DEVELOPMENT AND IMPLEMENTATION OF EMERGENCY ACTION PLAN (EAP) FOR KONAR DAM - A CASE STUDY

ABHISHEK SHUKLA
Executive Engineer (Civil), Damodar Valley Corporation, Dhanbad, Jharkhand, India

SATYABRATA BANERJEE
Chief Engineer (Civil), Damodar Valley Corporation, Dhanbad, Jharkhand, India

ABSTRACT

Dams are important structures constructed across rivers to serve multiple purposes for benefit of mankind. These structures are generally huge in size and impound significant amount of water. Failure of such structure is characterized by sudden uncontrolled release of stored water, generally coinciding with severe climatological events causing catastrophic damage leading to huge loss of lives and properties and severe impact on environment. Thus, it becomes obligatory for dam owner to prepare and implement an Emergency Action Plan (EAP) to minimize the consequences of an unlikely event of dam failure. The paper discusses about the development and implementation of Tier-I EAP for Konar dam of Damodar Valley Corporation located in Hazaribagh district of Jharkhand. The development of EAP of Konar Dam involved documenting the dam operation and safety evaluation procedure, determination of emergencies and categorizing levels, consequences estimation using Dam Break Analysis for two failure scenarios (overtopping & piping) and Large Controlled release, designating roles and responsibilities of all concerned authorities during emergency, identification of resources, etc. The consequence estimation and development of Inundation maps for Konar dam was carried out by Central Water Commission (CWC) under Dam Rehabilitation & Improvement Project (DRIP). Dam failure floods resulting in breaching from overtopping and internal erosion (piping) were simulated by solving numerically the two-dimensional, depth-averaged flow equations using the HEC-RAS computer program. Flooding caused by a steady large controlled-release (LCR) from the reservoir was simulated to provide hazard produced by a non-failure event. The Hazard classification, evacuation & mitigation plans was later developed by DVC utilizing the information obtained from Inundation maps. The approved EAP was shared among all stakeholders including disaster management authorities prior to Stakeholders meeting. The stakeholders meeting was organized at Konar dam with the principle objective of highlighting the need for EAP as a safety protocol to enhance the emergency preparedness of all concerned agencies and to further upgrade the document to handle any rare exigency related to uncontrolled release of water from dam. The meeting was attended by all stakeholders from several fields including the representatives of downstream affected villages & industries. Based on the feedback of stakeholders, the EAP was further improved to include notification to Block level officials and Mukhiyas of immediate downstream villages. It was also discussed to arrange such awareness program at block and school levels for effective implementation. Also, the document needs to be updated frequently to incorporate latest information for achieving a sustainable dam safety management practice.

***Keywords** : Safety of Dams, Dam failure, Inundation maps, Emergency Action Plan (EAP)*

1. PURPOSE

India, ranked third in the world in dam construction after US and China, has 5,745 large dams including 411 dams under construction (National Register of Large Dam - 2019) of which as many as 4,500 dams are more than 20 years old. These large dams collectively stores over 300 billion cubic metres of water to facilitate flood control, water supply, hydroelectric power generation, irrigation etc. and therefore their health and safety are of paramount importance for sustainable utilization of these valuable assets, besides protecting people, property, and the environment.

One of the key requirements of any dam project, which unfortunately has not been given its due weightage, is dam safety. Modern dam safety practices involve holistic approach which can primarily be classified into three aspects (1)

Preventive – which includes dam monitoring and surveillance, comprehensive dam safety evaluation, maintenance against ageing etc. (2) Actionable – which includes repair and rehabilitation methods (3) Emergency Planning in case of dam failure. A good operation and maintenance (O&M) practices can certainly minimize the risk of dam failures, however, situations may develop sometimes which can lead to dam failure – structural or operational and therefore requires a contingency plan.

A carefully conceived and implemented Emergency Action Plan (EAP) is one positive step to accomplish dam safety objectives which shall comprehensively cover requirements for notification flow charts, emergency conditions, inundation maps, emergency detection, evaluation and classification, emergency preparedness and implementation methodologies. The implementation of EAP requires coordinated efforts of both dam owning/operating agencies and also disaster management authorities at district / state / national level. The central idea is to lay down a set of procedures in simple and clear manner to protect lives and damage to environment, ecology, infrastructure and property from an uncontrolled outflow of water from dam.

