likely affected areas to the possible extent.

Determination of Areas of the Probable Risk

With the help of the topographical contour maps of downstream area, digital terrain models and demarcation of past historical inundation one can specifically determine probable area at risk due to flash flood in particular river basin.

Mechanism or Mitigation

For integral decision in the light of basin level intensity of flood event, role for decision making, coordination, dissemination of release message and evacuation warning to downstream authorities are required to be clearly defined. On the basis of past historical event data, tentative likely scenario generation and action plans can be worked out.

Flood Forecasting and Warning to the People of Affected Areas

With the help of flood forecasting and now casting techniques, though close estimation of flood volume may not be possible, with approximate forecasted volume of flood, using flood routing techniques, outflows can be determined in accordance with releases from other dams in the basin and decision taken can be communicated to people of downstream areas likely to come under influence with the help of local authorities and by short messaging system(SMS), television news bulletins, radio news etc.

Creating Awareness and Preparedness

Awareness in the downstream area can be created by conducting public addressing meetings at village level appraising them about the potential risk with some rationalization so that they may be mentally prepared to face the situation and they not panic due to rumours. Mock drills can be helpful to ascertain efficacy of the programme.

HOW TO TAKE THE ACTION FOR EFFECTIVE FLOOD ROUTING ?

This is a case study of a flash flood event occurred in August 2020 at Aji-III dam and Bhadar-II dam situated in Saurashtra region of the state of Gujarat. Following mechanism was functional during this event:

State Level

At state level, flood management is being closely monitored by state disaster management authority and central flood control cell which are situated in Gandhinagar in the state of Gujarat to monitor and take appropriate action to mitigate the effect of damage due to flood. Central flood cell collects round the clock data of precipitation and water storage of 205 important reservoirs from 13 regional flood control cells to provide alert message and mitigate evacuation during upcoming situation.

Basin Level

Basin level flood management is crucial for flood management and effective flood routing. At basin level, dam authority is continuously in touch with upstream dam, revenue authority and local sources of information to analyse incoming runoff in the dam. After calculating probable incoming discharge, during expected time duration dam authority takes decision to pre-deplete water level and create possible cushion to store incoming runoff and reduce the peak of flood to reduce downstream potential hazards

District Level

Disaster management authority of district continuously monitors situation and takes appropriate action based on flood release from the upstream reservoirs and inundation map of downstream areas.

Local Level

Before releasing flood from the reservoir, dam authority warns downstream population and relevant downstream authorities of important structures situated on the river.

BRIEF DESCRIPTION

AJI-III Water Resource Project(WRP)

Aji-III Irrigation Scheme is constructed across river Aji near Village Khajurdi in Padadhari Taluka of Rajkot District. The construction of Head Works was started in the year 1979 and the project was completed in year 1988. The scheme has 18 Nos Radial type gate of size 12.50 m X 8.23 m. The catchment area of scheme is 1378.54 sq. km. Main tributaries of Aji River is Dondi, Nyari, Khokhad-Nadi etc. Aji-III Dam is constructed on the downstream side of the Aji-I, Aji-II, Dondi, Nyari-I and Nyari-II Dam.

Salient features of Aji-III Dam

Table 1 Salient features of Aji-III Dam

Location :	near Village Khajurdi about 16.00 km from Padadhari Taluka :- Padadhari District:- Rajkot.
Latitude :	220 31’ 00” N , Longitude 700 34’ 25” E
Name of river :	AJI-III
Catchment area :	1378.53 sq. km,
Average rainfall :	22.36 inches / 559 mm
Design flood :	488477 cusec /13832 cumecs Original / Silt Survey 2015
Gross storage :	2187.58 Mcft / 1756.78 Mcft, 61.94 Mcum / 49.74 Mcum
Dead storage :	167.39 Mcft. / 127.84 Mcft. 4.74 Mcum / 3.62 Mcum.
Live storage :	2020.00 Mcft/ 1628.94 Mcft 57.20 Mcum/ 46.12 Mcum.
H.F.L. :	R.L. 178.93 ft. (54.54 m)
F.S.L. :	R.L. 174.37 ft. (53.15 m)
C.C.A. :	6635.00 Ha
G.C.A. :	8108.00 Ha

Aji-III reservoir Photo

Fig. 1 Photo of Aji-III dam

Line diagram showing ***(Fig. 2)*** *various reservoirs on U/S of Aji-III WRP*

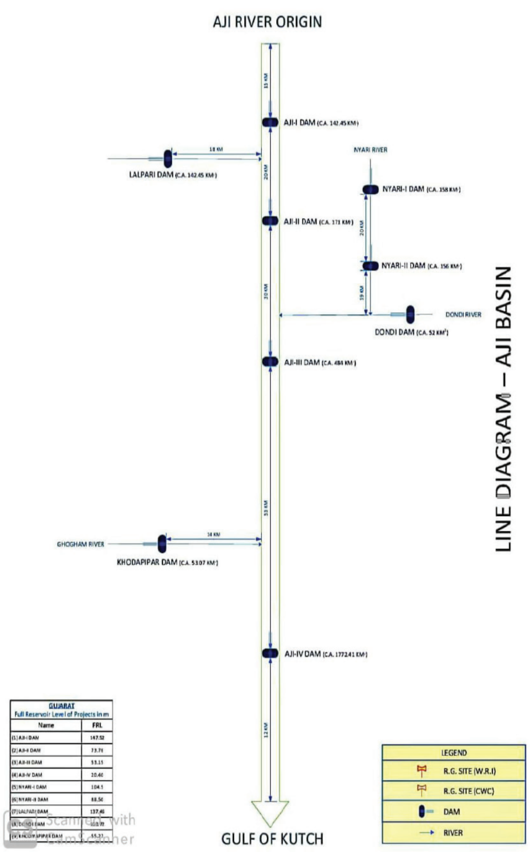


Fig. 2 Various dam on U/S of Aji-III WRP

Aji-III Fan Type Catchment area map in ***Fig. 3****.*

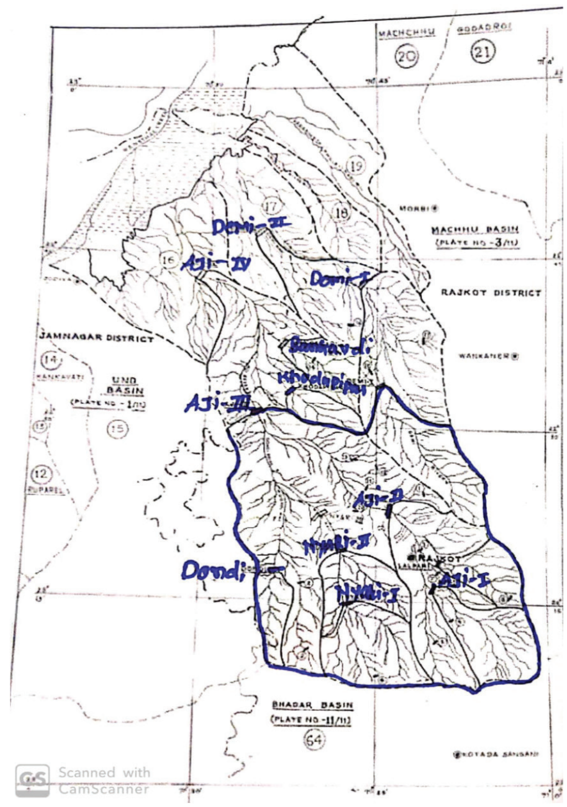


Fig. 3 Aji-III fan type catchment area map

Rule level Tables.

Table 2 Rule level tables

Date	Rule Level.		Gross Capacity	
	ft.	m	M.C.F.T.	M.C.M.
1/7/2020	172.41	52.55	1819.60	51.520
1/8/2020	173.40	52.85	1990.53	56.365
1/9/2020	174.37	53.15	2187.58	61.945
1/10/2020	174.37	53.15	2187.58	61.945

Bhadar-II WRP

Bhadar-II Reservoir Project is situated near village Bhukhi about 8.50 km from Dhoraji city of District Rajkot and located across River Bhadar of Bhadar Basin. The project is meant for irrigation and but also devised to meet the demand of water supply in shortages. The reservoir has gross storage capacity of 49.00 mm³ and live storage of 41.85 mm³ at FRL 53.10 m.

The project comprises of 3025meter long earth dam. The spillway is located in river gorge portion/in - saddle with corresponding Approach Channel and Tail Channel. The length of spillway is 405 m having 22 nos. of radial gates of size 14.93 x 10.67 m. (49'x35'). The non-overflow section to the left of spillway is 50.00 m. and to the right side is 50.00 m.

Salient features of Bhadar-2 Dam

Table 3 Salient features of Bhadar-2 dam

Location	:	On river Bhadar- near – village Bhukhi- about -8.50- km from Dhoraji-town of District Rajkot.
Latitude	:	21° 44' 40"N, Longitude 70°-25' 24"E
Name of river	:	Bhadar
Catchment area	:	4465.16 Sq. Km
Average rainfall	:	22.36 Inches ./ 559 mm
Design Flood (SPF)	:	26380.12 Cumecs (931589 Cusecs)
Design Flood (MPF)		**:**30338.18 Cumecs(1071327.30Cusecs)
Gross storage	:	49.00 Mm^3
Dead storage	:	7.15 Mm^3
Live storage	:	41.85 Mm^3
H.F.L.	:	53.10m
F.R.L.	:	53.10 m
G.C.A.	:	13608Hact.
C.C.A.	:	9965Hact.

Photo of Bhadar-2 shown in **Fig. 4**.

Fig. 4 Photo of Bhadar 2

Rule level Tables in **Table 4**.

Table 4 Rule level tables

Date	Rule Level.		Gross Capacity	
	ft	m	M.C.F.T.	M.C.M.
1/7/2020	167.32	51.00	1134.89	32.1
1/8/2020	170.60	52.00	1403.49	39.74
1/9/2020	173.88	53.00	1697.47	48.07
1/10/2020	174.21	53.10	1730.44	

Total 16 no's of reservoirs are situated on u/s of bhadar-2 dam. Line diagram showing **(Fig. 5)** Various reservoirs on U/S of Bhadar-2 WRP.

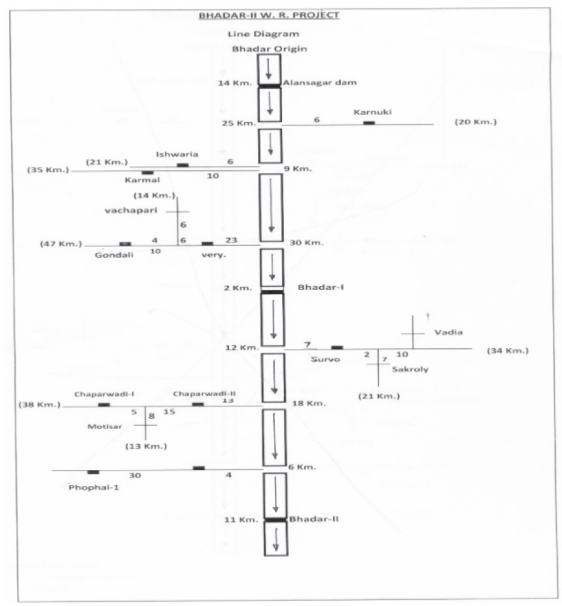


Fig. 5 Various dam on U/S of Bhadar-2 WRP

Photo of Catchment area of Bhadar-2 WRP in **Fig. 6**.

Fig. 6 Bhadar-2 fan type Catchment area map

NORMAL SCENARIO AND DETAILS DURING THE CALAMITIES OF FLASH FLOOD OCCURRENCE, PEAK FLOOD AND HIGH INTENSITY WITH SHORT DURATION

At the fag end of August month, IMD issued forecast of heavy to very heavy downpour for Saurashtra region. Based on this forecast, focal officers and concerned dam authorities were kept on high alert. Very heavy precipitation started as per IMD forecast. The dam authority was continuously in touch with upstream authorities, local source of information of catchment and were continuously analysing the rainfall data. As per prediction of IMD, precipitation of high intensity occurred and due to this surface run-off was very high. To mitigate this situation dam authority has preplanned to create cushion to store surplus flood water. Illustration is shown in **Fig. 7**.

STEPS TAKEN BY THE DEPARTMENT AND LOCAL AUTHORITIES FOR MITIGATION OF FLOODS

During IMD forecast period, concerned dam authority was on high alert and vigilant by collecting information from various website, satellite images and predicted possible rainfall on the day. Based on basin information like shape of catchment, infiltration rate, run-off coefficient etc. dam authority has decided to pre deplete the water level of dam based on calculated expected run-off and upstream dam condition as per the concept of flood routing, peak of the flood has been reduced and no serious incidents occurred in downstream of the river portion. Routed curves based on the and inflow outflow data of Bhadar-2 Dam and Aji-III Dam are shown below which clearly indicates positive results of flood routing and pre depletion of reservoirs.

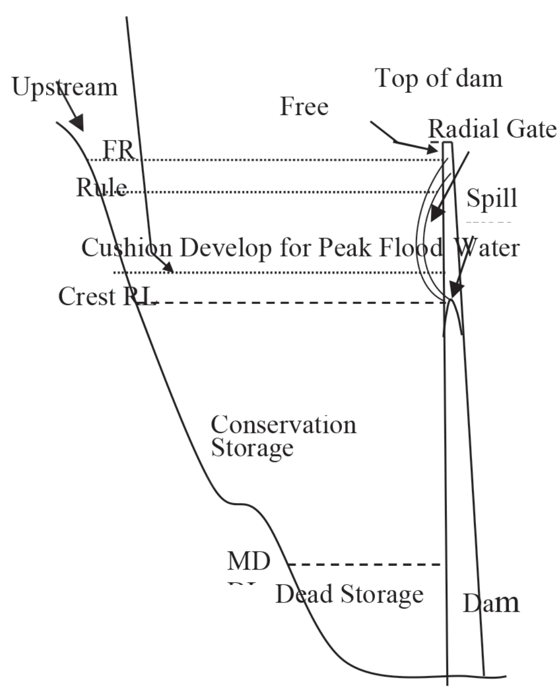


Fig. 7 Illustration of Pre depilation of flood discharge

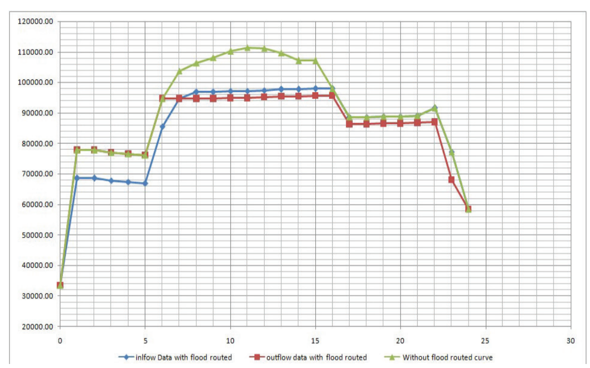


Fig. 8 Bhadar-2 flood routed curve

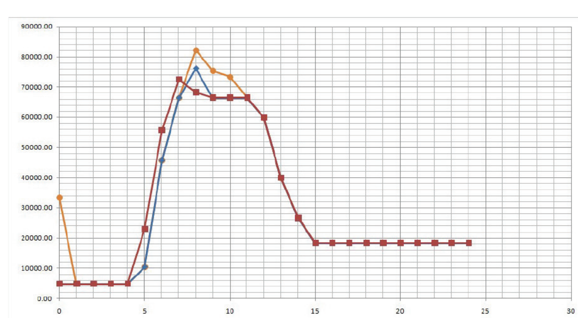


Fig. 9 Aji-III flood routed curve

Table 4 Cumulative discharge table

Name of Dam	Design Storage (MCFT)	Cumulative Discharge Passed in Monsoon Season 2020 (MCFT)	Percentage of Cumulative Discharge passed with respect to Design storage
Aji-III Dam	1756.78	33608	1913 %
Bhadar-II Dam	1730.44	81517	4710 %

CONCLUSION

Due to heavy downpour in the catchment areas of both dams, event of flash flood has taken place. The flood wave was negotiated with pre-depletion and peak of outflow was reduced compared to inflow peak for both reservoirs by taking real time appropriate decisions by the dam authority. Based on the experience of Aji-III and Bhadar-II Dam it is found that for taking quick decisions, past historic flood data are required to be kept handy such as Rainfall-Runoff coefficient, past inundations etc. This kind of flood situation can be handled with effective gate operation and applying flood routing techniques which can substantially reduce potential hazards in downstream of the reservoir.

ACKNOWLEDGMENT

In this monsoon season of year 2020 three flash flood was observed in such critical period of flash flood our focal officer & Superintending Engineer & Special Secretary Saurashtra guided us very well. Due to extensive experience and expertise of our Superintending Engineer & Special Secretary Saurashtra we were able to bring the flood under control without any potential hazards in downstream of river portion.

We are thankful to Special Secretary, Saurashtra Region and The Chief Engineer and Director, Gujarat Engineering Research Institute, Vadodara and Superintending Engineer, Rajkot irrigation circle Rajkot for offering their valuable time, providing important inputs, suggestions and valuable guidance to prepare this paper.

REFERENCES

1. A. G. Colombo, J. Hervás and A. L. Vetere Arellano, “Guidelines on Flash Flood Prevention and Mitigation”, European Commission Joint Research Centre, EUR 20386 EN, 2002.
2. Recent Experiences from Central and Eastern Europe, “Guidance on Flash Flood Management”, December 2007.
3. B. E. Montz, E. Gruntfest, “Flash flood mitigation: recommendations for research and applications”, Environmental Hazards 4, pp. 15–22, 2002.
4. C. A. Doswell Iii, H. E. Brooks and R. A. Maddox, “Flash Flood Forecasting: An Ingredients-Based Methodology”, Weather and forecasting, Vol. II, 1996.
5. K. M. Vandana, Dr. Sri Ram, “Flash Flood in Jammu and Kashmir”, International Journal for Scientific Research & Development|, Vol. 2, Issue 10, 2014.
6. A. D. L. Zanchetta, and P. Coulibaly “Recent Advances in Real Time Pluvial Flash Flood Forecasting”, Water, MDPI, February 2020.
7. “Flash floods: Observations and analysis of hydro-meteorological controls”, Journal of Hydrology 394, pp.1–3, November 2010 [8] Indian Standard code IS 7323: 1994 Operation of Reservoirs - Guidelines (First Revision, reaffirmed 1999).
9. Dam Safety Rehabilitation Directorate, “Guidelines for Safety Inspection of Dams”, Central Water Commission, New Delhi January 2018.

Flash Flood Hazard mapping using Satellite Images and GIS: A Case Study of Alaknanda River Basin

Sachchidanand Singh, M L Kansal
Department of Water Resources Development and Management, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand
mlk@wr.iitr.ac.in

ABSTRACT

Flash floods are one of the most catastrophic natural hazards, often characterized by fast-flowing water having short response time, increases the risk to individuals and property. In hilly areas followed by steep topography add to the adversity of flash floods. It is impossible to prevent or eliminate the consequences of flooding, but it is possible to work towards reducing its effects. One of the powerful tools for this purpose is flash flood hazard mapping to identify sites of high-risk flood areas. In this study, an attempt has been made to use satellite images and GIS tools to produce flash flood maps of the Alaknanda River Basin, located in Uttarakhand. Analytical Hierarchical Process (AHP) is used that estimates the relative impact weight of the flash flood causative factors. The causative factors identified are rainfall, slope, surface roughness, drainage density, time of travel, and curve number. Eventually, all the data used are combined into a GIS environment to create a flash-flood hazard map for the study area. The most affected villages are identified and are validated from the historical news reports and literature study. These results would help the policy makers to plan for effective disaster response strategies.

Keywords: Flash flood, Remote sensing, GIS, Analytical Hierarchy Process, Uttarakhand

INTRODUCTION

Uttarakhand, due to its proximity to geo-dynamically active locations and unusual climate patterns, is vulnerable to numerous natural hazards. These two factors also contribute to natural hazards such as flash floods, cloudbursts, earthquakes and landslides occurring in various combinations in different parts of the state [1]. The area of the North West of the Himalayas, according to [2], is exposed to rain-convinced dangers which lead to cloud bursts, flash floods and glacial explosions of lake. This state has endured several hydro-meteorological disasters (HMD). The HMD's severity and frequency have increased in the last 2 decades or so. Major HMD calamities are reported in 1970, 1986, 1991, 1998, 2001, 2002, 2004, 2005, 2008, 2009, 2010 and 2013, 2016 and 2018. Here, disaster severity is defined as the loss due to the instability of the physical, ecological & socioeconomic system [3].

Flash floods are among the most devastating natural hazards, often characterized by deep, fast-flowing water with limited response time, which raises the danger to individuals and properties. Flash floods contribute to riverbanks failures, undercutting of dams, accumulated waste and pollution, degradation of riverbanks, etc. Remote sensing and GIS assistance for water-related scientific research quickly [4], [5]. An important method to track threats and indigenous preparation considering the degree of vulnerability is flash flood risk mapping [6], [7]. Many flash flood threat studies have allowed us to understand, alleviate, strategize and enable us to progress commercially. While predictability helps minimize casualties that warn against evacuation, flood damage and economic losses cannot be decreased. The governance plays a significant role in mitigating flood by implementing effective risk management approaches including analysis of danger and uncertainty, space preparation, infrastructure management, disaster planning and control, flood hazard and danger modeling and insurance schemes [8].

STUDY AREA

The study area, Alaknanda River Basin, arises from the Satopanth and Bhagirath Kharak Glaciers, which come up in India from the Chaukhamba in the western Himalayas of Garhwal and is located between 78º 45’ E to 80º 15’ E longitudes and 30º 10’ N to 31º 5’ N, in Uttarakhand. The basin area is about 10278 sq. km., having outlet near Rudraprayag. The northern part of study region experiences severe cold climate. The elevation ranges from 594m to 7801 m.

The basin has a tropical monsoon climate with almost 75% of the rainfall in June – September [9]. The average annual rainfall lies around 1600mm. The region is highly prone to various natural disasters such as earthquakes, landslides, flash floods, cloudbursts, etc. The study area map is shown in **Fig. 1**.

MATERIALS AND METHODS

To classify flash-flood prone areas, this study used GIS-based spatial data for multicriteria analysis. The relative weights of the multi-parameters are determined using the Analytical Hierarchical Process (AHP) method [10] by way of structurally evaluating the relationships between chosen criteria and its effect on flash-flood. This method

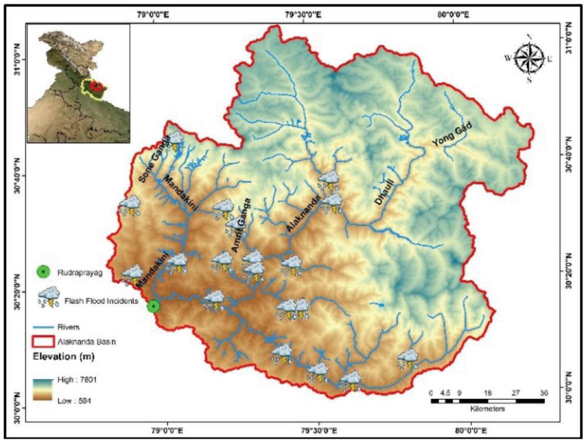


Fig. 1 The study area: Alaknanda river basin map

can be summarized in six steps, i.e., (1) define the unstructured problem, (2) establish the AHP hierarchy, (3) form the pair-wise comparison table, (4) calculate the relative weights, (5) check consistency and (6) validation of results. The thematic layers of the chosen factors were prepared and clustered for assigning rankings. Natural breaks classification technique is popularly used in MCDA-based flash-flood studies as it divides the data range into natural group-based clusters [11]. This method minimizes the variance within the classes and maximizes interclass variability [12]. The flash-flood hazard map is prepared in the GIS setting combining the relative weight of the parameters with parameter scores.

A. Factors Selection

In the semi-quantitative MCDA process, the selection of suitable parameters is most important. Earlier studies used multiple factors that affect the physical flash-flood mechanism [7], [13]. Since the region under study is characterized by high slope and elevation, dominated by numerous stream networks, six important criteria, namely, rainfall (R), slope (S), surface roughness (M), drainage density (DD), travel time (T), and curve number (CN) related to physiography, hydrology and surface characteristics are identified. In determining the risk of flash-flooding, rainfall is the most important parameter. Likewise, slope and surface roughness control the flow velocity over the surface. The drainage density reflects

Table 1 Various datasets used in the study

S. No.	Types	Data Description	Resolution/ Scale	Source
1	Topographical data	Digital Elevation Model (DEM)- SRTM	30 m	Google Earth Engine https://code.earthengine.google.com/
2	Land Use Land Cover (LULC)	Land Use Land Cover Map	1:250000	Indian Space Research Organization Geosphere Biosphere Program (ISRO GBP), India
3	Slope	Slope Map	30 m	From DEM
4	Soil data	Soil maps	1: 50000	National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur
5	Rainfall	Rainfall map- CHIRPS	0.05°	Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)
6	Travel Time	Sub-basin wise Time of travel map	30 m	Hec-GeoHMS in ArcGIS
7	Surface Roughness	Manning's Coefficient	30 m	According to LULC
8	Drainage density	Drainage density map	30 m	From DEM

the ability to drain out excess rainfall; travel time determines the time required for the rainfall to reach the outlet. Curve number depends upon the land use land cover and soil types, which determine the water holding and infiltration capacity of the area and consequently affect the flash-flood susceptibility. Various sources of datasets are provided in **Table 1**.

B. Scoring for Factors Weight

The AHP method is a semi-quantitative methodology that allows the weight estimation of factors, based on the opinion on the relative importance of factors against another for flash-flooding.

The important physical parameters are assigned values in a rating scale from 1 to 9. Next, in determining the relative importance of each criterion, the rating scores have been used as pairwise matrix comparison. The pairwise comparison matrix is shown in **Table 2** using 6 x 6 matrix, where diagonal elements are equal to 1. The values of each row are compared with each column to define the relative importance of each factors to obtain rating score. The score matrix was then normalized to get each parameter's corresponding weight. Ultimately, each parameter's weight was determined by taking the mean value of the corresponding row in the normalized matrix **(Table 3)**.

Table 2 Pairwise comparison of the factors

	R	S	M	DD	T	CN
R	1.00	2.00	3.00	5.00	7.00	9.00
S	0.50	1.00	2.00	3.00	5.00	7.00
M	0.33	0.50	1.00	2.00	4.00	6.00
DD	0.20	0.33	0.50	1.00	2.00	4.00
T	0.14	0.20	0.25	0.50	1.00	2.00
CN	0.11	0.14	0.17	0.25	0.50	1.00

C. Consistency Check

In the AHP method, the weight assigned to the criterion must be tested for consistency [14], that can be done using (1) [15].

$$CR = \frac{CI}{RI} \quad (1)$$

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

where CR is the consistency ratio, CI is the consistency index, and RI is the random index that depends on the number of parameters considered. Ref. [10] established RI for a variety

Table 3 Estimation of normalized weights (W)

	R	S	M	DD	T	CN	Weights (%age)
R	0.44	0.48	0.43	0.43	0.36	0.31	40.74
S	0.22	0.24	0.29	0.26	0.26	0.24	25.01
M	0.15	0.12	0.14	0.17	0.21	0.21	16.54
DD	0.09	0.08	0.07	0.09	0.10	0.14	9.42
T	0.06	0.05	0.04	0.04	0.05	0.07	5.15
CN	0.05	0.03	0.02	0.02	0.03	0.03	3.14

of parameters. Accordingly, RI is 1.25 for this analysis, as six parameters were chosen. In the AHP system, the weight assigned to the criterion must be tested consistently [14]. CI is calculated from (2) where λ_{max} corresponds to the maximum value of the matrix of comparison, and n is the total number of factors.

After analyzing **Table 2**, the value of λ_{max} comes out to be 6.09 and CI is computed to be 0.018. Eventually, using (1), the calculated consistency ratio is 0.014, which is lower than the threshold 0.1, this approves that the weights are consistent.

D. Factors Categorization

The value range of each parameter is reclassified to increase the objectivity. Each of the six factors are grouped into five classes using the grading method of natural breaks. Taking into consideration the influence of each flash-flood factor, pixels for every factor in each group have been allocated between 2 (for minimum influence) and 10 (for maximum influence; **Table 4**). Pixels with high rainfall, for instance, have been assigned a value of 10.

E. Flash Flood Hazard Index (FHI)

In GIS environment, these parameters are updated with new classified classes into five hazard zones, namely very low, low, moderate, high and very high. The equation (3) is used to prepare the Flood Hazard Index (FHI) with the help of the raster calculator tool in ArcGIS after calculating the weights and ratings of each parameter.

$$FHI = \sum_{i=1}^{n} p * Wi = R * W1 + S * W2 + M * W3 + D * W4 + T * W5 + CN * W6 \quad (3)$$

Table 4 Classification of the parameters and their rating score

Parameters	Class	Rating	Weights
Rainfall (mm)	1,270 - 1,467	10	40.74
	1,072 - 1,269	8	
	874 - 1,071	6	
	676 - 873	4	
	477 - 675	2	
Slope (%age)	166-668	10	25.01
	108-165	8	
	72-107	6	
	40-71	4	
	0 - 39	2	
Manning's Coefficient ($s/m^{1/3}$)	< 0.002	10	16.54
	0.002-0.011	8	
	0.011-0.04	6	
	0.04-0.06	4	
	0.06-0.15	2	
Drainage Density (km/ sq. km)	18-22	10	9.42
	14-17	8	
	10-13	6	
	5-9	4	
	< 4	2	
Travel Time (hr.)	< 1	10	5.15
	1-2	8	
	2-3	6	
	3-4	4	
	> 4	2	
Curve Number	91-100	10	3.14
	80-90	8	
	63 - 79	6	
	47 - 62	4	
	30 - 46	2	

where n = number of parameters, Wi = weight of each parameter, p = Parameter used (in terms of rating score)

Finally, the values of the FHI raster layer were categorized into five classes (natural break method) to obtain flash-flood hazard zones.

F. Validation

The historical reports for the period 1990-2019 obtained from the various research papers, news agency and published reports of Uttarakhand State Disaster Management Authority are combined to validate the produced flash-floods map.

RESULTS

1) Factors Affecting Flash Flood

Rainfall (R): The higher amount of rainfall typically increases the risk of flash-floods susceptibility. Annual average rainfall map is prepared by using CHIRPS daily datasets in Google Earth Engine from 1981 to 2019 and is reclassified into five classes. The annual average rainfall ranges from 477 to 1467 mm (Table 4), with the higher values located in the south-eastern part of the study area. Annual average rainfall map of the study region is shown in **Fig. 2(a)**.

Slope (S): The slope of an area impacts the amount of infiltration, surface runoff as well as the velocity of flow. Flash-floods occur where the slope gets steeper. It was observed that the slope in per cent rise ranges from 0 to 668 **(Table 4)**. Slope map of the study region is shown in Fig. 2(b).

Surface Roughness (M): Surface roughness determined by Manning's coefficient is an empirical value which is dependent on land use pattern. Less surface roughness indicates faster flow velocity and less infiltration. The surface roughness ranges from 0.001-0.15 $s/m^{1/3}$ **(Table 4)** in the study region. Surface Roughness map of the study region is shown in **Fig. 2(c)**.

Drainage Density (DD): Drainage density is the ratio of the length of all channels within the basin and area of the basin, and higher density indicates higher flow accumulation. For the study region it ranges from 0-22 km/sq. km. **(Table 5)**. Drainage Density map of the study region is shown in **Fig. 2(d)**.

Travel Time (T): Flash-floods is characterized by rapid flow; thus, the travel time indirectly represents the flow velocity and topography of the area. Hence, a lesser time of travel is assigned the higher rating. The time of travel ranges from 0-4.5 hours (Table 4) in the study region. Travel

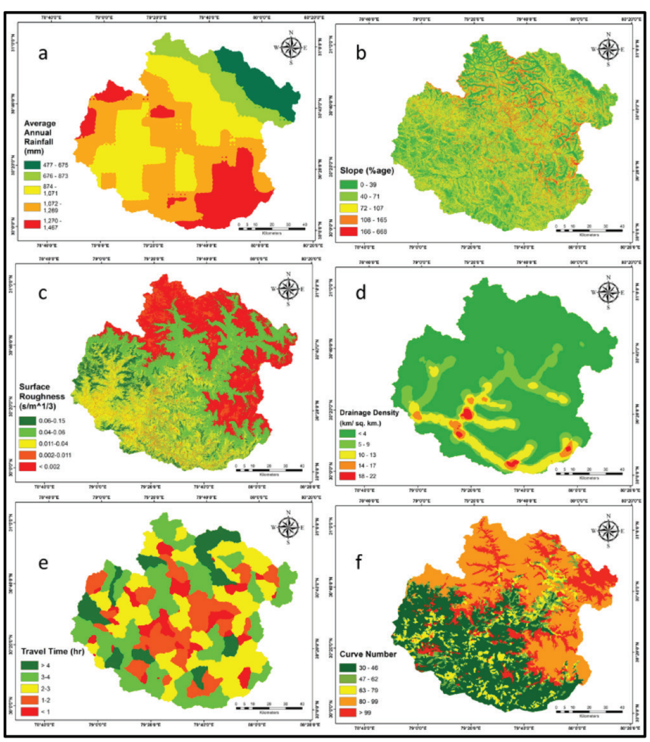


Fig. 2 (a) Rainfall (R) map; (b) Slope (S) map; (c) Surface Roughness (M) map (d) Drainage Density (DD) map; (e) Travel Time (T) map; (f) Curve number (CN) map

Time map of the study region is shown in **Fig. 2(e)**.

Curve Number (CN): Curve number accounts for the type of vegetation, built-up areas, soil type, and texture, which determine the water holding and infiltration capacity of the area and consequently affect the flash-flood susceptibility. Areas having high CN values are more likely to be flooded. CN values range from 30 to 100 **(Table 4)**, with higher values in the Eastern and Northern parts of the study area. Curve number map of the study region is shown in **Fig. 2(f)**.

2) Flash Flood Hazard Zonation

The weights of criteria obtained through AHP for MCDA are presented in **Table 4**. Combining six parameters and their corresponding weights, FHI is created. The hazard index is classified into five classes **(Fig 3)**.

Almost 17 villages namely Wachham, Surag, Kilpara, Khati, Bahantara, Kei Painti, Pinaun Laga Balan, Suiyan, Dharkot Laga Suiyan, Padmala, Jhaliya, Dhara talla, Kothiyara, Naldhura, Melkhet, Balan Chack Bhrikuti, and Kothagi were found lying in the very high flash flood hazard zones.

The present research indicates that AHP can be used as an effective means of identifying and tracking hazardous areas in the GIS system. It is clear that the possibility of flash flooding is

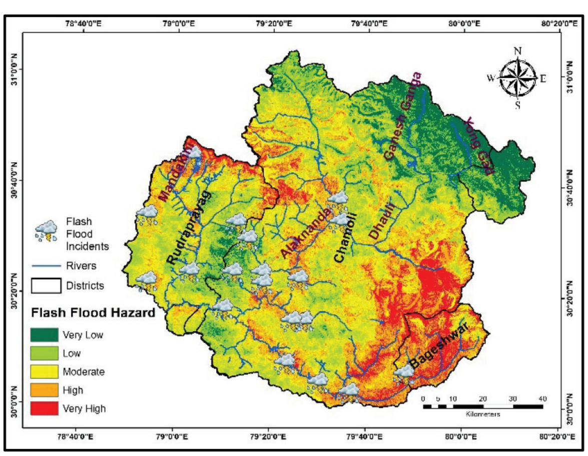


Fig. 3 Flash flood hazard map for the Alaknanda river basin

correlated with combined interference of several factors. However, results can be improved by using high-resolution Spatio-temporal images and hydraulic/hydrologic modelling simulations for efficient flash-floods management and monitoring [16].

CONCLUSION

The main purpose of the study was to identify flash-flood hazard zones in the Alaknanda River Basin in Uttarakhand, India, using an AHP model, which facilitates multi-source data combinations. The adopted methodology spatially analyses the six physical parameters, namely rainfall, slope, surface roughness, drainage density, travel time and curve number. The results depicted that the eastern and central part of the Alaknanda River Basin are susceptible to flash-floods which are mainly governed by heavy rainfall and high runoff characteristics. Almost 17 villages and area about 965 sq. km. were found lying in the very high hazard zones. The reliability of the application of this methodology is further confirmed by the reported locations of the previous flash-floods incidents. This map can therefore provide policy makers with recommendations for future anticipatory intervention, better land use planning and risk control.

REFERENCES

1. V. P. Sati, "Climate Disasters in the Himalaya : Risk and Vulnerability," Conf. Pap. Mt. Hazards, no. September 2011, 2011, doi: 10.13140/2.1.3797.4403.
2. V. Joshi and K. Kumar, "Extreme rainfall events and associated natural hazards in Alaknanda valley, Indian Himalayan region," J. Mt. Sci., vol. 3, no. 3, pp. 228–236, 2006, doi: 10.1007/s11629-006-0228-0.
3. S. D. Kotal, S. Sen Roy, and S. K. Roy Bhowmik, "Catastrophic heavy rainfall episode over Uttarakhand during 16-18 June 2013 - observational aspects," Curr. Sci., vol. 107, no. 2, pp. 234–245, 2014.
4. S. Singh et al., "Estimation of revised capacity in Gobind Sagar reservoir using Google Earth

Engine and GIS," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., vol. 42, no. 5, pp. 20–23, 2018.

5. K. Khosravi et al., "A comparative assessment of flood susceptibility modeling using Multi-Criteria Decision-Making Analysis and Machine Learning Methods," J. Hydrol., vol. 573, no. March, pp. 311–323, 2019, doi: 10.1016/j.jhydrol.2019.03.073.

6. M. Spreafico, "Flash floods in mountain areas," no. November, pp. 232–238, 2006.

7. C. Liu and Y. Li, "GIS-based dynamic modelling and analysis of flash floods considering land-use planning," Int. J. Geogr. Inf. Sci., vol. 31, no. 3, 2017, doi: 10.1080/13658816.2016.1207774.

8. R. K. Waghwala and P. G. Agnihotri, "Flood risk assessment and resilience strategies for flood risk management: A case study of Surat City," Int. J. Disaster Risk Reduct., vol. 40, no. April, p. 101155, 2019, doi: 10.1016/j.ijdrr.2019.101155.

9. D. Kumar Jha, M. Sabesan, A. Das, N. V Vinithkumar, and R. Kirubagaran, "Evaluation of Interpolation Technique for Air Quality Parameters in Port Blair, India," Univers. J. Environ. Res. Technol., vol. 1, no. 3, pp. 301–310, 2011.

