PROCEEDINGS OF

ONE-DAY NATIONAL LEVEL WORKSHOP

ON

"MANAGEMENT OF FLOODS: RESERVOIR MANAGEMENT"

Organised by

National Disaster Management Authority
(NDMA)

&

Ministry of Jal Shakti
Department of Water Resources, River Development &
Ganga Rejuvenation

(18th October, 2019)

Contents

Executive Summary

Floods have been a recurrent phenomenon in India and cause huge losses to lives, properties, livelihood systems, infrastructure and public utilities. India's high risk and vulnerability are highlighted by the fact that 40 million hectares out of a geographical area of 3,290 lakh hectares are prone to floods. On an average, every year, 1,600 lives are lost and the damage caused to crops, houses and public utilities stands at Rs. 1,805 crores. The frequency of major floods is more than once in five years.

NDMA had released two guidelines on Management of Flood and Urban Flooding in 2008 and 2010, respectively. NDMA has also worked out short, medium and long term goals for addressing urban flooding. Also, study reports on Gujarat (2017) and Tamil Nadu Floods: Lessons learnt & best practices (2015) were prepared and circulated to all the concerned stakeholders. CWC disseminates water level (flood) forecast to States, which, in turn, issue warning(s) based on their understanding of the situation. This forecast is also available to the general public as it is put up on different social media platforms.

Reservoirs store large volumes of water and play an important role in meeting the needs for irrigation, hydropower generation and other water needs of communities living in their vicinity. They are one of the most important structural measures for reducing the impact of floods, and their well-thought-out operationalisation is a pre-requisite to minimising the frequency, duration and impact of floods in downstream areas. In the aftermath of Kerala floods, NDMA organised a meeting on 18th September, 2018 with representatives of Central Water Commission (CWC) and India Meteorological Department (IMD) to discuss and understand reservoir management. Issues that came up during the meeting and required action by State/UT Governments were forwarded to the Chief Secretaries of all the States / UTs on 3rd October, 2018.

As a follow-up to the same, NDMA organized a one-day workshop on 18th October, 2019 on **"Management of Floods: Reservoir Management".** The workshop discussed issues pertaining to effective management of reservoirs with a focus on challenges that surface during the rainy season and utilisation of Rule Curve.

During the workshop, resource persons highlighted various challenges such as difficulties in correlating the rule curve and rainfall data for estimating the amount of water to be released from the reservoirs. There is a gap in the accuracy of the forecast of heavy rainfall events and Quantitative Precipitation Forecast (QPF), and the need to improve Numerical Weather Prediction (NWP) modelling with sub-basin wise categorical rainfall forecast. Preparation of Emergency Action Plans (EAPs) for major dams as per CWC guidelines will improve emergency preparedness and response capabilities. There is a need for better coordination among different agencies and States sharing rivers for data and information exchange. There is a need for training and capacity building of manpower involved in operating the dams by State Governments /SDMAs/stakeholder agencies. Awareness and preparedness programmes for all stakeholders are also needed.

1. Introduction

Reservoirs store water during floods the quantum of which depends on the availability of space in the reservoir thereby reducing the flood peak downstream. The stored water is released from the reservoir for meeting water requirements for irrigation, power generation, drinking and industrial purposes. The water is also released into the river downstream subject to its safe storage capacity to make space in the reservoir for accommodating future floods as per the reservoir regulation manual. Reservoirs provide a good long-term solution to the problem of floods. The National Water Policy (2002) has recommended the provision of an adequate flood cushion in water storage projects and that flood control be given an overriding consideration in the reservoir regulation policy.

Reservoirs may not offer absolute flood protection and embankments along the downstream river are often required as a supplementary measure to contain the residual floods. However, they are an important component in flood management and also ensure optimum utilization of water resources.

Floods cause extensive damage not only to lives but also to livestock, property, crops, etc. thereby causing long-term physical and economic losses for the community and affected areas. In the past three years (2016-17 to 2018-19), rain and related events have led to the loss of 6,089 human lives in the country. During the same period, the loss of livestock stood at 1,95,726, the number of houses/huts damaged stood at 33,00,792 and crops were affected in 83.88 lakh hectares. For the current year (as on 18th July 2019), similar events have led to the loss of 496 human lives and 7,102 livestock. A total of 5,99,955 houses have been damaged and crops affected in 4.01 lakh hectares (**Source: Ministry of Home Affairs, 2019**).