2. DESCRIPTION

Konar dam, owned and operated by Damodar Valley Corporation (DVC), is situated across river Konar amidst the picturesque surroundings of the forests of Hazaribagh & Bokaro district of Jharkhand at about 30 km above its confluence with the river Damodar. It is the second of the four dams included in the first phase programme of unified development of the Damodar Valley and was completed in 1955. It is an earth-cum-concrete dam about 3682 m long where a 277 m long concrete gravity structure is constructed across the river channel of bed width 76.2 m, flanked by rolled fill earthen sections on each bank. The ogee type spillway consist of 9 crest gates each of 10.36 m (wide) x 9.91 m (high). The reservoir is expected to attain Maximum Water Level (MWL) of 429.77 m while passing the revised Probable Maximum Flood (PMF) of 9551 cumec. A vicinity map showing the location of the dam is presented in Fig - 1.

A well-established Flood Management Operation, monitoring system as well as maintenance system is already in place as per the existing Damodar Valley Reservoir Operation Manual & O&M manual. However, in addition to ensuring safety by proper upkeep of the dams, it is also important that we are prepared to face any emergencies caused by a dam failure.

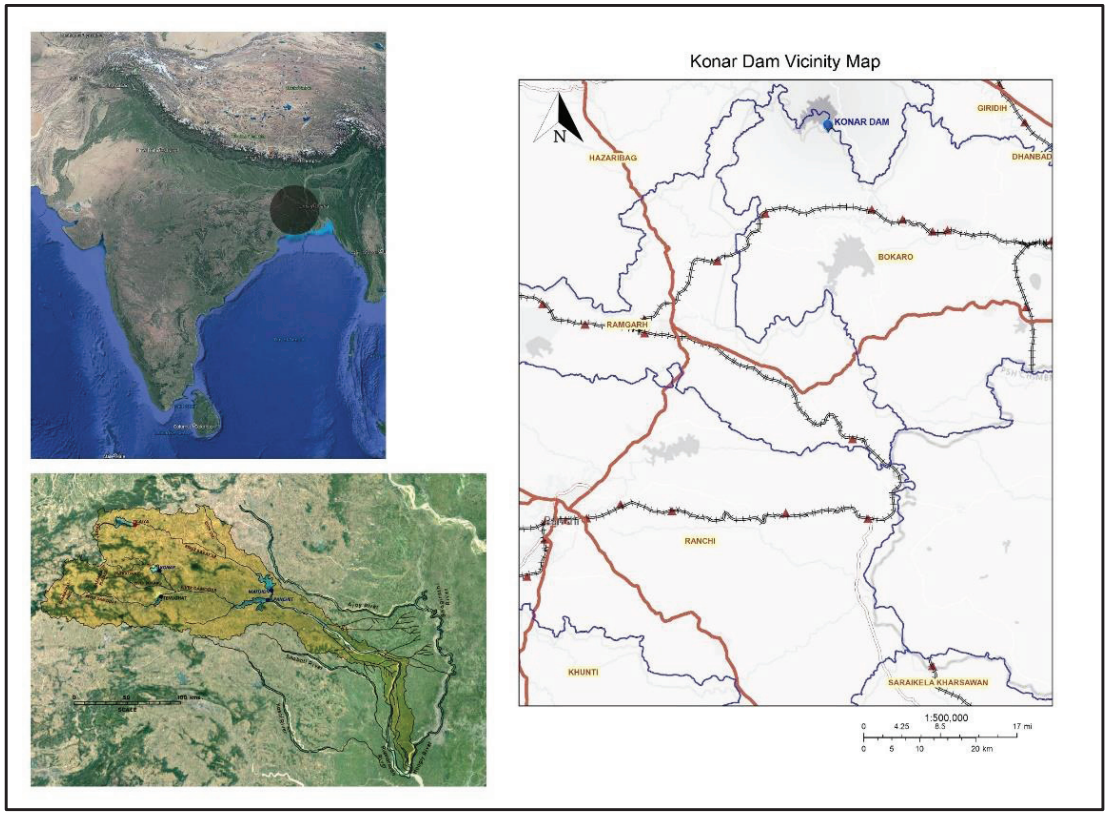

Figure 1 : Konar Dam Vicinity Map

3. CONSEQUENCE ANALYSIS AND EVACUATION PLAN

3.1 Development of Inundation Maps

One of the biggest advances in dam safety practices has been the evolution of computation technology for flood routing for dam break scenarios, availability of free and accurate topographic data and satellite imaging along with improvement

of the software and methods of modelling. These data set and methods can be utilised for assessing, modelling, and mapping of a dam failure flood for development of EAP. The level of analysis correlates with the sophistication and accuracy of the analyses with the scale and complexity of the dam and downstream area under investigation. In general, as the sophistication of the modelling increases, so does the level of effort, time, and cost needed to carry out the analysis.

