Joint paper 26th ICOLD Congress

July 2018

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DAMSAFE

Innovative technologies for enhancing dam safety and water management in India

Joint paper 26th ICOLD Congress

D2.2

July 2018

iPresas Risk Analysis

Joint paper 26th ICOLD Congress is a report conducted within the framework of the DAMSAFE project (Deliverable D2.2), including the paper "ENHANCING DAM SAFETY AND WATER RESOURCES MANAGEMENT IN INDIA: INNOVATIVE TECHNOLOGIES FOR DAM MONITORING AND RISK ANALYSIS FOR BHADRA DAM (KARNATAKA)", presented during the 26th ICOLD Congress held in Vienna in July 2018.

ACKNOWLEDGMENTS

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In addition, authors would like to thank Karnataka Water Resources Department for their collaboration within the DAMSAFE project, for their willingness to share data, knowledge, and experience, and the Central Water Commission of India (CWC) for providing information regarding Bhadra dam-reservoir system.

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Reference:

Peters, T., Giri, S., Verbruggen, C., van Hamersveld, L., Benninga, J., van den Berg, F., Xu, M., Castillo-Rodríguez, J.T., Morales-Torres, A., and, Escuder-Bueno, I. (2018): ENHANCING DAM SAFETY AND WATER RESOURCES MANAGEMENT IN INDIA: INNOVATIVE TECHNOLOGIES FOR DAM MONITORING AND RISK ANALYSIS FOR BHADRA DAM (KARNATAKA), in Proc. of Twenty-Sixth International Congress on Large Dams, Q101 - R52, ISBN 9781138612280, CRC Press, Taylor & Francis, June 2018.

COMMISSION INTERNATIONALE
DES GRANDES BARRAGES

VINGT SIXIÈME CONGRÈS
DES GRANDS BARRAGES
Vienne, Juillet 2018

ENHANCING DAM SAFETY AND WATER RESOURCES MANAGEMENT IN INDIA: THE CASE OF BHADRA DAM (KARNATAKA)*

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* *Amélioration de la sécurité des barrages et gestion de ressources en eau en Inde: le cas du barrage de Bhadra (Karnataka)*

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SUMMARY

Multi-purpose water reservoirs and dams play a major role for water supply, irrigation, flood protection and hydropower generation in India. In order to ensure long-term operation and safety of the dams, adaptation planning, maintenance, and rehabilitation actions are needed. The DAMSAFE project is a joint initiative, sponsored by the Dutch Partners for Water program, aiming at supporting decision making in a long-term integrated approach in order to enhance dam safety. The DAMSAFE consortium consists of Deltares (The Netherlands, as project coordinator), SkyGeo, Royal Eijkelkamp (The Netherlands) and iPresas Risk Analysis (Spain).

In the period 2017-2018, the DAMSAFE project includes actions for integrating different technologies, implemented in an integrated manner in DAMSAFE, which have been developed and proven in other cases, and will be applied for a pilot dam-reservoir system, Bhadra dam, located in Karnataka State. The system consists of a masonry dam and three embankment dams (saddle dams).

A quantitative risk analysis is being conducted for the Bhadra dam-reservoir system, where monitoring technologies will also be combined with forecasting modelling and early warning systems. Online monitoring and PSInSAR technologies will be applied and further integrated into Delft-FEWS, a platform that will allow to perform computations automatically using different sources of data and numerical models, like DAM-live for this project.

The main goal is to evaluate existing risks and to analyze the potential impact of risk reduction measures to improve dam safety management actions and the benefits of improved monitoring actions. Outcomes from this demonstration project will help to enhance safety of all types of dams (masonry, concrete, earthen) and to boost the application of risk analysis and innovative monitoring techniques in India.

Keywords: Bhadra dam, risk analysis, safety of dams, monitoring, flood forecasting.

RÉSUMÉ

Les barrages jouent un rôle majeur pour l'approvisionnement en eau, l'irrigation, la protection contre les inondations et la production hydroélectrique en Inde. Afin d'assurer le fonctionnement à long terme et la sécurité des barrages, des actions de planification, de maintenance et de réhabilitation sont nécessaires. Le projet DAMSAFE est une initiative conjointe, parrainée par le programme Partners for Water, visant à soutenir la prise de décision dans une approche intégrée à long terme afin d'améliorer la sécurité des barrages. Le consortium DAMSAFE se compose de Deltares (Pays-Bas, coordinateur), SkyGeo (Pays-Bas), Royal Eijkelkamp (Pays-Bas) et iPresas Risk Analysis (Espagne).