10. T. Analytic and H. Process, "The analytic hierarchy process," Eur. J. Oper. Res., vol. 45, no. 2–3, p. 378, 2003, doi: 10.1016/0377-2217(90)90209-t.

11. G. Papaioannou, L. Vasiliades, and A. Loukas, "Multi-Criteria Analysis Framework for Potential Flood Prone Areas Mapping," Water Resour. Manag., vol. 29, no. 2, pp. 399–418, 2015, doi: 10.1007/s11269-014-0817-6.

12. H. Huan, J. Wang, and Y. Teng, "Assessment and validation of groundwater vulnerability to nitrate based on a modified DRASTIC model: A case study in Jilin City of northeast China," Sci. Total Environ., vol. 440, pp. 14–23, 2012, doi: 10.1016/j.scitotenv.2012.08.037.

13. I. Elkhrachy, "Flash Flood Hazard Mapping Using Satellite Images and GIS Tools: A case study of Najran City, Kingdom of Saudi Arabia (KSA)," Egypt. J. Remote Sens. Sp. Sci., vol. 18, no. 2, pp. 261–278, 2015, doi: 10.1016/j.ejrs.2015.06.007.

14. M. M. De Brito and M. Evers, "Multi-criteria decision-making for flood risk management: A survey of the current state of the art," Nat. Hazards Earth Syst. Sci., vol. 16, no. 4, pp. 1019–1033, 2016, doi: 10.5194/nhess-16-1019-2016.

15. E. F. Lane and W. A. Verdini, "A Consistency Test for AHP Decision Makers," Decis. Sci., vol. 20, no. 3, pp. 575–590, 1989, doi: 10.1111/j.1540-5915.1989.tb01568.x.

16. B. A. M. Talisay, G. R. Puno, and R. A. L. Amper, "Flood hazard mapping in an urban area using combined hydrologic-hydraulic models and geospatial technologies," Glob. Journanal Environ. Sci., vol. 5, no. 2, pp. 139–154, 2019, doi: 10.22034/gjesm.2019.02.000.

Flash Flood Management & Challenges to Overcome Flood in Bihar

Nikhil Kumar

Department of Civil Engineering, Pranveer Singh Institute of Technology, College of Engineering, Bhauti, Kanpur, Uttar Pradesh

nikhil4943@gmailcom

ABSTRACT

A flash flood is such an event which results into loss of life and property to people mostly living in countryside. The occurrence of flash flood, in our country, mostly takes place in northern part of Bihar due to surplus amount of water being discharged by in rivers from Nepal like Gandak which ultimately increases the current of the river. Occurrence of flash floods also lead to erosion of banks of rivers which increases the risk of collapse of bunds which eventually pushes water in the villages affecting the life of people living in that region. So, in anti-erosion work engineers basically try to look into this problem and they have come up with certain solution like construction of Teeth Bars whose main objective is to deflect the water away from the banks of the river and thereby protect the banks from high currents of water which otherwise would have eroded them.

Water Resources Department of various states take preventive measure to control flood and certain precaution are taken up especially at the banks of river which are vulnerable to erosive action of the river. Such measures include building up of teeth bar along the banks of the river which is most vulnerable to erosive action of the river, which would otherwise cut down the bandh and flood down the plain area. Such teeth bar helps in deflecting the flood water and hence banks are being protected from being cut down. Such teeth bar is actually being made from Nylon Crate and Gabion which consists of EC Bags and Geobags respectively. Apron design is the key feature of this preventive measure which is done by launching NC in the river for making the base over which NC and Gabion would be placed.

Keywords : Geobags, Gabions, Nylon crate, Anti-Erosion work, Teeth bar

INTRODUCTION

The Gandaki River (also known as the Narayani in southern Nepal and the Gandak in India) is one of the major rivers of Nepal and tributary of the Ganges in India. The entry point of the river is at the Indo–Nepal border. The Gandak flows southeast 300 kilometers across the Gangetic plain of Bihar through West Champaran, Gopalganj, Saran and Muzaffarpur Districts. It joins the Ganges near Patna just downstream of Hajipur at Sonepur.

Bank erosion is a natural process without which, rivers would not meander and change course. In many places, irrespective of banks being stable or not, people try to keep a river in a single place. This can be done for environmental reclamation or to prevent a river from changing course into land that is being used by people. One way of doing this is by placing riprap (rock or other material used to armor shorelines) or gabions along the bank. A common natural method to reduce bank erosion is the re-plantation of native plant species in the area. The expansive root systems of these plants provide support within the soil and prevents erosion due to rain runoff.

In order to provide protection to the people, short & medium-term measures were taken up by the Water Resources Department of Bihar. Recently, the flood protection works and anti-erosion works are designed using geotextile and geobags and aims to provide protection of the bed and bank from the erosive forces of the Gandak River. Woven and nonwoven geotextiles, filters, geomembranes, geonets, geogrids, glass fibre paving mat, G.I wires, polymer rope gabions and geocomposite are used in drainage, earthwork and erosion control applications. Launching NC is a part of bed protection. Polymer rope gabions filled with geobags and Nylon crate were placed at regular intervals to impart stability to the scour protection measure.

EC bags were filled with sand to the specified height to ensure that appropriate density is achieved by filling. After ensuring that the bags were filled to the required height, the open ends of the bags were closed by stitching the bags at location using hand stitching machines. Stitched bags were manually transported to the site location for installation (Burnett, 2012).

Flood management and bank erosion control have become prime matter of concern due to its impact towards life and property. Many anti-erosion techniques are used as engineered solutions to the problems. Among them, construction of revetment is an easy method for carrying out anti-erosion work. Revetments are constructed along the bank of the river and protects the bank from erosion of the flood water. It consists of the armour layer which provides protection against wave action of the flood water. Consists filter below it which supports the armour and prevents washing out of underlying soil. It also allows water to flow through the structure. It also consists of Toe protection which prevents displacement of seaward edge of the revetment. Such method is very beneficial against the flood water which may otherwise erode the bank of the river and flood the floodplain area (Bender, 2013).

OBJECTIVE OF THE PRESENT WORK

Based on the above introduction, we now focus on the aim of the present work which are as follows.

- Anti-Erosion Work to prevent the scouring and erosive action of the river against the bank of the river.
- Formation of Teeth Bar as shown in **Fig. 1**, for the quick protection of the river bank which is the projection formed towards the river which serve the purpose of deflecting flood water and protecting the banks from getting eroded.
- Effective use of Geobags and EC bags to form the teeth bar which act as a deflector against the downstream floodwater (Suresh, 2013).
- Precise stacking of Gabions and Nylon Crate in various sizes over each other.
- Formation of requisite number of Teeth Bars along the bank of the river to deflect heavy flash downpour in the river.
- Working and careful supervision on the launching of NC in the river.
- Estimating the amount of NC and gabions used in the AE work along with requisite number of Geobags and EC Bags.

Fig. 1 Teeth Bar along the Gandak River, PD ring bandh (West Champaran, Bihar)

MATERIALS AND METHODS

The aim of the reported work is to take preventive measures to protect the scouring and erosive action of the river against the bank of the river. Here we have used EC bags & Geobags in NC and Gabions respectively. Both, Gabion as shown in **Fig. 2** and Nylon Crate (NC) as shown in **Fig. 3** are important in the construction of the teeth bar at the bank of river to protect it from the erosive action of the water. The main purpose of it is to deflect the flood water which would otherwise cut the bank and could damage the levee.

So, the aim of flood fighting here is to form teeth bar for the protection of the river bank which is the projection formed towards the river which serve the purpose of deflecting flood water and protect the banks from getting eroded. The minimum distance between two teeth bar is taken to be 20m. The teeth bar is generally of the dimension 9mX6m, where along its length we have 6m i.e. on land and 3m is in river.

Making of teeth bar starts with the filling of EC bags with sand of proper size. Such filling work may take place at site or in other case filled EC bag may be brought up to the site with the help of suitable means like tractor. After that they are unloaded from tractor and stacked along levee. After being filled with sand their weight should be between 50-60 kg. The general dimension of the EC bag is 450 x 625 x 145 mm. Such EC bags play various role which includes forming base over which gabions could be placed.

Fig. 2 Polymer rope Gabion, PD ring bandh (West Champaran, Bihar)

Fig. 3 Nylon crate work along Gandak river (West Champaran, Bihar)

Process of forming Teeth Bar

The process of making teeth bar includes: -

- Filling and transportation of EC bags.
- Laying a base of NC onto the land and in river.
- Launching of NC into the river by suitable means.
- Filling of Geobags and its transportation at the site.
- Laying of Gabion over the NC to form the base.

Laying of gabion over NC is done manually. These gabions contain geobags which are stacked in a particular pattern depending upon size of the gabion. In a gabion of dimension 1.8m x 1.2m, we can use 12 geobags, as shown in **Fig. 4**, but in gabion of dimension 1.8m x 1.8m, we can use 18 geobags.

In a teeth bar of dimension 6m x 9m, a total of 25 gabions could be used of size 1.8m x 1.2m and 15 gabions could be used of size 1.8m x 1.8m.

Fig. 4 shows a well depictive layout of the stacking of the geobags.

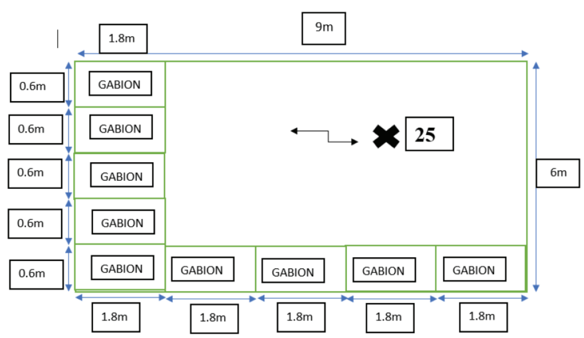


Fig. 4 Layout of the teeth bar

Fig. 4 shows the layout of the teeth bar. From the above layout we infer that for a teeth bar of size 9m x 6m, and gabion of size 1.8m x 1.2m x .5m, the total number of gabions required would be 5*5=25. Now, since geobag are stacked one over another so, total no. of geobag in one gabion is 4*3=12.

RESULTS AND DISCUSSIONS

Anti-erosion work is an essential and important work which must be carried out prior to the flooding period in order to reduce and minimize the adverse impact of the flood. Among the various ways to prevent the erosion, use of geobags filled with soil and empty cement bags filled with sand provides the most effective means to prevent the toe erosion of the bunds. Gabions filled with geobags applies a great amount of pressure on the Nylon Crate which is placed partially on the land and partially on the toe of the river bank to form the teeth bar which acts as a deflector against the heavy rainwater downpour and protects the banks of the river. Such preventive measure finally protects the bunds and the country side.

Consider the gabion of size 1.8m x 1.8m x .5m, where size of geobag taken into consideration is .9m x .6m x .15m. So, hence from the above layout we infer that for a teeth bar of size 9m x 6m, and gabion of size 1.8m x 1.8m x .5m, the total number of gabion required would be 5*3=15 Now, since geobag are stacked one over another so, total no. of geobag in one gabion is 6*3=18 So height of gabion would be the summation of height of individual geobag, so height of gabion is (0.15+0.15+0.15) m =0.45m ~0.5m So, total no. of geobag in one teeth bar would be 15*18=270 geobags. We had a total of 22 teeth bar means 22*270=5940 geobags were used in anti-erosion work.

CONCLUSION

Flood fighting is essential to prevent levee failure and consequently protect the life of people who would otherwise be affected by the outrageous flood water. Certain precautionary steps are needed to be taken prior to the flood period which includes revetment design, teeth bar making etc. For making of teeth bar it requires geobags and EC bags, which is to be stacked in an order (Sunder, 2015).

Flood protection is a very important work of water resources development and they insure proper and efficient step is taken so, that flood causality is less. India is a country where flood is common during rainy season, but situation gets worst when dams releases too much water which increases the water level and consequently increases the chances of flood. It doesn't matter how much precaution do we take we cannot fully control the flood but could only reduce the extent of risk and damage. It's control impact is not in our hands, but we could certainly reduce its impact on us.

ACKNOWLEDGMENT

I would like to acknowledge the contributions of the Executive Engineer and SDO for their supervision and support. Along with them I would also like to thank the entire team of Water Resources Department for their continuous support and cooperation.

REFERENCES

1. Burnett, Ric. & Bryson, Elizabeth (2012). California Natural Resources Agency, Department of Water Resources stated about Flood Fighting Methods, Volume 2, Revised 1987.
2. In River Flood Control (Bender, T.R, & Wilson, J.M., no date) stated about Leeves, Reservoir & Floodways.

3. Coastal and River Control (Erosion, no date) stated about Revetments and the use of Polymer Rope Gabions.
4. Maurya, Suresh & Gupta, Manish. (2013). International Journal of Latest Trends in Engineering and Technology (IJLTET), Use of Geosynthetics in Restoration and Bank Protection from Dhola-Hatiguli to Rohmoria along the River Brahmaputra - A Case Study, Vol. 3 ISSN: 2278-621X.
5. Gabion, Erosion Protection (Gabion boxes, no date) stated about structural integrity of a gabion wall is dependent on its ability to function as a unit.
6. (Sunder.V., 2015). Department of Ocean Engineering, IIT Madras, Module-4 Geosynthetics Refer Slide Time: 30:05.

Flood Frequency Analysis for Panam Catchment, Gujarat

Pranav B Mistry, Mugdha Trivedi, T M V Suryanarayana
Water Resources Engineering and Management Faculty of Technology and Engineering
The Maharaja Sayajirao University of Baroda
✉ *drsurya-wremi@msubaroda.ac.in*

ABSTRACT

Flood is a common incidence in any river basin. However, in recent times it has become quite irregular and its frequency has increased significantly. In the present study,peak flood discharge data of Panam River for 30 years is considered and analyzed using four important frequency distributions namely Gumbel Distribution, Log Pearson Type III, Log Normal and Normal Distribution. The frequency analysis is carried out using the above said four methods and the probable peak flood discharges at various recurrence intervals, i.e. 2, 5, 10, 25, 50 and 100 years have been determined. The observed and expected maximum discharge data were then compared by D index and PAD test. The observed maximum discharge was also predicted as a function of return period with linear logarithmic regression model and coefficient of determination for various distributions. It was observed that the Gumbel distribution gave the best fit to predict the maximum yearly peak flood discharge of Panam River for different return periods. The results obtained in this study are useful in works related to water resources engineering, agricultural engineering, in planning and designing of soil and water conservation structures, irrigation and drainage systems etc. in the study area.

Keywords : Flood, Frequency analysis, D-index, PAD test.

INTRODUCTION

Extreme events like floods and droughts are of concern for any country in the context of the damage caused to life as well as property. Flood is the one which causes natural disasters in India all most every year. It is commonly considered to be an unusually high stage of a river. It occurs generally during monsoon months i.e. June to October.

Frequency analysis is generally used in hydrology for the possibility of discharge extremes, mainly for low flow or high flow. The application of the frequency analysis methods has been widely recognized by the numerous researchers in the field. Flood frequency analysis is an important mathematical modelling technique in determining the return period of the probability of witnessing a particular discharge in a river, especially a peak discharge. Flood frequency analysis is the most important statistical technique in understanding the nature and magnitude of high discharge in a river. [1]performed flood frequency analysis for North Brahmaputra region of India using L-moments method. Gumbel Extreme Value distribution was found to be the best fit distribution for flood estimation at various return periods. Due to unavailability of proper data [2] applied flood frequency analysis on several Mediterranean catchments based on random and systematic errors using historical data. Another study was carried by [3] for Tel Basin of Mahanadi River based on annual maximum (AM) and peak over threshold (POT) flood series. Fourteen distributions were applied on both the series and Generalized Pareto (GP) and Log-Normal (3P) distribution were found to show better results for AM and POT flood series. River can be extremely disastrous when it flows over its bank. For safe design of hydraulic structures, [4]presented a comparative study of three statistical methods for flood frequency analysis with an objective to suggest the optimum method and recommended Gumbel method for safe design. For ungauged catchments, [5] presented a comparative study on flood frequency analysis using statistical and simulation methods along with regionalization scheme based on regression and spatial proximity. Another frequency analysis of Krishna River of Prakasam Barrage at Vijayawada was performed by [6] using Gumbel, California and Hazen methods. For areal planning and infrastructure development, [7] investigated the use of historical records in more efficient flood estimation trying to overcome the challenge due to mismatch between length of records and need of return periods to be evaluated. The authors concluded that stability and reliability improve precisely for shorter record length and longer return periods.

The analysis of flood frequency of river catchment has therefore become imperative in order to curtail hazards of this nature. Flood frequency analysis uses observed annual peak flow discharge data to compute statistical information such as mean values, standard deviation, skewness and recurrence interval of flood. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedance probability. Flood frequency distribution can take many forms depending on the equations used to carry out the statistical analysis.

This paper tries to evaluate the magnitude of peak flood for various return periods using frequency analysis. The objective of the frequency analysis is to relate the magnitude of events to their frequency of occurrence through probability distributions. The present study focuses on developing a best suitable model to fit maximum annual flood data. In order to verify the suitable distribution that best describes the maximum yearly discharge, D index and Percentage Absolute Difference (PAD) tests have been performed.

STUDY AREA AND DATA COLLECTION

To demonstrate the performance of different probability distributions, catchment of Panam Dam located in Panchmahal District of Gujarat State, is considered in the present study. It is located between 22°15’ N latitude and 73° 30’ to 74° 30’ E longitude. Panam River is the major tributary of Mahi River. The yearly discharge data of 30 years from 1977 to 2006 have been collected from State Water Data Center, Gandhinagar.

METHODOLOGY

Probability distribution functions of peak flood discharge may be calculated by using the following distributions:

Gumbel distribution

Log-Pearson type III distribution

Log-Normal distribution

Normal distribution

Annual maximum discharge data of Panam River for 30 years (1977-2006) were fitted to four probability distribution functions for various return periods.

A. Gumbel Distribution

The Probability density function of this distribution is given by:-

$f_z = a\exp[-a(x-\beta) - \exp\{-a(x-\beta)\}]$

where α = scale parameter β = location parameter

B. Log Pearson Type-III Distribution

The Probability density function of this distribution is given by:

$$f_z = \frac{\lambda^{\eta}}{\Gamma()}(\ln x - A)^{\eta-1} e^{-\lambda(\ln x - A)}$$

where λ= scale parameter, η = shape parameter, Γ is gamma function and A = location parameter.

C. Log normal Distribution

The Probability density function of this distribution is given by:

$$f_z = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left[-\frac{\left(x-\mu_y\right)^2}{2\sigma_y^2}\right]$$

where y = logx, μ_y and σ_y are the mean and standard deviation of variate 'x' respectively.

D. Normal Distribution

For the normal distribution, the frequency factor, Ktwas determined by the following relation as proposed by (Chow et al., 2010).

$K_t = (x_t - \mu)/\sigma$

This is the same as the standard normal variate z as the frequency factor, K_t for the normal distribution is equal to z. The value z corresponding to an exceedance of probability of p, (p = 1/T) was calculated by finding the value of an intermediate variable w calculated as:

$$W = \left[\frac{1}{p^2}\right]^{1/2}, (0 < P \leq 0.50) \quad (1)$$

The value of z was estimated using the approximation as :

$$Z = W - \frac{2.515517 + 0.802853\,W + 0.010328\,W^2}{1 + 1.432788\,W + 0.189269\,W^2 + 0.001308\,W^3} \quad (2)$$

when p > 0.5, 1-p is substituted for p in equation (1) and the value of the z computed by equation (2) is given negative sign (Bhakar et al., 2006).

Testing the Probability Distribution

The expected values of peak flood discharge were calculated by four well known probability distributions, viz., Gumbel distribution Log-Pearson type III, Lognormal, and Normal distribution at different selected return periods. Among these four distributions, the best fit distribution is decided by performing D index and PAD tests to observed values.

D-Index Test

D-Index Test is performed to find out the best method for estimating peak flood discharge in the present study area. D-Index is given by

$$D\text{ index} = \frac{1}{Q}\sum_{i=1}^{4}|X - X^*|$$

where, Q is mean of the annual peak discharge series, x is the i^{th} highest recorded discharge and x* is the i^{th} highest estimated discharge. The distribution with lowest value of D-Index will be considered as the best distribution for estimating peak discharge for a given return period.

Percentage Absolute Deviation (PAD)

The goodness of fit of the computed and observed peak flood discharge was also tested using percentage absolute deviation (PAD) which is expressed as:

$$PAD = \left|\frac{X - Y}{X}\right| * 100$$

where, PAD is the percentage absolute deviation of the compound extreme peak discharge values with respect to the observed values.

RESULTS AND ANALYSIS

The graph of annual peak discharge and time series of Panam River for years 1977 to 2006 is shown below in **Fig. 1**. The maximum discharge of 15031.92 cumecs was observed in 1990 and the minimum discharge was 417.26 cumecs in 1999. The difference in flow magnitudes can be recognized to intermittent ephemeral nature of the stream flow which usually dry up or have reduced flow in peak dry season or years with reduced rainfall events resulting in droughts.

The basic statistical parameters of peak flood discharge record have been shown below in **Table 1**. The lower value of Cs indicates that data is almost symmetrical and can easily fit with

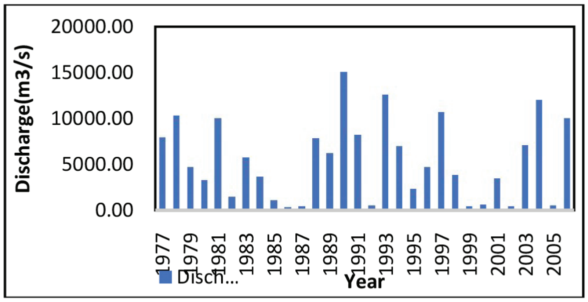


Fig. 1 Annual discharge of Mahi river

Table 1 Statistical analysis of present data

Average	5417.86
Standard deviation	4301.89
Skewness	0.4745
Kurtosis	-0.8155

any distribution method. The negative (excess) kurtosis means that the outlier character of data is less extreme that expected had the data come from a normal distribution.

The expected discharge using various frequency distribution methods are shown above in **Table 2**. The discharges are also represented graphically for 2, 5, 10, 25, 50 and 100 years return periods in **Fig. 2**.

From trend line equation, Coefficient of determination (R^2) values obtained from **Fig. 2** are presented in **Table 3**. It has been found that Gumbel distribution shows maximum (R^2) value as 0.9984. Hence, for predicting expected peak flood discharge in Panam River, Gumbel distribution is the best suitable distribution.

It is clear from **Table 2** and **Fig. 1**, that the Gumbel's Extreme Value Distribution gives lower values of peak discharge as compared to the other distributions. On the contrary, Log Normal Distribution gives higher values for 10, 25, 50 and 100 years compared to the other two distributions except for 2-year return period. The equations developed in **Table 3**, can effectively be used to extrapolate values of expected peak discharges for several return periods in order to promote integrated water resources planning and management. Further improvement of the curves might, however, be possible by considering discharge data from several nearby sites.

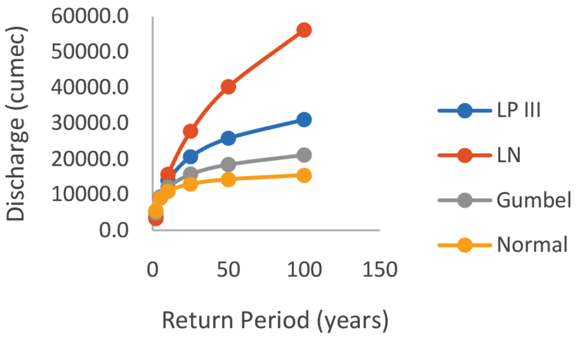


Fig. 2 Graphical representation of various distributions

Table 2 Expected discharge using various distribution for various return period

Return Period	Gumbel	LP III	LN	Normal
2	4758.64	3671.11	3217.36	5417.85
5	9141.85	9210.45	9042.45	9037.71
10	12043.91	13885.76	15516.94	10931.71
25	15710.68	20476.89	27591.99	12950.79
50	18430.90	25648.94	40020.45	14254.75
100	21131.03	30890.08	55880.21	15427.43

To test the best probability distribution for estimating the peak discharge, D-Index values for each distribution have been calculated. The D-Indices are calculated using recorded peak discharge and estimated peak discharge for different return periods for all the distributions. The lowest value of D-Index statistically means the lowest deviation from the recorded data. From **Table 4** it can be concluded the lowest value of D-Index and PAD is obtained for the Gumbel distribution as 0.77 and 12.22, respectively.

Table 3 Logarithmic regression equation and coefficient of determination

Frequency distribution	Logarithmic regression equation	R^2
Gumbel	4146.5LN(X) + 2242.9	0.9984
LP III	7001.3LN(X) - 1771.2	0.9983
LN	13338LN(X) - 11114	0.9530
Normal	2487.5LN(X) + 4561.9	0.9724

Table 4 Results of D index and pad

	Gumbel	LP III	LN	Normal
D index	0.77	2.57	5.18	0.97
PAD	12.22	13.39	12.84	22.17

Hence, it is recommended to use the Gumbel distribution for predicting peak flood discharge in the present study area.

CONCLUSIONS

The results of frequency distributions in estimating maximum peak flood discharges with different return periods showed that predicted values in Gumbel distribution had the best fitting with observational data and it had the maximum co-efficient of determination with a value of 0.9984 as compared to the other distributions.

Also, from PAD and D index test it has been found that 12.22 and 0.77 are the minimum values, respectively, obtained for Gumbel distribution. Therefore, Gumbel distribution is the most suitable probability distribution for estimation of maximum peak discharges for Panam River and is suggested to be employed for future flood prediction.

The future scope of the present work is that the values of return period of flood discharges can be used to construct the flood hazard zones and define the river space. This river space is to be preserved for the sake of ecology, riparian vegetation and nutrient recycling during floods. It signifies the horizontal connectivity in a fluvial system.

REFERENCES

1. R. Kumar, and C. Chatterjee, "Regional flood frequency analysis using L-moments for North Brahmaputra region of India," Journal of Hydrologic Engineering, vol. 10, no. 1, pp. 1-7, 2005.

2. L. Neppel, B. Renard, M. Lang, P. A. Ayral, D. Coeur, E. Gaume, F. Vinet, "Flood frequency analysis using historical data: accounting for random and systematic errors," Hydrological Sciences Journal–Journal des Sciences Hydrologiques, vol. 55, no. 2, pp. 192-208, 2010.

3. N. Guru, R. Jha, "Flood frequency analysis of Tel Basin of Mahanadi river system, India using annual maximum and POT flood data," Aquatic Procedia, vol. 4, pp. 427-434, 2015.

4. N. Mowrin, K. H. Limon, M. R. I. Khan, "Comparative Study of Flood Frequency Analysis of Different Rivers in Bangladesh," AJIRSET, 2017.

5. J. Odry, P. Arnaud, "Comparison of flood frequency analysis methods for ungauged catchments in France," Geosciences, vol. 7, no. 3, pp. 88, 2017.

6. K. Ganamala, P. S. Kumar, "A case study on flood frequency analysis," International Journal of Civil Engineering and Technology, vol. 8, no. 4,pp. 1762-1767, 2017.

7. K. Engeland, D. Wilson, P. Borsányi, L. Roald, E. Holmqvist, "Use of historical data in flood frequency analysis: a case study for four catchments in Norway," Hydrology Research, vol. 49, no. 2, pp. 466-486, 2018.

Flash Flood Utilization (FFU) for Indian Farmers

Pramoda Kumar Behera
PhD Scholar, Jharkhand Rai University, Ranchi, Jharkhand
pkbmines@gmail.com

ABSTRACT

Flash floods happens when dams break, when levees fail or when an ice jam releases a large amount of water by melting or as huge ice block slides and often due to sudden change in climatic condition owing to global warming resulting in flash flood which is a natural hazard with immense damaging potential. The main danger associated with flash flood is its velocity and speed with which it develops and resulting powerful water flows. The risks arise from related phenomena such as tangible assets & debris flow, ice jam melts, surface water flooding, etc. The most comprehensive way to provide warnings is to install gauges both at and upstream of areas at risk and to use the outputs from forecasting models to help to extend warning lead times. This article tries to focus on the causes of flash flood and especially the remedial part which is optimum utilization of flash flood for agricultural irrigation purpose.

Keywords : Flash flood utilization (FFU), Rainfall quantity, Rainfall intensity, Tangible assets, Natural hazards, Debris flow, Ice jam, Information and communication technology (ICT), Solar pump system(SPS).

INTRODUCTION

Flash floods is considered as the most common natural disaster worldwide over the last few decades. Their consequences are not only environmental but also economic, since they may cause damage to urban areas and may even result in the loss of life and eco-systems[1]. Rapid growth of population, expansion of industrialization and huge urbanization have led to encroachments within stream beds and land use changes to catchments in rivers, nalas, drainages etc including the upper urban centers. It is worth mentioning that many times flood phenomena could have been avoided if no anthropogenic interventions existed within stream beds. Moreover, due to climate change, flash floods will continually growing day by day. A flash flood is a rapid flooding of low-lying areas: washes, rivers, dry lakes and depressions. It may be caused by heavy rain associated with a severe thunderstorm, hurricane, tropical storm, or melt water from ice or snow flowing over ice sheets or snowfields. Flash floods may occur after the collapse of a natural ice or debris dam, or a human structure such as a man-made dam, as occurred. Flash floods are distinguished from regular floods by having a timescale of fewer than six to seven hours between rainfall and the onset of flooding[2] .

OBJECTIVE

The objective of this research paper is to ;

01. To measure and identify the risk associated with flash flood impacts in order to protect the life, health, infrastructures, property and welfare of the community's residents and visitors.

02. To analyze and ensure the development towards long-term and flexible funding strategy planning systems for river flash flood hazard management.

03. To ensure the support compatible human uses, economic activities, and improve habitat conditions in flash flood-prone and channel migration areas.

04. To ensure that local and state government entities have the capabilities to develop, implement and maintain the effective flash flood plain management programs exclusively in the flash flood prone areas/region.

05. To increase the different public awareness methodologies towards the flash flood affected peoples for preventions from hazards and preparation for flash flooding.

SIGNIFICANCE

1. The paper objectives shall offer an opportunity for collective problem defining, measuring, analyzing, solving, improving the knowledge sharing, socioeconomic exchange and community-wide participation at local, national and international level with respect to the flash flood events.

2. The paper hypothesis will help and benefit to lead to an insight into the information through ICT (Information and Communication Technology) and preparedness requirements of local communities and development of solutions adapted to the social realities with respect to the flash flood hazards.

3. The subject objective shall provide to lead the closer cooperation, support, guidance and coordination for flash flood forecasting and warning services of public institutions based on user requirements.

4. Based on study of the paper regarding flash flood hazards and including consultations with affected communities and other recipients of flood warnings, improved technical means of detecting the areas at imminent risk and warning more effectively, will be developed.

5. By controlling and conserving the flash flood excess water through suitable methodology & technology and the same water can benefit farmers for their crop irrigation through solar pump system (SPS) as per their future requirements and which shall also the save ground water depletion and global warming. Also, the flash floods will ensure that there is water drinking water in dry places.

6. Flash flood waters can carry nutrient-rich sediments which contribute to a fertile environment for vegetation.

7. Flood plains are beneficial for wildlife by creating a variety of habitats for fish and other animals.

8. The subject will be helpful for other researchers who will be interested in doing advance work on same topic through Define, Measure, Analyze, Improve and Control(DMAIC) putting proper PDCA(Plan, Do, Check & Act) rule with organized, safe and environmentally sound manner with the social ethics of Transparency, Accountability, Integrity and Professionalism ways and means towards flood management.

MAIN CAUSES OF FLASH FLOODS

Most flash floods happen after extremely intense rainfall from severe thunderstorms over a short period of time (normally 6 hours or less) [3]. The key elements to determine flash flooding are as follows:

a. Rainfall rate and quantity, Rainfall duration and intensity. Flash floods also happen when dams break, when levees fail or when an ice jam releases a large amount of water by melting or as huge ice block and global warming.

b. Rapid industrialization, population growth, huge urbanization, encroachment of river beds, excessive rain from tropical storm systems making landfall, persistent thunderstorms over the same area for extended periods, combined rainfall and snowmelt, ice jam.

c. Excessive sand, stone and mineral exploration from the river beds[4].

d. Dumping and throwing of garbage to the rivers and jamming the drainage systems.

e. Blocking of river canals due to bad agricultural practices.

f. Tropical cyclones, Tsunami, Higher-than-average tides, Low pressure creation over the sea, Climatic Change and global warming and Periodical monsoon cycles.

g. Sudden creation of Low pressure depression over the sea beds, Abnormal Astronomical tide, Wind pressure, Velocity and volume, Waves, Low atmospheric pressure differences.

h. Negligence of maintenance of urban drainage systems by Municipality corporations, low-capacity and having poor quantity of drainage equipment, Paved roads and streets and dense buildings not as per town planning[5] .

i. Low amounts of green space available in the urban areas, Haphazard dumping of garbage and Excess of Biological non-gradable items.

IMPACTS OF FLASH FLOOD

There are actually many dangerous flash flooding effects. Besides physical danger, flash floods also cause economic and social problems. The details are as follows:

Loss of Lives

The gravest effect of flash flooding is death. In fact, flash flooding is the number one severe weather killer. Flash floods kill by carrying people away in fast-moving water or drowning them[6].

Property Damage

Since, it only takes two feet of flood water to wash a car away, flooding can also cause great loss of property. This is why it is so important to avoid flooded areas when driving[7]. Flooding also causes damage to buildings by blowing out windows, sweeping away doors, corroding walls and foundations, and sending debris into infrastructure at a fast pace[8].

Economic Impacts

The economic impacts of flash flooding can be devastating to a community. This brings business activities in an area to a standstill and major flooding results in dislocation of normal life long after flood waters recede[9]. In frequently flooded areas, there is less likelihood of investment in infrastructure and other developed activities.

Psychosocial Effects

Flooding can also create lasting trauma for victims. The loss of loved ones or homes can take a steep emotional toll, especially on children. Displacement from one's home and loss of livelihood can cause continuing stress and produce lasting psychological effect[10].

Pollution

Floods will wash chemicals and sewage into the water. The contaminated water will spread quickly over an area – causing public health issues and destroying aquatic lives.

Destruction of wildlife Habitat

Flash Floods will destroy places where river animals and fish might have breeding grounds. Even slight changes to river temperature and water patterns can upset natural ecosystems .

Water Recharge

Flash floods can bring water back to dry areas. The excess flash flood water can be stored and conserved either in check dams, ponds/lakes and the same water can be used by the farmer for crop irrigation purposes through solar pumping system(SPS) as per their requirements in the future. Also, the flash floods will ensure that there is water drinking water in dry places .

Social Impacts

It refers to how a management method will affect people. It will look at how it impacts their houses and where they live, how it will affect their daily lives and their food and water supply.

Environmental Impacts

Flash flood leaves an adverse impact on the natural environment. It affects the development of animals and plant life.

MEASURES TO BE TAKEN DURING THE FLASH FLOOD

If, there are steps one can take to stay safe. The first and most important thing to remember is to steer clear of flood waters.

Turn around, don't drown. Flash flood waters can rise or gain intensity in the blink of an eye. Stay away from flash flood water at all costs.

Another important tip that will help one survive a flash flood is to listen to evacuation orders from authorities. Also stress that you listen to evacuation orders the first time you hear them. Waiting even just a few minutes can be the difference between life and death. And staying behind can put you and others at risk if you need to be rescued from rising waters.

One last useful tip is to stay away from rooms where water covers electrical outlets. This is pretty self-explanatory, you don't want to be electrocuted walking through your flooded home or business.

MEASURES TO BE TAKEN AFTER THE FLASH FLOOD

Once the flood waters recede, one might think that he/she is safe. However, there are still plenty of flooding dangers that can threaten one's health and property. There are also things one should follow in case a flood damages one's property.

1. One of the most important safety precautions after a flood is to make sure that the available drinking water is safe for consuming. Groundwater may have been contaminated during the flood and hence it is not safe to assume that the faucet and the water is safe. Local authorities will let you know if water is safe to drink or if you should boil it before using.

2. After a flood, standing water is also a danger. While it might look placid compared to a raging flood, standing water left behind is a breeding ground for bacteria and can carry toxins or chemicals. While standing in flood water for cleanup or any other reason, protect gears like rubber gloves, boots etc. should be used.

3. Floodwaters can also hide sharp or dangerous objects, so it's best to avoid going into the water.

4. Once the flood water recedes it is advisable to wait for the all clear from local officials to return to buildings or areas compromised by the flood. While one's home or office might look safe, there could be major structural or electrical dangers. Always wait for the all clear.

METHODOLOGY

The methodology adopted in this research paper is both descriptive and analytical. The following segments has been considered for the study;

Hard-Engineering Systems

Check Dam Systems: Built along the course of a river to control the amount of discharge. Water is held back by the dam and released in a controlled way.

Flash Flood wall Systems: Can be used to raise the height of the river bank to a level where the river might not burst its banks.

Levees and embankment Systems: Artificial levees can be built along river banks so that if the river floods, the water will not be able to breach the wall and cause damage. Levees can be expensive and can spoil the look of rivers.

Straightening and Deepening Systems: The river channel may be widened or deepened allowing it to carry more water. A river channel may be straightened so that water can travel faster along the course. The channel course of the river can also be altered, diverting floodwaters away from settlements.

Soft-Engineering Systems

Wash lands Systems: These are areas of land where water can wash into during a flash flood. They are usually found in the lower course of a river. Sluice gates will be opened to allow excess water to flow into the area and flash flood marginal land.

Afforestation Systems: Afforestation cannot prevent flooding but it can help reduce its likelihood.

CONSERVATION & UTILIZATION OF FLASH FLOOD WATER

By above methodologies, the excess flash flood water can be stored and conserved either in check dams, ponds/lakes and the same water can be used by the farmer for irrigation purposes through solar pumping system(SPS) as per their requirements in the future. And also, the flash floods will ensure that there is drinking water in dry places[11].

CONCLUSION

Climate change is expected to affect flash flooding through changes in rainfall, temperature, rise in sea level and river processes. Climate change will exacerbate the existing effects of flooding on infrastructure and community services, including roads, storm water and wastewater systems and drainage, river flood mitigation works, and private and public assets including houses, businesses and schools. Climate change may change flash flood risk management priorities and may even increase the risk from flooding to unacceptable levels at some places. It is therefore important that flood risk assessments incorporate an understanding of the impacts of climate change on the flood hazard.