With the freely available data, Dam break studies of Konar dam were carried out by Central Water Commission (CWC) under Dam Rehabilitation and Improvement Project (DRIP) for the following three scenarios:

1. A dam failure caused by overtopping from the inflow design flood leading to breaching and uncontrolled release of impounded water.
2. A non-flood dam failure caused by internal erosion (piping) with the reservoir at full supply level (often called a "fair-weather failure") leading to breaching and uncontrolled release of impounded water.
3. A large controlled-release flood without dam failure.

Dam failure floods resulting in breaching from overtopping by floodwaters and from internal erosion (piping) were simulated by solving numerically the two-dimensional, depth-averaged flow equations on an unstructured computational mesh using the HEC-RAS computer program (Brunner 2016). Breaches were modelled as trapezoidal openings that form at the crest of the dam and then grow in size, first vertically downward until the specified breach bottom elevation is reached, and then horizontally as outflows continue to widen the opening.

Flooding caused by a steady large controlled-release (LCR) from the reservoir was simulated to provide an idea of the hazard produced by a non-failure event.

The digital elevation model (DEM) used to prepare the two-dimensional computational mesh to simulate flooding was derived from the Japan Aerospace Exploration Agency (JAXA) global digital surface model (DSM) dataset with a horizontal resolution of approximately 30 meters (1 arc-sec).

Inundation maps were prepared for each scenarios showing 1) maximum water depth, (2) maximum water velocity, and (3) maximum water-surface elevation as well as (4) Time of arrival of flood. The outcome of the dam break models as well as inundation maps were shared with DVC for development of Tier I EAP.

3.2 Development of Evacuation & Mitigation Plans

Based on the results obtained from dam break analysis and the inundation maps, the data set depicting maximum water depth was analysed in Arc-GIS and later exported to Google Earth Pro for marking the settlements with in the Inundation maps. The marked settlements were cross-checked with Google Satellite images and a few locations were verified from random field visits.

Further, the data related to village boundary, panchayat boundary, block boundary, district boundary, schools, hospitals, police station etc. were obtained from website of Jharkhand Space Application Centre. These data were utilized for marking shelter points and assigning roles and responsibilities as per administrative jurisdiction.

Evacuation route for each settlement towards designated shelter points were also drawn in Google Earth Pro. All the information marked in Google Earth Pro viz. Settlements, Shelter Points, Evacuation Routes, bridges etc. were exported back into Arc-GIS platform for further processing with regard to determination of maximum water depth, maximum water velocity, maximum water-surface elevation as well as Time of arrival of flood at each settlement for each of the three scenarios and Inundation cum Evacuation Maps (as shown in Figure 2) were developed supported by table of Flood Hazard Reference Value cum evacuation plan (as shown in Figure 3) indicating all relevant information useful during implementation of EAP. This marks the end of consequence analysis for each of the failure scenarios and beginning of development of EAP of Konar Dam.

4. DEVELOPMENT OF AN EFFECTIVE EAP

Development of an effective EAP involves description of dam and its operation procedure, identification of possible emergency situations, emergency level determination, dam break analysis or consequence estimation, establishment of roles and responsibilities of all concerned, development of notification flowchart and response procedure along with other information pertaining to resources and supplies, media partners etc (Guidelines for developing EAP for Dams, CWC). The core idea of each of these information is to minimize the information gap during emergency and clearly outlining WHO DOES WHAT, WHERE, WHEN and HOW?

General data pertaining to Konar dam and its flood management operation guidelines were incorporated as per the available data and guidelines provided in CWC approved Damodar Valley Reservoir Regulation Manual (DVRR) manual.