Au cours de la période 2017-2018, le projet DAMSAFE comprend des actions visant à intégrer différentes technologies, mises en œuvre de manière intégrée dans DAMSAFE, qui ont été développées et éprouvées dans d'autres cas, et seront appliquées pour un système pilote de barrage-réservoir, le barrage de Bhadra, situé dans l'État de Karnataka. Le système se compose d'un barrage de maçonnerie et de trois barrages de remblai (barrages de selle).

Une analyse quantitative des risques est en cours pour le système de barrage-réservoir de Bhadra, où les technologies de surveillance seront également combinées avec la modélisation des prévisions et les systèmes d'alerte précoce. La surveillance en ligne et les technologies PSInSAR seront appliquées et intégrées dans Delft-FEWS, une plate-forme qui permettra d'effectuer des calculs automatiquement à l'aide de différentes sources de données et de modèles numériques, comme DAM-live pour ce projet.

L'objectif principal est d'évaluer les risques existants et d'analyser l'impact potentiel des mesures de réduction des risques pour améliorer les actions de gestion de la sécurité des barrages et les avantages d'une amélioration des actions de surveillance. Les résultats de ce projet de démonstration contribueront à améliorer la sécurité de tous types de barrages (maçonnerie, béton, terre) et à stimuler l'application de l'analyse des risques et des techniques de surveillance innovantes en Inde.

Mots-clés: Barrage de Bhadra, calcul du risque, sécurité des barrages, auscultation, prévision des crues.

1. INTRODUCTION TO THE DAMSAFE PROJECT

Demand for water is increasing throughout the world and conflicting interests generate a complex and delicate field of work. In this context, multi-purpose water reservoirs and dams play a major role for water supply and flood protection in

India. There are 5187 large dams in India (4839 completed and 348 under construction) and several thousand of smaller dams provide a range of economic, environmental, and social benefits, including hydroelectric power, irrigation, water supply, flood control, and tourism.

However, like all other infrastructures, dams age and deteriorate, posing a potential threat to life, health, property, and the environment. In addition, dam owners are facing different circumstances than when these dams were designed, often decades or more ago. This is due to changes in land use, socio-economic developments and climate change. In order to ensure long-term operation and safety of dams, investments have to be made in inspection, maintenance, repair and retrofitting.

India has a history of dam failures. Recently, India has extended actions, policies and legislation to improve dam safety and to secure water supply. Water reservoirs in India are of vital importance to urban and rural areas and are used for irrigation (food production), water distribution for domestic and industrial use (e.g. drinking water supply), power generation (energy) as well as for protection against flooding. Therefore, the responsible government agencies both at national and state level are looking for methods to regulate their reservoir system in an optimal and sustainable manner to improve water management and safety considering social, environmental and economic aspects.

1.1. Goal of the DAMSAFE project

The overarching goal of the DAMSAFE project is to develop and demonstrate an integrated platform with innovative tools, technology and approach in the form of a pilot project, which will be applied to enhance dam safety and reservoir management in India. This goal is achieved by delivery of the following actions:

- Dam safety and water reservoir management:
  - Set up monitoring program with real-time observation associated with weather and water quantity as well as structural behavior.
  - Develop and demonstrate a forecasting system of reservoir inflow and outflow to improve reservoir performance and more controlled release of water.
  - Demonstrate innovative tools and technology for assessment of the dam condition resulting in optimization of Operation and Maintenance (O&M).
  - Develop and demonstrate innovative tools for risk assessment in order to provide information for dam safety management and emergency response.

- Training and knowledge dissemination:
  - Provide training, capacity building and exchange of data, knowledge and technology.
  - Organise open sessions with stakeholders, end-users and the broader water and dam safety communities in order to discuss project plans, execution, dissemination and effective utilization.

The focus of the DAMSAFE project is on integrating solutions to support decision-making on dam safety of end-users.

The key end-user of the project outcome is the Karnataka Water Resources Department (KaWRD), one of the major departments in the Government of Karnataka, headed by the Minister for Major and Medium Irrigation, and has 230 large dams.

1.2. Integrated approach to dam safety

Dam safety management incorporates a significant part of governance components in a multi-stakeholder context. Integration and application of innovative knowledge and technologies are imperative prerequisites for safe and sustainable dam and reservoir management.