Managing present-day and future risk from flooding involves a combination of risk-avoidance and risk-reduction activities. The treatment options could be a combination of avoiding risk where possible, controlling risk through structural or regulatory measures, transferring risk through insurance, accepting risk, emergency management planning, warning systems, and communicating risk (including residual risk) to affected parties. The best combination will consider the needs of future generations and not lock communities into a future of increasing risks from flooding.

REFERENCES

1. Self study during my PhD research guided by Dr. Khaleda Rehman, JRU, Ranchi, JH.
2. European Commission, 2006. Floods and climate change. http://www.eurosfaire.prd.fr/7pc/bibliotheque/consulter.php?id=920 ECLAC, 2003. Handbook for Estimating the Socio-economic and Environmental Effects Disasters.
3. http://www.proventionconsortium.org/themes/default/pdfs/ECLAC_handbook.pdf FEMA, Flood hazard mitigation handbook, 2002. Federal Emergency Management Agency
4. U.S. Department of Homeland Security http://www.conservationtech.com/FEMA-WEB/FEMAsubweb-flood/index.htm. Ferris, E. 2010. Earthquakes and Floods. Comparing Haiti and Pakistan.
5. http://www.brookings.edu/papers/2010/0826_earthquakes_floods_ferris.aspx Forster T (2009). Sanitation in Urban Flood Settings. A Global WASH Cluster Technical Briefing for Emergency Response.
6. www.humanitarianreform.org/Default.aspx?tabid=770 HPN 2007, Public health in crisis affected populations; a practical guide for decision-makers.
7. http://www.odihpn.org/documents/networkpaper061.pdf IFRC, 2000, Disaster Emergency Needs Assessment. 2001, Beira.
8. http://www.alnap.org/pool/files/erd-2945-full.pdf USGS, 'Flood hazards – A national threat' Factsheet.

9. http://pubs.usgs.gov/fs/2006/3026/2006. 3026.pdf WASH Cluster, 2009. Lessons learned in WASH Response during Urban Flood Emergencies.

10. http://www.humanitarianreform.org/humanitarianreform/Portals/1/cluster%20 approach%20page/cl usters%20pages/WASH/Urban_Floods_WASH_Lessons_Learned.pdf WFP, UNICEF, Save the Children Alliance 2007. Inter-Agency Rapid Flood Assessment. Nepal, August 2007. http://documents.wfp.org/stellent/groups/public/documents/ena/wfp140334.pdf WHO, 2010. Floods, Technical Hazard Sheet, Natural Disaster Profile.

11. http://www.who.int/hac/techguidance/ems/floods/en/index.html WHO, 2005. Flooding and communicable diseases factsheet. Risk assessment and preventive. measures. http://www.who.int/hac/techguidance/ems/flood_cds/en/ WHO, 2010. Communicable disease risk among populations affected by flooding in Pakistan, August 2010.

Flood Risk Assessment, Forecasting and Geosynthetics in Flash Floods Management

Jnan Ranjan Pal
Chief Engineer (Retd.), Irrigation Department, Lucknow, Uttar Pradesh
✉ *jrpal0909@gmail.com*

ABSTRACT

For planning of any feasible and sustainable flood control system, it is necessary to ascertain the magnitude and occurrence of all great floods in the past and the expected flood exceeding earlier values in future. Any method is not perfect in predicting with certainty the time and size of any flood that may take place in future. Floods occurrence and magnitude are as uncertain as the meteorological phenomenon and contributing factors which are responsible for causing devastating floods. Probability of occurrence of major floods is greatest at a certain time of the year, which, in the case of the Indian rivers is the middle of the monsoon season i.e. the month of July and August. To reduce the impact of floods, it is very appropriate for a planned combination of water control structures, flood plain zoning and review of Flood Risk Assessment (FRA) in India and understand the best practices globally to take proactive measures to reduce risk and ensure sustainable development. It is worth mentioning that Geosynthetics can find immense use in flood control structures and also useful for use in concrete, earth and rockfill dams. If Geosynthetics are meticulously designed and correctly installed for all types of water resources structures, they can contribute to increase safety.

Keywords : Flood, Natural disaster, Risk-management, Forecasting, Catchment, Flood peak, Flood frequencies, Meteorological, Geosynthetics, Geotextile.

INTRODUCTION

From time immemorial flood plains are most suitable for human settlement, as evident from the fact that major civilizations such as Indus civilization, Mesopotamia civilization and Egyptian civilization flourished on the banks of rivers Indus, Euphrates,and Nile, respectively. Even today, high density of population resides in flood plains of various river basins in India and in other parts of the world. India is one of the most flood-affected countries in the world in terms of affected geographical areas. In India, rivers have been the lifelines of growth and culture. India is drained by twelve major river systems, with several smaller rivers and streams. The annual precipitation including snowfall over India is estimated as 4000 BCM.

Flood risk is a matter of national concern and is an important aspect of consideration for land use planning. The National Water Mission (NWM) clearly states the need to give focused attention to vulnerable areas including over-exploited areas through a systematic approach for coping with floods. Out of 29 states in India, 11 states are prone to flood and some of these states often experience more than one flood event a year. The economic losses to the nation are huge, the recent Chennai flood losses are estimated at INR 20,034 crore, Uttarakhand flood alone has resulted in economic losses of INR 6600 crore. Devastating floods of Jammu and Kashmir have caused an immediate loss of INR 5,400-5,700 crore, well exceeding 10% of the state's GDP. The losses due to recent devastating flood of Kerala is yet to be assessed.

Over the last six decades, India has taken several initiatives towards flood risk management and effective utilization of the water resources for food security and national development. Across the globe, the approach towards flood risk management has changed based on the learning and experience focusing an integrated approach to flood risk management. This is truly relevant in the case of India, which has a large density of rivers and population.

A. Evalution of Mean Annual Flood Peak

A few aspects of flood problem are capable of being formulated into fundamental propositions and those can be used as a basis for further study. One problem in finding floods in case of station, where flood peaks are available for short periods.

Floods of different frequencies for another neighboring catchment, having long term flood data and divide those floods by the mean annual flood peak of the index station by which the frequencies in terms of mean peak annual floods can be estimated. These flood frequencies are taken as such for the station in question, where stream flow records are inadequate. If the flood peaks for 10-15 years are available, their arithmetic mean will give quite reliable results. Frequencies of maximum probable flood can be calculated by Flood Frequency Method, such as Gumbel's Method.

For a particular region, a relation between catchment vs mean annual peak floods can be determined, which can be used to give mean annual flood peak for any new gauge site. Statistical relations have been derived by Dr. R.S. Varshneybased on "least square method" [1].

$Q_{mean} = 1295 + 0.468$ A.

And based on "arithmetic regression".

$Q_{mean} = 5278 + 0.465\ (A - 8510)$.

Q_{mean} = mean annual flood peak in cumec.

If we know mean annual flood peak of long term index station, say Q_{mi} (catchment area A_I) and if we have to find Q_{mS} of the short term station in question (catchment area A_S), then on the basis of Dicken's formula for northern India,

$$Q_{mS} = Q_{mi}\ (A_S/A_i)^{3/4}$$

And based on Ryve's formula for Southern India,

$$Q_{mS} = Q_{mi}\ (A_S/A_i)^{2/3}$$

If a big dam is to be located immediately upstream from a large city, where its failure could result in large loss of life or property, its design may even be based on probable maximum flood. The determination of the maximum probable flood should be based on a study of storm potential, the run-off potential and the run-off distribution as related to the physical characteristics of the watershed.

B. New Technologies and Approaches for Flood Forecasting and Management

Beneficial effects of the planned economy of India were being neutralized by the devastating floods, which often affect various parts of the country. Hence, during first Five-Year Plan attention was focused by the planners on the need for systematic and scientific approach to the flood problem. Hydrology wing of the Indian Meteorological Department was strengthened, and emphasis shifted subsequently from flood control to flood forecasting. The Ministry of Irrigation and Power Government of India, set up a Technical Committee in 1963, with the Director General of Observatories as one of its members, to develop a scientific flood forecasting and warning system in India. The recommendations of the committee were accepted in 1968. Accordingly, meteorological flood forecasting techniques are being implemented since then. Flood risk management and forecasting data required, can be classified into different categories, such as data on the basin entail digital elevation maps (DEM), in as much detail as possible; data on soil and land use; and data on the river network. Data on embankments and other line elements is often incomplete. Moreover, much data is presently only available in hard copy, which requires digitization before it can be used. As this is a time-consuming effort, it is often done on a project- by project approach creating inconsistent and incomplete data sets. Data need to be of consistent quality to be used.

Urban planning in India is mainly based on Town and Country Planning Act of the United Kingdom of 1947 and is mainly focused on detailed land use zoning emphasizing economic growth over a time horizon of nearly 20 years. Urban flood management needs to consider an integrated approach taking into account, location specific problems. For instance, plans for effective solid waste management and regulating the encroachment of river channels need to be integrated into the flood management plan. A river basin flood Management approach consisting of a mix of Structural and Non-structural measures based on the understanding of the flood characteristic, community issues and needs and taking climate change projection can be adopted.

C. Ganga Basin Flood Risk Assessment

The Ganges River Basin is the most populace in the world and lies in India, Nepal, China, and Bangladesh, with a total drainage area of about 9,84076 sq. km and a total population of 474.45 million. Of this around 80% of the total basin lies within India. The river presents great opportunities and greater challenges. It provides drinking water, agricultural water, hydropower generation and navigation and ecosystem services across more than one million sq. km. But the river is devastative as well; devastating floods and periodic draughts are routine and undermine development. Benefits from potential hydropower development and agricultural modernization remain largely untapped, while flood and draught management systems are inadequate to protect lives and livelihoods.

In this context, it is proper to mention that Tehri Hydropower Plant with a 260.5 m high, Earth & Rock Fill Dam, having gross storage of 3.54 BCM, live storage 2.615 BCM and underground power house of installed capacity of 1000 MW (4*250 MW) is fully operational from 2006-07 and producing much needed power to the northern grid. Tehri Hydropower Project is a multipurpose scheme designed for storing surplus water of river Bhagirathi during monsoon period in its Tehri Dam reservoir and releasing the stored water after monsoon period from the reservoir through power house to fulfil the irrigation and drinking water requirements of downstream region. Tehri Dam has safeguarded the downstream city of Rishikesh and Hardwar and other region from the fury of floods of 2010, 2011 and 2013. Tehri Dam has been significantly augmenting the lean season discharge of River Ganga, thus maintaining its religious significance of Ganga Ghats, and providing irrigation support to 8.74 Lac Ha land in U.P. by way of additional irrigation to 2.70 Lac. Ha area and stabilization of 6.04 Lac. Ha already irrigated area. It has created biggest reservoir in this region, which has vast potential for recreational activities and tourism. THDCIL, is adopting technologies and reservoir management program for optimizing the storage and release of water for the use and safety of downstream population and safety of structures from flash floods.

D. Flood Disaster Challenges and Mitigation Strategies of Kerala Flood in 2018

The flood that occurred in the month of August 2018 in Kerala, due to excessive rains during 15-17 August caused a large-scale devastation in terms of lives and property along with causing misery to a large section of population. The worst affected sub-basins in Kerala were Periyar, Pamba, and Chalakudy. The storm of 15-17 August 2018 was spread over the entire Kerala, with eye centered at Peermade, a place between Periyar and Pamba sub-basins. The three-day rainfall between 15-17. August 2018 was comparable to the devastating rainfall in Kerala known as Devikulam storm of, 16-18 July 1924 i.e. 94 years ago.

CWC, New Delhi, had conducted a study to analyze the rainfall and consequent flooding, even along with the reservoir operation component, to assess, whether this particular flood could have been averted or mitigated through flood forecasting and prudent reservoir operation. CWC, also suggested to formulate Rule Levels for various major reservoirs of Kerala, so that some dynamic flood-cushion can be provided to accommodate flood events of lower return periods, e.g. 1 in 25 years return period or 1 in 50 years return periods.

Three main reservoirs such as Kakki reservoir, (Pamba basin), Idukki reservoir, (Periyar basin), and Idamalayar reservoir, (Periyar basin), are multipurpose reservoirs. So, a balanced approach has been adopted to formulate Rule Levels by studying all aspects, such as: reliability of fulfilment of designated demands; probability of filling the reservoir by the end of monsoon; and moderation of floods. Since due to steep terrain and heavy rainfall, less time of concentration are available in almost all basins of Kerala. Hence, making forecasting is an exceedingly difficult task. The operation of reservoir on probability-based Rule Curves, can be a possible solution for some flood relief to this heavy rainfall State of Kerala. [2]

E. Measures to be Adopted for Solution to Flood Problem

Natural Disaster have become an aggressive frequent occurrences phenomenon, due to effect of climate change and other reasons such as CO^2 emission. While natural disasters cannot be prevented, much can be done to reduce the loss of human and animal life and property. Floods are natural phenomena except the situations involving failure of flood control structures or faulty regulation of reservoirs; and permanent immunity against floods is not techno-economically feasible. However, impacts of floods can be mitigated to a certain degree by adopting appropriate structural and non-structural measures. In this context following measures are being adopted to find a lasting solution to flood problems.

Structural Measures:

- Reservoirs
- Detention Basins
- Embankments
- Channelizing of rivers
- Channel Improvements
- Drainage Improvement
- Diversion of Flood waters
- Watershed Management.

Nonstructural Measures:

- Flood Plain Zoning
- Flood Forecasting.

Reservoirs and flood plain zoning are generally considered as long terms solutions to the problem of floods. Flood management has a strong linkage with real-time hydrological analysis and information generation on demand. A dynamic flood forecasting is becoming increasingly necessary as we are witnessing several intense and unpredictable rain events, leading to floods in area hitherto not known for the same. Hydrologic simulation techniques coupled with the terrain modelling for hydrodynamic simulation can provide a good way to generate advisories for such areas. The advisories with a probabilistic basis can help the disaster management agencies to take up advance preparations towards deployment of resources and information dissemination amongst the affected communities to make them resilient. [2]

F. Flood Disaster Mitigation Measures using Geosynthetics

Geosynthetics are synthetic products used to stabilize terrain. Engineers of various Government departments like Roads and Buildings, Irrigation and Disaster Mitigating Agencies are facing tremendous problem due to the natural disasters like floods, river bank erosion, costal erosion and land slide, which can be minimized by using geosynthetics as protecting material such as water barrier, drainage, filtration, protection and reinforcement.

Geosynthetic is defined by the International Geosynthetic society as a planner, polymeric (synthetic or natural) material used in contact with soil/rock and/or any other geotechnical material in civil engineering application. [3]

Geotextile, a generic member of the Geosynthetic family, are generally polymeric products used to solve civil engineering problems. This includes eight main product categories, such as, geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geofoam, geocells and geo-composites. The polymeric nature of the products makes them suitable for use in the ground where high levels of durability are required. They can also be used in exposed applications.

Geosynthetics are available in a wide range of forms and materials. These products have a wide range of applications and are currently used in many civil , geotechnical, transportation, governmental, and hydraulic developments including roads,air-fields, rail roads, embankments, retaining structures, reservoir, canals, dams, erosion control,sediment control, land fill liners, land fill covers, mining, aquaculture and agriculture.

Types of Geotextiles

Geotextiles are textiles consisting of synthetics fibers rather than natural ones such as cotton, wool, or silk. This makes them less susceptible to biodegradation. These synthetic fibers are made into porous fabrics by standard weaving machinery or are matted together in a random nonwoven manner. Some are also knitted. Geotextiles are porous to liquid flow across their manufactured plane and within their thickness,

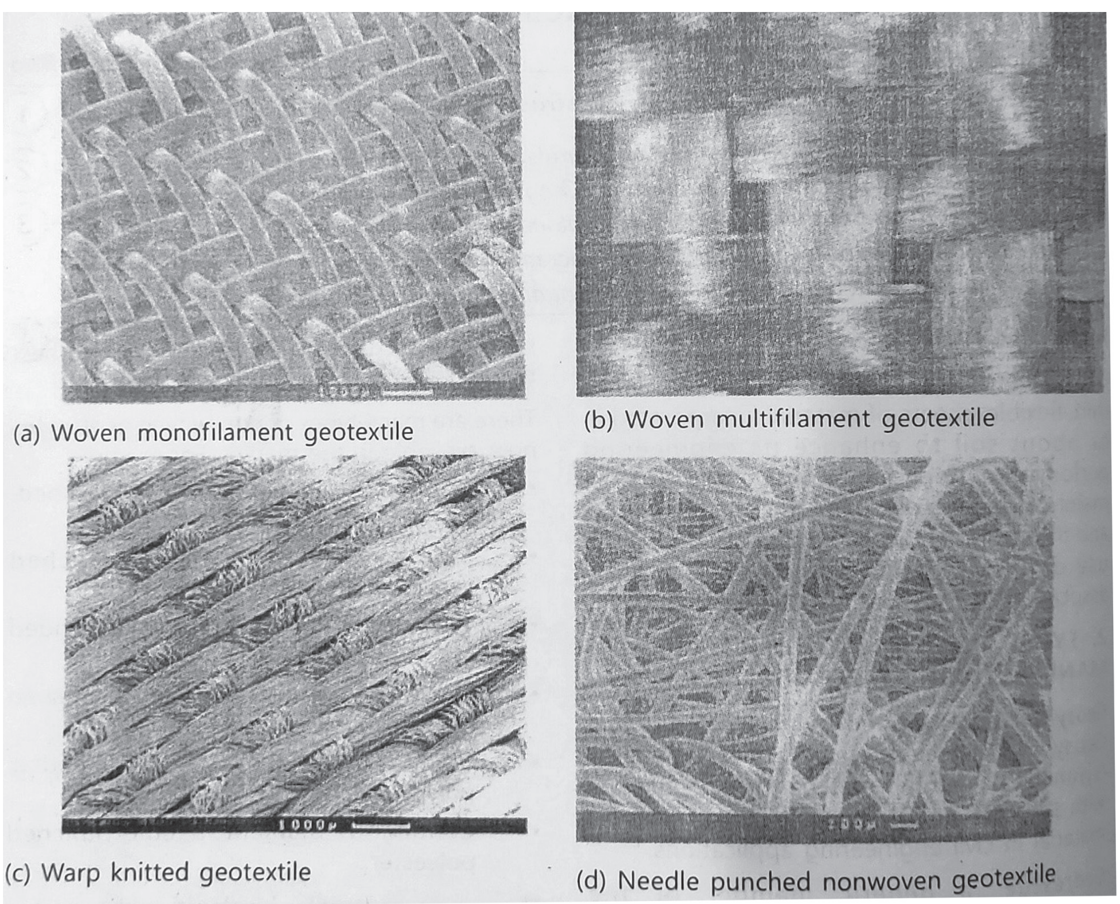


Fig. 1 Scanning electron Micrograph View of woven, knitted, and non-woven geotextile

but to a widely varying degree. Geotextiles have been developed for about 100 specific areas of application. However, the fabric always performs at least one of four functions, such as, separation, reinforcement, filtration and/ or drainage, barriers, erosion control containment and protection.

Generally, woven geotextiles exhibit high-tensile strength, high modulus, and low elongation. Non-woven geotextiles have high permeability and conformability, because of their high elongation characteristics. The woven geotextiles available in the market are generally:

- Slit film tape woven.
- Monofilament, and multi-filament woven.

Fig. 1 shows woven, knitted, and non-woven geotextile. [3]

Geosynthetics are Used in Civil Engineering in the Following Way.

I. Soil reinforcement structure.

II. Basal reinforcement to support the soil reinforcement structure.

III. Filtration behind all hydraulic structures.

IV. To drain seepage water in earth dams and water from base of embankment. Drainage control at the top to collect any seepage water coming from the other side of the embankment to avoid contamination on the structural fill. The use of geosynthetics in earth dams may serve several functions such as water barrier, drainage, filtration protections and reinforcement.

V. Separation between the in-situ soil and the imported soil to prevent mixing, which can reduce any mechanical performance.

VI. To protect the drainage medium and to provide drainage medium.

VII. Erosion control blanket to protect the slope at the top and avoid erosion. Geosynthetics have been used trustfully in concrete and masonry dams for rehabilitation works, while they have been used for both rehabilitation and new construction for earth and rockfilldams.

Geotextile Filters in Flood Management Works

For better performance of embankments, retaining walls, pavements and other structures, drains are provided to relieve hydrostatic pressure by allowing passage of water, while preventing loss of soil. Traditionally granular filters are provided to serve these two functions. In last 25 years or so, geotextile filters have emerged as a better alternative to traditional granular filter. Usually, gabions, geotextiles and mattresses are used for erosion protection. Furthermore, geotextile filter and geotextile reinforcement ensure stability during saturation in the rainy season and sudden drawdown conditions. Nonwoven geotextile act as filter separators, drains and reinforcement. Many of the shortcomings of traditional filter can be overcome by using geotextile. An economical pre-formed unit, made of double-twisted mesh to provide primary reinforcement, is used for erosion control. Specially, a single layer of geotextile fabric can replace a graded filter comprising of two or three layers. Geotextiles are easy to install, especially, working under water becomes much easier because the filter system can be assembled above the water and lowered into position.

Soil reinforcement, using Geosynthetics are now a favorable practice. Geo-grid used are high-tension polyester, encased in a LLDPE (linear low-density polyethylene) coating to prevent installation damage, acting as a primary reinforcement. Usually Geosynthetics for soil reinforcement are laid in one of the following scenarios, such as, when either the soil bearing capacity is low or the layers are compressible; when in a land slide prone zone; when there is excessive rutting and; when there are uneven settlements.

G. Protection of Bank Erosion in Farakka Barrage Project, West Bengal

Geotextile filter has been successfully used in, Farakka Barrage Project. The Farakka Barrage Project is designed to serve the need of preservation and maintenance of Kolkata Port by improving the

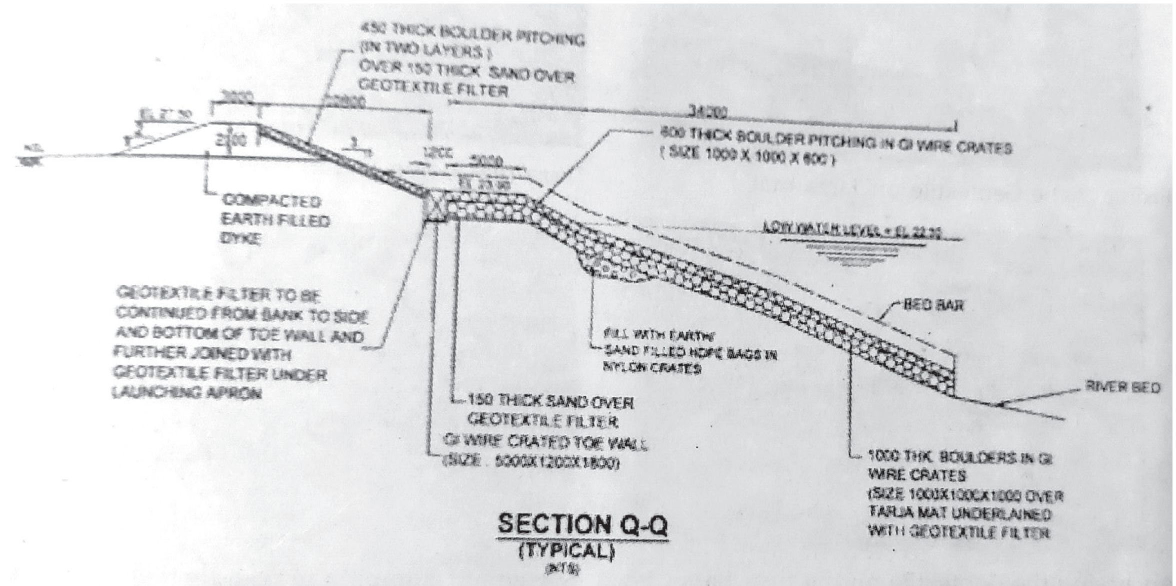


Fig. 2 Typical design section of anti-erosion works at Farakka

regime and navigation of the Bhagirathi-Hoogly River system. Farakka Barrage was constructed across River Ganga at Farakka to divert 1135 cumecs of water into the Bhagirathi River to revive it and was commissioned in 1975. The Bhagirathi River is one of the important spill channels, taking off from Ganga and feeding the Hooogly system, which is the lifeline of this region, where a large industrial complex has developed. The rail-cum road bridge built on the Barrage to link the North-Eastern states and Navigation lock at Farakka form part of the Haldia-Allahabad Inland Water Way (National Water Way no-1). Hence, this project is of National importance.

In Ganga, the whirling action of flood waters sucks the loose unconsolidated sandy material from below the apron, resulting in progressive launching of apron leading to sinking of toe wall and consequent falling of pitching. For this anti-erosion works Geotextile filter is introduced and placed below the launching apron. This prevented the erosion of bed material.

The anti-erosion works mainly involve laying of Geosynthetic fabric filter under Tarza mat in water as well as on the land depending on site conditions and over that boulder filled G.I. wire-crates of 1.6 m thickness(two layers of I m and 0.6 m each) in 34 m long apron laid/dumped to arrest scour due to high discharge intensities. The protection works for the river bank erosion around the Farakka Barrage project are a highly engineered solution and due care has to be taken for designing and choosing the products, structural integrity of the system, and experienced designer and contractors should be employed. **Fig.2** shows a typical design section of the anti-erosion works at Farakka Barrage. [3]

The Farakka Barrage Project Authority has restored the damaged banks of the river Ganges successfully and has imbibed a sense of security in the minds of the inhabitants of the area.

Geotextiles are sensitive to UV exposure and punching. Hence due care must be taken, during installation of Geotextiles. Geotextiles are comparatively costlier, but more effective with longer serviceability.

CONCLUSION

Different regions of India have different climates and rainfall patterns. Almost every year floods of varying magnitude affect some parts of the country or the other. The adverse impacts of floods include loss of life and property; mass migration of people and animals; and shortage of food, energy, water,and other basic needs. The degree of vulnerability to such natural disasters has been highest to the poor, who suffer the most as sheer necessity forces them to occupy the most vulnerable areas.

It is vital to understand the interplay between floods, the development process and poverty, in order to ascertain the way in which current and future development planning and implementation leads to or has the potential to increase vulnerability and risk. The economic growth triggered through various initiatives of Government and external funding programs, which vary from watershed management, rural development to smart city initiative, all need to consider flood risk aspects to ensure that the investment on these development program, will fetch the expected sustainable economic benefits.

Apart from the long-term mitigation measures, it is also necessary to have short and medium-term forecasting measures for providing adequate warning for disaster management agencies. Many a times, it is seen that the actions are post setting in, of the draught conditions, whereas the most precious resources, water is already consumed or wasted in the earlier periods. It is necessary that prediction and advance action strategies are put in place well in time.

To understand the geographical impacts of floods on various sectors, a comprehensive database (including residential, commercial, industrial, essential facilities, infrastructure and agriculture) is to be created at block/district level for the entire Basin to help the public, stakeholders and decision makers for better flood management and mitigation planning.

REFERENCES

1. R. S. Varshney, Engineering Hydrology, 2nd. Edn. 1979, pp 670-673.
2. Reference taken from Seminar conducted by NWDA, New Delhi in "India Water Week," 2016 and "India Water Week," 2017 & 2019.
3. Reference and Fig. 1 taken from Article written by Dr. G. Venkatappa Rao and Reference and Fig. 2 taken from Article written by Shri Murari Ratnam, Dr. R. Chitra, Dr. Manish Gupta in the Souvenir of All India Seminar on Geosynthetics in Natural Disaster Mitigation, 2015 organized by IEI(India), AP & Telangana State Center.

Gabion Retaining Wall- time Efficient, Cost Efficient and Environmental Friendly Structure to Control Flood

Ganesh C Chikute

Ph.D. Student, Department of Civil Engineering, Government College of Engineering Pune COEP

chikute.ganesh@gmail.com

Dr Ishwar P. Sonar

Assistant professor, Department of Civil Engineering, Government College of Engineering Pune COEP

ips.civil@coep.ac.in

ABSTRACT

Prediction of duration, location, and amount of flood is still having so many challenges. Presently, structures used for control of flood are masonry or concrete structures. These structures are rigid type and have more chance of failure due huge lateral flood pressure and erosion of foundation soil. Time required for construction of such types of structures also more. Gabion retaining wall is one of best option to control flood due to its flexible nature, cost and time effectiveness. This paper describes the details of Gabion wall, like materials used for construction, construction procedures, application area, and cost comparison. Author research in modification of Gabion wall to make it more space efficient, economical and ecofriendly is also described in paper.

Keywords : Gabion wall, Flood control structure, Cost comparison

INTRODUCTION

Drastic changing rainfall pattern due to climatic changes [1], human made obstruction in natural water bodies leads to flood risk to a great extent, which not only causes economic losses but results in loss of human life as well.

Structures used for flood control are one sort of retaining wall which may be made of stone or brick masonry wall, concrete wall or reinforced concrete wall [2]. Flood control structures are basically subjected to lateral water pressure. During high flood this lateral water pressure suddenly increases beyond the retaining capacities of these types of structures explained above which are rigid, develop crack and fails suddenly. Secondly, during flood there is localized or total erosion of soil at foundation which leads to stress concentration at a particular location and causes unequal settlement of structure. As above mentioned structures are rigid in nature they could not bear such stress concentration and unequal settlement which may lead to sudden failure of such structures.

Above mentioned problem is due to rigid nature of existing flood control structure. This problem can be minimize by using such material for flood control structure which have are flexible in nature and can bear such stress concentration and unequal settlement occurring during flood. Gabion wall is somewhat flexible in nature can bear stresses beyond its design limit to a great extent, resulting from stress concentration and unequal settlement.

In such case tension bearing capacity of Gabion mesh is utilized to bear such excess stresses and hence sudden failure of flood control structure during flood can be eliminated.

As existing flood control structures are either masonry or concrete they require curing and or shuttering period of at least 28 days. This results in increase in construction period of such structures. Secondly, such structure could not be constructed at once for the entire height due to restriction of lift and hence the actual construction period of such type of structure may get extended beyond 28 days. Hence, such existing structures cannot be used in case when there is not much time available for construction, especially during flood.

Gabion wall consists of stone filled mesh boxes which are tied together to form a shape of retaining wall. It does not require any curing or shuttering period and also there is no lift restriction on construction. Gabion wall construction proceeds continuously without requirement of curing period. Hence, construction of Gabion wall is very fast.

For construction of Gabion wall only naturally available stones and gabion mesh boxes are required and the structures are ecofriendly. The present work is on replacement of stones in Gabion wall, by eco-friendly recycled concrete blocks [3]. Such replacement of stones by recycled concrete blocks also helps in reducing seepage through body of stone filled Gabion wall. Further, to make entire Gabion structure entirely water tight if required, HDPE geomembranes [4] sheet can provide on the face of Gabion wall.

As Gabion wall made up of stone filled metallic boxes tied together to form wall, construction cost of Gabion wall is less [5] compared to other types of walls. Details of cost comparison of Gabion wall is explained further.

All above considerations makes Gabion wall more time & cost efficient and environmental friendly structure to control flood.

MATERIAL AND METHOD

Gabion wall is nothing but boulder filled box type cage formed by standard nets made of steel wire or polymer ropes. The netting is from mechanically double twisted hexagonal wired mesh made of heavily galvanized steel wire. The boxes are properly wired and laced together to form flexible, monolithic, confined building blocks, which are called as Gabion walls. Gabions in conjunction with boulders act as wall which retains water or soil as water front structures, as bridge abutment retaining structures and as slope stabilizing, erosion controlling systems, aprons and revetment construction etc. These walls are stable by self-weight and it does not require any foundation or anchorage.

Details of Metallic Gabion Box

The steel wire Gabion boxes and mattresses are factory-fabricated boxes manufactured using Mechanically Woven Double Twisted Hexagonal shaped wire meshes. Mechanically Woven Double Twisted wire meshes are non-ravelling, manufactured by twisting continuous pairs of wires through three one-half turns (commonly called double-twisted) to form hexagonal shaped mesh openings which are then inter-connected to adjacent wires to form hexagonal meshes. The edges of the mesh are toughened with a thicker wire called the selvedge/edge wire. Details of Gabion wall is given in IS 16014-2012 [6] and MoRTH 5th revision 3100 [7].

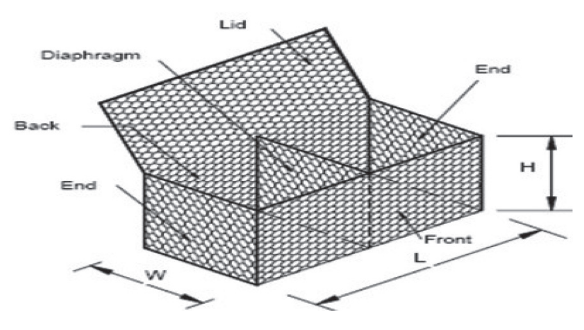


Fig. 1 Metallic Gabion box

Table 1 Specification for wires for Gabion box

Parameter	Mesh wire	Selvedge / Edge wire	Lacing wire
Diameter (mm)	2.7	3.4	2.2
Tolerance (mm)	± 0.06	± 0.07	± 0.06
Zinc coating (g/sq.m)	245 m	265 m.	230 m
Diameter (mm)	3.0	3.9	2.2
Tolerance (mm)	± 0.07	± 0.1	± 0.06
Zinc coating (g/sq.m)	270 m	275 m	230 m
Diameter (mm)	3.4	4.4	2.2
Tolerance (mm)	± 0.07	± 0.1	± 0.06
Zinc coating (g/sq.m)	265 m	290 m	230 m
Zinc Adherence	Flaking or cracking should not be observed on rubbing with bare fingers.		
Elongation (%)	10 m		

Wire- wire used for production of Gabion box is galvanized wire confirming to IS 280-2006 [8], have tensile strength of 350 to 550 MPa. Diameter of wires has range of 2.2 mm to 3.4 mm.

Wire Mesh- The wire used in the manufacture of mechanically woven, GI double twisted, hexagonal shaped mesh for the use in gabions, shall conform to IS 16014-2012. The details, as per reference [6], are shown in the **Table 1**.

Gabion box connection details and various types of wires are shown in **Fig. 2**.

Mesh Size- The mesh size is nothing but opening size of mesh is provided in **Table 2** and shown in **Fig. 3**.

Gabion Box sizes and Tolerances [9] - Gabion boxes are available in various sizes and shown in **Table 3**.

Stone- Locally available stones are used to fill Gabion Box; their sizes are as shown in **Table 4**.

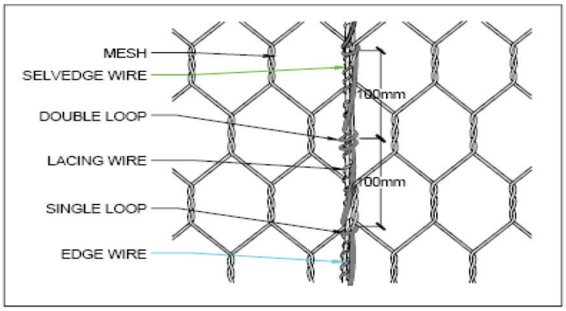


Fig. 2 Gabion box connection details

Table 2 Gabion box mesh size

Mesh Type	D (mm)	Tolerance for D	Diameter (mm)
60 x 80	60	(+16%, -4%)	2.2, 2.7
80 x 100	80	(+16%, -4%)	2.7, 3.0
100 x 120	100	(+16%, -4%)	2.7, 3.0

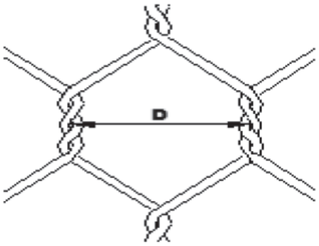


Fig. 3 Double twisted hexagonal wire mesh

Table 3 Gabion box sizes and tolerances

L(m)	W(m)	H(m)	Diaphragm nos.	Tolerance
2	1	1	1	+/- 5%
3	1	1	2	
4	1	1	3	
2	1	0.5	1	
3	1	0.5	2	
4	1	0.5	3	
2	1	0.3	1	
3	1	0.3	2	
4	1	0.3	3	

Table 4 Details of stone used in Gabion

Gabion Basket or Mattress Height	Predominant Rock Size	Minimum Rock Dimension	Maximum Rock Dimension
300, 450,900 mm Basket	100 to 200 mm	100 mm	230 mm
150, 230, 300 mm mattress	75 to 150 mm	75 mm	175 mm

Tests Conducted on Gabion Mesh

i) Tensile test- Tensile test on Gabion mesh is conducted as per MoRTH 2500 Rev. 5 and IS 16014-2012. In this test Gabion mesh of 0.8m length and 0.5m height is tested in UTM with specially designed mesh clamping attachment.

ii) Punching test- Punching test on Gabion mesh is conducted as per MoRTH 2500 Rev. 5 and IS 16014-2012. In this test Gabion mesh of size 1m × 1m is clamped from all size in horizontal plane with special test frame.

Upward load is applied on centre of mesh by plunger of 0.3m diameter.

iii) Zinc coating test- This test is conducted according to IS code 4826-1979, in which adhesion of zinc coating with wire is tested.

iv) PVC coating test- This test is conducted according to IS code 16014-2012.

Construction Procedures

Step-1 Geotechnical Investigation- Geotechnical Investigation is carried out to find out required engineering properties of soil.

Step-2 Design and Drawing- Gabion wall is designed and a detail drawing is prepared based on the data received from geotechnical investigation.

Step-3 Foundation Preparation- Foundation bed is levelled and all soft and unsuitable material are removed and replaced with suitable material, which shall then be compacted to at least 95% of maximum laboratory dry density for top 300 mm of soil.

Step-4 Filter Cloth or Filter Stone- Upon final foundation preparation, the filter cloth or filter stone shall be placed directly on the foundation at locations shown on the plans. All end and side laps shall be a minimum of 450mm for the filter cloth.

Step-5 Gabion Assembly - Gabions shall be fabricated in such a manner that the sides, ends, lid, and diaphragms can be assembled at the construction site into rectangular baskets. Gabions shall be of single unit construction, as shown **Fig. 4** i.e., the base, lid, ends, and sides shall be either woven into a single unit or one edge of these members connected to the base section of the Gabion in such a manner that strength and flexibility at the point of connection is at least equal to that of the mesh. Gabion units shall be equally divided by diaphragms of the same mesh and gauge, into cells whose length does not exceed the horizontal width. All perimeter edges of the mesh forming the Gabion shall be securely selvedged so that the joints formed by tying the selvedges have at least the same strength as the body of the mesh. Lacing wire or connecting wire shall be supplied in sufficient quantity for securely fastening all diaphragms and edges of the Gabion.