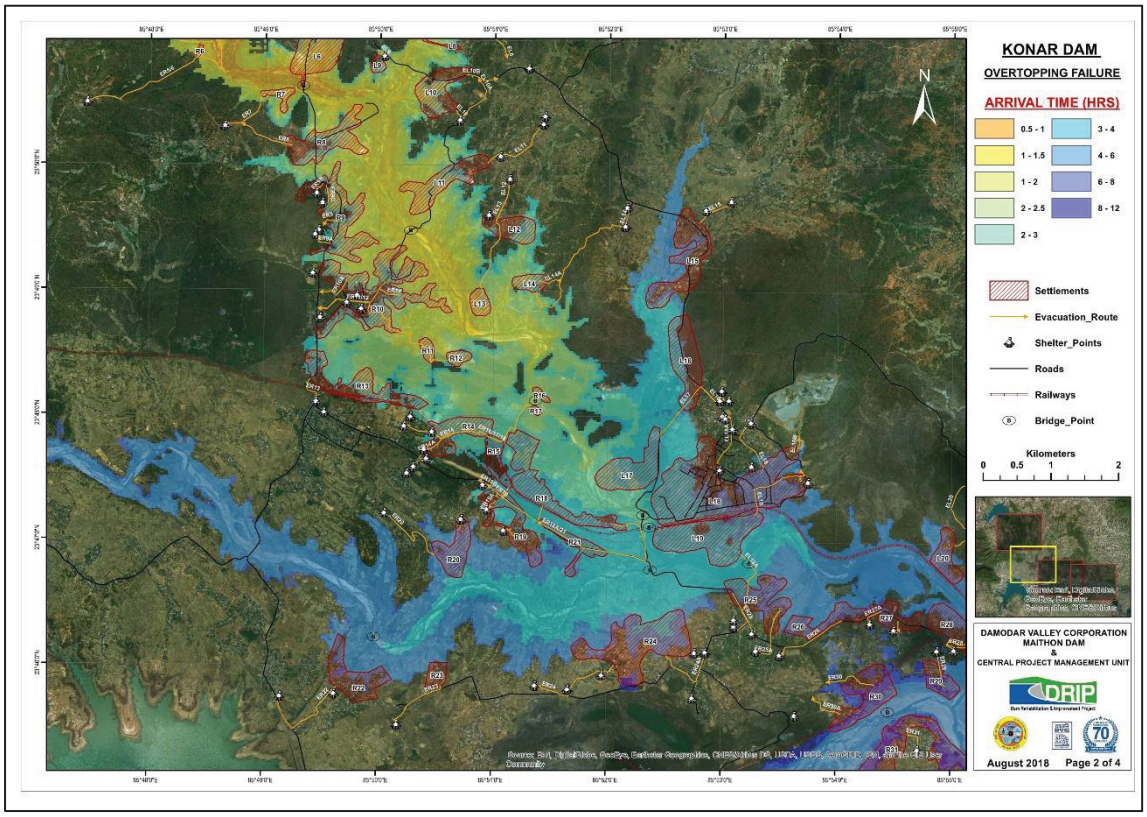

Figure 2 : Inundation cum Evacuation Map

FLOOD HAZARD REFERENCE VALUE CUM EVACUATION PLAN

FAILURE CONDITION : OVERTOPPING (EXTREME FLOOD FAILURE)