1.1 Rationale

India has 5,334 large dams in operation and another 411 under construction. In addition, there are several thousand smaller dams. These dams are vital for ensuring water security in the country; and this constitutes a major responsibility in terms of asset management and safety. In April 2012, Ministry of Jal Shakti through the CWC started the 'Dam Rehabilitation and Improvement Project (DRIP)'. CWC has since released various relevant Guidelines such as 'Developing Emergency Action Plan for Dams (February, 2016)', 'Instrumentation of Large Dams (January, 2017)' and 'Mapping Flood Risks Associated with Dams (January, 2018)', etc.

Instances of unregulated release of water from the reservoirs resulted in an increase in the impact of flood events (Kerala 2018 and Madhya Pradesh 2019). In June 2014, sudden water release from Larji Hydroelectric dam in Mandi, Himachal Pradesh, resulted in the death of several tourists. Therefore, a mechanism for monitoring the water levels in dams, and dissemination of flood alerts and warnings in the downstream catchment area during monsoons needs to be developed.

Since water is a State subject, necessary steps have to be taken by the State Governments, dam authorities and other stakeholders for integrated flood risk management. To discuss issues pertinent to operation and management of reservoirs, NDMA organized this workshop on **'**Management of Flood: Reservoir Management' on 18th October, 2019.

1.2 Programme Schedule

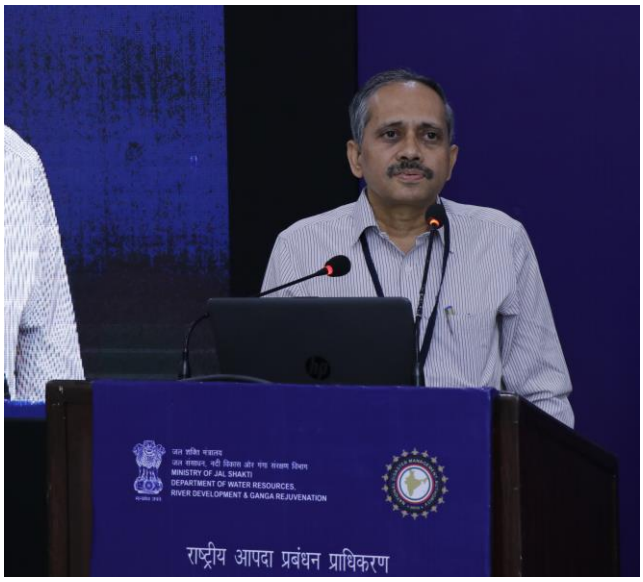
One-Day National Level Workshop
on
Management of Floods: Reservoir Management

18th October 2019 (Friday) at Kautilya Hall, Hotel Samrat, New Delhi

SN	Timings		Particulars	Topic details	Speakers
1	09:30 – 10:00		**Registration**	-	-
2	10:00 – 10:05		**Welcome & Opening Remarks**	-	**Shri G. V. V. Sarma, IAS, Member Secretary NDMA**
3	10:05 – 11:37	10.05-10.15 (10 min)	**NDMA**	(Theme of the Workshop)	**Shri Anuj Tiwari, Sr. Consultant PPM, NDMA**
		10.15-10.25 (10 min)	**CWC**	Flood Forecasting & Early warning	**Shri Sharat Chandra, Director (FAM)**
		10.25-10.35 (10 min)	**IMD**	Floods	**Shri Sh. B P Yadav, DDGM, IMD**
		10.35-10.45 (10 min)	**SANDRP**	Reservoir Management as if Flood Management matter	**Shri Himanshu Thakkar, Coordinator, SANDRP**
		10.45-10.55 (10 min)	**CWC**	Reservoir Operation for Flood Management	**Shri Rishi Srivastava, Director, Reservoir Ops**
		10.55-11.02 (7 min)	**ODISHA**	Management of Flood: Reservoir management	**Shri Pradip Kumar Jena, IAS, Principal Secretary, Government of Odisha**
		11.02-11.09 (7 min)	**WRD Maharashtra**	Management of Flood: Reservoir management and Other Preventive Measures	**Shri Rajendra Pawar/ Shri Hanumant Dhumal , Superintending Engineer**
		11.09-11.16 (7 min)	**WRD Uttar Pradesh**	Salient Features and Regulation Order for Dams	**Shri Sharad Kumar Singh, SE, Irrigation**
		11.16-11.23 (7 min)	**On Behalf of Disaster Management AP**	Integrated Early Warning framework implemented in AP	**Shri P. V. Ramana Murthy, Director, APSDPS**
		11.23-11.30 (7 min)	**Karnataka State Natural Disaster Monitoring Centre (KSNDMC)**	Flood Reservoir management	**Dr. C. N. Prabhu, Senior Scientific Officer, KSNDMC**
4	11:37 – 12:00 (23 min)		**Tea Break (Lounge Area)**		
	12:00 – 12:45 (45 Min)		**Open House Discussions**		-
5	12:45 – 13:00 (15 Min)		**Remarks by Secretary, WRD, GR & RD (Min. of Jal Shakti)**		**Shri Upendra Singh, IAS, Secretary, WRD, GR & RD**
	13:00 – 13:15 (15 Min)		**Concluding Remarks by Member Secretary, NDMA**		**Shri G. V. V. Sarma, IAS, Member Secretary, NDMA**
6	13:15 – 13:20 (05 Min)		**Vote of Thanks**		**Lt. Col. Rahul Devrani JA (MP&P), NDMA**
7	13:20 – Onwards Lunch		*Lunch (The Hunt Hall)*		