The relevant technical topics, associated with the governmental aspects of dam safety, can be outlined as follows:

- Meteorological and hydrologic observation and prediction,
- Reservoir inflow forecasting (real-time),
- Reservoir operation and optimization,
- Observation and assessment of dam performance,
- Dam failure identification and analysis, and
- Risk assessment, and,
- Emergency Action Planning (EAP).

Consequently, an integrated approach is desirable with a long-term scope considering its continuous development, adaptation and application for all type of dams and reservoirs.

The DAMSAFE project has included the application of three solutions to support decision making in this long-term integrated approach. Therefore, risk assessment and monitoring technology (in-situ and remote) are combined with forecasting modelling and early warning systems. The main step forward is the use of modelling software to better forecast system performance and reduce uncertainties of future flood forecasting projections.

Different technologies, that have been developed and proven elsewhere, provide high quality and reliable information to the end-user. They are implemented in an integrated manner in DAMSAFE, including an innovative technique of data acquiring, using online monitoring and PSInSAR remote sensing technology. The data acquired are processed by DAM software, developed by Deltares. Results representation is provided by the Delft-FEWS platform. In addition, results will be used to further update input data for risk analysis, developed using iPresas Calc software.

Aforementioned technologies have been applied to a pilot case in India and are further described in this paper.

2. PILOT CASE DESCRIPTION

The pilot case of the DAMSAFE project is the Bhadra dam-reservoir system. Bhadra Dam is located across Bhadra River near Lakkavalli village, Tarikere Taluk, Chikkamagalore District of Karnataka State at an elevation of 601.00 m above Mean Sea Level (MSL). This is a multi-purpose dam, including irrigation, water supply and hydropower generation.

Fig.1
Masonry dam, Bhadra dam-reservoir system.
Barrage de maçonnerie, système de barrage-réservoir de Bhadra

The dam was finished in 1962. It includes a main masonry dam (Fig. 1) and two saddle (earthen) dams. The main dam includes a spillway with four gates and a total length of 76.8 m. The reservoir capacity is 2026 hm^3. The maximum height is 76.8 m for the masonry dam (main dam). The maximum height is 49.4 m for saddle dam 1 and 32.3 m for saddle dam 2. The base level is located at 583.39 m [1914 ft] in the masonry dam (main dam), and at 612.95 m [2011 ft] and 630.02 m [2067 ft] for saddle dams 1 and 2, respectively. The maximum water level in normal operation is established at 657.76 m [2158 ft], being 657.15 m [2156 ft] during the monsoon season. The spillway has a maximum discharge of 3012 m^3/s [106700 cusecs]. The spillway crest level is located at elevation 650.60 m [2134.5 ft]. The maximum spillway opening height is 7.16 m [23.5 ft].

3. IMPLEMENTED TECHNOLOGIES WITHIN THE DAMSAFE PROJECT

3.1. Risk informed dam safety analysis

Establishing a vision and a road map to smart governance in dam safety management is not an easy task for any country, public agency or private corporation, and it requires aligning policies, tools (for assessment of all relevant processes) and capacities, especially in terms of qualified personnel, to carry out a practical and successful implementation.

The aim of the work conducted within the DAMSAFE project is to provide a reference example to build such a paradigm shift in India.

As described by ICOLD in its Bulletin 130 (2005) [1] and by Escuder-Bueno and Matheu in the Proceedings of the Third International Week on the Application of Risk Analysis to Dam Safety [2], the journey from implementation of (traditional) dam safety systems to its full incorporation into a (modern) risk management framework requires a roadmap that is not independent of the starting situation or the context. Recommendations have been issued in other countries on how to perform the risk management process, including tolerability recommendations and principles to prioritize safety investments based on equity and efficiency principles for risk reduction [3,4].

The methodology applied for Bhadra dam risk analysis is based on the methodology explained in the Technical Guide Nº.8: "Risk Analysis Applied to Dam Safety Management" published by SPANCOLD in 2012 [5]. The process starts with data and information gathering and analysis and a technical visit to the dam to analyze its current situation. Next, failure modes are identified, which will later be introduced in the quantitative risk model, including the required data on loads, failure probabilities, and consequences, in a structured model. Finally, risk results are evaluated based on international tolerability recommendations and are used to establish potential risk reduction measures.