Evacuation Window	Priority Order	Settlement id	Village name or nearby area	Block & District	Distance from Konar Dam (in km)	Max. Water Surface Elevation (RL in metre)	Evacuation Route / Road	Remarks on Alternate Route	Shelter Points / Refugee	Responsibility of Evacuation	Contact Details
1 hr 30 min - 2 hour	15	R9	Khamhara & Sasbera (IEL Colony, Kaswagarh)	Gumia, Bokaro	15.8	271.6	Towards marked shelter points (via Route ER8, ER 9A, ER 9B & ER 9C)		Rajkiyakrit Middle School IELGomia Modern High School Gomia Other Shelter Points As Marked.	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	16	L10	Gandake - Centre	Bermo, Bokaro	15.4	272.0	Towards Marked Shelter Point (Route EL 10, EL 10A & EL 10B) - along BTPS Main Road		Rajkiyakrit Primary School Gandake Govt. Rajkiyakrit Middle School Budgada Public / Residential Building at Marked Shelter Point	Circle Officer, Bermo Md. Moddasar Nazar Ansari	8084266714 bermoco7@gmail.com
	17	L13	Armo - South 1	Bermo, Bokaro	17.6	270.8	Towards Marked Shelter Point (Route EL 13)		Govt. Rajkiyakrit High School Armo Govt. Primary School Nadidhar	Circle Officer, Bermo Md. Moddasar Nazar Ansari	8084266714 bermoco7@gmail.com
	18	R11	Karmatia Basti (Pipradih - Sawangi) -1	Gumia, Bokaro	19.0	270.3	Towards marked shelter points (via Route ER 11/12)		High School Gomia Dih Rajkiyakrit Middle School Gomiya Rajkiyakrit Primary School Gomiya (Kanya)	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	19	L8	Gandake - North	Bermo, Bokaro	14.2	272.0	Towards village Burgara Narki (Route EL8)		At Higher Location of Burgara village. Suitable Shelter Points may be Located.	Circle Officer, Bermo Md. Moddasar Nazar Ansari	8084266714 bermoco7@gmail.com
	20	R12	Karmatia Basti (Pipradih - Sawangi) -2	Gumia, Bokaro	19.0	270.2	Towards marked shelter points (via Route ER 11/12)		High School Gomia Dih Rajkiyakrit Middle School Gomiya Rajkiyakrit Primary School Gomiya (Kanya)	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	21	L2	Arjari - East (Near Patharchelwa)	Bishnugarh, Hazaribagh	6.6	315.5	Towards village Arjari (Route EL2 & EL2A)		At Higher Location of Arjari Village. Suitable Shelter Points may be Located.	Circle Officer, Bishnugrah	Mobile- 9934174688; Email id-cobishnugarh.1234@gmail.com
2 hour - 2 hr 30 min	22	R13	Gumai Rly. Stn. & nearby area (Pallhari Gurudih & Sawangi)	Gumia, Bokaro	19.6	270.4	Towards Marked Shelter Points.along MDR 75 (Route ER13)		Shishu Shiksha Sadan Sawang Kalachand Deo Smarak Kanya Vidyalaya Holy India Public School	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	23	L14	Armo - South 2	Bermo, Bokaro	17.6	269.7	Towards Marked Shelter Point (Route EL 14 & EL 14A)		Govt. Primary School Lukubad Public / Residential Building at Marked Shelter Point	Circle Officer, Bermo Md. Moddasar Nazar Ansari	8084266714 bermoco7@gmail.com
	24	R14	Khudagdda - North & Sawangi South (New Miners Colony, 1/C Colony)	Gumia, Bokaro	20.0	268.4	Road towards Marked Shelter Points along Kathara Gomia Main Road (Route ER14, ER 14A)		Govt. Rajkiyakrit Middle School Swang Adarsh Middle School, Jhirkey DAV Public School Sawang	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	25	L12	Armo - Centre	Bermo, Bokaro	17.6	271.6	Towards Marked Shelter Point (Route EL 12)		Govt. Rajkiyakrit High School Armo Govt. Primary School Nadidhar	Circle Officer, Bermo Md. Moddasar Nazar Ansari	8084266714 bermoco7@gmail.com
	26	L7	Barki Narki - South East	Bishnugarh, Hazaribagh	14.0	272.0	Towards centre of village Barki Narki (Route EL7)		At Higher Location of Barki Narki. Suitable Shelter Points may be Located.	Circle Officer, Bishnugrah	Mobile- 9934174688; Email id-cobishnugarh.1234@gmail.com
	27	R16	Sawangi (Near CCL Phase II Open Mines , South East of Karmatia Basti) - 1	Gumia, Bokaro	20.8	265.0	Road towards Marked Shelter Points (Crossing Settlement id R14) (Route ER 16/17/18)		Izrail Ansari English Medium School Jhirkey	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	28	R17	Sawangi (Near CCL Phase II Open Mines , South East of Karmatia Basti) - 2	Gumia, Bokaro	20.8	264.7	Road towards Marked Shelter Points (Crossing Settlement id R14) (Route ER 16/17/18)		Izrail Ansari English Medium School Jhirkey	Circle Officer, Gomia Yashwant Nayak	9470128210 cogomia15@gmail.com
	29	L9	Narki Kurd - East	Bishnugarh, Hazaribagh	14.6	272.0	Towards Marked Shelter Point (Route EL 9)		Govt. P.S. Boro, Narki Kurd	Circle Officer, Bishnugrah	Mobile- 9934174688; Email id-cobishnugarh.1234@gmail.com
	30	L5	Rangamati - Kharki	Bishnugarh, Hazaribagh	9.6	293.6	Towards Marked Shelter Points (Route EL 5 & EL 5A)		Govt. P.S. Sajot, Kharki Govt. P.S. Dumuhan, Kharki	Circle Officer, Bishnugrah	Mobile- 9934174688; Email id-cobishnugarh.1234@gmail.com