2. Welcome & Opening Remarks

2.1 Shri G. V. V. Sarma, IAS, Member Secretary, NDMA



Shri G. V. V. Sarma began by welcoming the dignitaries and participants. Explaining the rationale of the workshop, he said that floods annually result in the loss of an unacceptably high number of human lives and property. He said flood risk management requires the collaboration of concerned Ministries / Departments, State Governments, Civil Society Organisations and other stakeholders.

He referred to NDMA's Guidelines on ‘Management of Floods (2008)' and ‘Management of Urban Flooding (2010)’ which elaborate several action points for various agencies and State governments for flood risk management such as watershed management, flood plain zoning and other measures.

He mentioned that every State Government should have latest flood forecasting technologies, especially for monitoring reservoir inflow and analysing data on a real-time basis. He said there was a need to update rule curves every three years.

Shri Sarma highlighted that disaster risk management should be integrated into all developmental planning, as has been urged by the Hon’ble Prime Minister. He also mentioned the global Coalition for Disaster Resilient Infrastructure, which was launched by the Hon’ble Prime Minister during the Global Climate Action Summit. He said that 2015 was a Watershed Year for the global community as three important frameworks i.e., Sendai Framework for Disaster Risk Reductions (SFDRR), Sustainable Development Goals (SDGs) and the Paris Agreement were signed in that year. India is a signatory to all these three frameworks that deal with sustainability, disaster risk reduction and vulnerability reduction.

Parliament is ready to finalize the Dam Safety Bill, which focuses on the structural safety of dams and will improve coordination among various stakeholders. Further, he called upon State Governments and other stakeholders to correlate the rainfall prediction data with the 'Rule Curve' data for operationalising the dams. He also urged them to coordinate their efforts towards improved reservoir management in the country.

The purpose of this workshop is to assess whether we can develop a workable mechanism to address the issue of reservoir management in a systematic manner. He expressed hope that the workshop would see fruitful deliberations and would help stakeholders come up with the way forward.

3. Technical Presentations

3.1 Management of Floods: Reservoir Management by NDMA

Giving an overview of flood management in the country, Shri Anuj Tiwari, Senior Consultant, NDMA**,** mentioned the inadequate carrying capacity of rivers, varying rainfall distribution, poor drainage facilities and excess irrigation, etc., as major reasons behind floods. Other reasons include silting of river beds, reduced carrying capacity of river channels, erosion of river beds and river banks leading to a change in the course of rivers, obstruction to flow due to landslides, etc. and synchronisation of floods in the main and tributary rivers. The case of 2018 Kerala floods clearly showcased that lack of effective reservoir management can result in floods.

He listed out the various institutes that are involved in flood management such as the Ministry of Home Affairs, NDMA, IMD, CWC, Ganga Flood Control Commission (GFCC), Bhramaputra Board, National Centre for Medium Range Weather Forecasting (NCMWRF), National Remote Sensing Centre(NRSC) CWC is the nodal agency to forecast flood-related

warnings. Further, he mentioned the steps taken by NDMA towards better management of floods and urban floods.

Inflow forecasting for real-time reservoir management, outflow data and updation of rule curves are major pain points between CWC and States/dam authorities, he said.

NDMA and The Energy and Resources Institute (TERI)are developing a flood early warning system for Guwahati town. As per NDMA guidelines, all States should have a legal framework to make it necessary to obtain clearance for construction of infrastructure in flood-prone areas.

Ministry of Jal Shakti has started preparing Emergency Action Plans (EAPs) for major dams. Shri Tiwari stressed that salient features of EAPs should be widely disseminated and similar EAPs developed for more and more dams. There is a need to achieve better coordination among stakeholders and zero in on best-suited structural and non-structural measures for better reservoir management.