Step-6 Placing & Filling of Gabion Boxes to form Gabion wall- Empty assembled Gabion units are placed on prepared foundation base. All adjoining empty Gabion units must be connected by tie wire lacing along the perimeter of their contact surfaces in order to obtain a monolithic structure as shown

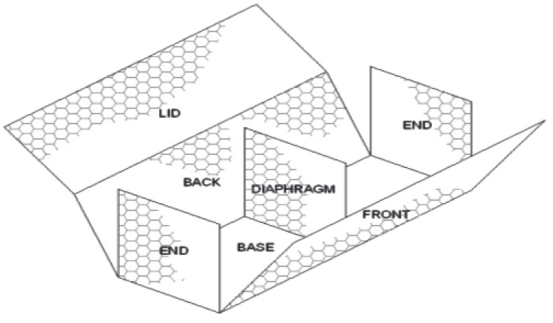


Fig. 4 Gabion box assembly details

in **Fig. 2**. Lacing of adjoining basket units shall be accomplished by continuous stitching with alternating single and double loops at intervals of not more than 125mm. All lacing wire terminals shall be securely fastened.

Stone filling operations shall be carefully proceeded with placement by hand or machine so as not to damage galvanized wire coating, minimum of voids in stones, no damage to the underlying filter blanket, and maintaining alignment of wall during stone filling. The maximum height from which the stone may be dropped into the basket units shall be 300 mm. Along all exposed faces, the outer layer of stone shall be carefully placed and arranged by hand to ensure a neat and compact appearance. The last layer of stone shall be levelled with the top of the Gabions to allow for the proper closing of the lid and to provide an even surface that is uniform in appearance.

Lids shall be stretched tight with tie wire along all edges, ends and internal cell diaphragms by continuous stitching with alternating single and double loops at intervals of not more than 125 mm. Turn all projections or wire ends carefully to avoid injury. Single Gabion or one compartment of Gabion box at time, filled it equally at a time.

Step-7 Backfilling- Backfilling of the Gabion wall shall follow erection as closely as possible and in no case should the height of the wall be greater than seven feet above the backfill. The top 300 mm layer shall be compacted to at least 100 percent of the maximum laboratory dry density. The backfill material shall consist of broken or crushed stone, gravel, sand, slag or other suitable coarse granular material to ensure proper drainage. Shale, clay or cinders shall not be permitted as backfill material.

Application Areas

Gabion wall have been used in various locations like retaining wall in hilly and water prone area [10], river bank protection [11], erosion protection of piers and abutments of brides, cannel lining, weirs etc. shown in following Photo 1.

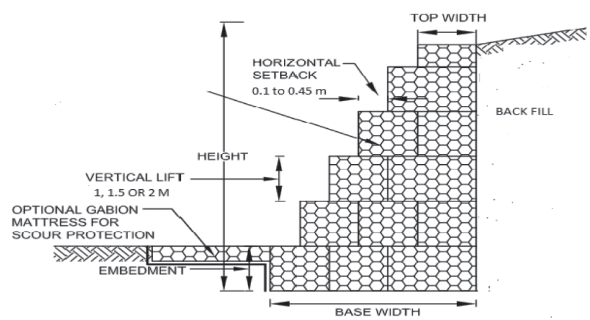


Fig. 5 Typical Gabion wall cross section

COST COMPARISON

Author had conducted cost comparison [3] of Gabion wall with other conventional retaining walls, namely Stone masonry, RCC cantilever and RCC Counterfort wall. In this study, all above types of wall are designed for common height and common input data. All checks as per IS code 456-2000 were carried out. From the design point of view, costs of all types of walls are worked out by using schedule rates, Government of India Central Public Work Department [13] as shown in **Table 5**.

Above cost comparison shows that Gabion wall is one of best economical option for retaining wall.

ROLE OF GABION WALL IN FLOOD SITUATION

Since, Gabion wall has high permeability, seepage water does not create additional pressure like concrete retaining wall. Since stones are

Table 5 Cost comparison of different retaining walls

	Stone Masonry	RCC Cantilever	RCC Counterfort	Gabion Wall
Per Rmt Cost	54,172	83,467	59,961	54,156
% variation	0.03	54.12	10.72	0

more durable as compared to bricks, their life is more. Since Gabion wall is gravity type wall so additional reinforcements are not required (except mesh which are galvanised and polymer coated). In flood situations, impact due to the tidal forces or unexpected high pressure get reduced due to porosity and voids available in Gabion wall. There is scope for research in calculations of wave energy absorption capacity of Gabion wall. Due to wider base width, and higher weight, there is less possibility of overturing. The ductile wire meshes show warning before failure. Local damage may occur in Gabion wall. Excavation for foundation is normally not required in case of Gabion wall.

RESEARCH ON GABION WALL MODIFICATION

As Gabion wall is gravity type of wall (resist load by self weight) it requires large cross section area. Height to base width ratio for Gabion wall is very high (About 0.7 to 0.9) as compare with other types of retaining wall, hence, Gabion wall requires large space for construction which may not be available on site. Secondly, high strength Gabion box acts as stone holding cage, though it has sufficient tension taking capacity.

Author is working on his research on modification of Gabion wall, in which he is trying to use tensile capacity of Gabion mesh by converting gravity action of conventional Gabion wall to partial cantilever action.

In this way, one can reduced depth of Gabion wall by about 50%. This modified Gabion wall have lesser cross section area than conventional Gabion wall and hence can be accommodated in narrow area and also more economical.

Another major problem with Gabion wall is non-availability of proper shaped and strong stones at all time, leading to buldging and subsequent failure of Gabion wall.

Author is working on replacing these stones by recycled concrete block, which makes Gabion box more stable, intact and also ecofriendly by reusing demolished concrete blocks.

Modification of Gabion Wall is shown in **Fig. 6**.

CONCLUSION

Considering all aspects as summarised below, the Gabion wall is one of best option for controlling and managing flood.

i) Construction time is less and hence can be erected within a short-time in emergency like situation resulting from flood.

ii) Construction is easy as it can be constructed with locally available labours and materials.

iii) Best suited for structure in water prone area due to its flexible nature, rather than rigid nature of conventional structure. Unlike

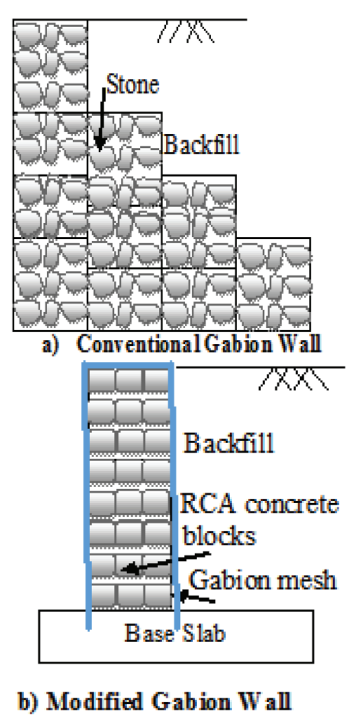


Fig. 6 Conventional and modified Gabion wall

conventional structures, these structures does not fail suddenly and hence allows sufficient time for evacuating flooded areas saving considerable number of lives and property.

iv) It has wide applications ranging from protection of bank erosion of river, retaining earth back fill, to control erosion of bridge piers and abutments.

ACKNOWLEDGMENT

The author would like to express his gratitude for his Doctoral guide from Government College of Engineering Pune, for his continuous support and motivation.

REFERENCES

1. Zbigniew W. Kundzewicz and Shinjiro Kanae, "Flood risk and climate chane: global and regional perspectives", Hydrological Sciences Journal, vol.59, issue 1, 2014.
2. Audu Zanuwa, Luckman Abdulmumin and Jabir Abdulkadir, "Assessment of causative and preventive measures of flood Menance in urban Zaria L.G.A. f Kaduna, state Nigeria", IJRISS, ISSN2454-6186, vol. 2, issue 6, June 2018.
3. G. C. Chikute & I. P Sonar (2018). "Techno-Economical Analysis of Recycled Masonry block for Eco friendly and Economical construction". Proceeding ASCE India conference 2017 at New Delhi, Dec. 2017, pp 12-14.
4. Product sheet of Geomembranes, Tacoma Global.
5. Ganesh C. Chikute and Ishwar P. Sonar, "Techno-Economical Analysis of Gabion retaining wall against conventional retaining walls", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, Vol.6, Issue: 08 Aug 2019.
6. IS CODE 16014-2012- "Mechanically woven, double-twisted, hexagonal wire mesh Gabions, revet mattresses and rock fall netting (galvanized steel wire or galvanized steel wire with pvc coating) –specification"
7. Ministry of Road Transport and Highways (MoRTH), 3100, Specifications for road and bridge works, 5th revision, IRC, 2013 New Delhi
8. IS CODE 280-2006, "Steel wire for general engineering purposes".
9. ASTM A975-2016, Standard "specification for double twisted hexagonal mesh Gabions".
10. Ankita R. Jayswal, Fatema S. Malekwala, Chanda Rautela (2014), "Flood Protection Work by Terramesh Wall," IJSRD,Vol. 2, issue 01, 2014/060.
11. Ghislain Brunet, Randall Shuey- "Stream Bank Stabilization with Vegetated Gabion by 'Intervale Country Club Golf Course' Manchester,New Hampshire.
12. IS Code 456-2000- "Plain and Reinforced Concrete code of practice."
13. 'District Schedule Rate', Central Public Work Department, Government of India.
14. BS 8002:1994 - Code of practice for Earth retaining structures.

Glacial lakes and Outburst Flood Hazard in Northwestern Himalayas

Saket Dubey, Manish Kumar Goyal
Department of Civil Engineering, India Institute of Technology, Indore, Madhya Pradesh
✉ *mkgoyal@iiti.ac.in*
Nitin Joshi
Department of Civil Engineering, India Institute of Technology, Jammu, Jammu & Kashmir
✉ *nitin.joshi@iitjammu.ac.in*

ABSTRACT

Glacial lakes located in North Western Himalayas can threaten downstream population and can lead to high socio-economic impact in case of a breach. The present study assessed all the glacial lakes greater than 0.028 km^2 located in Himachal Pradesh. To assess the spatiotemporal change of lake dimensions, a glacial lake inventory for the year 1993, 2000, 2013 and 2018 was prepared using LANDSAT multispectral images. Over the period of 26 years, 4 new glacial lakes were formed (>0.028 km^2) and the total glacial lake area changed from 3.39 ± 0.46 km^2 to 5.72 ± 0.78 km^2. A new combination of parameters was applied to identify critical lakes. Stochastic simulation of probable downstream flood from these lakes suggest about the flooding of many tourist camps and hydropower systems which needs immediate attention. Ten lakes were identified as potentially dangerous glacial lakes (PDGLs) with six of them having PFV greater than 3×106 m^3.

Keywords : Glacial lake, Glacial lake outburst flood (GLOF), Himachal Pradesh, Landsat images

INTRODUCTION

Glacier retreat is a well-known outcome caused mainly due to global climate warming. It poses a great level of threat to the environment [1–3]. Himachal Pradesh located in India is home to about 2100 glaciers [4]. The warming of the Tibetan plateau and the eastern Himalayas has a high influence on the retreat of Himalayan glaciers. However, the retreat of the individual glacier is a characteristic of its own location and climatic condition. Thinning and retreating of large glaciers such as Bara Shigri, Chadra and Chota Shigri is evident from Previous studies [5–7], these retreating glaciers expose over deepenings leading to the formation and expansion of glacial lakes. Glacial lake outburst flood (GLOF) is an event where a rapid discharge of significant amount of water along with debris occurs because of either breach or over topping of the damming structure. Development and enlargement of glacial lakes increases the chances of a GLOF event. In addition to this, majority of these lakes are dammed by unstable and loosely consolidated end-moraines which can generate a breach even with a small instability in the system [8]. The downstream impact worsens when the flow path is steep and erodible as in case of the Kedarnath GLOF event which took place on 16th June 2013, leading to destructive debris flows causing death of more than 6000 people[9–11]. Many other such events have occurred in the past such as the ice avalanche induced GLOF in lake Palcacocha[12] on 13th December 1941 which destroyed town Huarez killing around 1800 people, Dig cho lake outburst in Nepal in 1985, etc[13–15]. Hence, it is evident that these glacial lakes are potentially dangerous and there is a need to monitor and develop a warning system to plan and adopt mitigation measures.

As most of these glacial lakes are situated in remote locations, it becomes challenging, unmanageable and, time-consuming to analyse them through field studies. With the availability of chronologically ordered multispectral satellite data, an attempt to remotely monitor and analyse these lakes can prove to be beneficial. In the recent past, glacierized regions are monitored and analysed using remote sensing techniques [3,16–19]. This study presents an approach utilizing digital elevation model (DEM) to determine the steep lakefront area (SLA) which will further aid in estimating the potential lowering of the moraine dam in case of a breach. This potential lowering, in conjunction with other morphometric characteristics, were used to assess the outburst susceptibility of GLOF event for each lake.

METHOD

Parameters assessed in the present study **(Fig. 1)** to mark a lake as potentially dangerous are basic lake characteristics in conjunction with moraine's stability parameter using the concept of SLA as it estimates the flood volume in case of breach, irrespective of its triggering mechanism.

Lake Characteristics

1. Type of glacial lake - glacial lakes are classified as moraine-dammed lake, ice-dammed lake, glacier erosion lake, cirque lake, debris dammed lake and artificial lake. Moraine-dammed lakes and ice-dammed lakes are usually the most dangerous and unstable structure considering the unpacked damming structure. Past studies also signify that these lakes have shown the highest number of GLOF events [20], followed by the glacier erosion lake and the debris dammed lakes. Cirque lakes are considered least dangerous as they have closely packed dense damming structure with marginal variation over time.
2. Proximity to parent glacier – ice calving and avalanches have caused a large number of GLOF events due to the formation of tsunami-like wave which overtops or breaches the damming structures. The probability of ice calving and avalanche increases with the increase in proximity of the lake to its parent glacier.
3. Elevation of the glacial lake – the presence of glacial lake at higher elevation provides higher potential to flooding water which will eventually lead to higher runout length and a larger amount of debris flow along its path 21.
4. Expansion rate – most of the glacial lakes that have undergone a GLOF event have shown a significant enlargement over time. Additionally, expansion of the glacial lake changes the damming condition by shifting the damming structure from the pre-consolidated dam to the unconsolidated loosely packed damming structure [22–24].

Moraine's Stability

5. Potential Flood volume – downstream impact of a GLOF event is closely related to potential flood volume as it significantly influences the amount of debris flow, runout length and inundation area.

RESULTS

Each lake (> 0.028 km^2) in Himachal Pradesh that was within 10 km of glacier boundary (RGI) was considered in the study, the threshold of 10 km was applied to incorporate as many lakes as possible. The threshold of 0.028 km^2 on lake size was based on the smallest size of the lake that has caused casualties to downstream communities in

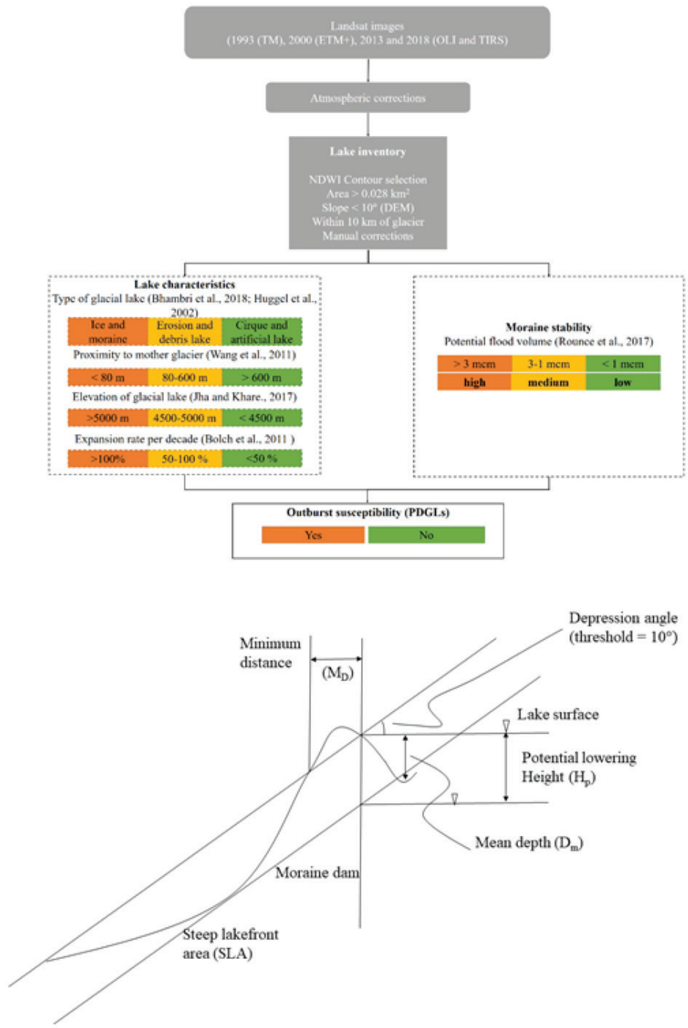


Fig. 1 Overview of methodology and SLA schematic

case of an outburst [25]. These lakes were verified using Google Earth images as well as from the Himachal Pradesh glacial lake inventory created using high resolution (Linear Imaging Self-Scanning Sensor-4) LISS-4 multispectral images in Bhambri et al., 2018. A total of fifty lakes were found to have a size greater than 0.028 km^2 **(Fig. 2)**.

Among these lakes, Samudri Tapu Lake (lake ID 50) has the maximum area of 1.254 km^2 as of October 2018. It was observed that the elevation profile of these lake lies between 2973 to 5583 m.a.s.l. Forty-seven out of fifty lakes lie above the elevation range of 4000 m. The distance of these lakes from their parent glacier ranged from 0 to 6.685 km. The size of the lake varied from 0.018 km^2 to 1.25 km^2 with a mean value of 0.114 km^2 for the year 2018. Moraine-dammed and ice-dammed lakes are highly susceptible to GLOF (High hazard), whereas debris dammed and glacier erosional lakes are moderately susceptible (medium-hazard category). Cirque lakes and the artificial lakes are stable (low-hazard category). Lake area for different lake type shows uniform distribution, where no particular lake type has shown a greater area **(Fig. 3)**. Like other Himalayan regions, Distribution of different lake types along various elevation zones was uniform in Himachal Pradesh **(Fig. 3 (a))**. Usually, genesis of lake is elevation dependent as ice-dammed

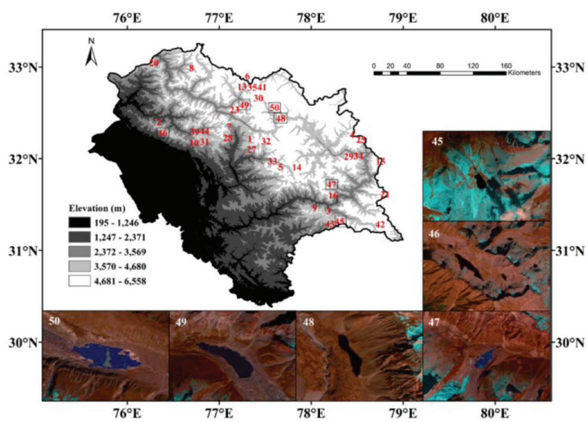


Fig. 2 Elevation profile of Himachal Pradesh. Numbers on the map shows the lake ID assigned in the study. The figure also shows Landsat 8 image (False colour composite) for October 2018 for 6 largest lakes in Himachal Pradesh with their lake ID.

and moraine-dammed lakes are formed at higher elevation whereas debris dammed and erosion lakes are formed at lower elevation. **Fig. 3 (b)** demonstrates the distance of lakes from their parent glacier. From the proximity distribution of various lakes, it was observed that, most of ice-dammed and moraine-dammed lakes lie in close proximity to parent glacier with the exception of only 3 lakes which were found to lie beyond 500 m. The close proximity of moraine and ice-dammed glacier to their parent glacier make them furthermore susceptible to significant expansion and GLOF events. SLA average angle as described in Fujita et al. (2013) defines an alternate way to estimate moraine's stability. **Fig. 3 (c)** demonstrates the SLA average angle value for all the lakes considered in the study.

Lakes directly connected to their parent glacier have shown a higher risk of hazard. Lakes within 80 m were considered in the high-hazard category, 80 m to 600 m in the medium hazard category and beyond 600 meters were considered in the low-hazard category [26]. Twenty-eight lakes out of fifty fell in a high-hazard category with an average distance of 7.71 m, Eight lakes fell in the medium hazard category with an average distance of 247.83 m and fourteen lakes fell in the low-hazard category with an average distance of 1985.14 m. Lakes lying above 5000 m were considered in the high-hazard category, whereas the ones lying between 5000-4500 were considered in the medium hazard category and lakes lying below 4500 were considered in the low-hazard category. Out of fifty lakes, 10 fell in the high-hazard category, 13 in the medium hazard category and 27 in the low-hazard category.

The total lake area changed from 3.54 ± 0.48 km^2 in 1993 to 5.72 ± 0.78 km^2 in the year 2018. The percentage expansion during 1993-2000 was ~29.66%, during 2000-2013 was ~17.82% and during 2013-2018 was ~5.68%. Lakes showing an increment in the lake area greater than 100% per decade 27 were considered substantially expanded (high hazard category) whereas, the ones showing an increment between 50 to 100%

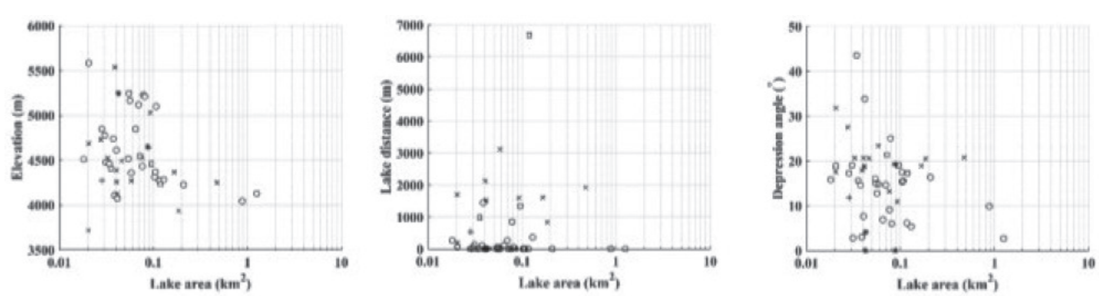


Fig. 3 Lake distribution based on (a) various elevation range, (b) lake distance to parent glacier, (c) SLA average lake angle against lake area in October 2018. Where circle (o) denotes moraine-dammed lake, cross (x) denotes glacier erosion lake, square (□) denotes cirque lake, star (*) denotes ice-dammed lake, and plus (+) denotes debris dammed lake

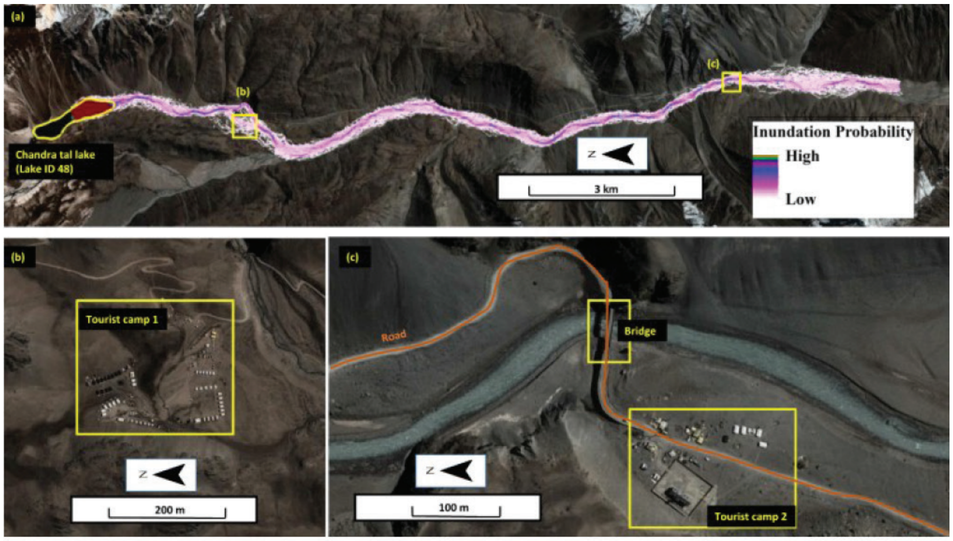


Fig. 4 (a) Inundation map of Chandra tal lake (lake ID 48) prepared considering DEM root mean square error of 15 meters. (b) Tourist camp site 1 highly vulnerable to flooding. (C) Tourist camp site 2 along with road and bridge highly vulnerable to flooding in case of GLOF

were considered moderately expanded (medium hazard category), lakes showing expansion less than 50% were considered in low-hazard category. six out of fifty lakes significantly expanded during 1993-2018 and, among these 6 lakes, 3 were newly formed.

We applied SLA analysis on all the lakes considered in the study and found that 12 lakes do not have a SLA, and hence no PFV. Rounce et al., 2017 studied glacial lakes in Nepal Himalayas and estimated that PFV less than 3 ×106 m^3 have not caused noticeable catastrophic flood events in the past; therefore, this assumption was utilized to classify between medium and high-hazard lakes. Among the fifty lakes, seven lakes observed a PFV greater than 3×106 m^3 among which six were directly considered as PDGL with an exception of one cirque lake which was excluded due to its closely packed damming structure. Additionally, all the lakes having PFV greater than 1×106 m^3 and were characterized as high hazard in any three lake characteristic criteria were also considered PDGL. Based on preliminary assessment ten lakes were identified as PDGLs in the Himachal Pradesh, among the ten lakes, seven (Lake ID 47, 40, 39, 34, 26, 25, and 20) had moraine based damming structure, five (Lake ID 47, 40, 39, 26, and 20) were directly connected to their parent glacier, three (Lake ID 34, 26, and 25) lied above mean elevation of 5000 m, four (Lake ID 40, 39, 34, and 20) experienced expansion greater than 100% per decade, six (Lake ID 48, 47, 46, 45, 40, and 39) had PFV greater than 3×106 m^3.

To assess the downstream impact from these PDGLs, Monte-Carlo least cost path model (MC-LCP) (for details on MC-LCP model please refer Watson et al. 2015) was applied to determine the inundation probability map for each lake considering a uniform runout length of 50 km. Results from MC-LCP model reveals that the lake with highest PFV (Chandra tal lake, lake ID 48) can cause a devastating downstream impact, flooding many tourist base camps, as the area is widely known for tracking activities, adding to this the road leading to this lake has been recognized to cause many traffic accidents in the past due to steep terrain which may add to unfavourable impact in case of a GLOF **(Fig. 4)**. Inundation mapping of other PDGLs shows that lake (ID 47) can threaten a hydropower system, lake (ID 46) can threaten 4 bridges along its inundation path. Almost all the lakes are capable of causing impact on human settlement except for lake (ID 26 and ID 45) which are remotely located.

ACKNOWLEDGMENT

We are grateful to the Ministry of Environment, forest and Climate Change, Government of India for sponsoring this research project (GBPNI/NMHS-2017-18/SG10) under NMHS Program.

REFERENCES

1. Bajracharya, S. R., Pradeep, K. M. & Basanta, R. S. Global climate change and melting of Himalayan glaciers. Melting Glaciers Rising Sea Levels Impacts Implic. 28–46 (2008).
2. Kaser, G., Hardy, D. R., Mölg, T., Bradley, R. S. & Hyera, T. M. Modern glacier retreat on Kilimanjaro as evidence of climate change: observations and facts. Int. J. Climatol. A J. R. Meteorol. Soc. 24, 329–339 (2004).
3. Worni, R., Huggel, C. & Stoffel, M. Glacial lakes in the Indian Himalayas — From an area-wide glacial lake inventory to on-site and modeling based risk assessment of critical glacial lakes. Sci. Total Environ. 468–469, S71–S84 (2013).
4. Bhambri, R. et al. Glacier Lake inventory of Himachal Pradesh. Himal. Geol. 39, 1–32 (2018).
5. Berthier, E. et al. Remote sensing estimates of glacier mass balances in the Himachal Pradesh (Western Himalaya, India). Remote Sens. Environ. 108, 327–338 (2007).
6. Wagnon, P. et al. Four years of mass balance on Chhota Shigri Glacier, Himachal Pradesh, India, a new benchmark glacier in the western Himalaya. J. Glaciol. 53, 603–611 (2007).
7. Kulkarni, A. V, Rathore, B. P., Mahajan, S. & Mathur, P. Beas basin, Himachal Pradesh. Curr. Sci. 88, 1844 (2005).
8. Fujita, K. et al. Potential flood volume of Himalayan glacial lakes. Nat. Hazards Earth Syst. Sci. 13, 1827–1839 (2013).
9. Cui, P., Dang, C., Cheng, Z. & Scott, K. M. Debris Flows Resulting From Glacial-Lake Outburst Floods in Tibet, China. Phys. Geogr. 31, 508–527 (2011).
10. Allen, S. K., Rastner, P., Arora, M., Huggel, C. & Stoffel, M. Lake outburst and debris flow disaster at Kedarnath, June 2013: hydrometeorological triggering and topographic predisposition. Landslides 13, 1479–1491 (2016).
11. Breien, H., De Blasio, F. V., Elverhøi, A. & Høeg, K. Erosion and morphology of a debris flow caused by a glacial lake outburst flood, Western Norway. Landslides 5, 271–280 (2008).
12. Chisolm, R. E. & McKinney, D. C. Dynamics of avalanche-generated impulse waves: three-dimensional hydrodynamic simulations and sensitivity analysis. Nat. Hazards Earth Syst. Sci. 18, 1373–1393 (2018).
13. Gurung, D. R. et al. Lemthang Tsho glacial Lake outburst flood (GLOF) in Bhutan: cause and impact. Geoenvironmental Disasters 4, 17 (2017).
14. Somos-Valenzuela, M. A. et al. Assessing downstream flood impacts due to a potential GLOF from Imja Tsho in Nepal. Hydrol. Earth Syst. Sci. 19, 1401–1412 (2015).
15. Rafiq, M., Romshoo, S. A., Mishra, A. K. & Jalal, F. Modelling Chorabari Lake outburst flood, Kedarnath, India. J. Mt. Sci. 16, 64–76 (2019).
16. Raj, K. B. G., Remya, S. N. & Kumar, K. V. Remote sensing-based hazard assessment of glacial lakes in Sikkim Himalaya. Curr. Sci. 359–364 (2013).
17. Xin, W. et al. Using Remote Sensing Data to Quantify Changes in Glacial Lakes in the Chinese Himalaya. Mt. Res. Dev. 32, 203–212 (2012).
18. Quincey, D. J. et al. Early recognition of glacial lake hazards in the Himalaya using remote sensing datasets. Glob. Planet. Change 56, 137–152 (2007).
19. Petrov, M. A. et al. Glacial lake inventory and lake outburst potential in Uzbekistan. Sci. Total Environ. 592, 228–242 (2017).
20. Clague, J. A review of catastrophic drainage of moraine-dammed lakes in British Columbia. Quat. Sci. Rev. 19, 1763–1783 (2002).
21. Khanal, N. R. et al. A comprehensive approach and methods for glacial lake outburst flood risk assessment, with examples from Nepal and the transboundary area. Int. J. Water Resour. Dev. 31, 219–237 (2015).

22. Ageta, Y. et al. Expansion of glacier lakes in recent decades in the Bhutan Himalayas. IAHS Publ. 165–176 (2000).

23. Rounce, D. R., Watson, C. S. & McKinney, D. C. Identification of hazard and risk for glacial lakes in the Nepal Himalaya using satellite imagery from 2000-2015. Remote Sens. 9, (2017).

24. Fujita, K., Sakai, A., Nuimura, T., Yamaguchi, S. & Sharma, R. R. Recent changes in Imja Glacial Lake and its damming moraine in the Nepal Himalaya revealed by in situ surveys and multi-temporal ASTER imagery. Environ. Res. Lett. 4, 45205 (2009).

25. Richardson, S. D. & Reynolds, J. M. An overview of glacial hazards in the Himalayas. Quat. Int. 65–66, 31–47 (2000).

26. Wang, W., Yao, T. & Yang, X. Variations of glacial lakes and glaciers in the Boshula mountain range, southeast Tibet, from the 1970s to 2009. Ann. Glaciol. 52, 9–17 (2011).

27. Bolch, T. et al. Identification of potentially dangerous glacial lakes in the northern Tien Shan. Nat. Hazards 59, 1691–1714 (2011).

Historical Background of Flood Management

A Krishna Murthy
Engineer-in-Chief (Retd), Irrigation Dept, Govt of Telangana
akmurty1@gmail

ABSTRACT

Flood management is practiced by mankind along with the growth of civilisation. The initial flood management started with the management of floods in natural streams and later extended to management of floods in the flood storage structures like tanks, anicuts, reservoirs built by mankind. Few flood management methods which do not require any manual operation are discussed in this article.

Keywords : Flood management, Floods, Gates.

INTRODUCTION

This paper outlines the historical background of Flood Management in India.

Flood occurs in the natural streams and rivers during rainy season. It is a natural phenomenon of flow of excess rain water through the natural streams and rivers.

As civilisation grew, the mankind started flood management for the benefit of humanity. The excess flood in the local streams was diverted by digging flood flow channels taking off from the stream and the agricultural fields adjoining the stream at lower level are irrigated. This may be the initial/oldest flood management.

As the civilisation grew further, Tanks, Reservoirs, Anicuts, Dams etc were built across the streams/ rivers to store / divert the flood waters for drinking/agriculture purposes.

The various flood management methods being used are as discussed subsequently.

TANKS:- The tanks are constructed across minor streams with earthen bund as the barrier. Masonry / concrete weirs of suitable length are constructed at suitable location in the the bund with top level equal to FTL (Full Tank Level) of the Tank. Any excess flood over and above the FTL of the tank will pass over the weir, as and when received, with out any manual operation as shown in **Fig. 1** below. They are the best flood management structures even today.

Fig. 1 Surplus Weir of a Tank overflowing the excess flood

ANICUTS:- The Anicuts are constructed across major streams. They are masonry/ concrete structures constructed across full width of the stream, with a suitable top level, without submerging the adjacent lands . Any excess flood in the stream above this level will pass over the Anicut as shown in **Fig. 2**, without requiring any manual operation. This is also one of the oldest method of flood management.

RESERVOIRS:- Reservoirs are constructed across major streams / rivers to impound flood waters and use it for irrigation, power generation etc purposes. These are formed with earthen bunds or concrete dams with suitable spillways to dispose off the excess flood. The crest level of the spillway will be equal to FRL (Full Reservoir Level) of the reservoir. The top of the earth bund will be more than the MWL (Maximum Water Level) of the reservoir to avoid overflow of flood waters above the bund.

SPILLWAYS:-The spillways are masonry or concrete structures built with or without gates. The spillways without gates will dispose off the excess flood without any manual operation/ intervention.

Fig. 2 Anicut across a stream overflowing the excess flood water

Fig. 3 Reservoir with a Spillway with gates

Whereas, the spillways with gates require manual operation of gates. The spillway gates are either mechanically operated or electrically operated.

Where the spillway gates are to be manually operated, lot of care and attention is required. The gate's condition/functioning is to be checked every year before monsoon and the required maintenance is to be carried out without fail. The staff required for maintenance have to be deployed and they have to be trained for effective operation and proper maintenance of gates. Similarly, where the gates are operated electrically the availability of uninterrupted power supply during rainy season is to be ensured. Wherever uninterrupted power supply is doubtful, alternate arrangements like generators etc have to be made, before onset of monsoon .

Majority of the failures in flood management are due to

a) Non functioning of gates due to poor maintenance.

b) Non availability of men and machinery required for the operation of gates.

c) Non availability of power supply and generator sets etc.

d) Non communication of the flood data from upper reaches.

e) Non prediction of high rainfall.

To circumvent these problems, the fallowing flood management methods can be adopted.

AUTOMATIC FALLING GATES

The automatic falling gates were invented/ installed by our legend Dr Mokshagundam Visvesvaraya in Krishna Raja Sagar Dam as early as 1920. Later they were installed on many projects in North India. They function as shown in **Fig. 4**, as and when the water level increases due to flood, and dispose off the flood without any manual operation and intervention.

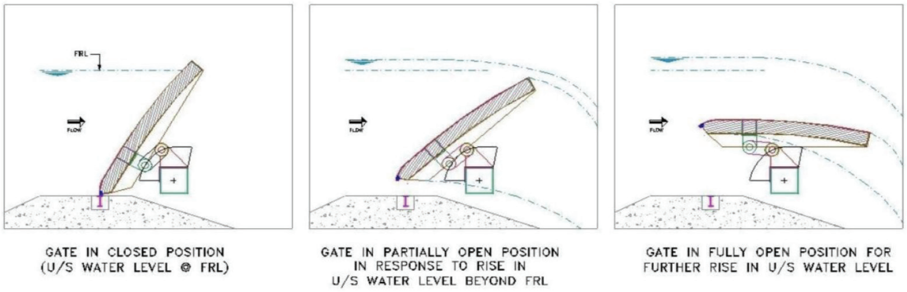


Fig. 4 Automatic falling gates in an Anicut

Fig. 5 Syphon Spillway of Sarala Sagar Project in Telangana

SYPHON SPILLWAY

The Sarala Sagar Reservoir in Telangana constructed in 1959 was provided with Syphon Spillway, a unique technology borrowed from California State of USA. As and when the water level rises above FRL, the Syphon spillways starts functioning and disposes off the excess flood without any manual operation or intervention. This spillway is functioning successfully even now practically without any maintenance.

BREACHING SECTION

Breaching section is a loosely formed bund portion above MWL level at a suitable location in the bund. When the water level rises above the MWL level due to excess floods, the loosely formed bund in the breaching section breaches and the flood water gets disposed off without endangering the whole bund. This requires no manual operation or intervention.

CONCLUSION

The above three methods of flood management i.e Automatic falling gates, Syphon spillway, Breaching section etc which require no manual operation and intervention deserve to be practiced by the modern engineers/planners to avoid flood disasters in Minor. Medium, Major Irrigation Projects.

REFERENCES

Photo Courtesy :- Google Photos.