Figure 3 : Flood Hazard Reference Value cum Evacuation Map

4.1 Roles & Responsibilities

The roles and responsibilities of Dam Site engineers, Emergency Planning Managers, advisors of DVC were tabulated as mentioned in Table 1. The responsibilities of evacuation were handed over to the District Disaster Management Authorities of Bokaro and Hazaribagh as per their jurisdiction. The table of Flood Hazard Reference Values suggesting Flood wave arrival time, evacuation route, shelter points etc. and the Inundation cum Evacuation Map as developed for three failure scenarios were also enclosed to serve as ready reference to the District Disaster Management Authorities.

Table 1 : Roles & Responsibilities

Sl.No.	Dam / Emergency Personnel	Responsibility (During Normal & Emergency conditions)
1.	*Dam Site Engineers* Shri Pawan Kumar EE (Civil), DVC, Konar Shri A. Saha EA (Civil), DVC, Konar Shri Rautu Soren JE(Civil), DVC, Konar	• Routine dam maintenance work. • Monitoring & surveillance of dam and appurtenant structures including instruments & looking for evidence of distress as mentioned under Annexure - 9. • Notifying Dam Emergency Managers during any potential emergency situations. • As per advice, will operate dam gates / undersluices as well as contact the suppliers / resources available for executing actions during emergencies.
2.	*Emergency Planning Managers* Shri Sanjeet Kumar Sinha DCE(C), DVC, Konar Shri D.N. Patel SDE (Civil), T.K.Division, DVC, Konar	• Examine the distress conditions / emergency as notified by site engineers and ensure to address the issue immediately. • Discuss the issue with Dy. Chief Engineer (Civil), Water Resources, DVC, Maithon & Dy. Chief Engineer (Civil), E&P and other experts and follow up the advice. • Will contact the suppliers / resources available for executing actions during emergencies and inform dam site engineers to carry out the required action. • Will establish Emergency Control Centre. • Will classify the events into type of Emergency alerts and direct specific, incident appropriate actions during an emergency. • Will notify the Disaster Management Authority and others as per the notification flow Chart. • Will coordinate with the emergency team / personnel for initiating & implementing EAP.
3.	Shri S.K. Maji Dy. Chief Engineer(Civil), Water Resources, DVC, Maithon	• To issue release advices which shall be strictly adhered to by the Dam Emergency Manager & Dam Site Engineers. • To contact with the Regional CWC offices for integrated reservoir operation in Damodar Valley Area citing the emergency of Konar Dam.
4.	Shri Bijay Sarkar Dy. Chief Engineer (Civil), Engineering & Planning, DVC, Maithon	• To check for safety of the dam from design aspects and advise/ visit the dam site for any needful actions regarding structural stability.

4.2 Event Detection & Emergency Level Determination

It is the responsibility of dam site engineers to identify the situations or events that could trigger an emergency condition which are unique to each dam. All the possible events and situations which could result to emergency situation in Konar dam were identified and documented in the EAP. The possible failure conditions and their signs were also included in the document for early detection by dam site engineers during routine inspections before triggering to the level of failure. Each condition / sign was classified into one of the established emergency levels - BLUE, ORANGE & RED, based on the severity of the initiating condition or triggering events.

A BLUE emergency level does not lead to immediate threat however, the situation needs to be monitored closely to make sure the condition does not worsen.

An ORANGE emergency level depicts a condition that will probably cause the dam to fail and produce a devastating flood. The Dam Site Engineers will initiate immediate repairs and keep monitoring the overall situation and take necessary actions for notification.

A RED emergency level is triggered when dam failure is about to occur or has already occurred. An order for evacuation of residents will be issued immediately by the Emergency planning Manager / disaster management team.

A general information related to previous known problems were also included the EAP of Konar dam to enable Dam Site Engineers to look for the possible failure conditions. Preventive measures shall immediately be taken in an emergency to prevent the catastrophic failure of the dam, but such repairs should be undertaken with extreme caution.

Appropriate notification procedure must be followed when any of the above conditions are met. Assistance from other local jurisdictions, agencies, and industry, or contractors for supply of equipment, materials, or personnel as mentioned in the EAP shall be taken as per requirement.