3.2 Flood Forecasting & Early Warning System by CWC

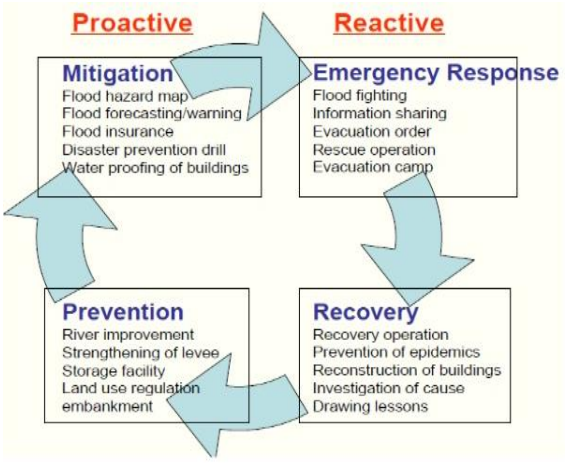
Shri Sharad Chandra, Director (FFM), CWC**,** said that India and other south Asian countries face numerous floods annually, which cause heavy damage. Since 1953, the CWC has been maintaining the repository of the flood and rainfall damage data. The annual average damage in monetary terms is nearly Rs. 5819 crores. He said Ganga and Bhramputra are main flood flow basins affecting Assam, Bihar and Bengal.

He explained the flood risk asa function of hazard, exposure and vulnerability. He highlighted the fact that while the intensity of rainfall has increased, the number of rainy days has decreased. Further, he mentioned that from the perspective of Water Resource engineering, dams arenot designed to cause floods but, if not operated properly, it can cause floods.

Patna floods were not an example of fluvial flooding rather but that of pluvial flooding. Water levels in the three rivers bordering Bihar i.e., Son, Punpun and Ganga were high but due to obstructed drainage in these river basins, the rivers swelled and led to flooding in the region. He suggested that before monsoons, drainage should be cleared to avoid any obstruction. Also, no maintenance of river embankments is another reason for flooding. In coastal regions, exits for excess rainfall water to the sea are narrow, which cause flooding. e.g. Kerala Floods 2018

He mentioned that there are two stages of the disaster management cycle, one is the proactive phase and other is the reactive phase. To prevent floods, flood management elements

such as strengthening of levee, storage capacity, land use regulation, etc. should be implemented. Flood hazard mapping, flood forecast warning, flood insurance, disaster warning and water proofing of the buildings can be undertaken during the mitigation stage.



After a disaster; during the response phase, information sharing, evacuation order, evacuation camps, etc. should be done on priority. In the recovery phase, different elements of rescue operation, prevention of epidemic, reconstruction of buildings and reconstruction of gauges should be undertaken. Lessons should be learnt and documented for future. Complete immunity from floods is not possible but we can work towards minimising its impact.

He said that integrated flood management involves a combination of structural (embankments, levees etc.) as well as non structural measures (training, awareness and capacity building). Flood risk management should be planned for the whole basin rather than the critical reaches of the river. For example, during the extreme hydrological event in the Chambal basin, flooding was severe even in the non-critical regions. Flood forecasting is the most cost-effective non-structural measure. The stages of flood forecasting are: Data Collection, Data Transmission, Monitoring, Processing for flood forecasting in the modeling centers, dissemination of the forecast and finally involvement of the National Disaster Response Force (NDRF) and the State Disaster Response Force (SDRF).

He mentioned that it is important to review the flood forecasting process. It is also important to judge the accuracy of the forecast and refine the forecast processes to determine the extent of the flood forecasting network. He also highlighted that CWC has switched from gauge reading to telemetry system, which has lesser human intervention in data collection. Also, for flood forecasting, CWC has switched from the statistical modeling to rainfall runoff models. Inundation forecasting has also been started by CWC for a few basins of the country. CWC disseminates the flood level forecast to the states with an understanding that the State is the first responder and will issue warning as per their understanding of the situation. However, now, the same is also available to the general public via different social media platforms and two dedicated websites. At the regional level, a flood is forecasted and disseminated to the civil authorities and the media. Also, the same forecast is transmitted to Central Flood Control Room in New Delhi, Central Ministries and MHA. The central control room has been converted into a 24-hour control room ever since the Ministry of Jal Shakti has been designated as the nodal ministry for any flood-like situation.

CWC has 325 flood forecasting stations; of which 197 are rainfall level forecasting and 128 are inflow forecasting stations. Data from inflow forecasting station is important to understand the flood patterns. The CWC has directed all the States to implement inflow

forecasting station on all the reservoirs in the State. The largest number of flood forecasting systems have been installed on the Ganga river basin. With an increase in the number of flood forecasting stations, the relative percentage of lives lost has decreased. If the water level in the reservoir rises above the danger level but is below the High Flood Level, three hourly bulletins are issued (orange/red bulletins) to the Prime Minister's Office and the Secretary. CWC has signed a MOU with Google Inc. to use artificial intelligence to provide real time inundation level / forecast. In conclusion, he mentioned the following important points:-

- Reservoirs for flood moderation – their flood cushion should be used effectively. Rule Curve for all reservoirs should be prepared and updated timely.
- In new water resource projects, storage may be decided with provisions for flood moderation with dynamic flood cushion.
- Inflow forecasting is an important tool for real time reservoir operations.
- EAPs for dam break / extreme flood situations – Dam break flood inundation, flood waves & time analysis.
- Better coordination of data flow with different agencies is the need of the hour.
- Revision of threshold values, danger and warning level.