Moderating Flash Floods in the Light of Experience of the Ajoy River

Tapobrata Sanyal
Retd. Chief Hydraulic Engineer, Calcutta Port Trust
sanyaltapobrata@gmail.com

INTRODUCTION

Flash floods, unlike normal floods, occur when surface run-off generated as a result of intense precipitation such as cloudbursts in river-catchments rushes with great rapidity towards outfall. Waterways which are essentially drainage conduits fail to drain it off within reasonable time, resulting in sudden overflowing of their banks inundating contiguous areas. Sudden release of huge quantities of water from dams and severe breaches in dams/levees could also be concomitant causes behind such sudden rush of huge amount of overland flow over a catchment. Usually, a flash flood occurs within about six hours of the onset of heavy downpour. Flash floods hardly allow any time to smother the effects of their fury.

Flash floods are usually of a brief duration unlike usual floods. Steepness of ground gradient, abetted by poor hydraulic conductivity of soil of the basin bereft of greenery, hastens increased celerity of surface run-off rushing towards the outfall points. Overland flow ultimately finds its way to a trunk river which acts as the main drainage conduit. High and sudden overland discharge at the outfall may at times reach unwieldy levels. Higher water-level of the trunk river at the outfall point often obstructs entry of flood water. Besides, blockade caused due to rise and advances of tide from the opposite direction hinder passage of surface run-off. However, the dominant reason behind delayed and failed drainage through rivers is their capacity-insufficiency.

In this paper suggestions have been placed for moderating and managing flash floods in the light of experience gained from flash floods in the river Ajoy of West Bengal. Before dwelling on the core of topic, it will be pertinent to indicate the location of the Ajoy River and its basin and the nature of flash floods experienced in the river.

Brief Description of the Ajoy, Its Course & Basin

River Ajoy originates from a small hill about 300 m high located at southwest of Mungher in Bihar. It then flows across Jharkhand and enters West Bengal at Simjuri, near Chittaranjan. It demarcates the boundaries of Burdwan and Birbhum districts of West Bengal and finally joins the Bhagirathi River near Katwa town of East Burdwan district of the state. The Bhagirathi is the name of the sea-going branch of the Ganga flowing across the state of West Bengal after bifurcation of its main flow just down of Farakka barrage.The stronger and the more ebullient branch of the Ganga flows eastward into Bangladesh assuming the name of ‘Padma’.

Total length of the Ajoy is 288 km out of which 152 km lies in West Bengal. The important tributaries of Ajoy are Pathro and Jayanti in Jharkhand, Hinglo in Birbhum and Kunur in Burdwan district of West Bengal. There is a barrage across river Ajoy constructed by Govt. of Jharkhand at Sikatia. The Ajoy carries the discharge of two tributaries in the sub-hill catchments of Pathro, Jayanti and Kunur. There are some low-lying areas in the Ajoy-Kunur catchment which are prone to inundation. Sometimes the monsoon discharge of the Ajoy synchronizes with that of the rivers Mayurakshi and Dwarka. The combined monsoon discharge often inundates large parts of Burdwan, Birbhum and Murshidabad districts of West Bengal. An irrigation dam has been constructed over its tributary at Hinglo which serves a portion of Birbhum district. The total catchment area of this sub-basin is 6,093 sq.km out of which an area measuring 2797 sq. km falls under Bihar state. The catchment-shape of the Ajoy is long and narrow.

Basin-wise there are several rivers on the right of the Bhagirathi. These rivers are Pagla-Bansloi, the Dwarka-Brahmani, the Mayurakshi-Babla-Uttarasan, the Bakreswar-Kuye and the Ajoy. They emerge from the Jharkhand Plateau and flow southeast to meet Bhagirathi. These rivers drain an area of 17,684 km. spread over the state of Jharkhand (the old Bihar Plateau) and districts of Birbhum, Murshidabad (its western part) and Burdwan in the state of West Bengal. The carrying capacity of the Bhagirathi from Jangipur in Murshidabad district to Kalna in the East Burdwan distruct is of the order of 1.3 lakh cusecs. It has been estimated that if all the rivers in this basin receive rainfall simultaneously in their catchments, the total run-off volume may add up to the tune of 4-6 lakh cusecs. In this vast tract of land there is only one dam to contain flood discharge viz. Massanjore dam which can contain flood discharge of only about 11% of aforesaid combined catchments.

The Bhagirathi is the main drainage conduit of the southern part of West Bengal. Its tributaries spew huge amount of monsoon discharge into it. During the rainless months these tributaries starve for water and get rejuvenated by precipitation during the monsoon in their upper catchments. Before construction of Farakka Barrage in the upstream, the Bhagirathi used to get hardly any significant replenishment from the Ganga during dry periods of the year as the lion's share of the discharge used to flow into Bangladesh along the course of the Padma. The situation changed after regular release of water from the barrage-reservoir. However the cubature of the Bhagirathi and its tributaries has not improved subsequently to the extent desired. As a consequence, sudden high discharge does not usually remain confined within the spill-zones of either the Bhagirathi or the Ajoy, but spread beyond their precincts. We find references of flash floods in the Ajoy way back in 1916 (ref: Rivers of Bengal—Vol II West Bengal District Gazetteers-compiled by Kumudranjan Biswas) and subsequent writings of river-researchers. The limited space of the present article will not permit description of the details of previous flash floods in the river. A piece of information is however deemed relevant in the context. The flood-discharge through the Ajoy was once stated to have reached a peak of 5 lakh cusecs during a flash flood in the past which was about five times the accommodating capacity of the Bhagirathi at its outfall.

REASONS BEHIND FLASH FLOODS IN THE AJOY BASIN

The basic reasons of flash floods in this zone may be summed up from past experience as under—

i) High monsoon discharge as a result of intensive precipitation in its basin due to cloudbursts with accompanying storms and cyclones has often been a feature of this region. In this context the incidence of heavy precipitation in 2000 AD may be cited. The catchment of the Ajoy received rainfall of 550 mm to 582 mm in 24 hours on 21.09.2000. Its level rose by about 4 meters over topping and breaching embankments on its either side.

ii) Rapidity of the resultant overland flow can be attributed to steep ground profile of the catchment which hastened movement of the run-off towards the outfall. The ground slopes down from a high altitude plateau to a flat terrain in the vicinity of the outfall point at the Bhagirathi near Katwa town.

iii) Limited intake capacity of the Bhagirathi at the outfall point often fails to accommodate the high discharge of the Ajoy during flash floods causing overflow of the banks of both the rivers and inundation of low-lying contiguous areas. As already indicated higher level of water at the outfall of the Bhagirathi at Katwa and opposing tides during the monsoon obstructs passage of overland flow resulting in heaving up and overflow of water.

iv) It may be mentioned that tidal blockade is usually experienced during the monsoon especially in the month of September. The outfall point at Katwa is located in the upper threshold of the tidal compartment of the Bhagirathi (known as the Hugli river). Passage of the run-off into the Bhagirathi sometimes gets throttled as a result. The upstream catchments of the river system in the west and beyond Berhampur in the district of Murshidabad are flooded as a result. Usually parts of Murshidabad and Nadia districts are affected.

v) In fact, rivers in the basin are fast losing their capacity due to sediment brought by their feeder rivers and as a result of erosion of river banks. The dominant contributor of Sediment-load is eroded bank soil. The Ganga-Brahmaputra delta is a creation of alluvial deposits over millennia. Geologically, the delta is a recent formation vulnerable to erosive forces of rivers. Soil in river-banks of this region easily succumbs to abrasive fluvial currents, vortices at bank-toes and large draw-down (water-level variation) generating huge quantities of sediment part of which settle on river-bed under favorable hydraulic conditions. Bed-aggradation and inability of the waterways to transport /flush out the suspended sediment load to the sea incapacitates rivers of this region.

vi) Backflow from contiguous basins is another concern for Ajoy basin. Rivers Bhairab, Jalangi and Churni known as the Nadia Group of rivers of the basin generates backflow blocking passage of surface run-off.

vii) Flood detention reservoirs attached to dams are also fast losing their impounding capacity due to sedimentation. It is relevant to mention in this context that not all dams/ barrages were designed for flood control. This is why abrupt release of water from them sometimes becomes a matter of compulsion for safety of dams. Experts like Gregory L Morris predicted some time back that by the year 2020 over 20% of India's reservoirs could lose 50% of their storage capacity due to sedimentation. Sedimentation rate in three of the DVC dams at Panchet, Maithon and Mayurakshi, according to a data published by Central Board of Irrigation & Power, ranges from 1.05 mm/year to 1.63 mm/year. The said rate applies more or less to other reservoirs in the region.

viii) In addition, river systems on the west bank of the river Bhagirathi-Hooghly like Pagla-Bansloi, Dwarka-Brahmani, Mayurakshi-Babla and Ajoy together drain out flood water from an area of 18,177 sq. km, spread over the state of Jharkhand (the old Bihar Plateau) and the districts of Birbhum, part of Murshidabad (west of Bhagirathi) and Burdwan of West Bengal into the Bhagirathi. Carrying capacity of the river Bhagirathi is only about 25% of the combined peak flood discharges generated from these basins in the case of simultaneous heavy downpour, as happened during the flood of September 2000. In this vast tract of land there is one major dam - Massanjore dam over the river Mayurakshi which can, as already indicated, contain flood discharge of only about 11% of the aforesaid combined catchments.

LESSONS LEARNT FROM FLASH FLOODS IN THE AJOY RIVER

As already indicated the Ajoy basin is a steep terrain which hastens movement of overland flow. Natural water-retaining bodies in the basin of the Ajoy are few. The first effort to lessen the impact of flash floods would be to slow down the celerity of surface run-off. It is important to study the ground contours of the catchments of the Ajoy and its feeder-rivers to explore possibilities of creating retention-pools in the basin for impoundment of a part of the overland flow resulting from heavy precipitation, apart from taking steps to deepen encumbrance-free low-lying areas to augment capacity for holding a part of surface run-off before it could reach its outfall point in the Bhagirathi. This is a labor-intensive measure and may perhaps be implementable through Panchayets.

Rapid urbanization of the Ajoy basin makes implementation of the task of surface retention of flood water difficult. The growth of settlement has been largely unplanned obstructing infiltration and interception of water. It is well nigh impossible to clear up the urban settlements to allow uninterrupted passage of flood water across them without strong political and administrative good-will.

One feature of the Ajoy basin is existence of impervious crystalline rocks/lateritic layer under a thin layer of soil especially in the district of Birbhum which hinders infiltration. Low rate of evapo-transpiration in the region affects capacity of surface water-retention. Flood problem in the Ajoy River incidentally is mostly confined to the lower reach of the Ajoy River after its confluence with Hinglo River.

MODERATION PRINCIPLE

It may be pointed out that the combined effects of upstream fluvial interventions, geology, basin physiography and its changing land-use pattern play significant roles in abetting both normal and flash floods. Frequency of floods in the Ajoy basin has rendered its soil productive attracting human settlement and ushering in rapid change in land-use pattern in its basin. Climate change also influences frequency and intensity of floods in this region. The situation is dynamic needing adjustments in flood-moderation.

On the basis of the situation experienced in the case of the Ajoy so far, severity of flashfloods may be moderated to a reasonable extent by adopting the following measures.

a) Slowing down of the velocity of surface run-off

Possibility of constructing low earthen cross-bunds at appropriate locations in the catchment built across the direction of surface run-off in consonance with ground contours may be explored. The dimensions of bunds and their spacing should be optimized by undertaking simulation study taking into account flood-volume in extreme events. These bunds will act as ‘speed-breakers’ to buy time for preparedness to combat the sudden flooding. The extent of progressive reduction of velocity of overland flow by construction of such a series of low bunds can be mathematically estimated from first principles of Structural Mechanics based on the height of cross bunds, spacing between each of them and the average slope of the ground. Additionally, it is suggested to construct retention-pools in between the bunds. The earth excavated from the pools may be utilized in making the cross-bunds. Such a measure may have ‘pool and riffle effect’ as encountered in the case of rivers. A field trial under the guidance of academics of an engineering institute is advisable, if feasible, to study the effects of the proposed measure.

b) Augmentation of the retention capacity of the basin

Low-lying pockets and existing water-bodies may be deepened to act as retention pools for augmenting surface retention capacity of the basin. Large water-bodies, locally known as “beel”, exist in the basin. These are mostly detached river-links which over the years have turned into swamps over the years.

c) De-siltation of reservoirs of dams

Measures such as ‘sediment routing’ may be considered in reservoirs of dams/barrages along with de-silting measures at appropriate intervals. Sediment routing is essentially flushing out of the initial monsoon run-off laden with sediment after emptying reservoirs prior to the onset of the monsoon for balancing sediment inflow and outgo. The technique has reportedly met with success in China.

d) Construction of relief channels

Excavation of relief channels in the vicinity of the main outfall point after proper simulation study is also worth considering. The outfall point in the Bhagirathi with higher ambient water level can be kept at a lower level suitable for passage of run-off by means of such relief channels. A simulation study with extreme event conditions is worth carrying out to determine the location and dimensions of such channels.

e) Construction of flood bypasses

Possibility of construction of flood bypasses may be explored to channelize excess flood water to the drainage conduits considering the prevailing ground conditions.

f) Improvement of warning system

Communication technology has vastly improved of late. Flood warning system has to be improved to ensure real-time communication with the Disaster Management group by the site engineers. Strong weather-radar echoes may be installed and their responses decoded.

g) Possibility of constructing run-off guiding channels to be explored

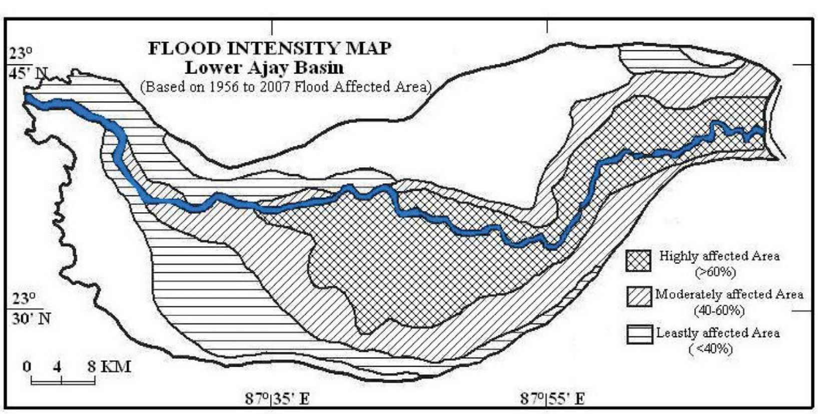
Flood-water from flash floods gets dispersed over a large area without finding passage to appropriate conduits for drainage. It is worthwhile exploring possibility of construction of run-off-guiding channels leading to the outfall points in the catchment. Guided passage of overland flow in tandem with other measures suggested above may help prevent flood water dispersion over large areas. These channels are different from relief channels to be constructed for preventing heaving up due to sudden onrush of monsoon discharge.

h) Resuscitation of rivers

This is a massive project to be undertaken after careful phased planning jointly by the Govt of India and the State Governments concerned. All rivers in the Ganga-Brahmaputra delta is affected by unabated sedimentation. Carrying capacity of rivers requires augmentation for draining out flood water. Periodical de-silting of rivers by dredging based on regular bathymetric surveys is a surer combative step.

i) Watershed management

One overlooked aspect in India is lack of management of watersheds. Well-managed watersheds can go a long way in slowing down the velocity of surface run-off. Watershed management, soil conservation and afforestation can go a long way in ensuring interception of precipitation. The other benefit accruing out of watershed management is reduction of surface soil erosion. Detachment of soil as a result of kinetic energy of raindrops and their conveyance to rivers along with



surface run-off can be largely prevented which in turn help reduce sediment load of rivers.

It will not be out of context to mention in this connection that floods in West Bengal in general have a bearing on the uncertain morphology of rivers in the region. Change in sinuosity, transport and accretion pattern of varying sediment load coupled with fluctuating river-discharge, occasional course-shifts of rivers contribute to mutating morphology of the Ganga-Brahmaputra delta which is yet to attain geotechnical stability. The geology of the delta notably features a few deep-seated faults.

The National Commission on Floods (Report-Vol 1) recommends that maintenance of measures taken for soil conservation and watershed management should be carried out for 3 to 4 years. The cost is proposed to be met out of the contingent funds @ 4-5% of the original project cost. Thereafter, the responsibility of upkeep of the assets should devolve upon beneficiaries. In addition, flood plain management and structural changes, like raising of land, may have to be thought of in appropriate cases.

Classification of susceptibility of a flood plain is advised in the case of flood management. For flash floods also a suitable categorization in regard to flood susceptibility may be considered. A flood plain is in principle segregated into three zones viz prohibitive, restrictive and cautionary for flood management. Of the three categories cautionary zone may be attributed to areas frequented by flash floods for pre-empting steps to manage the disaster to the extent feasible.

Ground water recharge of flood water is not a tried concept in our country. Part of overland flow may be made to enter into the ground through injection wells or other natural means if conditions permit.

CONCLUSION

Climate change has enhanced chances of occurrence of extreme natural events such as flash floods. Besides suggestions indicated above, proper land-use planning is an important step. It is also important to take care of compaction of soil to facilitate infiltration of precipitation. More importantly, waterways need be resuscitated with proper planning which require both money and political goodwill. More wetlands also need to be created. Concurrently, flood warning system should be improved taking advantage of the latest communication technology. It is important to bear in mind that that the approach to flash flood moderation should be dynamic and flexible for accommodating future improvements in water resource management and adjustments for flood moderation in the basin.

REFERENCES

1. Morris G L (2005)-Reservoirs & Sedimentation Issues-World-wide & India-(In India Hydro (Feb New Delhi-10-21)

2. Roy Suvendu et al- ‘Spatial Variation of Floods in the Lower Ajoy River Basin, West Bengal—A Geo-hydrological Analysis’ (source--Research Gate in the internet).

Occurrence of Flash Floods–Damages and Mitigation

P S Bhogal
Council Member IEI and Former Chief Engineer, Water Resources, Govt of Punjab.
Member State Expert Appraisal Committee, Punjab.
bhogal_ps@yahoo.co.in

ABSTRACT

Flash floods are result of quick rise and fall of high discharges in a river/reservoir, which causes severe damages because of suddenness. Main factors that contribute strongly to the occurrence of flash floods are intense rainfall and steep slopes. In terrains of higher altitudes having formation of glaciers, the sudden outburst of artificial glacial lake causes the fatalities and severe damages associated with flash floods. In this paper case study of flash floods have been discussed such as: flash floods in river Sutlej on 1st August, 2000 in its upper reach in Himachal Pradesh which caused lot of unprecedented damage, serious cloudburst in Kulu valley near Bhuntar (HP) resulting in unprecedented flash flood on 16th July 2003 and flash floods due to glacial lake outburst in higher reaches of Kargil region during 2014-15.

To mitigate damages in such cases, the crisis management planning in advance is very important which includes prompt information and warning system. There is need to establish "Quick Reaction Teams both at District level and State level to deal with such situations promptly in hilly areas. In high altitudes region having glaciers or glacial lakes, the study of hazard potential of glacial lakes is important and also it would be ideal if ground verification of the glacial lakes could be carried out using appropriate means such as remote sensing etc.

INTRODUCTION

Flash floods occur in hilly regions and sloping lands where heavy rainfall, thunderstorms and cloudbursts are common. Sudden release of waters from upstream reservoirs or dams or breaches embankments on the banks of the rivers leads to disastrous floods. Flash floods have been occurring frequently in India in various hilly States such as Arunachal Pradesh, Assam, Orissa, Himachal Pradesh, Uttarkhand and the Western Ghats. It is difficult to arrest flash floods but various possible measures in such areas to mitigate flood losses must be planned and arranged in advance.

FLASH FLOOD

Flash floods are distinguished from other types of floods, as flash flood-producing rainfall occurs for less than 6 hours duration in a small spatial scale (generally less than 1000 km^2) of drainage basins. Aside from intense rainfall, main factor that contribute strongly to flash flooding is impervious ground surface and steep slopes. In high altitude, glacial lake outburst flow contribute significantly to the fatalities and damage associated with flash floods. Severe floods in Himachal Pradesh in August 2000 and June 2005 and in Arunachal Pardesh in 2000 are some of the examples of flash floods caused by breaches in landslide dams.

Floods in Assam, Bihar, Uttar Pradesh, Odisha and Andhra Pradesh are generally caused by breaches in embankments.

FLASH FLOODS IN RIVER SUTLEJ

During 1990-2000, a total of 4 flash floods in the river Sutlej, with peak discharge varying from 1753 to 5100 cumecs have been observed causing severe losses of human lives and properties. The growing incidents of cloudbursts and flash floods in Kinnaur and Shimla districts of Himachal Pradesh (HP) in fast flowing river Sutlej and its tributaries has left this hill state vulnerable to tragedies. The unprecedented flash flood had caused immense loss of life, property and the costly infrastructure created through years of painstaking efforts by investment of huge funds was washed away in a few hours. Various measures to mitigate flood losses like building better data base, effective monitoring and creation of storages upstream, installation of flood forecasting and flood warning system etc. have become imperative due to suddenness of such floods.

Case Study

River Sutlej experienced flash floods on 1st August, 2000 in its upper reach in Himachal Pradesh and caused lot of unprecedented damage. The flash flood, which is reported to have originated in the midnight intervening 31.7.2000 and 1.8.2000 in Tibet, entered India near Khab in Kinnaur at about 0100 hours. This devastating flood reached Nathpa Jhakri project near Rampur at around 0515. According to the project authorities, the water level in river Sutlej rose by around 15 meters in a short span of time. The discharge data at Rampur shows that the discharge suddenly shot up from 1480 cumecs at 030 hours on 1.8.2000 to 5100 cumecs at 0530 hours and then again came down quickly to 1416 cumecs at 0900 hrs. The base period of the flood was thus 6 hours only. At the confluence of rivers Sutlej and Spiti, though huge flood occurred in river Sutlej, there was practically no flood in river Spiti.

Role of Bhakra Reservoir

In fact Bhakra reservoir was instrumental in controlling disastrous effect of the flood wave and no losses occurred downstream of Bhakra Dam. Bhakra reservoir levels and average daily inflows into the reservoir from 1.8.2000 are as follows :

Date	Time	Reservoir Level (feet)	Average daily inflow (Cusec)
01.08.2000	0600	1598.36	72,856
02.08.2000	0600	1603.98	1,02,724
03.08.2000	0600	1607.63	76,527

It is seen that the above inflow into the Bhakra reservoir are not unusual for this part of the year. Since the flood lasted for about 6 hours the water level in the reservoir rose by about 5.62 feet on 2.8.2000 and for the other days the rise is about 3 feet, which is quite normal for this period of the year. The FRL of Bhakra reservoir is 1680 feet and the reservoir level yet is below normal. The crest level of the spillway gates of Bhakra is 1645 feet and hence no releases were yet possible from the spillway. In view of this and not much rainfall in the downstream catchment, there had been no effect of this flood downstream of Bhakra reservoir. The flood peak of this flash had been the highest observed so far but the total quantum of water reaching reservoir was much less in comparison to similar earlier floods.

Flood Losses

The devastating flood, which gained momentum as it passed down the river from heights of Kinnaur district, almost destroyed everything in its way including the costly infrastructures, thus pushing back the clock of development by decades. The flood affected areas had been Kinnaur, Shimla, and Mandi districts. The major damages caused by this flash flood are as under:-

- More than 150 people were swept away and several people got buried under the huge mass of rubble and the area remained inaccessible for several days due to which many deaths remained unreported.
- Extensive damages was caused to the infrastructure such as: about 48 number

bridges from Khab to Sunni and about 50 km of Hindustan Tibet highway which is the lifeline of Kinnaur and Lahoul Spiti districts were washed away. The damages to the Hindustan Tibet highway had a tremendous adverse impact on the economy of the state. The apple crop worth crores of rupees and other cash crops like peas, which is a major source of income for the people of Kinnaur and Shimla, could not be transported to the markets and was perished, affecting livelihood of people of the affected districts. Many Government and private buildings and tourist spots were also damaged.

- The sudden rise in water level by about 15 metre at 1500 MW Nathpa Jhakri Project caused the back flowing of water through tailrace tunnel along with tons of rubble and silt which severely damaged the generation units, which were in an advanced stage of installation. The project suffered extensive damages estimated at about Rs. 7000 millions.
- Operational hydropower projects like Sanjay Vidyut Pariyojana, Ghanvi and Chava Powerhouses also suffered major damages and became non-operational. This has resulted in the losses to the tune of several crores in terms of damage to installations and loss of power generation.
- The total loss due to this flash flood was estimated to be of the order of Rs. 25000 millions.

Causes of the Flash Flood and Mitigation Measures

The analysis of the hydrograph from the data observed by Bhakra Beas Management Board (BBMB) indicates that the major cause of destruction was approximately 40 million cum of additional water which had passed the river concentrated only in the six hours of the event. The noticeable fact during the flash flood was that the Spiti River was flowing normal and River Sutlej was on rampage. Based on the analysis of the rainfall data and flood data for this and previous years flash floods the probable reasons for the flash flood in the upper reaches of Sutlej basin could be: (i) Heavy rainfall in the catchment (ii) Temporary blockage of the river due to landslide (iii) A breach in glacial lake in upper reaches (iv) Cloud burst.

It is difficult to arrest flash floods but various possible measures in an area prone to such floods to mitigate flood losses must be planned and arranged in advance. It is costly to construct all types of structural works that could mitigate flash flood disasters. Various measures to mitigate flood losses like effective monitoring and creation of storages upstream, installation of flood forecasting and flood warning system must be provided. Nevertheless, since too many people still dwell along small streams that may be flooded, community warning systems and self-help programs provide the only practical safeguard for many small flood plain communities. Effective master plan for flood management in the basin is required. Flood protection models may be customised as per specific operational requirement of an area and implement real time operation of reservoir coupled with timely flood forecasting and warnings.

FLASH FLOOD IN RIVER GHAGGAR

River Ghaggar is a non-perennial river and flash floods are often seen in Punjab in this river during monsoon. Neither any storage reservoir has been constructed over this river nor has it been channelized by constructing embankments. Thus, this river is prone to flash floods twice or thrice in monsoon season and creates havoc every year, thereby causing damages to thousand acres of agriculture land and villages near to this river on its both sides in Punjab and Haryana. It has a total length of 241 km, out of which 165 km falls in Punjab State and the rest lies in Haryana State. River Ghaggar enters into Haryana territory at Moonak and after traversing through Haryana, it re-enters in Punjab at village Lohgarh in Mansa District. It traverses a length of about 23 km in

Punjab territory and again crosses to Haryana State and finally vanishes in sand dunes of Rajasthan. During flash floods, water overflows in the river upstream Chandpur syphon and inundates numerous villages of Punjab and Haryana. A bund named Chandpur bund constructed on right side provides, only little relief to the area.

During heavy flash floods, the water normally over flow or gushes out of breached embankments and spreads in the adjoining areas causing damages to the agriculture land and abadies mainly in the district of Patiala, Sangrur and Mansa of Punjab. Every year a huge amount of compensation is paid by the Government for the damage to crops in the area through which Ghaggar River flows. Though, flood protection works such as embankments, boulder stone studs, spurs, pitching apron have been constructed from time to time for the protection of local areas, there is an urgent need for preparation of a master plan to tackle the floods in this River as a whole through interstate coordination.

This seasonal river Ghaggar had experienced peak discharge of 3542, 2265 & 5600 cumecs in the years 1988, 1992 and 2000 respectively. It is mentioned that just two days freak rainfall during July 2000 in the area around Chandigarh and upper catchment in HP transformed the dormant Ghaggar into a raging torrent causing widespread flood havoc in the states of Punjab and Haryana. This highlights the need for taking immediate steps to tame the river with most appropriate way to avoid flooding of the adjoining areas. A thought may also be given for canalisation of the river in view of the experience gained from other rivers in Punjab. On the way of the river, there are bottlenecks due to restricted water way under canals resulting flooding of the areas. To mention, the junction of Bhakra Main Line canal crossing this river is notable. The inadequate capacities of the aqueducts result in heading up of water upstream causing flooding of the adjoining area and threaten the canal to breach. The problem needs attention of both States for remedial measures to save villages and habitants from floods.

FLASH FLOOD IN RIVER YAMUNA

Yamuna River is the longest western tributary of the Ganga. It originates from the Yamunotri Glaciers and on the way it is joined by Tons river near Dak Pathar (Uttarakhand). From Dak Pathar, it enters into the plains near Hathanikund in Haryana, where it flows in a broad curve making a boundary between Haryana and Uttar Pradesh.

The river Yamuna is one of the major rivers of India which has not been dammed so far. At present, there is no storage reservoir on Yamuna to absorb any flood from upstream. In absence of any storage reservoir, the Yamuna river during monsoon receives frequent flash floods due to cloud bursts in its catchment area and in catchment of its tributaries like river Tons. Due to sudden flood peaks in monsoon, it causes severe damage to crops and livestock due to breaches in embankments, both in Haryana and Uttar Pradesh.

FLASH FLOOD IN RIVER BRAHMAPUTRA.

This river system has so far remained almost untamed due to which flash flood recurring is an annual event in Assam/Brahmaputra Valley. The rainfall in the outer Himalayas and sub-mountain areas is very high ranging roughly between 2000 mm to 4000 mm per annum of which 85% occurs during May to October. Heavy rainfall lashing on the steep slopes of the hills, cause a great deal of soil erosion in the basin. Landslides are caused by soil erosion and soil surcharged with rain water on the steep slopes.

Mathematical model studies were carried out with the historical floods of 1962, 1977 and so on to study the flood moderation aspect of these reservoirs in the downstream reaches. Results of the model studies show that with the Dehang dam in position, the flood of 1962 at Guwahati get reduced from its peak of 73000 cumecs to 43000 cumecs. It is also seen that there is reduction in peak floods at Pandu in and similarly Subansiri dam also lowered flood peak. The implementation of the schemes for dams will help in mitigation of floods in Brahmaputra basin.

CASE STUDIES

Case Study-1, Flash Flood due to Cloud Burst at Shilagarh-Kullu (HP)- 2003

Due to locational and geographical features, the hill State of Himachal Pradesh is one of the major disaster prone states in the country in respect of earthquakes, flash floods triggered by cloud bursts, landslides, avalanches and forest fires.

A serious cloudburst occurred in the Gadsa area of the Kulu valley near Bhuntar and resulted in flash flood on 16th July 2003 (at 2.30-3.00 AM), refer **Fig. 1**. This disaster occurred at such a time when everybody was asleep. Suddenly about 5-10 meter sheet of water was flowing in the area. There have been three camps located on the left bank of the tributary - one upstream of the bridge, the other downstream and the third was at the Barau khud, about 3 km from the first camp. Each of these camps had 30 to 35 workers. This event gave them no time to escape before the bridge collapsed. While some got out in time and the others got stuck in the debris and died. Those in the lower camp suffered fewer casualties. About 30 workers feared killed in this cloud burst.

The causes of such disasters thus are both natural and manmade. Whereas nothing can be done about topographical, geological and geographical features responsible for calamities, but the contributory factors by humans can certainly be identified and controlled to a great extent.

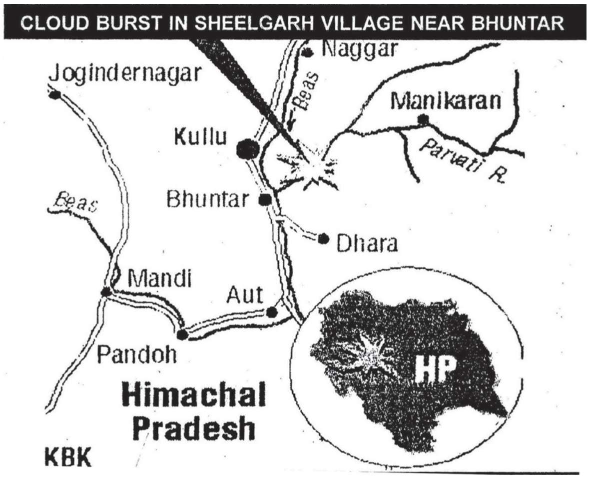


Fig. 1 Location of cloud burst in Gadsa area

The large-scale deforestation, excavation and haphazard disposal of debris, boulders and rock fragments after blasting, for the construction of Hydro Projects, therefore need to be controlled and checked. Maximum stones from the excavated earth and rock cutting should be retrieved and stacked which will not only minimise the damage to the eco-system and limited agricultural land in hills but can also be fruitfully utilised in a cost-effective way on protective works.

Loss on Parbati Hydro Power Project

The NHPC who was executing work of prestigious Parbati Hydro Power Project of 2051 MW has suffered loss of property worth Rs. 1 crore in the cloud-burst that struck the makeshift camp of laborers on the night of July 16, 2003 at Pulia Nallah. A huge RCC bridge constructed by NHPC over Pulia Nallah collapsed causing the loss of property to the NHPC and hampered the movement of workers to the other side of the swollen Pulia Nallah.

Crisis Management

The lndo-Tibetan Border Police (ITBP) was deputed for disaster mitigation by Ministry of Home Affairs in the Himalayan region. The ITBP units are well equipped for carrying out specialized search and rescue operations. The rescue operations, however, hampered as the ITBP was not having heavy machinery to remove boulders. The landslides, boulders and trees flowed with flood caused casualties.

To mitigate damages in such cases, the crisis management planning in advance is very important which includes prompt information and warning system. Public awareness and participation is therefore crucial in limiting the loss of life and public assets. On occurrence of such calamities, the response speed and its quality are of great importance in saving lives. There is thus need to establish "Quick Reaction Teams" both at District level and State level to deal with such situations promptly. A dependable information technology with proper modes of dissemination of flood warning system should be established.

Case Study – 2, Flash Flood due to Glacial Lake Outburst

Glacial lake is defined as water mass existing in sufficient quantities, extending with a free surface in or around a glacier. Glacial lakes and glaciers are also repositories of climate changes and they remain sensitive to global temperature conditions.

Glaciers hold large quantity of bounded water, which may be suddenly released with melting of ice block resulting into Glacial Lake Outburst Floods (GLOFs). Concentrated flow originating from glacier activities such as excess melting of snow/ glacier in a confined catchment area causes the Glacial Lake Outburst.

A glacial lake outburst flood (GLOF) is a type of flood that occurs when the temporary dam containing a glacial lake fails. GLOF can also be described where a body of water contained by a glacier, melts and overflows. The dam catchment in higher hilly ranges consists of glacier or a terminal moraine. The rivers originating from the Himalayas in the northern part of the country, which are also fed by snowmelt from glaciers, are prone to flash floods.

Flash Flood at Hydro Power Project Tawang, 2014-15

The study relates to the Hydro Power Project of NHPC in Tawang Basin which experienced severe flash flood due to glacial lake outburst during 2014-15. Catchment area of Power Project, Tawang Stage-I and II has number of glacial lakes at high altitude varying from 4000 to 5200 metre. This mountainous area infested with glacial lakes of varying size, starting from the largest glacial lake named "Nara Yu Tsho" (area of 23.68 sq km) has been shown in **Fig. 2**.

- Hydroelectric Projects-Tawang Stage-I: 600 MW, Barrage 15 metre high, Catchment Area 2937 km^2 (sq km) and Tawang Stage-II: 800 MW, Barrage 12 metre high, Catchment Area 3419 sq km. Large portion of the project catchment lies above permanent snowline. About 60% area lies in Tibet where application of remote sensing was only feasible means of study and aerial photography not possible. National Remote Sensing Centre (NRSC), Hyderabad was entrusted to carry out the study of glacial lakes in Tawang basin using latest satellite data. A total of 121 glacial lakes / water bodies were identified by NRSC using satellite images and out of these lakes, 14 lakes have area more than 25 hectares.
- A rough estimate made using empirical relations to know the discharge generated due to GLOF of these lakes showed a value of about 57000 cumecs at Stage-I whereas as the design flood estimated for Stage-I is only 4264 cumecs. The spillway capacity required for accounting for the flood due to GLOF in this case would have been enormous, thus making the project unviable.
- This being a cardinal point in feasibility of the project, various agencies were involved in GLOF related study such as TERI, Wadia Institute of Himalayan Geology, State Remote Sensing Centre, Arunachal Pradesh. Nothing meaningful came out and finally the

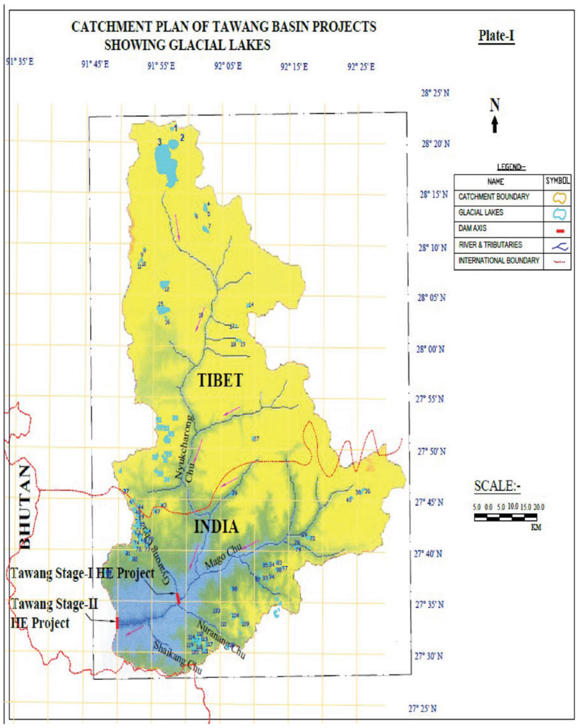


Fig. 2 Catchment Plan of Tawang Basin Projects

International Centre for Integrated Mountain Development (ICIMOD) was approached. ICIMOD is an authority on the glaciers and glacial lakes and have also carried out a lot of work in the Himalayas pertaining to GLOF. ICIMOD opined that the two largest lakes having an area of 23.68 sq km and 2.59 sq km could be eliminated as these lakes are slowly drying out and no glacier feeding the lake is visible in the catchment.

- All other lakes were then examined one by one and the hazardous ones were segregated on basis of data. Based on this study, a cirque type glacial lake having an area of 49.34 hectare and located at a distance of about 40 km from Tawang Stage-I, further 18 km from Stage-II was considered to be potentially hazardous and finally approved for all purposes relating to Project, Tawang Stage-I and Stage-II.