Based on results and conclusions from a working session on failure mode identification and analysis held in February 2017, including 39 participants, the following potential failure modes were identified for Bhadra dam-reservoir system:

- FM1: Overtopping failure in the main dam.
- FM2: Overtopping failure in saddle dams.
- FM3: Sliding in the main dam (interface at rock foundation).
- FM4: Sliding in the main dam (interface at dam-foundation contact).
- FM5: Sliding in the main dam (degradation of masonry material).
- FM6: Sliding in a seismic event (main dam).
- FM7: Overtopping in a seismic event (saddle dams).
- FM8: Internal erosion (saddle dams).
- FM9: Failure due to settlement at U/S face (saddle dams).
- FM10: Collapse of irrigation channel wall. Right abutment (main dam).

Following recommendations developed by international organizations related to dam safety [5], identified failure modes were classified. Three of them were considered to be included into the quantitative risk model for Bhadra (FM1, MF2 and FM4). Figure 2 represents the risk model architecture for the model developed for Bhadra dam. Input data on loads, system response, and consequences are incorporated into each node of the risk model. This diagram offers a visual representation of the risk model.

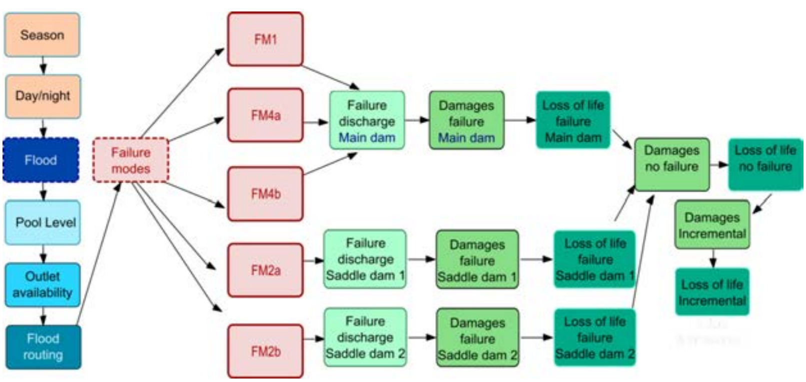

Fig.2
Risk model architecture for Bhadra dam.
Architecture du modèle de risque pour le barrage de Bhadra

An event tree is a logical mathematical structure that includes all possible event chains that can lead to dam failure and calculates the probability of each of these branches. Hence, an event tree is a detailed representation of all events that may lead to flooding in a system. The iPresas Calc software, developed by iPresas, was used for performing risk calculation and analysis, allowing risk representation to compare outcomes with international tolerability recommendations to evaluate risk of Bhadra dam-reservoir system.

3.2. In-situ monitoring dam and reservoir

A monitoring system has been designed and installed by Royal Eijkelkamp at the Bhadra dam and reservoir with focus on weather, water quantity and dam behavior. Therefore, the online monitoring system includes:

- weather stations in the catchment area to measure rainfall, temperature, wind and sun radiation,
- devices for measuring surface water levels at the dam and at the rivers flowing into the reservoir, and,
- water pressures in the dam and in the dam foundation.

The acquired data in combination with other historical data for the pilot dam, will be vital input for the numerical computations for dam safety, forecasting and early warning.

The measurements are fully automated and real-time available on a secured internet platform accessible worldwide for stakeholders and project partners. Monitoring activities will also include a dashboard within the Bhadra dam control room to present the results to the dam operator and maintenance staff.

Result of the recently installed online monitoring system show almost 2.5 m increase of the water level at the dam over the period mid September to mid October and strong fluctuations at the two rivers flowing into the reservoir. This is due to rainfall in the monsoon season.

3.3. PS-INSAR satellite dam monitoring

PS-InSAR (Persistent Scatterer Interferometric Synthetic Aperture Radar) is a technique that maps millimeter-scale deformations of the earth’s surface with radar satellite measurements. Given the continuous change of the Earth’s surface, the ability to yield measurements at night and throughout any weather condition makes this technique extremely valuable.

The satellite measures both the amplitude and the phase of the radar signal reflected from the Earth's surface. The amplitude is the strength of the signal that is recorded, and the phase is the fraction of a complete waves cycle that reaches the sensor. The phase measurement is extremely important for measuring deformation. A difference in phase between two sequential measurements means that something has changed. Technical background of InSAR techniques can be found at skygeo.com.

PS-InSAR has a number of practical advantages and limitations. Strengths are its millimeter precision, regular measurements (every eleven days in the DAMSAFE study area), independence of weather conditions, the large number of measurement points, direct availability without the need for IT system interventions or physical site access, and the wide area capabilities, all for a low price. The main limitations of the technology are the asymmetrical distribution of measurement points and the impact of the choice of reference points and assumptions on deformation behavior. Therefore the technology works best in combination with terrestrial measurements and by closely collaborating with dam operators who have the contextual deformation situation for the dam.