4.3 Notification Flowchart & Communication

The whole process of development of EAP involves in providing a mechanism for coordination among all the agencies and defining their roles and responsibilities and the actions to be taken to minimize loss of life and damage to environment and property. Notification flowchart depicting relevant information like sequence of notification, contact numbers becomes handy in emergency situation. The Notification flow chart for watch condition (Blue Level at Figure 4) and Failure Conditions (Orange & Red Levels) were incorporated in the document.

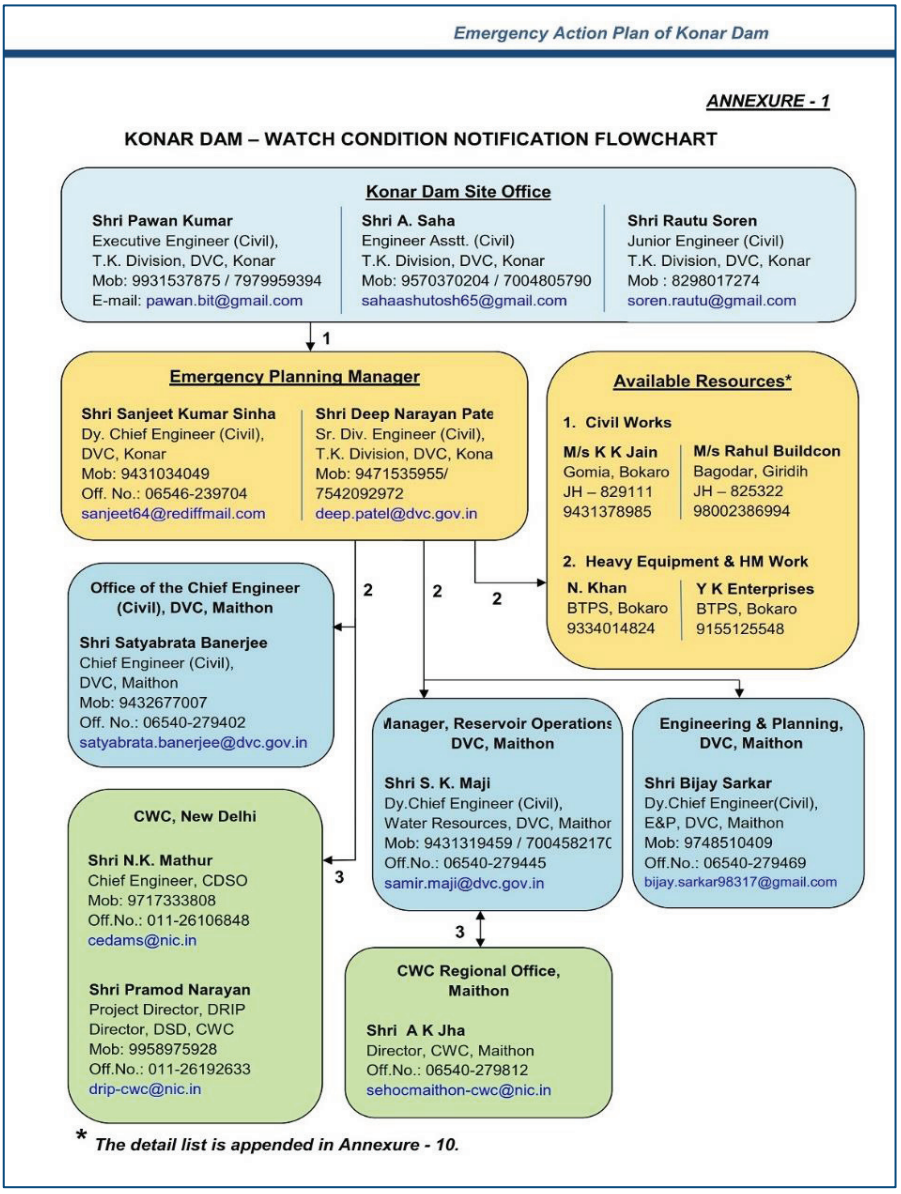

Figure 4 : Notification flowchart for Watch Condition

The Emergency Planning Managers are responsible for monitoring of emergency situations at the dam and based on Emergency levels keeping authorities informed based on the Notification Flowcharts. The Emergency Planning Managers are also responsible for declaring that an emergency at the dam is terminated.