3.3 Localised Hydro-Meteorological Services of IMD for Flood Forecast by IMD

Shri. B.P. Yadav, Deputy Director General of Meteorology, IMD, said that one-third of all disasters are floods and their intensity has almost doubled in the past 20 years. The resultant losses have also scaled up simultaneously.

As per CWC's request for the quantitative precipitation forecast (QPF) for 153 sub-basins in the country, IMD provides the same through its network of nearly 4,600 observatories at 10 stations. Given IMD's real-time monitoring system, this forecast can also be viewed by the public on the IMD website.

IMD is providing high-resolution short-term rainfall forecast image using the weather research and forecasting (WRF) model, which has a spatial resolution of 9 km × 9 km and gives a forecast for three days. Using some other models, IMD also provides medium-range rainfall forecast images. However, these image outputs can only be used for representational purposes and not for flood modelling as with an increase in time, the forecasting error increases considerably.

In flood forecasting, the flow through a river channel is one of the important parameters. However, in most of the major river channels, actual river cross-sections have not been maintained properly. River sections without automated river gauge stations cannot give real-

time based idea of flow propagation. Preparation of a data base on river cross-sections with real-time data acquisition on flow propagation can help in flood modelling and forecast.

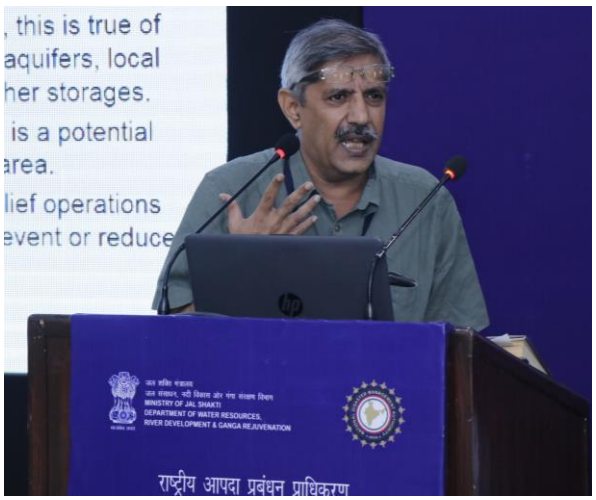
Shri Yadav informed that three new dedicated flood management offices have been setup at Srinagar, Chennai and Bengaluru. A daily bulletin is prepared in collaboration with CWC to monitor the flood levels in the various river basins and sub-basins in the country. As the deterministic forecast experiences some problem in capturing extreme rainfall events, IMD also evaluates the probabilistic forecast to cover for it. In fact, the probabilistic forecast for the recent Patna flood showed quite accurate values when compared with the real values. The probabilistic forecast has an accuracy factor of 70 per cent.

He mentioned that flood forecasting for the north-eastern region is not accurate and it needs to be worked upon. As river flood monitoring methodology is not suitable for flash floods, IMD in collaboration with World Meteorological Organisation (WMO), US National Weather Service, Hydrologic Research Centre (HRC) and USAID's Office of U.S. Foreign Disaster Assistance (USAID/OFDA) is developing the capability to issue flash flood guidance for India and neighbouring countries such as Bangladesh, Bhutan, Nepal and Sri Lanka. It takes into account the rainfall monitored using satellites, soil moisture and the forecast variables of the model.IMD is moving from weather forecast to impact-based forecast, which gives an idea about the likely levels of inundation and flood.

Following gap areas were highlighted by him:-

- Accuracy of forecast of heavy rainfall events & Quantitative Precipitation Forecast (QPF).
- Scope for improving Numerical Weather Prediction (NWP) modelling.
- Multi-model ensemble for probabilistic sub-basin wise categorical rainfall forecast.
- Coordination and exchange of information among stakeholders.

3.4 Reservoir Management as if Flood Management Matters by SANDRP



Shri Himanshu Thakkar, Coordinator, South Asia Network on Dams, Rivers and People (SANDRP), began by insisting that as Flood Management, Reservoir Management, Flood Forecasting, Disaster Management and Dam Safety are public interest activities, there should be

complete transparency with all information available in public domain. Theoretically, every dam can help in the moderation of floods and they should be maintained with this objective.