The DAMSAFE project is both exciting and innovative when it comes to the application of PS-InSAR. First of all, thanks to the European Space Agency, the Sentinel 1A and 1B SAR satellites provide radar imagery over most of India since the satellite constellation became fully operational in Q3 2016. Moreover, the DAMSAFE project will work on a concept to integrate PS-INSAR data into the overall DAMSAFE toolbox.

Figure 3 shows first processing results of Bhadra dam using 26 Sentinel 1 images over a one year period. It shows a small deformation per year that is rather homogenously distributed over the dam area.

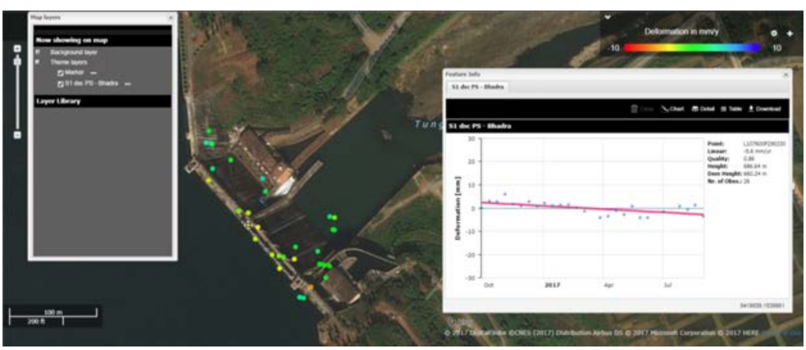

Fig. 3
*PS-InSAR data p*rocessing results of Bhadra dam
PS-InSAR résultats du barrage de Bhadra

3.4. Forecasting and early warning system

The forecasting and early warning system considered within the DAMSAFE project is framed by the data management tool Delft-FEWS, developed by Deltares. It is an open platform to integrate real-time measurement and forecasting data, such as precipitation, temperature, and model outcomes, in order to facilitate dam operation and safety analysis. Figure 4 illustrates the overview of the FEWS system.

Earth observation precipitation and Global Forecasting System (GFS) precipitation are used as inputs of the hydrological model (namely HEC-HMS) of the Bhadra catchment. Figure 5 illustrates the example of GFS precipitation for the three Bhadra sub-catchments. The hydraulic routing procedure is modelled by HEC-RAS, with the input from the hydrological model.

Currently, the Bhadra dam is analyzed through two different approaches. The two saddle dams are modelled through the Dam strength Analysis Module (DAM) to analyze the sliding stability and macro-stability downstream.

The possibilities of DAM are suitable for operational purposes in monitoring the actual stability (sliding, macro, overturning, etc.) of dams with installation of water pressure sensors. This application of DAM, called DAM-Live, already applied for the case of Paraitinga dam in Brazil [6], is implemented in the operational system Delft-FEWS for this case. With DAM-Live, real-time and forecasted sliding- and macrostability estimations can be obtained.

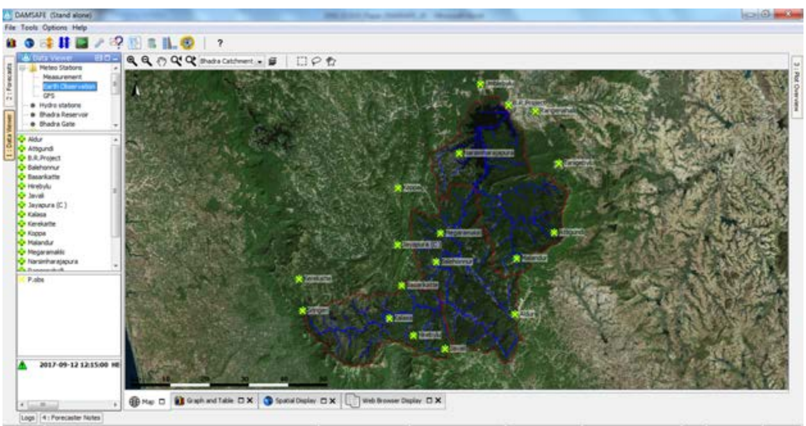

Fig. 4
Overview of the FEWS system for DAMSAFE
Vue d'ensemble du FEWS système pour DAMSAFE