Case Study -3, Flash Flood on River Phutkal – May, 2015

- This case study relates to flash flood on account of outburst of artificial glacier lake that formed due to landslides at high altitude in Kargil region in River Phutkal. An artificial lake was formed in course of River Phutkal, a tributary of River Zanskar, due to landslide at about 200 km upstream of Indus-Zanskar confluence on 31st December 2014. Surface area (55 hectare) of this artificial lake was completely frozen and blocked the river flow, blockade length and width of 600 and 90 metre respectively, refer **Figs. 3 and 4**.

Fig. 3 View of frozen artificial lake

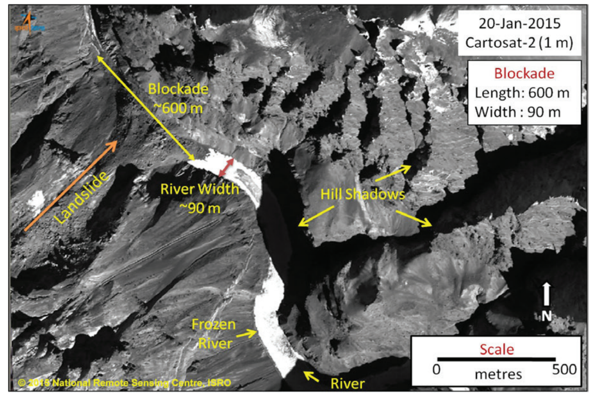


Fig. 3 View of river Phutkal with blockaded area due to landslide

- During January 2015, a study to estimate the discharge on outburst of this artificial lake was carried out. Nimmo-Bazgo Power Project of NHPC is located on Indus River about 200 km downstream of this lake. The lake finally busted on 07 May 2015 early morning causing flash floods. Heavy discharge of about 2757 cumecs reached the reservoir with a lag time of 11 hours.

Analysis of Lake Outburst

Based on this study in Jan 2015, it was estimated that on the outburst of artificial lake, a discharge of about 1400 cumecs would reach at tail end of Nimmo-Bazgo reservoir with the time lag of about 11 hours.

- With the rise in temperatures, the frozen water thawed out and the artificial lake got suddenly busted on 07 May 2015 early morning causing flash floods. As per actual data observed at dam site during this period, it was observed that the outburst resulted in an inflow of about 2757 cumecs and had a lag time of about 12 hrs.
- The dam controlled the flood water in such a way that the water level in the downstream was kept below 3 metre depth averting the

disaster. Reservoir helped absorbing the flood and the flood peak curtailed to 1600 cumecs.

CONCLUSION

It has been concluded that GLOF could create a flood as large as 100 year return period and therefore a study is recommended for derivation of design floods of projects located in glacial lakes dominated areas. The hazard potential rating of glacial lakes is an important factor for GLOF study, as simply considering the largest lake in the catchment as potential to generate GLOF may sometimes hamper the viability of the project. It would be ideal if ground verification of the lakes could be carried out using appropriate means, nevertheless remote sensing data as well as critical analysis of physiography of the glacial lakes could lead to near correct solution.

Possibilities of Application of Porous Concrete Slabs for Storm Water Carrying Drainages in Flood Prone Areas of Bengaluru City

Shreyas H C, Chaya K N

Department of Civil Engineering, Gopalan College of Engineering and Management, Bengaluru

shreyas.hc23@yahoo.in

chaya.rashu@gmail.com

ABSTRACT

Flooding and water logging are the major problems in most of the urban areas mainly during rainy seasons. This study has been carried out with the possibilities of application of pervious concrete for existing drainages which carries storm water from roads and streets. Porous concrete blocks are prepared with various ratios of water to cement. Various tests were conducted in order to determine best mix for preparation of slab. The tests are carried out to determine compression strength, permeability test, porosity and void ratio of the specimen to determine most appropriate w/c ratio for preparation of slab for the purpose. The values of above tests are tabulated and analyzed, and was found that of all the water cement ratio value gives best possible results, value 0.34 gives most optimized result and hence it is used in present work. Later the selected mix is used to prepare the porous concrete slabs which will be used in existing drainages as a bed, which are generally designed to carry storm water. The article also provides an overview on applications of pervious concrete other than as a road construction material. As a part of this study quantity of porous concrete required for application in flood prone localities is calculated in terms of area as well as volume and also it provides construction cost of the material.

Keywords: Impermeable pavement, Infiltration capacity, Pervious Concrete, Permeability.

INTRODUCTION

Rapid development of unplanned urbanization in many countries causes serious problems. Bengaluru is one of the cities which suffer because of the above cause. For example, in the recent times, extreme rain in the city unavoidably causes water logging, which poses a huge threat to the livelihood and assets security [1].

The main causes for flooding and water logging in the city are:

1. Conversion of large permeable wet lands into impermeable surfaces.
2. Abusing natural storm water drains and occupying storage tanks for layout developments.
3. Rapid increase in built up areas.
4. Deforestation.
5. Concretizing of roads.
6. Lack in maintenance of existing drainage system.
7. Narrowing and concretizing of Raja Kaluves.

Rajakaluves are the main storm carrying canals. They connects various lakes, those are constructed previously by the rulers of city. During earlier periods the city used to have more than hundred numbers of lakes. Encroachment and construction activities for urban infrastructure expansion vanished most of the lakes. Once upon a time the city had 280-285 lakes, among which 7 cannot be traced, 7 are reduced as small water pools, 18 have been intruded in an unauthorized manner by slums and private parties, and 14 have dried up and are leased out by the Government. Bengaluru Development Authority used 28 lakes to distribute sites and build extensions for residential areas. The remaining lakes are in fairly advanced state of deterioration. During 1973 Bengaluru city was covered with 68% of vegetation, 8% of built up area and 24% of surface water bodies. In 2017 it has turned into that 6.5% of vegetation, 79% of built up area and 14.5% of water bodies. For 2020 it is estimated that 3% of vegetation, 93% of built up are and only 4% water bodies will be available [1].

The data shown in the **Table 1** is collected from Indian meteorological department website and BBMP website [2] [3] .

Table 1 Hydrological and Meteorological data of the Bengaluru City

Particulars	Amount
Normal annual rainfall	978 mm
Annual Peak rainfall	1615 mm
24 hr peak rainfall	162.1 mm
Maximum rainfall intensity	72 mm/hr
Daily Water Demand	1450 MLD
Maximum soil infiltration rate	10 mm/hr
Road Networks	1500 km
Length of storm water drain (Raja Kaluve)	842 km
Ground Water Table depth below surface	2.5 m to 65 m
Drainage Area of City	741 km^2

POROUS CONCRETE

Pervious concrete is a mixture of cement, coarse aggregate, and water that provide a considerable amount of porosity which allows water to percolate into the sub-grade. It is different than conventional concrete which usually contains a nominal amount of fine aggregate [4]. Pervious concrete is prepared with single size aggregates which result in larger air voids than conventional concrete. Pervious concrete is traditionally used in parking areas, light traffic areas, residential streets, footpaths, and greenhouses [5]. It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality. Pervious concrete behaves like a storm water infiltration basin and allows the storm water to infiltrate into the soil over a large area, thus make easier the recharge of precious groundwater supplies locally. All of these benefits lead to more effective land use. Pervious concrete can also reduce the impact of development on trees. A pervious concrete pavement allows the transfer of both water and air to root systems allowing trees to flourish even in highly developed areas [5].

In the present study, pervious concrete slabs were prepared and used in existing road drainages [4] by partially replacing its bed in order to control flooding and water logging in Bangaluru city which frequently causes severe damages during rainy seasons.

METHODOLOGY

The methodology used in this work can be summarized into a series of steps as below:

1) A review on various papers on the study and construction of pervious concrete.
2) The materials are procured from various sources from concrete mix [6].
3) Specimens (Pervious concrete cubes) are prepared with various water cement ratios [6].
4) The specimens are moulded, cured and tested for 28days [7] [8].

5) The results of each test is tabulated and analyzed.

6) Preparation of pervious concrete slab for definite purpose (Drainage works).

7) Calculating the cost for preparation of pervious concrete slab.

8) Installation at site.

RESULTS AND DISCUSSION

Table 2, shows the comparison of all the results. Graph 1 shows the tendency of the results. Since the concrete material is used as a storm drainage bed, the strength is not considered as that much significant but it should be moderate with considerable voids and permeability.

From the comparisons it is observed that the compressive strength of the concrete increases with increase in water-cement ratio, whereas the permeability, porosity and void ratios decrease with increase in water-cement ratio and also permeability increases with increase in porosity and void ratio. It can be noticed that, the increased porosity and void ratio will have both advantages and disadvantages. From the above results it can be determined that all the mixes can acceptable for preparing porous concrete, but the mix prepared with water cement ratio of 0.34 was the best one for the present purpose and it obeying all the requirements moderately.

Table 2 Comparison of results

W/C Ratio	Compressive strength in N/mm²	Porosity	Voids ratio	Permeability in cm/sec
0.5	9.6	0.16	0.19	0.125
0.48	8.9	0.18	0.23	0.132
0.46	7.9	0.21	0.26	0.135
0.44	7.6	0.23	0.31	0.160
0.42	7.5	0.25	0.34	0.206
0.40	6.1	0.26	0.35	0.217
0.38	5.8	0.27	0.36	0.219
0.36	5.5	0.28	0.39	0.251
0.34	4.7	0.29	0.42	0.292
0.32	3.3	0.30	0.42	0.292

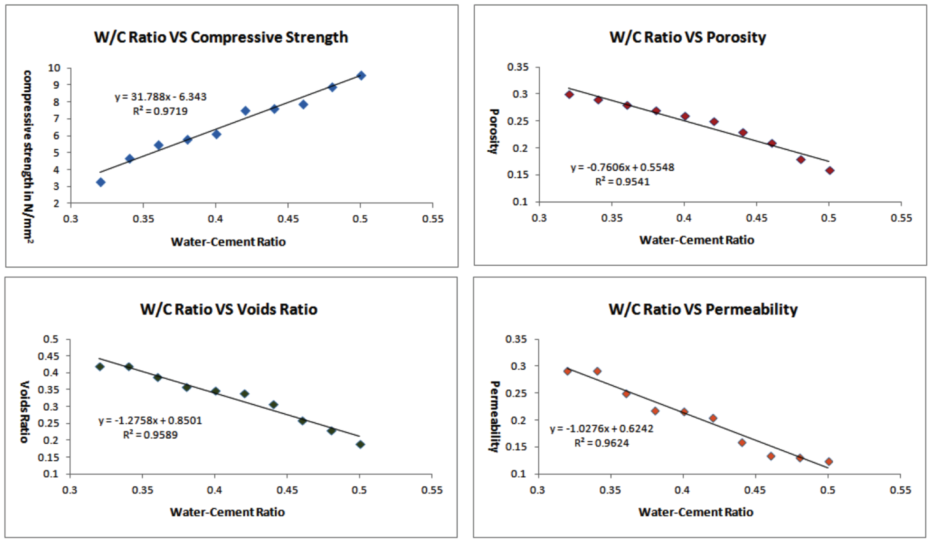
Since the permeability of the system exceeds 15 times the maximum rainfall intensity of the area (72 mm/ hr) [2], it can be used in drainages of flood prone areas as a bed.

APPLICATION AT SITE

Karnataka State Natural Disaster Monitoring Centre (KSNDMC) has noticed 174 low lying areas of Bengaluru city, where flooding and water logging problems occurs frequently during rainy seasons [3]. From the present study it can concluded that, it is possible by applying porous concrete to the storm water carrying open drains of affected areas of the city the problem of flooding can be mitigated. The method of application of pervious concrete is as shown in the **Fig. 1**.

COST ANALYSIS

- Size of the specimen(porous concrete slab) = 12” x 12” x 4” = 0.3m x 0.3m x 0.1m
- Cement aggregate ratio = 1:6
- Water – cement ratio = 0.34
- Voids ratio of specimen = 0.34
- Mass of dry Specimen = 14kg
- Density of OPC cement = 1440kg/m^3
- Density of coarse aggregate = 1680kg/m^3
- Size of aggregate =12.5mm-10mm
- Total ratio of specimen= 1 + 6 = 7
- Mass of cement = (1/7) × 14 = 2kg
- Volume of cement = mass of cement /density of cement =2/1440 = 0.00139 m^3
- Unit market price for OPC cement = Rs.370/ bag (1 Bag of Cement =35 liters= 0.0351 m3) =370/0.0351 = Rs. 10,542/m3
- Amount of cement/slab = volume of cement/ slab × price of cement per unit volume = 0.00139X10542 = Rs.15
- Mass of coarse aggregate = (6/7) × 14 = 12kg



Graph 1 Graphical comparison of various test results

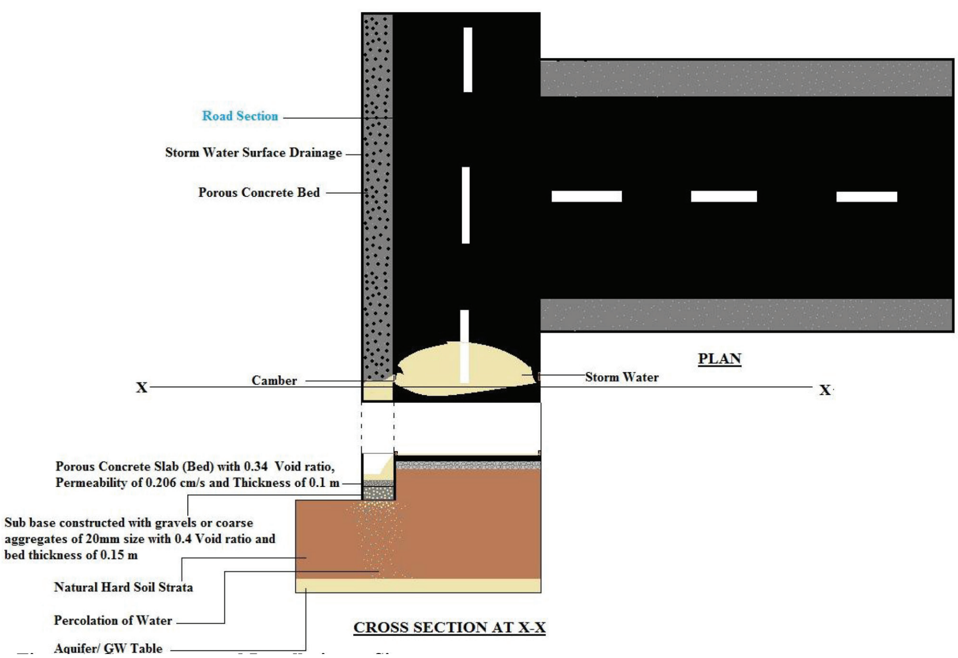


Fig. 1 Components and installation at site

- Volume of coarse aggregate = mass of coarse aggregate/density of coarse aggregate = 12/1680= 0.00714 m^3
- Market price for coarse aggregate = Rs.990/ m^3
- Amount of coarse aggregate = volume of CA × price of CA = 0.00714x990 = Rs.8
- Total cost of construction of porous concrete slab of size 0.3 m × 0.3 m × 0.1 m = Amount of cement + Amount of coarse aggregate = 15+8 = 23
- Rs. 26/ Slab (Including 10% wastage charges) [7].

CONCLUSION

Since the compressive of pervious concrete is very less when compared to conventional concrete, it is not suitable in road constructions for the city like Bengaluru, as it cannot withstand passing of heavy vehicles above it.

From the present work it is observed that the selected porous concrete block can be used as a bed in a drainage system, which are designed to carry storm water in urban area, in order to

- Reduce flooding
- Reduce water logging
- Recharge ground water
- Overcome from the problems like inundation of roads during flood
- Managing the water resources of the city systematically
- Reduce the water crisis of the city in future.

Even though it looks very simple, it can give immediate relief. This idea can become the most effective solution to overcome the problems which occur due to natural disaster like floods and water logging which has made Bengaluru city suffer from many years. Since the flood carries silts and other sediments, there is a possibility of clogging in the pores of concrete; this may reduce the effectiveness of concrete. Hence, the frequent maintenance is necessary to remove the clogged sediments. The silts and sediments can be removed through vacuum sweeping before starting of rainy seasons. With the proper maintenance the pervious concrete slab can be used effectively for about 4-5 years. Besides being used as a storm drainage bed these slabs can also be used in constructions of foot paths, play grounds, gardens, parking lots, animal stalls and under paths etc. Its strength can be increased by adding proper admixtures.

REFERENCES

1. T V Ramachandra, Vinay S, Bharath H Aithal - Koramangala floods: Causes , ENVIS Technical Report 131, Environmental Information System, IISC, Bengaluru-62, 2017.
2. www.imd.gov.in
3. http://bbmp.gov.in
4. Stephen A Arhin and Rezene Madhi,"Optimal Mix Designs for Pervious concrete for an Urban Area"- International Journal of Engineering research and Technology, ISSN: 2278-0181, Vol.3 Issue 12, Dec 2014.
5. Krishna Raju –"Concrete mix design", Sehgal Publishers.
6. M. Sonebi et al., "Pervious Concrete: Mix design, Properties and Applications"- RILEM Technical letters, Vol.1:109-115, (2016).
7. S O Ajamu, A A Jimoh and J R Oluremi, "Evaluation of structural performance of pervious concrete in construction", international journal of engineering and technology, vol.2, Issue 5, May 2012.
8. Dev Pratap Mani Tripathi et al, "An experimental study on pervious concrete (mix ratio, strength and porous properties)"- International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 6 Issue 12, December – 2017.

Rapid Inundation Mapping using Sentinel-1 Data for Southwest Rainstorm Season in Kerala

Vikas Kumar Rana, T.M.VSuryanarayana
Water Resources Engineering and Management Institute, The Maharaja Sayajirao University of Baroda, Gujarat
drsurya-wremi@msubaroda.ac.in

ABSTRACT

This research aims to closely determine inundation extents due to high precipitation and flooding in real-time using multi-temporal satellite SAR data set, using methods that can be rapidly and efficiently implemented in wide areas as new data become available. Kerala encountered an abnormally high precipitation from 1 June 2018 to 19 August 2018. The average annual precipitation in Kerala State is around 3000 mm. As per the report published by India Meteorological Department, precipitation over Kerala amid southwest rainstorm season 2018 (1 June to 19 August, 2018) has been incredibly high. This rainfall was about 42% above the normal. Inundated areas in districts (Alappuzha and Kottayam) and partially (Kollam, Pattanamtitta, Idukki and Ernakulam) as on 21 August 2018 have been mapped by processing of Sentinel-1 ground range detected (GRD) data acquired in interferometric wide swath (IW) mode with VV polarisation, which are routinely being acquired over several land masses. Two subsets of a scene of Sentinel-1 GRD VV and Sentinel-2 (B3 and B8 bands) derived Normalized Difference Water Index map have been used to carry out the research, and the derived inundation extent has been validated against cloud free optical data.

Keywords : Floods, SAR and NDWI

INTRODUCTION

In recent years severe rainfall events have afflicted the Kerala causing a lot of damage to houses and infrastructure. During severe rainfall events remotely sensed data can provide significant mapping capabilities. However, obtaining remotely sensed data that represents the ideal combination of fine spatial and temporal resolution, and the ability to see through clouds and/or to discriminate flooding under forest cover is a troublesome task. The extent of inundation, whether caused by river flooding or coastal storm surges, is required quickly to enable the planning of emergency relief and repairs to communications and services. The precipitation over Kerala amid June, July and August (1-19 August 2018) has been 15%, 18% and 164% above ordinary respectively. Due to the rainfall scenario prevailed till the terminus of July 2018 over Kerala [1], all the major reservoirs were proximate to the full reservoir level and had no buffer storage to accommodate the inflows from 10th August, 2018. Serious spell of precipitation began from the fourteenth of August and proceeded till the nineteenth of August, bringing about appalling flooding in 13 out of 14 districts. The perpetuated exceptional rainfall in August (170% above normal) in the catchment areas had compelled the authorities to resort to heftily ponderous releases downstream into the rivers [2].

With an increasing number of satellites, higher spatial and temporal resolution, and different kinds of active and passive remote sensing systems available, remotely-sensed data are gaining importance in all phases of disaster management. Multi-source satellite imagery and effective image processing can be used efficiently in the field of emergency and crisis response assistance for rapid mapping activities. Remote sensing has thus long been seen as a potential solution, with many studies demonstrating the use of both air and space borne imagery to map damage [3].Floods are a stand out amongst the most decimating common risks that have happened repeatedly over the Earth's records. In late decades, because of the Earth-wide temperature boost and broad urbanization, floods resulting from increasing extreme weather have ended up being dynamically unsafe and unpredictable. Many studies have shown the efficiency of the use of satellite images for flood damage evaluation. Different types of damages due to floods are mapped and assessed using remote sensing imagery: urban areas, agriculture (crop) areas or general land cover types. Therefore, it is utterly necessary and urgent to enhance flood control in these incredibly populous areas. Remote sensing promises exceptional capacity in catastrophe control due to its regular acquisition functionality over big spatial extent.

Compared to inadequate surface data including rive gauge details and reports of stations, in flood assessment and vegetation response in Australia, [4] earlier work has reported use of Landsat TM / ETM + images.

Nevertheless, detection of flooding from SAR images remains a very challenging task in an operational context. Over the past decades, several studies have used SAR data to map flood bodies with different techniques, such as simple visual interpretation [5], change detection by direct comparing [6] and by post-classification comparing [7]. The high resolution SAR data are suitable for identifying the change of fish-pond. The backscatter and texture characteristics shown between the images with short time interval can provide efficient information for fast change detection [7]. However, fully automated, time efficient, accurate and stable flood extracting algorithms are scarce [8]. Two flood-extraction algorithms based on SAR, called 'M1' and 'M2a' have recently been proposed [8]. The hypothesis is that the histogram of the backscatter values in the SAR flood data can be represented as two partly overlapping histograms: one histogram derived from the backscatter values representing 'open water' in the SAR data and another histogram from the backscatter values representing non-inundated areas. Since 'open water' characteristics can assumed to be a homogeneous surface, a normal distribution of the 'open water' backscatter values can be hypothesized. The occurrence of water in the SAR data therefore can be linked to the bimodal form of its histogram, whereas the histograms of images without flooding are usually uni-modal [9].

Sentinel-1A launched on 3 April 2014, from Kourou, French Guiana has C-band synthetic aperture radar (SAR) which provides 1 dB radiometric accuracy with a central frequency at 5.405 GHz capable of providing data in all light and weather conditions. It has different operational modes like Interferometric wide-swath (IW), Strip Map (SM), Extra Wide Swath (EW) and Wave (WV). Commonly used SAR flood extent mapping techniques include Radiometric thresholding, Statistical distribution of water backscatter values from a SAR flood image, region growing to extract all water bodies and change detection with respect to a non-flood image is applied in order to remove areas with non-significant changes between the flood and non-flood acquisition [8] and simple visual interpretation [10]. Study conducted by Ref.[11] concluded that when flooding with Sentinel-1 data is identified, VV is slightly advantageous.

The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features showed by [12] is very useful if the imagery is

Table 1 Specification of sentinel-1 products

	PRODUCT NAME	REPEAT CYCLE	INSTRUMENT	PRODUCT TYPE	ACQUISITION MODE	SENSING DATE	PASS	TRACK	ORBIT	POLARIZATION
SENTINEL-1A	S1A_IW_GRDH_1SDV_20180821T004044_20180821T004109_023337_0289D5_D07A	12 days	C-SAR	Ground Range Detected	Interferometric Wide swath (IW)	21-AUG- 2018	Descending	165	23337	DV (dual VV+VH polarisation)
	S1A_IW_GRDH_1SDV_20180821T004109_20180821T004134_023337_0289D5_B2B2					21-AUG- 2018			23337	
	S1A_IW_GRDH_1SDV_20180318T004036_20180318T004101_021062_0242D9_BD7C					18-MAR-2018			21062	
	S1A_IW_GRDH_1SDV_20180411T004102_20180411T004126_021412_024DD9_C654					11-APR-2018			21412	

cloud free, during the southwest rainy season it is nearly impossible to obtain 100% cloud free data, however, small extent of the cloud free data can be used for validation. NDWI is defined as ((B03) − (B08)/ (B03) + (B08)), where B03 is green band and B08 is near infrared band. When NDWI is applied over multispectral image the water feature have positive values while soil and terrestrial vegetation features have zero or negative values, because NIR is absorbed strongly by water and is reflected just as strongly by terrestrial vegetation and dry soil, while in green light water has high reflectance than terrestrial vegetation and soil.

STUDY AREA AND DATASETS

Part of Kerala State, India has been taken up under the study. The damage caused by the floods and heavy rainfall has been severe and varied. The state has witnessed heavy floods in years 1924 and 1961. The rainfall depths from IMD rainfall records for 15-17 August 2018 have been found comparable to the rigorous storm that occurred in the year 1924 [2]. Two sets of remote data are acquired for flood mapping; one set comprised of data acquired before the storm event and the other collected during the event. The Sentinel-1 data that were available closest to event date were acquired on 21-AUG-2018 at 00:40:44 and 00:41:09 hrs, and two archive data prior to the crisis acquired on 18-MAR-2018 at 00:39:29 hrs and 11-APR-2018 at 00:41:02 hrs to cover the part of Kerala State to analyze the event. The specific parameters of the Sentinel-1 products are shown in **Table 1**.

For validation, part of cloud free Sentinel-2 data acquired on 22 August 2018 has been used to calculate the Normalized Difference Water Index.

METHODOLOGY

In the pre-processing phase, the Sentinel-1 data acquired on 21-Aug-2018, 18-Mar-2018 and 11-Apr-2018 with band amplitude VV were radiometrically calibrated. The purpose of calibration is to convert the digital level values to backscattering coefficient values (σ_0). Calibration is implemented using the SNAP platform. Lee filter 3×3 was used as suggested by [13]. The linear σ_0 backscatter coefficient values were then converted to dB (logarithmic scale). Range-Doppler Terrain Correction was performed using SRTM 3 sec DEM to make the corrections with bilinear interpolation method. The resulting corrected data remains in its actual correct geographic orientation, the final coordinates are in geographical WGS84 projection. Tile based thresholding has been adopted for rapid extraction of inundation in SAR data. A backscatter threshold value has been chosen for individual scene below which the image elements is called water. Thresholding has been implemented by visually inspecting the histograms of the data. For visualising the standing water and inundation occurred on the crisis date, the post crisis data has been passed through red channel and the crisis data has been passed through green and blue channel. The inundated areas appear red while standing water appears black and the rest

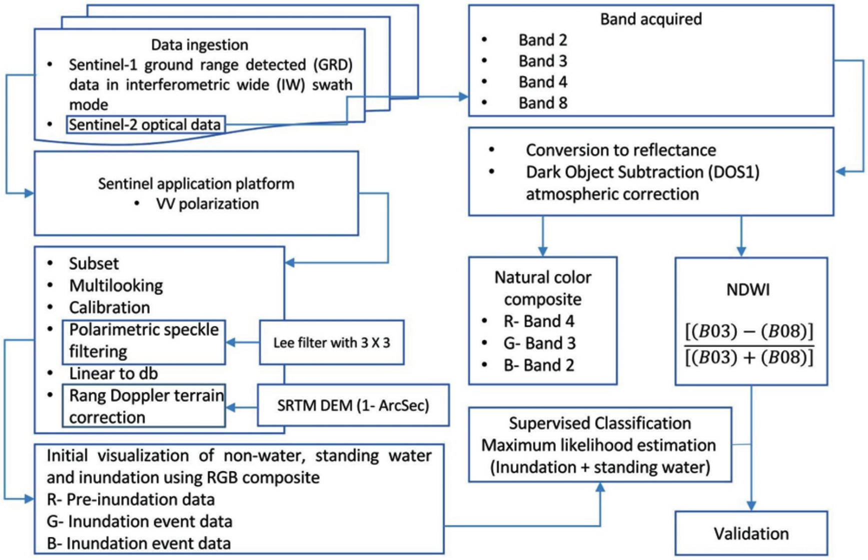


Fig.1 Flow diagram for methodology

of the areas appear as grey colour. In the final step the stacked dataset has been classified using maximum likelihood algorithm in ArcGIS. Part of cloud free optical data from Sentinel 2 acquired on 22-Aug-2018 has been used to compute the Normalized Difference.

Water Index was determined using equation [(B03)-(B08)] /[(B03)+(B08)]. The resulted data contains water features with positive values while the soil and terrestrial vegetation features have zero or negative values which help to identify the water from the rest of the areas.

Two subsets of sentinel 1 data of same region acquired on 11-Apr-2018 and 21-Aug-2018 have been used to show the results. In order to carry out an experimental analysis aimed at assessing the map, the classification result is compared with a reference map created by visual interpretation and computed NDWI, for which data was acquired on 22-Aug-2018 as the cloud free optical data was not available on 21-Aug-2018. No critical change in the inundation extents was observable due to time-offset between the SAR and optical data sets verified with consecutive satellite over passes. The raw SAR data in VV-polarization prior to crisis event acquired on 11-April-2018 and during the crisis event grey levels by analysing the bimodal distribution. The -13.09 and -13.08 dB backscatter coefficient threshold values are selected to separate water from non-water to data acquired on 11-April-2018 and 21-Aug-2018 respectively. Later, these two data have been used for change detection by creating RGB composite in which the data prior to crisis event is passed through red channel and the crisis event data is passed through green and blue channel, the resulting image is shown in **Fig. 3(a)**. Maximum likelihood algorithm has been applied for the final classification (Standing water + Inundated areas due to heavy rainfall) and the result is shown in **Fig. 3(b)**. The inundated area in the extent is acquired on 21-Aug-2018 are shown in **Fig. 2(a)** and **2(d)**. SAR imagery **Fig. 2(a)** and **2(d)** is not projected on the map coordinates of each pixel but still in the original coordinate position of data (rows/columns) in the field of ground range. The calibrated and Range-Doppler Terrain Corrected data of the respective dates are shown in **Fig. 2(b)** and **2(e)** and their histograms in **Fig. 2(c)** and **2(f)**. In the orthorectified imagery each of pixels that have been corrected and projected will visually appear in the actual position. To get initial classification done segmentation has been applied over 65.21%, which is 35.86 km^2. The NDWI calculated for the extent shown in **Fig. 4(d)**.The Inundated area in the extent is 72.29% which is 39.75 km^2.

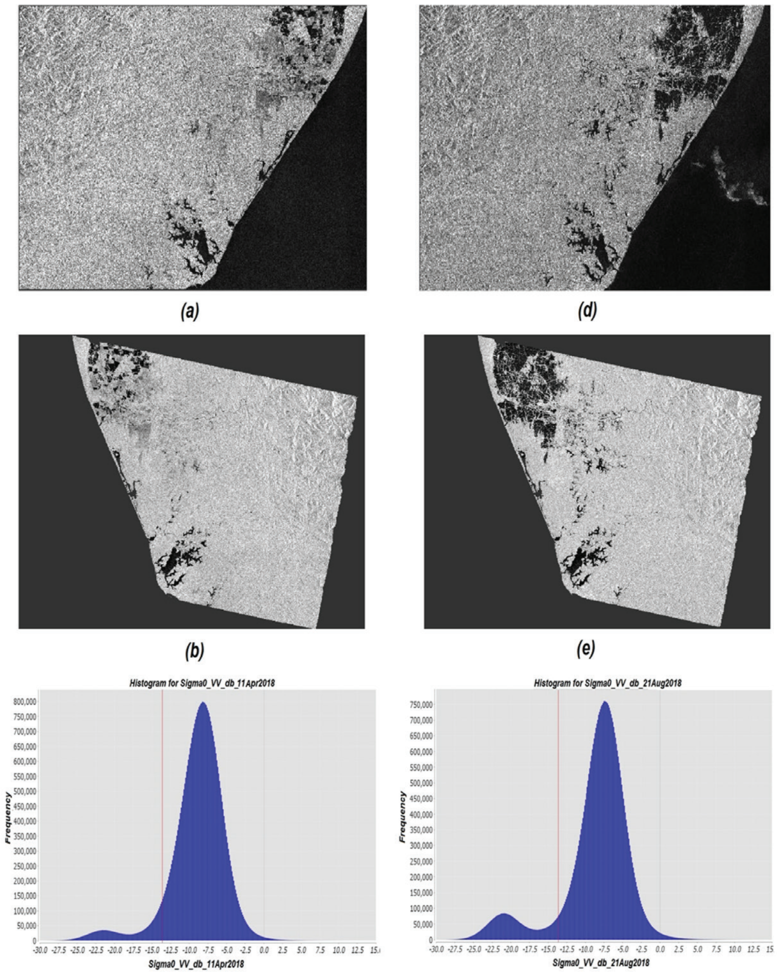


Fig. 2 (a) Pre crisis raw data (b) Pre crisis calibrated and corrected data (c) Histogram showing threshold value for pre-crisis data separating water and land (d) During crisis raw data (e) During crisis calibrated and corrected data (f) Histograms showing threshold value for during crisis data separating water and land

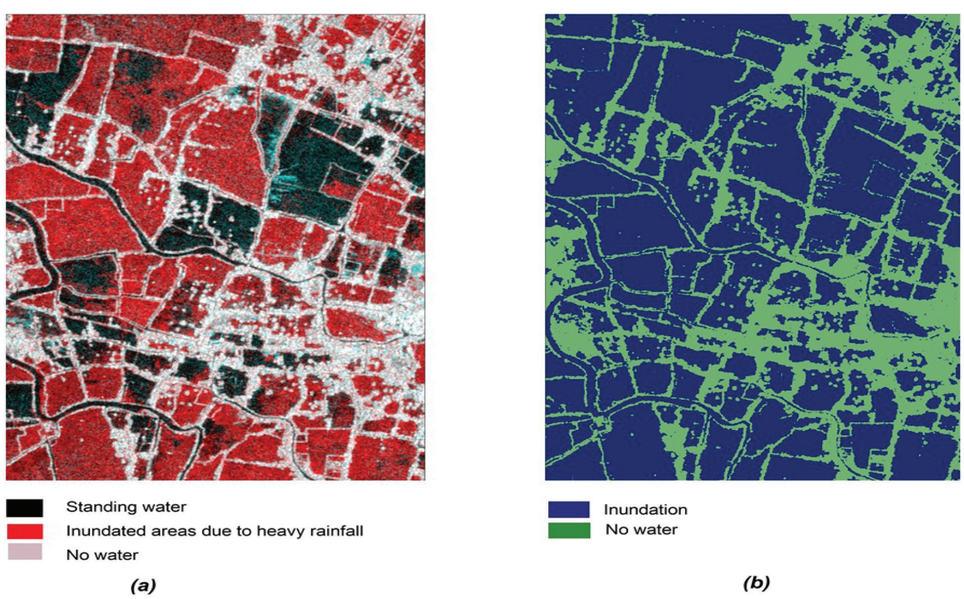


Fig. 3 (a) Change detection using RGB composite (b) Classified inundation

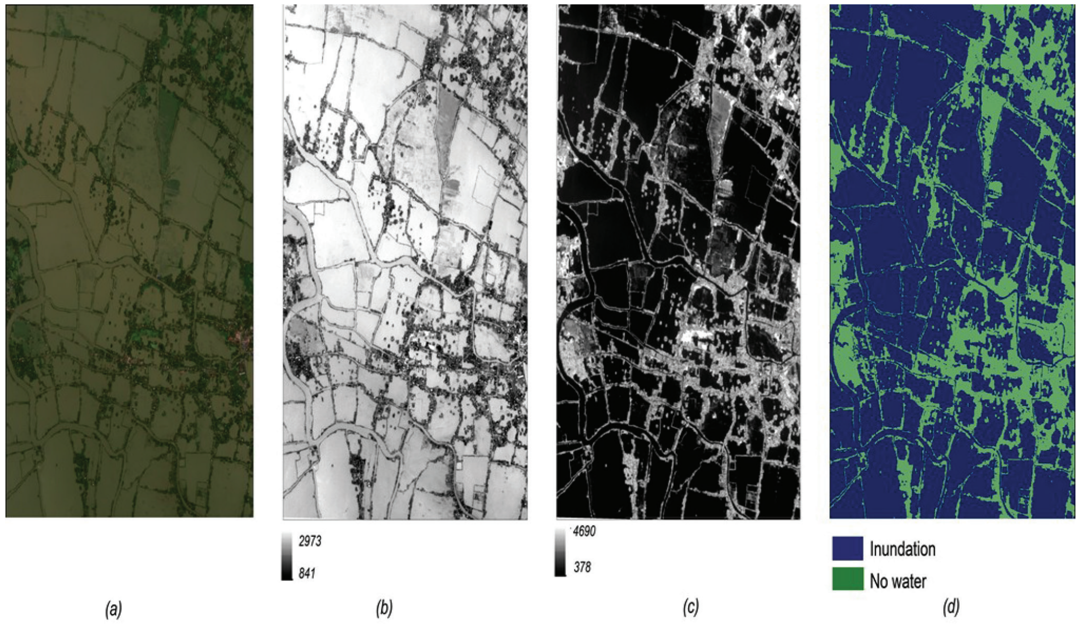


Fig 4 (a) Natural colour composite R-B04 G-B03 B-B02, (b) Green band (c) Near infrared (d) Calculated NDWI

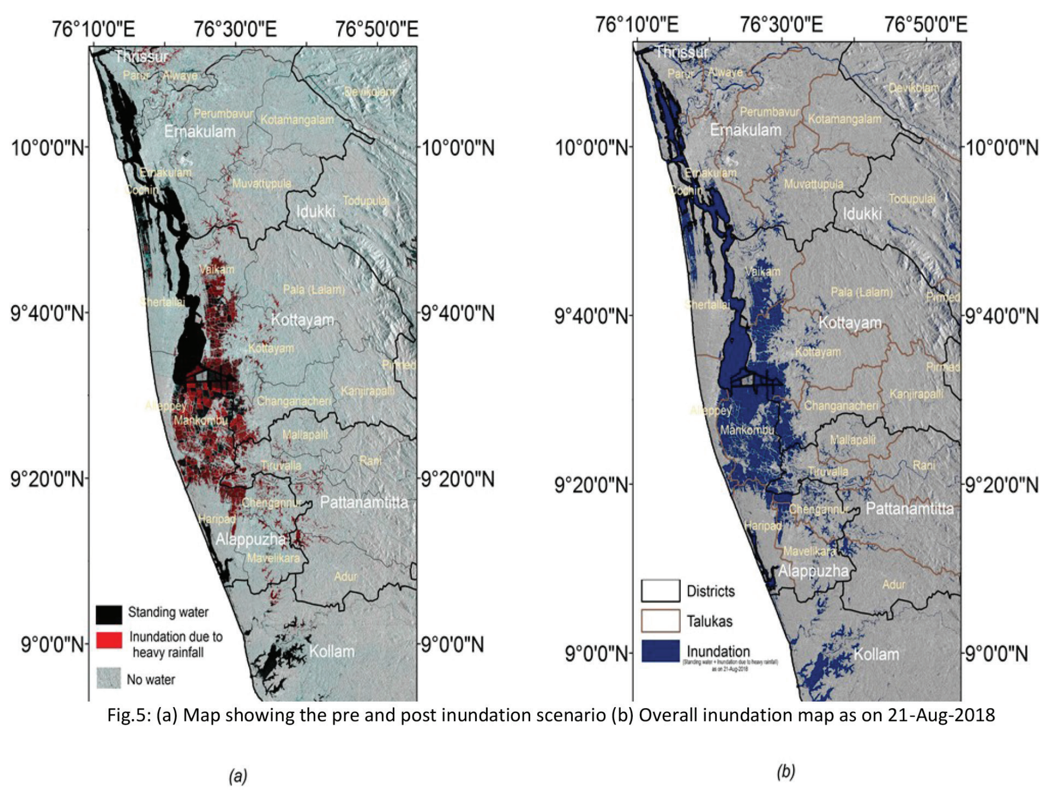


Fig 5 (a) Map showing the pre and post inundation scenario (b) Overall inundation map as on 21-Aug-2018

Considering and analysing the inundated area calculated by SAR data and optical data it can be said that they are quite comparable. The affected Kerala's districts for which the SAR data was available, the inundation as on 21-Aug-2018 has been mapped. To visualize the proximity of urban and rural centres, the administrative delimitation of these areas is also included and shown in **Fig. 5**. In **Fig. 5(a)** inundation as on 21-Aug-2018 due to heavy rainfall is shown in red colour, while the water present prior to the crisis event is termed as standing water and shown in black colour for districts (Alappuzha and Kottayam) and partially (Kollam, Pattanamtitta, Idukki and Ernakulam).