Once a dam is built, the situation downstream changes such as the carrying capacity of the river decreases and encroachment increases. Also, it changes the character and damage potential of floods. Whenever a reservoir releases more water than the carrying capacity of the river downstream, it causes flood. Shri Thakkar mentioned the 1979 incidence of Machu Dam where the resultant flood had caused a massive loss of lives and property. While a lot has been done for relief and response, we need to work on preparedness and prevention such as alerts and warnings through hooters and sirens whenever a reservoir is about to release water.

Several dams are ageing and their structural safety needs to be monitored and rectified. Also, reports by the dam authorities should tell whether the rule curve was followed or not.

He proposed the following action points for all stakeholders to help improve the management of reservoirs:-

- Need for actionable information for dam operators. For e.g. expected precipitation in a particular catchment during a given time period.
- The High Flood Level (HFL) should be prominently put on the website of the respective authorities.
- Data from different authorities for the same district has a 20-30 per cent difference. This needs to be rectified.
- IMD does not have basin-wise rainfall data for five river basins out of a total of 60 river basins. This needs to be fixed.
- Rule curves should be mentioned on relevant websites so that one can verify if they are being adhered to or not.
- Medium-term goals should form the foundation of National Flood Management Policy.

3.5 Reservoir Operation for Flood Management by CWC

At the outset, Shri Rishi Srivastava, Director (Remote Sensing Unit), Central Water Commission, described the principles of operation of single purpose reservoirs as per IS7323:1994 (issued by Bureau of Indian Standards). Such reservoirs are generally meant for conservation or flood control purposes.

Shri Srivastava further explained the process of flood routing through gated and ungated dams. He also explained the concept of Rule Curves and the methodology used to arrive at them keeping in mind a dynamic flood cushion.

He further explained the principles of operation of multi-purpose reservoirs, their storage zones and capacity allocation.

For integrated operations for the system of reservoirs, he suggested that all the reservoirs in a basin/sub-basin need to be under the same operating authority for which basin-level Management Boards/Authorities should be formulated. With this, flood moderation as well as conservational benefits can be better realised.

Rule Curves should be drawn considering basin-level flooding conditions so as to effect releases in a manner that delays release(s) from reservoirs when a downstream area is already inundated. Moreover, Rule Curves are a trade-off in case of multi-purpose reservoirs and should not be mistaken for having been designed to provide complete absorption of flood. This is especially true of a flood event that occurs during last leg of monsoon.

3.6 Management of Floods: Reservoir Management by Odisha

Shri Pradip Kumar Jena, IAS, Principal Secretary, Government of Odisha, sketched a profile of Odisha, including river basins, climate and rainfall pattern, reservoirs, rain gauges, existing forecasting system, issues, difficulties and challenges in handling extreme rainfall and cyclonic events, rainfall observations, inflow forecast, reservoir rule curve, etc.

Shri Jena informed that rainfall in various river basins of the State are monitored through 258 rain gauge stations and 314 block stations. The frequency of observation is once in a day (24hrs).

He suggested a set of measures as follows for improved reservoir management:-

- At present, there is no appropriate mechanism to capture episodic as well as point rainfall in a river basin. As there is a wide variation of rainfall in time, space and magnitude, a real-time rainfall data acquisition system should be devised. Automated rain gauge stations in a grid dimension of 9km × 9km or an even denser grid with real-time data transmission system should be installed.

- The location of these rain gauge stations in a river catchment should take care of the river/stream network. This will help in assessing whether a flood is rainfall-induced or is a result of an upstream reservoir release.
- In case of a large forest catchment, the number of rain gauges are sparse as a result of which information about the flow from such catchments is not properly addressed.
- At present, IMD forecasts heavy rainfall, thunderstorm accompanied with lightning, etc. These forecasts are highly subjective and do not give precise rainfall forecast and predictive analysis of localised rainfalls thereby limiting the ability of State agencies to accurately forecast flood and take preparedness actions. IMD predicts cyclone tracks very specifically and we expect its rainfall forecast to be as accurate, said Shri Jena. As the forecast model's spatial resolution is a district's area, it gives erroneous results in local precipitation. IMD should strive to provide a downscale forecast. Moreover, among co-basin States a seamless flow of data should be ensured. This is important because co-basin rainfall data as well as stream flow plays an important role in downstream riparian flow forecast as well as reservoir management.