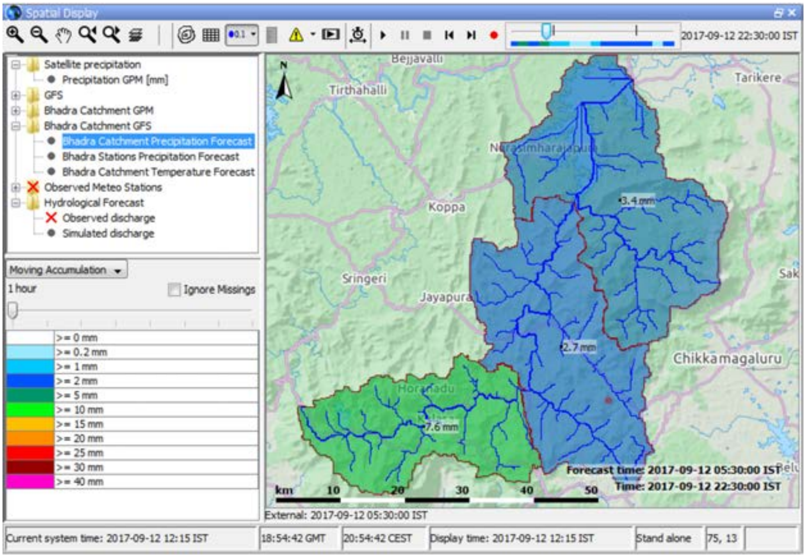

Fig. 5
GFS precipitation interpolated upon Bhadra sub-catchments
Interpolation des précipitations GFS sur les sous-bassins versants de Bhadra

Within the FEWS framework, the end user is able to run hydrological and hydraulic forecasting using real-time measurements, as well as user defined scenarios or maximal extreme scenarios, making real-time data processing, analysis and forecasting much easier in practice.

4. CONCLUSIONS AND THE WAY FORWARD

Conducted and ongoing activities within the DAMSAFE project are described in this paper. The goal of this project is to demonstrate innovative solutions for dam safety and reservoir management for a pilot dam in India, including the application and integration of different technologies: online monitoring and PS-InSAR remote sensing technology, risk analysis and, forecasting and early warning systems.

Outcomes from the online monitoring and PS-InSAR data processing, now in a first evaluation stage, will help to update existing knowledge on Bhadra dam-reservoir system and to better characterize risks. Quantitative risk analyses, including analysis of floods into the reservoir, potential failure modes and consequences in case of dam failure or uncontrolled releases, are now under development.

Outcomes from this pilot case will support decisions for dam safety and reservoir management, representing a reference example for potential replication and upscaling in Karnataka state, India and worldwide.

ACKNOWLEDGEMENTS

Authors would like to thank Karnataka Water Resources Department for their collaboration within the DAMSAFE project, for their willingness to share data, knowledge, and experience. DAMSAFE is a demonstration project sponsored by the Dutch Partners for Water program (http://www.damsafe.eu/).

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PART II. PRESENTATION

This part includes the content of the presentation by Jessica Castillo (iPresas Risk Analysis) during the 2018 ICOLD Annual Meeting and 26th ICOLD Congress held in Vienna (Austria) from July 1 to July 7.

ENHANCING DAM SAFETY AND WATER RESOURCES MANAGEMENT IN INDIA: THE CASE OF BHADRA DAM (KARNATAKA)

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DAMSAFE project

Period: 2017-2018

Co-funded by the Partners for Water Programme (NL).

Collaborating with Karnataka Water Resources Department.

Partners:
- Deltares [NL]
- Royal Eijkelkamp [NL]
- SkyGeo [NL]
- iPresas [ES]

Bhadra dam (pilot case)

Contents

DAMSAFE project: Motivation

India Facts & Figures on dam safety

x2

1324 millions of inhabitants

**Life expectancy:
68.5 yr (2016)
41.2 yr (1960)**

GDP 2005-2016 x3

Source: World Bank

DAMSAFE project: Motivation

India
Facts & Figures
on dam safety

India ranks third in number of large dams worldwide.

Large dams per country (ICOLD Register)

5254 large dams and **447** under construction

DAMSAFE project: Motivation

India
Facts & Figures
on dam safety

Dams are key infrastructures in India

Dam safety

36 dam failure cases

- First registered event: 1917 **Tigra dam** (shortly after first filling)
- Most consequences: 1979 **Machu dam** [2000 fatalities] (ov. failure)

DAMSAFE project: Motivation

Scope

- Promote **integrated** water resources management.
- Promote **risk-informed** dam safety management.

Actions

- Provide **tools** for improved water resources and dam safety management.
- Activities for **capacity** building.