CONCLUSION

Effective and quick response is required during the disasters like flooding. Rapid mapping of such event will be beneficial to urban and infrastructure planners, risk managers and disaster response during extreme and intense rainfall events. The study shows simple and efficient method for mapping inundation extent over part of Kerala, occurred during amid southwest rainstorm season 2018 (1 June to 19 August, 2018). Surface roughness makes it difficult to have contrast between the tones of the land-water covers. Backscattering coefficient value become high as the water roughness cause the high signal return which decreases the contrast which makes the separation of the land-water covers difficult. Due to the difference in acquisition dates in sentinel-1 and sentinel-2 data and the surface roughness in SAR data, care should be taken when interpreting the data as an accurate representation of the flood. The results of this study show the potential for monitoring the damages, providing basic information that can help local communities manage water related risk, planning land and water management as well as other activities like flood control programs.

ACKNOWLEDGEMENTS

The authors would like to thank the European Space Agency for providing the data and tools for Sentinel-1 and Sentinel-2 data processing.

REFERENCES

1. Kerala Floods August 2018. (2018). Retrieved from http://cwc.gov.in/main/downloads/KeralaFloodReport/Rev-1.pdf
2. IMD. (2018). Rainfall over Kerala during Monsoon Season-2018 and forecast for next 5 days. Retrieved from https://www.imdtvm.gov.in/images/rainfall over kerala during monsoon season-2018 and forecast for next 5 days.pdf
3. Voigt, S., Kemper, T., Riedlinger, T., Kiefl, R., Scholte, K., & Mehl, H. (2007). Satellite Image Analysis for Disaster and Crisis-Management Support, 45(6), 1520–1528.
4. Tulbure, M. G., & Broich, M. (2013). Spatio temporal dynamic of surface water bodies using Land sat time-series data from 1999 to 2011. ISPRS Journal of Photogrammetry and Remote Sensing, 79, 44–52. https://doi.org/10.1016/j.isprsjprs.2013.01.010
5. Serpico, B. S. B., Ieee, F., Dellepiane, S., Ieee, M., Boni, G., Moser, G., … Rudari, R. (2012). Remote Sensing Images for Flood Monitoring and Damage Evaluation. Proceedings of the IEEE, 100(10).
6. Lu, J., Giustarini, L., Xiong, B., Zhao, L., Jiang, Y., & Kuang, G. (2014). Automated flood detection with improved robustness and efficiency using multi-temporal SAR data. Remote Sensing Letters, 5(3), 240–248. https://doi.org/10.1080/2150704X.2014.898190
7. Liu, K., Ai, B., & Wang, S. (2010). Fish-pond change detection based on short term time series of RADARSAT images and object-oriented method. Proceedings - 2010 3rd International Congress on Image and Signal Processing, CISP 2010, 5, 2175–2179. https://doi.org/10.1109/CISP.2010.5647643
8. Matgen, P., Hostache, R., Schumann, G., Pfister, L., Hoffmann, L., & Savenije, H. H. G. (2011). Towards an automated SAR-based flood monitoring system: Lessons learned from two case studies. Physics and Chemistry of the Earth, 36(7–8), 241–252. https://doi.org/10.1016/j.pce.2010.12.009
9. Hostache, R., Matgen, P., & Wagner, W. (2012). Change detection approaches for flood extent mapping: How to select the most adequate reference image from online archives? International Journal of Applied Earth Observation

and Geoinformation, 19(1), 205–213. https://doi.org/10.1016/j.jag.2012.05.003

10. Oberstadler, R., Hönsch, H., & Huth, D. (1996). Assessment of the mapping capabilities of ERS-1 SAR data for flood mapping: A case study in Germany. European Space Agency, (Special Publication) ESA SP, 11(383), 247–252. https://doi.org/10.1002/(SICI)1099-1085(199708)11:10<1415::AID-HYP532>3.0.CO;2-2
11. Twele, A., Cao, W., Plank, S., & Martinis, S. (2016). Sentinel-1-based flood mapping: a fully automated processing chain. International Journal of Remote Sensing, 37(13), 2990–3004. https://doi.org/10.1080/01431161.2016.1192304
12. Mcfeeters, S. K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. International Journal of Remote Sensing. https://doi.org/10.1080/01431169608948714
13. Rana, V. K. & Suryanarayana, T. M. V. (2019). Evaluation of SAR speckle filter technique for inundation mapping. Remote Sensing Applications: Society and Environment, 16, 100271.

Recent Flash Flood in Gujarat: Case Study of Banas Basin

Mayank Adhaduk
Water Resources Department, Government of Gujarat (Narmada, Water Resources, Water Supply and Kalpsar Department) Gandhinagar, Gujarat
✉ *mayank.dee.wrd@gmail.com*

ABSTRACT

Water is one of the most important resources for planet and prosperity of life but sometimes it becomes disastrous and dangerous opponent resulting into detrimental floods leading to devastation of infrastructure, damage to public utilities and loss of many human lives. Our future depends on our understanding and proper sustainable use of water. Gujarat is vulnerable to floods to large extent. Similar flash flood was experienced in Gujarat during July 2015 and July 2017 which ravaged the state for many days. North-East cities of Gujarat, Banaskantha, Patan, Morbi, Surendranagar were severely affected. Flood of July 2017 was more severe than that of July 2015 flood. This extensive case study shows its causes, impacts on human lives, response and rescue operation adopted by state and its mitigation management learning lessons to make Gujarat sustainable against such disaster in future.

Keywords : Unprecedented rainfall, Disaster management plan, Mitigation measures

INTRODUCTION

India is having a long history of devastating flood and landmass of India is very vulnerable to floods. Vulnerability towards flood is also exacerbated in last few years mainly due to climate change,change in rainfall pattern, unplanned urban planning, encroachment in river flood plain,etc. which resulted into disastrous floods. Study shows that 12% of the total landmass of the country (40 million hectare) is flood prone[1]. Series of floods has aggravated situation in Gujarat also. Gujarat is endowed with moderate to torrential rain which mainly contributes to large river basins like Tapi, Narmada, Mahi, Banas, etc. which have their catchment in the central uplands of Indian peninsula. Unprecedented rainfall in upper region becomes reason of severe flooding in these river basins. Recent flood was experienced in Banaskantha, north-eastern district of Gujarat during July 2015 and July 2017. In the year of 2015, flood was mainly due to unprecedented rainfall (cloud bursting) in upper catchment of Banas River which falls in Mount Abu hills, Rajasthan whereas in the year of 2017,flood was due to combination of two flood storm systems generated simultaneously and caused heavy rainfall in a very short period of time. This study focuses mainly on flood of July 2017 as it was more severe and disastrous. The floods were reported to have caused total 224 deaths between 1st June and 31st July 2017[2]. Indian Meteorological Department data shows that the state received 65% excess rainfall than average during the above period. Banaskantha

District of state was severely affected. Due to this flood large area was submerged resulting into huge damage to public utilities, infrastructure and private properties. Cities of Banaskantha District, i.e. Dhanera City was fully inundated whereas Deesa and Radhanpur were partially inundated. Preparedness prior to flood, swift rescue operation and admirable disaster management by the state government alleviated damage to infrastructure and public utilities.

A. Geology of Banaskantha

The Banaskantha District takes its name from the river Banas, which flows through it. District is surrounded by Rajasthan in north, Sabarkantha in east and Mahesana in south. Geographic variation of the district sprawls from Aravalli Hills in east to Rann of Kutch in west. **Fig. 1** shows geographic alluvial representation in Gujarat. The elevation in the Banaskantha ranges from less than 10 m in the western part to more than 800 meters from mean sea level in the north eastern part[3]. Runoff caused by such steep gradient is key element behind occurrence of flash flood. Banas River originates from Aravalli Hills, Rajasthan, passes through Banaskantha District and meets into Rann of Kutch with total length as 266 km. Sipu is right bank's main tributary and Khari is left bank's main tributary of Banas. There is Dantiwada Dam on Banas River at 105.00 km distance. Sipu Dam is situated at 60 km distance on Sipu River.

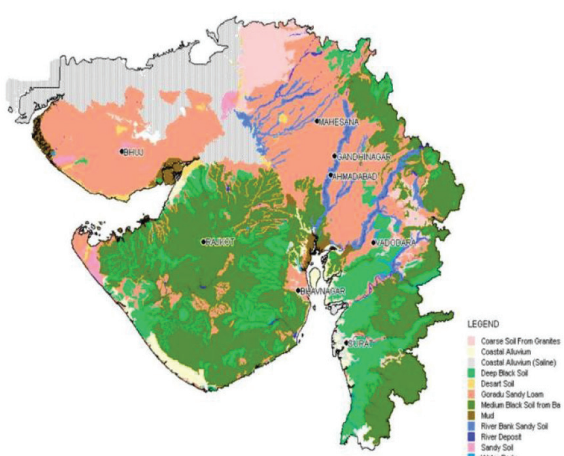


Fig. 1 Geographic alluvial variation in Gujarat

CAUSES

Gujarat experienced unprecedented torrential rain in the third and fourth week of July 2020. The districts of North Gujarat along with Banaskantha, Patan, Mahesana and Surendranagar were the worst affected. Incessant torrential rain was caused due to simultaneous activation of Arabian Sea and Bay of Bengal low-pressure systems (a rare phenomenon) has resulted into devastating floods in many part of Gujarat[4]. Almost half of state's entire monsoon season's average rainfall was received by 21 July 2017 and 26.57% of season's average rainfall was received in next seven days. Banaskantha recorded historical 348 mm of rainfall, more than 50% of the annual monsoon rainfall in nearly 24 hours during 24-27 July 2017 which resulted into flash flood in the district leading to very heavy inflow into the dams such as Sipu, Dantiwada, Machhu, Dharoi, etc. Banaskantha reported 163.02% of annual average rainfall during 24-27 July 2017. More than 64 inches rainfall was reported in Rajasthan during these two days which caused devastation in downstream basin which falls in Gujarat. Deesa,taluka of Banaskantha, is at downstream of confluence point of Sipu and Banas River. It received 254mm rainfall in just 8 hours. Heavy inflow from Banas and Sipu River and also unprecedented rainfall in short span of time devastated Deesa City. Dantiwada, Taluka of Banaskantha District, received 805 mm rainfall during 24-27 July 2017. It was close to the heaviest rainfall in 112 years in the affected region.

IMPACTS

The fury or intensity of the flood was varying; nevertheless, the damage caused was enormous. Almost whole Gujarat has witnessed deluge during that period. Flood has continued to ravage the state which leads to devastation and destruction of infrastructure, disruption in public utilities and loss of many human lives. Surendranagar was first hit by heavy downpour that started from July 14. The district received over 110 mm of rainfall – nearly 20% of its annual average in nearly 24 hours on July 21-22, 2017[4]. Flash flood in Banaskantha led to water-logging and devastation at many places. Dhanera, Taluka in Banaskantha, was swamped in flood with water level up to 1 floor. Almost all city was inundated and cut-off for 48 hours as all approach roads were submerged. Breach in training walls and embankment failure made situation worse. Dhanera had no electricity for 48 hours. Agricultural Product Marketing Complex (APMC) was completely submerged and the rotting of the stored food grains posed a potential health hazard. Flood caused up to one fourth loss in kharif sowing across crops. About 492 villages had no power supply, out of which 418 were in Banaskantha District[5]. The flood were reported to have caused total 224 deaths in Gujarat and 16 deaths in Rajasthan state by 31st July,2017[6].

RESPONSE

Gujarat handled situation in very deliberately manner and timely response by state government saved many lives that would otherwise have been exposed to severe threat. Gujarat encapsulated essential service in all possible way during flood. Emergency rescue and relief operation was launched in whole state. In all, about 1,12,878 people of which 68,672 people were from Banaskantha and Patan, were evacuated in time thus preventing a huge loss of life[4]. The magnitude of the flood was such that the administration needed the assistance of the Amy and Air Force almost from the beginning of the flood. Besides the State Disaster Response Force and fire brigade personnel, National Disaster Response Force (NDRF), Air Force and Army were deployed for the rescue of marooned villagers. State government published list of twitter accounts of all districts collectors to disseminate real time information and warning. Government also encouraged people to use these twitter handles for two way communication and to assess ground situation which can be useful in rescue operation. In these two districts, around 70,000 people were shifted overnight (45,000 from Banaskantha alone). More than 1,20,000 people were evacuated across the state[4]. Advanced warning also ensured that people moved out with their cattle. Drones were used to supply food packets, water, blankets and a mobile phone with SIM for communication. 85% road network was restored at fast pace to have seamless transportation for relief operation. Water supply and electricity was started as soon as possible in almost all villages of Banaskantha District. No outbreak of epidemics was reported. Animal carcass, rotten food grains, etc. were disposed of with proper care. Health and sanitation work were carried out in areas where water logging was reported[4]. Huge Sanitation programme was also launched to combat outbreak of post flood epidemic. Disaster Management Plan and timely intervention of state government minimized infrastructure losses and saved many human lives.

HYDROLOGICAL DATA

A. Main Features and Response of Dantiwada Dam

Dantiwada Dam is located across Banas River and on foothills of Aravalli mountain range. Catchment of Dantiwada Dam is on leeward side of Mount Abu Hills and it generally experiences very less rainfall. Catchment area at Dantiwada Dam site is of 2862 km^2. Construction of dam was completed in 1965. Very less hydrological data were available to calculate design flood at time of design of dam. Based on empirical formulae and by taking one single value of bed gradient, design was carried out[7]. Design flood was computed as 6650.5 m^3/s. Severe flood hit dam soon after construction of dam on 31 August 1973. Peak of flood was almost double than design flood of the dam. Flood had severely damaged all parts of dam but dam was able to sustain flood. In order to protect dam in future from such flash flood, revision of hydrology and some changes in design of dam were made and additional spillway was constructed. Revised Probable Maximum Flood was worked out as 18653 m^3/s. Design gross storage is 393.62 million cubic meter. Full Reservoir Level of dam is 184.15 m. Generally, water availability was common issue in catchment of Dantiwada Dam. Only seven times in history the dam has received water upto its Full Reservoir Level[7]. On 22nd July, all dams of North Gujarat were filled only 24.88% of its gross storage but in next 5 days all dams were filled upto 75.13% of its gross storage. It shows intensity of rainfall which resulted into 50% of gross storage of 15 dams of North-Gujarat getting filled in only 5 days. Total gross storage in dams of Banaskantha District was increased from 15.21% to 84.47% in five days. Dantiwada received 250 mm rainfall in two hours on 24 July 2017. Simultaneous heavy rainfall in Mount Abu region worsened situation and resulted in huge inflow to Dantiwada Dam. **Fig. 2** shows inflow during flood and **Table 1** shows water level, gross storage and 24 hour rainfall during 22-27 July 2017. In Dantiwada Dam, flood level rise was 7.97 m in just 24 hours(which indicates significant rate at almost 1 m rise in every 3 hour). Due to this additional spillway, dam managed to absorb flash flood in the year of 2015 and 2017.

B. Main Features and Response of Sipu Dam

Sipu is right bank's main tributary of Banas River and Sipu Dam was constructed across Sipu River 1990. Length of dam is 8200 m. It is having catchment area of 1221 km^2. Spillway has 12 radial gates of size 12.5 m X 8.23 m each. Flood of year of 1973 provided reliable data at the time of construction and design of the dam. Full reservoir level is worked out as 186.43 m and Gross storage capacity is 161.53 Million cubic meter. Design flood was estimated as 8601 m^3/s. During year 2015, flood peak was recorded as 4200 m^3/s where as in 2017 peak inflow was recorded as 10860 m^3/s which is more than design flood. Simultaneously rain gauges in upstream sent alarming data. Moreover, Indian Meteorological Department had forecasted for heavy rainfall for next 2-3 days. By considering above facts, it was looking like situation may worsen and therefore outflow was gradually increased from 1456 m^3/s to 10860 m^3/s which resulted into historical inflow in Sipu River. **Table 2** shows water level, gross storage and 24 hour rainfall during 22 -27 July 2017 for Sipu Dam. Sipu Dam was having inflow of 5000 cumec mainly due to heavy torrential rain in upper catchment which usually ranges from 150-200 cumec in past. RL of Banas River was increased from 186.6 m to 191.6 m (5.00 m rise in river depth) in just 48 hours which inundated large area of the district. Deesa at downstream of confluence point of Sipu and Banas River experienced huge inflow from both river and it inundated large area of Deesa City. Left side guide wall was severely damaged but devastation due to dambreak could be avoided in spite of huge intensity flood only due to timely operation of gates and commendable management of handling such situation. Flood of

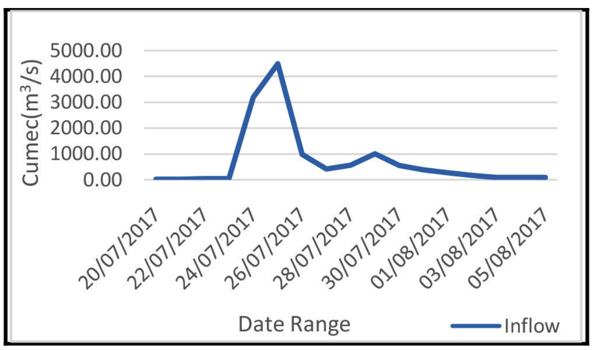


Fig. 2 Inflow data of Dantiwada Dam during 20 July - 05 Aug 2017

Table 1 Hydrological data of Dantiwada Dam

Date	Water Level (m)	Gross Storage (MCM)	24 hour Rainfall (mm)
22-07-2017	171.45	71.57	17
23-07-2017	171.56	73.13	72
24-07-2017	179.53	249.57	348
25-07-2017	182.03	324.80	441
26-07-2017	182.54	341.23	10
27-07-2017	183.12	360.10	21

Table 1 Hydrological data of Sipu dam

Date	Water Level (m)	Gross Storage (MCM)	24 hour Rainfall (mm)
22-07-2017	176.23	15.32	7
23-07-2017	176.32	15.71	58
24-07-2017	183.68	101.67	254
25-07-2017	183.80	103.89	353
26-07-2017	182.38	79.32	110
27-07-2017	183.98	107.20	20

year of 2017 was historic, severe and challenging than that of flood of years 1973 and 2015.

LESSON LEARNT AND MITIGATION MEASURES

It is almost impossible to anticipate such flash flood but we can certainly curtain calamity and disseminate best practices for other state. Flash flood was mainly due to unprecedented rainfall in catchment area of river system. Banas River share its boundary with two states,so it is advisable to form such committee or institution for sharing real time data of outflow from upstream dam of river system. It can be helpful in pre-planning to combat such flash flood. Local administration can also take key learning from this disaster and update respective disaster management plan which can be useful for better handling of disaster. In order to take preventive actions for minimizing the impact on assets and citizens, HYDROMETER, a hydro-modelling software can prove to be beneficial. Precipitation and forecast of flash flood can be done using this software which take input data as forecast data of probable precipitation in next few days. Early flash flood warnings are produced from continuous hydrodynamic simulation and issued few days ahead and with some local knowledge. Tail end treatment of downstream basin to pass runoff efficiently in such flash flood can be tailored to disaster risk reduction. Climate change has now become a serious problem and due to that not only frequency but also intensity of such disaster has elevated. High resolution Digital Terrain Model (DTM) is essential for study and for generation of inundation map. Integrated contribution of civil administration, Army personnel, community and institution is necessary for sustainable disaster risk reduction. This can be useful to convert flood vulnerability into resilience.

ACKNOWLEDGMENT

I thank Narmada,Water Resources,Water Supply and Kalpsar Department for assistance throughout all aspects of this study and for help in writing this paper. I extend my gratitude to all officers whoever helped in this study. I am thankful to Gujarat Institute of Disaster Management for their role.

REFERENCES

1. Mehul Pandya “Indian Floods 2017”, issue no. 161, All India Disaster Mitigation Institute, August, 2017.
2. “Flood Terror:224 Died in Gujarat, Highest in Banaskantha at 61,” Gujarat Samachar. 2nd August 2017, p.2, in press.
3. B. K. Gupta, Groundwater Brochure Banaskantha District, Technical Report Series, Central Ground Water Board, Ahmedabad ,September 2011.
4. Gujarat flood 2017:A case study, Gujarat Institute of Disaster Management, 2017.
5. Management of floods, National Disaster Management Guidelines, National Disaster Management Authority, January 2008.
6. Sphere India, Situation Reports in India-2, Press, 28th July2017 pp-1.
7. Vivek P Kapadia, “Uncertainties in Flood Assessment and Corrections in Existing Dams: Case Study of Banas Basin,Gujarat,India”, International Dam Safety Conference-2019, Bhubaneshwar, Odisha, India.

Reflecting on Chennai Flash Floods and Sumerian Floods in Historical Context

Sandana Socrates
Research Scholar, Department of Ocean Engineering,IITM, Chennai
✉ *socrates3069@gmail.com*
Purushothaman P
Professor, Department of Civil Engineering, Agni College of Technology, Chennai
✉ *ellapura@gmail.com*
Suresh ESM
Professor and Head of Department of Civil Engineering, NITTTR, Chennai
✉ *esmsuresh@gmail.com*

ABSTRACT

Chennai flash floods of year 2015 and Sumerian's flood story (written at about 5000 years back) are considered for reflections along with the Tsunami of year 2004. People of Tamil Nadu and especially Chennai have direct experience facing the flash floods during 2004 and 2015. The Sumerian flood story is revisited through recent translation works. These flood situations are considered in the historical context reflecting and relating in the context of life-long learning and professional development of practicing civil engineers. We find that certain ancient wisdoms are still valid, particularly locating or selection of residential building sites on high rise lands;this is apart from what we have as advanced technologies in prediction of floods in general. People have been facing floods and managing them through ancient times as recorded in Sumerian flood story. Moreover, in the case of Tsunami during 2004 and flash floods of Chennai in the year 2015, avoidance could be a preferred general rule, particularly while selecting best sites for house construction. The Chennai flash floods of year 2015 raises issues on professional ethics, practice and informing the public on city planning and development for appropriate decision making.

Keywords : Flash floods, Ancient floods, Tsunami, Deluge, Site selection

INTRODUCTION

The Chennai flash floods during the year 2015 and Sumatra Tsunami of 2004 adversely impacted people of the Chennai City and Tamilnadu. In both cases millions of people were affected[1-3]. In Chennai, homes were inundated due to flash floods and homes were destroyed by tsunami water along Tamilnadu coastlines. Tamilnadu people have a traditional knowledge that their home land, a continent called Lemuria or Kumari Kandam was swallowed in the distant past by sea[4]. People of Pazhaiyar at the confluence of River Kollidam have specific knowledge that a small village nearby had been completely washed away by the Sumatra Tsunami in the year 2004 and nobody survived from that village. People were divided on proper choice of site location for their new shelters during post tsunami relief works [5, 6].

Flash floods could be summarized and understood as sudden rushing or inundation of water, mostly without much of warning, causing hardship, damage to properties and loss of life. Flash floods may accompany other hazards man-made or natural. The flash floods are characteristic of less frequent, but acting for short durations bringing intensive damages and occurring world over with various causes. Women, children and aged are most vulnerable, though flash floods affect all. When this happens in dense populated urban settings, the loss is disproportionate than in remote places[7-10]. Flash floods or floods in general, particularly in metropolitan cities, like in Chennai, Tamilnadu could be treated as natural and man-made disasters as these affect everyday life of common people. There is a necessity to identify the likely places of flash flooding and vulnerable areas [7]. Floods, storms, earthquakes and landslides are frequently faced by us as civil engineers in India and an NPTEL course work on natural hazards and disasters [11] aptly covers the basic knowledge necessary for civil engineers. Such a specialization was not available during 70s-80s, students graduated then have retired from active professional practice, but they could reflect and add knowledge based on their experiences of flash floods as had seen, worked or heard from seniors in the context of lifelong learning and professional development.

The apathy of the Chennai floods-2015 as a major disaster was aptly summed up by a social media caption as, "Water - Water everywhere, but not a drop to Drink". The flood brought in untold misery: People lost their peace of mind, lost their savings, there was no drinking water, lost food items and food grains which were either wet or washed away by flood water, no electricity and no telephone; those who could move to upper floors or to terrace, could not climb down.

Chennai encompasses the drainage plains of few rivers (Adayar, Coovam, Kosathalaiyar) discharging into Bay of Bengal and the metropolitan is under heavy pressures due to dense human settlements and altered landscape posing perennial flooding of few habitations. As these happen even today with so much technology advancements make us to wonder, reflect, compare and relate our field practice. It would be interesting to know what Sumerians passed down as their experiences of floods through written intelligence, some 5000 years back [12, 13]. This paper considers as an outcome, the needs of informing civil engineering students on issues relating to selection of sites for residential purpose, particularly with respect to floods and flash floods and from the perspectives of practicing engineers.

CASE STUDIES

Few case studies and few instances are considered for comparisons and to reflect from our experiences to draw upon few inferences and learning with respect to floods, flash floods and disasters. Flash floods, floods and disasters are synonymously used in this paper as all these calamities destroy our normal life and result in loss of life and materials. In olden days, normal floods in villages, forests and remote places were flash floods as people would rarely get fore-warning of such floods. In olden days, whenever villagers crossed major dry rivers or local rivers by foot, they used to cross the rivers with fear of flash floods. So also, those living close to banks used to live with such fear of breaches in leeways or low lever banks due to high floods or flash floods.The current practice at Chennai along the natural drains and at Sirkali in Tamilnadu, along the banks of River Kollidom is to evacuate people living on low-lying areas whenever high floods are expected which is a perennial problem.

A. Chennai Floods in the year 2015

Rapid assessment of Chennai floods-2015 was carried out by Narasimhan and others[1, 14]. Further, Chandra and Majumdar [7] reviewed recent trends on flood modelling; they consider that Chennai -2015 floods was a flash flood. They reviewed latest developments and advancements in flood prediction modelling and note such advancements are useful in town planning. They also note that India is facing lots of challenges in prediction of floods. Recent studies [10] suggest that the Chennai Floods could have been the result of sea changes and volcanic eruptions near Sumatra. The climate changes, global warming, land use patterns are several other factors that influence recent heavy rainfalls all over India. Further, mismanagement of regulating or sudden release of surplus water from upstream drinking water storage reservoirs was attributed as one of a major contributing factor for Chennai Floods - 2015 [1,14]. Chennai Floods -2015 is treated as infrequent and once in a hundreds year flood, however, experts predict such occurrence would happen in future frequently due to climate changes. We are already facing severe problems due to cyclone, floods and landslides in India and every year leading to loss of lives as well as economic loss. As practicing civil engineers, we do face multitude of challenges in fast changing natural climate,land use, population pressures in urban areas and political situations as highlighted in rapid assessment of Chennai Floods [1].

B. The Sumatra Tsunami in the year 2004 Affecting Tamilnadu

The tsunami in the year 2004 affected the whole eastern coast line of Tamilnadu as a flash flood. Many lost lives and left scary images and traumatized many in particular children and women. This tsunami was attributed to Sumatra tectonic plate movements. The lessons learnt were interesting that it didn't spare people who were good swimmers; those structures which offered resistance were turned down; had high impact on closer to coast line constructions; where there were natural resistance due to thick forests or sand bar ridges or on high grounds, hamlets and houses were saved. The sea water wave fronts acted only for a short duration but left people with disbelief, shock and horror. The rehabilitation works went on for many years after the incident and like the Kumari Kandam or Lemuria continent submergence memory is deep rooted in the minds of people of Tamil Nadu [2-6].

C. The Sumerian Flood Story, Written about 5000 years back

Kramer [15] noted that the Sumerian Flood Story was written earlier at about 3000BC and would have impacted the Bible deluge story, as both appear similar in descriptions. Purushothaman [13, 16] revisited the Sumerian Flood Story from a different angle and found that the very intention appear to be passing of intelligence about floods of ancient period. Using remote sensing, Morozova [17]has brought out how the major two rivers of Mesopotamia changed their courses and flooding zones in the past. Jotheri et al [18] have shown that even boat-ways and buffalo herding paths in the past in the marshy lands of Mesopotamian plains could be visualized through remote sensing.

It will be interesting to know as a sample of how the flood was described by Sumerians: We can take the line numbered C174.D.5 through standard translation [12] as, "Boat (ma), to be thick (gur),water (a), to be big (gal), destructive storm (im-hul), to shake (tuku)". Whereas revisiting same line through Tamil translation [13] can be seen as, "All ships, trees, wood floating, moving here and there, with muddy water, the deluge is in strong force." It will be interesting to know from ETCSL standard translation few of building and civil engineering terms from the lines: Line C174.B.5 as, " builder(sidim), the land(kalam), foundation(us), to be firm(gen), to dig(ba-al)" giving the meaning that the builders of the land dig solid foundations. Likewise line C174.B.18 gives us: Water course (id), to be small (tur), to clean (luh),place (gar); giving the standard translation as, "and with the cleansing of the small canals …… were established."The words shown inside bracket are Sumerian terms.

D. Disaster Management Courses in Civil Engineering Degree Programs

NPTEL offers courses on disaster management for engineering students [11]. The major items in the course are on earth quake, floods, storms, landslides and so on. The students have good opportunity to prepare themselves on issues relating to disasters in general. However, taking note of issues relating to Chennai floods and as planners, we may have to critically think on professional ethics and conflicts on how planners approve vulnerable sites for residential purpose under socio-economic and political pressures, but finally the common people suffer.

DISCUSSIONS

A. Site investigations and site selection are major decisions making in our professional field practice, taking various site conditions and other considerations. Some of the major items during site investigations or reconnaissance survey are conducting MSL (Mean Sea Level) and HFL (Highest Flood Level) from any known reference closer-by including noting down ground water table level. Often, where such references are not readily available, field engineers would find out from local elderly people as from their experiences or knowledge during floods in the past. The traditional Vastu do prescribe not to locate housing plots on downstream of any water body or reservoir or vulnerable locations. The National Buildings Code specifies to provide plinth level of buildings at least 300mm above crown level of the road in front of it. The technical specifications for road construction require the subgrade level of roads should preferably be 1500mm above highest flood level or local ground water table. When, these specifications or prescription are followed, we could expect a good level of protection from rising water tables or floods in general. But, we also knew in Chennai urban areas that most vulnerable populations and migrant workers settle along the unlikely habitat of banks of Coovum River and other water bodies which are highly polluted, stinking and strewn with all waste materials. Whereas, the Chennai Floods -2015, affected all sections of people, the vulnerable on the banks and those who built their houses on low lying areas, including areas which were not normally prone to flooding, bringing surprise to all. There were many theories such as sudden release of water from reservoirs, heavy and continuous down pour on account of climate change; unplanned and uncontrolled urban development as few strong factors causing the flash flood; we as practicing engineers wonder on feasible solutions: Slum clearance attempts by government for those who dowel on river banks and lakes, providing them alternative shelters were good arrangements; uncontrolled city development could be due to population pressure; there are difficulties for farmers to convert their land for other purposes and selling, when they are no longer performing cultivation; land mafia have undesirable impact making huge profits even from land unfit for residential sites; people both educated and uneducated falling prey to mafia. Specific problems of this nature could be addressed by education and passing proper information, say for example making available the flood path, maximum flood water table contours and the risk factors for flooding of each zone or location[7-9]. The engineers and architects while approving site plans should place warnings or assess risk factors on the building plans or layout plans, informing the clients or the users.

B. The Bible story of the Ark of Nova can be seen as pre warning given on the basis of various natural cues or by god to protect people from destruction or from disasters. This also reflects our innate need to protect us from natural perils. Chennai Floods -2015 reflects a situation that the very residential houses or shelters became useless, though for a short period in its service life, but that has left a memory not easily erasable. We do design river crossings, causeways and minor bridges to get flooded or submergence on few occasions in a year and this is not the case when it comes to our residential house sites. When we consider, a particular method of temple construction by Sumerians that they built new temples on existing or old temple foundations taking advantage of raised levels [19]. We can also consider the very particular local knowledge of people in temple cities like Thanjavur and Chidambaram that the temples never get flooded or submerged, though surrounding areas often get flooded. The flood story of Sumerian helps us in interpreting and outlining the flooding situations; how to protect people and how to make use of the river silt deposits as fertile land for cultivation and passing down of these historical knowledge. It is also interesting to note one of the name of River Euphrates as, "Purattu" and if this is taken as a Tamil word, this would directly mean in English as flip, turn upside down or turbulent. Infact, the floods whether general or flash floods, they change our life upside down. The Mesopotamian Rivers were characteristics of carrying heavy loads of silt. Even recent floods in Assam, Bihar, West Bengal and in Himalayas bring havoc in our normal life.

C. There are professional ethics and conflicts which we face when we carry out site selection, as engineers[5, 6]. Therefore, students could be briefed beforehand about conflicts while recommending or approving sites. There were times that no one could touch however small an irrigation canal or drain without permission or approval, so also public roads and public properties like lakes, ponds, river adjoining properties could not be touched; whereas, the encroachments are order of the day; wide spread corruption in every sections, departments, public or private, political or non-political had also increased the burden on engineers on site selection. Availability of suitable land for residential buildings or layouts are scarce not only in metropolitan cities but in other places, also. Earmarking high rise and suitable lands with immediate drainage are major requirements in and around major cities particularly so for cities adjoining coastal lines with flat ground levels or contours.

D. The chances of Flash floods occurring in Chennai City may be rare. One of major characteristics of flash flood is its unpredictability. Once, the surprise element is removed, damages may be reduced, though flooding and inundation problems persist. People from low lying locations should be evacuated and provided temporary shelter in schools, after declaring holidays for school children. Few affordable persons have jacked up the whole house building and plinth after knowing the new high flood water levels. The local administration and engineers have also learnt it as wise to raise the road level building up over existing roads than milling the top layer to maintain constant road level. Due to global warming and ice deposits melting, there is a general fear of rising sea water level and this fear when turns out as a real threat, the city may have to spread out towards Western highlands, away from sea, after identifying suitable land for expansion.

E. The Sumerians built strong walls near city limits abutting one side of the banks, perhaps protecting the bank from erosion and training the rivers thus protecting cities [19]. We learn that the river Euphrates was flowing alone and formed its twin river Tigris later; likewise the courses changed many times; breaches and avulsions would have made floods as flash floods [17]. Going by one of Euphrates River name, "Purattu" and its direct meaning in Tamil neatly reflect huge flood or flash floods some 5000 years from present time. It is also interesting, as in our villages, they predicted rain and floods by judging how thick and dark clouds were. In the past, we had flash flood problems when rain was intense in far-off catchments or when breaches happened without warning, or change of courses without our knowledge in the downstream.

F. The methods adopted using remote sensing and comparing field data at ground to explore the past and present river courses, including construction of digital elevation models and predicting inundation patterns through floods and flash floods, give us hope to replan the city habitats [7-9]. There is scope for future research in these directions, but, these technologies should result in informing the common people at appropriate time, before they build any facility.

G. Every opportunity could be taken to inform the engineering students to both motivate and prepare them to face engineering challenges by touching on topics of current interest and challenges. Professional bodies or societies need to prescribe at least one faculty for civil engineering – construction having vast field practice and experience, so that students are exposed to current practice and integrating field practice in the class room teaching[20]. As part of active learning teaching basic civil engineering, students were asked to reflect on then circulating media caption during Chennai floods, "Water - Water everywhere, but no water to Drink!". Students were also asked to watch few portions of NPTEL study materials at home, as flipping class room lectures and further discussing at classrooms. Using and applying tools and data relating to digital elevation models [21] could be encouraged at every engineering college students.

CONCLUSIONS

There are situations where high floods can become flash floods through breeches, unforeseen events and practically have similar consequences affecting our normal life. With respect to residential layouts and buildings, selection of sites at high rise locations happens to be a general norm right from Sumerian periods. Prescriptions by Vastu not to build houses directly downstream water bodies appear to be still valid. Due to population pressures and scarcity of suitable land, people go for inferior sites. The recent developments on predictions of floods and inundation of land mass could be useful not only to warn people, but also plan new settlements or townships. The climate changes bring in uncertainties and new norms are being set-in, as more floods and flash floods could be expected frequently, particularly due to global and sea warming. There is a general need for Chennai City to expand on the Western direction to highlands catering to future needs and protecting from floods, flash floods and tsunami.

REFERENCES

1. B. Narasimhan, M. S. Bhallamudi, A. Mondal, S. Ghosh, and P. Mujumdar, "Chennai Floods 2015 : A Rapid Assessment", Published by : Interdisciplinary Centre for Water Research (ICWaR), IISc Bangalore, May 2016

2. P. Bult, et al, "Tsunami India – Two Years After"A joint report of the United Nations, the World Bank and the Asian Development Bank, 2006

3. J. Telford, J. Cosgrave and R Houghton, "Joint Evaluation of the international response to the Indian Ocean tsunami: Synthesis Report". London: Tsunami Evaluation Coalition, 2006.