3.7 Management of Flood: Reservoir Management and Other Preventive Measures by Water Resources Department (WRD), Maharashtra

Shri Rajendra Pawar, Secretary, CAD, WRD, Maharashtra, highlighted the changing pattern of monsoon in the State. He spoke about the recent flood situation in Maharashtra when the water it received was three to four times higher than that of the capacity of the dams in the region. Also, it saw a high to very high intensity rainfall in a short duration with Mahabaleshwar hill station recording more than 9000 mm of average annual rainfall. At a distance of just 100 m towards its east, the average annual rainfall was just 300mm. Such huge variation within such a short distance has aggravated droughts and floods. As dams in the State are designed for drought mitigation, many of them are built on the tributaries which are not adequate to control flood situations.

Shri Pawar informed that Real Time Data Acquisition System (RTDAS) and Real Time Decision Support System (Flood Forecasting) (RRTDSS) helped the State in managing the recent flood. Quick and easy access to data can help in taking proper decisions, he said.

He was of the opinion that diverting or temporarily storing excess water in dams and embankments, and restoring natural drainage systems in cities is needed.

He stressed on the following:

- Upgradation of existing Rule Curves with the help of latest technology.
- Scientific approach for deciding river cross-sections.
- Need for increasing existing network of river gauge and rain gauge stations.
- Increased constraints on releasing water from dams due to encroachments on waterways (city habitation) requires redesigning Reservoir Operating Systems.

3.8 Salient Features and Regulation Order for Dams by Water Resources Department (WRD), Uttar Pradesh

Shri Sharad Kumar Singh, Superintending Engineer, Irrigation, WRD, Uttar Pradesh**,** presented details of three dams - Nanak Sagar Dam, Baigul Dam, Dhora Dam - which fall in Uttarakhand but are being maintained by the Irrigation Department of Uttar Pradesh.

The 19 km long Nanak Sagar has a spillway capacity of 56,500 cusecs and dam capacity of 175 million cubic metres (MCM). Shri Singh mentioned the August 2018 flooding event, which could have been dealt in a better way if rainfall data and its inflow information was available at the field level. Baigul dam with a 300km catchment area is functioning well with respect to flood control, he said. Dhora dam has a capacity of 45 MCM with a 20,000 cusec spillway capacity. Even after a 95 per cent rainfall, the dam is filled only upto 50 per cent of its capacity.

Shri Singh emphasised on the need to implement the right Rule Curve and timely sharing of data. Such data should be interpreted well and action points should then be shared with the ground staff.

3.9 Integrated Early Warning Framework Implemented in Andhra Pradesh by APSDPS, Planning Department, Andhra Pradesh

Shri P. V. Ramana Murthy, Director, APSDPS, began by informing that Andhra Pradesh has implemented an integrated flood early warning system with a dense network of gauges. The State now uses hydrodynamic models like Mike 11 to forecast water levels at various locations along the river systems. Further, he presented a case study of the 2009 flooding along the Krishna river. It involved two reservoirs i.e. Srisailam on the upstream and Nagarjunasagar on the downstream. Srisailam witnessed a surprising inflow as major catchments of this dam are in Maharashtra and Karnataka. There was a gap between the precipitation estimates and flow/ inflow estimate given by national agencies and the actual flow owing to the lack of a sufficient rain gauge network in the region. To bridge this gap, the State has augmented its rain gauge network and improved its hydrological models (5 km by 5 km grids instead of 20 km by 20 km grid present earlier) to improve rainfall forecast. The inflow forecast for Nagarjunasagar almost matched with the actual situation.

He listed out the following points for consideration for an efficient flood Early Warning System:-

- A robust numerical weather prediction model to improve the quality of the inflow forecast to the reservoirs.
- An automated River Gauging Network capable of measuring and transmitting data to a central server at required intervals.
- Distributed and semi-distributed hydrological models to estimate runoff with remote sense based inputs.
- Automated rain gauges evenly spread over the entire catchment area.
- Precipitation forecast at higher resolutions.
- Need of decision support systems that automatically generate event maps at required administrative boundaries.
- Need for developing strong spatial databases including high-resolution topographic data and easy accessibility of Light Detection and Ranging (LIDAR) data for better forecast.

3.10 Floods in Karnataka: Monitoring & Management by Karnataka State Natural Disaster Monitoring Centre (KSNDMC)

Karnataka is highly vulnerable to hydro-meteorological disasters and therefore, the State has developed a dense network of sensors to control floods and monitor landslides, said Shri C.N. Prabhu, Senior Scientific Officer, KSNDMC. Rainfall data shared by various agencies is further processed and disseminated to the end users. The data, including the reservoir outflow levels, is also made available on the KSNDMC website i.e. www.ksndmc.org.

He expressed concern over erratic rainfall patterns by citing Karnataka's example for this year. The State was facing a drought-like situation till July but received an unprecedented rainfall in the first week of August. Moreover, water released from a dam in Maharashtra also caused major damage in the Krishna basin. He suggested that an inter-State mechanism should be developed in collaboration with the IMD and the CWC so that the rainfall data can be shared with all the stakeholders in a coordinated and timely manner. The network of monitoring stations should be strengthened, reservoir operators should be trained and decision making should be done at the highest level for coordinated release of water from upstream reservoirs to avert flooding.