BHADRA dam: The pilot case

- **Karnataka**
  - 231 dams (5th in number of large dams)
  - Bengaluru (5th city in the country)

- **Bhadra dam**
  - 1962
  - 2026 hm^3
  - Main dam and 3 saddle dams.

  - Water supply, irrigation and hydropower.
  - Classified as one of the **69 key dams** in India.

Bhadra dam (main dam)

BHADRA dam: The pilot case

- **Actions withint DAMSAFE project**
  - ❑Improved **monitoring**
  - ❑ Analysis of **movements** using PS-InSAR technology
  - ❑ **Water resources** management (flood forecasting)
  - ❑ Quantitative **risk analysis**

Eijkelkamp Soil & Water

SKY GEO

Deltares Enabling Delta Life

iPresas Risk Analysis

iPresas Risk Analysis

BHADRA dam: The risk analysis process

Hällby dam (Sweden)

River Caroní dam (Venezuela)

Paso Severino dam (Uruguay)

Koman dam (Albania)

iPresas Risk Analysis

BHADRA dam: The risk analysis process

Key steps

- Review of information.
- Site visit.
- Identification of potential failure modes.
- Risk model architecture.
- Risk analysis and evaluation.
- Prioritization of risk reduction measures.

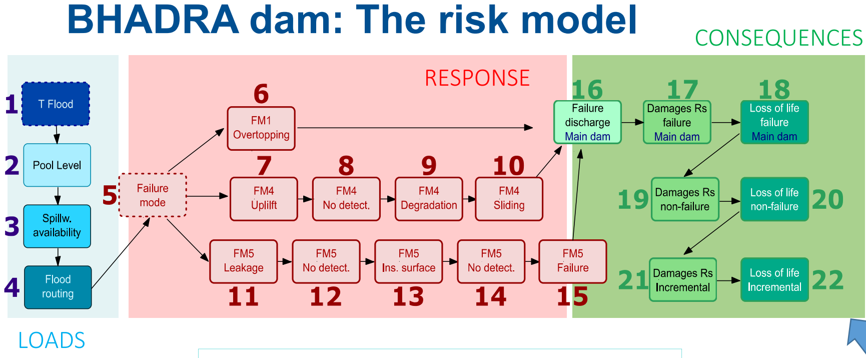
Based on SPANCOLD Technical Guideline (2012)

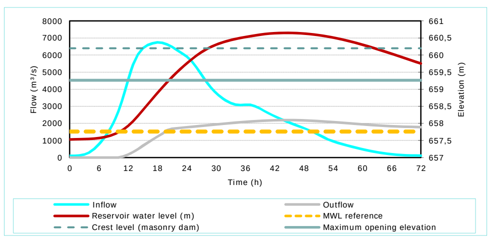
Failure mode identification session in Shimoga (Feb 2017)

iPresas Risk Analysis

ICOLD 2018 - 26th Congress - 86th Annual Meeting - 1 - 7 JULY, VIENNA ICOLD AUSTRIA 2018 http://www.icoldaustria2018.com CIGB 2018 - 26ème Congrès - 86ème Réunion Annuelle - 1 - 7 JUILLET, VIENNE

BHADRA dam: The risk model





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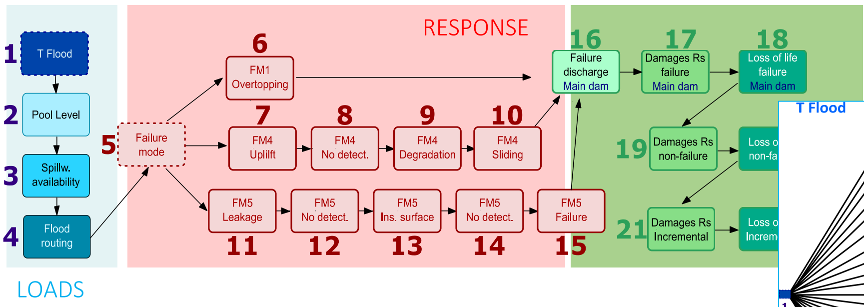
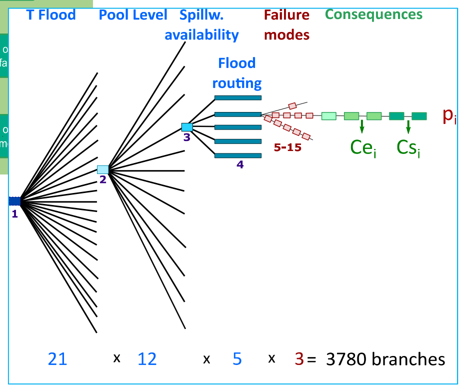
BHADRA dam: The risk model