4. Wikipedia: Kumari Kandam https://en.m.wikipedia.org/wiki/Kumari_Kandam, accessed on 1st Sep., 2020.

5. P. Purushothaman, "Shelter with Care & Love", Shelter project by CARE - INDIA & GRI, (A case study in progress), A paper presented in the International Workshop on, Economy of Permanence and Dynamics of a Sharing Community, Gandhigram Rural University, Gandhigram, and the Focolare Movement, Italy 25 and 26 July 2005

6. P. Purushothaman and E.S.M. Suresh, "Training of youth and workers from tsunami affected areas through participative methods in building technologies", The Indian Journal of Technical Education, Vol.No.34, Issue No. 03, September 2011, pp-1-8

7. R. R. Chandra and P. P. Mujumdar, "Flood Modelling: Recent Indian Contributions", Proc Indian Natn Sci Acad 85 No. 4 December 2019 pp. 705-722

8. Nektarios N. Kourgialas & George P. Karatzas "Flood management and a GIS modelling method to assess flood-hazard areas—a case study", ISSN: 0262-6667 (Print) 2150-3435 (Online) Journal homepage: https://www.tandfonline.com/loi/thsj20

9. JOY SANYAL and X. X. LU ,"Application of Remote Sensing in Flood Management with Special Reference to Monsoon Asia: A Review", Department of Geographrfy, Faculty of Arts and

Social Science, National University of Singapore, 1 Arts Link, Singapore 117570

10. A.Akilan, S. Balaji and K. Abdul Azeez,“Source and causes of 2015 great pluvial flood of Chennai, Tamil Nadu and its surroundings”. J Geol Soc India 90, 602–608, abstract, 2017.
11. J.Malik,NPTEL,Naturalhazards,IIT Kanpur,2018, https://nptel.ac.in/courses/105/104/105104183/
12. ETCSL, Flood Story, http://etcsl.orinst.ox.ac.uk/cgi-bin/etcsl..cgi?text=t.1.7.4&display=Crit&charenc=gcirc&lineid=t174.p1#t174.p1
13. P. Purushothaman, “Sumerian Flood Story”, 2019, https://www.academia.edu/35095369/Through_Tamil_Revisiting_Flood_Story_of_Sumerian_A_crude_translation
14. S. Shekhar and C. D’Souza, “Mapping floods to assess risks and vulnerabilities in the Chennai Metropolitan Area A GIS analysis of the floods in Chennai in December -2015”, published 2016.
15. Kramer, S. N., 1963, “The Sumerians, Their History, Culture and Character”, The University of Chicago Press, London.
16. Purushothaman, Sumerian Works, https://www.academia.edu/37658209/Comparing_flood_story_of_Sumerian_with_Tamil_version_for_genesis_of_god
17. S. G. Morozova, “A review of Holocene avulsions of the Tigris and Euphrates Rivers and possible effects on the evolution of civilizations in Lower Mesopotamia”, Geoarchaeology • April 2005 DOI: 10.1002/gea.20057
18. J. Jotheri, M. W. de. Gruchy, R. Almaliki and M. Feadha, “Remote Sensing the Archaeological Traces of Boat Movement in the Marshes of Southern Mesopotamia”, Remote Sens. 2019, 11, 2474; doi:10.3390/rs11212474
19. J. N. Postgate, Early Mesopotamia, Routledge, London &New york, 2004.
20. P. Purushothaman,S. Suppiah and E.S.M. Suresh, “Designand Development of Curriculum for B.Tech. Civil Engineering Students with leading choices in Multidisciplinary areas”, Institution of Engineers, India,2016.
21. NRSC/ISRO, Technical Methodology for Country wide DEM and Ortho Product Generation for India Using Cartosat-1 Stereo Data, Version-1, 2013.

Some Discussions on Hydrological Observation at the Bifurcation Point of the River Kangsabati at Saldahari, Kapastikri, West Midnapur District

S S De Dalal, S Chattopadhyay, B C Barman, A Roy, D Dev
River Research Institute, I&W Directorate, Govt. of West Bengal, Mohanpur, Nadia, West Bangal
✉ *bcbrri@gmail.com*

ABSTRACT

Natural phenomena like meandering, bifurcation, etc. are typical features of a river course. Bifurcation is generally seen in middle/ lower reach of a river, but equal sharing of river flow is hardly observed. One branch may be deficient of water that may cause problems like salinity (if the river is near a sea front) in some months of a year, while flooding may occur in the other branch. Again, sharing may not be the same at various stages of the river due to different reasons, namely, silting at the river mouth of the bifurcation point, etc. In the state of West Bengal there are many rivers branching at different points, like the Ganga, Mahananda, Damodar, Kangsabati, Silabati and others. The branches do not carry equal flow, resulting in inundation of some low lying areas particularly in the peak monsoon months. Ghatal subdivision of West Midnapur district is a place severely affected due to branches of the Silabati, Kangsabati and their tributaries. A series of hydrological observation have been taken at Saldahari site on the river Kangsabati from 2012 to 2016. In this study sharing of water of the main river into the bifurcation channels have been observed along with physico-chemical characteristics of water and grain size characteristics of moving on sand trapped in Uppal Sampler. It has been observed that at 500 cumec discharge the share is 65 : 35 and at 1000 cumec discharge it is 60 : 40.

Keywords : Bifurcation, Discharge, Meandering, Sharing

INTRODUCTION

Natural phenomena like meandering, bifurcation, erosion and deposition etc. are typical features of a running river. Bifurcation is sometimes seen in middle/ lower reach of a river, but equitable sharing of river flow is seldom found. In one branch there may be shortage of water that may result in problems like salinity in some months of a year, while flooding may occur in the other branch. Again, sharing may not be the same at different stages of the river due to different reasons like silting at the river mouth at the branching point, bifurcation angle, etc. With the increase in population the sources of both the surface and ground water are getting scarce due to various natural and man-made causes and society is seldom ready to withstand both scarcity and flooding simultaneously from the same river branching at some point. So control structures are sometimes resorted to so that all the river courses remain beneficial to people living in the region for most parts of a year [1].

In the state of West Bengal there are many rivers bifurcating at different points, like the Ganga, Mahananda, Damodar, Kangsabati, Silabati and others as shown in **Fig. 1** (Kangsabati bifurcation). The branches do not carry equal flow, resulting in inundation of some low lying areas particularly in the peak monsoon months. Ghatal subdivision of West Midnapur district is a place severely affected due to branches of the Silabati, Kangsabati and their tributaries [4]. For mitigation of the adverse effects of the flood in the region, control structures or other means are being thought of. Such planning is based on systematic hydrological observation on the rivers at different reaches particularly at the bifurcation points [2]. Both the hydrological observations and surveying of the terrain are necessary. River gauging, that is measuring velocity, cross section, discharge together with acquiring information of the bed and suspended load are needed. These informations help in running the model of the prospective project to reach at a sustainable solution that can be implemented. In this paper some discussions have been made on the hydrological observations for a period of 2012 – 2016 at the bifurcation point of the river Kangsabati in West Midnapur district.

Guiding formulae of designing a regime channel show that the slopes, cross section details, roughness of bed mainly control velocity and discharge. A formula was initially presented by Kennedy but Lacey's formula seems to be more practical as it emphasizes on the whole wetted perimeter of the channel and the grain size of the material forming the channel. The use of this formula is extended to the natural stream flow and various hydraulic structures. River is a live entity, its section changes from time to time, flood to flood. Deposition and erosion take place at different stages of the river. A river status is popularly monitored by gauge discharge curve but a single curve seems to be not accurate for a long time and requires to be modified after some years.

The most popular way of hydrological observation is the use of current meter (Price's current meter) and conventional surveying devices. Now a days "Acoustic Doppler Current Profiler" commonly known as ADCP and modern surveying techniques are being adopted, which are quite accurate and require less manpower. In the conventional method cross section of the river is taken during lean period using leveling instruments. Later during observation period in monsoon the section is adjusted with the help of tape and pole. For hydrological observation the section in partitioned in suitable numbers (compartments) using a long rope stretched from bank to bank. From the centre of the compartment the current meter is lowered from the boat and velocity is observed at depths 0.2d, 0.4d, 0.6d and 0.8d (d - depth of the river at that point). The average velocity multiplied with the area of the compartment gives the discharge [3]. The discharges of different compartments are then summed up and the total discharge of the section is obtained.

METHODOLOGY

At Kapastikri/Saldahari three observation stations were selected one each on the Main Kasai (Kangsabati River), Old Kasai (Left arm) and New Kasai (Right arm) as shown in **Fig. 1**. These were chosen where the river reach is straight, the section is uniform and the river banks are well defined. The section was divided into approximately equal four compartments. The boat was led to the centre of each compartment, the Current meter was lowered gradually to the required depths and readings

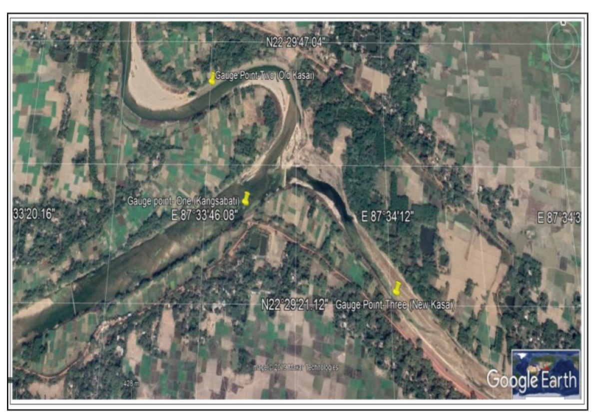


Fig. 1 Showing Location of Site of Saldahari (source Google)

were taken for determination of velocity. In each day observations were taken on the main Kasai and subsequently on either the Old Kasai or New Kasai. The discharge of one branch was taken as the difference of the values obtained at the main Kasai and the other branch that is Old Kasai or New Kasai. These observations were taken daily in the monsoon months from July to end of October. Occasionally observations were taken twice in a day time. However no observation could be taken at night. So the results obtained represent roughly half the data of the monsoon period. In August and September (2012) some river water samples were taken approximately 30cm below the surface for determining suspended load concentration. In 2013 a Bottle Sampler was devised and some water samples were taken from roughly d/3 (d – river depth) at the three observation stations (July – September 2013).

Some bed samples were collected in a Cylindrical Sampler (closed at one end) driving the boat against the river flow. These were taken for determination of silt factor. For evaluation of rate of bed load movement Uppal Sampler was used. It was lowered from the boat and when it touched the bed, the front gate was opened. Care was taken so that the opening faced the river movement. The boat was kept stationary for half an hour. Then the Sampler was lifted up and the sand trapped in the racks of the Uppal Sampler was taken out. All the collected sands and river water samples were sent to River Research Institute Campus, Mohanpur, Nadia for different laboratory analyses.

OBSERVATION

All the hydrological observation data were processed for determination of the values of velocity and discharge of different dates. These data have been used in the figures and discussion in this paper. Initially the tables of discharges of different dates of the monsoon months have been made for the main river and the branches. Then the numbers equal to or more than 25, 50, 100, 200, 500 cumec and higher values of discharges have been counted manually. It is to mention that these are point values as observation was made generally once in a day (day time only). If the observations of a section were done over a long period and hydrographs were drawn, then discussion could have been made on the amount of water passing the section and its share between the branches.

Numbers of exceedance (No. of cases exceeding) versus discharge plots are given in **Fig. 2** for the year 2013.

Percentage share or distribution of discharge of Main Kasai between two branches are given in **Fig. 3**. From **Fig. 3** it is noted (results of 2012-16) that the Old Kasai was the main carrier for lower discharges and with greater discharges in Main Kasai sharing between two was better. Beyond 300 cumec discharge sharing of Old and New Kasai was roughly in the proportion 60 : 40 . While cases of exceedance in Main Kasai for discharge 200 cumec were 21, these were 10 in

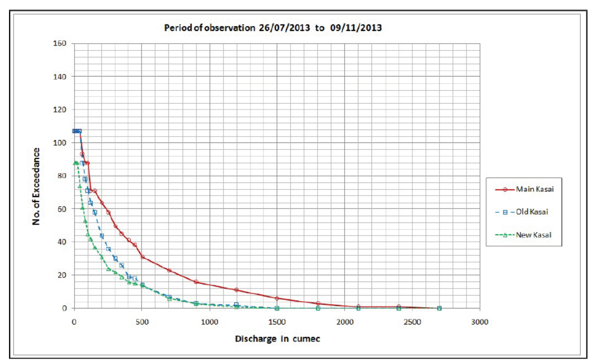


Fig. 2 No. of Exceedance versus Discharge of Kangsabati/ Kasai 2013

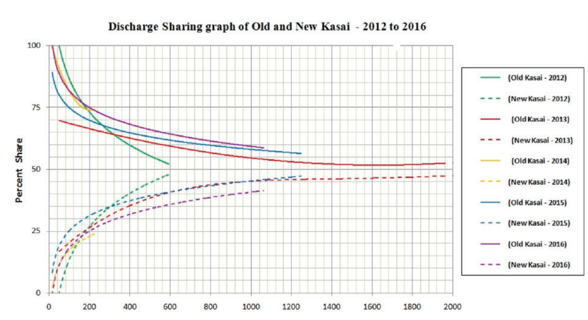


Fig. 3 Percent share of the branches versus Discharge in Main Kasai / Kangsabati– 2012-2016

Old Kasai and 6 in the New Kasai. From **Fig. 2** (observation year 2013) and **Fig. 3** (observation year 2012-16) it is found that the discharge of 200 cumec occurred 64 times, 500 cumec occurred 31 times, 1000 cumec 14 times, 1500 cumec 6 times and 2000 cumec 2 times in main Kasai. The values were 44, 14, 3, 0 and 0 in the Old Kasai and 31, 14, 3, 0 and 0 in the New Kasai. At 500 cumec discharge in the Main Kasai the share was 60 : 40 but beyond 1000 cumec it was 55 : 45 tending to almost equal share for higher discharges. In year 2014 it is noted that occurrences of 100 cumec discharges were 24 in the main Kasai but 8 and 0 in the Old and New Kasai. Beyond 200 cumec discharge the share was 76 : 24 in the branches **Fig. 2** (observation year 2013) and **Fig. 3** (observation year 2012-16) [5].

From **Figs. 3 and 4** (year 2015) it is found that at 200 cumec discharge the share was 70 : 30 but at 1000 cumec discharge the share was roughly 56 : 44 . Occurrences of 200 cumec discharge were 29 times in the Main Kasai and 21 and 12 in the branches. The discharge of 500 cumec ran through the Main Kasai 14 times, while 11 and 4 in the branches. The discharge of 1000 cumec occurred 7 times in the Main Kasai and zero in the branches. From **Fig. 3** (year 2016) it is found that 200 cumec discharges occurred 60 times in the Main Kasai and 36 and 13 times in the branches. The discharge of 500 cumec occurred 15 times and 1000 cumec 3 times in the Main Kasai. The numbers were 6 and 0 and 1 and 0 in the branches.

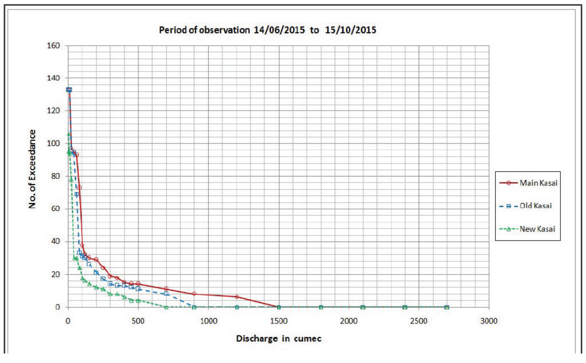


Fig. 4 No. of Exceedance versus Discharge of Kangsabati 2015

The share of discharge at 500 cumec was 66 : 34 and at 1000 cumec it was 60 : 40 .

The discharge share data of two branch channels have been plotted in F**ig. 5** for the period 2012 – 2016 (all combined). There are some variations in the plot for different reasons **(Fig. 3 and 5)**. Actually the section is changes to some extent in different days. The change is generally prominent after flood. The bed is expected to be deeper

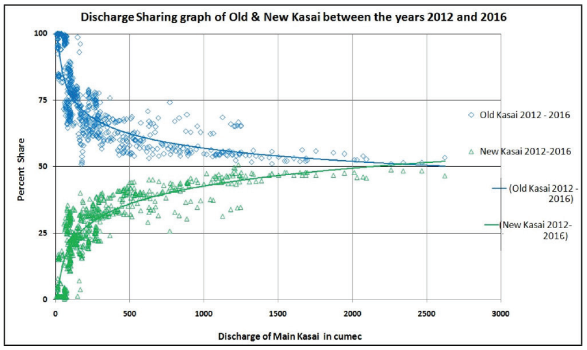


Fig. 5 Percent Share versus Discharge in Main Kasai during the year 2012 to 2016(all combined)

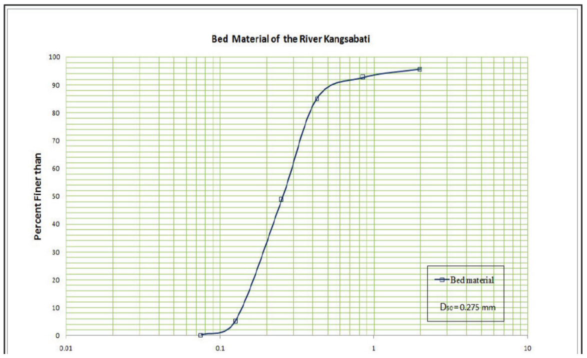


Fig. 6 Particle Size Distribution of a Typical Bed Sand

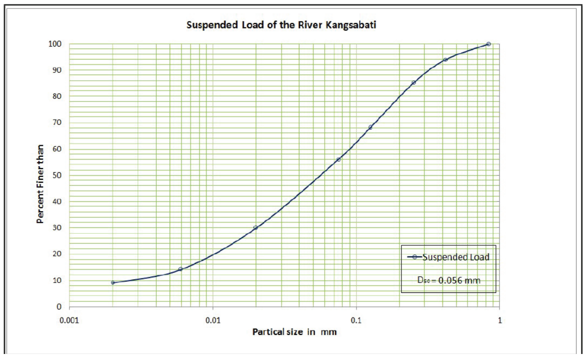


Fig. 7 Particle Size Distribution of Suspended load

during peak monsoon while in late monsoon or after monsoon there is deposition and noticeable change.

Another point is changing roughness of bed material. **Fig. 6** presents grain size distribution of bed load and **Fig. 7** gives size distribution of suspended load. Bed sample has been found coarser when velocity is higher (D50 = 0.275 mm for average velocity = 0.55 m/sec and D50 = 0.285 mm for average velocity = 1.04 m/sec). The suspended load is loamy with clay around 10% or so. The rate of bed load movement depends on velocity and in monsoon months it was found around 25 kg/m/hr. The sampler used gives an approximate value (trap efficiency or such device is max 50% as per available literature). The average suspended load was found 360 mg/L.

CONCLUSIONS

In this study it has been found that

- Bed load is about 1% of the suspended load.
- Considering limitations of the sampling devices it is suggested to consider a suspended value of 700 – 800 mg/L and bed load 5% of suspended load for this site.
- At 500 cumec discharge the share is 65 : 35 and at 1000 cumec discharge it is 60 : 40 .

Ways should be devised so that at discharges lower than 500 cumec the branches may carry equitable discharges. In other words discharges to Old Kasai are required to be lessened as this branch runs towards the Ghatal Subdivision.

ACKNOWLEDGMENT

Sincere thanks are due to Sri Subrata Basu, S.O., RRI WB and Sri Debabrata Das, S.O., RRI WB for conducting hydrological observations over the years. The authors are indebted to other staff and officers of River Research Institute, WB, Mohanpur, Nadia for their contributions in the field and laboratory works and preparing this paper.

REFERENCES

1. R.K. Linsley, M.A. Kohler and J.L.H. Paulhus "Hydrology for Engineers" ISE, McGraw-Hill International Book Company, 3rd edition, 1984.
2. R.L. Singh, "India – A Regional Geography", Edited by; NGSI, Varanasi (1991).
3. Yang Xiaoquing, "Manual on Sediment Management and Measurement", World Meteorological Organization; Operational Hydrology Report No.47 (2003).
4. The Director, "River Systems of West Bengal", Published by River Research Institute, I&W Directorate, Mohanpur, Nadia, WB (June, 1989).
5. Technical Reports "A Report on Hydrological Observation of the River Kangsabati and its Bifurcated Channels at Kapastikri, West Midnapur in the Monsoon of 2012, 2013, 2014, 2015 and 2016" of River Research Institute, I&W Directorate, Mohanpur, Nadia, WB – (2012, 2013, 2014, 2015, 2016).

Stochastic Prediction of Peak Floods with Land-use, Land-cover Mapping - A Case Study

Rewa Bochare
Department of Civil Engineering, Prestige Institute of Engineering, Management & Research, Indore
✉ *rbochre@piemr.edu.in*

ABSTRACT

The incidences of flash flooding are arguably the worst form in which humans have faced the wrath of nature, have increased considerably in the past. One of the pivotal challenges for hydrologists is the prediction of the occurrence of flooding and the study attempts the same. The 48 years long rainfall data of regions in and around Indore have been analyzed for prediction of peak floods in the study. The novel of Land-use/ Land/Cover maps generated using ArcGIS has been employed for accurate estimation of constants in the standard formulae. Unbiased statistical approach for the identification of best-fit distribution has also been applied and peak floods have been predicted a return period of up to 200 years. Similar and more meticulous models may be developed for different region to attain better suitability and explicit results in other study areas.

Keywords : Flash flooding; Prediction; Land-use/ Land-Cover; Models.

INTRODUCTION

The Prithvi Sukta in Atharva Veda quotes "Earth is my mother and I am her son" However, for decades now, humans have exploited natural resources of mother Earth. With the growing population, and increased urbanism in recent past, the lifestyle of people dwelling in cities has undergone phenomenal change. This has led to a huge upsurge in the demand for scarce resources like land, food and water. Arguably, this has led to a major chunk of interference in the natural processes.

Natural regime of rivers and streams are no exception to this obtrusion. The diversion as well as storage schemes are commonly adopted practices today. However, the long-term impacts of these projects on the eco-system and the climatology on the whole are still debatable.

Facing the wrath of nature, the world has encountered various natural hazards in the past. One of the most dangerous hazards is the phenomenon of flash floods. Everyone is well conscious of the devastating effects of this catastrophe. Sadly, the frequency and intensity of these flash floods events is only on an increasing trend. Whether it is the Mumbai Floods of 2005, the Uttarakhand of 2016 or the Kerela Flash Floods of 2018, the stories are getting grimmer day by day.

The prediction of floods has always been a daunting task for hydrologists. The problem may seem even more peculiar when the question of prediction of flash floods arises.

However, a sterling effort has been made in this study, to assess the trend and prediction of peak floods. The author feels that this may help the agencies involved in disaster management sense an early warning signal and they will be well prepared for the aftermath.

METHODOLOGY

A case study data of regions in and around Indore was procured for carrying out the analysis. The data collected was rainfall in mm. The time series range from the year 1971 to 2018 (48 years) is shown in **Table 1**.

After the data was procured, the next step of the analysis was the identification of the best fit distribution to this data. The literature deals with a number of statistical approaches that have been proposed to identify the best fit distribution for a huge amount of data. Of these numerous techniques, the L-moment approach has been adopted. L-moments are measure of the location, scale, and shape of probability distributions or data samples. They are based on linear combinations of order statistics. Hosking (1990) and Hosking and Wallis (1997, chap. 2) give expositions of the theory of L-moments and L-moment ratios.The advantage of this method is that it is unbiased and simple to use.

Table 1 Rainfall data procured for the study (in mm)

Year	Indore	Mhow	San-wer	Depal-pur	Goutam-pura
1971	922.8	935.6	802.7	954.9	986
1972	611.3	738.7	531.9	485.3	518.4
1973	2080.6	2205	1862.9	1389.7	1110.3
1974	812.5	782.4	835.6	697.4	692.4
1975	1031	1492	1014.6	855.6	539
1976	1167.6	1247	1014.7	1058	0.0
1977	809.2	853.3	843.2	690.7	800
1978	912.6	609.4	812.3	739.6	0.0
1979	778.7	554.3	634.5	870.3	0.0
1980	1190.6	779	944.1	950	0.0
1981	1049	893	639.9	866.6	0.0
1982	671.4	535	444	626.5	0.0
1983	100.4	1268	527.7	987.3	0.0
1984	891.6	765.7	838	801.2	0.0
1985	699.7	426.4	761.7	415.2	428
1986	966.6	653.2	996.7	886	0.0
1987	796.7	610.8	675	456	0.0
1988	1089.3	791.9	945.4	814	0.0
1989	687.6	488.8	672.6	738	678
1990	1068	653.6	1008.4	1183	0.0
1991	734.4	593	660.6	653	0.0
1992	736.8	357.9	588.3	562	0.0
1993	1027.6	701	1120.6	979	938.4
1994	1123.1	1148	1235.2	1112	0.0
1995	1032.3	856	1108	879	826
1996	1130.6	1059	1031.3	1059.1	893
1997	1040	961	980	1198	1065
1998	933.5	855	856	1045.4	1150
1999	973.4	845.7	950	713	640
2000	590.9	402.1	475	566	407
2001	625.1	538	477	580	661
2002	656.1	640	710	621	580
2003	1226.7	1159	902	1121	1008
2004	840.9	797	832	816.2	881
2005	800.6	890.9	621	566.4	463
2006	800.6	797	672	574.4	463
2007	1098.6	915	1198	1412	1403
2008	923.7	944	811	927	948
2009	1081.6	1105.2	929	1044	1072
2010	737.7	865	936	1072	550
2011	843.8	1048	989	1284	714
2012	1027.8	1195	1233	1031	1111
2013	935.1	994.9	1041	1124.7	1146
2014	1572.2	1688	1217	1690	1531
2015	937.8	761	603	963	778
2016	1128.7	1026	1080	1458	1225
2017	927.1	685.2	1122.2	1141	891
2018	856.2	779.7	692.8	747	731

Using this, L-skewness and L-kurtosis values were calculated for the data. These were plotted on a graph. Also theoretical L-moment curves were plotted for the following parameter distributions:

- Generalized Logistic (GLO)
- Generalized Extreme Value Distributions (GEV)
- Generalized Pareto (GP)
- Lognormal three parameter (LN)
- Pearson Type III (PTIII).

Upon visual interpretation, the best fit distribution to the rainfall data-set was identified.

The next part of the analysis was the prediction of peak floods. In order to achieve the same, it was required to generate the run-off or discharge for the study area. Thus, one of the most popular and traditional methods; the Rational formula' was employed for the same.

The formula, even though primitive in nature, yields effective results in prediction of flow values.

The commonly used formula in field application, the Rational Formula given by:

$$Q_P = \frac{1}{3.6} C(i_{tc,p})A \quad (1)$$

where

Q_p = peak discharge (m^3/s)

C = coefficient of run-off

$i_{tc,p}$ = the mean intensity of precipitation (mm/hr) for a duration equal to t_c and an exceedence probability P

A = drainage area in km^2

Time of concentration t_c is the time taken for a drop of water from the farthest point of the catchment to reach the outlet. There are many methods available to calculate the t_c. However, we have used Kirpich Equation (1940) for the study. It is given by:

$$t_c = 0.01947L0.77S-0.385 \quad (2)$$

where

t_c = time of concentration in minutes

L = maximum length of travel of water (m)

S = slope of catchment = ΔH/L

ΔH = difference in elevation between the most remote point on the catchment and the outlet.

The rainfall-frequency-duration relationship is of the form:

$$i_{tc,p} = KT^x / (t_c + a)^n \quad (3)$$

where K, a, x and n are constants specific to a given area and T is the return period for probability P.

Sometimes a non-homogeneous catchment may have complicated sub-catchments. The run-off coefficient C, which represents the effect of catchment losses, would in such case be calculated

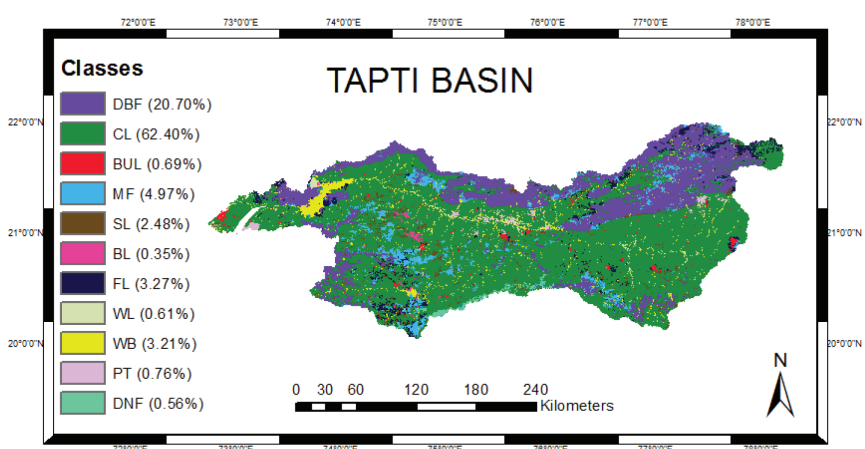


Fig. 1 Land-use land cover map for Tapi River Basin

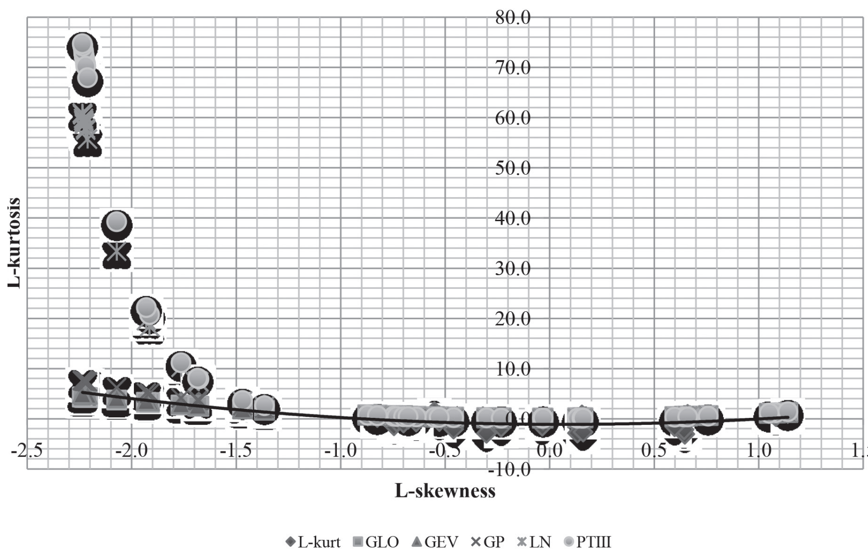


Fig. 2 L-moment diagram for the study

by proportionate average of the aerial extent of sub- catchment area given by:

$$C = \sum_i^N CiAi/A \qquad (4)$$

where A_i is the areal extent of the sub area I having a run-off coefficient C_i and N is the number of sub areas in the catchment.

In the study, the values of L, ΔH and C for each catchment has been obtained using the Land Use / Land Cover maps which were produced with the aid of USGS Earth Explorer and EARTHDATA (NASA) websites. The value of C varies with the type of soil for the agricultural area and the type of habitation is urban areas (residential, industrial etc.) Using the maps and equation 4 above, value of C has been obtained for each catchment.

Fig. 1 shows the generated LU/LC map for Tapi Basin.

Lastly after obtaining the flow/discharge values, the peak floods along with their return periods, were calculated by the standard statistical procedure for flood frequency analysis for Log-Pearson type the distribution.

The Log-Pearson Type III distribution employed here is a statistical technique for fitting frequency distribution data to predict the design flood for a river at some site. Once the statistical information is calculated for the river site, a frequency distribution can be constructed. The probabilities of floods of various sizes can be extracted from the curve. The advantage of this particular technique is that extrapolation can be made of the values for events with return periods well beyond the observed flood events.

RESULTS

As per the methodology stated above, the L-moment diagram for the given data yielded Pearson-Type III distribution as the best fit for the rainfall data for the study area. **Fig. 2** depicts the L-moment curves obtained for the data as well as all other distributions.

Table 2 Peak flow obtained in Cumces

Return Period	Skew Coefficient	Discharge (cumecs)
2	0	28.0
5	0.8	31.0
10	1.3	32.6
25	1.8	34.5
50	2.1	35.8
100	2.3	36.9
200	2.6	38.1

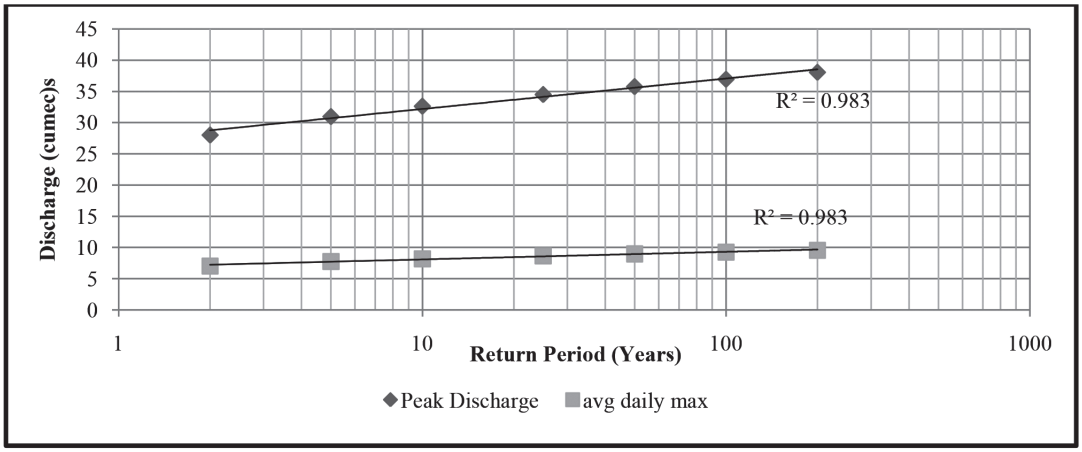


Fig. 3 Comparison of peak discharge v/s average daily discharge

Upon generation of the peak floods, the results obtained are summarized in **Table 2** and **Fig. 3.**

CONCLUSIONS

- Flash flooding is a natural phenomenon and its prediction of occurrence is seldom possible.
- An attempt has been made in this case study of regions around Indore to predict the peak discharges through a systematic process of predicting high flood values using the rainfall data record of 48 years.
- The best-fit distribution for the rainfall time series was identified using the L-moment approach. From Fig. 2 it may be observed through visual interpretation that Pearson Type III distribution seems to fit our data better as compared to other distributions in the graph.
- **Fig. 3** shows comparison of flood frequency analysis completed using mean daily data versus instantaneous discharge data. As can be seen, had this analysis been completed using instantaneous peak discharge data, the result would have been a more conservative estimation of the discharges associated with each return period. For instance considering a return period of 10 years, from Fig. 3 the daily average max discharge is around 8 cumecs whereas the peak discharge is around 33 cumecs.
- This method may assist the hydrologists in predicting the worst case scenario of flood in any area. Thus, if any anomaly is observed in the peak discharges at any site, the same may be conveyed to relevant authorities and agencies. These may in turn help them be prepared and take necessary course of actions.
- Also similar and more meticulous models may be developed for different region to attain better suitability and explicit results.

REFERENCES

1. Kuria, F. W., & Vogel, R. M. (2014). "A global water supply reservoir yield model with uncertainty analysis." Environmental Research Letters, Vol. 9, Issue 9, pp.-7.

2. Raheem, E., & Khan, S. H. (2002) Combining probability of emptiness and mean first overflow time of a dam to determine its capacity. Journal of Spatial Hydrology, Vol. 2, Issue 2, pp. 1-7.

3. Srivastava, D. K., & Awchi, T. A. (2009). "Storage-yield evaluation and operation of Mula Reservoir, India. Journal of Water Resources Planning and Management", Vol. 135, Issue 6, pp. 414-425.

4. Vogel, R. M., Sieber, J., Archfield, S. A., Smith, M. P., Apse, C. D., & Huber-Lee, A. (2007). "Relations among storage, yield, and instream flow." Water Resources Research, Vol. 43, Issue 5, pp. 1-41.

5. Silva A.T. & Portel M.M. (2013) Stochastic Assessment of Reservoir Storage-Yield Relationships in Portugal "Journal of Hydrologic Engineering, Vol.18, No. 5, pp. 567-575.

6. Vogel, R. M., & Stedinger, J. R. (1987). "Generalized storage-reliability-yield relationships" Journal of Hydrology, Vol. 89, Issue 3, pp. 303-327.

7. Raheem E, Khan SH. Combining probability of emptiness and mean first overflow time of a dam to determine its capacity. Journal of Spatial Hydrology. 2002 Nov 12;2(2).

8. McMahon, T. A., Vogel, R. M., Pegram, G. G., Peel, M. C., & Etkin, D. (2007). "Global Streamflows–Part 2: Reservoir storage–yield performance." Journal of Hydrology, Vol. 347, Issue 3, pp. 260-271.

9. McMahon, T. A., & Adeloye, A.J.(2005) "Water resources yield."Water Resources Publication, pp. 1, 6, 7,48,49,50.

10. McMahon, T. A., Peel, M. C., Vogel, R. M., & Pegram, G. G. (2007). "Global stream flows–Part 3: Country and climate zone characteristics." Journal of Hydrology, Vol. 347, Issue 3, pp. 272-291.

11. McMahon, T. A., Pegram, G. G., Vogel, R. M., & Peel, M. C. (2007). "Revisiting reservoir storage–yield relationships using a global stream flow database" Advances in Water Resources, Vol. 30, Issue 8, pp. 1858-1872.

12. McMahon, T. A., Vogel, R. M., Peel, M. C., & Pegram, G. G. (2007). "Global stream flows–Part 1: Characteristics of annual stream flows." Journal of Hydrology, Vol. 347, Issue 3, pp. 243-259.

13. Vogel RM, Lane M, Ravindiran RS, Kirshen P. Storage reservoir behavior in the United States. Journal of Water Resources Planning and Management. 1999 Sep; 125 (5):245-54.

978-81-950662-7-8
IEI Centenary publication of
Civil Engineering Division

The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700 020
Phone : +91 (033) 2223-8311/14/15/16, 2223-8333/34
Fax : +91 (033) 2223-8345
Website : http://www.ieindia.org
e-mail : cvdb@ieindia.org