4. Open House Discussions

4.1 Prof. Vinod Kumar Sharma, Vice-Chairman, Sikkim State Disaster Management Authority (SSDMA), complimented NDMA and Ministry of Jal Shakti for organising such a workshop after the monsoon season was over. Ironically, floods and droughts are two major problems faced by our country and the resultant damage and economic losses are constantly increasing every year. He suggested that multi-disciplinary and multi-departmental approach based integrated guidelines should be prepared and shared with the States. Early Warnings should be properly disseminated so the alerts can reach the public in time, which can save a lot of lives.

4.2 Shri Randeep Kumar Rana, Deputy Inspector General, NDRF, underlined the need to ensure that forecasts help us reduce losses as in spite of accurate early warnings, losses are increasing every year. He also requested a separate session on how to use forecast and warnings to minimise losses.

4.3 Shri Shankar Mahto, Former Chairperson, Brahmputra Board, said IMD and CWC have shown substantial improvement in rainfall forecasting and runoff modelling, which can help us better manage our reservoir systems. He mentioned that the rule curve is just a guide and not a rigid factor; and capacity building and skill development of reservoir operators is the need of the hour.

5. Remarks

5.1 Shri Upendra Singh, IAS, Secretary, Ministry of Jal Shakti

Shri Upendra Singh said that Climate Change is evident in the increasing intensity and frequency of events like floods and droughts. Dams do not cause floods; they act as a moderator of floods, he said. In the wake of urbanisation, we have encroached upon small natural lakes and reservoirs, and there is no room for the river or rainwater to collect in the catchment area. This is the major reason for flooding.

Based on the rainfall patterns in a region, there was a need to revisit the rule curves for many dams, said Shri Singh. Dam overtopping is a non-issue because even if the water level exceeds the Full Reservoir Level (FRL), there is still a freeboard. There is a need for spillways as per the dam safety manuals. Siltation, he said, is not a major problem. Moreover, de-silting is not an option for managing silt in such large quantities is not feasible. There is a need to build resilient reservoirs and dam structures. All the relevant data should be shared on a public platform so the general public can access it.

6. Concluding Remarks

6.1 Shri G.V.V. Sarma, IAS, Member Secretary, NDMA

Shri G.V.V. Sarma said that NDMA will soon revise its Guidelines on the Management of Floods. He requested States and other stakeholder agencies to share data and update rule curves. There is a need for better flood response and preparedness in terms of overall coordination among all stakeholder agencies, he said.

He said that the discussions at the workshop would help us prepare a roadmap for the future course of action.

7. Lessons Learnt & Way Forward

- Operating and managing a dam for controlled release of water is the primary responsibility of dam authorities and State Governments. Therefore, they are required to review and improve safety standards such as alerts, warnings and the Standard Operating Procedure (SOP).
- Modernisation of early warning and alert system is required for evacuating people during discharge of water from a reservoir.
- Need for review and revision of rule curves as per actual inflow and discharge data.
- Correlation between rule curve and controlled release of water needs to be established through capacity building of dam authorities and other concerned stakeholders.
- Identification of reservoirs for reviewing and modifying the operation manuals/rule curves by State Governments in consultation with dam authorities, CWC and other stakeholders.
- Establishing a mechanism for better coordination and joint operation for reservoirs on inter-State rivers by concerned State Governments/SDMAs with active inputs of Central Water Commission (CWC).
- Modernisation of flood forecasting, early warning and dissemination of information.
- Preparing Emergency Action Plans (EAPs) for reservoir management by dam owner agencies, State Governments / SDMAs and other stakeholders for improving emergency preparedness and response capabilities.
- Reviewing operation rules of all the existing reservoirs and modifying them according to the safety requirements of the structure, and flood moderation and other uses.
- Accuracy of forecast of heavy rainfall events & Quantitative Precipitation Forecast (QPF) is challenging and improvement in Numerical Weather Prediction (NWP) modelling is required.
- Need to develop multi-model ensemble for probabilistic sub-basin wise categorical rainfall forecast.
- Coordination and exchange of information and data among stakeholders is challenging. Therefore, there is a need to create a common platform for data sharing among Government Departments at the Centre and State levels.
- Need to sensitise reservoir management authorities through capacity building and training of reservoir operators.
- Mainstreaming and preparedness of local communities/villages living in the vicinity of dams through awareness is necessary.
- Need to ensure free display of reservoir inflow and outflow information through official websites.