Failure probability = $\sum p_i$

Economic risk = $\sum p_i \cdot Ce_i$

Societal risk = $\sum p_i \cdot Cs_i$



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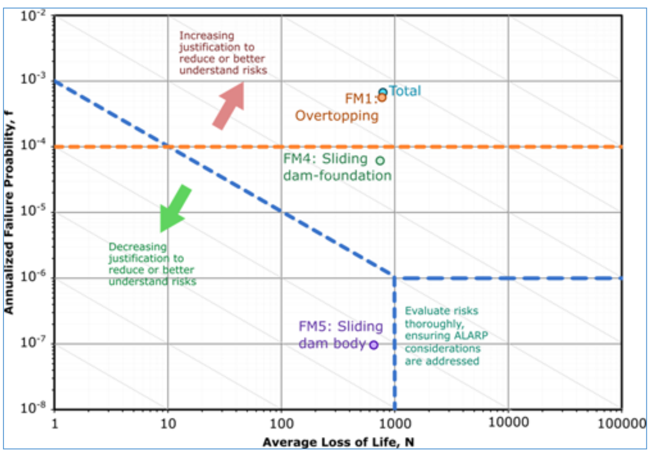
Jessica Castillo Rodríguez (UPV – iPresas)

BHADRA dam: Results

fN graph



- Comparing risk with international tolerability recommendations (USBR,USACE)
- Including sensitivity and uncertainty analysis on failure characterization.

iPresas Risk Analysis

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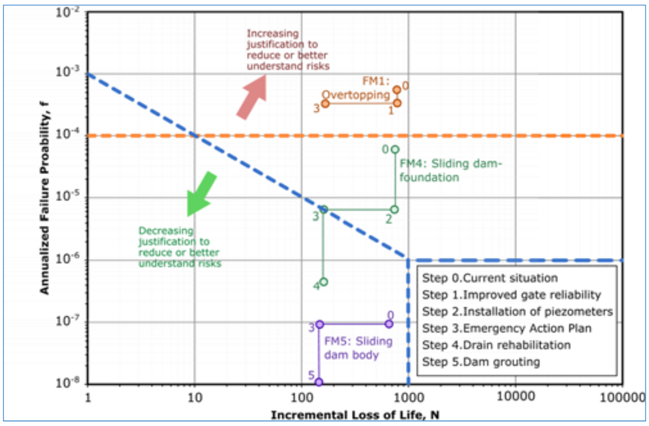
BHADRA dam: Results

fN graph



- Impact of risk reduction measures per failure mode.

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ICOLD 2018 - 26th Congress - 86th Annual Meeting - 1 - 7 JULY, VIENNA ICOLD AUSTRIA 2018 http://www.icoldaustria2018.com CIGB 2018 - 26ème Congrès - 86ème Réunion Annuelle - 1 - 7 JUILLET, VIENNE

LESSONS LEARNT

- **Current challenges for dam safety management:**
  - Need for reviewing and gathering further **information**.
  - Need for **monitoring**.
  - **Implementation** of planned structural and non-structural measures (EAPs).
  - First step towards risk-informed dam safety management in India.

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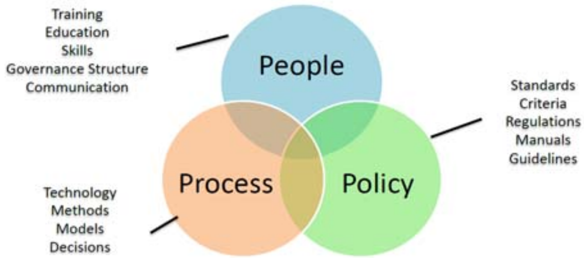
BENEFITS OF RISK-INFORMED DECISIONS

- **Prioritize** investments including **equity and efficiency principles.**
- **Justify** decisions and actions for allocating resources.
- **Gain** better **knowledge** of systems through the whole **risk-analysis process.**



USBR (2014)

iPresas Risk Analysis

THANK YOU!

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DAMSAFE

INNOVATIVE TECHNOLOGIES
FOR ENHANCING DAM SAFETY AND WATER MANAGEMENT IN INDIA

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Deltares (The Netherlands)

Royal Eijkelkamp (The Netherlands)

SkyGeo (The Netherlands)

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