In case of imminent failure, District Disaster Management Authorities, Local officials, downstream residents needs be notified by landline telephone, if available; otherwise via cell phones or emergency personnel (in person or using their radios). The contact numbers were appended in the Notification Flow chart and table of Flood Hazard Reference Value. Public Announcement through local Radio network, television, jeeps shall be broadcasted and sample public announcement as well as contact numbers of broadcasting partners were enclosed in the document.

4.4 Supplies and Resources

Should Damodar Valley Corporation personnel and resources prove to be inadequate during an emergency; requests would be made for assistance from other local jurisdictions, other agencies, and industry, as needed. Such assistance may include equipment, supplies, or personnel. All agreements would be entered into by authorized officials and should be in writing whenever possible. Emergency Planning Managers would have the authority to enter into agreements as deemed necessary to prevent the failure of the dam. Local contractors who can be contacted to provide equipment during an emergency event were listed.

4.5 Other requirement

Relevant information like Pre-monsoon and post-monsoon inspections of the dam must be kept handy all the time to evaluate its structural safety, stability, and operational adequacy. In the event of an abnormal occurrence, reference to these reports, particularly the photographs, can be beneficial in the evaluation of a potential problem.

Technical records such as drawings and inspection reports should be stored and carefully maintained both at Konar Dam Site office and Emergency Operations Centre at Dam site. All Emergency personnel of DVC, Konar Dam shall be familiar with the location of the documents in the event of an emergency.

5. IMPLEMENTATION

Any document which would not serve its intended purpose will be of no use no matter how much effort has been put into while developing the document. This is also true in case of EAP. The development of EAP is not the end of the process but merely the beginning of it and ensuring its implementation during emergency is the main objective.

The document will only be effective if people at risk from dam failure have adequate time for the evacuation process. The only way to test its effectiveness is testing the EAP procedure through table top exercise / drill. However, first the idea of EAP of dam needs to be informed to each stakeholder before carrying out annual table top drills.

With this view, the prepared EAP of Konar dam was shared with Central Water Commission, National, State & District Disaster Management Authorities & Relief Forces, major Industries of downstream affected areas and other stakeholders for their suggestions and necessary corrections. After receiving inputs towards modification, the approved document was once again shared with all stakeholders and before organizing stakeholders' consultation meet at Konar dam.

The stakeholders' consultation meet was organized on 28th June 2019 at Konar dam under ongoing Dam Rehabilitation and Improvement Project (DRIP) being implemented by Ministry of Jal Shakti through Central Water Commission and attended by around 120 participants representing various Central and State agencies involved in disaster management activities including Central Water Commission (CWC), the World Bank, representatives of other DRIP implementing agencies from five States, representatives of 10 villages downstream of the dam.

Some of the recommendations that came out from the deliberations, including need for involving local police stations and village Mukhias and providing them with maps which can be easily understood and arrange such awareness program at block and school levels for implementation to be really effective. Also, the notification of emergency should be done through loud siren followed by voice messages, informing about the impending disaster.

Disaster management Authorities shall use the EAP document for mapping of different resources for providing the relief and rescue operations along with complete contact numbers. Establishment of automatic weather stations in the catchment areas of the dam was also suggested to provide real-time flow characteristics.

6. CONCLUSION

The consequences of a dam failure are severe and may result in loss of thousands of lives and properties of unimaginable scale along with permanent damage to environment and ecology. An effective emergency plan thus plays an important role in minimizing the scale of impact caused by dam failure. The advantage of having an effective emergency plan and implementing the same during disaster cannot be overemphasized and one can look into several examples from past where an effective emergency preparedness has saved thousands of lives and properties amounting to millions.

Emergency Action Plan for Konar Dam of DVC was prepared under DRIP to facilitate a mechanism in case such emergency situations develops. Although all dam safety procedures are being followed as per Operation and Maintenance Manual of Konar dam, uncertainties related to dam failure can never be ignored. The developed EAP was shared with all concerned and a stakeholders' meeting was organized at Konar dam to understand views of stakeholders to make the document more effective. Based on the feedback of meeting the EAP was further improved to include notification to Block level officials and Mukhiyas of immediate downstream villages and it was also decided to arrange such awareness program at block and school levels for the implementation to be more effective and carry out Annual Table top-drills and the document needs to be updated annually incorporating latest information and suggestions which will ultimately help in achieving a common goal of sustainable dam safety management practice.

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